Rules for Building and Classing

Marine Vessels

Part 6
Specialized Items and Systems

ABS

July 2024

RULES FOR BUILDING AND CLASSING

MARINE VESSELS
JULY 2024

PART 6
SPECIALIZED ITEMS AND SYSTEMS

American Bureau of Shipping
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ABS Plaza
1701 City Plaza Drive
Spring, TX 77389 USA

PART 6

Specialized Items and Systems

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CHAPTER 1

Strengthening for Navigation in Ice

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PART 6

CHAPTER 1
Strengthening for Navigation in Ice

Foreword (2024)

This Chapter provides requirements for optional ice strengthening classes. Section 6-1-2 contains guidance for both the Polar Class and the First Year Ice Class ice strengthening requirements. The Polar Class ice strengthening requirements are based on IACS UR I1, I2, and I3, for vessels intended for operation in ice-covered Polar waters. The First Year Ice Class Rules are based upon the Finnish Swedish Ice Class Rules for **Ice Class IC** through **IAA** and are intended for operations in first year ice independently or with icebreaker escort. The lowest First Year Ice Classes, **ID** and **IE**, are intended for operations in very light and extremely light ice conditions.

The requirements in this Chapter are applicable to vessels of any length and are in addition to those in other Sections of the *Marine Vessel Rules*, as appropriate.

It is the responsibility of the owner to determine which ice class is most suitable for the intended service.

The attention of designers, owners and operators is directed to the ABS *Guide for Vessels Operating in Low Temperature Environments* for considerations not covered in this Chapter. Further, IMO statutory instruments having requirements specific to operations in polar water (IMO Polar Code) are to be considered.

PART 6

CHAPTER 1
Strengthening for Navigation in Ice

SECTION 1
Introduction *(2012)*

1 General *(2024)*

The ice class notations are as listed below in 6-1-1/1.3 TABLE 1. All ice class notations are optional. However, vessels intended for navigation in ice-infested waters are to comply with the appropriate goals and functional requirements, or specific requirements of Part 6, Chapter 1 of the ABS *Marine Vessel Rules*. Additional coastal state or IMO Polar Code requirements may apply.

1.1 Application - Ice Class *(2024)*

i) The goals and requirements for Polar Class Vessels apply to vessels constructed of steel and intended for independent navigation in ice-infested polar waters.

ii) The goals and requirements for First Year Ice Class Vessels apply to vessels constructed of steel and intended for either operations in the Baltic Sea area during winter or other areas where first year ice is present (Ice Classes **IAA** through **IC**). The goals and requirements for First Year Ice Classes **ID** and **IE** apply to vessels constructed of steel and intended to operate in very light and extremely light first year ice conditions.

iii) Vessels that comply with the goals or the requirements of this Section, Section 6-1-1, and Section 6-1-2 can be considered for a Polar Class notation as listed in 6-1-1/3.1 TABLE 2. The requirements of these Sections are in addition to the open water requirements of the Rules. If the hull and machinery are constructed such as to comply with the requirements of different Polar Classes, then both the hull and machinery are to be assigned the lower of these classes in the Certificate of Classification. Compliance of the hull or machinery with the requirements of a higher Polar Class is also to be indicated in the Certificate of Classification.

iv) Provided all Polar Class Vessel goals or requirements as specified in this Chapter are met, the vessels will be distinguished in the Record by **Ice Class** followed by ice class **PC 7** through **PC 1**, as applicable.

v) Vessels which are assigned a Polar Class notation and complying with the relevant goals or requirements of Sections 6-1-1, 6-1-2 and 6-1-3 may be given the additional notation **Ice Breaker**. **Ice Breaker** refers to any vessel having an operational profile that includes escort or ice management functions, having powering and dimensions that allow it to undertake aggressive operations in ice-covered waters. These vessels are to be distinguished in the *Record* by the notation **Ice Breaker** followed by an appropriate Ice Class notation in 6-1-1/3.1 (e.g., ✠ **A1, Ice Breaker, Ice Class PC3**)

vi) For vessels which are assigned a Polar Class notation, the hull form and propulsion power are to be such that the ship can operate independently and at continuous speed in a representative ice condition, as defined in 6-1-1/3.1 TABLE 2 for the corresponding Polar Class. For vessels and vessel-shaped units which are intentionally not designed to operate independently in ice, such operational intent or limitations are to be explicitly stated in the Certificate of Classification.

vii) For vessels which are assigned a Polar Class notation **PC1** through **PC5**, bows with vertical sides, and bulbous bows are to be avoided. Bow angles should be within the range specified in 6-1-2/5.1.v.

viii) For vessels which are assigned a Polar Class notation **PC6** and **PC7**, and are designed with a bow with vertical sides or bulbous bows, operational limitations (restricted from intentional ramming) in design conditions are to be stated in the Certificate of Classification.

ix) Vessels that comply with the goals or the requirements of Section 6-1-4 can be considered for a First Year Ice Class notation as listed in 6-1-1/1.3 TABLE 1. The requirements of Section 6-1-4 are in addition to the open water requirements of the Rules. If the hull and machinery are constructed to comply with the requirements of different First Year Ice Classes, then both the hull and machinery are to be assigned the lower of these classes in the Certificate of Classification. Compliance of the hull or machinery with the requirements of a higher First Year Ice Class is also to be indicated in the Certificate of Classification.

x) Vessels that comply with the IMO Polar Code and receive a Polar Ship Certificate can be considered for the **POLAR** notations in Section 11 of the ABS *Guide for Vessels Operating in Low Temperature Environments* (LTE Guide).

1.3 Objective *(2024)*

The goals and functional requirements for the topics covered in this Chapter are included in the respective sections.

TABLE 1
Ice Class Notations[1] *(1 July 2024)*

Polar Class (6-1-1, 6-1-2, 6-1-3)	*Polar Class, Ice Breaker (6-1-1, 6-1-2, 6-1-3)*	*First Year Ice Class (6-1-4)*
Ice Class PC1	Ice Breaker, Ice Class PC1	
Ice Class PC2	Ice Breaker, Ice Class PC2	
Ice Class PC3	Ice Breaker, Ice Class PC3	
Ice Class PC4	Ice Breaker, Ice Class PC4	
Ice Class PC5	Ice Breaker, Ice Class PC5	
Ice Class PC6	Ice Breaker, Ice Class PC6	Ice Class IAA
Ice Class PC7	Ice Breaker, Ice Class PC7	Ice Class IA
		Ice Class IB
		Ice Class IC
		Ice Class ID
		Ice Class IE

Note:

1 This table shows the approximate correspondence between different ABS ice class notations. It is not to be interpreted to imply direct equivalencies between ice classes.

3 Description of Ice Classes *(2024)*

3.1 Selection of Polar Classes *(2024)*

The Polar Class (PC) notations and descriptions are given in 6-1-1/3.1 TABLE 2. It is the responsibility of the Owner to select an appropriate Polar Class. The descriptions in 6-1-1/3.1 TABLE 2 are intended to guide the user in selecting an appropriate Polar Class to match the requirements for the vessel with its intended voyage or service.

The Polar Class notations are used throughout Sections 6-1-2 and 6-1-3to convey the differences between classes with respect to operational capability and strength.

TABLE 2
Polar Class Descriptions

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

* *Note:* "Old ice" means 2nd year ice or multi-year ice.

3.3 Selection of First Year Ice Classes *(2024)*

The First Year Ice Class notations and descriptions are given below. It is the responsibility of the Owner to select an appropriate Ice Class. The descriptions below are intended to guide the user in selecting an appropriate First Year Ice Class to match the requirements for the vessel with its intended voyage or service.

Vessels that intend to operate in the Baltic Sea area in winter are subject to approval of the Swedish and Finnish administrations and should select a First Year Ice Class notation between **IAA** through **IC**, depending on the intended operational profile of the vessel. First Year Ice Class notations **IAA** through **IC** align with the Finnish Swedish Ice Class Rules (2017).

First Year Ice Class notations are applicable and relevant to other parts of the world where first year ice is present. If the vessel does not intend to operate in the Baltic Sea area the vessel is not subject to Swedish and Finnish administration approval. However other flag administration rules may apply depending on the operational area.

First Year Ice Class notations **ID** and **IE** are intended for operations in very light and extremely light ice conditions respectively.

- **Ice Class IAA**: Vessels with such structure, engine output, and other properties that they are normally capable of navigating in difficult ice conditions without the assistance of icebreakers
- **Ice Class IA**: Vessels with such structure, engine output, and other properties that they are capable of navigating in difficult ice conditions, with the assistance of icebreakers when necessary
- **Ice Class IB**: Vessels with such structure, engine output, and other properties that they are capable of navigating in moderate ice conditions, with the assistance of icebreakers when necessary

- **Ice Class IC**: Vessels with such structure, engine output, and other properties that they are capable of navigating in light ice conditions, with the assistance of icebreakers when necessary
- **Ice Class ID**: Vessels with such structure, engine output, and other properties that they are capable of navigating in very light ice conditions, with the assistance of icebreakers when necessary
- **Ice Class IE**: Vessels with such structure, engine output, and other properties that they are capable of navigating in extremely light ice conditions in coastal areas, with the assistance of icebreakers when necessary

5 Definitions

5.1 Ice Belt

The ice belt is that reinforced portion of the shell and hull appendages that overlaps the upper and lower ice waterlines and is subject to the design ice loads. The required ice belt overlap extends from 1.5 m below the lower ice waterline to 1.0 m or 1.5 m above the upper ice waterline, depending upon Polar Class. In the bow area, the overlap increases linearly to 2.0 m above the upper ice waterline at the stem. See 6-1-2/3.1 FIGURE 1.

5.3 Upper and Lower Ice Waterlines

The upper and lower ice waterlines upon which the design of the vessel has been based are to be indicated on the Certificate of Classification. The upper ice waterline (UIWL) is to be defined by the maximum drafts fore, amidships and aft. The lower ice waterline (LIWL) is to be defined by the minimum drafts fore, amidships and aft.

The lower ice waterline is to be determined with due regard to the vessel's ice-going capability in the ballast loading conditions. The propeller is to be fully submerged at the lower ice waterline.

5.5 Displacement

The displacement, D, is the molded displacement in metric tons (long tons) at the upper ice waterline.

5.7 Length

The vessel's length, L, is as defined in 3-1-1/3.1, but measured on the upper ice waterline, in m (ft).

PART 6

CHAPTER 1

Strengthening for Navigation in Ice

SECTION 2

Structural Requirements for Polar Class Vessels *(1 July 2020)*

1 General *(2024)*

These goals and requirements apply to Polar Class vessels according to 6-1-1/1.1.

1.1 Objective *(2024)*

1.1.1 Goals *(2024)*

The structures covered in this section are to be designed, constructed, and maintained to:

Goal No.	*Goals*
STRU 1	in the intact condition, have sufficient structural strength to withstand the environmental conditions, loading conditions, and operational loads anticipated during the design life.
STRU 2	resist structural failure associated with accidental conditions.
STRU 3	provide protection to persons on board, environment and required safety services.
STRU 3.1	maintain mechanical properties during extreme temperatures.

Materials are to be suitable for the intended application in accordance with the following goals and support the Tier 1 goals as listed above.

Goal No.	*Goals*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.

The goals in the cross-referenced Rules are also to be met.

1.1.2 Functional Requirements *(2024)*

In order to achieve the above stated goals, the design, construction, and maintenance is to be in accordance with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
Structural (STRU)	
STRU-FR1	*Resist both global and local structural loads anticipated under the foreseen ice conditions. (POLAR Code)*
STRU-FR2	Deep structural members are to be designed to resist accidental overload beyond the foreseen ice conditions.
STRU-FR3	*Sufficient structural strength to resist cracking, buckling, deformation or corrosion which would impair the structural integrity of the ship. (SOLAS II-1)*
STRU-FR4	Adequate longitudinal strength is to be provided to resist bending moments and shear forces associated with the foreseen ice conditions.
Materials (MAT)	
MAT-FR1	*Materials used shall be suitable for operation at the ships polar service temperature or design temperature (POLAR Code)*

1.1.3 Compliance *(2024)*

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

Commentary:

- The requirements of Section 6-1-2 are based on IACS UR I2
- These requirements are in addition to those for non Polar Class vessels.

End of Commentary

1.3 Definitions *(2024)*

The length L_{UI} is the distance, in m (ft), measured horizontally from the fore side of the stem at the intersection with the upper ice waterline (UIWL) to the after side of the rudder post. L_{UI} is not to be less than 96%, and need not be greater than 97%, of the extreme length of the upper ice waterline (UIWL) measured horizontally from the fore side of the stem. In ships with unusual stern and bow arrangement the length L_{UI} will be specially considered.

The ship displacement D_{UI} is the displacement, in kiloton (kiloton, kLt), of the ship corresponding to the upper ice waterline (UIWL). Where multiple waterlines are used for determining the UIWL, the displacement is to be determined from the waterline corresponding to the greatest displacement.

Commentary:

- If there is no rudder post, L_{UI} is measured to the after side of the centerline of the rudder stock.
- If azimuthing propulsors are used, L_{UI} is measured to the after side of the centerline of the strut.

End of Commentary

3 Hull Areas

3.1 General *(2021)*

i) The hull of all Polar Class vessels is divided into areas reflecting the magnitude of the loads that are expected to act upon them. In the longitudinal direction, there are four regions: Bow, Bow Intermediate, Midbody and Stern. The Bow Intermediate, Midbody and Stern regions are further divided in the vertical direction into the Bottom, Lower and Icebelt regions. The extent of each Hull Area is illustrated in 6-1-2/3.1 FIGURE 1.

ii) The upper ice waterline (UIWL) and lower ice waterline (LIWL) are as defined in 6-1-1/5.3.

iii) 6-1-2/3.1 FIGURE 1 notwithstanding, at no time is the boundary between the Bow and Bow Intermediate regions to be forward of the intersection point of the line of the stem and the vessel baseline.

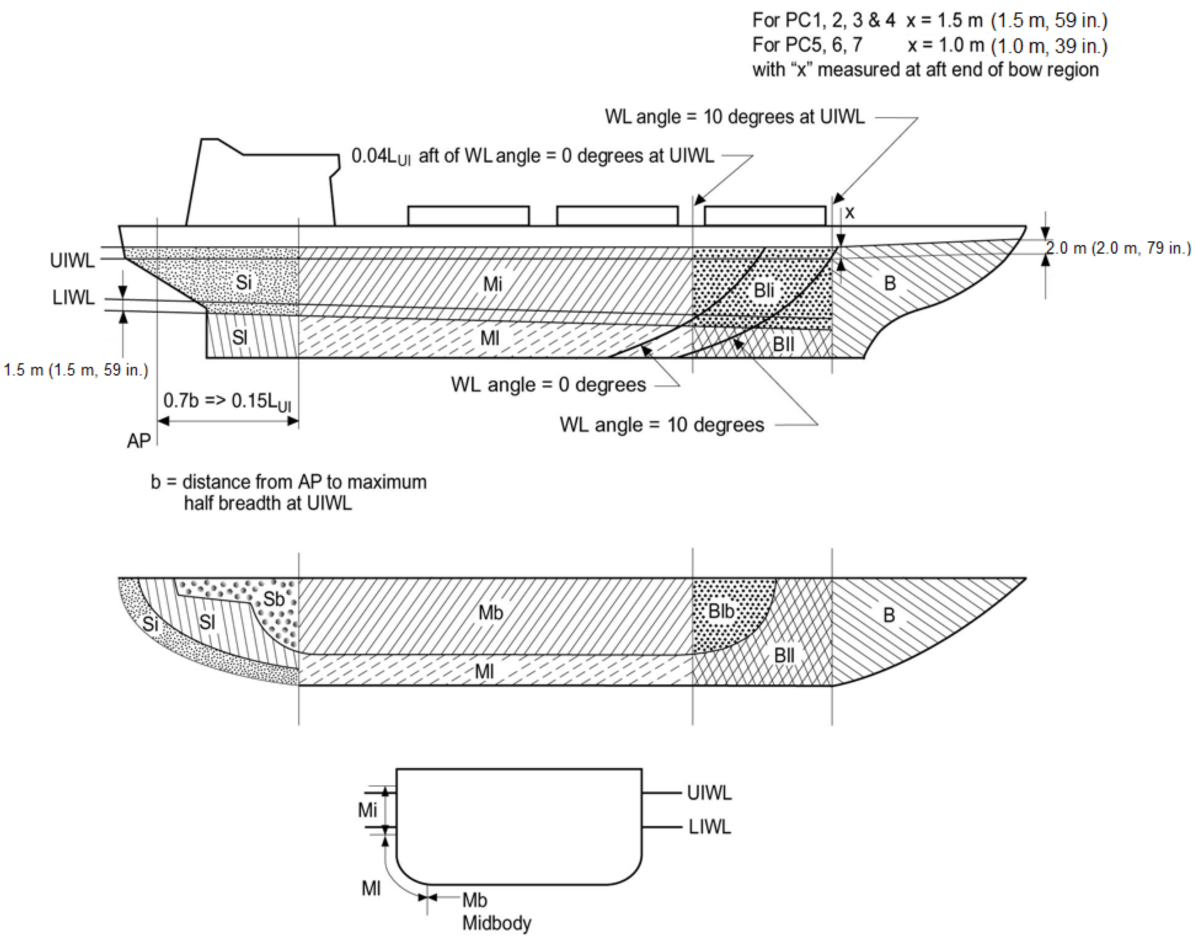
iv) 6-1-2/3.1 FIGURE 1 notwithstanding, the aft boundary of the Bow region need not be more than $0.45L_{UI}$ aft of the fore side of the stem at the intersection with the upper ice waterline (UIWL).

v) The boundary between the bottom and lower regions is to be taken at the point where the shell tangent is inclined 7 degrees from horizontal.

vi) If a vessel is intended to operate astern in ice regions, the aft section of the vessel is to be designed using the Bow and Bow Intermediate hull area requirements as prescribed in 6-1-2/3.1.vii.

vii) 6-1-2/3.1 FIGURE 1 notwithstanding, if the vessel is assigned the additional notation **Ice Breaker**, the forward boundary of the stern region is to be at least $0.04L_{UI}$ forward of the section where the parallel ship side at the upper ice waterline (UIWL) ends.

FIGURE 1
Hull Area Extents *(2021)*



5 Design Ice Loads

5.1 General *(2024)*

i) A glancing impact on the bow is the design scenario for determining the scantlings required to resist ice loads.

ii) The design ice load is characterized by an average pressure (P_{avg}) uniformly distributed over a rectangular load patch of height (b) and width (w).

iii) Within the Bow area of all Polar Class vessels, and within the Bow Intermediate Icebelt area of Polar Class **PC6** and **PC7**, the ice load parameters are functions of the actual bow shape. To determine the ice load parameters (P_{avg}, b and w), the following ice load characteristics are to be calculated the following ice load characteristics for sub-regions of the bow area; shape coefficient (fa_i), total glancing impact force (F_i), line load (Q_i) and pressure (P_i).

iv) In other ice-strengthened areas, the ice load parameters (P_{avg},b_{NonBow} and w_{NonBow}) are determined independently of the hull shape and based on a fixed load patch aspect ratio, $AR = 3.6$.

v) Design ice forces calculated according to 6-1-2/5.5.iii are applicable for bow forms where the buttock angle γ at the stem is positive and less than 80°, and the normal frame angle β' at the center of the foremost sub-region, as defined in 6-1-2/5.5.i, is greater than 10°.

vi) Design ice forces calculated according to 6-1-2/5.5.ivare applicable for ships which are assigned the Polar Class **PC6** or **PC7** and have a bow form with vertical sides. This includes bows where the normal frame angles β' at the considered sub-regions, as defined in 6-1-2/5.5.i, are between 0° and 10°.

vii) For ships which are assigned the Polar Class **PC6** or **PC7**, and equipped with bulbous bows, the design ice forces on the bow are to be determined according to 6-1-2/5.5.iv In addition, the design forces are not to be taken less than those given in 6-1-2/5.5.iii, assuming $fa = 0.6$ and AR =1.3.

viii) For ships with bow forms other than those defined in 6-1-2/5.1.v to 6-1-2/5.1.vii, design forces are to be specially considered.

Commentary:

- For other bow forms model testing, full scale ice load data from similar bow shapes, or ice loads models that consider the bow hull angles can be used to determine the design forces.
- Vessel structures that are not directly subjected to ice loads may still experience inertial loads of stowed cargo and equipment resulting from ship/ice interaction. These inertial loads, based on the maximum accelerations as given in 6-1-3/13, should be considered in the design of these structures.

End of Commentary

5.3 Glancing Impact Load Characteristics

The parameters defining the glancing impact load characteristics are reflected in the Class Factors listed in 6-1-2/5.3 TABLE 1 and 6-1-2/5.3 TABLE 2.

TABLE 1
Class Factors to be Used in 6-1-2/5.5.iii

Polar Class	*Crushing Failure Class Factor (CF_C)*	*Flexural Failure Class Factor (CF_F)*	*Load Patch Dimensions Class Factor (CF_D)*	*Displacement Class Factor (CF_{DIS})*	*Longitudinal Strength Class Factor (CF_L)*
PC1	17.69 (1804 ,1794)	68.60 (6995 ,6885)	2.01 (0.122 ,0.308)	250 (250 ,246)	7.46 (753,473)
PC2	9.89 (1009 ,1003)	46.80 (4772 ,4697)	1.75 (0.1062 ,0.268)	210 (210 ,207)	5.46 (551, 346)

Polar Class	*Crushing Failure Class Factor (CF_C)*	*Flexural Failure Class Factor (CF_F)*	*Load Patch Dimensions Class Factor (CF_D)*	*Displacement Class Factor (CF_{DIS})*	*Longitudinal Strength Class Factor (CF_L)*
PC3	6.06 (618 ,614)	21.17 (2159 ,2125)	1.53 (0.093 ,0.234)	180 (180 ,177)	4.17 (421, 264)
PC4	4.50 (459 ,456)	13.48 (1375 ,1353)	1.42 (0.086 ,0.218)	130 (130 ,128)	3.15 (318, 200)
PC5	3.10 (316 ,314)	9.00 (918 ,903)	1.31 (0.080 ,0.201)	70 (70 ,69)	2.50 (252, 158)
PC6	2.40 (245 ,243)	5.49 (560 ,551)	1.17 (0.071 ,0.179)	40 (40 ,39)	2.37 (239, 150)
PC7	1.80 (184 ,183)	4.06 (414 ,407)	1.11 (0.0673 ,0.170)	22 (22 ,22)	1.81 (183, 115)

Note: There are 3 system of units employed in this document. The first is SI, as is used in the IACS Unified Requirement. The second is the MKS system, and the third is the US customary units. In the document units and constants will be shown as SI (MKS, US), as for example: MPa (kgf/mm^2,psi). In many cases the SI and MKS values are the same, but 3 values are always given for complete clarity.

TABLE 2
Class Factors to be Used in 6-1-2/5.5.iv

Polar Class	*Crushing Failure Class Factor (CF_{CV})*	*Line Load Class Factor (CF_{QV})*	*Pressure Class Factor (CF_{PV})*
PC6	3.43 (350, 347)	2.82 (1.039, 2.608)	0.65 (0.00497, 7.137)
PC7	2.60 (265, 263)	2.33 (0.859, 2.155)	0.65 (0.00497, 7.137)

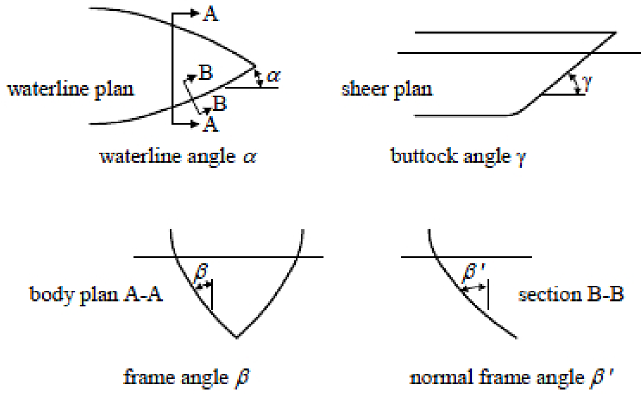
5.5 Bow Area *(2024)*

i) In the Bow area, the force (F), line load (Q), pressure (P) and load patch aspect ratio (AR) associated with the glancing impact load scenario are functions of the hull angles measured at the upper ice waterline (UIWL). The influence of the hull angles is captured through calculation of a bow shape coefficient (f_a). The hull angles are defined in 6-1-2/5.5.iii FIGURE 2.

ii) The waterline length of the bow region is generally to be divided into four sub-regions of equal length. The force (F), line load (Q), pressure (P) and load patch aspect ratio (AR) are to be calculated at the mid-length position of each sub-region (each maximum of F, Q and P is to be used in the calculation of the ice load parameters P_{avg}, b and w).

iii) The Bow area load characteristics for bow forms defined in 6-1-2/5.1.v are determined as follows:

FIGURE 2
Definition of Hull Angles



Note:

β'	=	normal frame angle at upper ice waterline, degrees
α	=	upper ice waterline angle, degreees
γ	=	buttock angle at upper ice waterline (angle of buttock line measured from horizontal), degrees
$\tan(\beta)$	=	$\tan(\alpha)/\tan(\gamma)$
$\tan(\beta')$	=	$\tan(\beta)\cos(\alpha)$

a) *Shape Coefficient*. Shape coefficient, fa_i, is to be taken as:

fa_i = minimum $(fa_{i,1}; fa_{i,2}; fa_{i,3})$

where

$fa_{i,1}$	=	$\left[0.097 - 0.68(x/L_{UI} - 0.15)^2\right] \cdot \alpha_i/(\beta_i')^{0.5}$
$fa_{i,2}$	=	$1.2 \cdot CF_F/\left(\sin(\beta_i') \cdot CF_C \cdot D_{UI}{}^{0.64}\right)$
$fa_{i,3}$	=	0.60
i	=	sub-region considered
L_{UI}	=	length as defined in 6-1-2/1.3, in m (m, ft)
x	=	distance from the fore side of the stem at the intersection with the upper ice waterline (UIWL) to station under consideration, in m (m, ft)
α	=	waterline angle, in degrees, see 6-1-2/5.5.iii FIGURE 2
β'	=	normal frame angle, in degrees, see 6-1-2/5.5.iii FIGURE 2
D_{UI}	=	displacement as defined in 6-1-2/1.3, not to be taken less than 5 kiloton (5 kiloton, 4.9 kLt)
CF_C	=	Crushing Failure Class Factor from 6-1-2/5.3 TABLE 1
CF_F	=	Flexural Failure Class Factor from 6-1-2/5.3 TABLE 1

b) *Force*. Force, F, in MN (tf, Ltf) is to be taken as:

$$F_i = fa_i \cdot CF_C \cdot D_{UI}{}^{0.64}$$

where

i	=	sub-region considered
fa_i	=	shape coefficient of sub-region i
CF_C	=	Crushing Failure Class Factor from 6-1-2/5.3 TABLE 1
D_{UI}	=	displacement as defined in 6-1-2/1.3, not to be taken less than 5 kiloton (5 kiloton, 4.9 kLt)

c) *Load Patch Aspect Ratio*. Load patch aspect ratio, AR, is to be taken as:

$$AR_i = 7.46 \cdot \sin(\beta_i') \geq 1.3$$

where

i	=	sub-region considered
β_i'	=	normal frame angle of sub-region i, in degrees

d) *Line Load*. Line load, Q, in MN/m (tf/cm, Ltf/in) is to be taken as:

$$Q_i = F_i^{0.61} \cdot CF_D / AR_i^{0.35}$$

where

i	=	sub-region considered
F_i	=	force of sub-region i, in MN (tf, Ltf)
CF_D	=	Load Patch Dimensions Class Factor from 6-1-2/5.3 TABLE 1
AR_i	=	load patch aspect ratio of sub-region i

e) *Pressure*. Pressure, P, in MPa (kgf/mm^2, psi) is to be taken as:

$$P_i = c_1 \cdot F_i^{0.22} \cdot CF_D^2 \cdot AR_i^{0.3}$$

where

i	=	sub-region considered
F_i	=	force of sub-region i, in MN (tf, Ltf)
CF_D	=	Load Patch Dimensions Class Factor from 6-1-2/5.3 TABLE 1
AR_i	=	load patch aspect ratio of sub-region i
c_1	=	1 (10, 2240)

iv) The Bow area load characteristics for bow forms defined in 6-1-2/5.1.vi are determined as follows:

a) *Shape Coefficient*

$$fa_i = \alpha_i/30$$

where

i	=	sub-region considered
α_i	=	waterline angle, in degrees, see 6-1-2/5.5.iii FIGURE 2

b) *Force*. Force, F, in MN (tf, Ltf) is to be taken as:

$$F_i = fa_i \cdot CF_{CV} \cdot D_{UI}{}^{0.47}$$

where

i	=	sub-region considered
fa_i	=	shape coefficient of sun region i
CF_{CV}	=	Crushing Failure Class Factor from 6-1-2/5.3 TABLE 2
D_{UI}	=	displacement as defined in 6-1-2/1.3, not to be taken less than 5 kiloton (5 kiloton, 4.9 kLt)

c) *Line Load*. Line load, Q, in MN/m (tf/cm, Ltf/in) is to be taken as:

$$Q_i = F_i^{0.22} \cdot CF_{QV}$$

where

i	=	sub-region considered
F_i	=	force of sub-region i, in MN (tf, Ltf)
CF_{QV}	=	Pressure Class Factor from 6-1-2/5.3 TABLE 2

d) *Pressure*. Pressure, P, in MPa (kgf/mm^2, psi) is to be taken as:

$$P_i = F_i^{0.56} \cdot CF_{PV}$$

where

i	=	sub-region considered
F_i	=	force of sub-region i, in MN (tf, Ltf)
CF_{PV}	=	Pressure Class Factor from 6-1-2/5.3 TABLE 2

5.7 Hull Areas Other Than the Bow

In the hull areas other than the bow, the force (F_{NonBow}) and line load (Q_{NonBow}) used in the determination of the load patch dimensions (b_{NonBow}, w_{NonBow}) and design pressure (P_{avg}) are determined as follows:

5.7.1 Force *(2021)*

Force, F_{NonBow}, in MN (tf, Ltf) is to be taken as:

$$F_{NonBow} = 0.36 \cdot CF_C \cdot DF$$

where

CF_C = Crushing Force Class Factor from 6-1-2/5.3 TABLE 1

DF = vessel displacement factor

= $D_{UI}^{0.64}$ if $D_{UI} \leq CF_{DIS}$

= $CF_{DIS}^{0.64} + 0.10(D_{UI} - CF_{DIS})$ if $D_{UI} > CF_{DIS}$

D_{UI} = displacement as defined in 6-1-2/1.3, not to be taken less than 10 kiloton (10 kiloton, 9.8 kLt)

CF_{DIS} = Displacement Class Factor from 6-1-2/5.3 TABLE 1

5.7.2 Line Load

Line Load, Q_{NonBow}, in MN/m (tf/cm, Ltf/in) is to be taken as:

$$Q_{NonBow} = 0.639 \cdot F_{NonBow}^{0.61} \cdot CF_D$$

where

F_{NonBow} = force from 6-1-2/5.7.1, in MN (tf, Ltf)

CF_D = Load Patch Dimensions Class Factor from 6-1-2/5.3 TABLE 1

5.9 Design Load Patch

5.9.1 Bow Area

In the Bow area, and the Bow Intermediate Ice belt area for vessels with class notation **PC6** and **PC7**, the design load patch has dimensions of width, w_{Bow}, and height, b_{Bow}, expressed in m (cm, in.) and defined as follows:

i) $w_{Bow} = F_{Bow}/Q_{Bow}$

ii) $b_{Bow} = c_1 Q_{Bow}/P_{Bow}$

where

F_{Bow} = maximum F_i in the Bow area, in MN (tf, Ltf)

Q_{Bow} = maximum Q_i in the Bow area, in MN/m (tf/cm, Ltf/in)

P_{Bow} = maximum P_i in the Bow area, in MPa (kgf/mm^2, psi)

c_1 = 1 (10, 2240)

5.9.2 Other Hull Areas

In hull areas other than those covered by 6-1-2/5.9.1, the design load patch has dimensions of width, w_{NonBow}, and height, b_{NonBow}, expressed in m (cm, in.) and defined as follows:

i) $w_{NonBow} = F_{NonBow}/Q_{NonBow}$

ii) $b_{NonBow} = w_{nonbow}/3.6$

where

F_{NonBow} = force determined using 6-1-2/5.7.1, in MN (tf, Ltf)

Q_{NonBow} = line load determined using 6-1-2/5.7.2, in MN/m (tf/cm, Ltf/in)

5.11 Pressure within the Design Load Patch

5.11.1 Average Pressure

The average pressure, P_{avg}, in MPa (kgf/mm², psi) within a design load patch is determined as follows:

$$P_{avg} = c_1 F/(b \cdot w)$$

where

F = F_{Bow} or F_{NonBow} as appropriate for the hull area under consideration, in MN (tf, Ltf)

b = b_{Bow} or b_{NonBow} as appropriate for the hull area under consideration, in m (cm, in.)

w = w_{Bow} or w_{NonBow} as appropriate for the hull area under consideration, in m (cm, in.)

c_1 = 1 (10, 2240)

5.11.2 Areas of Higher, Concentrated Pressure

Areas of higher, concentrated pressure exist within the load patch. In general, smaller areas have higher local pressures. Accordingly, the peak pressure factors listed in 6-1-2/5.11.2 TABLE 3 are used to account for the pressure concentration on localized structural members.

TABLE 3
Peak Pressure Factors *(2024)*

Structural Member		***Peak Pressure Factor (PPF_i)***	
Plating	Transversely Framed	$PPF_p = (1.8 - s/c_2) \geq 1.2$	
	Longitudinally Framed	$PPF_p = (2.2 - 1.2 \cdot s/c_2) \geq 1.5$	
Frames in Transverse Framing Systems	With Load Distributing Stringers	$PPF_t = (1.6 - s/c_2) \geq 1.0$	
	With No Load Distributing Stringers	$PPF_t = (1.8 - s/c_2) \geq 1.2$	
Frames in bottom structures		$PPF_s = 1.0$	
Load Carrying Stringers Side and Bottom Longitudinals Web Frames		$PPF_s = 1.0$,	if $S_w \geq 0.5 \cdot w$
		$PPF_s = 2.0 - 2.0 \cdot S_w/w$,	if $S_w < 0.5 \cdot w$

where

s = frame or longitudinal spacing, in m (m, in.)

c_2 = 1 (1, 39.4)

S_w = web frame spacing, in m (cm, in.)

w = ice load patch width, in m (cm, in.)

5.13 Hull Area Factors *(2024)*

i) Associated with each hull area is an Area Factor that reflects the relative magnitude of the load expected in that area. The Area Factors (AF) for each hull area for Polar Class vessels are listed in 6-1-2/5.13 TABLE 4 and 6-1-2/5.13 TABLE 5. For ships assigned the additional notation, **Ice Breaker**, the Area Factors (AF) for each hull area are listed in 6-1-2/5.13 TABLE 6 and 6-1-2/5.13 TABLE 7.

ii) In the event that a structural member spans across the boundary of a hull area, the largest hull area factor is to be used in the scantling determination of the member.

iii) Due to their increased maneuverability, vessels having propulsion arrangements with azimuthing thruster(s) or "podded" propellers are to have specially considered Stern Icebelt (S_i) and Stern Lower (S_ℓ) hull area factors. The adjusted hull area factors are listed in 6-1-2/5.13 TABLE 5 and 6-1-2/5.13 TABLE 7 for Polar Class vessels and ships assigned with the additional notation **Ice Breaker**, respectively.

Commentary:

Azimuthing or podded propulsors allow the vessel to maneuver more aggressively in ice, which can lead to higher ice loads in the stern shoulders. To account for the increase in loads, a greater area factor can be used.

End of Commentary

TABLE 4
Hull Area Factors (AF) for Vessels Intended to Operate Ahead Only

Hull Area		*Area*	*Polar Class*						
			PC1	PC2	PC3	PC4	PC5	PC6	PC7
Bow (B)	All	B	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bow Intermediate (BI)	Icebelt	BI_i	0.90	0.85	0.85	0.80	0.80	1.00*	1.00*
	Lower	BI_ℓ	0.70	0.65	0.65	0.60	0.55	0.55	0.50
	Bottom	BI_b	0.55	0.50	0.45	0.40	0.35	0.30	0.25
Midbody (M)	Icebelt	M_i	0.70	0.65	0.55	0.55	0.50	0.45	0.45
	Lower	M_ℓ	0.50	0.45	0.40	0.35	0.30	0.25	0.25
	Bottom	M_b	0.30	0.30	0.25	**	**	**	**
Stern (S)	Icebelt	S_i	0.75	0.70	0.65	0.60	0.50	0.40	0.35
	Lower	S_ℓ	0.45	0.40	0.35	0.30	0.25	0.25	0.25
	Bottom	S_b	0.35	0.30	0.30	0.25	0.15	**	**

Note:
* See 6-1-2/5.5.iii.;
** Indicates that strengthening for ice loads is not necessary.

TABLE 5
Hull Area Factors (AF) for Vessels Intended to Operate Ahead and Astern

Hull Area		*Area*	*Polar Class*						
			PC1	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**	**PC7**
Bow (B)	All	B	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bow Intermediate (BI)	Icebelt	BI_i	0.90	0.85	0.85	0.80	0.80	1.00*	1.00*
	Lower	BI_ℓ	0.70	0.65	0.65	0.60	0.55	0.55	0.50
	Bottom	BI_b	0.55	0.50	0.45	0.40	0.35	0.30	0.25
Midbody (M)	Icebelt	M_i	0.70	0.65	0.55	0.55	0.50	0.45	0.45
	Lower	M_ℓ	0.50	0.45	0.40	0.35	0.30	0.25	0.25
	Bottom	M_b	0.30	0.30	0.25	**	**	**	**
Stern Intermediate (SI)	Icebelt	SI_i	0.90	0.85	0.85	0.80	0.80	1.00*	1.00*
	Lower	SI_ℓ	0.70	0.65	0.65	0.60	0.55	0.55	0.50
	Bottom	SI_b	0.55	0.50	0.45	0.40	0.35	0.30	0.25
Stern (S)	All	S	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Note:
* See 6-1-2/5.5.iii;
** Indicates that strengthening for ice loads is not necessary.

TABLE 6
Hull Area Factors (AF) for Vessels with Additional Notation Ice Breaker and Intended to Operate Ahead Only

Hull Area		*Area*	*Polar Class*						
			PC1	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**	**PC7**
Bow (B)	All	B	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bow Intermediate (BI)	Icebelt	BI_i	0.90	0.85	0.85	0.85	0.85	1.00	1.00
	Lower	BI_ℓ	0.70	0.65	0.65	0.65	0.65	0.65	0.65
	Bottom	BI_b	0.55	0.50	0.45	0.45	0.45	0.45	0.45
Midbody (M)	Icebelt	M_i	0.70	0.65	0.55	0.55	0.55	0.55	0.55
	Lower	M_ℓ	0.50	0.45	0.40	0.40	0.40	0.40	0.40
	Bottom	M_b	0.30	0.30	0.25	0.25	0.25	0.25	0.25
Stern (S)	Icebelt	S_i	0.95	0.90	0.80	0.80	0.80	0.80	0.80
	Lower	S_ℓ	0.55	0.50	0.45	0.45	0.45	0.45	0.45
	Bottom	S_b	0.35	0.30	0.30	0.30	0.30	0.30	0.30

TABLE 7
Hull Area Factors (AF) for Vessels with Additional Notation Ice Breaker and Intended to Operate Ahead and Astern

Hull Area		*Area*	*Polar Class*						
			PC1	PC2	PC3	PC4	PC5	PC6	PC7
Bow (B)	All	B	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bow Intermediate (BI)	Icebelt	BI_i	0.90	0.85	0.85	0.85	0.85	1.00	1.00
	Lower	BI_ℓ	0.70	0.65	0.65	0.65	0.65	0.65	0.65
	Bottom	BI_b	0.55	0.50	0.45	0.45	0.45	0.45	0.45
Midbody (M)	Icebelt	M_i	0.70	0.65	0.55	0.55	0.55	0.55	0.55
	Lower	M_ℓ	0.50	0.45	0.40	0.40	0.40	0.40	0.40
	Bottom	M_b	0.30	0.30	0.25	0.25	0.25	0.25	0.25
Stern Intermediate (SI)	Icebelt	SI_i	0.90	0.85	0.85	0.85	0.85	1.00	1.00
	Lower	SI_ℓ	0.70	0.65	0.65	0.65	0.65	0.65	0.65
	Bottom	SI_b	0.55	0.50	0.45	0.45	0.45	0.45	0.45
Stern (S)	All	S	1.00	1.00	1.00	1.00	1.00	1.00	1.00

7 Shell Plate Requirements

7.1 Required Minimum Shell Plate Thickness *(2024)*

The required minimum shell plate thickness, t, expressed in mm (mm, in.), is given by:

$$t = t_{net} + t_s$$

where

t_{net} = plate thickness required to resist ice loads according to 6-1-2/7.3

t_s = corrosion and abrasion allowance according to 6-1-2/21

Shell plating thickness may be rounded to the nearest 0.5 mm (1/64 inch) as per 3-1-2/5.3.

7.3 Shell Plate Thickness to Resist Ice Load *(1 July 2018)*

The thickness of shell plating required to resist the design ice load, t_{net}, expressed in mm (mm, in.), depends on the orientation of the framing.

i) In the case of transversely-framed plating $\Omega \geq 70$ degrees), including all bottom plating (i.e., plating in hull areas BI_b, M_b and S_b), the net thickness is given by:

$$t_{net} = n_0 \cdot s \cdot \left[\left(AF \cdot PPF_p \cdot P_{avg}\right)/\sigma_y\right]^{0.5} / \left[1 + c_3 s/(2 \cdot b)\right]$$

ii) In the case of longitudinally-framed plating ($\Omega \leq 20$ degrees), when $b \geq s$, the net thickness is given by:

$$t_{net} = n_o \cdot s \cdot \left[\left(AF \cdot PPF_p \cdot P_{avg}\right)/\sigma_y\right]^{0.5} / \left[1 + s/(2 \cdot \ell)\right]$$

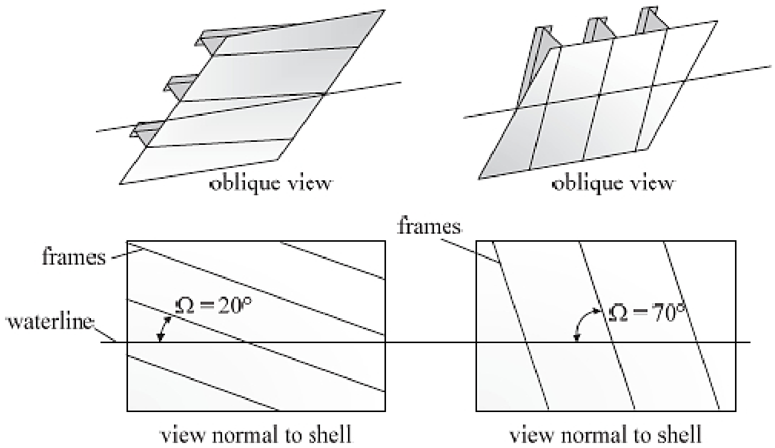
iii) In the case of longitudinally-framed plating ($\Omega \le 20$ degrees), when $b < s$, the net thickness is given by:

$$t_{net} = n_0 \cdot s \cdot \left[\left(AF \cdot PPF_p \cdot P_{avg}\right)/\sigma_y\right]^{0.5} \cdot \left[2 \cdot b/(c_3 s) - \left(b/(c_3 s)\right)^2\right]^{0.5} / \left[1 + s/(2 \cdot \ell)\right]$$

iv) In the case of obliquely-framed plating ($70 \ \text{deg} > \Omega > 20$ degrees), linear interpolation is to be used.

c_3	=	1 (100, 1)
n_0	=	500 (500, 0.5)
Ω	=	smallest angle between the chord of the waterline and the line of the first level framing as illustrated in 6-1-2/7.3.iv FIGURE 3, in degrees
s	=	transverse frame spacing in transversely-framed vessels or longitudinal frame spacing in longitudinally-framed vessels, in m (m, in.)
AF	=	Hull Area Factor from 6-1-2/5.13 TABLE 4, 6-1-2/5.13 TABLE 5, 6-1-2/5.13 TABLE 6, or 6-1-2/5.13 TABLE 7
PPF_p	=	Peak Pressure Factor from 6-1-2/5.11.2 TABLE 3
P_{avg}	=	average patch pressure determined by 6-1-2/5.11.1, in MPa (kgf/mm^2, psi)
σ_y	=	minimum upper yield stress of the material, in N/mm^2 (kgf/mm^2, psi), but not greater than 690 N/mm^2 (70 kgf/mm^2, 100000 psi)
b	=	height of design load patch, in m (cm, in.), where b is to be taken not greater than $(\ell - s/4)/c_3$ in the case of determination of the net thickness for transversely framed playing, 6-1-2/7.3.i
ℓ	=	distance between frame supports in m (m, in.) (i.e., equal to the frame span as given in 6-1-2/9.9), but not reduced for any fitted end brackets, in m (m, in.). When a load-distributing stringer is fitted, the length ℓ need not be taken greater than the distance from the stringer to the most distant frame support.

FIGURE 3
Shell Framing Angle Ω



7.5 Changes in Plating Thickness

Changes in plating thickness in the transverse direction from the ice belt to the bottom and in the longitudinal direction within the ice belt are to be gradually tapered.

9 Framing - General

9.1 General *(1 July 2020)*

Framing members of Polar Class vessels are to be designed to withstand the ice loads defined in6-1-2/5 for local transverse and longitudinal frames, and 6-1-2/15 for web frames and load-carrying stringers.

9.3 Application

The term "framing member" refers to transverse and longitudinal local frames, load-carrying stringers and load-carrying web frames in the areas of the hull exposed to ice pressure.

9.5 Fixity *(2024)*

The strength of a framing member is dependent upon the fixity that is provided at its supports. Fixity can be assumed where framing members are either continuous through the support or attached to a supporting section with a connection bracket. In other cases, simple support is to be assumed unless the connection can be demonstrated to provide significant rotational restraint. Fixity is to be ensured at the support of any framing which terminates within an ice-strengthened area. See the applicable sections in Part 3, Chapter 2 for minimum bracket dimensions.

9.7 Details *(2024)*

The details of framing member intersection with other framing members, including plated structures, as well as the details for securing the ends of framing members at supporting sections, are to be prepared and submitted for review. See the applicable sections in Part 3, Chapter 2 for intersection and end connection requirements.

9.9 Framing Span *(2024)*

The effective span of a framing member is to be determined on the basis of its molded length. If brackets are fitted, the effective span may be reduced provided the bracket is in accordance with 3-2-9/5.5 TABLE 1Aor 3-2-9/5.5 TABLE 1B, and the rigidity of the supporting member where the bracket being attached is adequate. Brackets are to be configured to provide stability in the elastic and post-yield response regions.

9.11 Scantlings

When calculating the section modulus and shear area of a framing member, net thicknesses of the web, flange (if fitted) and attached shell plating are to be used. The shear area of a framing member may include that material contained over the full depth of the member (i.e., web area including portion of flange, if fitted), but excluding attached shell plating.

9.13 Net Effective Shear Area

The actual net effective shear area, A_w, in cm^2 (cm^2, in^2) of a transverse or longitudinal local frame is given by:

$$A_w = h \cdot t_{wn} \cdot \sin\varphi_w / c_4^2$$

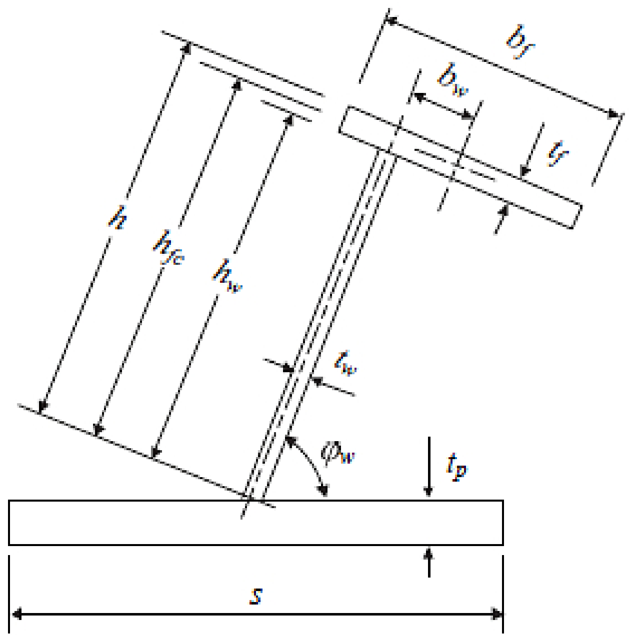
where

c_4	=	10 (10, 1)
h	=	height of stiffener, in mm (mm, in.), see 6-1-2/9.13 FIGURE 4
t_{wn}	=	net web thickness, in mm (mm, in.)
	=	$t_w - t_c$
t_w	=	as-built web thickness, in mm (mm, in.), see 6-1-2/9.13 FIGURE 4

t_c = corrosion deduction, in mm (mm, in.), to be subtracted from the web and flange thickness (but not less than as required by 6-1-2/21.5).

φ_w = smallest angle between shell plate and stiffener web, measured at the midspan of the stiffener, see 6-1-2/9.13 FIGURE 4. The angle φ_w may be taken as 90 deg provided the smallest angle is not less than 75 deg.

FIGURE 4
Stiffener Geometry



9.15 Net Effective Plastic Section Modulus *(2024)*

When the net cross-sectional area of the attached plate flange, A_{pn}, exceeds the net cross-sectional area of the frame, A_{frn}, to which the shell plate flange is attached, the actual net effective plastic section modulus, Z_p, in cm³ (cm³, in³), of a transverse or longitudinal frame is given by:

$$Z_p = A_{frn}t_{pn}/(2c_4) + \frac{h_w^2 t_{wn}\sin\varphi_w}{2 \cdot c_4^3} + A_{fn}\left(h_{fc}\sin\varphi_w - b_w\cos\varphi_w\right)/c_4$$

where

A_{pn} = net cross-sectional area of the attached plate flange, in cm² (cm², in²)

= $t_{pn}sc_4$

A_{frn} = net cross-sectional area of the local frame, in cm² (cm², in²)

= $\frac{h_w t_{wn} + b_f t_{fn}}{c_4^2}$

t_{pn} = fitted net shell plate thickness, in mm (mm, in.), (is to comply with t_{net} as required by 6-1-2/7.3)

h_w = height of local frame web, in mm (mm, in.), see 6-1-2/9.13 FIGURE 4

b_f = width of local frame flange, in (mm, in.), see 6-1-2/9.13 FIGURE 4

t_{fn} = net thickness of local frame flange, in (mm, in.), see 6-1-2/9.13 FIGURE 4

A_{fn} = net cross-sectional area of local frame flange, in cm^2 (cm^2, in^2)

= $\frac{b_f t_{fn}}{c_4^2}$

h_{fc} = height of local frame measured to center of the flange area, mm (mm, in.), see 6-1-2/9.13 FIGURE 4

= $h_w + \frac{t_{fn}}{2}$

b_w = distance from mid thickness plane of local frame web to the center of the flange area, in mm (mm, in.), see 6-1-2/9.13 FIGURE 4

c_4, h, t_{wn}, t_c and φ_w are as given in 6-1-2/9.13 and s is as given in 6-1-2/7.3.

When the net cross-sectional area of the local frame, A_{frn}, exceeds the net cross-sectional area of the attached plate flange, A_{pn}, the plastic neutral axis is located a distance z_{na}, in mm (mm, in.), above the attached shell plate, given by:

$$z_{na} = \left(c_4^2 A_{fn} + h_w t_{wn} - c_4^3 t_{pn} s\right)/(2t_{wn})$$

and the net effective plastic section modulus, Z_p, in cm^3 (cm^3, in^3), of a transverse or longitudinal frame is given by:

$$Z_p = t_{pn} s\left(z_{na} + t_{pn}/2\right)\sin\varphi_w + \left[\frac{\left[\left(h_w - z_{na}\right)^2 + z_{na}^2\right] t_{wn} \sin\varphi_w}{2 \cdot c_4^3} + A_{fn}\left[\left(h_{fc} - z_{na}\right)\sin\varphi_w - b_w \cos\varphi_w\right]/c_4\right]$$

9.17 Oblique Framing

In the case of oblique framing arrangement (70 degrees > *Ω* > 20 degrees, where *Ω* is defined as given in 6-1-2/7.3), linear interpolation is to be used.

11 Framing - Local Frames in Bottom Structures and Transverse Local Frames in Side Structures

11.1 Plastic Strength

The local frames in bottom structures (i.e., hull areas BI_b, M_b and S_b) and transverse local frames in side structures are to be dimensioned such that the combined effects of shear and bending do not exceed the plastic strength of the member. The plastic strength is defined by the magnitude of midspan load that causes the development of a plastic collapse mechanism. For bottom structure, the patch load is to be applied with the dimension *b* parallel with the frame direction.

11.3 Required Shear Area *(1 July 2018)*

The actual net effective shear area of the frame, A_w, as defined in 6-1-2/9.13, is to comply with the following condition: $A_w \geq A_t$ in cm^2 (cm^2, in^2) where:

$$A_t = 100^{n1} \cdot 0.5 \cdot LL \cdot s \cdot \left(AF \cdot PPF \cdot P_{avg}\right)/\left(0.577 \cdot \sigma_y\right)$$

where

n_1 = 2 (1, 0)

LL = length of loaded portion of span, the lesser of $a$and b, in m (cm, in.)

a = local frame span as defined in 6-1-2/9.9, in m (cm, in.)

b = height of design ice load patch according to 6-1-2/5.9.1.ii or 6-1-2/5.9.2.ii, in m (cm, in.)

s = spacing of local frame , in m (m, in.)

AF = Hull Area Factor from 6-1-2/5.13 TABLE 4 and 6-1-2/5.13 TABLE 5, 6-1-2/5.13 TABLE 6, or 6-1-2/5.13 TABLE 7

PPF = Peak Pressure Factor, PPF_t or PPF_s, as appropriate from 6-1-2/5.11.2 TABLE 3

P_{avg} = average pressure within load patch according to 6-1-2/5.11.1, in MPa (kgf/mm^2, psi)

σ_y = minimum upper yield stress of the material, in N/mm^2 (kgf/mm^2, psi), but not greater than 690 N/mm^2 (70 kgf/mm^2, 100000 psi)

11.5 Required Plastic Section Modulus

The actual net effective plastic section modulus of the plate/stiffener combination, Z_p, as defined in 6-1-2/9.15, is to comply with the following condition: $Z_p \geq Z_{pt}$, in cm^3 (cm^3, in^3) where Z_{pt} is to be the greater calculated on the basis of two load conditions:

i) Ice load acting at the midspan of the local frame, and

ii) The ice load acting near a support.

The A_1 parameter, in the equation below, reflects these two conditions.

$$Z_{pt} = 100^{n2} \cdot LL \cdot Y \cdot s \cdot \left(AF \cdot PPF \cdot P_{avg}\right) \cdot a \cdot A_1/\left(4 \cdot \sigma_y\right)$$

where

n_2 = 3 (1, 0)

Y = 1 - 0.5 · (LL/a)

A_1 = maximum of:

A_{1A} = $1/\left(1 + j/2 + k_w \cdot j/2 \cdot \left[\left(1 - a_1^2\right)^{0.5} - 1\right]\right)$

A_{1B} = $[1 - 1/(2 \cdot a_1 \cdot Y)]/\left(0.275 + 1.44 \cdot k_z^{0.7}\right)$

j = 1 for a local frame with one simple support outside the ice-strengthened areas

= 2 for a local frame without any simple supports

a_1 = A_t/A_w

A_t = minimum shear area of the local frame as given in 6-1-2/11.3, in cm^2 (cm^2, in^2)

A_w = net effective shear area of the local frame (calculated according to 6-1-2/9.13), in cm^2 (cm^2, in^2)

k_w = $1/\left(1 + 2 \cdot A_{fn}/A_w\right)$ with A_{fn} as given in 6-1-2/9.15

k_z = z_p/Z_p in general

= 0.0 when the frame is arranged with end bracket

z_p = sum of individual plastic section modulii of flange and shell plate as fitted, in cm³ (cm³, in³)

= $\left(b_f \cdot t_{fn}^2/4 + b_{eff} \cdot t_{pn}^2/4\right)/c_5$

c_5 = 1000 (1000, 1)

b_f = flange breadth, in mm (mm, in.), see 6-1-2/9.13 FIGURE 4

t_{fn} = net flange thickness, in mm (mm, in.)

= $t_f - t_c$ (t_c as given in 6-1-2/9.13)

t_f = as-built flange thickness, in mm (mm, in.), see 6-1-2/9.13 FIGURE 4

t_{pn} = fitted net shell plate thickness, in mm (mm, in.) (not to be less than t_{net} as given in 6-1-2/7)

b_{eff} = effective width of shell plate flange, in mm (mm, in.)

= $0.5\ c_5 \cdot s$

Z_p = net effective plastic section modulus of the local frame (calculated according to 6-1-2/9.15), in cm³ (cm³, in³)

$AF, PPF, P_{avg}, LL, b, s, a$ and σ_y are as given in 6-1-2/11.3.

11.7 Structural Stability

The scantlings of the local frame are to meet the structural stability requirements of 6-1-2/17.

13 Framing – Longitudinal Local Frames in Side Structures

13.1 Plastic Strength

Longitudinal local frames in side structures are to be dimensioned such that the combined effects of shear and bending do not exceed the plastic strength of the member. The plastic strength is defined by the magnitude of midspan load that causes the development of a plastic collapse mechanism.

13.3 Required Shear Area *(1 July 2018)*

The actual net effective shear area of the frame, A_w, as defined in 6-1-2/9.13, is to comply with the following condition: $A_w \geq A_L$, in cm² (cm², in²) where:

$$A_L = 100^{n3} \cdot \left(AF \cdot PPF_s \cdot P_{avg}\right) \cdot 0.5 \cdot b_1 \cdot a/\left(0.577 \cdot \sigma_y\right)$$

where

n_3 = 2 (0, 0)

AF = Hull Area Factor from 6-1-2/5.13 TABLE 4, 6-1-2/5.13 TABLE 5, 6-1-2/5.13 TABLE 6, or 6-1-2/5.13 TABLE 7

PPF_s = Peak Pressure Factor from 6-1-2/5.11.2 TABLE 3

P_{avg} = average pressure within load patch according to 6-1-2/5.11.1, in MPa (kgf/mm², psi)

b_1 = $k_o \cdot b_2$, in m (cm, in.)

k_o = $1 - 0.3/b'$

b' = $b/(s \cdot c_6)$

c_6 = 1 (100, 1)

b = height of design ice load patch from 6-1-2/5.9.1.ii or 6-1-2/5.9.2.ii, in m (cm, in.)

s = spacing of longitudinal frames, in m (m, in.)

b_2 = $b(1 - 0.25 \cdot b')$, in m (cm, in.) if $b' < 2$

= $s \cdot c_6$, in m (cm, in.) if $b' \geq 2$

a = effective span of longitudinal local frame as given in 6-1-2/9.9, in m (cm, in.)

σ_y = minimum upper yield stress of the material, in N/mm² (kgf/mm², psi), but not greater than 690 N/mm² (70 kgf/mm², 100000 psi)

13.5 Required Plastic Section Modulus

The actual net effective plastic section modulus of the plate/stiffener combination, Z_p, as defined in 6-1-2/9.15, is to comply with the following condition: $Z_p \geq Z_{pL}$ in cm³ (cm³, in³) where:

$$Z_{pL} = 100^{n4} \cdot \left(AF \cdot PPF_s \cdot P_{avg}\right) \cdot b_1 \cdot a^2 \cdot A_4 / \left(8 \cdot \sigma_y\right)$$

where

n_4 = 3 (0, 0)

A_4 = $1/\left(2 + k_{wl} \cdot \left[\left(1 - a_4^2\right)^{0.5} - 1\right]\right)$

a_4 = A_L / A_w

A_L = minimum shear area for longitudinal as given in 6-1-2/13.3, in cm² (cm², in²)

A_w = net effective shear area of longitudinal (calculated according to 6-1-2/9.13), in cm² (cm², in²)

k_{wl} = $1/\left(1 + 2 \cdot A_{fn}/A_w\right)$ with A_{fn} as given in 6-1-2/9.15

$AF, PPF_s, P_{avg}, b_1, a$ and σ_y are as given in 6-1-2/13.3.

13.7 Structural Stability

The scantlings of the longitudinals are to meet the structural stability requirements of 6-1-2/17.

15 Framing - Web Frames and Load-carrying Stringers

15.1 General *(2024)*

i) The structural performance of web frames and load-carrying stringers is to be evaluated utilizing direct calculation methods. The evaluation may be performed based on linear or nonlinear analysis. Recognized structural idealization and calculation methods are to be applied, with detailed requirements agreed upon with ABS.

ii) Although shell plating and local frames will typically be included in a direct calculation structural model, direct calculations are not to be utilized as an alternative to the design equations prescribed for the shell plating and local frame requirements given in 6-1-2/7, 6-1-2/11 and 6-1-2/13.

iii) Acceptance criteria are defined in 6-1-2/15.9 and 6-1-2/15.11.

Commentary:

- ABS recommends the use of nonlinear analysis methods for the strength evaluation of web frames and load-carrying stringers.

- For guidance on how to conduct a Nonlinear Finite Element Analysis (NLFEA) refer to the ABS *Guidance Notes on Nonlinear Finite Element Analysis of Marine Structures*.

End of Commentary

15.3 Application *(1 July 2020)*

i) Web frames and load-carrying stringers are to be designed to withstand the ice load patch as defined in 6-1-2/5. The load patch is to be applied, without being combined with any other loads. The load patch is to be applied at locations where the combined effects of bending and shear is maximized, or structural stability is at a minimum, such as the areas around cutouts, changes in geometry, or other stress concentrations.

ii) For linear analysis the structural response under the load patch and pressure as specified in 6-1-2/5 is to be evaluated.

15.5 Structural Stability *(1 July 2020)*

Where possible, the scantlings of web frames and load-carrying stringers are to meet the structural stability requirements of 6-1-2/17. if it is not possible to meet the stability requirements, NLFEA should be used to demonstrate that at the three load cases specified in 6-1-2/15.7 that no structural instability has occurred.

15.7 Load Patch *(1 July 2020)*

For linear analysis methods, where the structural configuration is such that the members do not form part of a grillage system, the appropriate peak pressure factor (PPF) in 6-1-2/5.11.2 TABLE 3 is to be used.

For nonlinear analysis methods, the structural response under three load cases is to be evaluated;

i) Design: The load patch and pressure specified in 6-1-2/5.

ii) Overload: The design load pressure multiplied by the Polar Class dependent Overload Capacity Factor (CF_O), specified in 6-1-2/15.7 TABLE 8 is to be applied to the design load patch.

iii) Reserve: The Overload case pressure multiplied by 1.25 is to be applied to the design load patch.

TABLE 8
Overload Capacity Factor *(1 July 2020)*

Polar Class	*Overload Capacity Factor (CF_O)*	
Structure has both web frames and load-carrying stringers?	*No - has only one type of structural member*	*Yes - has both types of structural members*
PC1 - PC3	1.20	1.10
PC4 - PC5	1.25	1.15
PC6 - PC7	1.30	1.20

15.9 Acceptance Criteria - Linear Analysis *(1 July 2020)*

If the web frames and load-carrying stringers are evaluated based on linear analysis methods, the following are to be considered:

i) Nominal shear stresses in member web plates is to be less than $0.577\sigma_y$ at the design load.

ii) Nominal von Mises stresses in member flanges is to be less than $1.15\sigma_y$ at the design load.

iii) Web plate and flange elements in compression and shear do not exhibit signs of elastic buckling at the overload load case.

15.11 Acceptance Criteria - Nonlinear Analysis *(1 July 2020)*

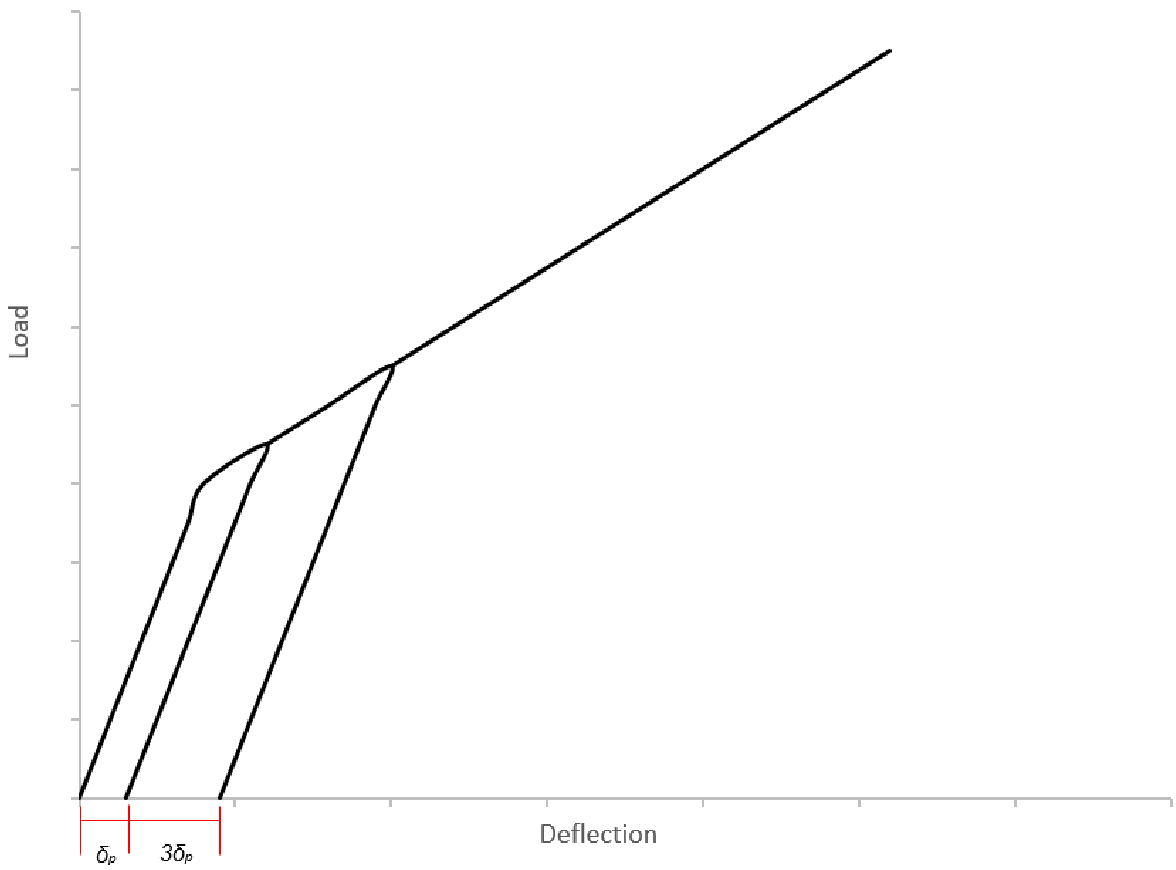
NLFEA is to be used to develop the maximum load deflection curve for the web frame or load-carrying stringer under consideration. The following criteria must be satisfied for the web frame or load-carrying stringer to be considered adequate:

i) The maximum permanent set (δ_p) after unloading from the design load case pressure specified in 6-1-2/15.7.i must be less than 0.3% of the web frame or load-carrying stringer span under consideration.

ii) The maximum permanent set (δ_p) after unloading from the overload load case pressure specified in 6-1-2/15.7.ii must be less than 0.9% of the web frame or load-carrying stringer span under consideration.

iii) The slope of the maximum load deflection curve must be positive and no structural instability has occurred at the reserve load case pressure specified in 6-1-2/15.7.iii.

FIGURE 5
Load Deflection Curve



17 Framing - Structural Stability

17.1 Framing Members *(1 July 2018)*

To prevent local buckling in the web, the ratio of web height (h_w) to net web thickness (t_{wn}) of any framing member is not to exceed:

- For flat bar sections: $h_w/t_{wn} \leq c_7/(\sigma_y)^{0.5}$
- For bulb, tee and angle sections: $h_w/t_{wn} \leq c_8/(\sigma_y)^{0.5}$

where

c_7 = 282 (90, 3396)

c_8 = 805 (257, 9695)

h_w = web height in mm (mm, in.)

t_{wn} = net web thickness in mm (mm, in.)

σ_y = minimum upper yield stress of the material, in N/mm^2 (kgf/mm^2, psi), but not greater than 690 N/mm^2 (70 kgf/mm^2, 100000 psi)

17.3 Web Stiffening *(1 July 2018)*

Framing members for which it is not practicable to meet the requirements of 6-1-2/17.1 (e.g., load-carrying stringers or deep web frames) are required to have their webs effectively stiffened. The scantlings of the web stiffeners are to provide the structural stability of the framing member. The minimum net web thickness, t_{wn}, in mm (mm, in.), for these framing members (see 6-1-2/17.3 FIGURE 6 below) is given by:

$$t_{wn} = 2.63 \cdot 10^{-3} \cdot h_u \cdot \left[\sigma_y/\left(c_{11} + c_{12} \cdot (h_u/L_w)^2\right)\right]^{0.5}$$

where

h_u = $h_w - 0.8h_f$ mm (mm, in.)

h_w = web height of stringer/web frame , in mm (mm, in.)

h_f = height of framing member penetrating the member under consideration (0 if no such framing member), in mm (mm, in.)

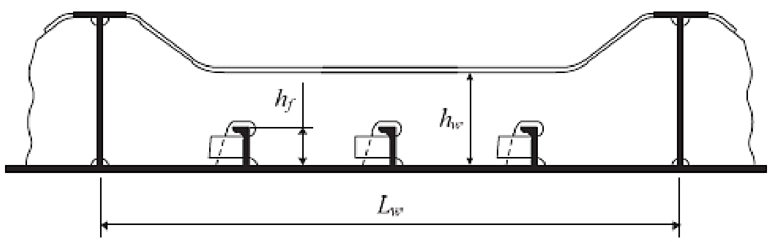
L_w = spacing between supporting structure oriented perpendicular to the member under consideration, in mm (mm, in.)

c_{11} = 5.34 (0.545, 775)

c_{12} = 4 (0.41, 580)

σ_y = minimum upper yield stress of the material, in N/mm^2 (kgf/mm^2, psi), but not greater than 690 N/mm^2 (70 kgf/mm^2, 100000 psi)

FIGURE 6
Parameter Definition for Web Stiffening



17.5 Web Thickness

In addition, the following is to be satisfied:

$$t_{wn} \geq 0.35 \cdot t_{pn} \cdot \left(\sigma_y / c_{13}\right)^{0.5}$$

where

σ_y = minimum upper yield stress of the shell plate in way of the framing member, in N/mm² (kgf/mm², psi)

c_{13} = 235 (24, 34083)

t_{wn} = net thickness of the web, in mm (mm, in.)

t_{pn} = net thickness of the shell plate in way of the framing member, in mm (mm, in.)

17.7 Flange Width and Outstand *(1 July 2018)*

To prevent local flange buckling of welded profiles, the following are to be satisfied:

i) The flange width, b_f, is not to be less than five times the net thickness of the web, t_{wn}.

ii) The flange outstand, b_{out}, in mm (mm, in.), is to meet the following requirement:

$$b_{out} / t_{fn} \leq c_{14} / \left(\sigma_y\right)^{0.5}$$

where

c_{14} = 155 (49.5, 1867)

t_{fn} = net thickness of flange, in mm (mm, in.)

σ_y = minimum upper yield stress of the material, in N/mm² (kgf/mm², psi), but not greater than 690 N/mm² (70 kgf/mm², 100000 psi)

19 Plated Structures

19.1 General *(1 July 2020)*

Plated structures are those stiffened plate elements in contact with the hull and subject to ice loads. Plated structures are to meet the requirements specified in 6-1-2/15. These requirements are applicable to an inboard extent which is the lesser of:

i) Web height of adjacent parallel web frame or stringer; or

ii) 2.5 times the depth of framing that intersects the plated structure

19.3 End Fixity

The thickness of the plating and the scantlings of attached stiffeners are to be such that the degree of end fixity necessary for the shell framing is ensured.

19.5 Stability *(1 July 2020)*

The stability of the plated structure is to adequately withstand the ice loads defined in 6-1-2/5, and 6-1-2/15 for plated structures with attached web frames or load-carrying stringers.

21 Corrosion/Abrasion Additions and Steel Renewal

21.1 General

Effective protection against corrosion and ice-induced abrasion is recommended for all external surfaces of the shell plating for all Polar Class vessels.

21.3 Corrosion/Abrasion Additions for Shell Plating

The values of corrosion/abrasion additions, t_s, in mm (mm, in.) to be used in determining the shell plate thickness are listed in 6-1-2/21.7 TABLE 9 and 6-1-2/21.7 TABLE 10.

21.5 Corrosion/Abrasion Additions for Internal Structures

Polar Class vessels are to have a minimum corrosion/abrasion addition of t_s = 1.0 mm (1.0 mm, 0.0394 in.) applied to all internal structures within the ice-strengthened hull areas, including plated members adjacent to the shell, as well as stiffener webs and flanges.

21.7 Steel Renewal

Steel renewal for ice strengthened structures is required when the gauged thickness is less than t_{net} + 0.5 mm (0.5 mm, 0.02 in.).

TABLE 9
Corrosion/Abrasion Additions for Shell Plating for Vessels Intended to Operate Ahead Only

Hull Area	*t_s, mm (mm, in.)*					
	With Effective Protection			*Without Effective Protection*		
	PC1 - PC3	**PC4 & PC5**	**PC6 & PC7**	**PC1 - PC3**	**PC4 & PC5**	**PC6 & PC7**
Bow; Bow Intermediate Icebelt	3.5 (3.5, 0.138)	2.5 (2.5, 0.098)	2.0 (2.0, 0.079)	7.0 (7.0, 0.276)	5.0 (5.0, 0.197)	4.0 (4.0, 0.158)
Bow Intermediate Lower; Midbody & Stern Icebelt	2.5 (2.5, 0.098)	2.0 (2.0, 0.079)	2.0 (2.0, 0.079)	5.0 (5.0, 0.197)	4.0 (4.0, 0.158)	3.0 (3.0, 0.118)
Midbody & Stern Lower; Bottom	2.0 (2.0, 0.079)	2.0 (2.0, 0.079)	2.0 (2.0, 0.079)	4.0 (4.0, 0.158)	3.0 (3.0, 0.118)	2.5 (2.5, 0.098)

TABLE 10
Corrosion/Abrasion Additions for Shell Plating for Vessels Intended to Operate Ahead and Astern

Hull Area	*t_s , mm (mm, in.)*					
	With Effective Protection			*Without Effective Protection*		
	PC1 - PC3	**PC4 & PC5**	**PC6 & PC7**	**PC1 - PC3**	**PC4 & PC5**	**PC6 & PC7**
Bow; Bow Intermediate Icebelt; Stern; Stern Intermediate Icebelt	3.5 (3.5, 0.138)	2.5 (2.5, 0.098)	2.0 (2.0, 0.079)	7.0 (7.0, 0.276)	5.0 (5.0, 0.197)	4.0 (4.0, 0.158)
Bow Intermediate Lower; Midbody Icebelt & Stern Intermediate lower	2.5 (2.5, 0.098)	2.0 (2.0, 0.079)	2.0 (2.0, 0.079)	5.0 (5.0, 0.197)	4.0 (4.0, 0.158)	3.0 (3.0, 0.118)
Midbody Lower; Bottom	2.0 (2.0, 0.079)	2.0 (2.0, 0.079)	2.0 (2.0, 0.079)	4.0 (4.0, 0.158)	3.0 (3.0, 0.118)	2.5 (2.5, 0.098)

23 Materials

All hull structural materials are to be in accordance with the requirements of Part 2, Chapter 1 and the following paragraphs.

23.1 General

Steel grades of plating for hull structures are to be not less than those given in 6-1-2/23.7 TABLE 12 based on the as-built thickness, the Polar Class and the Material Class of structural members according to 6-1-2/23.3.

23.3 Material Classes *(2024)*

Material classes specified in3-1-2/3.1 TABLE 2A and3-1-2/3.1 TABLE 2B are applicable to Polar Class vessels. In addition, material classes for weather and sea exposed structural members and for members attached to the weather and sea exposed plating of Polar Class vessels are given in 6-1-2/23.3 TABLE 11. Where the material classes in 6-1-2/23.3 TABLE 11 and those in 3-1-2/TABLE 2A and 3-1-2/TABLE 2B differ, the higher material class is to be applied.

TABLE 11
Material Classes for Structural Members of Polar Class Vessels *(2021)*

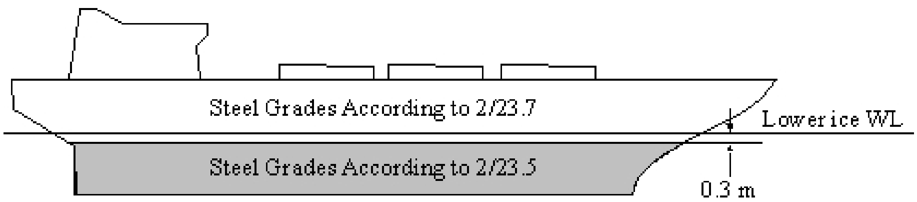
Structural Members	*Material Class*
Shell plating within the bow and bow intermediate icebelt hull areas (B, BI_i)	II
All weather and sea exposed SECONDARY and PRIMARY, as defined in 3-1-2/3.1 TABLE 2A, structural members outside $0.4L_{UI}$ amidships	I
Plating materials for stem and stern frames, rudder horn, rudder, propeller nozzle, shaft brackets, ice skeg, ice knife and other appendages subject to ice impact loads	II
All inboard framing members attached to the weather and sea-exposed plating including any contiguous inboard member within 600 mm (600 mm, 23.6 in.) of the plating	I

Structural Members	*Material Class*
Weather-exposed plating and attached framing in cargo holds of vessels which by nature of their trade have their cargo hold hatches open during cold weather operations	I
All weather and sea exposed SPECIAL, as defined in 3-1-2/3.1 TABLE 2A, structural members within $0.2L_{UI}$ from FP	II

23.5 Steel Grades *(1 July 2020)*

Steel grades for all plating and attached framing of hull structures and appendages situated below the level of 0.3 m (0.3 m, 12 in.) below the lower waterline, as shown in 6-1-2/23.5 FIGURE 7, are to be obtained from 3-1-2/3.1 TABLE 1 based on the Material Class for Structural Members in 6-1-2/23.3 TABLE 11 above, regardless of Polar Class.

FIGURE 7
Steel Grade Requirements for Submerged and Weather Exposed Shell Plating



23.7 Steel Grades for Weather Exposed Plating *(1 July 2020)*

Steel grades for all weather exposed plating of hull structures and appendages situated above the level of 0.3 m (0.3m, 12 in.) below the lower ice waterline, as shown in 6-1-2/23.5 FIGURE 7, are to be not less than given in 6-1-2/23.7 TABLE 12.

TABLE 12
Steel Grades for Weather Exposed Plating[1, 2] *(2021)*

Thickness, t mm (in.)	*Material Class I*						*Material Class II*						*Material Class III*								
	PC1-5			**PC6 &7**			**PC1-5**			**PC6 &7**			**PC1-3**			**PC4 & 5**			**PC6 &7**		
	MS	*HT*	*XHT*	*MS*	*HT*	*XHT*	*MS*	*HT*	*XHT*	*MS*	*HT*	*XHT*	*MS*	*HT*	*XHT*	*MS*	*HT*	*XHT*	*MS*	*HT*	*XHT*
$t \leq 10$ $t \leq 0.394$	B	AH	AQ	B	AH	AQ	B	AH	AQ	B	AH	AQ	E	EH	EQ	E	EH	EQ	B	AH	AQ
$10 < t \leq 15$ $0.394 < t \leq 0.591$	B	AH	AQ	B	AH	AQ	D	DH	DQ	B	AH	AQ	E	EH	EQ	E	EH	EQ	D	DH	DQ
$15 < t \leq 20$ $0.591 < t \leq 0.787$	D	DH	DQ	B	AH	AQ	D	DH	DQ	B	AH	AQ	E	EH	EQ	E	EH	EQ	D	DH	DQ
$20 < t \leq 25$ $0.787 < t \leq 0.984$	D	DH	DQ	B	AH	AQ	D	DH	DQ	B	AH	AQ	E	EH	EQ	E	EH	EQ	D	DH	DQ
$25 < t \leq 30$ $0.984 < t \leq 1.18$	D	DH	DQ	B	AH	AQ	E	EH	EQ	D	DH	DQ	E	EH	EQ	E	EH	EQ	E	EH	EQ
$30 < t \leq 35$ $1.18 < t \leq 1.38$	D	DH	DQ	B	AH	AQ	E	EH	EQ	D	DH	DQ	E	EH	EQ	E	EH	EQ	E	EH	EQ
$35 < t \leq 40$ $1.38 < t \leq 1.58$	D	DH	DQ	D	DH	DQ	E	EH	EQ	D	DH	DQ	Ø	FH	FQ	E	EH	EQ	E	EH	EQ
$40 < t \leq 45$ $1.58 < t \leq 1.77$	E	EH	EQ	D	DH	EQ	E	EH	EQ	D	DH	DQ	Ø	FH	FQ	E	EH	EQ	E	EH	EQ
$45 < t \leq 50$ $1.77 < t \leq 1.97$	E	EH	EQ	D	DH	EQ	E	EH	EQ	D	DH	DQ	Ø	FH	FQ	Ø	FH	FQ	E	EH	EQ

Ø Not Applicable

Notes:

1 MS: Ordinary strength steel, HT: High strength steel, XHT: Extra high strength steel

2 Includes weather-exposed plating of hull structures and appendages, as well as their outboard framing members, situated above a level of 0.3 m (0.3 m, 12 in.) below the lowest ice waterline.

3 Grades D, DH are allowed for a single strake of side shell playing not more than 1.8 , (1.8 m, 70.9 in.) wide from 0.3 m (0.3 m, 12 in.) below the lowest ice waterline.

23.9 Castings *(1 July 2020)*

Castings are to have specified properties consistent with the expected service temperature for the cast component.

25 Longitudinal Strength

25.1 Application *(2024)*

i) A ramming impact on the bow is the design scenario for the evaluation of the longitudinal strength of the hull.

ii) Intentional ramming is not considered as a design scenario for ships which are designed with vertical or bulbous bows, see 6-1-1/1.1.viii. Hence the longitudinal strength requirements given in this section are not to be considered for ships with stem angle γ_{stem} stem equal to or larger than 80°.

iii) Ice loads are only to be combined with still water loads. The combined stresses are to be compared against permissible stresses at different locations along the vessel's length. In addition, sufficient local buckling strength is also to be maintained.

25.3 Design Vertical Ice Force at the Bow *(2021)*

The design vertical ice force at the bow, F_{IB}, in MN (tf, Ltf) is to be taken as:

$F_{IB} =$ minimum $\left(F_{IB,1}; F_{IB,2}\right)$

where

$F_{IB,1}$ = $0.534 \cdot K_I^{0.15} \cdot \sin^{0.2}(\gamma_{stem}) \cdot (D_{UI} \cdot K_h)^{0.5} \cdot CF_L$

$F_{IB,2}$ = $1.20 \cdot CF_F$

K_I = indentation parameter = K_f / K_h

a) *For the case of a blunt bow form:*

K_f = $c_{15}\left[2 \cdot C \cdot (B_{UI}/c_{16})^{1-e_b} / (1+e_b)\right]^{0.9} \cdot \tan(\gamma_{stem})^{-0.9(1+e_b)}$ MN/m (tf/cm, Ltf/in)

c_{15} = 1 (1.02, 2.54)

c_{16} = 1 (1, 3.28)

e_b = bow shape exponent which best describes the waterplane (see 6-1-2/25.3 FIGURE 8 and 6-1-2/25.3 FIGURE 9)

= 1.0 for a simple wedge bow form

= 0.4 to 0.6 for a spoon bow form

= 0 for a landing craft bow form

An approximate e_b determined by a simple fit is acceptable

b) *For the case of wedge bow form* $(\alpha_{stem} < 80\ deg)$, $e_b = 1$ *and the above simplifies to:*

K_f = $\left[\tan(\alpha_{stem}) / \tan^2(\gamma_{stem})\right]^{0.9}$ MN/m (tf/cm, Ltf/in)

K_h = $c_{17} A_{wp}$ MN/m (tf/cm, Ltf/in)

c_{17} = 0.01 (0.01, 0.00237) MN/m^3 [tf/(m^2-cm), Ltf/(ft^2-in)]

CF_L = Longitudinal Strength Class Factor from 6-1-2/5.3 TABLE 1

γ_{stem} = stem angle to be measured between the horizontal axis and the stem tangent at the upper ice waterline , in degrees (buttock angle as per 6-1-2/5.5.iii FIGURE 2 measured on the centerline)

α_{stem} = waterline angle measured in way of the stem at the upper ice waterline (UIWL), in degrees (see 6-1-2/25.3 FIGURE 8)

C = $1/\left[2 \cdot (L_B/B_{UI})^{eb}\right]$

B_{UI} = molded breadth corresponding to the upper ice waterline (UIWL), in m (m, ft)

L_B = bow length used in the equation $y = B_{UI}/2 \cdot (x/L_B)^{eb}$, in m (m, ft) (see 6-1-2/25.3 FIGURE 8 and 6-1-2/25.3 FIGURE 9)

D_{UI} = displacement as defined in 6-1-2/1.3, not to be taken less than 10 kiloton (10 kiloton, 9.8 kLt)

A_{wp} = waterplane area corresponding to the upper ice waterline (UIWL), in m^2 (m^2, ft^2)

CF_F = Flexural Failure Class Factor from 6-1-2/5.3 TABLE 1

FIGURE 8
Bow Shape Definition *(2021)*

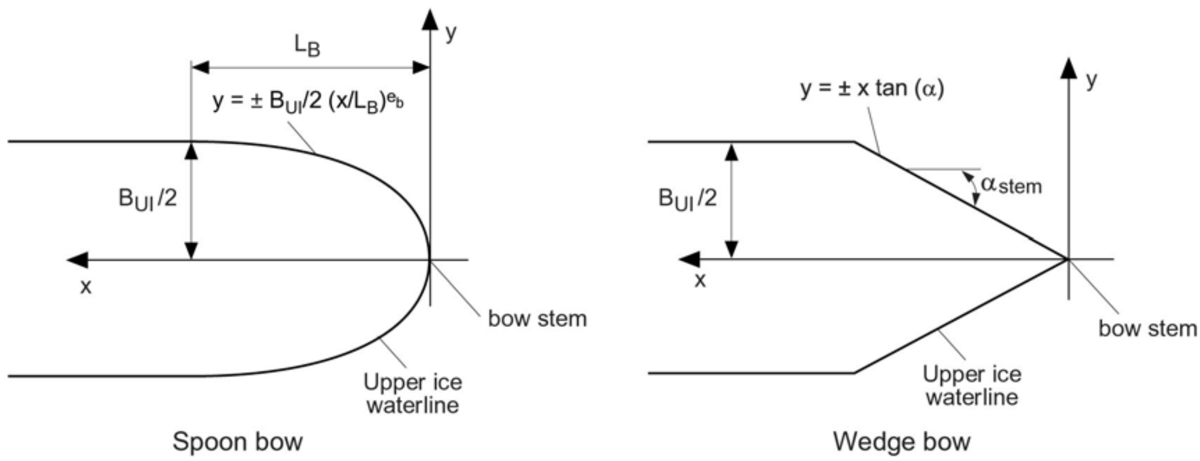
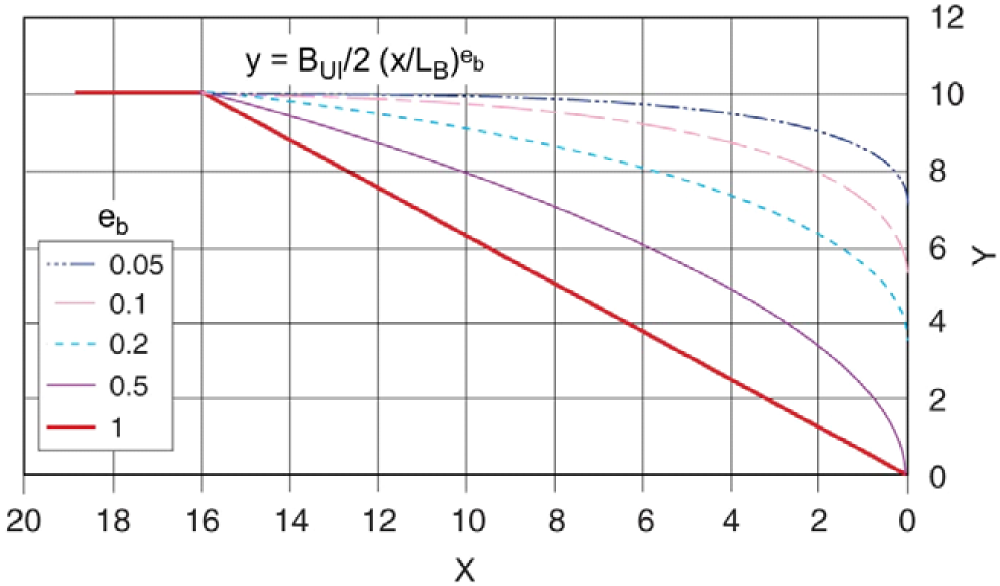


FIGURE 9
Illustration of e_b Effect on the Bow Shape for B_{UI} = 20 and L_B = 16 *(2021)*



25.5 Design Vertical Shear Force

25.5.1 *(2021)*

The design vertical ice shear force, F_I, in MN (tf, Ltf) along the hull girder is to be taken as:

$F_I = C_f \cdot F_{IB}$

where

C_f = longitudinal distribution factor to be taken as follows:

i) *Positive shear force*

C_f = 0.0 between the aft end of L_{UI} and $0.6L_{UI}$ from aft

= 1.0 between $0.9L_{UI}$ from aft and the forward end of L_{UI}

ii) *Negative shear force*

C_f = 0.0 at the aft end of L_{UI}

= -0.5 between $0.2L_{UI}$ and $0.6L_{UI}$ from aft

= 0.0 between $0.8L_{UI}$ from aft and the forward end of L_{UI}

Intermediate values are to be determined by linear interpolation

25.5.2

The applied vertical shear stress, τ_a, is to be determined along the hull girder in a similar manner as in 3-2-1/3.9 by substituting the design vertical ice shear force for the design vertical wave shear force.

25.7 Design Vertical Ice Bending Moment

25.7.1 *(2021)*

The design vertical ice bending moment, M_I, in MN-m (tf-m, Ltf-ft) along the hull girder is to be taken as:

$$M_I = 0.1 \cdot C_m \cdot L_{UI} \cdot \sin^{-0.2}(\gamma_{stem}) \cdot F_{IB}$$

where

L_{UI} = length as defined in6-1-2/1.3, in m (m, ft)

γ_{stem} = as given in 6-1-2/25.3

F_{IB} = design vertical ice force at the bow, in MN (tf, Ltf)

C_m = longitudinal distribution factor for design vertical ice bending moment to be taken as follows:

= 0.0 at the aft end of L_{UI}

= 1.0 between $0.5L_{UI}$ and $0.7L_{UI}$ from aft

= 0.3 at $0.95L_{UI}$ from aft

= 0.0 at the forward end of L_{UI}

Intermediate values are to be determined by linear interpolation

25.7.2 *(2021)*

The applied vertical bending stress, σ_a, is to be determined along the hull girder in a similar manner as in 3-2-1/3.7 by substituting the design vertical ice bending moment for the design vertical wave bending moment. The vessel still water bending moment is to be taken as the permissible still water bending moment in sagging condition.

25.9 Longitudinal Strength Criteria *(1 July 2020)*

The strength criteria provided in 6-1-2/25.9 TABLE 13 are to be satisfied. The design stress is not to exceed the permissible stress.

TABLE 13
Longitudinal Strength Criteria

Failure Mode	*Applied Stress*	*Permissible Stress when* $\sigma_y/\sigma_u \le 0.7$	*Permissible Stress when* $\sigma_y/\sigma_u > 0.7$
Tension	σ_a	$\eta \cdot \sigma_y$	$\eta \cdot 0.41(\sigma_u + \sigma_y)$
Shear	τ_a	$\eta \cdot \sigma_y/(3)^{0.5}$	$\eta \cdot 0.41(\sigma_u + \sigma_y)/(3)^{0.5}$
Buckling	σ_a	σ_c	for plating and for web plating of stiffeners
		$\sigma_c/1.1$	for stiffeners
	τ_a	τ_c	

where

σ_a = applied vertical bending stress, in N/mm^2 (kgf/mm^2, psi)

τ_a = applied vertical shear stress, in N/mm^2 (kgf/mm^2, psi)

σ_y = minimum upper yield stress of the material, in N/mm^2 (kgf/mm^2, psi), but not greater than 690 N/mm^2 (70 kgf/mm^2, 100000 psi)

σ_u = ultimate tensile strength of material, in N/mm^2 (kgf/mm^2, psi)

σ_c = critical buckling stress in compression, according to Appendix 3-2-A4, in N/mm^2 (kgf/mm^2, psi)

τ_c = critical buckling stress in shear, according to Appendix 3-2-A4, in N/mm^2 (kgf/mm^2, psi)

η = 0.6 for ships which are assigned the additional notation **Ice Breaker**

= 0.8, otherwise

27 Stem and Stern Frames

For Polar Class **PC6** and **PC7** vessels requiring Baltic Ice Class **1AA** or **1A** equivalency of Section 6-1-4, the stem and stern requirements of the Finnish-Swedish Ice Class Rules may need to be additionally considered.

29 Appendages

29.1 General

All appendages are to be designed to withstand forces appropriate for the location of their attachment to the hull structure or their position within a hull area.

29.3 Load Definition and Response Criteria *(2024)*

Load definition and response criteria are to be determined on a case-by-case basis.

Commentary:

- Model testing, full scale ice load data, or ice specific ice loads models can be used to develop the appendage loads.
- Refer to the ABS *Guidance Notes on Ice Loads on Azimuthing Propulsion Units* for a baseline for determining propulsion appendage loads.

End of Commentary

31 Local Details

31.1 General

For the purpose of transferring ice-induced loads to supporting structure (bending moments and shear forces), local design details are to prepared and submitted for review.

31.3 Cut-outs

The loads carried by a member in way of cut-outs are not to cause instability. Where necessary, the structures are to be stiffened.

33 Welding

33.1 General

Hull construction welding design is to comply with 3-2-19. All welding within ice-strengthened areas is to be of the double continuous type.

33.3 Continuity of Strength

Continuity of strength is to be provided at all structural connections.

33.5 Filler Metals

When the ABS ordinary and higher strength hull steels of 2-1-2/15.9 TABLE 5 or 2-1-3/7.3 TABLE 5 are applied in accordance with 6-1-2/23.7 TABLE 12, approved filler metals appropriate to the grades shown in Part 2, Appendix 3 may be used.

33.7 Hull Steels Other than the ABS Grades *(2024)*

Where the use of steels other than ABS has approved for the welding of hull steels other than the ABS grades in 6-1-2/23.7 TABLE 12, weld metal is to exhibit a Charpy V-Notch toughness value at least equivalent to the transverse base metal requirements ($^2/_3$ of longitudinal base metal requirements).

PART 6

CHAPTER 1

Strengthening for Navigation in Ice

SECTION 3

Machinery Requirements for Polar Class Vessels

1 General *(2024)*

1.1 Application

The contents of this section apply to main propulsion, steering gear, emergency and essential auxiliary systems essential for the safety of the vessel and the survivability of the crew.

1.2 Objective *(2024)*

1.2.1 Goals

The machinery for Polar Class vessels covered in this section is to be designed, constructed, operated and maintained to:

Goal No.	*Goals*
PROP1	Provide sufficient thrust/power to move or maneuver the vessel when required.
PROP2	Provide redundancy and/or reliability to maintain propulsion.
PROP5	Provide redundancy and/or reliability to maintain maneuverability.
ENV1.1	Minimize pollution from lubricants and additives likely to come in contact with the marine environment.
POW2	Provide power to enable the machinery/equipment/electrical installation to perform its required functions necessary for the safe operation of the vessel.
POW4	*Enable all electrical services required for safety to be available during emergency condition. (SOLAS II-1 Reg 40-1.2)*
HAB1.1	Effectively control the indoor environmental parameters in all conditions of weather and climate.
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.
STAB 2	Have adequate subdivision and stability to provide survivability to damage or accidental conditions.
STAB 6	Provide means to control the overall vessel weight and distribution to maintain adequate trim and stability.

The goals in the cross-referenced Rules/Regulations are also to be met.

1.2.2 Functional Requirements

In order to achieve the above stated goals, the design, construction, and maintenance of the machinery of Polar Class Vessels are to be in accordance with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
Propulsion, Maneuvering, Station Keeping - (PROP)	
PROP-FR1	Systems and machinery are to be strengthened to maintain propulsion and steering during operations in ice conditions and temperatures appropriate for the ice class of the vessel.
PROP-FR2	Auxiliary machinery & associated systems are to be protected from the harmful effects of low air temperatures, ice or snow.
PROP-FR3	Provide contingency plans for high ice class vessels (PC5 and above) to reach the vessel to a safe location in case of propeller damage.
PROP-FR4	Provide means to release a stuck propeller.
PROP-FR5	The propeller is to be able to withstand the loads and stresses due to ice interaction.
PROP-FR6	The propulsion system is to withstand the most severe condition of coincident bending, thrust and torsional dynamics without yielding or fatiguing of any propulsion components.
PROP-FR7	The Azimuthing Propulsion Unit(APU) is to be able to withstand a blade failure in the worst possible location without yielding.
PROP-FR8	Components of controllable pitch propellers such as flange, pitch change mechanism, stud bolts are to be designed to have adequate strength to withstand design pitch conditions during ice operation.
PROP-FR9	Appropriate pressure to maintain the propeller in the hub and prevent deformation under ice operation is required, during fitting of the keyless propeller.
PROP-FR10	Load-bearing parts are to be designed to withstand without deleterious deflection and prevent fatigue failure during the anticipated design life.
PROP-FR11	Gear teeth are to be designed to withstand contact stress without progressive pitting or scuffing.
PROP-FR12	Gear teeth roots are to be designed to withstand the bending stress without causing tooth root fillet cracking or fracture.
PROP-FR13	A means is to be provided to connect the power-generating source to the propulsor that is capable of being engaged in an emergency in a reasonably short time.
PROP-FR14	Elastic/flexible couplings are to be able to withstand the anticipated loads/torque while encountering ice blocks.
PROP-FR15 (ENV)	Shaft seals are to be able to maintain the seal in ambient temperature to prevent the egress of pollutants.
PROP-FR16	Propulsion prime movers are designed for producing the rated power in specified ambient conditions.
PROP-FR17	Essential equipment and their supports are to be capable of withstanding accelerations associated with vessel-ice interactions.
PROP-FR18	Cooling media inlets are to be designed and arranged to minimize or prevent ingestion of ice into the machinery that is essential for the propulsion and safety of the vessel.

Functional Requirement No.	*Functional Requirements*
PROP-FR19	Able to maintain the continuous flow of water for cooling suitable for the installed power.
PROP-FR20	Provide means to separate ice and breathe air in ice boxes.
PROP-FR21	Provide means to access ice boxes for inspection, maintenance/repair.
PROP-FR22	Enable clearing of any ice build-up.
PROP-FR23	Steering systems are to be protected from ice loads which include ice loads from the vessel backing in ice.
PROP-FR24	The steering system is to be able to maintain steering direction during ice loads expected for the ice class of the vessel.
PROP-FR25	Ice loads that exceed the steering system's holding capacity are not to cause damage to the steering system and steering capability is to be quickly regained after an overload.
Materials (MAT)	
MAT-FR1	Materials exposed to low temperatures are to withstand the maximum working stresses without any deformation or fatigue failure.
MAT-FR2	The material elongation is to be sufficiently high so that it can withstand accidental shock or impact loads during service.
Stability (STAB)	
STAB-FR1	Piping is to be designed, arranged, or protected to minimize flooding risks.
STAB-FR2	Ballast tanks are to be protected from freezing.
Habitability (HAB)	
HAB-FR1	Air handling systems are to control the air temperature to a level suitable for the intended application while the vessel is in ambient air temperatures expected.
Power Generation & Distribution (POW)	
POW-FR1	An emergency source of power is to be readily available considering the anticipated temperatures and environmental conditions.

The functional requirements in the cross-referenced Rules/Regulations are also to be met.

1.2.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved, refer to Part 1D, Chapter 2.

1.2.4 Definitions of symbols *(1 July 2024)*

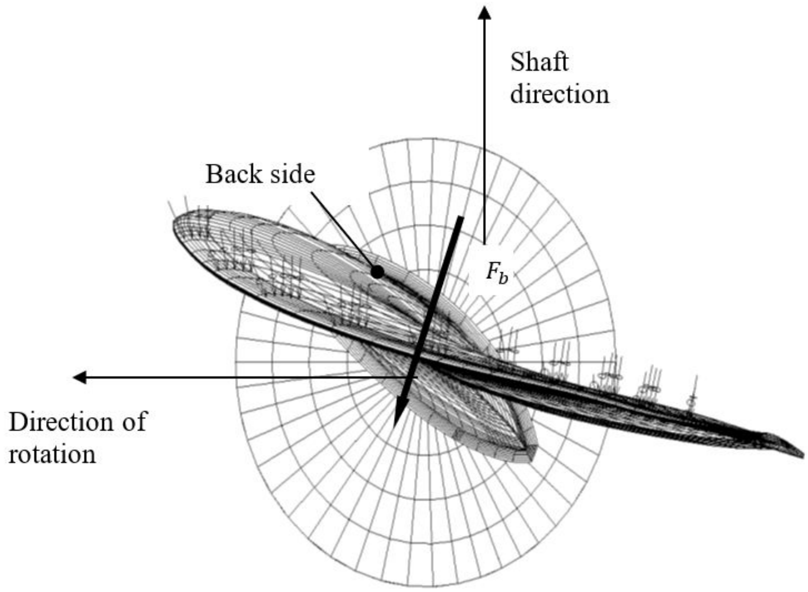
Symbol	*Unit*	*Definition*
c	m	chord length of blade section
$c_{0.7}$	m	chord length of blade section at 0.7R propeller radius
CP	-	controllable pitch
D	m	propeller diameter
d	m	external diameter of propeller hub (at propeller plane)
d_{pin}	mm	diameter of shear pin

Symbol	*Unit*	*Definition*
D_{limit}	m	limit value of propeller diameter
EAR	-	expanded blade area ratio
F_b	kN	maximum backward blade force for the ship's service life (negative sign)
F_{ex}	kN	ultimate blade load resulting from blade failure through plastic bending
F_f	kN	maximum forward blade force for the ship's service life (positive sign)
F_{ice}	kN	ice load
$(F_{ice})_{max}$	kN	maximum ice load for the ship's service life
FP	-	fixed pitch
h_0	m	depth of the propeller centreline from lower ice waterline (LIWL)
(H_{ice})	m	Ice block dimension for propeller load definition
I	kgm^2	equivalent mass moment of inertia of all parts on engine side of component under consideration
I_t	kgm^2	equivalent mass moment of inertia of the whole propulsion system
k	-	shape parameter for Weibull distribution
$LIWL$	m	lower ice waterline
m	-	slope for S-N curve in log/log scale
M_{BL}	kNm	blade bending moment
MCR		maximum continuous rating
N	-	number of ice load cycles
n	rev/s	propeller rotational speed
n_n	rev/s	nominal propeller rotational speed at MCR in free running condition
N_{class}	-	reference number of ice impacts per propeller revolution per ice class
N_{ice}	-	total number of ice load cycles on propeller blade for the ship's service life
N_R	-	reference number of ice load cycles for equivalent fatigue stress (10^8 cycles)
N_Q	-	number of propeller revolutions during a milling sequence
$P_{0.7}$	m	propeller pitch at 0.7R radius
$P_{0.7n}$	m	propeller pitch at 0.7R radius at MCR in free running condition
$P_{0.7b}$	m	propeller pitch at 0.7R radius at MCR in bollard condition
PCD	m	pitch circle diameter
$Q(\phi)$	kNm	Torque
Q_{Amax}	kNm	maximum response torque amplitude as a simulation result
Q_{emax}	kNm	maximum engine torque
$Q_F(\phi)$	kNm	Ice torque excitation for frequency domain calculations
Q_{fr}	kNm	friction torque in pitching mechanism; reduction of spindle torque
Q_{max}	kNm	maximum torque on the propeller resulting from propeller/ice interaction

Symbol	*Unit*	*Definition*
Q_{motor}	kNm	electric motor peak torque
Q_n	kNm	nominal torque at MCR in free running condition
$Q_r(t)$	kNm	response torque along the propeller shaft line
Q_{peak}	kNm	maximum of the response torque $Q_r(t)$
Q_{smax}	kNm	maximum spindle torque of the blade for the ship's service life
Q_{sex}	kNm	extreme spindle torque corresponding to the blade failure load F_{ex}
Q_{vib}	kNm	Vibratory torque at considered component, taken from frequency domain open water TVC
R	m	propeller radius
r	m	blade section radius
S	-	Safety factor
S_{fat}	-	Safety factor for fatigue
S_{ice}	-	Ice strength index for blade ice force
T	kN	Hydrodynamic propeller thrust in bollard condition
T_b	kN	maximum backward propeller ice thrust for the ship's service life
T_f	kN	maximum forward propeller ice thrust for the ship's service life
T_n	kN	propeller thrust at MCR in free running condition
T_r	kN	maximum response thrust along the shaft line
T_{kmax}	kNm	maximum torque capacity of flexible coupling
T_{kmax2}	kNm	T_{kmax} at N=1 load cycle
T_{max1}	kNm	T_{kmax} at N=5x10^4 load cycles
T_{kv}	kNm	vibratory torque amplitude at N=10^6 load cycles
ΔT_{kmax}	kNm	maximum range of T_{kmax} at N=5x10^4 load cycles
t	m	maximum blade section thickness
z	-	number of propeller blades
z_{pin}	-	number of shear pins
α_i	deg	duration of propeller blade/ice interaction expressed in rotation angle
γ_ε	-	the reduction factor for fatigue; scatter and test specimen size effect
γ_v	-	the reduction factor for fatigue; variable amplitude loading effect
γ_m	-	the reduction factor for fatigue; mean stress effect
ρ	-	a reduction factor for fatigue correlating the maximum stress amplitude to the equivalent fatigue stress for 10^8 stress cycles
$\sigma_{0.2}$	MPa	proof yield strength (at 0.2% plastic strain) of material
σ_{exp}	MPa	mean fatigue strength of blade material at 10^8 cycles to failure in sea water
σ_{fat}	MPa	equivalent fatigue ice load stress amplitude for 10^8 stress cycles
σ_{fl}	MPa	characteristic fatigue strength for blade material

Symbol	*Unit*	*Definition*
σ_{ref1}	MPa	reference stress $\sigma_{ref1} = 0.6\sigma_{0.2} + 0.4\sigma_u$
σ_{ref2}	MPa	reference stress, whichever is less of the following: $\sigma_{ref2} = 0.7\sigma_u$ $\sigma_{ref2} = 0.6\sigma_{0.2} + 0.4\sigma_u$
σ_{st}	MPa	maximum stress resulting from F_b or F_f
σ_u	MPa	ultimate tensile strength of blade material
$(\sigma_{ice})_{bmax}$	MPa	principal stress caused by the maximum backward propeller ice load
$(\sigma_{ice})_{fmax}$	MPa	principal stress caused by the maximum forward propeller ice load
$(\sigma_{ice})_{Amax}$	MPa	maximum ice load stress amplitude at the considered location on the blade
σ_{mean}	MPa	mean stress
$(\sigma_{ice})_A(N)$	MPa	blade stress amplitude distribution

1.2.5 Definition of Loads *(1 July 2024)*



	Definition	*Use of the load in design process*
F_b	The maximum lifetime backward force on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade. The direction of the force is perpendicular to 0.7R chord line. See Figure.	Design force for strength calculation of the propeller blade.
F_f	The maximum lifetime forward force on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade. The direction of the force is perpendicular to 0.7R chord line.	Design force for calculation of strength of the propeller blade.

	Definition	*Use of the load in design process*
Q_{smax}	The maximum lifetime spindle torque on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade.	In designing the propeller strength, the spindle torque is automatically taken into account because the propeller load is acting on the blade as distributed pressure on the leading edge or tip area.
T_b	The maximum lifetime thrust on propeller (all blades) resulting from propeller/ice interaction. The direction of the thrust is the propeller shaft direction and the force is opposite to the hydrodynamic thrust.	Is used for estimation of the response thrust T_r. T_b can be used as an estimate of excitation for axial vibration calculations. However, axial vibration calculations are not required in the rules
T_f	The maximum lifetime thrust on propeller (all blades) resulting from propeller/ice interaction. The direction of the thrust is the propeller shaft direction acting in the direction of hydrodynamic thrust.	Is used for estimation of the response thrust T_r. T_f can be used as an estimate of excitation for axial vibration calculations. However, axial vibration calculations are not required in the rules
Q_{max}	The maximum ice-induced torque resulting from propeller/ice interaction on one propeller blade, including hydrodynamic loads on that blade.	Is used for estimation of the response torque Q_r along the propulsion shaft line and as excitation for torsional vibration calculations.
F_{ex}	Ultimate blade load resulting from blade loss through plastic bending. The force that is needed to cause total failure of the blade so that plastic hinge is caused to the root area. The force is acting on 0.8R.	Blade failure load is used to dimension the blade bolts, pitch control mechanism, propeller shaft, propeller shaft bearing and trust bearing. The objective is to guarantee that total propeller blade failure should not cause damage to other components.
Q_{sex}	Maximum spindle torque resulting from blade failure load.	Is used to ensure pyramid strength principle for the pitching mechanism.
Q_r	Maximum response torque along the propeller shaft line, taking into account the dynamic behaviour of the shaft line for ice excitation (torsional vibration) and hydrodynamic mean torque on propeller.	Design torque for propeller shaft line components.
T_r	Maximum response thrust along shaft line, taking into account the dynamic behaviour of the shaft line for ice excitation (axial vibration) and hydrodynamic mean thrust on propeller.	Design thrust for propeller shaft line components.

3 Drawings and Particulars to be Submitted

3.1 Environmental Conditions

Details of the environmental conditions and the required ice class for the machinery, if different from vessel's ice class.

3.3 Drawings

Detailed drawings of the main propulsion machinery. Description of the main propulsion, steering, emergency and essential auxiliaries are to include operational limitations. Information on essential main propulsion load control functions.

3.5 Description Detailing

Description detailing how main, emergency and auxiliary systems are located and protected to prevent problems from freezing, ice and snow and evidence of their capability to operate in intended environmental conditions.

3.7 Calculations and Documentation *(1 July 2019)*

Calculations and documentation indicating compliance with the requirements of this section.

The following table shows a sample list of information and calculations required to be submitted:

General	*Torsional vibration calculations addressing the effect of ice/ propeller interaction (including as a minimum: i) Shaft speed drop curve (s) due to ice impact ii) Shaft response torque curve(s) etc.)* *Fatigue calculations for the propulsion line components considering ice loads (including: S-N curves, Miner's Rule calculations etc.)*
Main Engine	Main engine power curve (power supply), Geometrical details (i.e. overall dimensions and detailed dimensions of the crankthrows) and material properties of the crankshaft, Harmonic packs (i.e. excitation tables), Torsional damping coefficients between journals.
Propeller	Propeller power curve (power demand), Main particulars, Inertial properties, Water entrained factors, Torsional and axial damping coefficients.
Shaftline (including crankshaft)	Bearing offsets, Bearing clearances, Bearing radial and axial stiffnesses, Bearing torsional and axial damping coefficients.

5 System Design

5.1 General

All machinery is to be suitable for operation under the environmental conditions to which it will be exposed in service and is to include all necessary special provisions for that purpose.

5.3 Governmental Authority

Attention is directed to the appropriate governmental authorities in the intended regions of operation for additional requirements in consideration of operation in ice such as fuel capacity, refueling capability, water capacity, radio communications requirements, etc.

5.5 Damage by Freezing *(2024)*

Systems, subject to damage by freezing, are to be drainable.

Commentary:

This applies to systems essential to the operation of the propulsion machinery, steering or power production necessary for the safety of the vessel. For non-ice class related low temperature protection of vessel's systems and machinery, refer to the ABS *Guide for Vessels Operating in Low Temperature Environments*.

End of Commentary

5.7 Propeller Damage *(2024)*

Vessels classed **PC1** to **PC5** inclusive are to have means to provide sufficient vessel operation in the case of propeller damage including CP-mechanism (i.e., pitch control mechanism).

Commentary:

Sufficient vessel operation means that the vessel should be able to reach safe harbor (safe location) where repair can be undertaken in case of propeller damage. This may be achieved either by a temporary repair at sea, or by towing assuming assistance is available (condition for approval).

End of Commentary

5.9 Turning Gear *(2024)*

Means are to be provided to free a stuck propeller by turning backwards.

Commentary:

This means that a plant intended for unidirectional rotation should be equipped at least with a sufficient turning gear that is capable of turning the propeller in reverse direction.

End of Commentary

5.11 Propeller *(1 July 2024)*

The propeller is to be fully submerged at the ships LIWL.

7 Materials *(1 July 2024)*

Materials are to be of an approved ductile material. Ferritic nodular cast iron may be used for parts other than bolts. For nodular cast iron an averaged impact energy value of 10 J at testing temperature is regarded as equivalent to the Charpy V test requirements defined below.

7.1 Materials Exposed to Sea Water *(1 July 2024)*

Materials exposed to sea water, such as propeller blades, propeller hub, cast thruster bodies are to have an elongation not less than 15% on a test specimen according to Part 2 of the Rules.

Charpy V impact tests are to be carried out for materials other than bronze and austenitic steel. Average impact energy of 20 J (20 J, 14.75 lbf-ft) taken from three Charpy V tests is to be obtained at -10°C (-10°C, +14°F). However, Charpy V impact test requirements of 2-3-7 or 2-3-9 of the Rules as applicable for ships with ice class notation, are also to be applied to ships covered by this section.

7.3 Materials Exposed to Sea Water Temperature *(1 July 2024)*

Materials exposed to sea water temperature are to be of steel or other approved ductile material. Charpy V impact tests are to be carried out for materials other than bronze and austenitic steel. Average impact energy value of 20 J (20 J, 14.75 lbf-ft) taken from three Charpy V tests is to be obtained -10°C (-10°C, +14°F). However, the Charpy V impact test requirements of 2-3-7 of the Rules as applicable for ships with ice class notation, are also to be applied to ships covered by this section.

This requirement applies to components such as but not limited to blade bolts, CP-mechanisms, shaft bolts, propeller shaft, strut-pod connecting bolts, etc. This does not apply to surface hardened components, such as bearings and gear teeth or sea water cooling lines (heat exchangers, pipes, valves, fitting etc.).

For definition of structural boundaries exposed to sea water temperature see 6-1-2/23.5 FIGURE 7.

7.5 Materials Exposed to Low Air Temperature *(1 July 2024)*

Materials of essential components exposed to low air temperature are to be of steel or other approved ductile material. Average impact energy value of 20 J (20 J, 14.75 lbf-ft) taken from three Charpy V tests is to be obtained at 10°C (10°C, 50°F) below the lowest design temperature. Charpy V impact tests are not required for bronze and austenitic steel.

This does not apply to surface hardened components, such as bearings and gear teeth.

For definition of structural boundaries exposed to air temperature see 6-1-2/23.5 FIGURE 7.

Commentary:

If a design service temperature is not assigned, the design service temperature for the materials exposed to low air temperature should be considered as (-10°C, +14°F).

End of Commentary

9 Ice Interaction Load

9.1 Propeller-Ice Interaction *(1 July 2024)*

These Rules cover open and ducted type propellers situated at the stern of a vessel having controllable pitch or fixed pitch blades. Ice loads on bow propellers are subject to ABS technical assessment and approval. The given loads are expected, single occurrence, maximum values for the whole ships service life for normal operational conditions, including loads resulting from directional change of rotation where applicable. These loads do not cover off-design operational conditions, for example when a stopped propeller is dragged through ice. These Rules also cover loads due to propeller ice interaction for azimuth and fixed thrusters with geared transmission or integrated electric motor ("geared and podded propulsors"). However, the load models of the Rules do not include propeller/ice interaction loads when ice enters the propeller of a turned azimuthing thruster from the side (radially) or load case when ice block hits on the propeller hub of a pulling propeller. Ice loads resulting from ice impacts on the body of thrusters are to be estimated on a case by case basis, however are not included within the following section.

The loads given in section 6-1-3/9 are total loads including ice-induced loads and hydrodynamic loads (unless otherwise stated) during ice interaction and are to be applied separately (unless otherwise stated) and are intended for component strength calculations only.

F_b is the maximum force experienced during the lifetime of the ship that bends a propeller blade backwards when the propeller mills an ice block while rotating ahead. F_f is the maximum force experienced during the lifetime of the ship that bends a propeller blade forwards when a propeller interacts with an ice block while rotating ahead. F_b and F_f originate from different propeller/ice interaction phenomena, which do not act simultaneously. Hence they are to be applied separately.

9.3 Ice Class Factors *(1 July 2024)*

6-1-3/9.3 TABLE 1 below lists the design ice thickness and ice strength index to be used for estimation of the propeller ice loads. The dimensions of the considered design ice block are H_{ice}x2H_{ice}x3H_{ice}. The design ice block and ice strength index (S_{ice}) are used for the estimation of propeller ice loads.

TABLE 1
Design Ice Thickness and Ice Strength Index

Ice Class	H_{ice} , *m (m, ft)*	S_{ice} , *[-]*
PC1	4.0 (4.0, 13.12)	1.2
PC2	3.5 (3.5, 11.48)	1.1
PC3	3.0 (3.0, 9.84)	1.1
PC4	2.5 (2.5, 8.20)	1.1

Ice Class	H_{ice} *, m (m, ft)*	S_{ice} *, [-]*
PC5	2.0 (2.0, 6.56)	1.1
PC6	1.75 (1.75, 5.74)	1
PC7	1.5 (1.5, 4.92)	1

where

H_{ice} = ice thickness in m (m, ft) for machinery strength design

S_{ice} = ice strength index for blade ice force

9.5 Design Ice Loads for Open Propeller

9.5.1 Maximum Backward Blade Force *(1 July 2024)*

The maximum backward blade force, F_b, in kN (tf, Ltf), is to be taken as:

- when $D < D_{limit}$:

$$Fb = c_0 \cdot S_{ice}[n \cdot D]^{0.7} \cdot \left[\frac{EAR}{Z}\right]^{0.3} \cdot D^2$$

- when $D \geq D_{limit}$:

$$F_b = c_1 \cdot S_{ice}[n \cdot D]^{0.7} \cdot \left[\frac{EAR}{Z}\right]^{0.3} \cdot [H_{ice}]^{1.4} \cdot D$$

where

D_{limit} = $c_2 \cdot (H_{ice})^{1.4}$ m (m, ft)

c_0 = 27 (2.753, 0.1096)

c_1 = 23 (2.345, 0.0580)

c_2 = 0.85 (0.85, 0.528

n = nominal rotational speed, in rev/s, (at MCR free running condition) for CP-propeller and 85% of the nominal rotational speed (at MCR free running condition) for a FP-propeller (regardless driving engine type)

D = propeller diameter, in m (m, ft)

EAR = expanded blade area ratio

Z = number of propeller blades

F_b is to be applied as a uniform pressure distribution to an area on the back (suction) side of the blade for the following load cases:

- *Load Case 1:* From 0.6R to the tip and from the blade leading edge to a value of 0.2 chord lengths.
- *Load Case 2:* A load equal to 50% of the F_b is to be applied on the propeller tip area outside of 0.9R.

- *Load Case 5:* For reversible propellers, a load equal to 60% of the F_b is to be applied from 0.6 R to the tip and from the blade trailing edge to a value of 0.2 chord lengths measured from trailing edge.

See load cases 1, 2, and 5 in 6-1-3/9.5.5 TABLE 2.

For vessels with the additional notation **Icebreaker**, the above stated backward blade force is to be multiplied by a factor of 1.1.

9.5.2 Maximum Forward Blade Force

The maximum forward blade force, F_f, in kN (tf, Ltf) is to be taken as:

- when $D < D_{limit}$:

  $$F_f = c_3 \cdot \left[\frac{EAR}{Z}\right] \cdot D^2$$

- when $D \geq D_{limit}$:

  $$F_f = 2c_3\left[\frac{1}{1 - d/D}\right] \cdot H_{ice} \cdot \left[\frac{EAR}{Z}\right] \cdot D$$

where

D_{limit}	=	$\left[\frac{2}{1 - d/D}\right] \cdot H_{ice}$ m(m, ft)
c_3	=	250 (25.493, 2.331)
d	=	propeller hub diameter, in m (m, ft)
D	=	propeller diameter, in m (m, ft)
EAR	=	expanded blade area ratio
Z	=	number of propeller blades

F_f is to be applied as a uniform pressure distribution to an area on the face (pressure) side of the blade for the following loads cases:

- *Load Case 3:* From 0.6R to the tip and from the blade leading edge to a value of 0.2 chord length.
- *Load Case 4:* A load equal to 50 % of the F_f is to be applied on the propeller tip area outside of 0.9R.
- *Load Case 5:* For reversible propellers, a load equal to 60% of F_f is to be applied from 0.6R to the tip and from the blade trailing edge to a value of 0.2 chord lengths measured from trailing edge.

See load cases 3, 4, and 5 in 6-1-3/9.5.5 TABLE 2.

9.5.3 Maximum Blade Spindle Torque *(1 July 2024)*

Spindle torque, Q_{smax}, in kN-m (tf-m, Ltf-ft), around the spindle axis of the blade fitting is to be calculated both for the load cases described in 6-1-3/9.5.1 and 6-1-3/9.5.2 for F_b and F_f. If these spindle torque values are less than the default value given below, the default minimum value to be used.

Default Value: $Q_{smax} = 0.25 \cdot F \cdot c_{0.7}$

where

$c_{0.7}$ = length of the blade chord at 0.7R radius, in m (m, ft)

F = either F_b or F_f, in kN (tf, Ltf), whichever has the greater absolute value

The blade failure spindle torque Q_{sex} is defined in 6-1-3/9.11.5.

9.5.4 Maximum Propeller Ice Torque Applied to the Propeller *(1 July 2024)*

The maximum propeller ice torque, $Q_{\max}$, in kN-m (tf-m, Ltf-ft) applied to the propeller is to be taken as:

- when $D < D_{limit}$:

$$Q_{\max} = k_{open} \cdot \left[1 - \frac{d}{D}\right] \cdot \left[\frac{P_{0.7}}{D}\right]^{0.16} \cdot [n \cdot D]^{0.17} \cdot D^3$$

where

k_{open} = 14.7 (1.50, 0.112) for PC1 - PC5; and

k_{open} = 10.9 (1.11, 0.083) for PC6 - PC7

- when $D \geq D_{limit}$:

$$Q_{\max} = 1.9 \cdot k_{open} \cdot \left[1 - \frac{d}{D}\right] \cdot [H_{ice}]^{1.1} \cdot \left[\frac{P_{0.7}}{D}\right]^{0.16} \cdot [n \cdot D]^{0.17} \cdot D^{1.9}$$

where

D_{limit} = $1.8H_{ice}$ m (m, ft)

$P_{0.7}$ = propeller pitch at 0.7R, in m (m, ft)

n = rotational propeller speed, in rev/s, at bollard condition. If not known, n is to be taken as follows:

Propeller Type	n
CP propellers	n_n
FP propellers driven by turbine or electric motor	n_n
FP propellers driven by diesel engine	$0.85n_n$

where n_n is the nominal rotational speed at MCR, free running condition

For CP propellers, propeller pitch, $P_{0.7}$, is to correspond to MCR in bollard condition. If not known, $P_{0.7}$ is to be taken as $0.7P_{0.7n}$, where $P_{0.7n}$ is propeller pitch at MCR free running condition.

9.5.5 Maximum Propeller Ice Thrust Applied to the Shaft

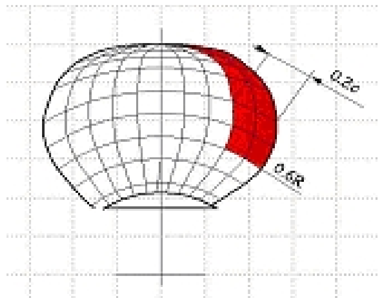
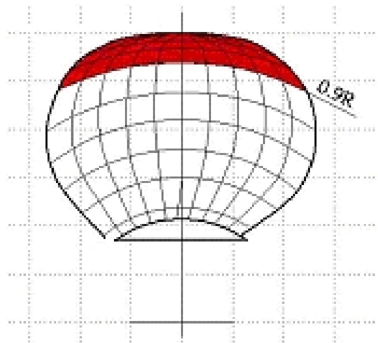
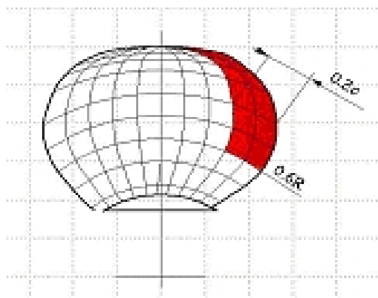
The maximum propeller ice thrust, in kN (tf, Ltf), applied to the shaft is to be taken as:

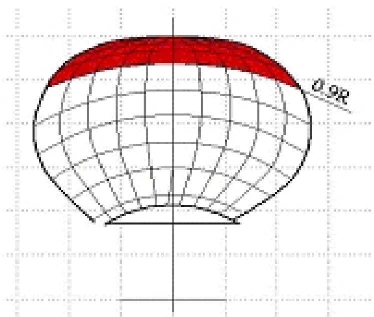
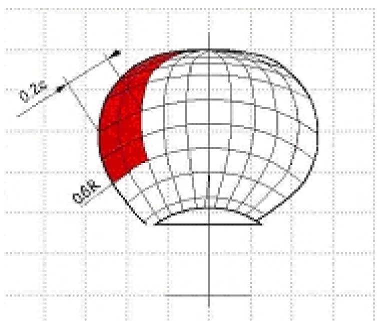
$$T_f = 1.1 \cdot F_f$$

$$T_b = 1.1 \cdot F_b$$

However, the load models of these Rules do not include propeller/ice interaction loads when ice block hits on the propeller hub of a pulling propeller.

TABLE 2
Load Cases for Open Propeller (1 July 2024)

	Force	*Loaded Area*	*Right handed propeller blade seen from back*
Load case 1	F_b	Uniform pressure applied on the back of the blade (suction side) to an area from 0.6R to the tip and from the leading edge to 0.2 times the chord length	
Load case 2	50% of F_b	Uniform pressure applied on the back of the blade (suction side) on the propeller tip area outside of 0.9R radius.	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0.6R to the tip and from the leading edge to 0.2 times the chord length.	

	Force	*Loaded Area*	*Right handed propeller blade seen from back*
Load case 4	50% of F_f	Uniform pressure applied on propeller face (pressure side) on the propeller tip area outside of 0.9R radius.	
Load case 5	60% of F_f or 60% of F_b whichever is greater	Uniform pressure applied on propeller face (pressure side) to an area from 0.6R to the tip and from the trailing edge to 0.2 times the chord length	

9.7 Design Ice Loads for Ducted Propeller

9.7.1 Maximum Backward Blade Force *(1 July 2024)*

The maximum backward blade force, F_b, in kN (tf, Ltf) is to be taken as:

- when $D < D_{limit}$:

$$F_b = c_4 \cdot S_{ice}[n \cdot D]^{0.7} \cdot \left[\frac{EAR}{Z}\right]^{0.3} \cdot D^2$$

- when $D \geq D_{limit}$:

$$F_b = c_5 \cdot S_{ice}[n \cdot D]^{0.7} \cdot \left[\frac{EAR}{Z}\right]^{0.3} \cdot [H_{ice}]^{1.4} \cdot D^{0.6}$$

where

D_{limit}	=	$4H_{ice}$ m (m, ft)
c_4	=	9.5 (0.969, 0.0386)
c_5	=	66 (6.730, 0.2679)

n is to be taken as in 6-1-3/9.5.1.

F_b is to be applied as a uniform pressure distribution to an area on the back side for the following load cases:

- *Load Case 1:* On the back of the blade from 0.6R to the tip and from the blade leading edge to a value of 0.2 chord lengths.
- *Load Case 5:* For reversible rotation propellers, a load equal to 60% of F_b is applied on the blade face from 0.6R to the tip and from the blade trailing edge to a value of 0.2 chord lengths measured from trailing edge.

See load cases 1 and 5 in 6-1-3/9.7.5 TABLE 3.

For vessels with the additional notation **Icebreaker**, the above stated backward blade force is to be multiplied by a factor 1.1

9.7.2 Maximum Forward Blade Force

The maximum forward blade force, F_f, in kN (tf, Ltf), is to be taken as:

- when $D \leq D_{limit}$:

$$F_f = c_3 \cdot \left[\frac{EAR}{Z}\right] \cdot D^2$$

- when $D > D_{limit}$:

$$F_f = 2c_3\left[\frac{1}{1 - d/D}\right] \cdot H_{ice} \cdot \left[\frac{EAR}{Z}\right] \cdot D$$

where

D_{limit} = $\frac{2}{1-(d/D)} \cdot H_{ice}$ m(m, ft)

c_3 = 250 (25.493, 2.331)

F_f is to be applied as a uniform pressure distribution to an area on the face (pressure) side for the following load cases:

- *Load Case 3:* On the blade face from 0.6R to the tip and from the blade leading edge to a value of 0.5 chord lengths.
- *Load Case 5:* A load equal to 60% F_f is to be applied from 0.6R to the tip and from the blade leading edge to a value of 0.2 chord lengths measured from trailing edge.
- See load cases 3 and 5 in 6-1-3/9.7.5 TABLE 3.

9.7.3 Maximum Blade Spindle Torque *(1 July 2024)*

Spindle torque, Q_{smax}, in kN-m (tf-m, Ltf-ft), around the spindle axis of the blade fitting is to be calculated for the load case described in 6-1-3/9.1. If these spindle torque values are less than the default value given below, the default value is to be used.

Default Value: $Q_{smax} = 0.25 \cdot F \cdot c_{0.7}$

where

$c_{0.7}$ = length of the blade chord at 0.7R radius, in m (m, ft)

F = either F_b or F_f, in kN (tf, Ltf) whichever has the greater absolute value.

The blade failure spindle torque Q_{sex} is defined in 6-1-3/9.11.5.

9.7.4 Maximum Propeller Ice Torque Applied to the Propeller *(1 July 2024)*

$Q_{\max}$, in kN-m (tf-m, Ltf-ft), is the maximum torque on a propeller due to ice-propeller interaction.

- when $D \leq D_{limit}$:

$$Q_{\max} = k_{ducted} \cdot \left[1 - \frac{d}{D}\right] \cdot \left[\frac{P_{0.7}}{D}\right]^{0.16} \cdot [n \,.\, D]^{0.17} \cdot D^3$$

where

k_{ducted}	=	10.4 (1.0605, 0.07923)	for PC1 -PC5
k_{ducted}	=	7.7 (0.785, 0.05866)	for PC6 -PC7

- when $D > D_{limit}$:

$$Q_{\max} = 1.9 \cdot k_{ducted} \cdot \left[1 - \frac{d}{D}\right] \cdot [H_{ice}]^{1.1} \cdot \left[\frac{P_{0.7}}{D}\right]^{0.16} \cdot [n \cdot D]^{0.17} \cdot D^{1.9}$$

where

D_{limit} = $1.8H_{ice}$ m (m, ft)

n = rotational propeller speed, in rps, at bollard condition. If not known, n is to be taken as follows:

Propeller Type	n
CP propellers	n_n
FP propellers driven by turbine or electric motor	N_n
FP propellers driven by diesel engine	$0.85n_n$

where n_n is the nominal rotational speed at MCR, free running condition

For CP propellers, propeller pitch, $P_{0.7}$ is to correspond to MCR in bollard condition. If not known, $P_{0.7}$ is to be taken as $0.7P_{0.7n}$, where $P_{0.7n}$ is propeller pitch at MCR free running condition.

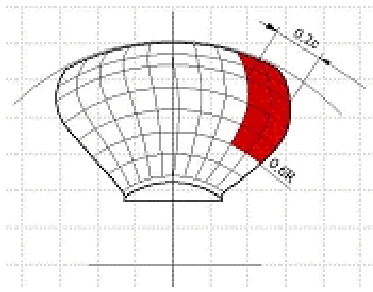
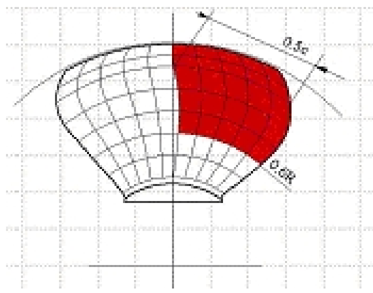
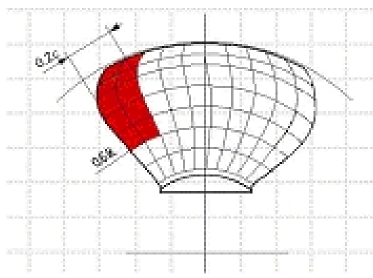
9.7.5 Maximum Propeller Ice Thrust (applied to the shaft at the location of the propeller)

The maximum propeller ice thrust in kN (tf, Ltf), (applied to the shaft at the location of the propeller) is:

T_f = $1.1 \cdot F_f$

T_b = $1.1 \cdot F_b$

TABLE 3
Load Cases for Ducted Propeller *(1 July 2024)*

	Force	*Loaded Area*	*Right handed propeller blade seen from back*
Load case 1	F_b	Uniform pressure applied on the back of the blade (suction side) to an area from 0.6R to the tip and from the leading edge to 0.2 times the chord length	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0.6R to the tip and from the leading edge to 0.5 times the chord length.	
Load case 5	60% of F_f or 60% of F_b whichever is greater	Uniform pressure applied on propeller face (pressure side) to an area from 0.6R to the tip and from the trailing edge to 0.2 times the chord length	

9.9 Propeller Blade Loads and Stresses for Fatigue Analysis

9.9.1 Blade Stresses

The blade stresses at various selected load levels for fatigue analysis are to be taken proportional to the stresses calculated for maximum loads given in 6-1-3/9.5 and 6-1-3/9.7.

The peak stresses are those determined due to F_f and F_b.

9.11 Design Loads on Propulsion Line *(1 July 2024)*

Ice torque excitation for open and ducted propellers: The given excitations are used to estimate the maximum torque likely to be experienced once during the service life of the ship. The following load cases are intended to reflect the operational loads on the propulsion system when the propeller interacts with ice and the corresponding reaction of the complete system. The ice impact and system response cause loads in the individual shaft line components. The ice torque Q_{max} may be taken as a constant value in the complete speed range. When considerations at specific shaft speeds are performed a relevant Q_{max} may be calculated using the relevant speed.

Diesel engine plants without an elastic coupling are to be calculated at the least favourable phase angle for ice versus engine excitation, when calculated in time domain. The engine firing pulses are to be included in the calculations and their standard steady state harmonics can be used. A phase angle between ice and gas force excitation does not need to be regarded in frequency domain analysis. Misfiring does not need to be considered.

If there is a blade order resonance just above MCR speed, calculations shall cover the rotational speeds up to 105% of MCR speed.

See also Guidelines for calculations given in 6-1-3/9.11.7.

9.11.1 Torque Excitation (time domain) *(1 July 2024)*

The propeller ice torque excitation for shaft line transient dynamic analysis is to be described by a sequence of blade impacts which are of half sine shape and occur at the blade. The torque due to a single blade ice impact as a function of the propeller rotation angle is then:

$$Q(\varphi) = C_q \cdot Q_{\max} \cdot \sin[\varphi(180/\alpha_i)] \quad \text{when } \varphi = 0 \ldots \alpha_i \text{ plus integer revolutions}$$

$$Q(\varphi) = 0 \quad \text{when } \varphi = \alpha_i \ldots 360 \text{ plus integer revolutions}$$

where C_q and α_i are parameters given in 6-1-3/9.11.1 TABLE 4 below for different blade numbers. α_i is the duration of propeller blade/ice interaction expressed in propeller rotation angle.

TABLE 4
Parameters C_q and α_i *(1 July 2024)*

Torque Excitation	*Propeller-Ice Interaction*	C_q	α_i *Z=3*	α_i *Z=4*	α_i *Z=5*	α_i *Z=6*
Case 1	Single ice block	0.75	90	90	72	60
Case 2	Single ice block	1.0	135	135	135	135
Case 3	Two ice blocks (phase shift 360/(2·) deg.)	0.5	45	45	45	30
Case 4	Single ice block	0.5	45	45	45	30

The total ice torque is obtained by summing the torque of single blades taking into account the phase shift 360°/Z. The number of propeller revolutions during a milling sequence is to be obtained with the formula:

$$N_Q = c_6 \cdot H_{ice}$$

where

c_6 = 2 revs/m
= 0.6096 revs/ft

The number of impacts during one milling sequence for blade order excitation is $Z \cdot N_Q$.

At the beginning and at the end of the milling sequence (within calculated duration) linear ramp functions are to be used to increase C_q to its maximum within one propeller revolution and vice versa to decrease it to zero.

Commentary:

The initial impulse loading is softened by the ramp, and the ramp is associated with irregularly shaped floes entering the propeller. For vessels that are expected to operate in more serious ice conditions or more aggressively (e.g., Icebreakers), it is recommended that the ramp is ignored.

End of Commentary

The total excitation torque from the 4 cases will then look like 6-1-3/9.11.1 FIGURE 1 below. The dynamic simulation is to be performed for all excitation cases starting at MCR nominal, MCR bollard condition and just above all resonance speeds (1^{st} engine and 1^{st} blade harmonic), so that the resonant vibration responses can be obtained. For a fixed pitch propeller plant the dynamic simulation is to also cover bollard pull condition with a corresponding speed assuming maximum possible output of the engine.

If a speed drop occurs down to stand still of the main engine, it indicates that the engine may not be sufficiently powered for the intended service task. For the consideration of loads, the maximum occurring torque during the speed drop process is to be applied. On these cases, the excitation is to follow the shaft speed.

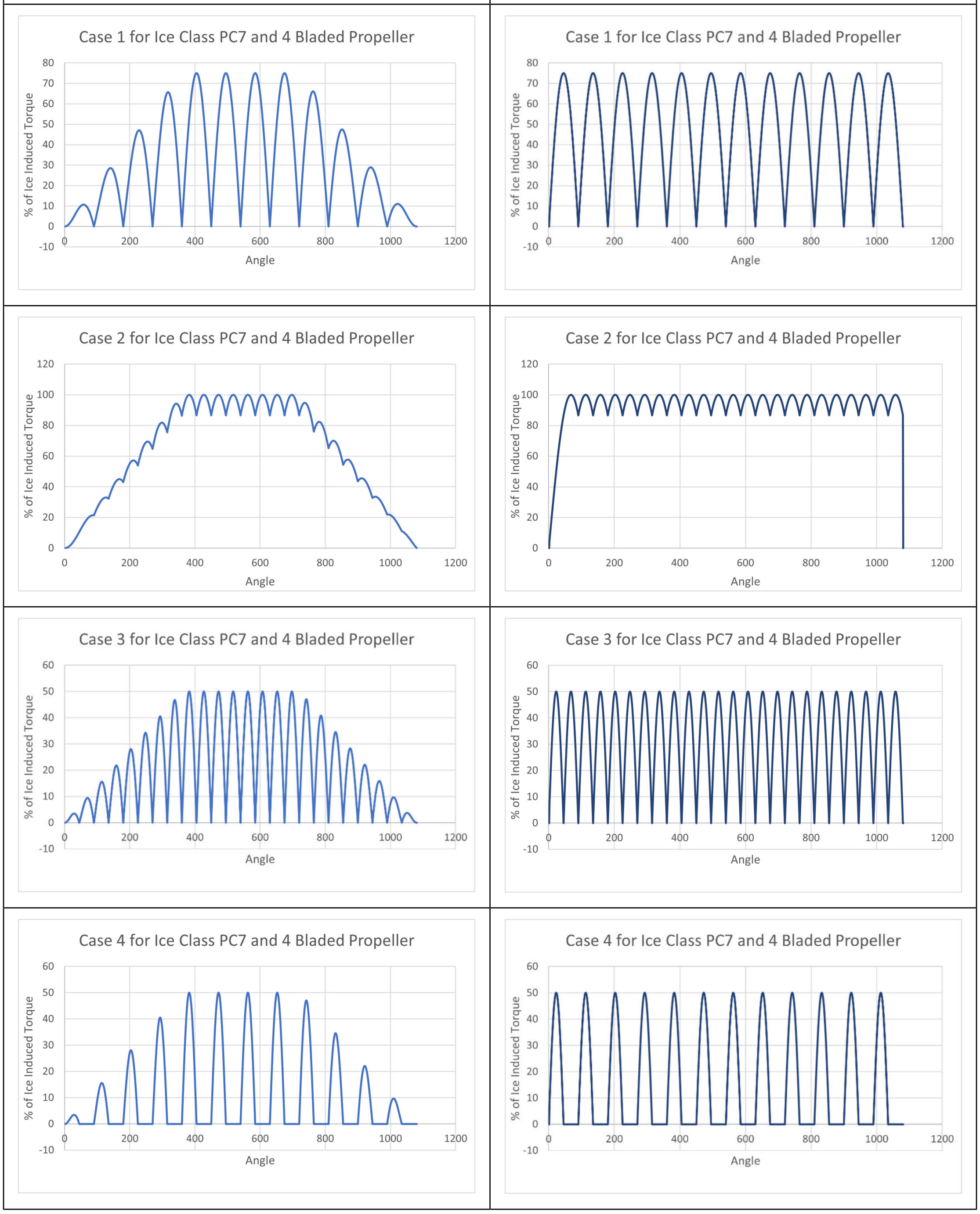
Milling torque sequence duration is not valid for pulling bow propellers, which are subject to ABS technical assessment and approval.

The response torque at any shaft component is to be analyzed considering excitation torque at the propeller, actual engine torque, Q_e, and the mass elastic system.

Q_e = actual maximum engine torque at considered speed

FIGURE 1
Shape of the Propeller Ice Torque Excitation for 45, 90, 135 degrees Single Blade Impact Sequences and 45 degrees Double Blade Impact Sequence (Two Ice Pieces) on a Four Bladed Propeller *(2024)*

With Ramp	*Without Ramp*



9.11.2 Response Torque in the Propulsion System (Frequency Domain) *(1 July 2024)*

For frequency domain calculations the following torque excitation may be used. The excitation has been derived so that the time domain half sine impact sequences have been assumed to be continuous and the Fourier series components for blade order and twice the blade order components have been derived. The frequency domain analysis is generally considered as conservative compared to the time domain simulation provided there is a first blade order resonance in the considered speed range.

$$Q_{F(\phi)} = Q_{max} . \left(C_{q0} + C_{q1} . \sin(Z . E_0 . \varphi + \alpha_1) + C_{q2} . \sin(2 . Z . E_0 . \varphi + \alpha_2)\right) \quad \text{[kNm]}$$

where

C_{q0} = mean torque component

C_{q1} = first blade order excitation amplitude

C_{q2} = second blade order excitation amplitude

φ = angle of rotation

$\alpha_{1,2}$ = phase angle of excitation component

Z = number of blades

E_0 = number of ice blocks in contact

Coefficients for simplified excitation torque estimation						
Torque excitation/ Z=3	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Excitation case 1	0.375	0.375	-90	0	0	1
Excitation case 2	0.7	0.33	-90	0.05	-45	1
Excitation case 3	0.25	0.25	-90	0	0	2
Excitation case 4	0.2	0.25	0	0.05	-90	1
Torque excitation/ Z=4	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Excitation case 1	0.45	0.36	-90	0.06	-90	1
Excitation case 2	0.9375	0	-90	0.0625	-90	1
Excitation case 3	0.25	0.251	-90	0	0	2
Excitation case 4	0.2	0.25	0	0.05	-90	1
Torque excitation/ Z=5	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Excitation case 1	0.45	0.36	-90	0.06	-90	1
Excitation case 2	1.19	0.17	-90	0.02	-90	1
Excitation case 3	0.3	0.25	-90	0.048	-90	2
Excitation case 4	0.2	0.25	0	0.05	-90	1
Torque excitation/ Z=6	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Excitation case 1	0.45	0.375	-90	0.05	-90	1
Excitation case 2	1.435	0.1	-90	0	0	1

Coefficients for simplified excitation torque estimation						
Excitation case 3	0.3	0.25	-90	0.048	-90	2
Excitation case 4	0.2	0.25	0	0.05	-90	1

The results of the 4 cases are to be used in the following way as illustrated in 6-1-3/9.11.2 FIGURE 2:

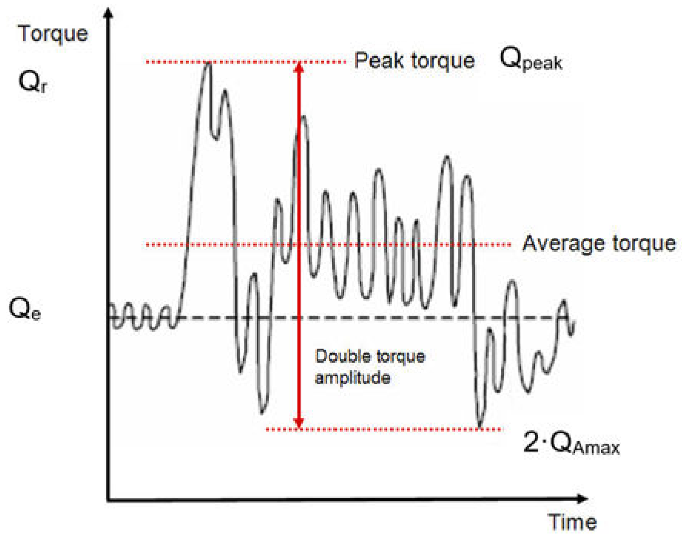
i) The highest peak torque (between the various lumped masses in the system) is in the following referred to as peak torque Q_{peak}.

ii) The highest torque amplitude during a sequence of impacts is to be determined as half of the range from max to min torque and is referred to as Q_{Amax}.

where

$$Q_{Amax} = \frac{max(Q_r(time)) - min(Q_r(time))}{2} \quad \text{[kNm]}$$

FIGURE 2
Definitions of Peak Torque and Torque Amplitude *(2024)*



Note:

For transient torsional vibration analysis (time domain), the model is to include the ice excitation at the propeller, the mean torque values provided by the prime mover and the hydrodynamic mean torque produced by the propeller as well as any other relevant excitations. The aim of torsional vibration calculations is to estimate the torsional loads for individual shaft line components in order to determine scantlings.

9.11.3 Maximum Response Thrust *(1 July 2024)*

Maximum thrust along the propeller shaft line is to be calculated with the formulae below. The greater value of the forward and backward directional load is to be taken as the design load for both directions. The factors 2.2 and 1.5 take into account the dynamic magnification due to axial vibration. Alternatively, the propeller thrust magnification factor may be calculated by dynamic analysis.

Maximum Shaft Thrust Forwards: $T_r = T + 2.2 \cdot T_f$

Maximum Shaft Thrust Backwards: $T_r = 1.5 \cdot T_b$

where

T = propeller bollard thrust, in kN (tf, Ltf)

T_f = maximum forward propeller ice thrust, in kN (tf, Ltf)

T_b = maximum backward propeller ice thrust, in kN (tf, Ltf)

If hydrodynamic bollard thrust, T, is not known, T is to be taken as given in 6-1-3/9.11.3 TABLE 5:

TABLE 5
Propeller Bollard Thrust

Propeller Type	*T*
CP propellers (open)	$1.25T_n$
CP propellers (ducted)	$1.1T_n$
FP propellers driven by turbine or electric motor	T_n
FP propellers driven by diesel engine (open)	$0.85T_n$
FP propellers driven by diesel engine (ducted)	$0.75T_n$

where

T_n = nominal propeller thrust at MCR at free running open water conditions, in kN (tf, Ltf)

For pulling type propellers ice interaction loads on propeller hub are to be considered in addition to the above.

9.11.4 Blade Failure Load for both Open and Nozzle Propellers *(1 July 2024)*

The minimum load required resulting in blade failure through plastic bending. This is to be calculated iteratively along the radius of the blade from blade root to 0.5R using below equation. The ultimate load is assumed acting at 0.8*R* in the weakest direction of the blade.

The blade failure load in kN (tf, Ltf) is:

$$F_{ex} = c_7 \cdot \frac{c \cdot t^2 \cdot \sigma_{ref1}}{0.8 \cdot D - 2 \cdot r} \cdot 10^3$$

where

σ_{ref1} = $0.6\sigma_{0.2} + 0.4\sigma_u$ in MPa (kgf/mm^2, psi)

σ_u = specified ultimate tensile strength in MPa (kgf/mm^2, psi) for the blade material

$\sigma_{0.2}$ = specified minimum yield or 0.2% proof strength in MPa (kgf/mm^2, psi) for the blade material

c_7 = 0.3 (0.3, 1.9286E-5)

c = actual chord length in m (m, ft)

t = thickness, in m (m, ft), of the cylindrical root section of the blade at the weakest section outside root fillet, typically at the termination of the fillet into the blade profile

r = radius, in m (m, ft), of the cylindrical root section of the blade at the weakest section outside root fillet, typically at the termination of the fillet into the blade profile

Commentary:

The blade failure formula should be applied to various sections of the propeller from just above the root fillet up towards the tip until the lowest blade failure load is determined.

End of Commentary

σ_u and $\sigma_{0.2}$ are representative values for the blade material. Representative in this respect means values for the considered section. These values are to be obtained by means of tests, or commonly accepted "thickness correction factors" approved by ABS. If not available, maximum specified values are to be used.

Alternatively the F_{ex} can be determined by means of an appropriate stress analysis reflecting the non-linear plastic material behaviour of the actual blade. A blade is regarded as having failed, if the tip is bent by more than 10% of the propeller diameter.

Commentary:

If material properties for the actual propeller blades is known, the highest achieved tensile strength and actual yield strengths are to be used for determining the F_{ex}.

End of Commentary

9.11.5 Spindle Torque *(1 July 2024)*

The maximum spindle torque due to a blade failure load acting at 0.8R is to be determined.

The force that causes blade failure typically reduces when moving from the propeller centre towards the leading and trailing edges. At a certain distance from the blade centre of rotation the maximum spindle torque will occur. This maximum spindle torque is to be defined by an appropriate stress analysis or using the below equation:

$$Q_{sex} = max \quad (c_{LE0.8}; 0.8c_{TE0.8}) \cdot C_{spex} \cdot F_{ex} \qquad \text{[kNm]}$$

where

$$C_{spex} = C_{sp} \cdot C_{fex} = 0.7\left(1 - \left(4\frac{EAR}{Z}\right)^3\right) \qquad (-)$$

C_{sp} is non-dimensional parameter taking into account the spindle arm

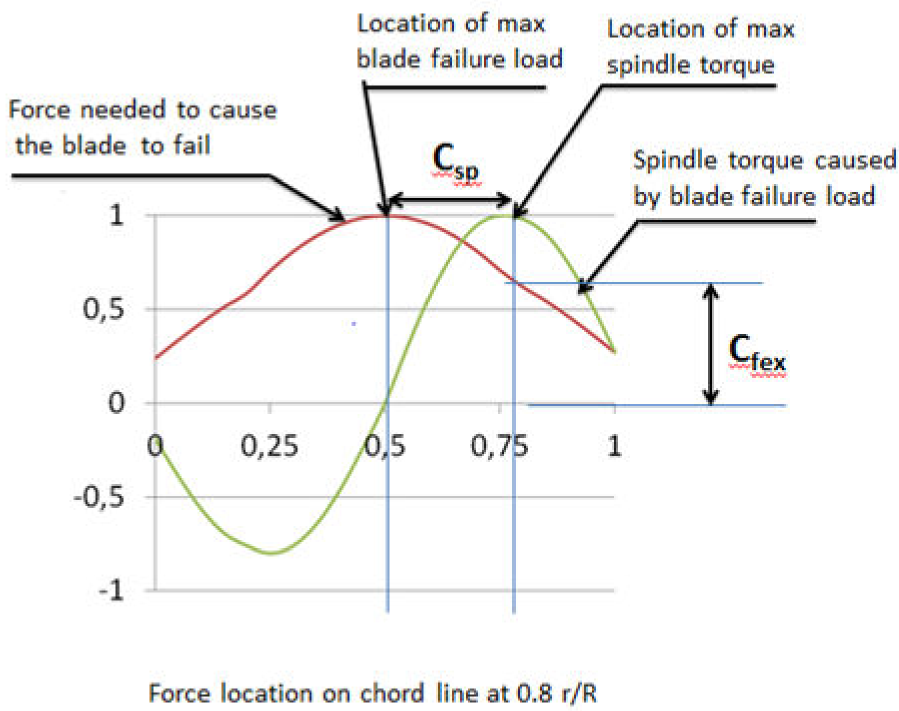
C_{fex} is non-dimensional parameter taking into account the reduction of blade failure force at the location of maximum spindle torque

If C_{spex} is below 0.3, a value of 0.3 is to be used for C_{spex}

$c_{LE0.8}$ is the leading edge portion of the chord length at 0.8R

$c_{TE0.8}$ is the trailing edge portion of the chord length at 0.8R

The figure illustrates the spindle torque values due to blade failure loads across the whole chord



length.

9.11.6 Design Torque along Shaft Line *(1 July 2024)*

9.11.6(a)

If there is no relevant first order propeller torsional resonance in the range 20% (of n_n) above and 20% below the maximum operating speed in bollard condition (see Table in 6-1-3/9.5.4) the following equations (respectively) of the maximum response torque can be used to calculate the design torque along the propeller shaft line.

$$Q_r = Q_{emax} + Q_{vib} + Q_{max} \cdot \frac{I}{I_t} \quad \text{[kNm]}$$

The equation is to be applied for directly coupled two stroke Diesel engines without flexible coupling. For all other plants:

$$Q_r = Q_{emax} + Q_{max} \cdot \frac{I}{I_t} \quad \text{[kNm]}$$

where I is equivalent mass moment of inertia of all parts on engine side of component under consideration and I_t is equivalent mass moment of inertia of the whole propulsion system.

All the torques and the inertia moments shall be reduced to the rotation speed of the component being examined.

If the maximum torque, Q_{emax}, is not known, it is to be taken as follows

Propeller type	Q_{emax}
Propellers driven by electric motor	Q_{motor}
CP propellers not driven by electric motor	Q_n
FP propellers driven by turbine	Q_n

Propeller type	Q_{emax}
FP propellers driven by diesel engine	$0.75Q_n$
Here Q_{motor} is the electric motor peak torque	

9.11.6(b)

If there is a first blade order torsional resonance in the range 20% (of n_n) above and 20% below the maximum operating speed (bollard condition), the design torque (Q_r) of the shaft component is to be determined by means of a dynamic torsional vibration analysis of the entire propulsion line in the time domain or alternatively in the frequency domain. It is then assumed that the plant is sufficiently designed to avoid harmful operation in barred speed range.

9.11.7 Guideline for Torsional Vibration Calculation *(1 July 2024)*

The aim of torsional vibration calculations is to estimate the torsional loads for individual shaft line components over the life time in order to determine scantlings for safe operation. The model can be taken from the normal lumped mass elastic torsional vibration model (frequency domain) including the damping. Standard harmonics may be used to consider the gas forces. The engine torque - speed curve of the actual plant is to be applied.

For time domain analysis the model should include the ice excitation at propeller, the mean torques provided by the prime mover and the hydrodynamic mean torque produced by the propeller as well as any other relevant excitations. The calculations should cover the variation of phase between the ice excitation and prime mover excitation. This is extremely relevant for propulsion lines with direct driven combustion engines.

For frequency domain calculations the load should be estimated as a Fourier component analysis of the continuous sequence of half sine load peaks. The first and second order blade components should be used for excitation. The calculation should cover the whole relevant shaft speed range. The analysis of the responses at the relevant torsional vibration resonances may be performed for open water (without ice excitation) and ice excitation separately. The resulting maximum torque can be obtained for directly coupled plants by the following superposition:

$$Q_{peak} = Q_{emax} + Q_{opw} + Q_{ice} \text{ [kNm]}$$

where Q_{emax} is the maximum engine torque at considered rotational speed, Q_{opw} is the maximum open water response of engine excitation at considered shaft speed and determined by frequency domain analysis and Q_{ice} is the calculated torque using frequency domain analysis for the relevant shaft speeds, ice excitation cases 1-4, resulting in the maximum response torque due to ice excitation.

11 Design

11.1 Design Principles *(1 July 2019)*

The propulsion line is to be designed according to the pyramid strength principle in terms of its strength. This means that the loss of the propeller blade is not to cause any significant damage to other propeller shaft line components. The propulsion line components are to withstand maximum and fatigue operational loads with the relevant safety margin. The loads do not need to be considered for shaft alignment or other calculations of normal operational conditions.

11.1.1 Fatigue Design - General *(1 July 2024)*

The design loads are to be based on the ice excitation and where necessary (shafting) dynamic analysis, as described by a sequence of blade impacts (6-1-3/9.11.1). The shaft response torque is to be determined by means of transient torsional vibration analysis of the propulsion line.

The components are to be designed so as to prevent accumulated fatigue failure when considering the loads according to 6-1-3/9.9 and 6-1-3/9.11 using the linear elastic Miner's rule.

$$D = \frac{n_1}{N_1} + \frac{n_2}{N_2} + \cdots + \frac{n_k}{N_k} \leq 1 \quad \text{or} \quad D = \sum_{J=1}^{j=k} \frac{n_j}{N_j} \leq 1$$

where

k	=	number of stress levels
N_{1-k}	=	number of load cycles to failure of the individual stress level class
n_{1-k}	=	accumulated number of load cycles of the case under consideration, per class
D	=	Miners damage sum

The stress distribution is to be divided into a frequency load spectrum having minimum 10 stress blocks (every 10% of the load). Calculation with 5 stress blocks has been found to be too conservative. The maximum allowable load is limited by σ_{ref2} for propeller blades and yield strength for all other components. The load distribution (spectrum) is to be in accordance with the Weibull distribution.

11.1.2 Load Distributions (Spectra) for Blade Loads and Number of Ice Loads *(1 July 2024)*

11.1.2(a) Load distributions (spectra) for blade loads (1 July 2024)

The load spectrum for backward loads is normally expected to have a lower number of cycles than the load spectrum for forward loads. Taking this into account in a fatigue analysis introduces complications that are not justified considering all uncertainties involved. The Weibull-type definition (probability that F_{ice} exceeds $(F_{ice})_{max}$) as given in Figure 3 is used for the fatigue design of the blade.

$$P\left(\frac{Fice}{(Fice)max} \geq \frac{F}{(Fice)max}\right) = e^{\left\{-\left(\frac{F}{(Fice)max}\right)^k \cdot \ln(Nice)\right\}}$$

where

k	=	shape parameter of the spectrum
N_{ice}	=	number of load cycles in the spectrum
F_{ice}	=	random variable for ice loads on the blade $0 \leq Fice \leq (Fice)max$

The blade stress amplitude distribution is therefore simplified (and at the same time disregarding mean stresses for fatigue purpose) and assumed to be as:

$$(\sigma_{ice})_A(N) = (\sigma_{ice})_{Amax} \cdot \left[1 - \frac{\log(N)}{\log(N_{ice})}\right]^{\frac{1}{k}}$$

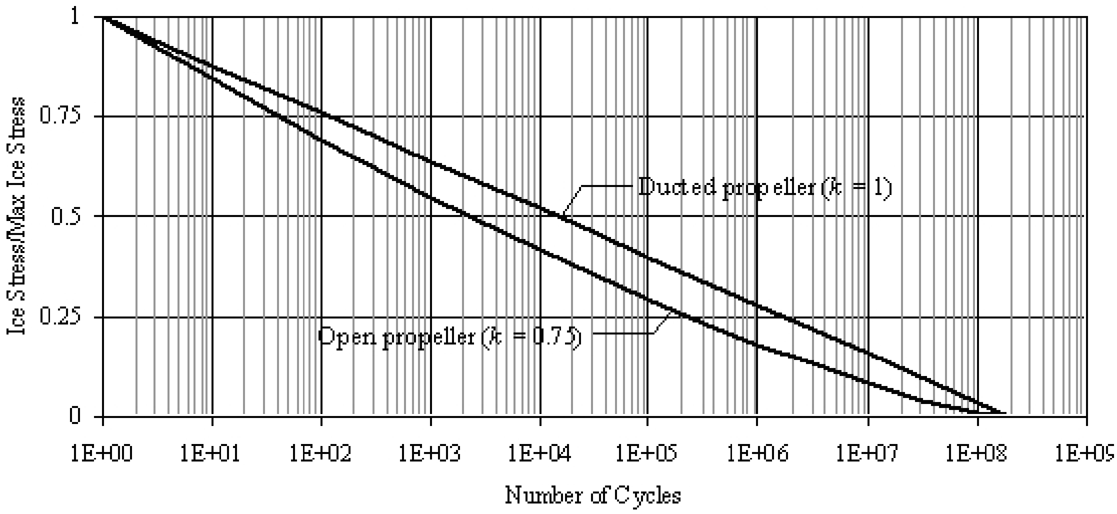
where

$$(\sigma_{ice})_{Amax} = \frac{(\sigma ice)fmax - (\sigma ice)bmax}{2}$$

k	=	Weibull exponent
	=	0.75 for open propeller
	=	1.0 for nozzle propeller

This is illustrated in the cumulative stress spectrum in 6-1-3/11.1.2 FIGURE 3.

FIGURE 3
Ice Load Distribution for Ducted and Open Propeller



11.1.2(b) Number of ice loads (1 July 2024)

Number of load cycles N_{ice} in the load spectrum per blade is to be determined according to the formula:

$$N_{ice} = k_1 \cdot k_2 \cdot N_{class} \cdot n$$

where

N_{class}	=	reference number of impacts per propeller rotation speed for each ice class as indicated in 6-1-3/11.1.2 TABLE 6	
k_1	=	1 for centre propeller	
	=	2 for wing propeller	
	=	3 for pulling propeller (wing and centre)	
	=	for pulling bow propellers number of load cycles is expected to increase in range of 10 times	
k_2	=	0.8 - f	when $f < 0$
	=	0.8 - 0.4·f	when $0 \leq f \leq 1$
	=	0.6 - 0.2·f	when $1 < f \leq 2.5$
	=	0.1	when $f > 2.5$
f	=	immersion function	
	=	$\frac{h_o - H_{ice}}{D/2} - 1$	
h_o	=	depth, in m (m, ft), of the propeller centerline at the minimum ballast waterline in ice (LIWL) of the ship.	

FIGURE 4
Submergence Thruster *(2024)*

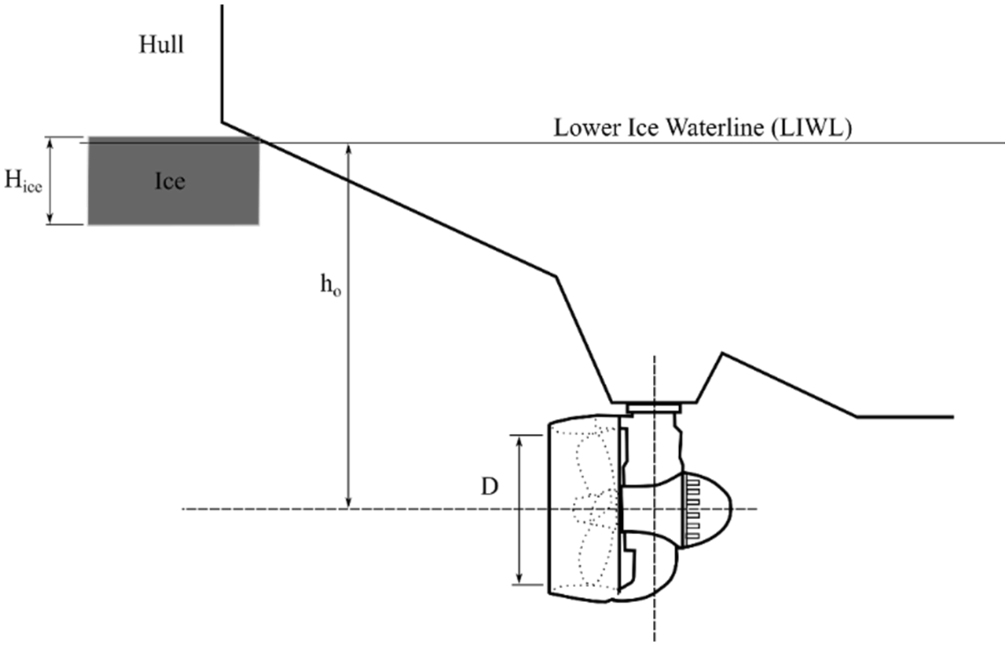


FIGURE 5
Submergence Pod *(2024)*

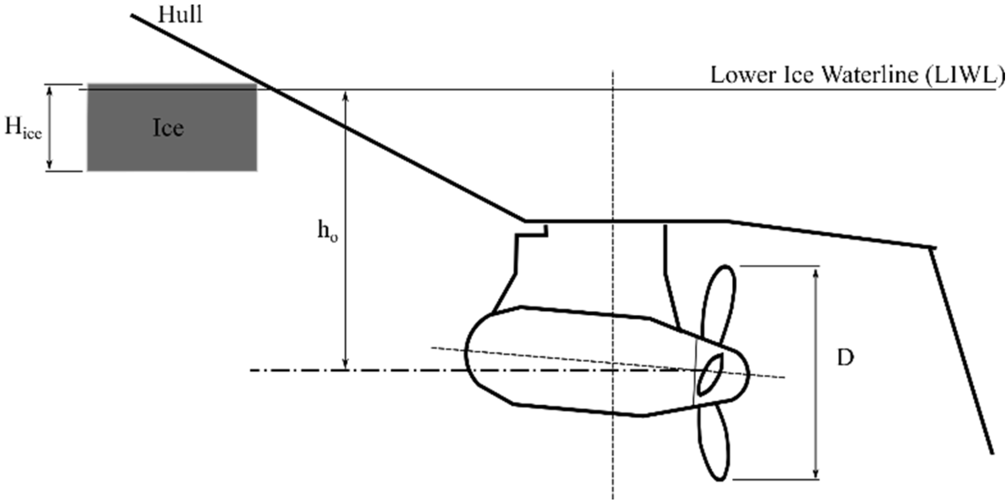


TABLE 6
Reference Number of Impacts Per Propeller Rotation Speed for Each Ice Class

Ice Class	*PC1*	*PC2*	*PC3*	*PC4*	*PC5*	*PC6*	*PC7*
N_{class}	21×10^6	17×10^6	15×10^6	13×10^6	11×10^6	9×10^6	6×10^6

For vessels with the additional notation Icebreaker, the above stated number of load cycles N_{ice} is to be multiplied by a factor of 3.

For components that are subject to loads resulting from propeller/ice interaction with all the propeller blades, the number of load cycles (N_{ice}) is to be multiplied by the number of propeller blades (Z).

11.1.3 Propulsion Line Components *(1 July 2024)*

The ultimate load resulting from total blade failure F_{ex} as defined in 6-1-3/9.11.4 is to consist of combined axial and bending load components, wherever this is significant. The minimum safety factor against yielding is to be 1.0 for all shaft line components.

The shafts and shafting components, such as bearings, couplings and flanges are to be designed to withstand the operational propeller/ice interaction loads as given in 6-1-3/9.5 and 6-1-3/9.7.

The given loads are not intended to be used for shaft alignment calculation.

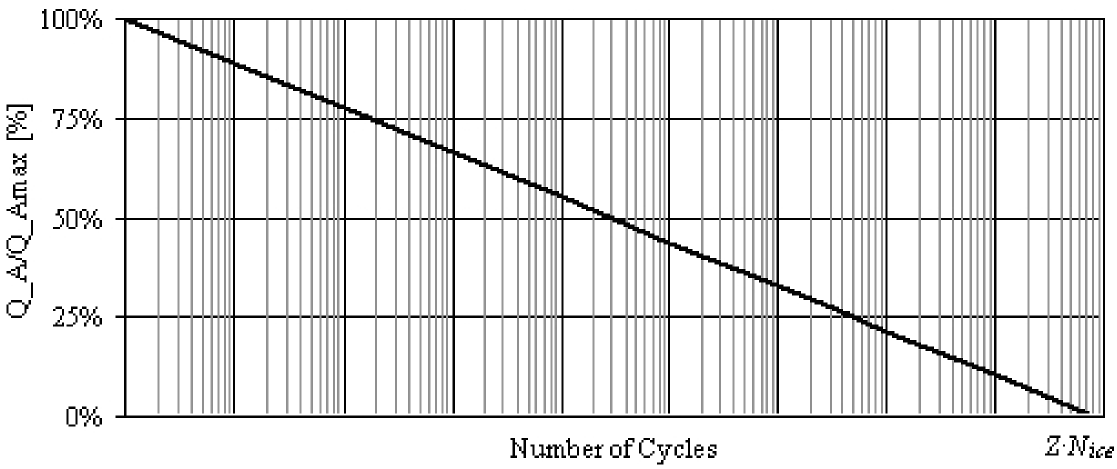
Cumulative fatigue calculations are to be made according to the Miner's rule. A fatigue calculation is not necessary, if the maximum stress is below fatigue strength at 10^8 load cycles.

The torque and thrust amplitude distribution (spectrum) in the propulsion line is to be taken as (because Weibull exponent k = 1):

$$Q_A(N) = Q_{A\max} \cdot \left\{1 - \frac{\log(N)}{\log(Z \cdot N_{ice})}\right\}$$

This is illustrated by the example in 6-1-3/11.1.3 FIGURE 6.

FIGURE 6
Cumulative Torque Distribution



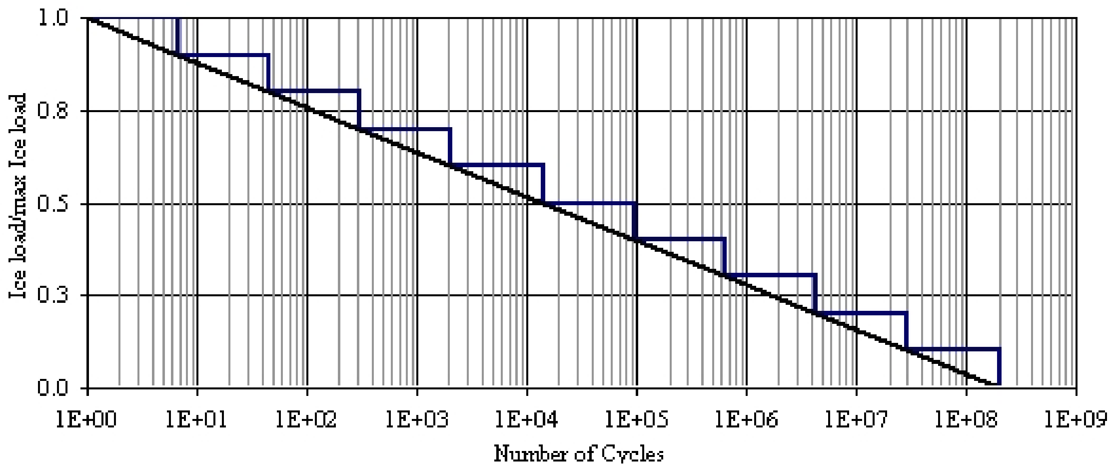
$Q_A max$ is the average response torque shown in 6-1-3/9.11.2 FIGURE 2.

The number of load cycles in the load spectrum is determined as $Z \cdot N_{ice}$.

The Weibull exponent is k = 1.0 both for open propeller torque and for ducted propeller torque (and bending forces). The load distribution is an accumulated load spectrum, and the load spectrum is divided into minimum ten load blocks for the Miner summarizing method.

The load spectrum used is counting the number cycles for 100% load to be the number of cycles above the next step (e.g.. 90% load) which means that the calculation is on the conservative side. Consequently, the fewer stress blocks used the more conservative is the calculated safety margin.

FIGURE 7
Example of Ice Load Distribution for the Shafting (k = 1), Divided Into Load Blocks



The load spectrum is divided into n_{bl}-number of load blocks for the Miner summarizing method. The following formula can be used for calculation of the number of cycles for each load block.

$$n_i = N_{ice}{}^{1-\left(1-\frac{i}{n_{bl}}\right)^k} - \sum_{i=1}^{i} n_{i-1}$$

where

i	=	single load block
n_{bl}	=	number of load blocks

11.3 Azimuthing Main Propulsors *(2024)*

In addition to the above requirements, ABS technical assessment is to be given to those loading cases which are extraordinary for propulsion units when compared with conventional propellers. The estimation of loading cases has to reflect the way of operation of the ship and the thrusters. In this respect, for example, the loads caused by the impacts of ice blocks on the propeller hub of a pulling propeller have to be considered. Furthermore, loads resulting from the thrusters operating at an oblique angle to the flow have to be considered. The steering mechanism, the fitting of the unit, and the body of the thruster is to be designed to withstand the loss of a blade without damage. The loss of a blade is to be considered for the propeller blade orientation which causes the maximum load on the component being studied. Typically, top-down blade orientation places the maximum bending loads on the thruster body.

Azimuth thrusters are also to be designed for estimated loads caused by thruster body/ice interaction. The thruster body has to stand the loads obtained when the maximum ice blocks, with the dimensions $H_{ice} \cdot 2H_{ice} \cdot 3H_{ice}$, strike the thruster body when the ship is at a typical ice operating speed. In addition, the design situation in which an ice sheet glides along the ship's hull and presses against the thruster body is to be considered. The thickness of the sheet is to be taken as the thickness of the maximum ice block entering the propeller, as defined in 6-1-3/9.3.

11.3.1 Design Criteria for Azimuthing Propulsors *(2024)*

Azimuth propulsors are to be designed for following loads:

i) Ice pressure on strut based on defined location area of the strut / ice interaction as per 6-1-2/29.

ii) Ice pressure on pod based on defined location area of thruster body / ice interaction as per 6-1-2/29.

iii) Plastic bending of one propeller blade in the worst position (typically top-down) without consequential damages to any other part

iv) Steering gear design torque, Q_{SG}, in kN-m (tf-m, Ltf-ft), is to be minimum 60% of steering torque expected at propeller ice milling condition defined as $Q_{\max}$

$$Q_{SG} = 0.6 \cdot \left(\frac{Q_{\max}}{0.8R}\right) \cdot \ell$$

where

ℓ = distance from propeller plane to steering (azimuth) axis, in m (m, ft)

v) Steering gear is to be protected by effective means limiting excessive torque caused by:

a) Ice milling torque exceeding design torque and leading to rotation of unit

b) Torque caused by plastic bending of one propeller blade in the worse position (related to steering gear) and leading to rotation of the unit

vi) Steering gear is to be ready for operation after above load, *v)a)* or *v)b)* has gone

Commentary:

For additional guidance, see the ABS *Guidance Notes on Ice Loads on Azimuthing Propulsion Units*.

End of Commentary

11.5 Propeller Blade Design

11.5.1 Maximum Blade Stresses due to static loads *(1 July 2024)*

Blade stresses (equivalent and principal stresses) are to be calculated using the backward and forward loads given in section 6-1-3/9.5 and 6-1-3/9.7. The stresses are to be calculated with recognized and well documented FE-analysis or other acceptable alternative method. The stresses on the blade are not to exceed the allowable stresses for the blade material given below.

The von Mises stresses, taken as σ_{st}, are to comply with the following:

$$\frac{\sigma_{ref2}}{\sigma_{st}} \geq 1.3$$

where σ_{st} is the calculated stress for the design loads. If FE analysis is used in estimating the stresses, von Mises stresses are to be used.

Alternatively, the following simplified equation can be used in estimating the blade stresses for all propellers in the root area (r/R < 0.5) :

$$\sigma_{st} = C_1 \frac{M_{BL}}{100ct^2} \quad \text{[MPa]}$$

where:

C_1 is the ratio of the actual stress to the stress obtained with beam equation.

If the actual value is not available, C_1 should be taken as 1.6.

M_{BL} = *(0.75-r/R) R F*, for relative radius r/R<0.5

F is the maximum of F_b and F_f, whichever is greater.

11.5.2 Blade Fatigue Design

Propeller blades are to be designed so as to prevent accumulated fatigue when considering the loads according to 6-1-3/11.1.2 and using the Miner's rule.

11.5.2(a) General (1 July 2024)

For materials with a two slope S-N curve (Figure 5) the fatigue calculations defined in this subsection are not required if the following criterion, in MPa, is fulfilled:

$$o_{exp} \geq B_1 . \sigma_{ref2}{}^{B_2} . \log(N_{ice})^{B_3}$$

where

B_1, B_2 and B_3, and are coefficients for open and ducted propellers, as given below:

Coefficients to check a dispense from fatigue calculation	*Open propeller*	*Ducted propeller*
B_1	0.00328	0.00223
B_2	1.0076	1.0071
B_3	2.101	2.471

Where the above criterion is not fulfilled the fatigue requirements defined below are to be applied:

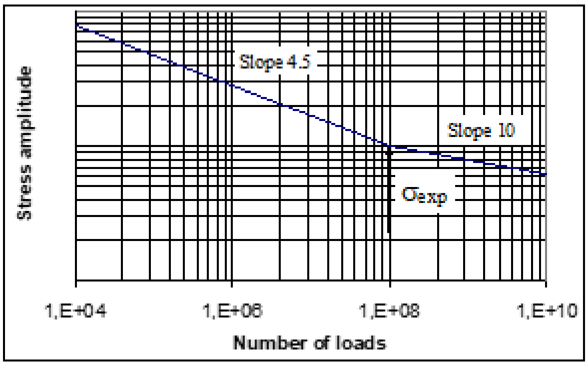
The fatigue design of the propeller blade is based on an estimated load distribution for the service life of the ship and the S-N curve for the blade material. An equivalent stress σ_{fat} that produces the same fatigue damage as the expected load distribution shall be calculated according to Miner's rule and the acceptability criterion for fatigue should be fulfilled as given in this section. The equivalent stress is normalised for 100 million cycles.

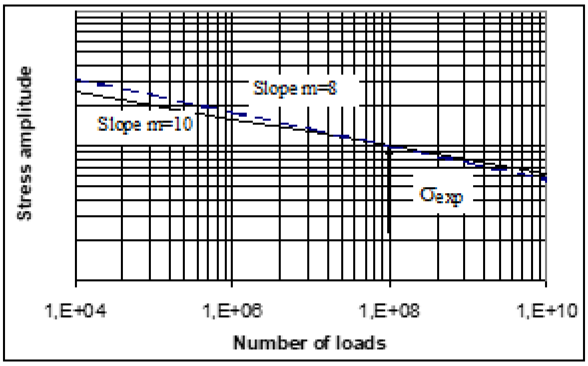
The blade stresses at various selected load levels for fatigue analysis are to be taken proportional to the stresses calculated for maximum loads given in 6-1-3/9.

The peak principal stresses σ_f and σ_b are determined from F_f and F_b using FEA. The peak stress range $\Delta \sigma_{max}$ [MPa] and the maximum stress amplitude σ_{Amax} [MPa] are determined on the basis of load cases 1 and 3, 2 and 4.

$$\Delta \sigma_{max} = 2 . \sigma_{Amax} = |(\sigma_{ice})_{fmax}| + |(\sigma_{ice})_{bmax}|$$

The load spectrum for backward loads is normally expected to have a lower number of cycles than the load spectrum for forward loads. Taking this into account in a fatigue analysis introduces complications that are not justified considering all uncertainties involved.For the calculation of equivalent stress two types of S-N curves are available: Two slope S-N curve (slopes 4.5 and 10) and One slope S-N curve (the slope can be chosen). The type of the S-N-curve is to be selected to correspond with the material properties of the blade. If the S-N-curve is not known the two slope S-N curve is to be used.





11.5.2(b) Equivalent fatigue stress (1 July 2024)

The equivalent fatigue stress for 10^8 cycles which produces the same fatigue damage as the load distribution is

$$\sigma_{fat} = \rho \, . (\sigma_{ice})_{max}$$

where

$(\sigma_{ice})_{max}$ =	$0.5 . ((\sigma_{ice})_{fmax} - (\sigma_{ice})_{bmax})$
$(\sigma_{ice})_{max}$ =	mean value of the principal stress amplitudes resulting from design forward and backward blade forces at the location being studied
$(\sigma_{ice})_{fmax}$=	principal stress resulting from forward load
$(\sigma_{ice})_{bmax}$=	principal stress resulting from backward load

In the calculation of $(\sigma_{ice})_{max}$, case 1 and case 3 or case 2 and case 4 are considered as pairs for $(\sigma_{ice})_{fmax}$, and$(\sigma_{ice})_{bmax}$ calculations. Case 5 is excluded from the fatigue analysis.

Calculation of parameter for two-slope S-N curve

The error of the following method to determine the parameter ρ is sufficiently small, if the number of load cycles N_{ice} is in the range

$$5 . 10^6 \leq N_{ice} \leq 10^8$$

The parameter ρrelates the maximum ice load to the distribution of ice loads according to the regression formula

$$\rho = C_1 . (\sigma_{ice})_{max}{}^{c2} . \sigma_{fl}{}^{c3} . \log(N_{ice})^{c4}$$

where

$\sigma_{fl} = \gamma_{\varepsilon 1} \cdot \gamma_{\varepsilon 2} \cdot \gamma_v \cdot \gamma_m \cdot \sigma_{exp}$

is the blade material fatigue strength at 10^8 load cycles, see 6-1-3/11.5.2(c).

The coefficients C_1, C_2, C_3 and C_4 are given in the below Table.

Coefficients to evaluate material fatigue strength	***Open propeller***	***Ducted propeller***
C_1	0.000747	0.000534
C_2	0.0645	0.0533
C_3	-0.0565	-0.0459
C_4	2.22	2.584

Calculation of parameter for constant-slope S-N curve:

For materials with a constant-slope S-N curve, the factorρ is to be calculated from the following formula:

$$\rho = \left(G\frac{N_{ice}}{N_R}\right)^{\frac{1}{m}} (\ln(N_{ice}))^{-\frac{1}{k}}$$

where

k	=	shape parameter of the Weibull distribution
k	=	1.0 for ducted propellers
k	=	0.75 for open propellers
N_R	=	reference number of load cycles ($=10^8$)

Values for the parameter G are given in the Table below. Linear interpolation may be used to calculate the value of for m/k ratios other than those given in the Table.

Value for the parameter G for different m/k ratios					
m/k	G	m/k	G	m/k	G
3	6	5.5	287.9	8	40320
3.5	11.6	6	720	8.5	119292
4	24	6.5	1871	9	362880
4.5	52.3	7	5040	9.5	$1.133\text{x}10^6$
5	120	7.5	14034	10	$3.623\text{x}10^6$

11.5.2(c) Acceptability criterion for fatigue *(1 July 2024)*

The equivalent fatigue stress σ_{fat} at all locations on the blade is to fulfil the following acceptability criterion:

$$\frac{\sigma_{fl}}{\sigma_{fat}} \geq 1.5$$

where

$\sigma_{fl} = \gamma_{\varepsilon 1} \cdot \gamma_{\varepsilon 2} \cdot \gamma_v \cdot \gamma_m \cdot \sigma_{exp}$

$\gamma_{\varepsilon 1}$	=	reduction factor due to scatter (equal to one standard deviation)
$\gamma_{\varepsilon 2}$	=	reduction factor for test specimen size effect
γ_v	=	reduction factor for variable amplitude loading
γ_m	=	reduction factor for mean stress
σ_{exp}	=	mean fatigue strength of the blade material at 10^8 cycles to failure in seawater

The maximum allowable stress for one or low number of cycles is limited to σ_{ref2}/S, with S=1.3 for static loads.

The fatigue strength σ_{fat} is the fatigue limit at 100 million load cycles.

The geometrical size factor $\gamma_{\varepsilon 2}$, or, K_{size}, is:

$$\gamma_{\varepsilon 2} = K_{size} = 1 - a \cdot \ln\left(\frac{t}{c_8}\right)$$

where

a	=	given in 6-1-3/11.5.2 TABLE 7
t	=	actual blade thickness at considered section, in mm (mm, in.)
c_8	=	25 (25, 0.98425)

The mean stress effect (γ_m) or (K_{mean}) is

$$\gamma_m = K_{mean} = 1.0 - \left(\frac{1.4 \cdot \sigma_{mean}}{\sigma_u}\right)^{0.75}$$

The S-N curve characteristics are based on two slopes, the first slope (4.5) is from 1000 to 100 million load cycles; the second slope (10) is above 10^8 load cycles.

σ_{exp}has been defined from the results of constant amplitude loading fatigue tests at 10^7 load cycles and 50% survival probability and has been extended to 10^8 load cycles. Fatigue strength values and correction factors other than those given in the Table may be used, provided the values are determined under conditions approved by ABS.

The following values should be used for the reduction factors if actual values are not available: $\gamma_{\varepsilon 1}$= 0.85, γ_v= 0.75, and γ_m= 0.75

TABLE 7
Mean Fatigue Strength, σ_{exp}, for Different Material Types at 10^8 load cycles and stress ratio R=-1 with a survival probability of 50%
(1 July 2024)

Bronze and Brass (a = 0.10)		*Stainless Steel (a = 0.05)*	
Type	σ_{exp} *MPa (kgf/mm², psi)*	*Type*	σ_{exp} *MPa (kgf/mm², psi)*
Mn-Bronze, CU1 (high tensile brass)	84 (8.566, 12183)	Ferritic (12Cr 1Ni)	144 (14.684, 20885) This value may be used, provided a perfect galvanic protection is active. Otherwise a reduction of about 30 MPa (3.059, 4351) is to be applied
Mn-Ni-Bronze, CU2 (high tensile brass)	84 (8.566, 12183)	Martensitic (13Cr 4Ni/ 13Cr 6Ni)	156 (15.908, 22625)
Ni-Al-Bronze, CU3	120 (12.237, 17405)	Martensitic (16Cr 5Ni)	168 (17.131, 24366)
Mn-Al-Bronze, CU4	113 (11.523, 16389)	Austenitic (19Cr 10Ni)	132 (13.460, 19145)

11.7 Blade Flange, Bolts and Propeller Hub and CP Mechanism

11.7.1 General *(1 July 2024)*

The blade bolts, the CP mechanism, the propeller boss, and the fitting of the propeller to the propeller shaft are to be designed to withstand the maximum and fatigue design loads, as defined in 6-1-3/9. The safety factor S against yielding due to static loads and against fatigue is to be greater than 1.5, if not stated otherwise. In addition, the safety factor for loads resulting from loss of the propeller blade through plastic bending, as defined in 6-1-3/9.11.4, is to be greater than 1 against yielding.

11.7.1(a) Blade bolts (1 July 2024)

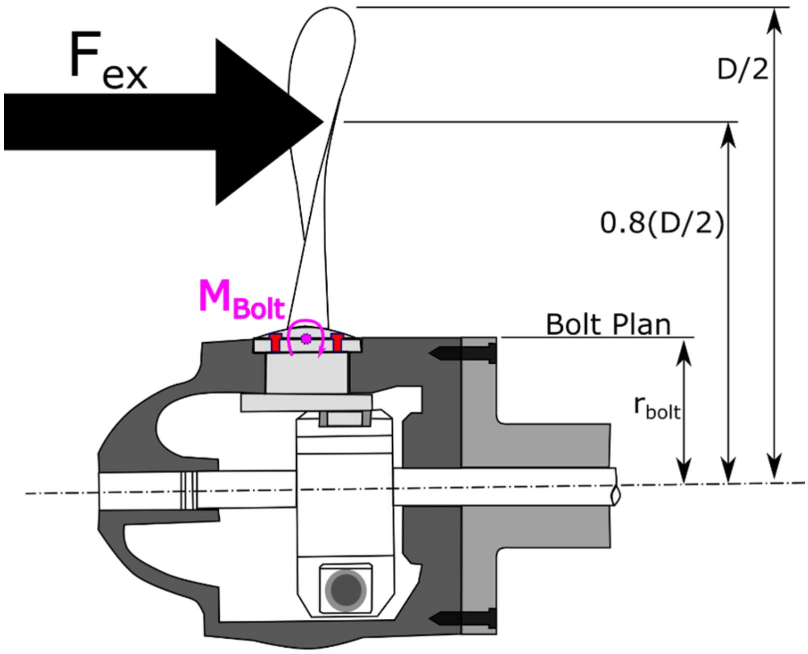
Blade bolts are to withstand following bending moment, M_{bolt}, in kN-m (tf-m, Ltf-ft) considered around bolt pitch circle, or another relevant axis for not circular joints, parallel to considered root section:

$$M_{bolt} = SF_{ex}\left(0.8\frac{D}{2} - r_{bolt}\right)$$

where

r_{bolt}	=	radius to the bolt plan, in m (m, ft)
S	=	1.0

FIGURE 8
Bending Moment, M_{bolt} (2024)



Blade bolt pre-tension is to be sufficient to avoid separation between mating surfaces with maximum forward and backward ice loads in 6-1-3/9.5 and 6-1-3/9.7 (open and ducted respectively). For conventional arrangements, the following formula may be applied:

$$d_{bb} = 41\sqrt{\frac{F_{ex}.(0.8.D - d).S.a}{\sigma_{0.2} \cdot Z_{bb} \cdot PCD}} \quad \text{[mm]}$$

where

α = 1.6 torque guided tightening
1.3 elongation guided
1.2 angle guided
1.1 elongated by other additional means
other factors may be used, if evidence is demonstrated

d_{bb} = effective diameter of blade bolt in way of thread [mm]

Z_{bb} = number of blade bolts

S = 1.0 safety factor

11.7.1(b) CP mechanism (1 July 2024)

Separate means (e.g. dowel pins) have to be provided in order to withstand a spindle torque resulting from blade failure Q_{sex} (6-1-3/9.11.4) or ice interaction Q_{smax} (6-1-3/9.7.3), whichever is greater. Other components of the CP mechanism are not to be damaged by the maximum spindle torques (Q_{smax}, Q_{sex}). One third of the spindle torque is assumed to be consumed by friction, if not otherwise documented trough further analysis. The diameter of fitted pins d_{fp} between the blade and blade carrier can be calculated using the formula:

$$d_{fp} = c_8\sqrt{\frac{Q_s - Q_{fr}}{PCD \cdot z_{pin} \cdot \sigma_{0.2}}} \quad \text{[mm]}$$

where

c_8	=	66	
S	=	1.3	for Q_{smax}
	=	1.0	for Q_{sex}
Q_s	=	$\max(S \cdot Q_{\max}; S \cdot Q_{sex})$	kN-m
Q_{fr}	=	friction between connected surfaces = $0.33 . Q_s$	

Friction coefficient = 0.15 is to be applied in calculation of Q_{fr} unless the actual friction coefficient is known in an alternative calculation for Q_{fr} subject to ABS technical assessment and approval,according to reaction forces due to F_{ex}, or F_f, F_b whichever is relevant.

The stress in the actuating pin can be estimated by

$$\sigma_{vMises} = \sqrt{\left(\frac{\left(F \cdot \frac{h_{pin}}{2}\right)}{\frac{\pi \cdot d_{pin}^3}{32}}\right)^2 + 3 \cdot \left(\frac{F}{\frac{\pi}{4} \cdot d_{pin}^2}\right)^2} \qquad \text{(MPa)}$$

where

$$F = \frac{Q_s - Q_{fr}}{l_m} \qquad \text{(kN)}$$

l_m	=	distance pitching centre of blade – axis of pin [m]
h_{pin}	=	height of actuating pin [mm]
d_{pin}	=	diameter of actuating pin [mm]
Q_{fr}	=	friction torque in blade bearings acting on the blade palm and caused by the reaction forces due to F_{ex}, or F_f, F_b whichever is relevant; taken to one third of spindle torque Q_s.

The blade failure spindle torque Q_{sex} is not to lead to any consequential damages.

Commentary:

Consequential damages apply to any component of the propulsion system that may experience loading as a result of Q_{sex}. Damages may be assumed to occur if any component experiences yield stresses with the application of Q_{sex}.

End of Commentary

Fatigue strength is to be considered for parts transmitting the spindle torque from blades to a servo system considering ice spindle torque acting on one blade. The maximum amplitude is defined as:

$$Q_{samax} = \frac{Q_{sb} + Q_{sf}}{2} \qquad \text{kN} - \text{m}$$

where

Q_{sb}	=	spindle torque due to $\lvert F_b \rvert$ [kNm]
Q_{sf}	=	spindle torque due to $\lvert F_f \rvert$ [kNm]

Provided that calculated stresses duly considering local stress concentrations are less than yield strength, or maximum 70% of σ_u of respective materials, detailed fatigue analysis is not required.

In opposite case, components are to be analyzed for cumulative fatigue. Similar approach as used for shafting may be applied.

11.7.2 Servo Pressure

Design pressure for servo system is to be taken as a pressure caused by Q_{smax} or Q_{sex} when not protected by relief valves, reduced by relevant friction losses in bearings caused by the respective ice loads. Design pressure is to be less than relief valve set pressure.

11.9 Propulsion Line Components *(1 July 2019)*

The main propulsion line's components (i.e. propulsion shafts, couplings etc.) are to be reviewed by applying the loads determined in 6-1-3/9.5.5, 6-1-3/9.7.5, 6-1-3/9.11.1, 6-1-3/9.11.2, 6-1-3/9.11.3 and 6-1-3/11.1.

The strength evaluation under the applied loads is to verify the loads corresponding to the propeller blade failure load do not cause damage or deformation in the remaining propulsion line components.

The fatigue strength evaluation is to be based on the cumulative fatigue analyses according to Miner's Rule, as applicable. The applicable highest peak torque and the corresponding load spectrum are to be determined for each of the components or connections in question, as applicable.

The requirements in this section are complementary to those described in Section 4-3-2 of the Rules. The loads considered in this section do not need to be considered for shaft alignment or other calculations of normal operational conditions.

11.9.1 Propeller Fitting to the Shaft

11.9.1(a) Keyless Cone Mounting (1 July 2024)

The friction capacity at 0°C (32°F) is to be at least S=2.0 times the highest peak torque, as determined in 6-1-3/9.11.2, without exceeding the permissible hub stresses.

The necessary surface pressure in MPa (kgf/mm², psi) can be determined as:

$$p_{0°C} = c_9 \frac{2 \cdot S \cdot Q_{peak}}{\pi \cdot \mu \cdot D_S^2 \cdot L}$$

where

c_9	=	0.001 (0.001, 15.556)	
μ	=	0.15	for steel-steel
	=	0.13	for steel-bronze
D_S	=	is the shrinkage diameter at mid-length of taper, in m (m, ft)	
L	=	is the effective length of taper, in m (m, ft)	

Above friction coefficients may be increased by 0.04 if glycerin is used in wet mounting

11.9.1(b) Key Mounting

Key mounting is not permitted.

11.9.1(c) Flange Mounting (1 July 2024)

i) The flange thickness is to be at least 25% of the required aft end shaft diameter.

ii) Any additional stress raisers such as recesses for bolt heads are not to interfere with the flange fillet unless the flange thickness is increased correspondingly.

iii) The flange fillet radius is to be at least 10% of the shaft diameter.

iv) The diameter of ream fitted (light press fit) bolts is to be chosen so that the peak torque does not cause shear stresses beyond 30% of the yield strength of the bolts.

The diameter of shear pins is to be calculated according to the following equation:

$$d_{pin} = 66 . \sqrt{\frac{Q_{peak} \cdot S}{PCD . z_{pin} \cdot \sigma_{0.2}}} \quad \text{[mm]}$$

where

Z_{pin}	=	number of shear pins and S=1.3 safety factor.

v) The bolts are to be designed so that the blade failure load F_{ex} (6-1-3/9.11.4) in backward direction does not cause yielding. The following equation can be applied:

$$\sigma_b = 41 . \sqrt{\frac{F_{ex}\left(0.8 . \frac{D}{PCD} + 1\right) . \alpha}{\sigma_{0.2} \cdot z_b}} \quad \text{[mm]}$$

where

α = 1.6 torque guided tightening
1.3 elongation guided
1.2 angle guided
1.1 elongated by other additional means
other factors may be used, if evidence is demonstrated

d_b = diameter flange bolt [mm]

z_b = number of flange bolts

11.9.2 Propeller Shaft *(1 July 2024)*

The propeller shaft is to be designed to fulfill the following:

i) The blade failure load F_{ex} (6-1-3/9.11.4) applied parallel to the shaft (forward or backwards) is not to cause yielding. Bending moment need not to be combined with any other loads. The diameter d, in mm (mm, in.), in way of the aft stern tube bearing is not to be less than:

$$d = c_{10} \cdot \sqrt[3]{\frac{F_{ex} \cdot D}{\sigma_{0.2} \cdot \left(1 - \frac{d_i^4}{d^4}\right)}}$$

where

c_{10} = 160 (160, 48)

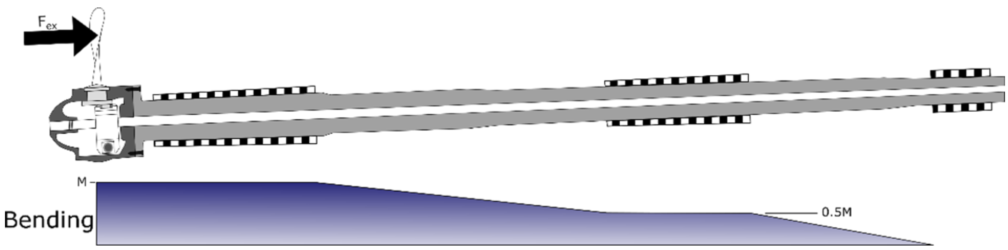
$\sigma_{0.2}$ = minimum specified yield or 0.2% proof strength of the propeller shaft material, in MPa (kgf/mm^2, psi)

d = propeller shaft diameter, in mm (mm, in.)

d_i = propeller shaft inner diameter, in mm (mm, in.)

Forward from the aft stern tube bearing the diameter may be reduced based on direct calculation of actual bending moments, or by the assumption that the bending moment caused by F_{ex} is linearly reduced to 25% at the next bearing and in front of this linearly to zero at third bearing.

FIGURE 9
Bending Moment in Propeller Shaft Forward of Aft Stern Tube Bearing *(2024)*



ii) Bending due to maximum blade forces F_b and F_f have been disregarded since the resulting stress levels are much below the stresses due to the blade failure load.

iii) The stresses due to the peak torque, Q_{peak}, in kN-m (tf-m, Ltf-ft), are to have a minimum safety factor of 1.5 against yielding in plain sections and 1.0 in way of stress concentrations in order to avoid bent shafts.

Minimum diameter of:

Plain shaft: $$d = c_{11} \cdot \sqrt[3]{\frac{Q_{peak} \cdot S}{\sigma_{0.2} \cdot \left(1 - \frac{d_i^4}{d^4}\right)}} \quad \text{mm(mm, in.)}$$

Notched shaft: $$d = c_{12} \cdot \sqrt[3]{\frac{Q_{peak} \cdot \alpha_t \cdot S}{\sigma_{0.2} \cdot \left(1 - \frac{d_i^4}{d^4}\right)}} \quad \text{mm(mm, in.)}$$

where

c_{11} = 210 (210, 63)

c_{12} = 210 (210, 63)

α_t = the local stress concentration factor in torsion. Notched shaft diameter shall in any case not be less than the required plain shaft diameter.

Commentary:

α_t can be determined in several ways such as:

1 Using geometrical formulations to recognized standards.

2 Use FEA on the shaft applying the Q_A and sufficient mesh size to identify stress intensity areas.

End of Commentary

iv) The torque amplitudes with the foreseen number of cycles are to be used in an accumulated fatigue evaluation where the safety factor is $S_{fat} = 1.5$. If the plant also has high engine excited torsional vibrations (e.g., direct coupled 2-stroke engines), this has also to be considered.

v) For plants with reversing direction of rotation, the stress range $\Delta\tau \cdot \alpha_t$ resulting from forward Q_{peakf} to astern Q_{peakb} is not to exceed twice the yield strength (in order to avoid stress-strain hysteresis loop) with a safety factor of 1.5, i.e.:

$$\Delta\tau \cdot \alpha_t \leq \frac{2 \cdot \sigma_y}{\sqrt{3} \cdot 1.5} \quad \text{MPa} \quad (\text{kgf/mm}^2, \quad \text{psi})$$

The fatigue strengths σ_F and τ_F (3 million cycles) of shaft materials are to be assessed on the basis of the material's yield or 0.2% proof strength as:

$$\sigma_F = 0.436 \cdot \sigma_{0.2} + 77 = \tau_F \cdot \sqrt{3} \quad \text{MPa}(\text{kgf/mm}^2, \text{psi})$$

This is valid for small polished specimens (no notch) and reversed stresses.

The high cycle fatigue (HCF) is to be assessed based on the above fatigue strengths, notch factors (i.e., geometrical stress concentration factors and notch sensitivity), size factors, mean stress influence and the required safety factor of 1.6 at 3 million cycles increasing to 1.8 at 10^9 cycles.

The low cycle fatigue (LCF) representing 10^4 cycles is to be based on the lower value of the smaller value of yield or 0.7 of tensile strength/$\sqrt{3}$. The criterion utilizes a safety factor of 1.25.

The LCF and HCF as given above represent the upper and lower knees in a stress-cycle diagram. Since the required safety factors are included in these values, a Miner sum of unity is acceptable.

11.9.3 Intermediate Shafts *(1 July 2024)*

The intermediate shafts are to be designed to fulfill the following:

i) The stresses due to the peak torque Q_{peak}, in kN-m (tf-m, Ltf-ft), are to have a minimum safety factor of 1.5 against yielding in plain sections and 1.0 in way of stress concentrations in order to avoid bent shafts.

Minimum diameter of:

Plain shaft:

$$d = c_{11} \cdot \sqrt[3]{\frac{Q_{peak} \cdot S}{\sigma_{0.2} \cdot \left(1 - \frac{d_i^4}{d^4}\right)}} \quad \text{mm(mm, in.)}$$

Notched shaft:

$$d = c_{12} \cdot \sqrt[3]{\frac{Q_{peak} \cdot \alpha_t \cdot S}{\sigma_{0.2} \cdot \left(1 - \frac{d_i^4}{d^4}\right)}} \quad \text{mm(mm, in.)}$$

where

c_{11} = 210 (210, 63)

c_{12} = 210 (210, 63)

α_t = local stress concentration factor in torsion.

$\sigma_{0.2}$ = minimum specified yield or 0.2% proof strength of the shaft material, in MPa (kgf/mm^2, psi)

d = shaft diameter, in mm (mm, in.)

d_i = shaft inner diameter, in mm (mm, in.)

ii) The torque amplitudes with the foreseen number of cycles are to be used in an accumulated fatigue evaluation where a minimum safety factor of 1.5 is required. If the plant also has high engine excited torsional vibrations (e.g., direct coupled 2-stroke engines), this has also to be considered.

iii) For plants with reversing direction of rotation the stress range $\Delta\tau \cdot \alpha_t$ resulting from forward Q_{peakf} to astern Q_{peakb} is not to exceed twice the yield strength (in order to avoid stress-strain hysteresis loop) with a safety factor of 1.5, i.e.:

$$\Delta\tau \cdot \alpha_t \le \frac{2 \cdot \sigma_y}{\sqrt{3} \cdot 1.5} \quad \text{MPa} \quad (\text{kgf/mm}^2, \quad \text{psi})$$

The fatigue strengths σ_F and τ_F (3 million cycles) of shaft materials are to be assessed on the basis of the material's yield or 0.2% proof strength as:

$$\sigma_F = 0.436 \cdot \sigma_{0.2} + 77 = \tau_F \cdot \sqrt{3} \quad \text{MPa} \quad (\text{kgf/mm}^2, \quad \text{psi})$$

This is valid for small polished specimens (no notch) and reversed stresses.

The high cycle fatigue (HCF) is to be assessed based on the above fatigue strengths, notch factors (i.e., geometrical stress concentration factors and notch sensitivity), size factors and the required safety factor of 1.6 at 3 million cycles increasing to 1.8 at 10^9cycles.

The low cycle fatigue (LCF) representing 10^3 cycles is to be based on the smaller value of yield or 0.7 of tensile strength/$\sqrt{3}$. The criterion utilizes a safety factor of 1.25.

The LCF and HCF as given above represent the upper and lower knees in a stress-cycle diagram. Since the required safety factors are included in these values, a Miner sum of unity is acceptable.

11.9.4 Shaft Connections

11.9.4(a) Shrink Fit Couplings (Keyless) (*1 July 2024*)

The friction capacity is to be at least 1.8 times the highest peak torque, Q_{peak}, in kN-m (tf-m, Ltf-ft), as determined in 6-1-3/9.11.2, without exceeding the permissible hub stresses.

The necessary surface pressure can be determined as:

$$p = c_9 \frac{2 \cdot 1.8 \cdot Q_{peak}}{\pi \cdot \mu \cdot D_S^2 \cdot L} \quad \text{MPa}(\text{kgf/mm}^2, \text{psi})$$

where

c_9 = 0.001 (0.001, 15.556)

μ = 0.15 for steel to steel with oil injection (0.18 if glycerine injection) and 0.13 for steel to bronze

D_S = is the shrinkage diameter at mid-length of taper, in m (m, ft)

L = is the effective length of taper, in m (m, ft)

11.9.4(b) Key Mounting

Key mounting is not permitted.

11.9.4(c) Flange Mounting (*1 July 2024*)

i) The flange thickness is to be at least 20% of the shaft diameter (see 4-3-2/5.19)

ii) Any additional stress raisers such as recesses for bolt heads are not to interfere with the flange fillet unless the flange thickness is increased correspondingly.

iii) The flange fillet radius is to be at least 8% of the shaft diameter (see 4-3-2/5.19)

iv) The diameter of ream fitted (light press fit) bolts or pins is to be chosen so that the peak torque is transmitted with a safety factor of 1.9. This accounts for a prestress. Pins are to transmit the peak torque with a safety factor of 1.5 against yielding (see 6-1-3/11.9.1(c)).

v) The bolts are to be designed so that the blade failure load (6-1-3/9.11.4) in backwards direction does not cause yielding.

11.9.4(d) Splined shaft connections (1 July 2024)

Splined shaft connections can be applied where no axial or bending loads occur. A safety factor of S = 1.5 against allowable contact and shear stress resulting from Q_{peak} is to be applied.

11.9.5 Gear Transmissions *(1 July 2024)*

11.9.5(a) Shafts

Shafts in gear transmissions are to meet the same safety level as intermediate shafts, but where relevant, bending stresses and torsional stresses are to be combined (e.g., by von Mises). Maximum permissible deflection in order to maintain sufficient tooth contact pattern is to be considered for the relevant parts of the gear shafts.

11.9.5(b) Gearing:

The gearing is to fulfill following 3 acceptance criteria:

i) Tooth root stresses

ii) Pitting of flanks

iii) Scuffing

In addition to the three above criteria subsurface fatigue is to be considered.

Common for all criteria is the influence of load distribution over the face width. All relevant parameters are to be considered, such as elastic deflections (of mesh, shafts and gear bodies), accuracy tolerances, helix modifications, and working positions in bearings (especially for twin input single output gears).

The load spectrum (see 6-1-3/11.1) is to be applied in such a way that the numbers of load cycles for the output wheel are multiplied by a factor of (number of pinions on the wheel / number of propeller blades Z). For pinions and wheels with higher speed the numbers of load cycles are found by multiplication with the gear ratios. The peak torque (Q_{peak}) is also to be considered during calculations.

Cylindrical gears are to be assessed on the basis of the international standard ISO 6336 Pt.1-6, provided that “methods B” are used. Other acceptable alternative methods may also be considered on a case-by-case basis.

Bevel gears are to be assessed in accordance with Section 4-3-1.

Tooth root safety is to be assessed against the peak torque, torque amplitudes (with the pertinent average torque) as well as the ordinary loads (free water running) by means of accumulated fatigue analyses. The resulting safety factor is to be at least 1.5. (Ref ISO 6336 Pt 1, 3 and 6)

The safety against pitting is to be assessed in the same way as tooth root stresses, but with a minimum resulting safety factor of 1.2. (Ref ISO 6336 Pt 1, 2 and 6)

The scuffing safety (flash temperature method - ref. ISO-TR 13989) based on the peak torque is to be at least 1.2 when the FZG class of the oil is assumed one stage below specification.

The safety against subsurface fatigue of flanks for surface hardened gears (oblique fracture from active flank to opposite root) is to be assessed.

Commentary:

As an alternative to 6-1-3/11.9.5 for gears, the requirements in Section 4-3-1 can be applied using the peak and amplitude torques (see 6-1-3/9.11.2) associated with milling ice.

End of Commentary

11.9.6 Gear Wheel Shaft Connections and Clutches *(1 July 2024)*

11.9.6(a) Gear wheel shaft connections (1 July 2024)

The torque capacity is to be at least 1.8 times the highest peak torque Q_{peak} (at considered rotational speed) as determined in 6-1-3/11.9 without exceeding the permissible hub stresses of 80% yield.

11.9.6(b) Clutches (1 July 2024)

Clutches are to have a static friction torque of at least 1.3 times the peak torque and dynamic friction torque $^2/_3$ of the static.

Emergency operation of clutch after failure (e.g., operating pressure) is to be made possible within reasonably short time. If this is arranged by bolts, it is to be on the engine side of the clutch that enables access to all bolts by turning the engine.

11.9.7 Elastic Couplings *(1 July 2024)*

There is to be a separation margin of at least 20% between the peak torque and the torque where any twist limitation is reached.

$$Q_{peak} < 0.8 . T_{kmax}(N = 1) \qquad \text{[kNm]}$$

There is to be a separation margin of at least 20% between the maximum response torque Q_{peak} and the torque where any mechanical twist limitation and/or the permissible maximum torque of the elastic coupling, valid for at least a single load cycle (N=1), is reached.

A sufficient fatigue strength shall be demonstrated at design torque level Q_r *(N=x)* and Q_A *(N=x)*. This may be demonstrated by interpolation in a Weibull torque distribution:

$$\frac{Q_r(N = x)}{Q_r(N = 1)} = 1 - \frac{\log(x)}{\log(Z . N_{ice})} \qquad [-]$$

respectively

$$\frac{Q_A(N = x)}{Q_A(N = 1)} = 1 - \frac{\log(x)}{\log(Z . N_{ice})} \qquad [-]$$

Where Q_r *(N=1)* corresponds to Q_{peak} and Q_A *(N=1)* to Q_{Amax}.

$$Q_r(N = 5E4) . S < T_{Kmax}(N = 5E4) \qquad \text{[kNm]}$$
$$Q_r(N = 1E6) . S < T_{KV} \qquad \text{[kNm]}$$
$$Q_A(N = 1E6) . S < \Delta T_{max}(N = 5E4) \qquad \text{[kNm]}$$

S is the general safety factor for fatigue, equal to 1.5.

The torque amplitude (or range Δ) is not to lead to fatigue cracking, i.e. exceeding the permissible vibratory torque. The permissible torque is to be determined by interpolation in a log-log (Weibull) torque-cycle diagram where $T_{K\max1}$ respectively $\Delta T_{K\max}$ refer to 50,000 cycles and T_{KV}

refer to 10^6 cycles. See illustration in 6-1-3/11.9.7 FIGURE 10, 6-1-3/11.9.7 FIGURE 11 and 6-1-3/11.9.7 FIGURE 12.

$$T_{Kmax1} \geq Q_r \quad at \quad 5.10^4 \quad load \quad cycles \qquad \text{[kNm]}$$

FIGURE 10
Log-log Torque-cycle Diagram Defining $T_{K\max1}$

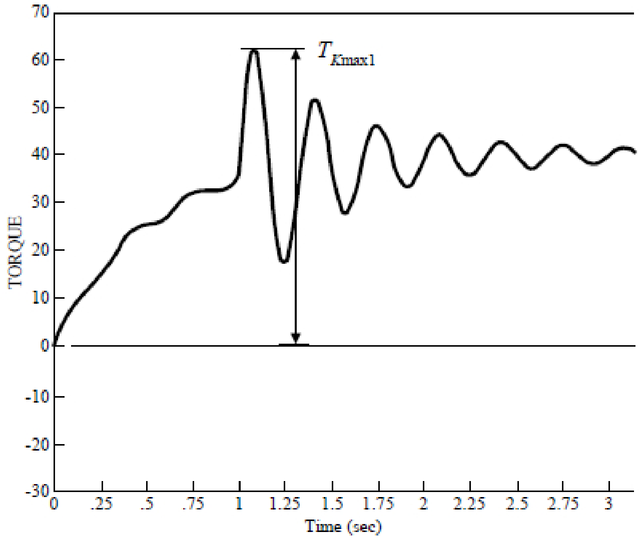


FIGURE 11
Log-log Torque-cycle Diagram Defining $\Delta T_{K\max}$

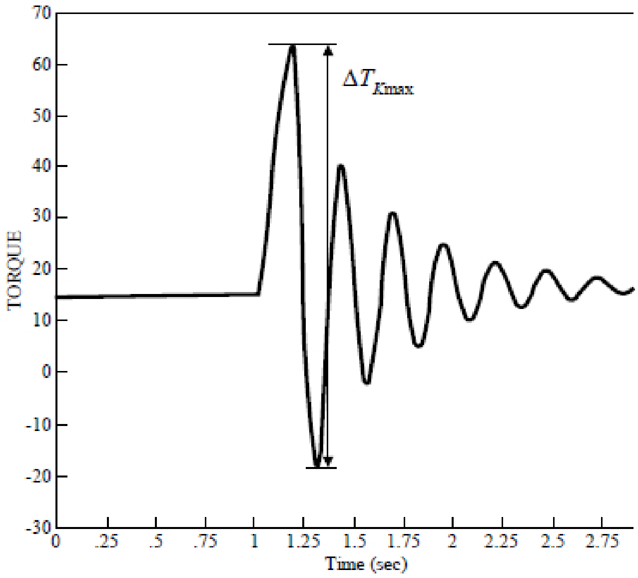
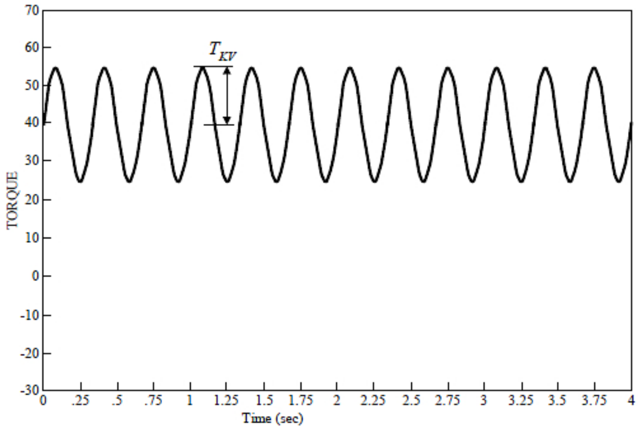


FIGURE 12
Log-log Torque-cycle Diagram Defining T_{KV}



11.9.8 Crankshafts *(1 July 2024)*

ABS technical assessment and approval apply for plants with large inertia (e.g., flywheel, tuning wheel or PTO) in the non-driving end of the engine (opposite to main power take off).

Commentary:

Large inertias on the non-driving end of an engine should be included in the transient torsional vibration analysis required in 6-1-3/9.11.2. The crankshaft should be assessed considering the peak torque calculated.

End of Commentary

11.9.9 Bearings *(1 July 2024)*

All shaft bearings are to be designed to withstand the propeller blade ice interaction loads according to 6-1-3/9.5 and 6-1-3/9.7. For the purpose of calculation the shafts are assumed to rotate at rated speed. Reaction forces due to the response torque (e.g. in gear transmissions) are to be considered.

Additionally the aft stern tube bearing as well as the next shaftline bearing are to withstand F_{ex} as given in 6-1-3/9.11.4, in such a way that the ship can maintain operational capability.

Rolling bearings are to have a L_{10a} lifetime of at least 40 000 hours according to ISO-281.

Thrust bearings and their housings are to be designed to withstand with a safety factor S=1.0 the maximum response thrust 6-1-3/9.11.3 and the axial force resulting from the blade failure force F_{ex} in 6-1-3/9.11.4. For the purpose of calculation except for F_{ex} the shafts are assumed to rotate at rated speed. For pulling propellers, ABS technical assessment is to be given to loads from ice interaction on propeller hub.

Commentary:

Ice loads on the hub of pulling propellers will result in a thrust reversal. The thrust bearing should be assessed for this thrust reversal and the dynamic return of pulling thrust.

End of Commentary

11.9.10 Seals *(1 July 2024)*

Seals are to prevent egress of pollutants, and be suitable for the operating temperatures. Contingency plans for preventing the egress of pollutants under failure conditions are to be documented.

Seals are to be of a design suitable for the intended application. The manufacturer is to provide service experience in similar applications and/or testing results for consideration.

11.11 Prime Movers

11.11.1 Propulsion Engines *(2024)*

Engines are to be capable of being started and running the propeller in bollard condition.

Propulsion plants with CP propeller are to be capable being started and operated even in case with the CP system in full pitch as limited by mechanical stoppers.

11.11.2 Emergency Power Units *(2024)*

Provisions are to be made for heating arrangements with sufficient capacity to enable starting of the cold emergency power units at an ambient temperature applicable to the Polar class of the ship.

Emergency power units are be equipped with starting devices with a stored energy capability of at least three consecutive starts at the lesser of the design temperature, or the coldest temperature the compartment will experience. The source of stored energy shall be protected to preclude critical depletion by the automatic starting system, unless a second independent means of starting is provided. A second source of energy is to be provided for an additional three starts within 30 min., unless manual starting can be demonstrated to be effective.

11.11.3 Starting arrangements *(1 July 2024)*

The capacity of the air receivers is to be sufficient to provide, without recharging, not less than 12 consecutive starts of the propulsion engine, if this has to be reversed for going astern or 6 consecutive starts if the propulsion engine does not have to be reversed for going astern.

If the air receivers serve any other purposes than starting the propulsion engine, they shall have additional capacity sufficient for these purposes.

The capacity of the air compressors is to be sufficient for charging the air receivers from atmospheric to full pressure in one (1) hour, except for a ship with the ice class PC6 to PC1, if its propulsion engine has to be reversed for going astern, in which case the compressor is to be able to charge the receivers in half an hour.

13 Machinery Fastening Loading Accelerations

13.1 General *(2024)*

Essential equipment and supports are to be suitable for the accelerations as indicated in as follows. Accelerations are to be considered acting independently.

Commentary:

Essential equipment is listed in 4-8-1/7.3.3. Piping systems servicing equipment listed in 4-8-1/7.3.3 is also considered essential equipment.

End of Commentary

13.3 Longitudinal Impact Accelerations

Maximum longitudinal impact acceleration, a_ℓ, at any point along the hull girder:

$$a_\ell = g_c \cdot (F_{IB}/\Delta) \cdot \{[1.1 \cdot \tan(\gamma + \varphi)] + [7 \cdot (\tfrac{H}{L})]\} \quad \mathrm{m/s^2 (m/s^2, ft/s^2)}$$

where

g_c = 1 (9.80665, 32.174)

13.5 Vertical Acceleration

Combined vertical impact acceleration, a_v, at any point along the hull girder:

$$a_v = g_c \cdot 2.5 \cdot (F_{IB}/\Delta) \cdot F_X \quad \mathrm{m/s^2 (m/s^2, ft/s^2)}$$

where

g_c = 1 (9.80665, 32.174)

F_X = 1.3 at FP

= 0.2 at midships

= 0.4 at AP

= 1.3 at AP for vessels conducting ice breaking astern

intermediate values to be interpolated linearly

13.7 Transverse Impact Acceleration

Combined transverse impact acceleration, a_t, at any point along hull girder:

$$a_t = g_c \cdot 3 \cdot F_i \cdot \frac{F_X}{\Delta} \quad \mathrm{m/s^2 (m/s^2, ft/s^2)}$$

where

g_c = 1 (9.80665, 32.174)

F_X = 1.5 at FP

= 0.25 at midships

= 0.5 at AP

= 1.5 at AP for vessels conducting ice breaking astern

intermediate values to be interpolated linearly

ϕ = maximum friction angle between steel and ice, normally taken as 10, in degrees

γ = bow stem angle at waterline, in degrees

Δ = displacement in (tonnes, tonnes, Lton)

L = length between perpendiculars, in m (m, ft)

H = distance from the water line to the point being considered, in m (m, ft)

F_{IB} = vertical impact force in kN (tf, Ltf), defined in 6-1-2/25.3

F_i = total force in kN (tf, Ltf) normal to shell plating in the bow area due to oblique ice impact, defined in 6-1-2/5.5

15 Auxiliary Systems

15.1 Machinery Protection

Machinery is to be protected from the harmful effects of ingestion or accumulation of ice or snow. Where continuous operation is necessary, means are to be provided to purge the system of accumulated ice or snow.

15.3 Freezing

Means are to be provided to prevent damage due to freezing, to tanks containing liquids.

15.5 Vent and Discharge Pipes

Vent pipes, intake and discharge pipes and associated systems are to be designed to prevent blockage due to freezing or ice and snow accumulation.

17 Sea Inlets and Cooling Water Systems

17.1 Cooling Water Systems for Machinery

Cooling water systems for machinery that are essential for the propulsion and safety of the vessel, including sea chests inlets, are to be designed for the environmental conditions applicable to the ice class.

17.3 Sea Chests

At least two sea chests are to be arranged as ice boxes for Polar Class **PC1** to **PC5** inclusive where the calculated volume for each of the ice boxes is to be at least 1 m^3 (1 m^3, 35.314 ft^3) for every 750 kW (750 kW, 1005 HP) of the total installed power.

For Polar Classes **PC6** and **PC7**, at least one ice box for supplying water for cooling and fire-fighting purposes is to be connected to the cooling-water discharge by a branch pipe having the same cross sectional area as the main pipe-line, in order to stay free from ice and slush ice. The sea inlet chest is to be situated well aft, adjacent to the keel, located preferably near the centerline.

17.5 Ice Boxes

Ice boxes are to be designed for an effective separation of ice and venting of air.

17.7 Sea Inlet Valves

Sea inlet valves are to be secured directly to the ice boxes. The valves are to be a full bore type.

17.9 Vent Pipes

Ice boxes and sea bays are to have vent pipes and are to have shut off valves connected direct to the shell.

17.11 Sea Bays Freezing Prevention

Means are to be provided to prevent freezing of sea bays, ice boxes, ship side valves and fittings above the load water line.

17.13 Cooling Seawater Re-circulation

Efficient means are to be provided to re-circulate cooling seawater to the ice box. Total sectional area of the circulating pipes is not to be less than the area of the cooling water discharge pipe.

17.15 Ice Boxes Access

Detachable gratings or manholes are to be provided for ice boxes. Manholes are to be located above the deepest load line. Access is to be provided to the ice box from above.

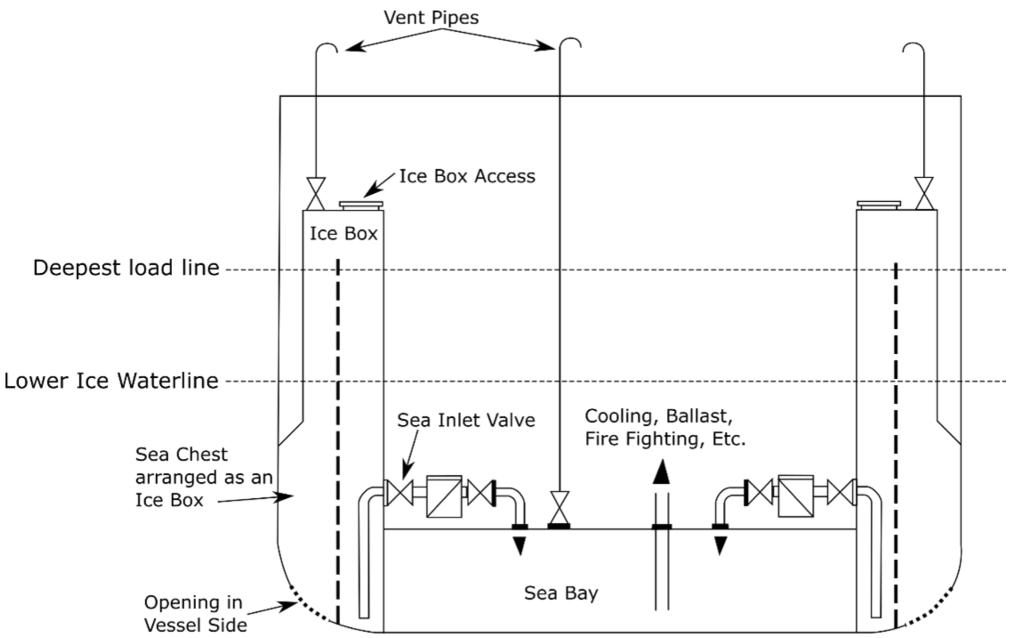
17.17 Openings in Vessel Sides *(1 July 2024)*

Openings in vessel sides for ice boxes are to be fitted with gratings, or holes or slots in shell plates. The net area through these openings is to be not less than 5 times the area of the inlet pipe. The diameter of holes and width of slot in shell plating is to be not less than 20 mm (20 mm, 0.787 in.). Gratings of the ice boxes are to be provided with a means of clearing. The means of clearing is to be of a type using low pressure steam. Clearing pipes are to be provided with screw-down type non return valves.

Commentary:

A4/5.3.2 "Cooling System" of the ABS *Guide for Vessels Operating in Low Temperature Environments* has examples of sea water intake arrangements. The below figure is another example that shows the terms used in 6-1-3/17.

FIGURE 13
Sample of See Water Intake Arrangement



End of Commentary

19 Ballast Tanks *(2024)*

Efficient means are to be provided to prevent freezing in fore and after peak tanks and wing tanks located above the waterline and where otherwise found necessary.

Commentary:

There are several ways of effectively preventing ballast tank freezing. Some examples are tanks located below the waterline, agitation by bubbler system, or heating.

End of Commentary

21 Ventilation System

21.1 Air Intakes Location *(2024)*

The air intakes for machinery and accommodation ventilation are to be located on both sides of the vessel.

Commentary:

The requirement for air intakes on both sides of the vessel is intended to minimize blockage from ice accretion. The locations should be accessible for manual de-icing. Anti-icing protection of the air inlets may be accepted as an equivalent solution to location on both sides of the ship. Multiple air intakes should be provided for the emergency generating set and should be as far apart as possible.

End of Commentary

21.3 Air Intakes Heating

Accommodation and ventilation air intakes are to be provided with means of heating.

21.5 Machinery Air Intakes *(1 July 2024)*

The temperature of inlets air provided to machinery from the air intakes is to be suitable for the safe operation of the machinery and the thermal comfort in the accommodation.

23 Steering Systems

23.1 General

Rudder stops are to be provided. The design ice force on the rudder is to be transmitted to the rudder stops without damage to the steering system.

An ice knife is to be fitted to protect the rudder in center position. The ice knife is to extend below BWL. Design forces are to be determined according to 6-1-2/29.

23.3 Rudder Actuator Holding Torque *(1 July 2024)*

The effective holding torque of the rudder actuator, at safety valve set pressure, is obtained by multiplying the open water requirement at design speed [maximum 9.26 m/s (9.26 m/s, 18 knots)] by the factors given in 6-1-3/23.3 TABLE 8.

TABLE 8
Rudder Actuator Holding Torque Multipliers *(1 July 2024)*

Ice Class	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Factor	5	5	3	3	3	1.5	1.5

The design pressure for calculations to determine the scantlings of the rudder actuator is to be at least 1.25 times the maximum working pressure corresponding to the holding torque defined above.

23.5 Torque Relief Arrangements *(1 July 2024)*

The rudder actuator is to be protected by torque relief arrangements, assuming the turning speeds given in 6-1-3/23.5 TABLE 9 without undue pressure rise:

TABLE 9
Assumed Turning Speeds for Torque Relief Arrangements *(1 July 2024)*

Ice Class	PC1-2	PC3-5	PC6 - 7
Turning speeds [deg/s]	10	7.5	6

If the rudder and actuator design can withstand such rapid loads, this special relief arrangement is not necessary and a conventional one may be used instead (see 4-3-4/9.1.6)

23.7 Fast Acting Torque Relief Arrangements *(1 July 2024)*

Additionally for icebreakers, fast-acting torque relief arrangements are to be fitted in order to provide effective protection of the rudder actuator in case of the rudder being pushed rapidly hard over against the stops.

For hydraulically operated steering gear, the fast acting torque relief arrangements (acting at 15% higher pressure than set pressure of safety valves in 6-1-3/23.5) are to provide effective protection of the rudder actuator in case of the rudder is pushed rapidly hard over against the stops assuming turning speeds given in 6-1-3/23.7 TABLE 10, taking also into account the oil viscosity at the lowest expected ambient temperature in the steering gear compartment. For alternative steering systems the fast-acting torque relief arrangement is to demonstrate an equivalent degree of protection to that required for hydraulically operated arrangements.

TABLE 10
Rudder Actuator Holding Torque Multipliers *(1 July 2024)*

Ice Class	PC1-2	PC3-5	PC6 - 7
Turning speeds [deg/s]	40	20	15

The arrangement is to be so that steering capacity can be speedily regained.

25 Alternative Designs *(2024)*

As an alternative to this section, a comprehensive design study is to be submitted to ABS for technical assessment and approval. The alternative design may be requested to be validated by an agreed test program.

PART 6

CHAPTER 1

Strengthening for Navigation in Ice

SECTION 4

First Year Ice Classes *(2024)*

1 General

These goals and requirements apply to First Year Ice Class vessels according to 6-1-4/1.1.

For operation in the Baltic Sea area, all vessels are to be self-propelled and equipped with a radio telephone (VHF).

1.1 Application

1.1.1 Goals *(2024)*

The structure and machinery covered in this section are to be designed, constructed, and maintained to:

Goal No.	*Goals*
STRU 1	in the intact condition, have sufficient structural strength to withstand the environmental conditions, loading conditions, and operational loads anticipated during the design life.
STRU 2	resist structural failure associated with accidental conditions.
STRU 3	provide protection to persons on board, environment and required safety services.
STRU 3.1	maintain mechanical properties during low air temperatures.
PROP 1	provide sufficient thrust/power to move or maneuver the vessel when required.
PROP 2	provide redundancy and/or reliability to maintain propulsion.
PROP 5	provide redundancy and/or reliability to maintain maneuverability.
Polar Code Part I-A/6.1	*ensure that machinery installations are capable of delivering the required functionality necessary for safe operation of ships.*
POW 2	provide power to enable machinery/equipment/electrical installation to perform its required functions necessary for the safe operation of the vessel.
POW 4	enable all electrical services required for safety to be available during emergency condition. (SOLAS II-1 Reg 40-1.2)
HAB 1.1	Effectively control the indoor environmental parameters in all conditions of weather and climate.

The goals in the cross-referenced Rules are also to be met.

1.1.2 Functional Requirements *(2024)*

In order to achieve the above slated goals, the design, construction, and maintenance are to be in accordance with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
Structure (STRU)	
STRU-FR1	*Resist both global and local structural loads anticipated under the foreseen ice conditions. (Polar Code)*
STRU-FR2	*Sufficient structural strength to resist cracking, buckling, deformation or corrosion which would impair the structural integrity of the ship. (SOLAS II-1)*
Propulsion, Maneuvering, Station Keeping (PROP)	
PROP-FR1	Systems and machinery are to be strengthened to maintain propulsion and steering during operations in ice conditions and temperatures appropriate for the ice class of the vessel.
PROP-FR2	The propeller is to be able to withstand the loads and stresses due to ice interaction.
PROP-FR3	Stresses in the propeller due to design ice loads are not to cause yielding or fatigue in the propeller.
PROP-FR4	The propulsion system is to withstand the most severe condition of coincident bending, thrust, and torsional dynamics without yielding or fatiguing of any propulsion components.
PROP-FR5	All components in the propulsion system are to be able to withstand, without yielding, the failure (plastic bending) of one propeller blade.
PROP-FR6	Azimuthing Propulsion Units (APU) are to be strengthened to withstand without yielding, the ice loads expected for the ice class of the vessel. The loading scenarios are to include loading on all parts of the APU's body, strut, propeller hub, and steering gear.
PROP-FR7	The propeller components are to withstand impacts with ice blocks without localized deformation.
PROP-FR8	The propeller blade bolts, the Controllable Pitch (CP) mechanism, the propeller boss, and the fitting of the propeller to the propeller shaft is to be sufficiently strengthened to withstand, without yielding, the maximum force the blade will experience in its service life.
PROP-FR9	Propulsion line connections are to be able to withstand vibrations associated with propeller ice interaction.
PROP-FR10	Load bearing parts are to be designed to withstand without deleterious deflection and prevent fatigue failing during the anticipated design life.
PROP-FR11	Elastic/flexible couplings are to be able to withstand the anticipated loads/torques while encountering ice blocks.
PROP-FR12	Auxiliary machinery necessary for the safe operation of the vessel are to be protected from the harmful effects of low air temperatures, ice, and snow.
PROP-FR13	Cooling media inlets are to be designed and arranged to minimize or prevent ingestion of ice to the machinery that are essential for the propulsion and safety of the vessel.
PROP-FR14	Steering systems are to be protected from ice loads which includes ice loads from the vessel backing in ice.
PROP-FR15	The steering system(s) is to be able to maintain steering direction during the expected ice loads for the ice class of the vessel.

Functional Requirement No.	*Functional Requirements*
PROP-FR16	Ice loads that exceed the steering system's holding capacity are not to cause damage to the steering system and steering capability is to be quickly regained after an overload.
Power Generation & Distribution (POW)	
POW-FR1	Emergency source of power to be readily available considering the anticipated temperatures and environmental conditions.
POW-FR2	Able to maintain continuous flow of water for cooling suitable for the installed power.
POW-FR3	The continuous propulsion power is sufficient for operations in the foreseen ice conditions.
Safety of Personnel (SAFE)	
SAFE-FR1	Enable clearing of any ice build-up.
SAFE-FR2	Cooling water inlets are to have a means of venting and isolating the vent line(s).
SAFE-FR3	Sea water systems above the load water line are to be protected from freezing and enable safe operations.
SAFE-FR4	Ballast tanks are to be protected from freezing and enable safe operations.
Habitability (HAB)	
HAB-FR1	Air handling systems are to condition the air temperature to a level suitable for the intended application while the vessel is in the expected ambient air temperatures.
Materials (MAT)	
MAT-FR1	*Materials used shall be suitable for operation at the ships polar service temperature or design temperature. (Polar Code)*

Note: References to the Polar Code in the table above are only to denote that the functional requirement is taken verbatim from the Polar Code. It does not indicate nor require compliance with the Polar Code.

The functional requirements covered in the cross-referenced Rules are also to be met.

1.1.3 Compliance *(2024)*

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved, refer to Part ID, Chapter 2.

Commentary:

- The requirements of Section 6-1-4 are based on the *Finnish Swedish Ice Class Rules*.
- Vessels that will operate in the Baltic Sea area during winter with an **Ice Class IC** through **IAA** notation must comply with the requirements of Section 6-1-4.
- These requirements are in addition to those for non-Ice Class vessels.

End of Commentary

1.3 Area of Operation *(2024)*

The ice strengthening requirements in this Section are in agreement with the *Finnish-Swedish Ice Class Rules 2017*, developed for vessels sailing in the Baltic Sea area in winter or in other sea areas in similar ice conditions for **Ice Class IC** through **IAA**. **Ice Class ID** and **IE** were developed for vessels operating in very light and extremely light ice conditions.

Where an Ice Class notation from this section is assigned to the vessel and operations are intended outside the Baltic Sea area, the operational limitations within this section may not be applicable.

1.5 Additional Guidance *(2024)*

For additional guidance, see the latest revision of the *Guidelines for the Application of the Finnish-Swedish Ice Class Rules* for **Ice Class IC** through **IAA**.

3 Assignment of Ice Class

3.1 Ice Class *(1 July 2024)*

The requirements for **Ice Class IC** through **IAA** in this Section are intended primarily for vessels operating in the Baltic Sea area in winter or in other sea areas in similar ice conditions and are assigned to ice classes as follows:

- **Ice Class IAA**: vessels with such structure, engine output and other properties that they are normally capable of navigating in difficult ice conditions without the assistance of icebreakers
- **Ice Class IA**: vessels with such structure, engine output and other properties that they are capable of navigating in difficult ice conditions, with the assistance of icebreakers when necessary
- **Ice Class IB**: vessels with such structure, engine output and other properties that they are capable of navigating in moderate ice conditions, with the assistance of icebreakers when necessary
- **Ice Class IC**: vessels with such structure, engine output and other properties that they are capable of navigating in light ice conditions, with the assistance of icebreakers when necessary
- **Ice Class ID**: vessels with such structure, engine output and other properties that they are capable of navigating in very light ice conditions, with the assistance of icebreakers when necessary
- **Ice Class IE:** vessel with such structure, engine output and other properties that they are capable of navigating in extremely light ice conditions, with the assistance of icebreakers when necessary

The minimum Rule required engine output power in kW will be specified in the Ice Class section of the Class Certificate for **Ice Class IC** through **IAA**. There is no minimum engine output required for **Ice Class ID** and **IE**.

The administrations of Sweden and Finland provide icebreaker assistance to vessels bound for their ports in winter. Depending on the ice conditions, restrictions by the administrations may apply to the size and ice class of the vessel.

An **Ice Class ID** or **IE** vessel that will sail in the Baltic Sea area would be considered an Ice Class II vessel by the administrations of Sweden and Finland. Vessels compliant with SOLAS that intend to operate in Polar Waters with an **Ice Class IE** through **IAA** are considered Category C vessels by the IMO Polar Code. See Section 11 of the ABS *Guide for Vessels Operating in Low Temperatures Enivronments (LTE Guide)* for the **POLAR** notations, guidance on Polar operations, and vessel winterization.

3.3 General Suitability for Operating in Ice *(2024)*

Where no specific requirements are given, vessels are assumed to be normal seagoing cargo vessels of conventional proportions, hull form and propulsion arrangement. A vessel having very unconventional proportions, hull form or propulsion arrangement, or any other characteristics, may have a lower ice class assigned by the administrations of Sweden and Finland for vessels operating in the Baltic Sea area during winter. Other flag Administrations may similarly assign a lower ice class.

3.5 General Suitability for Winter Conditions *(2024)*

Vessels that intend to operate in areas where ice is present will very likely operate in air temperatures is below 0°C (32°F). The air temperatures should be taken into account when designing structures, equipment and arrangements essential to the safety and operation of the ship. Matters to be borne in mind include (e.g., the functioning of hydraulic systems, the danger of water piping and tanks freezing, the start-up of emergency diesel engines, the strength of materials at low temperature, etc.).

Equipment and material exposed to the weather should be capable of withstanding and remaining operable at the design temperature for long periods.

The propulsion and auxiliary machinery should be capable of full operation in ambient conditions, as required in winter conditions. For example, the engine suction air should be sufficiently heated before entering the engine, or other alternative solutions, such as a specially adapted waste-gate, should be considered.

Historical temperature data should be referenced to determine if low temperature operations are expected (See Appendix A10 of the *LTE Guide*). If low temperatures are expected, then the vessel's hull steel grades, machinery, systems, and equipment are to be suitable for the expected temperatures. See the *LTE Guide* for additional guidance.

5 Definitions

5.1 Ice Belt

The *Ice Belt* is the area over which the shell plating is required to be reinforced for navigation in ice, see 6-1-4/13.1 and 6-1-4/11.3.3 FIGURE 4.

5.3 Upper and lower Ice Waterlines

The upper ice waterline (UIWL) is to be the envelope of highest points of the waterlines at which the vessel is intended to operate in ice. The line may be a broken line.

The lower ice waterline (LIWL) is to be the envelope of lowest points of the waterlines at which the vessel is intended to operate in ice. The line may be a broken line.

5.5 Main Frame

Main Frames are real, or in the case of longitudinal framing, imaginary transverse frames, whose spacing corresponds to that of the vessel clear of the ice strengthening area, or of the vessel if it were not ice-strengthened.

5.7 Propulsion Machinery Output *(1 July 2019)*

The *Propulsion Machinery Output*, P, is the maximum output in kW that the machinery can continuously deliver to the propeller(s). If the output is restricted by technical means or by any regulations applicable to the vessel, P is to be taken as the restricted output. If additional power sources are available for propulsion power (e.g., shaft motors), in addition to the power of the main engine(s), they shall also be included in the total propulsion machinery output. The *Propulsion Machinery Output* used for the calculation of the hull scantlings shall be clearly stated on the Shell Expansion drawing.

7 Maximum and Minimum Draft Fore and Aft *(1 July 2019)*

The maximum and minimum ice class drafts at fore and aft perpendiculars are to be determined in accordance with the upper and lower ice waterlines and the drafts of the ship at fore and aft perpendiculars, when ice conditions require the ship to be ice-strengthened, shall always be between the upper and lower ice waterlines.

Restrictions on drafts when operating in ice shall be documented and kept onboard readily available to the master. The maximum and minimum ice class drafts fore, amidships and aft are to be indicated in the classification certificate. For vessels built on or after 1 July 2007, if the summer load line in fresh water is anywhere located at a higher level than the UIWL, the vessel's sides are to be provided with a warning triangle and with an ice class draft mark at the maximum permissible ice class draft amidships (see Appendix 6-1-4-A1).

Vessels built before 1 July 2007 are to be provided with such a marking, if the UIWL is below the summer load line, not later than the first scheduled dry docking after 1 July 2007. The draft and trim, limited by the UIWL, must not be exceeded when the vessel is navigating in ice. The salinity of the sea water along the intended route shall be taken into account when loading the vessel.

The vessel is to always be loaded down at least to the draft of LIWL amidships when navigating in ice. Any ballast tank, situated above the LIWL and needed to load down the vessel to this waterline, is to be equipped with devices to prevent the water from freezing. In determining the LIWL, regard is to be paid to the need for ensuring a reasonable degree of ice-going capability in ballast. The highest point of the propeller is to be fully submerged, and if possible at a depth of at least h_i below the water surface in all loading conditions. The forward draft is to be at least:

$d_f = (2 + 0.00025\Delta)h_i$ m

$d_f = (2 + 0.000254\Delta)h_i$ ft

but need not exceed $4h_i$

where

Δ = displacement of the vessel, in metric tons (long tons), at the upper ice waterline (UIWL) amidships, as defined in 6-1-4/5.3

h_i = level ice thickness, in m (ft), as defined in 6-1-4/11.5

9 Power of Propulsion Machinery

The minimum required engine output power P is to be determined in accordance with 6-1-4/9.1.2 and stated in the Classification certificate.

9.1 Propulsion Machinery Output, Ice Classes IAA, IA, IB and IC*

*(*NOTE: For reference purposes, the propulsion machinery output requirements for* **IAA, IA, IB** *and* **IC** *in the 1985 Finnish-Swedish Ice Class Rules were amended as follows for vessels with the keel laid or which are at a similar stage of construction on or after 1 September 2003.)*

9.1.1 Definitions *(2024)*

The dimensions of the vessel are defined below in 6-1-4/9.1.1 FIGURE 1.

L = length of the vessel between perpendiculars at the UIWL, m (m, ft)

L_{BOW} = length of the bow, m (m, ft)

L_{PAR} = length of the parallel midship body, m (m, ft)

B = maximum breadth of the vessel at the UIWL, m (m, ft)

T = actual ice class drafts of the vessel in accordance with 6-1-4/9.1.2. Drafts to be used are the maximum draft amidships corresponding to UIWL and the minimum draft corresponding to LIWL, m (m, ft)

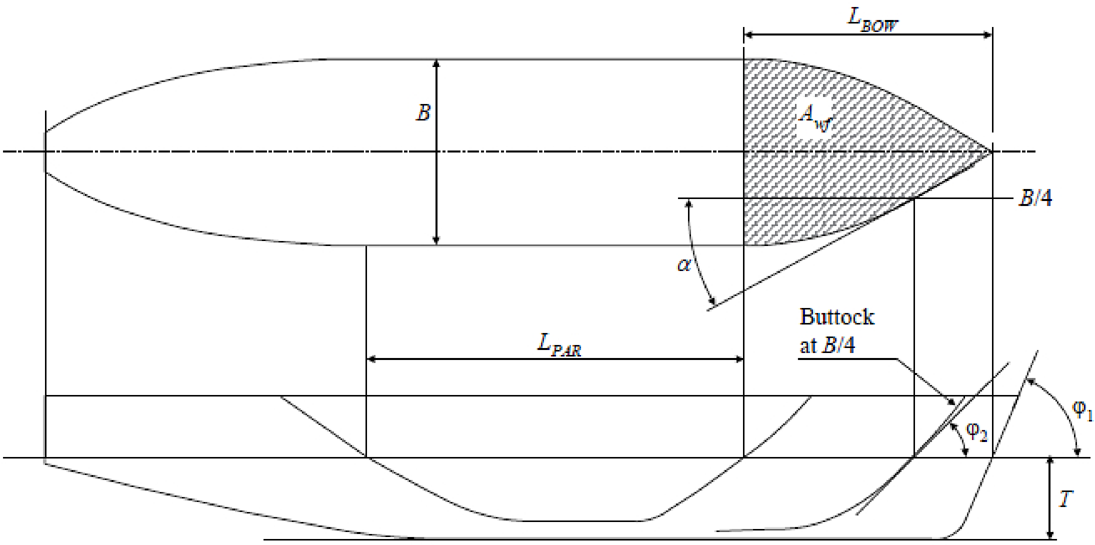
A_{Wf} = area of waterline of the bow, m^2 (m^2, ft^2)

H_F = thickness of the brash ice layer displaced by the bow, m (m, ft)

H_M = thickness of the brash ice in mid channel, m (m, ft)

α	=	the angle of the waterline at $B/4$, deg
φ_1	=	the rake of the stem at the centerline, deg
φ_2	=	the rake at the bow, at $B/4$, deg
Ψ	=	flare angle calculated as $\Psi = \arctan(\tan\varphi/\sin\alpha)$ using angles α and φ at each location. For 6-1-4/9, flare angle is calculated using $\varphi = \varphi_2$
D_P	=	diameter of the propeller, m (m, ft)

FIGURE 1
Vessels' Dimensions



For a vessel with a bulbous bow, φ1 is to be taken as 90°. No negative values of the rake of the bow at $B/4$ (φ_2) should be used in the calculation. If φ_2 has a negative value, φ_2 is to be taken as 90°.

9.1.2 Power Calculation *(2024)*

To be entitled to **Ice Class IAA**, **IA**, **IB** or **IC**, a vessel the keel of which is laid or which is at a similar stage of construction on or after 1 September 2003 is to comply with the following requirements regarding its engine output. The engine output requirement shall be calculated for two drafts. Drafts to be used are the maximum draft amidships referred to as UIWL and the minimum draft referred to as LIWL, as defined in 6-1-4/7. In the calculations, the vessel's parameters which depend on the draft are to be determined at the appropriate draft, but L and B are to be determined only at the UIWL.

The engine output shall not be less than the greater of these two outputs. The engine output is to be not less than determined by the formula below and in no case less than 1000 kW (1360 mhp; 1341 hp) for **Ice Class IA**, **IB**, and **IC**, and not less than 2800 kW (3807 mhp; 3754 hp) for **Ice Class IAA**. There is no required minimum engine output for **Ice Class ID** and **IE**.

$$p = K_c \frac{(R_{CH}/1000)^{3/2}}{D_p} \quad \text{kW(mhp, hp)}$$

where K_C is to be taken as follows:

Propeller Type or Propulsion Machinery	*Controllable Pitch Propeller or Electric or Hydraulic Propulsion Machinery*			*Fixed Pitch Propeller*		
	SI Units	*MKS Units*	*US Units*	*SI Units*	*MKS Units*	*US Units*
1 propeller	2.03	84.76	83.79	2.26	94.37	93.29
2 propellers	1.44	60.13	59.44	1.6	66.81	66.04
3 propellers	1.18	49.27	48.71	1.31	54.70	54.07

These K_C values apply for conventional propulsion systems. Other methods may be used for determining the required power for advanced propulsion systems (see 6-1-4/9.1.3).

R_{CH} is the ice resistance of the vessel in a channel with brash ice and a consolidated layer.

$$R_{CH} = C_1 + C_2 + C_3 C_\mu (H_F + H_M)^2 (B + C_\varnothing H_F) + C_4 L_{PAR} {H_F}^2 + C_5 \left[\frac{LT}{B^2}\right]^3 \frac{A_{Wf}}{L} \quad \text{N(kgf, lbf)}$$

where

C_μ	=	$0.15\cos\varphi_2 + \sin\Psi \sin\alpha$,	C_μ is to be taken equal or larger than 0.45
$C_\varnothing$	=	$0.047\Psi - 2.115$,	and $C_\varnothing = 0$ if $\Psi \le 45°$
H_F	=	$0.26 + (H_M B)^{0.5}$ m	
H_F	=	$0.85 + (H_M B)^{0.5}$ ft	
H_M	=	1.0 m (3.28 ft)	for **Ice Class IA** and **IAA**
	=	0.8 m (2.62 ft)	for **Ice Class IB**
	=	0.6 m (1.97 ft)	for **Ice Class IC**

The coefficients C_1 and C_2 take into account a consolidated upper layer of the brash ice and can be taken as zero for **Ice Class IA**, **IB**, and **IC**.

For **Ice Class IAA**:

$$C_1 = f_1 \frac{BL_{PAR}}{(2T/B) + 1} + (1 + 0.021\varphi_1)(f_2 B + f_3 L_{BOW} + f_4 B L_{BOW}) \quad \text{N (kgf, lbf)}$$

$$C_2 = (1 + 0.063\varphi_1)(g_1 + g_2 B) + g_3 (1 + 1.2T/B) \frac{B^2}{\sqrt{L}} \quad \text{N (kgf, lbf)}$$

	SI units	*MKS units*	*US units*
f_1	23 N/m^2	2.35 kgf/m^2	0.48 lbf/ft^2
f_2	45.8 N/m	4.67 kgf/m	3.138 lbf/ft
f_3	14.7 N/m	1.50 kgf/m	1.007 lbf/ft
f_4	29 N/m^2	2.96 kgf/m^2	0.61 lbf/ft^2
g_1	1530 N	156.02 kgf	343.96 lbf
g_2	170 N/m	17.34 kgf/m	11.649 lbf/ft
g_3	400 N/m$^{1.5}$	40.79 kgf/m$^{1.5}$	15.132 lbf/ft$^{1.5}$
C_3	845 N/m^3	86.2 kgf/m^3	5.38 lbf/ft^3

	SI units	*MKS units*	*US units*
C_4	42 N/m^3	4.28 kgf/m^3	0.267 lbf/ft^3
C_5	825 N/m	84.1 kgf/m	56.5 lbf/ft

Ψ = arctan[tan φ_2/sin α] deg.

If the value of the term $\left(\frac{LT}{B^2}\right)^3$ is less than 5, the value 5 shall be used and if the value of the term is more than 20, the value 20 shall be used.

9.1.3 Other Methods of Determining K_C and R_{CH} *(2024)*

The administrations of Sweden and Finland may for an individual vessel, in lieu of the K_C or R_{CH} values defined in 6-1-4/9.1 above, approve the use of K_C and R_{CH} values based on more exact calculations or values based on model tests for vessels that will operate in the Baltic Sea area during winter. Such an approval will be given on the understanding that it can be revoked if experience with the vessel's performance in practice motivates this.

The design requirement for ice classes is a minimum speed of 5 knots in the following brash ice channels:

IAA H_M = 1.0 m (3.28 ft) and a 0.1 m (0.328 ft) thick consolidated layer of ice

IA H_M = 1.0 m (3.28 ft)

IB H_M = 0.8 m (2.62 ft)

IC H_M = 0.6 m (1.97 ft)

11 Hull Structural Design

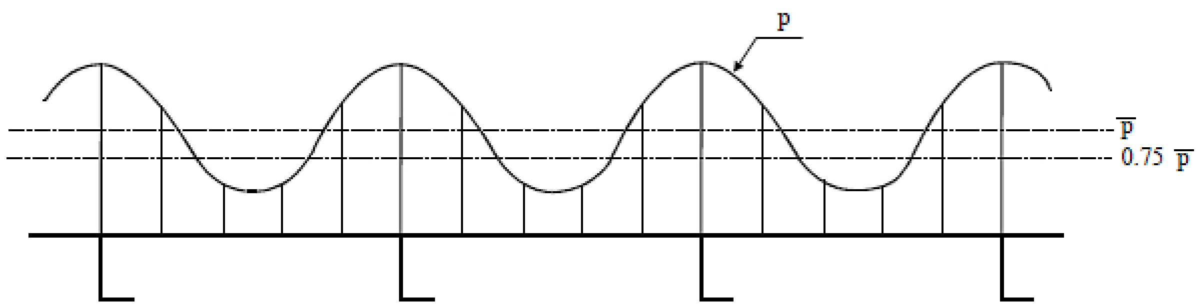
11.1 Application *(2024)*

The requirements for the hull scantlings are based on certain assumptions concerning the nature of the ice load on the structure. These assumptions are from full scale observations made in the Northern Baltic.

The local ice pressure on small areas can reach high values. This pressure may be well in excess of the normal uniaxial crushing strength of sea ice since the stress field is multi-axial.

It has also been observed that the ice pressure on a frame can be greater than on the shell plating at mid-spacing between frames. This is due to the different flexural stiffness of the frames and shell plating. The load distribution on the side structure is assumed to be as shown in 6-1-4/11.1 FIGURE 2.

FIGURE 2
Ice Load Distribution on Ship's Side



The formulae and values given in this section may be substituted by direct analysis if they are deemed by the flag Administration or ABS to be invalid or inapplicable for a given structural arrangement or detail. Otherwise, direct analysis is not to be utilized as an alternative to the analytical procedures prescribed by explicit requirements in 6-1-4/13 through 6-1-4/17.

Direct analyses are to be carried out using the load patch defined in 6-1-4/11.5 and 6-1-4/11.7 (p, h and ℓ_a). The pressure to be used is $1.8p$ where p is determined according to 6-1-4/11.7. The load patch is to be applied at locations where the capacity of the structure under the combined effects of bending and shear are minimized. In particular, the structure is to be checked with load centered at the UIWL, $0.5h_i$ below the LIWL, and positioned several vertical locations in between. Several horizontal locations should also be checked, especially the locations centered at the mid-span - or spacing. Further, if the load length ℓ_a cannot be determined directly from the arrangement of the structure, several values of ℓ_a should be checked using corresponding values for c_a.

Acceptance criterion for designs is that the combined stresses from bending and shear, using the von Mises yield criterion, are lower than the yield point σ_y. When the direct calculation is using beam theory, the allowable shear stress is not to be larger than $0.9\tau_y$, where $\tau_y = \sigma_y/\sqrt{3}$.

Where the scantlings given by these requirements are less than those required by the Rules for a non ice-strengthened vessel, the greater requirements are to apply.

11.1.1

The frame spacings and spans defined in the following text are normally (in accordance with the Rules) assumed to be measured along the plate and perpendicular to the axis of the stiffener for plates, along the flange for members with a flange, and along the free edge for flat bar stiffeners. For curved members the span (or spacing) is defined as the chord length between span (or spacing) points. The span points are defined by the intersection between the flange or upper edge of the member and the supporting structural element (stringer, web frame, deck or bulkhead). 6-1-4/11.1.3 FIGURE 3 illustrates the determination of span and spacing for curved members.

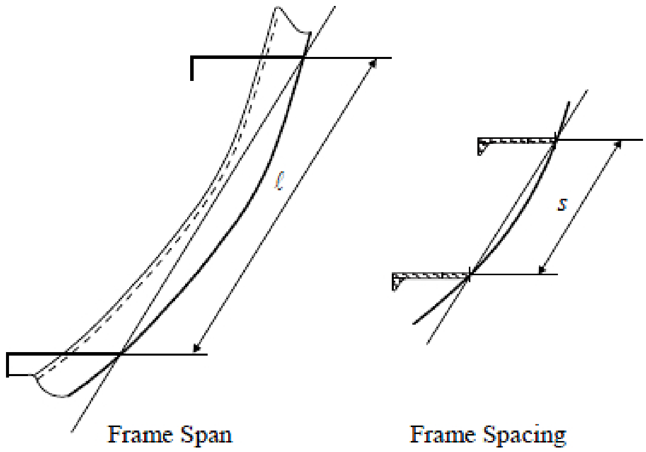
11.1.2

The effective breadth of the attached plate to be used for calculating the combined section modulus of the stiffener, stringer and web frame and attached plate is to be taken as the Rules require. The effective breadth is in no case to be more than what is stated in 3-1-2/13.3.

11.1.3

The requirements for the section modulus and shear area of the frames, stringers and web frames in 6-1-4/15, 6-1-4/17, and 6-1-4/19 are with respect to effective member cross section. For such cases where the member is not normal to the plating, the section properties are to be adjusted in accordance with the Rules.

FIGURE 3
Definition of the Frame Span and Frame Spacing for Curved Members



11.3 Hull Regions *(2024)*

For the application of this Section the vessel's ice belt is divided forward and aft into the following regions, see also 6-1-4/11.3.3 FIGURE 4. Only the bow area is strengthened to resist ice loads for **Ice Class ID** and **IE**.

11.3.1 Bow Region *(2024)*

From the stem to a line through the ice belt parallel to and 0.04*L* aft of the forward borderline of the part of the hull where the waterlines run parallel to the centerline. For **Ice Class IAA** and **IA**, the overlap over the borderline need not exceed 6 m (19.7 ft); for **Ice Class IB**, **IC**, **ID**, and **IE** this overlap need not exceed 5 m (16.4 ft).

11.3.2 Midbody Region *(1 July 2019)*

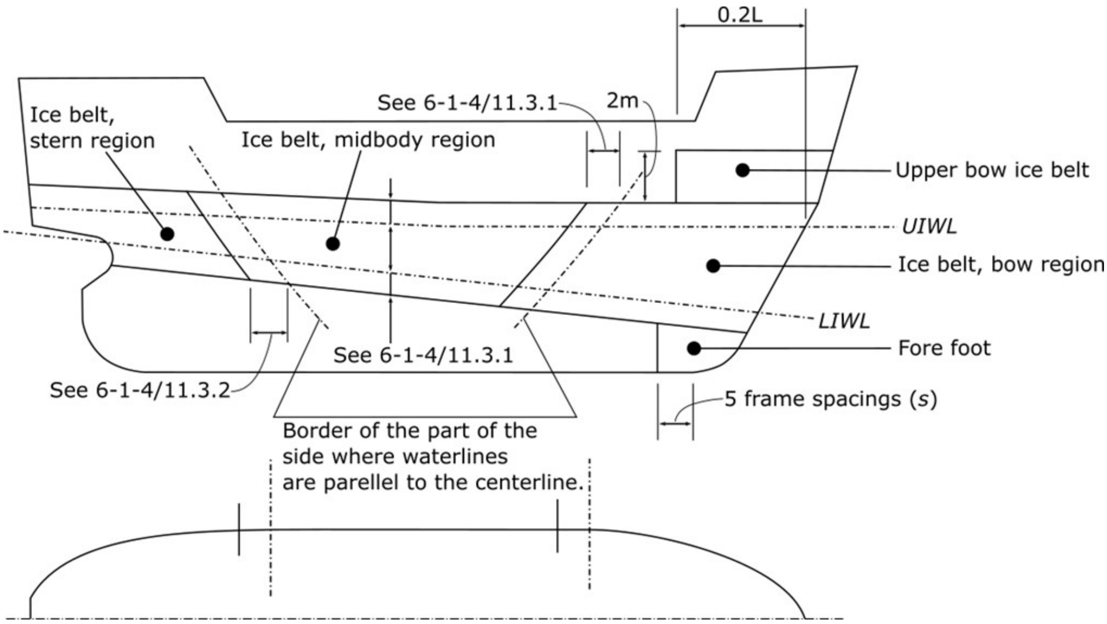
From the aft boundary of the Bow region to a line parallel to and 0.04*L* aft of the aft borderline of the part of the hull where the waterlines run parallel to the centerline. For **Ice Class IAA** and **IA**, the overlap over the borderline need not exceed 6 m (19.7 ft); for **Ice Class IB** and **IC**, this overlap need not exceed 5 m (16.4 ft).

11.3.3 Stern Region

From the aft boundary of the Midbody region to the stern.

L is to be taken as the vessel's rule length, as defined in 3-1-1/3.1.

FIGURE 4
Ice Strengthened Regions of the Hull



11.5 Vertical Extent of Design Ice Pressure *(2024)*

An ice strengthened vessel is assumed to operate in open sea conditions with level ice thickness not exceeding h_i. The design load height, h, of the area actually under ice pressure at any particular time is, however, assumed to be only a fraction of the ice thickness. The values for h_i and h are given in the following table:

Ice Class	h_o *m (ft)*	*h m (ft)*
IAA	1.0 (3.28)	0.35 (1.15)
IA	0.8 (2.62)	0.30 (0.98)
IB	0.6 (1.97)	0.25 (0.82)
IC	0.4 (1.31)	0.22 (0.72)
ID, IE	0.3 (1)	0.2 (0.66)

11.7 Design Ice Pressure *(2024)*

The design ice pressure is to be not less than given by the following equation:

$p = c_d \cdot c_1 \cdot c_a \cdot p_o$ N/mm²(kgf/mm², psi)

where

c_d = a factor which takes into account the influence of the size and propulsion machinery output of the vessel. This factor is taken as maximum $c_d = 1$. For non-self propelled vessels, c_d is to be taken as 1.

= $(ak + b)/1000$

k = $\sqrt{n \Delta P}\,/1000$

a and b are given in the following table:

	Region			
	Bow		*Midbody and Stern*	
	$k \le 12$	$k > 12$	$k \le 12$	$k > 12$
a	30	6	8	2
b	230	518	214	286

n = 1.0 (1.0, 1.016)

Δ = displacement of the vessel, in metric tons (long tons), at the upper ice waterline (UIWL) amidships, as defined in 6-1-4/5.3

P = the actual continuous propulsion machinery output, in kW, as defined in 6-1-4/5.7. P need not be taken greater than 1000 kW for **Ice Class IE**.

c_1 = factor which takes into account the probability that the design ice pressure occurs in a certain region of the hull for the particular ice class

The value of c_1 is given in the following table:

Ice Class	*Region*		
	Bow	*Midbody*	*Stern*
IAA	1.0	1.0	0.75
IA	1.0	0.85	0.65
IB	1.0	0.70	0.45
IC	1.0	0.50	0.25
ID, **IE**	1.0	N/A	N/A

c_a = a factor which takes into account the probability that the full length of the area under consideration will be under pressure at the same time

= $\sqrt{\frac{\ell_0}{\ell_a}}$, maximum 1.0, minimum 0.35

ℓ_0 = 0.6 m (2 ft)

ℓ_a is as given in the following table:

Structure	*Type of framing*	ℓ_a *m (ft)*
Shell	Transverse	Frame spacing
	Longitudinal	1.7 times spacing of frame
Frames	Transverse	Frame spacing
	Longitudinal	Span of frame
Ice stringer		Span of stringer
Web frame		2 times spacing of web frames

p_o = the nominal ice pressure; the value 5.6 N/mm² (0.571 kgf/mm², 812 psi) is to be used for **Ice Class IAA**, **IA**, **IB**, and **IC**

= 2.8 N/mm² (0.286 kgf/mm², 406 psi) for **Ice Class ID**

= 1.7 N/mm² (0.173 kgf/mm², 244 psi) for **Ice Class IE**

13 Shell Plating

13.1 Vertical Extent of Ice Strengthening for Plating (Ice Belt) *(2024)*

The vertical extension of the ice belt is given in the following table (see 6-1-4/11.3.3 FIGURE 4):

Ice Class	*Hull Region*	*Above UIWL m (ft)*	*Below LIWL m (ft)*
IAA	Bow	0.60 (1.97)	1.20 (3.94 ft)
	Midbody		
	Stern		1.0 (3.28 ft)
IA	Bow	0.50 (1.64)	0.90 (2.95)
	Midbody		0.75 (2.46)
	Stern		
IB and IC	Bow	0.40 (1.31)	0.70 (2.30)
	Midbody		0.6 (1.97)
	Stern		
ID and IE	Bow	0.40 (1.31)	0.70 (2.30)

Side lights, side scuttles, etc., are not to be situated in the ice belt.

In addition, the following areas are to be strengthened:

13.1.1 Fore Foot *(1 July 2019)*

For ice class **I AA**, the shell plating below the ice belt from the stem to a position five main frame spaces abaft the point where the bow profile departs from the keel line shall be ice-strengthened in the same way as the bow region.

13.1.2 Upper Bow Ice Belt *(1 July 2019)*

For **Ice Class IAA** and **IA**, on vessels with an open water service speed equal to or exceeding 18 knots, the shell plating from the upper limit of the ice belt to 2 m (6.56 ft) above it and from the stem to a position at least 0.2L abaft the forward perpendicular is to be at least the thickness required for the ice belt in the Midbody region. A similar strengthening of the bow region is also advisable for a ship with a lower service speed when, on the basis of the model tests, for example, it is evident that the ship will have a high bow wave.

If the weather deck in any part of the vessel is situated below the upper limit of the ice belt (e.g., in way of the well of a raised quarter decker), the bulwark is to be given at least the same strength as is required for the shell in the ice belt. The strength of the construction of the freeing ports is to meet the requirements for the bulwark.

13.3 Ice Belt Plating Thickness *(2024)*

With transverse framing, the thickness of the shell plating is to be not less than given by the following equation:

$$t = as\sqrt{f_1 P_{PL}/\sigma_y} + t_c \quad \text{mm(in.)}$$

With longitudinal framing, the thickness of the shell plating is to be not less than given by the following equation:

$$t = as\sqrt{p/f_2\sigma_y} + t_c \quad \text{mm(in.)}$$

where

s	=	frame spacing, in m (ft)
P_{PL}	=	0.75 p, in N/mm^2 (kgf/mm^2, psi)
p	=	as given in 6-1-4/11.7
f_1	=	1.3 - 4.2/[(h/s) + 1.8]^2; maximum 1.0
f_2	=	0.6 + 0.4/(h/s); when $h/s \le 1$
	=	1.4 - 0.4 (h/s); when $1 \le h/s < 1.8$
h	=	as given in 6-1-4/11.5, in m (ft)
σ_y	=	yield strength of the material, in N/mm^2 (kgf/mm^2, psi)
a	=	667 (8)

Use of steels with yield strengths greater than 390 N/mm^2 (40 kgf/mm^2, 56565 psi) are subject to special consideration.

t_c	=	increment for abrasion and corrosion, in mm (in.); normally, t_c is to be 2 mm (0.08 in.); however, if a special surface coating by experience is shown capable to withstand the abrasion of ice and is applied and maintained effective, lower values may be approved.

Shell plating thickness may be rounded to the nearest 0.5 mm (1/64 inch) as per 3-1-2/5.3.

15 Framing

15.1 General

15.1.1 End Attachments

Within the ice strengthened area, all frames are to be effectively attached to all supporting structures. A longitudinal frame shall be attached to all the supporting web frames and bulkheads by brackets. When a transversal frame terminates at a stringer or deck, a bracket or similar construction is to be fitted. When a frame is running through the supporting structure, both sides of the web plate of the frame are to be connected to the structure (by direct welding, collar plate or lug). When a bracket is installed, it is to have at least the same thickness as the web plate of the frame and the edge is to be appropriately stiffened against buckling.

15.1.2 Frames

15.1.2(a) Welding. Frames are to be attached to the shell by double continuous welding. Scallops are to be avoided, except where frames cross shell plate butts.

15.1.2(b) Web Thickness (1 July 2019)

The web thickness of the frames is to be at least the maximum of the following:

- $\dfrac{h_w\sqrt{\sigma_y}}{C}$

where

h_w	=	web height	
C	=	805 (257, 9695)	for profiles
	=	282 (90, 3396)	for flat bars

- Half of the net thickness of the shell plating, t - t_c. For the purpose of calculating the web thickness of frames, the required thickness of the shell plating is to be calculated according to 6-1-4/13.3 using the yield strength σ_y of the frames
- 9 mm (0.35 in.)

Where there is a deck, top or bottom plating of a tank, tank top or bulkhead in lieu of a frame, the plate thickness of it shall be calculated as above, to a depth corresponding to the height of the adjacent frames. In such a case, the material properties of the deck, top or bottom plating of the tank, tank top or bulkhead and the frame height h_w of the adjacent frames shall be used in the calculations, and the constant C shall be 805.

15.1.2(c) Slanted frames. Frames that are not normal to the plating or the profile is unsymmetrical, and the span exceeds 4.0 m (13.1 ft) are to be supported against tripping by brackets, intercostals, stringers or similar at a distance preferably not exceeding 1.3 m (4.25 ft). If the span is less than 4.0 m (13.1 ft), the supports against tripping are required for unsymmetrical profiles and stiffeners the web of which is not normal to plating in the following regions:

- **IAA** All hull regions
- **IA** Bow and Midbody regions
- **IB**, **IC**, **ID**, **IE** Bow region

15.3 Vertical Extent of Ice Strengthening for Framing *(2024)*

The vertical extent of the ice strengthening of framing is to be at least as given in the following table:

Ice Class	*Hull Region*	*Above UIWL*	*Below LIWL*
IAA	Bow	1.2 (3.94)	Down to double bottom or below top of floors
	Midbody		2.0 (6.56)
	Stern		1.6 (5.25)
IA, **IB**, **IC**	Bow	1.0 (3.28)	1.6 (5.25)
	Midbody		1.3 (4.27)
	Stern		1.0 (3.28)
ID and IE	Bow	0.5 (1.64)	1.0 (3.28)

Where an upper Bow ice belt is required, see 6-1-4/13.1, the ice strengthening of the framing is to be extended at least to the top of this ice belt.

Where the ice strengthening would go beyond a deck or a tanktop by not more than 250 mm (9.8 in.), it may be terminated at that deck or tanktop.

15.5 Transverse Framing

15.5.1 Section Modulus and Shear Area

The section modulus, *SM,* of a main or intermediate frame is to be not less than that obtained from the equation:

$$SM = n\left(\frac{p \cdot h \cdot s \cdot \ell}{m_t \cdot \sigma_y}\right) \quad \text{cm}^3\left(\text{in}^3\right)$$

and the effective shear area is calculated from

$$A = k\left(\frac{\sqrt{3} \cdot f_3 \cdot p \cdot h \cdot s}{2\sigma_y}\right) \quad \text{cm}^2\left(\text{in}^2\right)$$

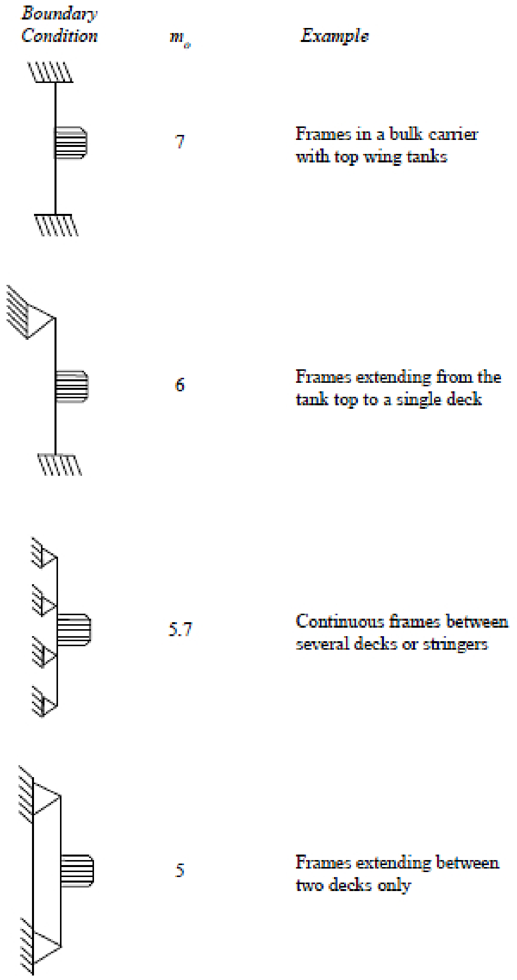
where

n	=	10^6 (1728)
k	=	10^4 (144)
p	=	ice pressure, as given in 6-1-4/11.7, in N/mm^2 (kgf/mm^2, psi)
s	=	frame spacing, in m (ft)
h	=	height of load area, as given in 6-1-4/11.5, in m (ft)
ℓ	=	span of the frame, in m (ft)
m_t	=	$7m_o/[7 - 5\,(h/\ell)]$
f_3	=	is a factor which takes into account the maximum shear force versus the load location and the shear stress distribution
	=	1.2
σ_y	=	yield strength, as defined in 6-1-4/13.3, in N/mm^2 (kgf/mm^2, psi)

m_o values are given in 6-1-4/15.5.1 FIGURE 5.

The boundary conditions shown are for the main and intermediate frames. Possible different conditions for the main frames are assumed to have been taken care of by interaction between the frames and are reflected in the m_o values. The load is considered applied at mid span. Where less than 15% of the span, ℓ, of the frame is situated within the ice-strengthening zone for frames as defined in 6-1-4/15.3, ordinary frame scantlings may be used.

FIGURE 5
Web Frame Model



15.5.2 Upper End of Transverse Frames *(2024)*

The upper end of an ice-strengthened part of a main frame and of an intermediate ice frame is to be attached to a deck or ice stringer, see 6-1-4/17.

Where an intermediate ice frame terminates above a deck or ice stringer that is situated at or above the upper limit of the ice belt, see 6-1-4/13.1, the part above the deck or stringer may have scantlings as required for a non-ice-strengthened vessel and the upper end of the intermediate frame may be connected to the adjacent main frames by a header of the same scantlings as the main frame.

For **Ice Class IE**, intermediate transverse frames may be omitted from the design. However, this will lead to a heavier main frame and plating for the ice strengthened bow area. If intermediate transverse frames are included in the **Ice Class IE** design, the intermediate frames have the option to be sniped down to a soft toe, terminating at a longitudinal member. The intermediate frame may start the snipe at the required ice belt framing extent, with the snipe having an angle no greater than 30 degrees.

15.5.3 Lower End of Transverse Framing *(2024)*

The lower end of an ice-strengthened part of a main frame and of an intermediate ice frame is to be attached to a deck, tanktop or ice stringer, see 6-1-4/17.

Where an intermediate ice frame terminates below a deck, tanktop or ice stringer which is situated at or below the lower limit of the ice belt, see 6-1-4/13.1, the lower end of the frame may be connected to the adjacent main frames by a header of the same scantlings as the main frame. Note that the main frames below the lower edge of the ice belt must be ice strengthened, see 6-1-4/15.3.

For **Ice Class IE**, intermediate transverse frames may be omitted from the design. However, this will lead to a heavier main frame and plating for the ice strengthened bow area. If intermediate transverse frames are included in the **Ice Class IE** design, the intermediate frames have the option to be sniped down to a soft toe, terminating at a longitudinal member. The intermediate frame may start the snipe at the required ice belt framing extent, with the snipe having an angle no greater than 30 degrees.

15.7 Longitudinal Framing

The following requirements are intended for longitudinal frames with all end conditions.

15.7.1 Frames with and without Brackets

The section modulus, *SM,* of a longitudinal frame is to be not less than that obtained from the equation:

$$SM = n(f_4 p\ h\ \ell^2/m_1\ \sigma_y) \text{ cm}^3 \text{ (in}^3\text{)}$$

The effective shear area, A, is to be not less than that obtained from the equation:

$$A = k(\sqrt{3} f_4 f_5 p\ h\ \ell/\sigma_y) \text{ cm}^2 \text{ (in}^2\text{)}$$

In calculating the actual shear area of the frames, the area of the brackets is not to be taken into account.

f_4 = factor which takes into account the load distribution to adjacent frames

= $(1 - 0.2h/s)$

f_5 = factor which takes into account the pressure definition and maximum shear force versus load location and also the shear stress distribution

= 2.16

p = ice pressure, as given in 6-1-4/11.7, in N/mm^2 (kgf/mm^2, psi)

h = height of load area, as given in 6-1-4/11.5, in m (ft)

s = frame spacing, in m (ft)

n = 10^6 (1728)

k = 5×10^3 (72)

ℓ = total span of frame, in m (ft)

m_1 = boundary condition factor; m_1 = 13.3 for a continuous beam. Where the boundary conditions deviate significantly from those of a continuous beam (e.g., in an end field), a smaller boundary factor may be required. For frames without brackets a value m_1 = 11.0 is to be used.

σ_y = yield strength, as defined in 6-1-4/13.3, in N/mm^2 (kgf/mm^2, psi)

17 Ice Stringers

17.1 Stringers within the Ice Belt

The section modulus, *SM*, of a stringer within the ice belt (see 6-1-4/13.1) is to be not less than that obtained from the equation:

$$SM = n\left(\frac{f_6 \cdot f_7 \cdot p \cdot h \cdot \ell^2}{m_1 \cdot \sigma_y}\right) \quad \text{cm}^3\left(\text{in}^3\right)$$

The effective shear area, *A,* is to be not less than that obtained from the equation:

$$A = k\left(\frac{\sqrt{3} \cdot f_6 \cdot f_7 \cdot f_8 \cdot p \cdot h \cdot \ell}{2\sigma_y}\right) \quad \text{cm}^2\left(\text{in}^2\right)$$

where

p = ice pressure, as given in 6-1-4/11.7, in N/mm² (kgf/mm², psi)

h = height of load area, as given in 6-1-4/11.5, in m (ft)

The product ($p \times h$) is not to be taken as less than 0.15 SI units (0.0153 MKS units, 71.4 US units)

n = 10^6 (1728)

k = 10^4 (144)

ℓ = span of stringer, in m (ft)

m_1 = boundary condition factor; as defined in 6-1-4/15.7

f_6 = factor which takes into account the distribution of the load on the transverse frames

= 0.9

f_7 = factor that takes into account the design point of stringers

= 1.8

f_8 = factor that takes into account the maximum shear force versus load location and the shear stress distribution

= 1.2

σ_y = yield strength, as defined in 6-1-4/13.3, in N/mm² (kgf/mm², psi)

17.3 Stringers Outside the Ice Belt

The section modulus, *SM,* of a stringer outside the ice belt that supports ice strengthened frames is to be not less than that obtained from the equation:

$$SM = n\left(\frac{f_9 \cdot f_{10} \cdot p \cdot h \cdot \ell^2}{m_s \cdot \sigma_y}\right)\left(1 - \frac{h_s}{\ell_s}\right) \quad \text{cm}^3\left(\text{in}^3\right)$$

The effective shear area, *A,* is to be not less than that obtained from the equation:

$$A = k\left(\frac{\sqrt{3} f_9 \cdot f_{10} \cdot f_{11} \cdot p \cdot h \cdot \ell}{2\sigma_y}\right)\left(1 - \frac{h_s}{\ell_s}\right) \quad \text{cm}^2\left(\text{in}^2\right)$$

where

p = ice pressure, as given in 6-1-4/11.7, in N/mm^2 (kgf/mm^2, psi)

h = height of load area, as given in 6-1-4/11.5, in m (ft)

The product ($p \times h$) is to be not taken as less than 0.15 SI units (0.0153 MKS units, 71.4 US units).

n = 10^6 (1728)

k = 10^4 (144)

ℓ = span of stringer, in m (ft)

m_s = boundary condition factor; m_s = 13.3 for a continuous beam

ℓ_s = the distance to the adjacent ice stringer, in m (ft)

h_s = the distance to the ice belt, in m (ft)

f_9 = factor which takes into account the distribution of load on transverse frames.

= 0.80

f_{10} = factor that takes into account the design point of stringers

= 1.8

f_{11} = factor that takes into account the maximum shear force versus load location and the shear stress distribution

= 1.2

σ_y = yield strength, as defined in 6-1-4/13.3, in N/mm^2 (kgf/mm^2, psi)

17.5 Deck Strips

The deck strips abreast of hatches serving as ice stringers are to comply with the section modulus and shear area requirementsin 6-1-4/17.1 and 6-1-4/17.3, respectively. In the case of very long hatches, the product ($p \times h$) may be taken as less than 0.15 SI units (0.0153 MKS units, 71.4 US units), but in no caseless than 0.10 SI units (0.0102 MKS units, 47.6 US units).

In designing weather deck hatch covers and their fittings, special attention is to be paid to the deflection of the vessel's sides due to ice pressure in way of very long (more than B/2) hatch openings.

19 Web Frames

19.1 Design Ice Load

The design load, F, on a web frame from an ice stringer or from longitudinal framing may be obtained from the following equation:

$F = n f_{12} phS$ kN (tf, Ltf)

where

n = 10^3 (0.0643)

f_{12} = a factor that takes into account the design point of web frames

= 1.8

p = ice pressure, as given in 6-1-4/11.7, in N/mm^2 (kgf/mm^2, psi); in calculating c_a however, ℓ_a is to be taken as 2S

h = height of ice load area, as given in 6-1-4/11.5, in m (ft)

The product ($p \times h$) is not to be taken as less than 0.15 SI units (0.0153 MKS units, 71.4 US units).

S = distance between web frames, in m (ft)

In case the supported stringer is outside the ice belt, the force F shall be multiplied by ($1 - h_s/\ell_s$), where h_s and ℓ_s shall be taken as defined in 6-1-4/17.3.

19.3 Section Modulus and Shear Area

The section modulus and shear area may be obtained from the following equations:

- *Effective Shear Area*

$$A = k\left(\frac{\sqrt{3}.f_{13}.\alpha.Q}{\sigma_y}\right) \text{ cm}^2\left(\text{in}^2\right)$$

where

Q = maximum calculated shear force under the load F, as given in 6-1-4/19.1

k = 10 (2240)

f_{13} = factor that takes into account the shear force distribution

= 1.1

α = as given in the Table below

σ_y = yield strength, as defined in 6-1-4/13.3, in N/mm² (kgf/mm², psi)

F = as in 6-1-4/19.1

- *Section Modulus*

$$SM = n\left(\frac{M}{\sigma_y}\right)\sqrt{\frac{1}{1-(\gamma A/A_a)^2}} \text{ cm}^3\left(\text{in}^3\right)$$

where

n = 1000 (26880)

M = maximum calculated bending moment under the load F; this is to be taken as

= $0.193F\ell$

γ = as given in the Table below

A = required shear area

A_a = actual cross sectional area of the web frame, in cm² (in²)

= $A_f + A_w$

- *Factors α and γ*

A_f = actual cross section area of free flange, in cm² (in²)

A_w = actual effective cross section area of web plate, in cm² (in²)

A_f/A_w	0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
α	1.5	1.23	1.16	1.11	1.09	1.07	1.06	1.05	1.05	1.04	1.04
γ	0	0.44	0.62	0.71	0.76	0.80	0.83	0.85	0.87	0.88	0.89

21 Bow

21.1 Stem

The stem may be made of rolled, cast or forged steel or of shaped steel plates as shown in 6-1-4/21.1 FIGURE 6.

The thickness of a shaped plate stem and, in the case of a blunt bow, any part of the shell where $\alpha \geq 30°$ and $\Psi \geq 75°$ (see 6-1-4/9.1.1 for angle definitions), is to be obtained from the equation in 6-1-4/13.3 where:

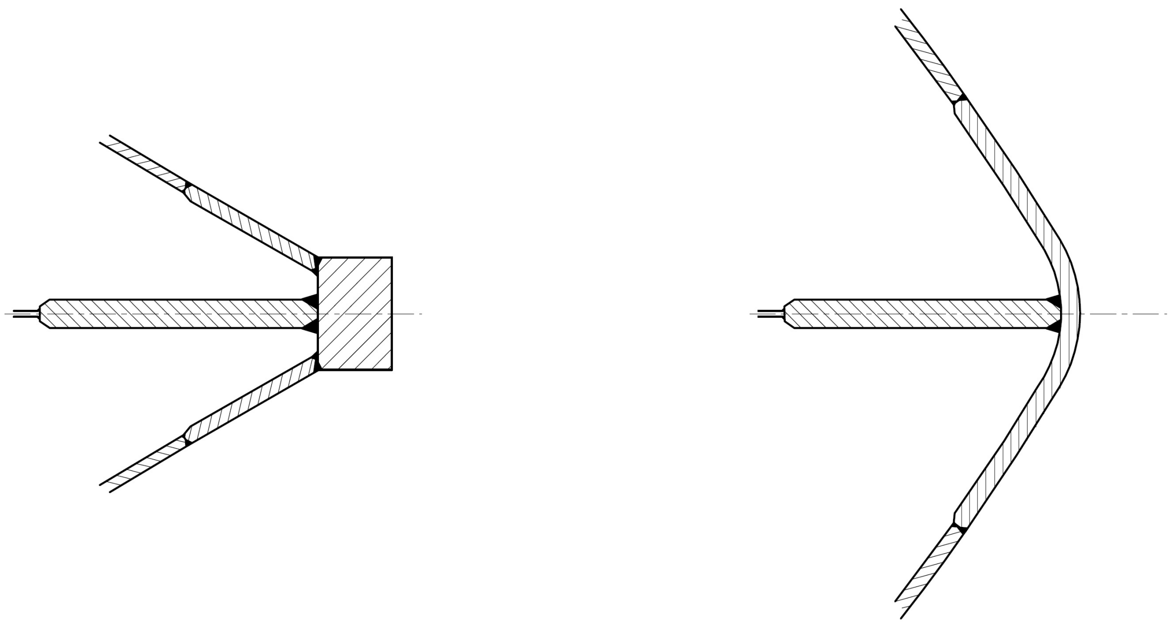
s = spacing of elements supporting the plate, in m (ft)

P_{PL} = p, in N/mm^2 (kgf/mm^2, psi), see 6-1-4/11.7

ℓ_a = spacing of vertical supporting elements, in m (ft)

The stem and that part of a blunt bow defined above is to be supported by floors, breasthooks or brackets spaced not more than 0.6 m (1.97 ft) apart and of a thickness atleast half the shell plate thickness. This reinforcement of the stem is to extend from the keel to a point 0.75 m (2.46 ft) above *UIWL*, or where an upper Bow ice belt is required, see 6-1-4/13.1, to the upper limit of this upper Bow ice belt.

FIGURE 6
Examples of Suitable Ice Stems



23 Stern *(2024)*

The introduction of new propulsion arrangements with azimuthing thrusters, which provide improved manoeuvrability, will result in increased ice loading of the Stern region structure. This fact should be considered in the design of the aft/stern structure for **Ice Class IC** through **IAA**.

In order to avoid very high loads on propeller blade tips, the minimum distance between propeller(s) and hull (including stern frame) should not be less than h_i (see 6-1-4/11.5).

On twin and triple screw vessels, the ice strengthening of the shell and framing is to extend to the double bottom for 1.5 meters (4.92 ft) forward and aft of the side propellers.

Shafting and stern tubes of side propellers are to be normally enclosed within plated bossing. If detached struts are used, their design, strength and attachment to the hull is to be duly considered for ice loading.

25 Rudder and Steering Arrangements *(1 July 2022)*

25.1 Minimum Design Speed

The scantlings of rudder post, rudder stock, pintles, steering gear etc., as well as the capacity of the steering gear are to comply with Section 3-2-14. Where the design ahead speed of the vessel, as defined in 3-2-14/3.1, is less than the minimum speed indicated in the table below, the latter speed is to be used in lieu of V in Section 3-2-14.

Class	*Minimum Speed*
IAA	20 knots
IA	18 knots
IB	16 knots
IC	14 knots

For use with the minimum ahead speeds in the above table, k_c may be taken as 80% of that specified in Section 3-2-14. Also, k_1 for rudders situated behind nozzles need not be taken as greater than 1.0.

The local scantlings of rudders are to be determined assuming that the whole rudder belongs to the ice belt. Further, the rudder plating and frames are to be designed using the ice pressure p for the plating and frames in the Midbody region.

25.3 Rudder and Rudder Stock Protection

For **Ice Class IAA** and **IA**, the rudder (rudder stock and the upper part of the rudder) are to be protected from direct contact with intact ice by an ice knife that extends below the *LIWL*, if practicable (or equivalent means). Special consideration shall be given to the design of the rudder and the ice knife for ships with flap-type rudders.

25.5 Overload Design *(1 July 2019)*

For **Ice Class IAA** and **IA**, due regard is to be given to the excessive loads caused by the rudder being forced out of the midship position when going astern in ice or backing into an ice ridge. Suitable arrangements such as rudder stops are to be installed to absorb these loads.

Relief valves for the hydraulic pressure in rudder turning mechanism(s) are to be installed. The components of the steering gear (e.g., rudder stock, rudder coupling, rudder horn, etc.) are to be dimensioned to withstand loads causing yield stresses within the required diameter of rudder stock.

27 Propulsion Machinery - IC through IAA *(2024)*

27.1 Scope *(1 July 2019)*

Requirements 6-1-4/27 apply to propulsion machinery covering open- and ducted-type propellers with controllable pitch or fixed pitch design for **Ice Class IAA**, **IA**, **IB** and **IC**. The given propeller loads are the expected ice loads for the whole ship's service life under normal operational conditions, including loads resulting from the changing rotational direction of FP propellers. However, these loads do not cover off-design operational conditions, for example when a stopped propeller is dragged through ice. The requirements also apply to azimuthing and fixed thrusters for main propulsion, considering loads resulting from propeller-ice interaction and loads on the thruster body-ice interaction. However, the load models do not include propeller/ice interaction loads when ice enters the propeller of a turned azimuthing thruster from the side (radially).

The given azimuthing thruster body loads are the expected ice loads for the ship's service life under normal operational conditions. The local strength of the thruster body shall be sufficient to withstand local ice pressure when the thruster body is designed for extreme loads.

The thruster global vibrations caused by blade order excitation on the propeller may cause significant vibratory loads.

27.3 Symbols *(2024)*

c	=	chord length of blade section, m (ft)
$c_{0.7}$	=	chord length of blade section at 0.7R propeller radius, m (ft)
CP	=	controllable pitch
D	=	propeller diameter, m (ft)
d	=	external diameter of propeller hub (at propeller plane), m (ft)
D_{limit}	=	limit value for propeller diameter, m (ft)
EAR	=	expanded blade area ratio
F_b	=	maximum backward blade force for the ship's service life, kN (kgf, lbf)
F_{ex}	=	ultimate blade load resulting from blade loss through plastic bending, kN (kgf, lbf)
F_f	=	maximum forward blade force for the ship's service life, kN (kgf, lbf)
F_{ice}	=	ice load, kN (kgf, lbf)
$(F_{ice})_{max}$	=	maximum ice load for the ship's service life, kN (kgf, lbf)
FP	=	fixed pitch
h_0	=	depth of the propeller centerline from the lower ice waterline, m (ft)
H_{ice}	=	thickness of maximum design ice block entering to propeller, m (ft)
H_{iced}	=	thickness of the design ice block impacting the thruster (2/3 of H_{ice})
I_e	=	equivalent mass moment of inertia of all parts on engine side of component under consideration, kg-m^2 (lb-ft^2)
I_t	=	equivalent mass moment of inertia of the whole propulsion system, kg-m^2 (lb-ft^2)
k	=	shape parameter for Weibull distribution
$LIWL$	=	lower ice waterline, m (ft)
m	=	slope for SN curve in log/log scale
M_{BL}	=	blade bending moment, kN-m (kgf-m, lbf-ft)

MCR	=	maximum continuous rating
n	=	propeller rotational speed, rev/s
n_n	=	nominal propeller rotational speed at MCR in free running condition, rev/s
N_{class}	=	reference number of impacts per propeller rotational speed per ice class
N_{ice}	=	total number of ice loads on propeller blade for the ship's service life
N_R	=	reference number of load for equivalent fatigue stress (10^8 cycles)
N_Q	=	number of propeller revolutions during a milling sequence
$P_{0.7}$	=	propeller pitch at 0.7Rradius, m (ft)
$P_{0.7n}$	=	propeller pitch at 0.7R radius at MCR in free running condition, m (ft)
$P_{0.7b}$	=	propeller pitch at 0.7R radius at MCR in bollard condition, m (ft)
Q	=	torque, kN-m (kgf-m, lbf-ft)
$Q_{e\,max}$	=	maximum engine torque, kN-m (kgf-m, lbf-ft)
Q_{max}	=	maximum torque on the propeller resulting from propeller-ice interaction, kN-m (kgf-m, lbf-ft)
Q_{max}^{n}	=	maximum torque on the propeller resulting from propeller-ice interaction reduced to the rotational speed in question, kN-m (kgf-m, lbf-ft)
Q_{motor}	=	electric motor peak torque, kN-m (kgf-m, lbf-ft)
Q_n	=	nominal torque at MCR in free running condition, kN-m (kgf-m, lbf-ft)
Q_r	=	maximum response torque along the propeller shaft line, kN-m (kgf-m, lbf-ft)
Q_{peak}	=	maximum of response torque Q_r, kN-m (kgf-m, lbf-ft)
$Q_{s\,max}$	=	maximum spindle torque of the blade for the ship's service life, kN-m (kgf-m, lbf-ft)
Q_{sex}	=	maximum spindle torque due to blade failure caused by plastic bending, kN-m (kgf-m, lbf-ft)
Q_{vib}	=	vibratory torque at considered component, taken from frequency domain open water torque vibration calculation (TVC), kN-m (kgf-m, lbf-ft)
R	=	propeller radius, m (ft)
r	=	blade section radius, m (ft)
T	=	propeller thrust, kN (kgf, lbf)
T_b	=	maximum backward propeller ice thrust for the ship's service life, kN (kgf, lbf)
T_f	=	maximum forward propeller ice thrust for the ship's service life, kN (kgf, lbf)
T_n	=	propeller thrust at MCR in free running condition, kN (kgf, lbf)
T_r	=	maximum response thrust along the shaft line, kN (kgf, lbf)
t	=	maximum blade section thickness, m (ft)
Z	=	number of propeller blades
α_i	=	duration of propeller blade/ice interaction expressed in rotation angle, deg
α_1	=	phase angle of propeller ice torque for blade order excitation component, deg
α_2	=	phase angle of propeller ice torque for twice the blade order excitation component, deg
$\gamma_{\varepsilon 1}$	=	reduction factor for fatigue; scatter effect

$\gamma_{\varepsilon 2}$ = reduction factor for fatigue; test specimen size effect

γ_v = reduction factor for fatigue; variable amplitude loading effect

γ_m = reduction factor for fatigue; mean stress effect

ρ = reduction factor for fatigue correlating the maximum stress amplitude to the equivalent fatigue stress for 10^8 stress cycles

$\sigma_{0.2}$ = proof yield strength (at 0.2% offset) of blade material, MPa (kgf/cm^2, psi)

σ_{exp} = mean fatigue strength of blade material at 10^8 cycles to failure in sea water, MPa (kgf/cm^2, psi)

σ_{fat} = equivalent fatigue ice load stress amplitude for 10^8 stress cycles, MPa (kgf/cm^2, psi)

σ_{fl} = characteristic fatigue strength for blade material, MPa (kgf/cm^2, psi)

$\sigma_{ref\,1}$ = reference stress $\sigma_{ref1} = 0.6\sigma_{0.2} + 0.4\sigma_u$, MPa (kgf/cm^2, psi)

$\sigma_{ref\,2}$ = reference stress $\sigma_{ref2} = 0.7\sigma_u$ or $\sigma_{ref2} = 0.6\sigma_{0.2} + 0.4\sigma_u$, whichever is less, MPa (kgf/cm^2, psi)

σ_{st} = maximum stress resulting from F_b or F_f, MPa (kgf/cm^2, psi)

σ_u = ultimate tensile strength of blade material, MPa (kgf/cm^2, psi)

$(\sigma_{ice})_{bmax}$ = principal stress caused by the maximum backward propeller ice load, MPa (kgf/cm^2, psi)

$(\sigma_{ice})_{fmax}$ = principal stress caused by the maximum forward propeller ice load, MPa (kgf/cm^2, psi)

$(\sigma_{ice})_{max}$ = maximum ice load stress amplitude, MPa (kgf/cm^2, psi)

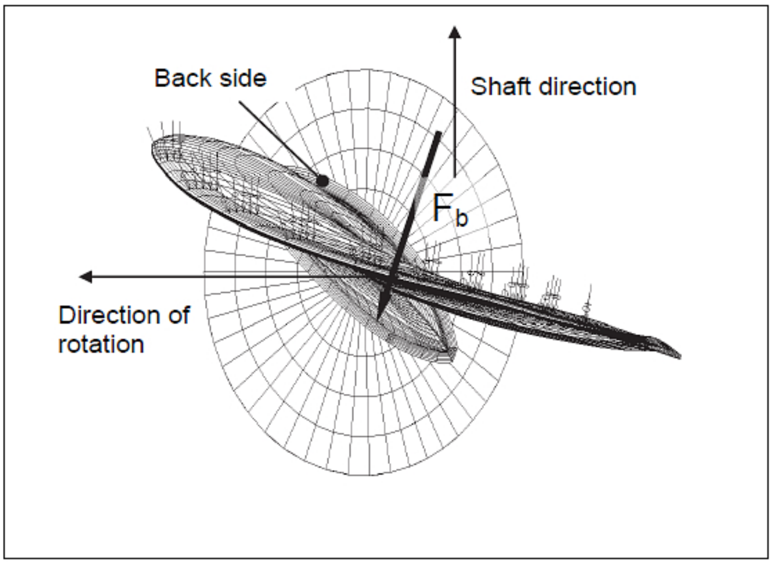
TABLE 1
Definition of Loads *(1 July 2019)*

	Definition	*Use of the load in design process*
F_b	The maximum lifetime backward force on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade. The direction of the force is perpendicular to 0.7*R* chord line. See 6-1-4/27.3 FIGURE 7	Design force for strength calculation of the propeller blade.
F_f	The maximum lifetime forward force on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade. The direction of the force is perpendicular to 0.7*R* chord line.	Design force for calculation of strength of the propeller blade.
$Q_{s\,max}$	The maximum lifetime spindle torque on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade.	In designing the propeller strength, the spindle torque is automatically taken into account because the propeller load is acting on the blade as distributed pressure on the leading edge or tip area.
T_b	The maximum lifetime thrust on a propeller (all blades) resulting from propeller/ice interaction. The direction of the thrust is the propeller shaft direction and the force is opposite to the hydrodynamic thrust.	Is used for estimation of the response thrust T_r. T_b can be used as an estimate of excitation for axial vibration calculations. However, axial vibration calculations are not required in the Rules.
T_f	The maximum lifetime thrust on a propeller (all blades) resulting from propeller/ice interaction. The direction of the thrust is the propeller shaft direction acting in the direction of hydrodynamic thrust.	Is used for estimation of the response thrust T_r. T_f can be used as an estimate of excitation for axial vibration calculations. However, axial vibration calculations are not required in the Rules.

	Definition	*Use of the load in design process*
Q_{max}	The maximum ice-induced torque resulting from propeller/ice interaction on one propeller blade, including hydrodynamic loads on that blade.	Is used for estimation of the response torque (Q_r) along the propulsion shaft line and as excitation for torsional vibration calculations.
F_{ex}	Ultimate blade load resulting from blade loss through plastic bending. The force that is needed to cause total failure of the blade so that plastic hinge appears in the root area. The force is acting on 0.8*R*. Spindle arm is to be taken as $^2/_3$ of the distance between the axis of blade rotation and leading/trailing edge (whichever is the greater) at the 0.8*R* radius.	Blade failure load is used to dimension the blade bolts, pitch control mechanism, propeller shaft, propeller shaft bearing and trust bearing. The objective is to guarantee that total propeller blade failure does not lead to damage to other components.
Q_r	Maximum response torque along the propeller shaft line, taking into account the dynamic behavior of the shaft line for ice excitation (torsional vibration) and the hydrodynamic mean torque on the propeller.	Design torque for propeller shaft line components.
T_r	Maximum response thrust along shaft line, taking into account the dynamic behavior of the shaft line for ice excitation (axial vibration) and the hydrodynamic mean thrust on the propeller.	Design thrust for propeller shaft line components.
F_{ti}	Maximum response force caused by ice block impacts on the thruster body or the propeller hub.	Design load for thruster body and slewing bearings.
F_{tr}	Maximum response force on the thruster body caused by ice ridge-thruster body interaction.	Design load for thruster body and slewing bearings.

FIGURE 7
Direction of the Backward Blade Force Resultant Taken Perpendicular to Chord Line at Radius 0.7*R* *(1 July 2019)*

Ice contact pressure at leading edge is shown with small arrows.



27.5 Design Ice Conditions

In estimating the ice loads of the propeller for ice classes, different types of operation as given in 6-1-4/11.1 FIGURE 2 were taken into account. For the estimation of design ice loads, a maximum ice block size is determined. The maximum design ice block entering the propeller is a rectangular ice block with the dimensions $H_{ice} \times 2H_{ice} \times 3H_{ice}$. The thickness of the ice block (H_{ice}) is given in 6-1-4/27.5 TABLE 3.

TABLE 2
Types of Ice Operation

Ice Class	*Operation of the Ship*
IAA	Operation in ice channels and in level ice The ship may proceed by ramming
IA, IB, IC	Operation in ice channels

TABLE 3
Thickness of the Ice Block (H_{ice})

	IAA	**IA**	**IB**	**IC**
Thickness of the design maximum ice block entering the propeller (H_{ice})	1.75 m (5.74 ft)	1.5 m (4.92 ft)	1.2 m (3.94 ft)	1.0 m (3.28 ft)

27.7 Materials

27.7.1 Materials Exposed to Sea Water *(1 July 2019)*

Materials of components exposed to sea water, such as propeller blades, propeller hubs, and thruster body, are to have an elongation of not less than 15% on a test specimen, the gauge length of which is five times the diameter. A Charpy V impact test is to be carried out for materials other than bronze and austenitic steel. An average impact energy value of 20 J (2.04 kgf-m, 14.75 lbf-ft) taken from three tests is to be obtained at minus 10°C (14°F). For nodular cast iron, average impact energy of 10 J at minus 10°C (14°F) is required accordingly.

27.7.2 Materials Exposed to Sea Water Temperature *(1 July 2019)*

Materials exposed to sea water temperature are to be of ductile material. An average impact energy value of 20 J (2.04 kgf-m, 14.75 lbf-ft) taken from three tests is to be obtained at minus 10°C (14°F). This requirement applies to the propeller shaft, blade bolts, CP mechanisms, shaft bolts, strut-pod connecting bolts etc. This does not apply to stoppers and surface hardened components, such as bearings and gear teeth. The nodular cast iron of a ferrite structure type may be used for relevant parts other than bolts. The average impact energy for nodular cast iron shall be a minimum of 10 J at minus 10 ºC (14°F).

27.9 Design Loads *(1 July 2019)*

The given loads are intended for component strength calculations only and are total loads including ice-induced loads and hydrodynamic loads during propeller/ice interaction. The presented maximum loads are based on a worst case scenario that occurs once during the service life of the vessel. Thus, the load level for a higher number of loads is lower.

The values of the parameters in the formulae in this section are to be given in the units shown in the symbol list in 6-1-4/27.3.

If the highest point of the propeller is not at a depth of at least h_i below the water surface when the ship is in ballast condition, the propulsion system is to be designed according to **Ice Class IA** for **Ice Class IB** and **IC**.

27.9.1 Design Loads on Propeller Blades

F_b is the maximum force experienced during the lifetime of the ship that bends a propeller blade backwards when the propeller mills an ice block while rotating ahead. F_f is the maximum force experienced during the lifetime of the ship that bends a propeller blade forwards when the propeller mills an ice block while rotating ahead. These forces originate from different propeller/ice interaction phenomena, not acting simultaneously. Hence, they are to be applied to one blade separately.

27.9.1(a) Maximum backward blade force, F_b, for open propellers:

$$F_b = k \cdot [n \cdot D]^{0.7}\left[\frac{EAR}{Z}\right]^{0.3} \cdot D^2$$ kN (kgf, lbf) when $D \le D_{limit}$

$k = 27$ (2753.23, 245.48)

$$F_b = k \cdot [n \cdot D]^{0.7} \cdot \left[\frac{EAR}{Z}\right]^{0.3} \cdot D \cdot H_{ice}^{1.4}$$ kN (kgf, lbf) when $D > D_{limit}$

$k = 23$ (2345.35, 130.01)

where

D_{limit} = $0.85 \cdot H_{ice}^{1.4}$ m

D_{limit} = $0.622 \times 0.85 \cdot H_{ice}^{1.4}$ (ft)

n = nominal rotational speed (at MCR in free running condition) for a CP propeller and 85% of the nominal rotational speed (at MCR in free running condition) for an FP propeller.

27.9.1(b) Maximum forward blade force, F_f, for open propellers:

$$F_f = k \cdot \left[\frac{EAR}{Z}\right] \cdot D^2$$ kN (kgf, lbf) when $D \le D_{limit}$

$k = 250$ (25492.9, 5221.36)

$$F_f = k \cdot \left[\frac{EAR}{Z}\right] \cdot D \cdot \frac{1}{\left(1 - \frac{d}{D}\right)} \cdot H_{ice}$$ kN (kgf, lbf) when $D > D_{limit}$

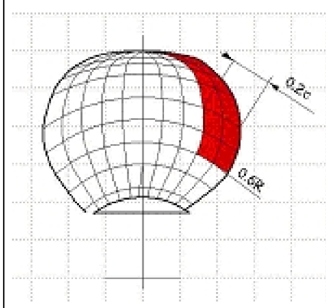
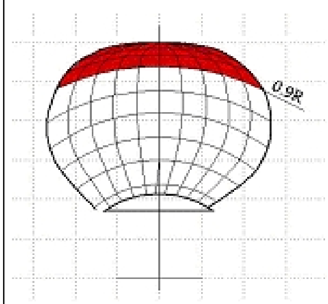
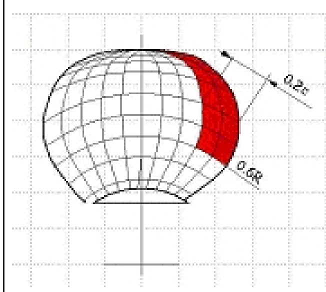
$k = 500$ (50985.81, 10442.72)

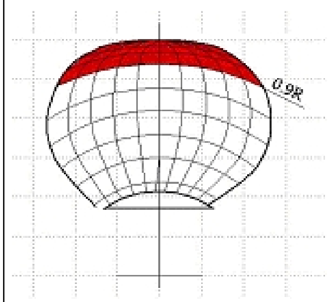
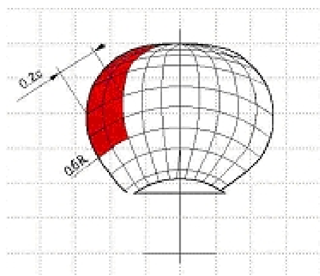
where

$$D_{limit} = \frac{2}{\left(1 - \frac{d}{D}\right)} \cdot H_{ice} \quad \text{m(ft)}$$

27.9.1(c) Loaded area on the blade for open propellers. Load cases 1-4 are to be covered, as given in 6-1-4/27.9.1(c) TABLE 4 below, for CP and FP propellers. In order to obtain blade ice loads for a reversing propeller, load case 5 also is to be covered for FP propellers.

TABLE 4
Load Cases for Open Propellers

	Force	*Loaded Area*	*Right-handed Propeller Blade Seen from Behind*
Load case 1	F_b	Uniform pressure applied on the back of the blade (suction side) to an area from 0.6*R* to the tip and from the leading edge to 0.2 times the chord length.	
Load case 2	50% of F_b	Uniform pressure applied on the back of the blade (suction side) on the propeller tip area outside 0.9*R* radius.	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0.6*R* to the tip and from the leading edge to 0.2 times the chord length.	

	Force	*Loaded Area*	*Right-handed Propeller Blade Seen from Behind*
Load case 4	50% of F_f	Uniform pressure applied on propeller face (pressure side) on the propeller tip area outside 0.9R radius.	
Load case 5	60% of F_f or F_b, whichever is greater	Uniform pressure applied on propeller face (pressure side) to an area from 0.6R to the tip and from the trailing edge to 0.2 times the chord length	

27.9.1(d) Maximum backward blade ice force, F_b, for ducted propellers:

$$F_b = k \cdot [n \cdot D]^{0.7} \cdot \left[\frac{EAR}{Z}\right]^{0.3} \cdot D^2 \quad \text{kN (kgf, lbf)} \quad \text{when } D \le D_{limit}$$

k= 9.5 (968.73, 86.37)

$$F_b = k \cdot [n \cdot D]^{0.7} \cdot \left[\frac{EAR}{Z}\right]^{0.3} D^{0.6} \cdot H_{ice}^{1.4} \quad \text{kN (kgf, lbf)} \quad \text{when } D > D_{limit}$$

k = 66 (6730.13, 600.06)

where

D_{limit} = $4 \cdot H_{ice}$ m (ft)

n = nominal rotational speed (at MCR in free running condition) for a CP propeller and 85% of the nominal rotational speed (at MCR in free running condition) for an FP propeller.

27.9.1(e) Maximum forward blade ice force, F_f, for ducted propellers:

$$F_f = k \cdot \left[\frac{EAR}{Z}\right] \cdot D^2 \quad \text{kN(kgf, lbf)} \quad \text{when } D \le D_{limit}$$

k = 250 (25492.91, 5221.35)

$$F_f = k \cdot \left[\frac{EAR}{Z}\right] \cdot D \cdot \frac{1}{\left(1 - \frac{d}{D}\right)} \cdot H_{ice} \quad \text{kN(kgf, lbf)} \quad \text{when } D > D_{limit}$$

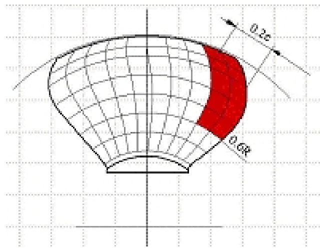
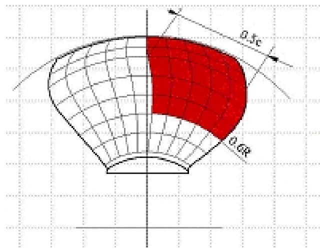
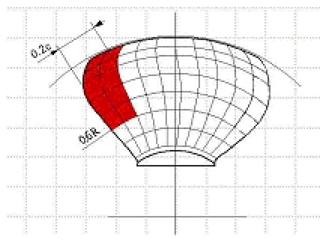
k = 500 (50985.91, 10442.72)

where

$$D_{limit} = \frac{2}{\left(1 - \frac{d}{D}\right)} \cdot H_{ice} \quad \text{m(ft)}$$

27.9.1(f) Loaded area on the blade for ducted propellers. Load cases 1 and 3 are to be covered as given in 6-1-4/27.9.1(f) TABLE 5 for all propellers, and an additional load case (load case 5) for an FP propeller, to cover ice loads when the propeller is reversed.

TABLE 5
Load Cases for Ducted Propellers

	Force	*Loaded Area*	*Right-handed Propeller Blade Seen from Behind*
Load case 1	F_b	Uniform pressure applied on the back of the blade (suction side) to an area from 0.6*R* to the tip and from the leading edge to 0.2 times the chord length.	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0.6*R* to the tip and from the leading edge to 0.5 times the chord length.	
Load case 5	60% of F_f or F_b, whichever is greater	Uniform pressure applied on propeller face (pressure side) to an area from 0.6*R* to the tip and from the trailing edge to 0.2 times the chord length.	

27.9.1(g) Maximum blade spindle torque, Q_{smax}, for open and ducted propellers. (1 July 2019)

The spindle torque, Q_{smax}, around the axis of the blade fitting is to be determined both for the maximum backward blade force, F_b, and forward blade force, F_f which are applied as in 6-1-4/27.9.1(c) TABLE 4 and 6-1-4/27.9.1(f) TABLE 5. The larger of the obtained torques is used as the dimensioning torque. If the above method gives a value which is less than the default value given by the formula below, the default value is to be used.

$Q_{s\ max} = 0.25 \cdot F \cdot c_{0.7}$ kN-m (kgf-m, lbf-ft)

where

$c_{0.7}$	=	length of the blade section at 0.7R radius
F	=	either F_b or F_f, whichever has the greater absolute value

27.9.1(h) Load distributions for blade loads. (1 July 2019)

The Weibull-type distribution (probability that F_{ice} exceeds $(F_{ice})_{max}$), as given in 6-1-4/27.9.1(h) FIGURE 8, is used for the fatigue design of the blade.

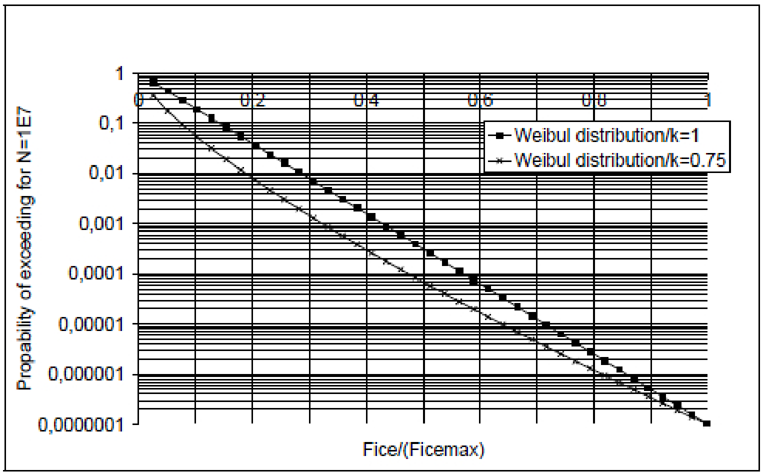
$$P\left(\frac{F_{ice}}{(F_{ice})max} \geq \frac{F}{(F_{ice})max}\right) = e^{\left(-\left(\frac{F}{(F_{ice})max}\right)^{k} .\ln(N_{ice})\right)}$$

where

k	=	shape parameter of the spectrum
N_{ice}	=	number of load cycles in the spectrum
F_{ice}	=	random variable for ice loads on the blade, $0 \leq F_{ice} \leq (F_{ice})_{max}$

The shape parameter k = 0.75 is to be used for the ice force distribution of an open propeller and the shape parameter k = 1.0 for that of a ducted propeller blade.

FIGURE 8
The Weibull-type Distribution (Probability that F_{ice} exceeds $(F_{ice})_{max}$) That is Used for Fatigue Design *(1 July 2019)*



27.9.1(i) Number of ice loads. The number of load cycles per propeller blade in the load spectrum is to be determined according to the formula:

$N_{ice} = k_1 k_2 k_3 N_{class} n_n$

where

Reference number of loads for ice classes N_{class}:

Class	IAA	IA	IB	IC
Impacts in life/n_n	9×10^6	6×10^6	3.4×10^6	2.1×10^6

Propeller location factor k_1:

Centerline Propeller Bow first operation	*Wing Propeller Bow first operation*	*Pulling propeller (wing and centerline) Bow propeller or Stern first operation*
1	2	3

The submersion factor, k_2, is determined from the equation:

$$
\begin{aligned}
k_2 &= 0.8 - f && \text{when } f < 0 \\
&= 0.8 - 0.4f && \text{when } 0 \le f \le 1 \\
&= 0.6 - 0.2f && \text{when } 1 \le f \le 2.5 \\
&= 0.1 && \text{when } f > 2.5
\end{aligned}
$$

Where the immersion function f is:

$$f = \frac{h_0 - H_{ice}}{D/2} - 1$$

where h_o is the depth of the propeller centerline at the lower ice waterline (LIWL) of the vessel.

Propulsion type factor k_3:

Type	*Fixed*	*Azimuthing*
k_3	1	1.2

For components that are subject to loads resulting from propeller/ice interaction with all the propeller blades, the number of load cycles (N_{ice}) is to be multiplied by the number of propeller blades (Z).

27.9.2 Axial Design Loads for Open and Ducted Propellers

27.9.2(a) Maximum ice thrust on propeller

The maximum forward and backward ice thrusts are:

$T_f = 1.1 \cdot F_f$ kN (kgf, lbf)

$T_b = 1.1 \cdot F_b$ kN (kgf, lbf)

27.9.2(b) Design thrust along the propulsion shaft line for open and ducted propellers.

The design thrust along the propeller shaft line is to be calculated with the formulae below. The greater value of the forward and backward direction loads is to be taken as the design load for both directions. The factors 2.2 and 1.5 take into account the dynamic magnification resulting from axial vibration.

In a forward direction:

$T_r = T + 2.2 \cdot T_f$ kN (kgf, lbf)

In a backward direction:

$T_r = 1.5 \cdot T_b$ kN (kgf, lbf)

If the hydrodynamic bollard thrust, T, is not known, T is to be taken as follows:

Propeller Type	*T*
CP propellers (open)	$1.25T_n$
CP propellers (ducted)	$1.1T_n$
FP propellers driven by turbine or electric motor	T_n
FP propellers driven by diesel engine (open)	$0.85T_n$
FP propellers driven by diesel engine (ducted)	$0.75T_n$

where T_n is the nominal propeller thrust at MCR in free running open water condition.

27.9.3 Torsional Design Loads

27.9.3(a) Design ice torque on propeller Q_{max} for open propellers. (1 July 2019)

Q_{max} is the maximum torque on a propeller resulting from ice/propeller interaction during the service life of the vessel.

$$Q_{max} = k \cdot \left[1 - \frac{d}{D}\right] \cdot \left[\frac{P_{0.7}}{D}\right]^{0.16} \cdot (nD)^{0.17} \cdot D^3 \quad \text{kN-m (kgf-m, lbf-ft)}$$

when $D \le D_{limit}$

$k = 10.9 \quad (1111.49, \quad 186.02)$

$$Q_{max} = k \cdot \left[1 - \frac{d}{D}\right] \cdot \left[\frac{P_{0.7}}{D}\right]^{0.16} \cdot (nD)^{0.17} \cdot D^{1.9} \cdot H_{ice}^{1.1} \quad \text{kN-m (kgf-m, lbf-ft)}$$

when $D > D_{limit}$

$k = 20.7 \quad (2110.81, \quad 353.26)$

where

$D_{limit} = 1.8 \cdot H_{ice}$ m (ft)

n is the rotational propeller speed at MCR in bollard condition. If unknown, n is to be attributed a value in accordance with the following table.

Propeller Type	*Rotational Speed, n*
CP propellers	n_n
FP propellers driven by turbine or electric motor	n_n
FP propellers driven by diesel engine	$0.85n_n$

where n_n is the nominal rotational speed at MCR in free running open water condition.

For CP propellers, the propeller pitch, $P_{0.7}$ shall correspond to MCR in bollard condition. If not known, $P_{0.7}$ is to be taken as $0.7P_{0.7n}$, where $P_{0.7n}$ is the propeller pitch at MCR in free running condition.

27.9.3(b) Design ice torque on propeller Q_{max} for ducted propellers. (1 July 2019)

Q_{max} is the maximum torque on a propeller during the service life of the ship resulting from ice/propeller interaction.

$$Q_{max} = k \cdot \left[1 - \frac{d}{D}\right] \cdot \left[\frac{P_{0.7}}{D}\right]^{0.16} \cdot (nD)^{0.17} \cdot D^3 \quad \text{kN-m (kgf-m, lbf-ft)}$$

when $D \leq D_{limit}$

$k = 7.7 \quad (785.18, \quad 131.41)$

$$Q_{max} = k \cdot \left[1 - \frac{d}{D}\right] \cdot \left[\frac{P_{0.7}}{D}\right]^{0.16} \cdot (nD)^{0.17} \cdot D^{1.9} \cdot H_{ice}^{1.1} \quad \text{kN-m (kgf-m, lbf-ft)}$$

when $D > D_{limit}$

$k = 14.6 \quad (1488.78, \quad 249.16)$

where

D_{limit}	=	$1.8 \cdot H_{ice}$ m (ft)
n	=	rotational propeller at MCR speed in bollard condition. If not known, n is to have a value according to the table in 6-1-4/27.9.3(a).

For CP propellers, the propeller pitch, $P_{0.7}$ shall correspond to MCR in bollard condition. If not known, $P_{0.7}$ is to be taken as $0.7P_{0.7n}$, where $P_{0.7n}$ is the propeller pitch at MCR in free running condition.

27.9.3(c) Design torque for non-resonant shaft lines. *(1 July 2019)*

If there is no relevant first blade order torsional resonance in the operational speed range or in the range 20% above and 20% below the maximum operating speeds (bollard condition), the following estimation of the maximum torque can be used.

Directly coupled two stroke diesel engines without flexible coupling

$$Q_{peak} = Q_{emax} + Q_{vib} + Q_{max} \cdot \frac{I_e}{I_t} \quad \text{kN-m(kgf-m,lbf-ft)}$$

and other plants

$$Q_{peak} = Q_{emax} + Q_{max} \cdot \frac{I_e}{I_t} \quad \text{kN} - \text{m} \quad (\text{kgf} - \text{m}, \text{lbf} - \text{ft})$$

where

I_e	=	equivalent mass moment of inertia of all parts on the engine side of the component under consideration
I_t	=	equivalent mass moment of inertia of the whole propulsion system

All the torques and the inertia moments shall be reduced to the rotation speed of the component being examined.

If the maximum torque, Q_{emax} is unknown, it is to be taken as follows:

TABLE 6
Default Values for Prime Mover Maximum Torque Q_{emax} *(1 July 2019)*

Propeller Type	Q_{emax}
Propellers driven by electric motor	* Q_{motor}
CP propellers not driven by electric motor	Q_n
FP propellers driven by turbine	Q_n
FP propellers driven by diesel engine	$0.75Q_n$

Note: * Q_{motor} is the electric motor peak torque.

27.9.3(d) Design torque for shaft lines having resonances (1 July 2019)

If there is a first blade order torsional resonance in the operational speed range or in the range 20% above and 20% below the maximum operating speed (bollard condition), the design torque (Q_{peak}) of the shaft component is to be determined by means of torsional vibration analysis of the propulsion line.

There are two alternative ways of performing the dynamic analysis.

i) Time domain calculation for estimated milling sequence excitation

ii) Frequency domain calculation for blade orders sinusoidal excitation

The frequency domain analysis is generally considered conservative compared to the time domain simulation, provided that there is a first blade order resonance in the considered speed range.

27.9.3(e) Time domain calculation of torsional response. (2024)

Time domain calculations are to be performed for the MCR condition, MCR bollard conditions and for blade order resonant rotational speeds so that the resonant vibration responses can be obtained.

The load sequence given herein, for a case where a propeller is milling an ice block, shall be used for the strength evaluation of the propulsion line. The given load sequence is not intended for propulsion system stalling analyses.

The following load cases are intended to reflect the operational loads on the propulsion system, when the propeller interacts with ice, and the respective reaction of the complete system. The ice impact and system response causes loads in the individual shaft line components. The ice torque Q_{max} may be taken as a constant value in the complete speed range. When considerations at specific shaft speeds are performed, a relevant Q_{max} may be calculated using the relevant speed according to section 6-1-4/27.9.3(a) or 6-1-4/27.9.3(b).

Diesel engine plants without an elastic coupling shall be calculated at the least favorable phase angle for ice versus engine excitation, when calculated in the time domain. The engine firing pulses shall be included in the calculations and their standard steady state harmonics can be used.

Calculations are to cover rotational speeds up to 105% of the MCR speed to check for blade order resonance above the MCR speed.

The propeller ice torque excitation for shaft line transient dynamic analysis in the time domain is defined as a sequence of blade impacts which are of half sine shape. The excitation frequency shall follow the propeller rotational speed during the ice interaction sequence. The torque due to a single blade ice impact as a function of the propeller rotation angle is then defined using the formula:

$Q(\varphi) = C_q \cdot Q_{max} \cdot \sin[\varphi(180/\alpha_i)]$ when $\varphi = 0 \ldots \alpha_i$

$Q(\varphi) = 0$ when $\varphi = \alpha_i \ldots 360$

where

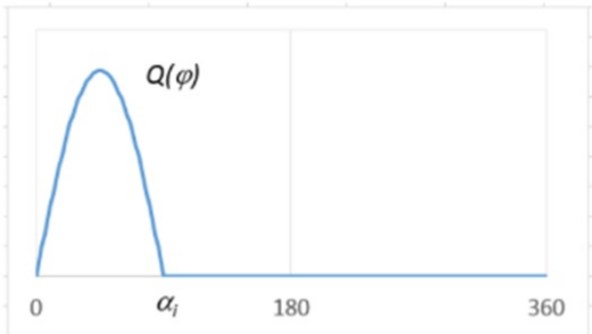
φ = the rotation angle from when the first impact occurs

C_q and α_i are given in the table below.

Torque Excitation	*Propeller/Ice Interaction*	C_q	α_i *[deg]*			
			Z=3	*Z=4*	*Z=5*	*Z=6*
Case 1	Single ice block	0.75	90	90	72	60
Case 2	Single ice block	1.0	135	135	135	135
Case 3	Two ice blocks (phase shift 360/(2·Z) deg.)	0.5	45	45	36	30
Case 4	Single ice block	0.5	45	45	36	30

α_i is duration of propeller blade/ice interaction expressed in terms of the propeller rotation angle (see 6-1-4/27.9.3(e) FIGURE 9).

FIGURE 9
Schematic Ice Torque due to a Single Blade Ice Impact as a Function of the Propeller Rotation Angle *(1 July 2019)*



The total ice torque is obtained by summing the torque of single blades, while taking account of the phase shift 360 deg/*Z*, see 6-1-4/27.9.3(e) FIGURE 10 or 6-1-4/27.9.3(e) FIGURE 11. At the beginning and end of the milling sequence (within the calculated duration) linear ramp functions shall be used to increase C_q to its maximum value within one propeller revolution and vice versa to decrease it to zero (see the examples of different *Z* numbers in 6-1-4/27.9.3(e) FIGURE 10 or 6-1-4/27.9.3(e) FIGURE 11.

The number of propeller revolutions during a milling sequence is to be obtained from the formula:

$N_Q = 2 \times H_{ice}$ where H_{ice} in m

$N_Q = 0.3048 \times 2 \times H_{ice}$ where H_{ice} in ft

The number of impacts is $Z \cdot N_Q$ for blade order excitation. An illustration of all excitation cases for different numbers of blades is given in 6-1-4/27.9.3(e) FIGURE 10 or 6-1-4/27.9.3(e) FIGURE 11.

A dynamic simulation is to be performed for all excitation cases at the operational rotational speed range. For a fixed pitch propeller propulsion plant, a dynamic simulation shall also cover the bollard pull condition with a corresponding rotational speed assuming the maximum possible output of the engine.

If a speed drop occurs until the main engine is at a standstill, this indicates that the engine may not be sufficiently powered for the intended service task. For the consideration of loads, the maximum occurring torque during the speed drop process is to be used.

FIGURE 10
Example Shape of the Propeller Ice Torque Excitation Sequences for Propellers with 3 or 4 Blades *(2024)*

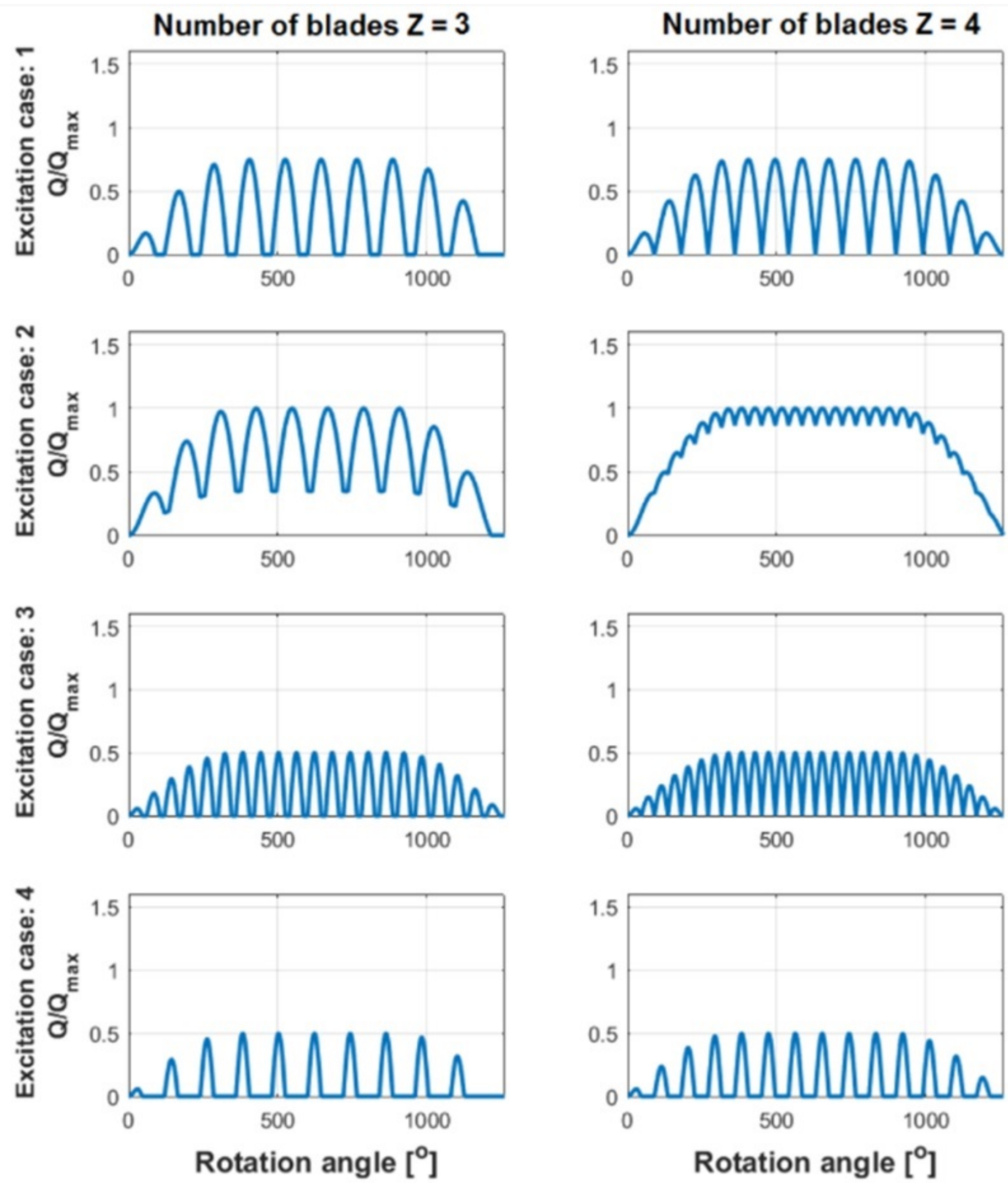
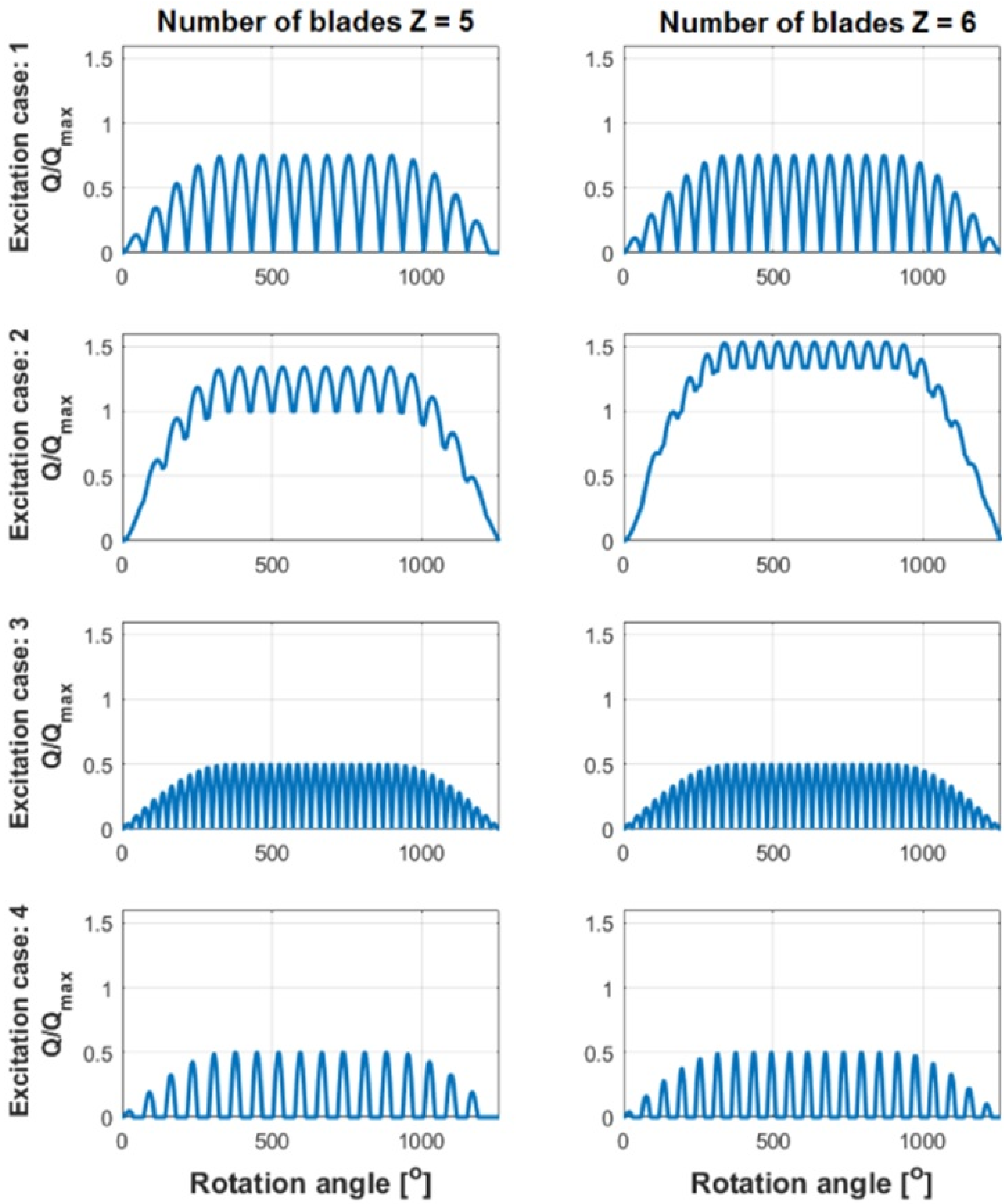


FIGURE 11
Example Shape of the Propeller Ice Torque Excitation Sequences for Propellers with 5 or 6 Blades *(2024)*



For the time domain calculation, the simulated response torque typically includes the engine mean torque and the propeller mean torque. If this is not the case, the response torques must be obtained using the formula:

$$Q_{peak} = Q_{emax} + Q_{rtd} \quad \text{kN} - \text{m}(\text{kgf} - \text{m}, \text{lbf} - \text{ft})$$

where Q_{rtd} is the maximum simulated torque obtained from the time domain analysis.

27.9.3(f) Frequency domain calculation of torsional response (1 July 2019)

For frequency domain calculations, blade order and twice-the-blade-order excitation may be used. The amplitudes for the blade order and twice-the-blade-order sinusoidal excitation have been derived based on the assumption that the time domain half sine impact sequences were continuous, and the Fourier series components for blade order and twice-the-blade-order components have been derived. The propeller ice torque is then:

$$Q_F(\varphi) = Q_{max}\left(C_{q0} + C_{q1}\sin(ZE_0\varphi + \alpha_1) + C_{q2}\sin(2ZE_0\varphi + \alpha_2)\right) \quad \text{kN} - \text{m}(\text{kgf} - \text{m}, \text{lbf} - \text{ft})$$

where

C_{q0}	=	mean torque parameter
C_{q1}	=	first blade order excitation parameter
C_{q2}	=	second blade order excitation parameter
α_1, α_2	=	phase angles of the excitation component
φ	=	angle of rotation
E_0	=	number of ice blocks in contact

The values of the parameters are given in the following table:

TABLE 7
Coefficient Values for Frequency Domain Excitation Calculation

	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Torque excitation Z=3						
Excitation case 1	0.375	0.36	-90	0	0	1
Excitation case 2	0.7	0.33	-90	0.05	-45	1
Excitation case 3	0.25	0.25	-90	0		2
Excitation case 4	0.2	0.25	0	0.05	-90	1
Torque excitation Z=4						
Excitation case 1	0.45	0.36	-90	0.06	-90	1
Excitation case 2	0.9375	0	-90	0.0625	-90	1
Excitation case 3	0.25	0.25	-90	0	0	2
Excitation case 4	0.2	0.25	0	0.05	-90	1
Torque excitation Z=5						
Excitation case 1	0.45	0.36	-90	0.06	-90	1
Excitation case 2	1.19	0.17	-90	0.02	-90	1
Excitation case 3	0.3	0.25	-90	0.048	-90	2
Excitation case 4	0.2	0.25	0	0.05	-90	1
Torque excitation Z=6						
Excitation case 1	0.45	0.36	-90	0.05	-90	1
Excitation case 2	1.435	0.1	-90	0	0	1

	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Excitation case 3	0.3	0.25	-90	0.048	-90	2
Excitation case 4	0.2	0.25	0	0.05	-90	1

The design torque for the frequency domain excitation case is to be obtained using the formula:

$$Q_{peak} = Q_{emax} + Q_{vib} + \left(Q_{max}^{n} C_{q0}\right)^{I_e}/_{I_t} + Q_{rf1} + Q_{rf2} \quad \text{kN} - \text{m}(\text{kgf} - \text{m}, \text{lbf} - \text{ft})$$

where

Q_{max}^{n} = maximum propeller ice torque at the operation speed in consideration

C_{q0} = mean static torque parameter from 6-1-4/27.9.3(f) TABLE 7

Q_{rf1} = blade order torsional response from the frequency domain analysis

Q_{rf2} = second order blade torsional response from the frequency domain analysis

If the prime mover maximum torque, Q_{emax}, is not known, it is to be taken as given in 6-1-4/27.9.3(c) TABLE 6. All the torque values are to be scaled to the shaft revolutions for the component in question.

27.9.3(g) Guidance for torsional vibration calculation *(1 July 2019)*

The aim of time domain torsional vibration simulations is to estimate the extreme torsional load for the ship's lifespan. The simulation model can be taken from the normal lumped mass elastic torsional vibration model, including damping. For a time domain analysis, the model should include the ice excitation at the propeller, other relevant excitations and the mean torques provided by the prime mover and hydrodynamic mean torque in the propeller. The calculations should cover variation of phase between the ice excitation and prime mover excitation. This is most relevant to propulsion lines with directly driven combustion engines. Time domain calculations shall be calculated for the MCR condition, MCR bollard conditions and for resonant speed, so that the resonant vibration responses can be obtained.

For frequency domain calculations, the load should be estimated as a Fourier component analysis of the continuous sequence of half sine load sequences. First and second order blade components should be used for excitation.

The calculation should cover the entire relevant rpm range and the simulation of responses at torsional vibration resonances.

27.9.4 Blade Failure Load

27.9.4(a) Bending force, F_{ex} *(1 July 2019)*

The ultimate load resulting from blade failure as a result of plastic bending around the blade root is to be calculated with the formula below, or alternatively by means of an appropriate stress analysis, reflecting the non-linear plastic material behavior of the actual blade. In such a case, the blade failure area may be outside the root section. The ultimate load is acting on the blade at the 0.8*R* radius in the weakest direction of the blade.

A blade is regarded as having failed if the tip is bent into an offset position by more than 10% of propeller diameter *D*.

$$F_{ex} = \frac{k \cdot c \cdot t^2 \cdot \sigma_{ref1}}{0.8 \cdot D - 2 \cdot r} \quad \text{kN}(\text{kgf}, \text{lbf})$$

k = 300 (300000, 43.20)

where

$\sigma_{ref\ 1}$	=	$0.6 \cdot \sigma_{0.2} + 0.4 \cdot \sigma_u$ MPa (kgf/cm^2, psi)
σ_u	=	minimum ultimate tensile strength to be specified on the drawing
$\sigma_{0.2}$	=	minimum yield or 0.2% proof strength to be specified on the drawing

c, t, and r are, respectively, the actual chord length, maximum thickness, and radius of the cylindrical root section of the blade, which is the weakest section outside the root fillet typically located at the point where the fillet terminates at the blade profile.

27.9.4(b) Spindle torque, Q_{sex} (1 July 2019)

The maximum spindle torque due to a blade failure load acting at 0.8R shall be determined. The force that causes blade failure typically reduces when moving from the propeller centre towards the leading and trailing edges. At a certain distance from the blade centre of rotation, the maximum spindle torque will occur. This maximum spindle torque shall be defined by an appropriate stress analysis or using the equation given below.

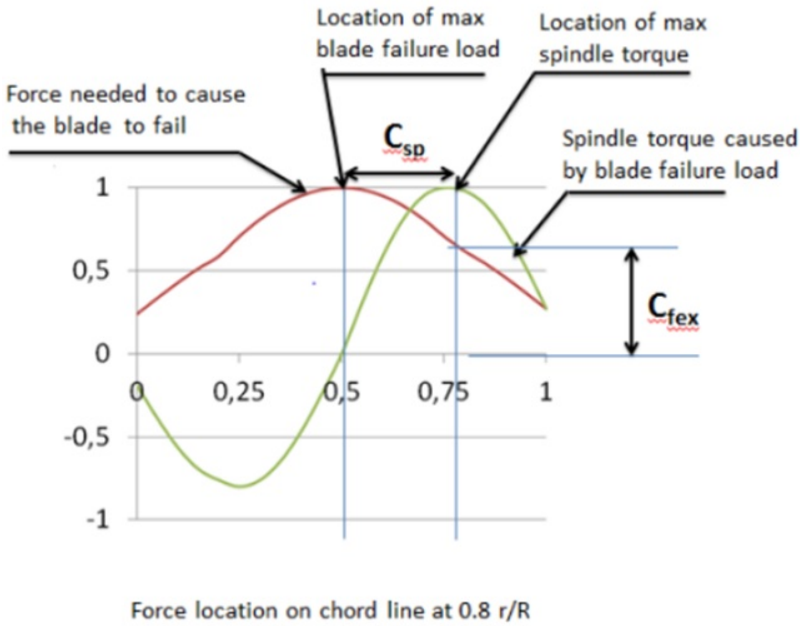
$$Q_{sex} = max[C_{LE0.8};\quad 0.8C_{TE0.8}]C_{spex}F_{ex}\quad \text{kN} - \text{m}(\text{kgf} - \text{m}, \text{lbf} - \text{ft})$$

where

C_{spex}	=	$C_{sp}C_{fex} = 0.7\left(1 - \left(\frac{4EAR}{Z}\right)^3\right)$ If C_{spex} is below 0.3, a value of 0.3 shall to be used for C_{spex}.
C_{sp}	=	non-dimensional parameter taking account of the spindle arm
C_{fex}	=	non-dimensional parameter taking account of the reduction of the blade failure force at the location of the maximum spindle torque
$C_{LE0.8}$	=	is the leading edge portion of the chord length at $0.8R$
$C_{TE0.8}$	=	is the trailing edge portion of the chord length at $0.8R$

6-1-4/27.9.4(b) FIGURE 12 illustrates the spindle torque values due to blade failure loads across the entire chord length.

FIGURE 12
Blade Failure Load and the Related Spindle Torque when the Force Acts at a Different Location on the Chord Line at Radius 0.8*R*



27.11 Design

27.11.1 Design Principle

The strength of the propulsion line is to be designed according to the pyramid strength principle. This means that the loss of the propeller blade is not to cause any significant damage to other propeller shaft line components.

27.11.2 Propeller Blade

27.11.2(a) Calculation of blade stresses.

The blade stresses are to be calculated for the design loads given in 6-1-4/27.9.1. Finite element analyses are to be used for stress analysis for final approval for all propellers.

The following simplified formulae can be used in estimating the blade stresses for all propellers at the root area (r/R< 0.5). The root area dimensions will be accepted even if the FEM analysis would show greater stresses at the root area.

$$\sigma_{st} = C_1 \frac{M_{BL}}{k \cdot ct^2} \quad \text{Mpa(kgf/cm}^2\text{, psi)}$$

$k = 10^2$ (10^3, 14.4)

where constant C_1 is the "actual stress"/"stress obtained with beam equation". If the actual value is not available, C_1 should be taken as 1.6.

$M_{BL} = (0.75 - r/R) \cdot R \cdot F$ for relative radius r/R < 0.5

F is the maximum of F_b and F_f, whichever is greater.

27.11.2(b) Acceptability criterion. *(1 July 2019)*

The following criterion for calculated blade stresses is to be fulfilled.

$$\frac{\sigma_{ref2}}{\sigma_{st}} \geq 1.3$$

where

σ_{st} = calculated stress for the design loads. If FE analysis is used in estimating the stresses, von Mises stresses shall be used

$\sigma_{ref\,2}$ = reference stress, defined as:

= $0.7 \cdot \sigma_u$ or

= $0.6 \cdot \sigma_{0.2} + 0.4 \cdot \sigma_u$, whichever is less

27.11.2(c) Fatigue design of propeller blade. (Note - SI units) (2024)

The fatigue design of the propeller blade is based on an estimated load distribution for the service life of the ship and the S-N curve for the blade material. An equivalent stress that produces the same fatigue damage as the expected load distribution shall be calculated and the acceptability criterion for fatigue should be fulfilled as given in this section. The equivalent stress is normalized for 10^8(100 million) cycles.

For materials with a two-slope SN curve (6-1-4/27.11.2(c) FIGURE 13), if the following criterion is fulfilled, fatigue calculations according to this section are not required.

$$\sigma_{exp} \geq B1 \cdot \left(\sigma_{ref2}\right)^{B2} \cdot [\log(N_{ice})]^{B3}$$

where $B1$, $B2$, and $B3$ are coefficients for open and nozzle propellers are given in the table below.

	Open Propeller	*Nozzle Propeller*
$B1$	0.00328	0.00223
$B2$	1.0076	1.0071
$B3$	2.101	2.471

For calculation of equivalent stress, two types of S-N curves are available:

1) Two slope S-N curve (slopes 4.5 and 10), see 6-1-4/27.11.2(c) FIGURE 13.

2) One slope S-N curve (the slope can be chosen), see 6-1-4/27.11.2(c) FIGURE 14.

The type of the S-N curve shall be selected to correspond to the material properties of the blade. If the S-N curve is not known the two slope S-N curve is to be used.

FIGURE 13
Two-slope S-N Curve *(1 July 2019)*

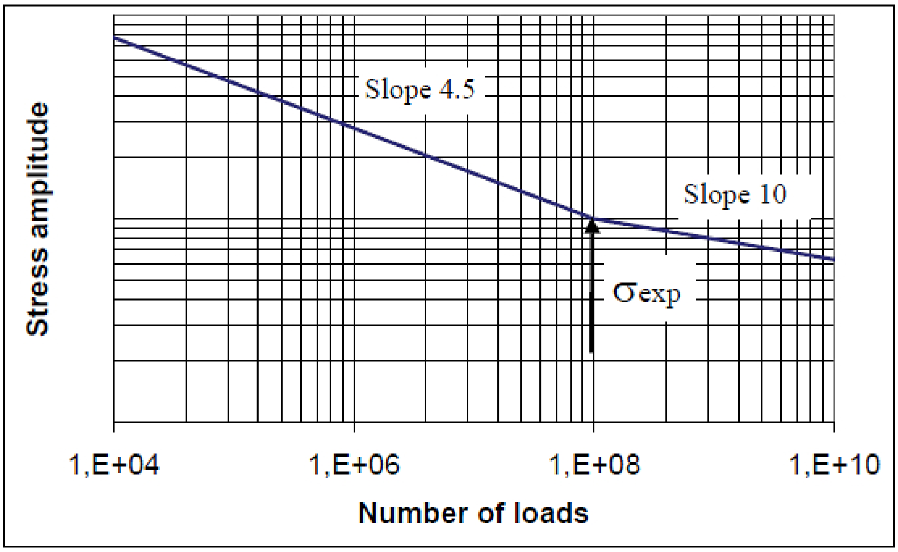
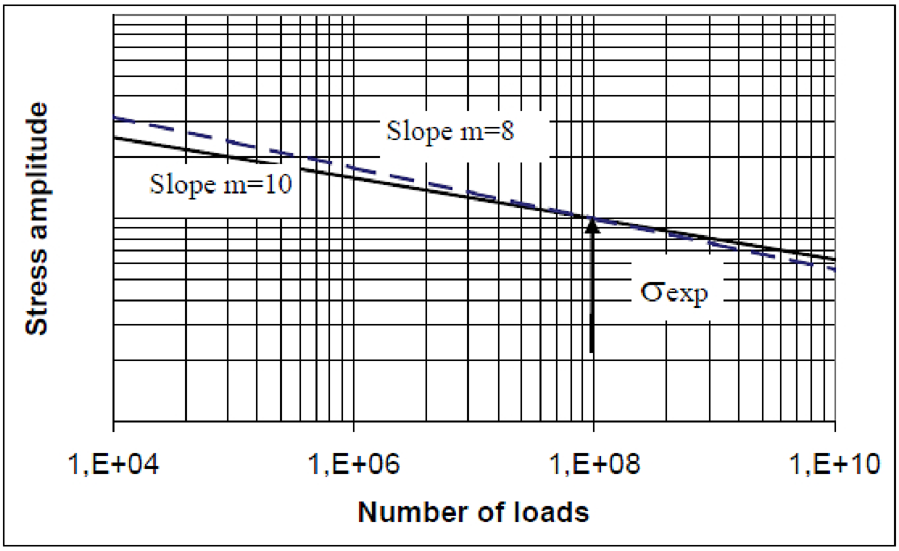


FIGURE 14
Constant-slope S-N Curve *(1 July 2019)*



i) *Equivalent fatigue stress.*

The equivalent fatigue stress for 10^8 (100 million) stress cycles which produces the same fatigue damage as the load distribution for the service life of the ship is:

$\sigma_{fat} = \rho \cdot (\sigma_{ice})_{max}$

where

$(\sigma_{ice})_{max}$	=	mean value of the principal stress amplitudes resulting from design forward and backward blade forces at the location being studied
	=	$0.5 \cdot [(\sigma_{ice})_{fmax} - (\sigma_{ice})_{bmax}]$

$(\sigma_{ice})_{f\max}$ = principal stress resulting from forward load

$(\sigma_{ice})_{b\max}$ = principal stress resulting from backward load

In calculation of $(\sigma_{ice})_{\max}$, case 1 and case 3 (or case 2 and case 4) are considered as a pair for $(\sigma_{ice})_{f\max}$, and $(\sigma_{ice})_{b\max}$ calculations. Case 5 is excluded from the fatigue analysis.

ii) *Calculation of ρ parameter for two-slope S-N curve.*

The parameter ρ relates the maximum ice load to the distribution of ice loads according to the regression formula:

$$\rho = C_1 \cdot (\sigma_{ice})_{max}^{C2} \cdot \sigma_{fl}^{C3} \cdot [\log(N_{ice})]^{C4}$$

where

σ_{fl} = $\gamma_{\varepsilon 1} \cdot \gamma_{\varepsilon 2} \cdot \gamma_v \cdot \gamma_m \cdot \sigma_{exp}$

$\gamma_{\varepsilon 1}$ = reduction factor due to scatter (equal to one standard deviation)

$\gamma_{\varepsilon 2}$ = reduction factor for test specimen size effect

γ_v = reduction factor for variable amplitude loading

γ_m = reduction factor for mean stress

σ_{exp} = mean fatigue strength of the blade material at 10^8 cycles to failure in seawater

The following values are to be used for the reduction factors if actual values are not available: $\gamma_\varepsilon = \gamma_{\varepsilon 1} \cdot \gamma_{\varepsilon 2} = 0.67$, $\gamma_v = 0.75$, and $\gamma_m = 0.75$.

The coefficients C_1, C_2, C_3, and C_4 are given in 6-1-4/27.11.2(c).ii TABLE 8, below. The applicable range of N_{ice} for calculating ρ is $5\text{x}10^6 \le N_{ice} \le 10^8$.

TABLE 8
Coefficients *C* *(1 July 2019)*

	Open Propeller	*Ducted Propeller*
*C*1	0.000747	0.000534
*C*2	0.0645	0.0533
*C*3	-0.0565	-0.0459
*C*4	2.22	2.584

iii) *Calculation of ρ parameter for constant-slope S-N curve.*

For materials with a constant-slope S-N curve, see 6-1-4/27.11.2(c) FIGURE 14, the ρ-factor is to be calculated with the following formula:

$$\rho = \left(G\frac{N_{ice}}{N_R}\right)^{1/m}[\ln(N_{ice})]^{-1/k}$$

where

k = shape parameter of the Weibull distribution

= 1.0 for ducted propellers

= 0.75 for open propellers

N_R = reference number of load cycles (= 10^8)

The applicable range of N_{ice} for calculating ρ is $5x10^6 \le N_{ice} \le 10^8$.

Values for the G parameter are given in 6-1-4/27.11.2(c).iii TABLE 9. Linear interpolation may be used to calculate the G value for other m/k ratios than given in the 6-1-4/27.11.2(c).iii TABLE 9.

TABLE 9
Value for the *G* Parameter for Different *m/k* Ratios *(1 July 2019)*

m/k	*G*	*m/k*	*G*	*m/k*	*G*	*m/k*	*G*
3	6	5.5	287.9	8	40320	10.5	$11.899x10^6$
3.5	11.6	6	720	8.5	119292	11	$39.917x10^6$
4	24	6.5	1871	9	362880	11.5	$136.843x10^6$
4.5	52.3	7	5040	9.5	1.133×10^6	12	$479.002x10^6$
5	120	7.5	14034	10	3.629×10^6	-	-

27.11.2(d) Acceptability criterion for fatigue. *(1 July 2019)*

The equivalent fatigue stress at all locations on the blade is to fulfill the following acceptability criterion:

$$\frac{\sigma_{fl}}{\sigma_{fat}} \ge 1.5$$

where

σ_{fl} = $\gamma_\varepsilon \cdot \gamma_{\varepsilon 2} \cdot \gamma_v \cdot \gamma_m \cdot \sigma_{exp}$

$\gamma_{\varepsilon 1}$ = reduction factor due to scatter (equal to one standard deviation)

$\gamma_{\varepsilon 2}$ = reduction factor for test specimen size effect

γ_v = reduction factor for variable amplitude loading

γ_m = reduction factor for mean stress

σ_{exp} = mean fatigue strength of the blade material at 10^8 cycles to failure in seawater

The following values are to be used for the reduction factors if actual values are not available: $\gamma_\varepsilon = \gamma_{\varepsilon 1} \cdot \gamma_{\varepsilon 2} = 0.67$, $\gamma_v = 0.75$, and $\gamma_m = 0.75$.

27.11.3 Propeller Bossing and CP Mechanism

The blade bolts, the CP mechanism, the propeller boss, and the fitting of the propeller to the propeller shaft shall be designed to withstand the maximum and fatigue design loads, as defined in 6-1-4/27.9. The safety factor against yielding shall be greater than 1.3 and that against fatigue greater than 1.5. In addition, the safety factor for loads resulting from loss of the propeller blade through plastic bending as defined in 6-1-4/27.9.4 is to be greater than 1.0 against yielding.

27.11.4 Propulsion Shaft Line *(1 July 2019)*

The shafts and shafting components, such as the thrust and stern tube bearings, couplings, flanges and sealings, are to be designed to withstand the propeller/ice interaction loads as given in

6-1-4/27.9. The safety factor is to be at least 1.3 against yielding for extreme operational loads, 1.5 for fatigue loads and 1.0 against yielding for the blade failure load.

27.11.4(a) Shafts and shafting components. *(1 July 2019)*

The ultimate load resulting from total blade failure as defined in 6-1-4/27.9.4 is not to cause yielding in shafts and shaft components. The loading shall consist of the combined axial, bending, and torsion loads, wherever this is significant. The minimum safety factor against yielding is to be 1.0 for bending and torsional stresses.

Note: The requirements in this section are complementary to those described in Section 4-3-2 of the Rules. For fatigue evaluation, cumulative fatigue analyses are to be performed (see 6-1-3/11.1.3for recommended method/practice). The applicable Q_{peak} and the corresponding load spectrum shall be determined for the component or connection in question, as described in 6-1-4/27.9.3.

27.11.5 Azimuthing Main Propulsors

27.11.5(a) Design principle *(1 July 2019)*

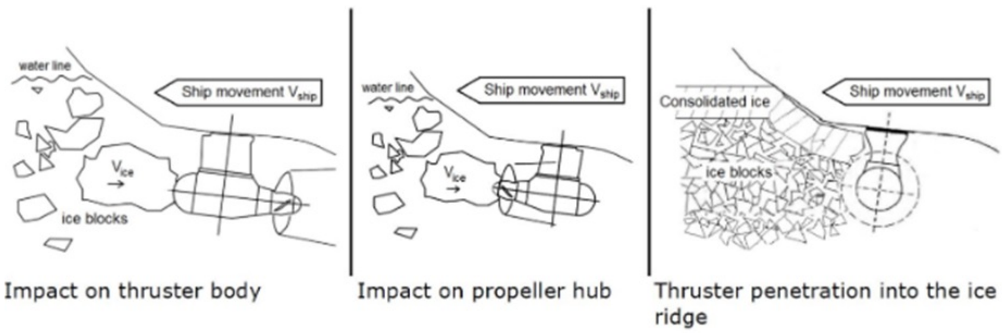
In addition to the above requirements for propeller blade dimensioning, azimuthing thrusters must be designed for thruster body/ice interaction loads. Load formulae are given for estimating once-in-a-lifetime extreme loads on the thruster body, based on the estimated ice condition and ship operational parameters. Two main ice load scenarios have been selected for defining the extreme ice loads. Examples of loads are illustrated in 6-1-4/27.11.5(a) FIGURE 15. In addition, blade order thruster body vibration responses may be estimated for propeller excitation. The following load scenario types are considered:

1) Ice block impact on the thruster body or propeller hub

2) Thruster penetration into an ice ridge that has a thick consolidated layer

3) Vibratory response of the thruster at blade order frequency

FIGURE 15
Examples of Load Scenario Types *(1 July 2019)*



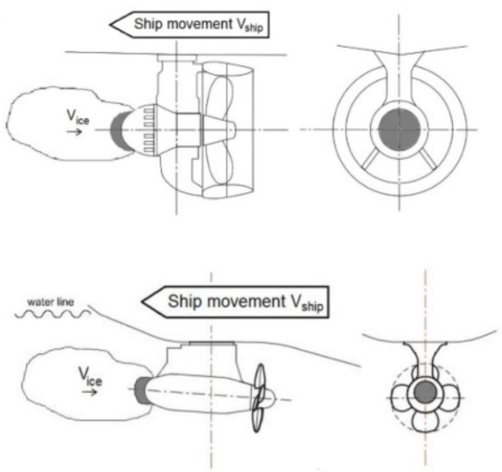
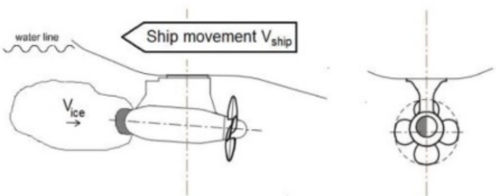
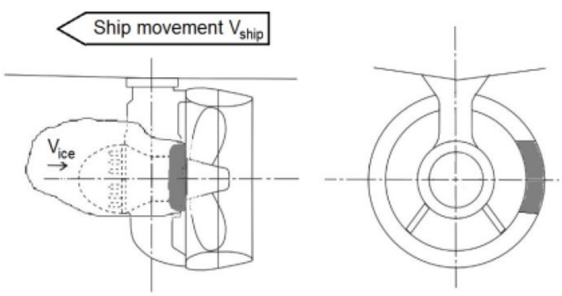
The steering mechanism, the fitting of the unit, and the body of the thruster shall be designed to withstand the plastic bending of a blade without damage. The loss of a blade must be taken into account for the propeller blade orientation causing the maximum load on the component being studied. Top-down blade orientation typically places the maximum bending loads on the thruster body.

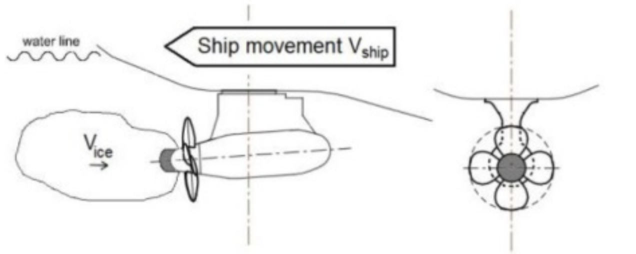
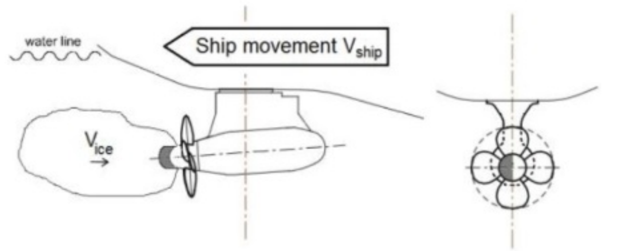
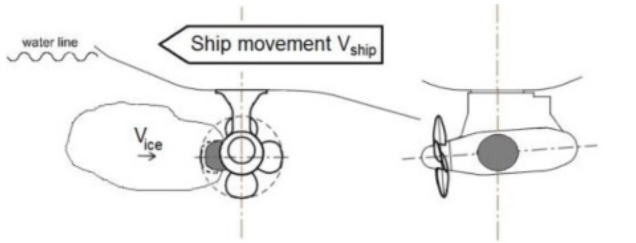
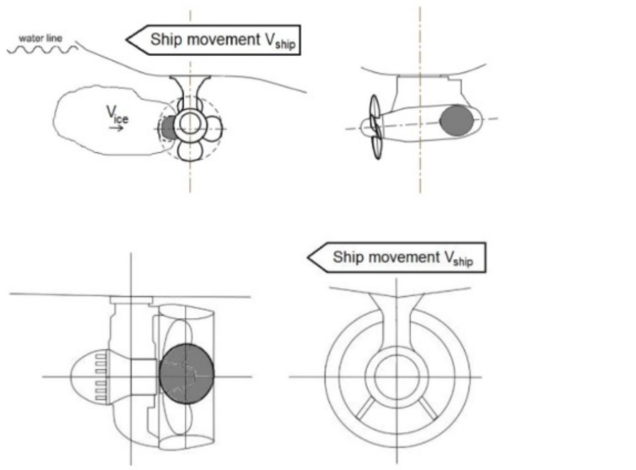
27.11.5(b) Extreme ice impact loads *(2024)*

When the ship is operated in ice conditions, ice blocks formed in channel side walls or from the ridge consolidated layer may impact on the thruster body and the propeller hub. Exposure to ice impact is very much dependent on the ship size and ship hull design, as well as the location of the thruster. The contact force will grow in terms of thruster/ice contact until the ice block reaches the ship speed.

The thruster must withstand the loads occurring when the design ice block defined in 6-1-4/27.5 TABLE 3 impacts on the thruster body when the ship is sailing at a typical ice operating speed. Load cases for impact loads are given in 6-1-4/27.11.5(b) TABLE 10. The contact geometry is estimated to be hemispherical in shape. If the actual contact geometry differs from the shape of the hemisphere, a sphere radius must be estimated so that the growth of the contact area as a function of penetration of ice corresponds as closely as possible to the actual geometrical shape penetration.

TABLE 10
Load Cases for Azimuthing Thruster Ice Impact Loads *(2024)*

	Force	*Loaded Area*	
Load case T1a Symmetric longitudinal ice impact on thruster	F_{ti}	Uniform distributed load or uniform pressure, which are applied symmetrically on the impact area.	
Load case T1b Non-symmetric longitudinal ice impact on thruster	*50% of* F_{ti}	Uniform distributed load or uniform pressure, which are applied on the other half of the impact area.	
Load case T1c Non-symmetric longitudinal ice impact on nozzle	F_{ti}	Uniform distributed load or uniform pressure, which are applied on the impact area. Contact area is equal to the nozzle thickness (H_{nz})*the contact height (H_{iced}).	

	Force	*Loaded Area*	
Load case T2a Symmetric longi-tudinal ice impact on propeller hub	F_{ti}	Uniform distributed load or uniform pressure, which are applied symmetrically on the impact area.	
Load case T2b Non-symmetric longitudinal ice impact on propeller hub	*50% of* F_{ti}	Uniform distributed load or uniform pressure, which are applied on the other half of the impact area.	
Load case T3a Symmetric lateral ice impact on thruster body	F_{ti}	Uniform distributed load or uniform pressure, which are applied symmetrically on the impact area.	
Load case T3b Non-symmetric lateral ice impact on thruster body or nozzle	F_{ti}	Uniform distributed load or uniform pressure, which are applied on the impact area. Nozzle contact radius R to be taken from the nozzle length (L_{nz}).	

The ice impact contact load must be calculated using the formula below. The related parameter values are given in 6-1-4/27.11.5(b) TABLE 11. The design operation speed in ice can be derived from 6-1-4/27.11.5(b) TABLE 12 and 6-1-4/27.11.5(b) TABLE 13, or the ship in question's actual design operation speed in ice can be used. The longitudinal impact speed in 6-1-4/27.11.5(b) TABLE 12 and 6-1-4/27.11.5(b) TABLE 13 refers to the impact in the thruster's main operational direction. For the pulling propeller configuration, the longitudinal impact speed is used for load case T2, impact on hub; and for the pushing propeller unit, the longitudinal impact speed is used for load case T1, impact on thruster end cap. For the opposite direction, the impact speed for transversal impact is applied.

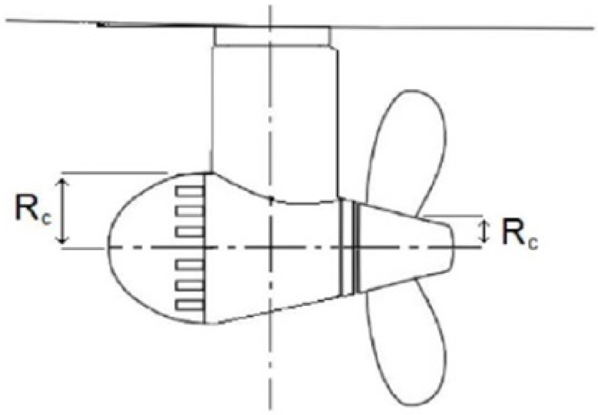
$$F_{ti} = C_{DMI}\ \ 34.5\ \ R_c{}^{0.5}\left(m_{ice} v_s{}^2\right)^{0.333} \qquad KN$$

$$F_{ti} = C_{DMI} \quad 2113.85 \quad R_c{}^{0.5} (m_{ice} v_s{}^2)^{0.333} \qquad lbf$$

where

R_c	=	impacting part sphere radius, in m (ft), see 6-1-4/27.11.5(b) FIGURE 16
m_{ice}	=	ice block mass, in kg (lbs)
v_s	=	ship speed at the time of contact, in m/s (knots)
C_{DMI}	=	dynamic magnification factor for impact loads. If unknown, it shall be taken from 6-1-4/27.11.5(b) TABLE 11

FIGURE 16
Dimensions used for R_c



For impacts on non-hemispherical areas, such as the impact on the nozzle, the equivalent impact sphere radius must be estimated using the equation below.

$$R_{ceq} = \sqrt{\frac{A}{\pi}} \qquad \text{m(ft)}$$

If the $2R_{ceq}$ is greater than the ice block design thickness H_{iced}, R_{ceq} is set to half of the ice block design thickness. This limitation is not valid for impact on the propeller hub or thruster end cap (load cases T1a and T2a). For the impact on the thruster side, the pod body diameter can be used as a basis for determining the radius R_c. For the impact on the propeller hub, the hub diameter can be used as a basis for the radius R_c.

TABLE 11
Parameter Values for Ice Dimensions and Dynamic Magnification *(2024)*

	IAA	IA	IB	IC
Thickness of the design ice block impacting thruster (H_{iced})	1.17 m 3.84 ft	1.0 m 3.28 ft	0.8 m 2.62 ft	0.67 m 2.2 ft
Extreme ice block mass (m_{ice})	8670 kg 19114 lb	5460 kg 12037 lb	2800 kg 6173 lb	1600 kg 3527 lb
C_{DMI} (if not known)	1.3	1.2	1.1	1

TABLE 12
Impact Speeds for Aft Centerline Thruster

Aft Centerline Thruster	IAA	IA	IB	IC
Longitudinal impact in main operational direction	6 m/s 11.67 knot	5 m/s 9.72 knot	5 m/s 9.72 knot	5 m/s 9.72 knot
Longitudinal impact in reversing direction (pushing unit propeller hub or pulling unit cover end cap impact)	4 m/s 7.78 knot	3 m/s 5.83 knot	3 m/s 5.83 knot	3 m/s 5.83 knot
Transversal impact in bow first operation	3 m/s 5.83 knot	2 m/s 3.89 knot	2 m/s 3.89 knot	2 m/s 3.89 knot
Transversal impact in stern first operation (double acting ship)	4 m/s 7.78 knot	3 m/s 5.83 knot	3 m/s 5.83 knot	3 m/s 5.83 knot

TABLE 13
Impact Speeds for Aft Wing, Bow Centerline and Bow Wing Thrusters

Aft Wing, Bow Centerline and Bow Wing Thruster	IAA	IA	IB	IC
Longitudinal impact in main operational direction	6 m/s 11.67 knot	5 m/s 9.72 knot	5 m/s 9.72 knot	5 m/s 9.72 knot
Longitudinal impact in reversing direction (pushing unit propeller hub or pulling unit cover end cap impact)	4 m/s 7.78 knot	3 m/s 5.83 knot	3 m/s 5.83 knot	3 m/s 5.83 knot
Transversal impact	4 m/s 7.78 knot	3 m/s 5.83 knot	3 m/s 5.83 knot	3 m/s 5.83 knot

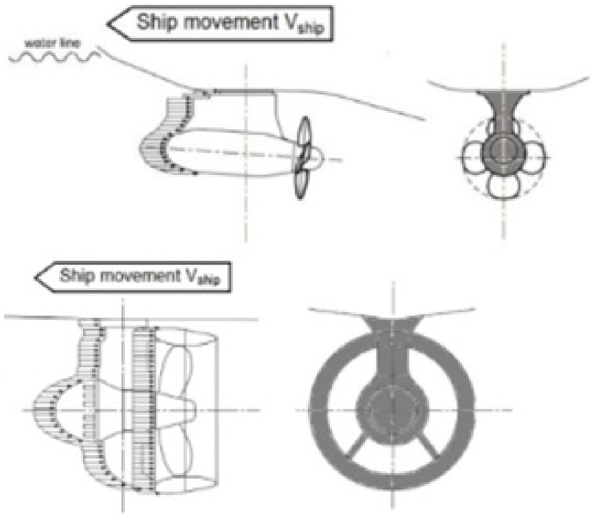
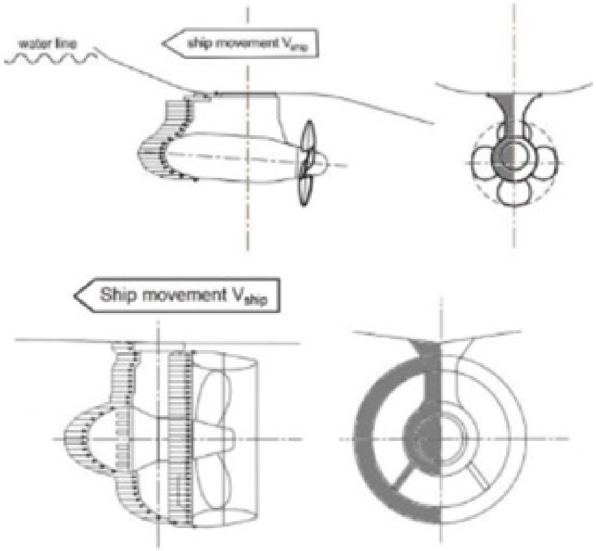
27.11.5(c) Extreme ice loads on thruster hull when penetrating an ice ridge (1 July 2019)

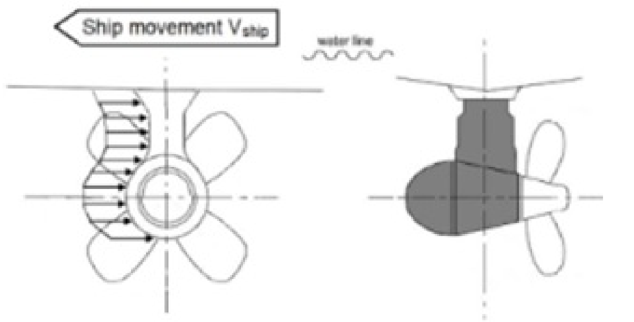
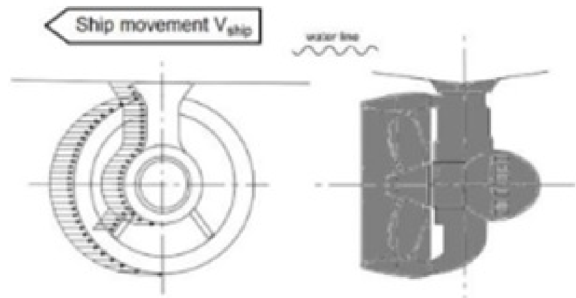
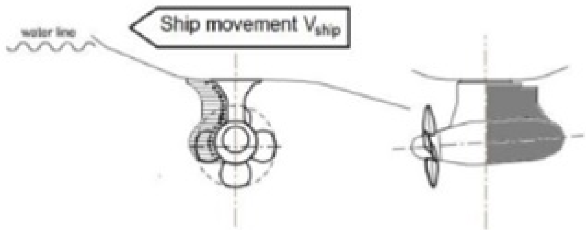
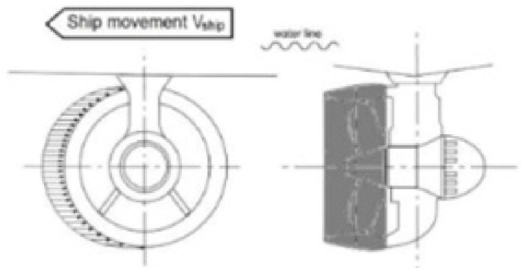
In icy conditions, ships typically operate in ice channels. When passing other ships, ships may be subject to loads caused by their thrusters penetrating ice channel walls. There is usually a consolidated layer at the ice surface, below which the ice blocks are loose. In addition, the thruster may penetrate ice ridges when backing. Such a situation is likely in the case of **IAA** ships in particular, because they may operate independently in difficult ice conditions. However, the thrusters in ships with lower ice classes may also have to withstand such a situation, but at a remarkably lower ship speed.

In this load scenario, the ship is penetrating a ridge in thruster first mode with an initial speed. This situation occurs when a ship with a thruster at the bow moves forward, or a ship with a thruster astern moves in backing mode. The maximum load during such an event is considered the extreme load. An event of this kind typically lasts several seconds, due to which the dynamic magnification is considered negligible and is not taken into account.

The load magnitude must be estimated for the load cases shown in 6-1-4/27.11.5(c) TABLE 14, using the equation after 6-1-4/27.11.5(c) TABLE 14. The parameter values for calculations are given in 6-1-4/27.11.5(c) TABLE 15 and 6-1-4/27.11.5(c) TABLE 16. The loads must be applied as uniform distributed load or uniform pressure over the thruster surface. The design operation speed in ice can be derived from 6-1-4/27.11.5(c) TABLE 15 or 6-1-4/27.11.5(c) TABLE 16. Alternatively, the actual design operation speed in ice of the ship in question can be used.

TABLE 14
Load Cases for Ridge Ice Loads

	Force	*Loaded area*	
Load case T4a Symmetric longitudinal ridge penetration loads	F_{tr}	Uniform distributed load or uniform pressure, which are applied symmetrically on the impact area.	
Load case T4b Non-symmetric longitudinal ridge penetration loads	*50% of* F_{tr}	Uniform distributed load or uniform pressure, which are applied on the other half of the contact area.	

	Force	*Loaded area*	
Load case T5a Symmetric lateral ridge penetration loads for ducted azimuthing unit and pushing open propeller unit	F_{tr}	Uniform distributed load or uniform pressure, which are applied symmetrically on the contact area.	 
Load case T5b Non-symmetric lateral ridge penetration loads for all azimuthing units	*50% of* F_{tr}	Uniform distributed load or uniform pressure, which are applied on the other half of the contact area.	 

$$F_{tr} = 32 v_s^{0.66} H_r^{0.9} A_t^{0.74} \qquad kN$$

$$F_{tr} = 274.432 v_s^{0.66} H_r^{0.9} A_t^{0.74} \qquad lbf$$

where

v_s = ship speed, in m/s (knots)

H_r = design ridge thickness (the thickness of the consolidated layer is 18% of the total ridge thickness), in m (ft)

A_t = projected area of the thruster, in m^2 (ft^2)

When calculating the contact area for thruster-ridge interaction, the loaded area in the vertical direction is limited to the ice ridge thickness, as shown in 6-1-4/27.11.5(c) FIGURE 17.

FIGURE 17
Schematic Figure Showing the Reduction of the Contact Area by the Maximum Ridge Thickness

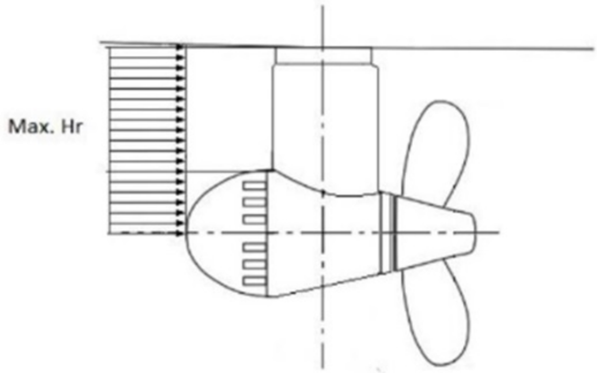


TABLE 15
Parameters for Calculating maximum Loads when the Thruster Penetrates an Ice Ridge
Aft thrusters. Bow first operation

	IAA	IA	IB	IC
Thickness of the design ridge consolidated layer	1.5 m 4.92 ft	1.5 m 4.92 ft	1.2 m 3.94 ft	1.0 m 3.28 ft
Total thickness of the design ridge, H_r	8 m 26.25 ft	8 m 26.25 ft	6.5 m 21.33 ft	5 m 16.40 ft
Initial ridge penetration speed (longitudinal loads)	4 m/s 7.78 knot	2 m/s 3.89 knot	2 m/s 3.89 knot	2 m/s 3.89 knot
Initial ridge penetration speed (transversal loads)	2 m/s 3.89 knot	1 m/s 1.94 knot	1 m/s 1.94 knot	1 m/s 1.94 knot

TABLE 16
Parameters for Calculating maximum Loads when the Thruster Penetrates an Ice Ridge
Thruster first mode such as double acting ships.

	IAA	IA	IB	IC
Thickness of the design ridge consolidated layer	1.5 m 4.92 ft	1.5 m 4.92 ft	1.2 m 3.94 ft	1.0 m 3.28 ft
Total thickness of the design ridge, H_r	8 m 26.25 ft	8 m 26.25 ft	6.5 m 21.33 ft	5 m 16.4 ft

	IAA	IA	IB	IC
Initial ridge penetration speed (longitudinal loads)	6 m/s 11.66 knot	4 m/s 7.78 knot	4 m/s 7.78 knot	4 m/s 7.78 knot
Initial ridge penetration speed (transversal loads)	3 m/s 5.83 knot	2 m/s 3.89 knot	2 m/s 3.89 knot	2 m/s 3.89 knot

27.11.5(d) Acceptability criterion for static loads *(1 July 2019)*

The stresses on the thruster must be calculated for the extreme once-in-a-lifetime loads described in 6-1-4/27.11.5. The nominal von Mises stresses on the thruster body must have a safety margin of 1.3 against the yielding strength of the material. At areas of local stress concentrations, stresses must have a safety margin of 1.0 against yielding. The slewing bearing, bolt connections and other components must be able to maintain operability without incurring damage that requires repair when subject to the loads given in 6-1-4/27.11.5(b) and 6-1-4/27.11.5(c) multiplied by a safety factor of 1.3.

27.11.5(e) Thruster body global vibration *(1 July 2019)*

Evaluating the global vibratory behavior of the thruster body is important, if the first blade order excitations are in the same frequency range with the thruster global modes of vibration, which occur when the propeller rotational speeds are in the high power range of the propulsion line. This evaluation is mandatory and it must be shown that there is either no global first blade order resonance at high operational propeller speeds (above 50% of maximum power) or that the structure is designed to withstand vibratory loads during resonance above 50% of maximum power.

When estimating thruster global natural frequencies in the longitudinal and transverse direction, the damping and added mass due to water must be taken into account. In addition to this, the effect of ship attachment stiffness must be modelled.

27.13 Alternative Design Procedure *(1 July 2019)*

27.13.1 Scope *(2024)*

As an alternative to 6-1-4/27.9 and 6-1-4/27.11, a comprehensive design study may be carried out to the satisfaction of the flag Administration. The study is to be based on ice conditions given for different ice classes in 6-1-4/27.5. It is to include both fatigue and maximum load design calculations and fulfill the pyramid strength principle, as given in 6-1-4/27.11.1.

27.13.2 Loading

Loads on the propeller blade and propulsion system shall be based on an acceptable estimation of hydrodynamic and ice loads.

27.13.3 Design Levels *(1 July 2019)*

The analysis is to indicate that all components transmitting random (occasional) forces, excluding propeller blade, are not subjected to stress levels in excess of the yield stress of the component material, with a reasonable safety margin.

Cumulative fatigue damage calculations are to indicate a reasonable safety factor. Due account is to be taken of material properties, stress raisers, and fatigue enhancements.

Vibration analysis is to be carried out and is to demonstrate that the overall dynamic system is free from harmful torsional resonances resulting from propeller/ice interaction.

28 Tunnel Thrusters - IC through IAA *(2024)*

Where **APS**, **PAS** or Dynamic Positioning Systems Notations are assigned, the mechanical components of a tunnel thruster (i.e., propellers, gears, shafts, couplings, etc.) are to meet the applicable requirements of Propulsion Systems in this Section.

Alternatively, Section 4-3-5 may be applied to the mechanical components of a tunnel thruster when a comprehensive study to determine the effect of ice is submitted for consideration.

29 Additional Ice Strengthening Requirements - IC through IAA *(2024)*

29.1 Starting Arrangements

The capacity of the air receivers required for reversible propulsion engines is to be sufficient for at least twelve consecutive starts and that for non-reversible propulsion engines is to be sufficient for six consecutive starts of each engine.

If the air receivers supply systems other than starting the propulsion engines, the additional capacity of the receivers is to be sufficient for continued operations of these systems after the capacity for the required number of consecutive engine starts has been used.

The capacity of the air compressors is to be sufficient for charging the air receivers from atmospheric to full pressure in one hour. For a vessel with **Ice Class IAA** that requires its propulsion engines to be reversed for astern operations, the compressors are to be able to charge the air receivers in half an hour.

29.3 Sea Inlet, Cooling Water Systems and Fire Main *(1 July 2019)*

The sea water system is to be designed to ensure a supply of water for the cooling water system and for at least one of the fire pumps when navigating in ice. For this purpose, at least one sea water inlet chest is to be arranged as follows.

i) The sea inlet shall be situated near the centerline of the ship and well aft, if possible.

ii) Guidance for designing the volume of the chest shall be around one cubic metre (35.3 cubic foot) for every 750 kW (1033 mhp; 1019 hp) in engine output of the ship, including the output of auxiliary engines necessary for the operation of the ship.

iii) The sea chest shall be sufficiently high to allow ice to accumulate above the inlet pipe.

iv) A pipe for discharge cooling water, allowing full capacity discharge, shall be connected to the sea chest.

v) The open area of the strainer plates shall be no less than four (4) times the inlet pipe sectional area.

Where it is impractical to meet the requirements of 6-1-4/29.3.ii and 6-1-4/29.3.iii above, two smaller sea chests may be arranged for alternating the intake and discharge of the cooling water, provided 6-1-4/29.3.i, 6-1-4/29.3.iv and 6-1-4/29.3.v above are complied with.

Heating coils, if necessary, may be installed in the upper part of the sea chest.

The use of ballast water for cooling purposes while in the ballast condition may be acceptable as an additional means but is not to be considered a permanent substitute for the above required sea inlet chest or chests.

31 Machinery - ID and IE *(2024)*

31.1 General

All machinery is to be suitable for operation under the environmental conditions to which it will be exposed in service and is to include all necessary special provisions for that purpose.

31.3 Propeller Nozzles

Propeller nozzles for **Ice Class ID** and **Ice Class IE** are accepted on a case-by-case basis based on calculations submitted per 3-2-13/9.

31.5 Sea Chests

For **Ice Class ID**, the sea water system is to be designed to provide a supply of water for the cooling water system and for at least one of the fire pumps when navigating in ice. For this purpose, at least one sea water inlet chest is to be arranged as follows:

i) The sea inlet is to be situated near the centerline of the vessel and well aft, if possible.

ii) The sea chest is to be sufficiently high to allow ice to accumulate above the inlet pipe.

iii) A pipe for discharge cooling water, allowing full capacity discharge, is to be connected to the sea chest.

31.7 Materials for Propellers and Propulsion Shafting

Propeller materials are to be in accordance with the applicable requirements of 4-3-3/3.

Shaft materials are to be in accordance with the applicable requirements of 4-3-2/3.

31.9 Propellers

31.9.1 Ice Torque

The ice torque (M) is to be calculated as follows:

$M = C_n m D^2$, in kN-m (tf-m,Ltf-ft)

where

m	=	value from 6-1-4/31.9.1 TABLE 17
D	=	propeller diameter, in m (ft)
C_n	=	nozzle coefficient
	=	1.0 for open propellers
	=	0.9 for propellers in nozzle

TABLE 17
Values of *m*

Ice Class	*SI Units*	*MKS Units*	*US Units*
ID	11.1	1.13	0.34
IE	8.8	0.90	0.27

31.9.2 Propeller Section

The thickness T and width W of propeller blade sections are to be determined so that the WT^2 calculated by the actual design W and T is not less than required by the following equations:

At 0.25 radius for solid propellers:

$$WT^2 = \left[\frac{a_1}{U(0.65 + 0.7P_{0.25})}\right]\left[\left(\frac{a_2 CN}{nR}\right) + a_3 M\right] \text{ cm}^3 \text{ (in}^3\text{)}$$

At 0.35 radius for solid propellers with hubs larger than 0.25 propeller diameter:

$$WT^2 = \left[\frac{a_4}{U(0.65 + 0.7P_{0.35})}\right]\left[\left(\frac{a_2CN}{nR}\right) + a_5M\right] \text{cm}^3 \text{ (in}^3\text{)}$$

At 0.35 radius for controllable pitch propellers:

$$WT^2 = \left[\frac{a_4}{U(0.65 + 0.49P_{nominal})}\right]\left[\left(\frac{a_2CN}{nR}\right) + a_5M\right] \text{cm}^3 \text{ (in}^3\text{)}$$

At 0.6 radius for solid propellers:

$$WT^2 = \left[\frac{a_6}{U(0.65 + 0.7P_{0.6})}\right]\left[\left(\frac{a_2CN}{nR}\right) + a_7M\right] \text{cm}^3 \text{ (in}^3\text{)}$$

at 0.6 radius for controllable pitch propellers:

$$WT^2 = \left[\frac{a_6}{U(0.65 + 0.49P_{nominal})}\right]\left[\left(\frac{a_2CN}{nR}\right) + a_7M\right] \text{cm}^3 \text{ (in}^3\text{)}$$

where

a_1 = 2650 (270, 27000)

a_2 = 272 (200,176)

a_3 = 22.4 (22, 59.134)

a_4 = 2108 (215, 21500)

a_5 = 23.5 (230, 61.822)

a_6 = 932 (95, 9500)

a_7 = 28.6 (280, 75.261)

W = expanded width of a cylindrical section at the appropriate radius, in cm (in.)

T = maximum thickness at the appropriate radius, in cm (in.)

U = tensile strength of propeller material, N/mm^2 (kgf/mm^2, psi)

P = pitch at the appropriate radius divided by the propeller diameter (for controllable pitch propellers, the nominal value of pitch is to be used)

N = total maximum continuous power delivered to the propellers, in kW (mhp, hp)

n = number of blades

R = RPM at the maximum continuous rating

M = ice torque, as defined in 6-1-4/31.9.1

C = 1 $\quad for\ N \le 7,640kW \quad (10,140hp, \quad 10,000hp)$

= $0.667 + \frac{N}{22480}$ $\quad for\ 7,460kW < N < 29.840kW$

= $0.667 + \frac{N}{30420}$ $\quad for\ 10,140mhp < N < 40,560mhp$

= $0.667 + \frac{N}{30000}$ $\quad for\ 10,000hp < N < 40,000hp$

= 2 $\quad for\ N \ge 29,840kW \quad (40,560mhp, \quad 40,000hp)$

When the blade thickness derived from the above equations is less than the required thickness detailed in 4-3-3/5.1 through 4-3-3/5.7, the latter is to be used. The thicknesses of propeller sections at radii intermediate to those specified are to be determined from fair curves connecting the required section thicknesses.

31.9.3 Blade Bolts

For built-up or controllable pitch propellers, the cross sectional area of the bolts at the root of the thread is to be determined by the following equation:

$$a = \frac{0.082UWT^2}{U_b n r}$$

where

a = area of each bolt at the root of thread, in mm^2 (in^2)

U = tensile strength of propeller material, N/mm^2 (kgf/mm^2, psi)

U_b = tensile strength of bolt material, N/mm^2 (kgf/mm^2, psi)

n = number of bolts on one side of the blade (if n is not the same on both sides of the blade, the smaller number is to be used)

r = radius of bolt pitch circle, in mm (in.)

W and T are defined in 6-1-4/31.9.2.

31.9.4 Highly Skewed Propellers

Where highly skewed propellers, as defined in 4-3-3/5.5, are utilized, stress calculations are to be submitted for review. The calculations are to consider the ice loads as defined in 6-1-4/27.9.1(a) through 6-1-4/27.9.1(f) as applicable. The blade stresses are to comply with the requirements found in 6-1-4/27.11.2(a) and 6-1-4/27.11.2(b). For the calculations the following ice thicknesses (H_{ice}) are to be used:

- **Ice Class ID**: H_{ice} = 0.75 m (2.46 ft)
- **Ice Class IE**: H_{ice} = 0.5 m (1.64 ft)

31.9.5 Friction Fitting of Propeller Hubs

Friction fitting of propeller hubs is to have a factor of safety against slip (S in 4-3-3/5.15.2(b)) of at least 2.4. Calculations are to consider both propulsion torque (Q in 4-3-3/5.15.2(b)) and ice torque (M in 6-1-4/31.9) simultaneously. Detailed stress and fitting calculations for all friction fitted components are to be submitted for review.

31.9.6 Bolted Fitting of Propeller Hubs

Bolt connections are to have at least the same bending strength as the tail shaft. The bending strength of the shaft is determined using the diameter of the shaft in way of the aft bearing.

The tail shaft flange connecting the propeller hub is to be sufficiently strengthened to withstand the yielding of the bolt(s) without yielding of the tail shaft flange or its connection to the tail shaft.

31.10 Propulsion Shaft Diameter

The diameter of the tail shaft is to be:

- Greater than or equal to the minimum tail shaft diameter determined in Section 4-3-2
- Not less than d in the following equation, but need not be greater than 1.05 times the diameter determined in Section 4-3-2.

$$d = k_o k_1 \sqrt[3]{\frac{W_a {T_a}^2 U}{Y}} \quad \text{mm} \quad (\text{in.})$$

where

d	=	diameter of the shaft being considered at the aft bearing, in mm (in.)
k_o	=	1
k_1	=	1.08 for solid propellers with hubs not larger than 0.25D
	=	1.15 for solid propellers with hubs larger than 0.25D and CPPs
W_a,T_a	=	actual values of the propeller blade expanded width and maximum thickness measured at the blade section at 0.25 radius for solid propellers with hubs not larger than 0.25D, and at 0.35 radius otherwise, mm (in.)
U	=	tensile strength of propeller material, N/mm^2 (kgf/mm^2, psi)
Y	=	yield strength of shaft steel, N/mm^2 (kgf/mm^2, psi)

33 Non-self-propelled Vessels *(2024)*

Non-self-propelled vessels designed and built to the requirements of this Section and related sections within the ABS *Rules for Building and Classing Mobile Offshore Units* or ABS *Rules for Building and Classing Steel Barges* can obtain a First Year Ice Class notation. The non-self-propelled vessel must meet the icebelt and structural requirements of this Section with c_d equal to 1 for the load calculation in 6-1-4/11.

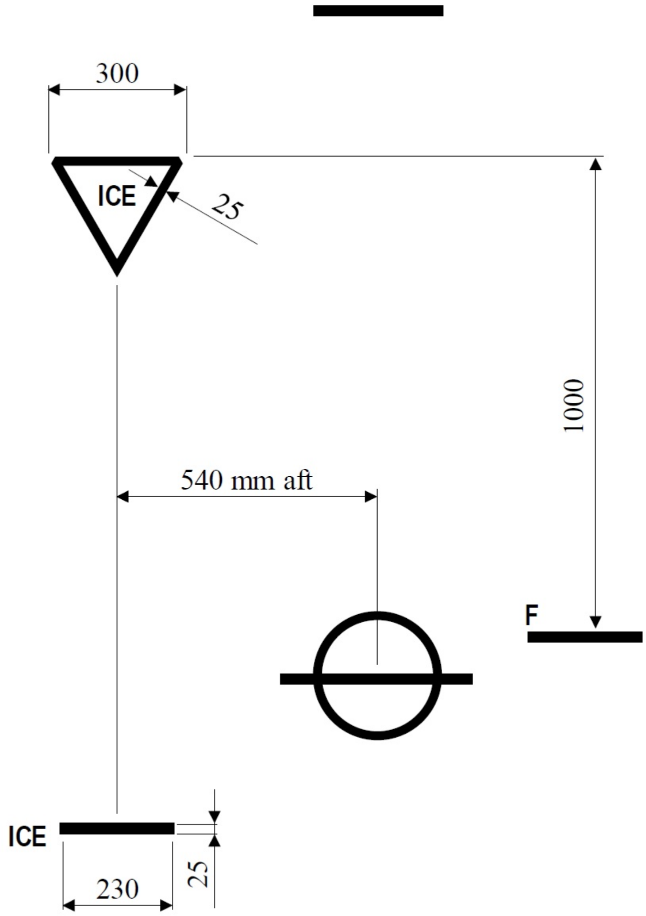
PART 6

CHAPTER 1
Strengthening for Navigation in Ice

SECTION 4
Appendix 1 - Ice Class Draft Marking

Subject to 6-1-4/7, the vessel's sides are to be provided with a warning triangle and with a draft mark at the maximum permissible ice class draft amidships (see 6-1-4-A1/ FIGURE 1). The purpose of the warning triangle is to provide information on the draft limitation of the vessel when it is sailing in ice for masters of icebreakers and for inspection personnel in ports.

FIGURE 1
Ice Class Draft Marking



Notes:

1 The upper edge of the warning triangle is to be located vertically above the "ICE" mark, 1000 mm higher than the Summer Load Line in fresh water but in no case higher than the deck line. The sides of the triangle are to be 300 mm in length.

2 The ice class draft mark is to be located 540 mm abaft the center of the load line ring or 540 mm abaft the vertical line of the timber load line mark, if applicable.

3 The marks and figures are to be cut out of 5 - 8 mm plate and then welded to the vessel's side. The marks and figures are to be painted in a red or yellow reflecting color in order to make the marks and figures plainly visible even in ice conditions.

4 The dimensions of all figures are to be the same as those used in the load line mark.

PART 6

CHAPTER 1

Strengthening for Navigation in Ice

SECTION 4

Appendix 2 - Parameters and Calculated Minimum Engine Power for Sample Ships *(1 July 2019)*

For checking the results of calculated powering requirements, the table below presents input data for a number of sample ships.

TABLE 1
Parameters and calculated minimum engine power of sample ships.

	Sample Ship No.								
	1	2	3	4	5	6	7	8	9
Ice Class	IAA	IA	IB	IC	IAA	IAA	IA	IA	IB
α, degrees	24	24	24	24	24	24	36	20	24
φ_1, degrees	90	90	90	90	30	90	30	30	90
φ_2, degrees	30	30	30	30	30	30	30	30	30
L, m (ft)	150 (492)	150 (492)	150 (492)	150 (492)	150 (492)	150 (492)	150 (492)	150 (492)	150 (492)
B, m (ft)	25 (82)	25 (82)	25 (82)	25 (82)	25 (82)	22 (72)	25 (82)	25 (82)	25 (82)
T, m (ft)	9 (29.5)	9 (29.5)	9 (29.5)	9 (29.5)	9 (29.5)	9 (29.5)	9 (29.5)	9 (29.5)	9 (29.5)
L_{BOW}, m (ft)	45 (147.6)	45 (147.6)	45 (147.6)	45 (147.6)	45 (147.6)	45 (147.6)	45 (147.6)	45 (147.6)	45 (147.6)
L_{PAR}, m (ft)	70 (229.7)	70 (229.7)	70 (229.7)	70 (229.7)	70 (229.7)	70 (229.7)	70 (229.7)	70 (229.7)	70 (229.7)
A_{wf} , m^2 (ft^2)	500 (5382)	500 (5382)	500 (5382)	500 (5382)	500 (5382)	500 (5382)	500 (5382)	500 (5382)	500 (5382)
D_P, m (ft)	5 (16.4)	5 (16.4)	5 (16.4)	5 (16.4)	5 (16.4)	5 (16.4)	5 (16.4)	5 (16.4)	5 (16.4)
Prop. No./Type	1/CP	1/CP	1/CP	1/CP	1/CP	1/CP	1/CP	1/CP	1/FP

New Ships kW (HP)	7840 (10514)	4941 (6626)	3478 (4664)	2253 (3021)	6799 (9118)	6406 (8591)	5343 (7165)	5017 (6728)	3872 (5192)
Existing Ships kW (HP)	9192 (12327)	6614 (8870)			8466 (11353)	7645 (10252)	6614 (8870)	6614 (8870)	

PART 6

CHAPTER 1
Strengthening for Navigation in Ice

SECTION 5
Requirements for Icebreaker* Notation *(2024)*

1 General

1.1 Application

Icebreakers are required to operate more aggressively in ice than most ice class cargo ships. Icebreakers often perform many different missions in varying ice conditions. Due to this increase in mission capability in varying ice conditions, icebreakers often require additional ice loads to be considered during the design, above and beyond the design loads for the specified ice class.

The optional **Icebreaker*** notation is available for designers and owners/operators requesting to further characterize the applied ice loads specifically for the icebreaker's operational profile.

The **Icebreaker*** notation is assigned to vessels where the arrangement, powering, and scantlings of the hull structure and propulsion machinery are determined based on the operational profile of the icebreaker and the corresponding ship-ice interaction scenarios.

The requirements given here for the **Icebreaker*** notation are in addition to the requirements required for an **Ice Class PC7** up to **Ice Class PC1** given in Sections 6-1-1, 6-1-2, and 6-1-3.

Where the critical ice load scenario pressures are greater than the design pressures from 6-1-2/5 for the specified ice class, the Hull Area Factors (AF) are to be scaled to match the pressures from the critical scenarios. Scantlings are to be determined using the methodology specified in 6-1-2/7 through 6-1-2/23 with the higher pressure for each hull area. For machinery, additional load cases can be developed if the scenarios indicate the propulsion system loads exceed those required by 6-1-3/9.5 or 6-1-3/9.7. Any additional load cases are to be assessed using the same acceptance criteria specified in 6-1-3/11.5.

1.3 Objective

1.3.1 Goals

The structure, machinery, systems, and equipment covered in this section are to be designed, constructed, and maintained to:

Goal No.	*Goals*
STRU 1	In the intact condition, have sufficient structural strength to withstand the environmental conditions, loading conditions, and operational loads anticipated during the design life.
PROP 1	Provide sufficient thrust/power to move or maneuver the vessel when required.

Goal No.	*Goals*
STAB 2	Have adequate subdivision and stability to provide survivability to damage or accidental conditions.
ENV 1	Prevent and minimize oil pollution due to vessel operation and accidents.
NAV 7	*To provide for safe navigation.* [while operating in an escort operation] *(Polar Code)*

The goals in the cross-referenced Rules are also to be met.

1.3.2 Functional Requirements

In order to achieve the above slated goals, the design, construction, and maintenance are to be in accordance with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
STRUCTURE (STRU)	
STRU-FR1	*Resist both global and local structural loads anticipated under the foreseen ice conditions. (POLAR Code)*
STRU-FR2	Supporting structures are to have sufficient strength to resist failure and excessive deformation associated with buckling and yielding when subjected to the loads anticipated throughout the service life.
STRU-FR3	FRP laminates are to have suitable mechanical properties (tensile strength, tensile and compressive modulus).
Propulsion, Maneuvering, Station Keeping (PROP)	
PROP-FR1	Systems and machinery are to be strengthened to maintain propulsion and steering during operations under the foreseen ice conditions.
PROP-FR2	The propeller is to be able to withstand the loads due to the foreseen ice conditions during interaction.
PROP-FR3	Cooling media inlets are to be designed and arranged to minimize or prevent ingestion of ice into the machinery that is essential for the propulsion and safety of the vessel.
PROP-FR4	The steering system is to be able to maintain steering direction under the foreseen ice conditions.
PROP-FR5	Ice loads that exceed the steering system's holding capacity are not to cause damage to the steering system and steering capability is to be quickly regained after an overload.
Power Generation & Distribution (POW)	
POW-FR1	The continuous propulsion power is sufficient for operations in the foreseen ice conditions.
Stability (STAB)	
STAB-FR1	The stability book shall consider ice accretion for all intact operating conditions.
STAB-FR2	Ballast tanks are to be protected from freezing.
Protection of Environment (ENV)	
ENV-FR1	Oil tanks are to be arranged in suitable locations to prevent and minimize oil pollution in the event of accidents.
Navigation (NAV)	

Functional Requirement No.	*Functional Requirements*
NAV-FR1	*Ships involved in operations with an icebreaker escort shall have suitable means to indicate when the ship is stopped. (Polar Code)*
Communications (COMM)	
COMM-FR1	*Suitable means of communications shall be provided when escort and convoy operations are expected. (Polar Code)*

Note:

References to the Polar Code in the table above are only to denote that the functional requirement is taken verbatim from the Polar Code. It does not indicate nor require compliance with the Polar Code.

The functional requirements covered in the cross-referenced Rules are also to be met.

1.3.3 Compliance

A vessel is considered to comply with the goals and functional requirements when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved, refer to Part 1D, Chapter 2.

3 Drawings and Plans to be Submitted *(1 July 2024)*

To obtain the optional **Icebreaker*** notation, the following are to be submitted for review:

i) Operational profile of the icebreaker (see 6-1-5/5) which is to include:

- ***a)*** The expected ice conditions for the given geographical locations and time of year. If the icebreaker will operate in different locations, the ice conditions are to be provided for all locations.
- ***b)*** Descriptions of the missions expected to be performed in the given ice conditions.
- ***c)*** For the expected ice conditions and missions, the following operating criteria is to be provided:
  - ***1)*** *Level icebreaking:* Ice thickness and vessel speed.
  - ***2)*** *Turning:* Ice type(s), concentration(s), ice floe size(s), ice thickness, turning diameter, and vessel speed.
  - ***3)*** *Ice ramming:* Ridge/ice type, ridge/ice characteristics (keel and sail height, multi-year or first year ridge, etc.), vessel speed (ahead and astern).
- ***d)*** Supporting data for the environmental conditions used in the operational profile.

ii) Ice load scenarios (see 6-1-5/7) based on the operational profile. The ice load scenarios are to include:

- ***a)*** The hull areas that will be loaded for each mission profile and the expected ice conditions. A description and reasoning is to be provided for the hull area divisions, along with supporting sketches of the ice load scenarios.
- ***b)*** The calculation methodology for developing the ice loads for the expected ice conditions. All supporting calculations and documentation is to be provided, including ice properties used in the calculation. The maximum expected ice conditions should be explicitly stated.
- ***c)*** Where the calculated loads (and pressures) differ from the design ice loads in 6-1-2/5, justification is to be provided.

iii) A summary of the critical scenarios for each hull area with associated ice loads and pressures (see6-1-5/7).

iv) Shell and framing expansion that clearly defines the hull areas.

v) Propulsion arrangement details and powering assessments proving sufficient ice going capability to achieve the missions stated in the operational profile.

5 Operational Profile

The operational profile is to be determined for the icebreaker and outlined in a report. The operational profile is to include the icebreaker mission profile(s) (research, low draft icebreaking, escort, ice management, etc.) and the environmental conditions for each mission.

For the mission definition, a range of speeds and maneuvering characteristics is to be provided.

For the environmental conditions, the range of expected ice thicknesses and type (first year or old sea ice, freshwater ice, etc.), ice characteristics (pressured ice, snow cover, etc.), and time of year are to be provided.

Commentary:

The data used to determine the environmental conditions should be submitted.

End of Commentary

The vessel's level icebreaking, turning, and ridge ramming capability is to be outlined in the operational profile document. The operational profile document is to be placed on board the vessel.

7 Ice Load Scenarios

For each mission profile, a series of scenarios that may lead to loading on each area of the hull is to be developed and documented. All mission profiles and all loading scenarios are to be assessed to determine the critical scenario for each hull area.

The hull areas may be defined at the discretion of the designer and owner/operator but justification is to be provided. At a minimum, each hull area outlined in 6-1-2/5.13 TABLE 4 or 6-1-2/5.13 TABLE 5 is to be used, depending on the operational profile of the vessel.

Note:

There are many different ice load calculation methodologies including empirical methods, model test data, and full scale trials data. For each mission and hull area the load calculation methodology is to be provided, including any calculations and supporting documentation. Where these loads differ from those in 6-1-2/5 justification is to be provided.

A summary table of the ice load scenarios is to be provided for each hull area for all missions. An example table of ice load scenarios with expected ice conditions is provided in 6-1-5/7 TABLE 1. The critical scenario for each hull area is the scenario that results in the highest load to that area.

The ice load scenario document is to be placed on board the vessel.

Commentary:

6-1-5/7 TABLE 1 assumes the hull areas for a vessel that will operate ahead only for simplicity. Vessels that will operate astern in ice should consider the stern intermediate hull areas. "MY" is multi-year ice.

End of Commentary

TABLE 1
Example Summary Table of Ice Load Scenarios *(1 July 2024)*

Scenario	*Primary Function/ Description*	*Loads on the Polar Class Hull Areas*									
		Bow	*Bow Intermediate*			*Midbody*			*Stern*		
		All	*Icebelt*	*Lower*	*Bottom*	*Icebelt*	Lower	Bottom	Icebelt	Lower	*Bottom*
1	Search and Rescue/High speed transit	XX knots contact with MY floe	XX knots contact with MY floe	-	-	-	-	-	-	-	-
2	Support/ Breaking through ridged shear zone (back & ram)	Rammin g impact with MY inclusio ns XX knots	Rammin g impact with MY inclusio ns XX knots	Riding up on ice	Riding up on ice	Shear creates impacts, assume MY floes speed of current ~ X knots	-	-	Possible MY floe impacts when backing, X knots	-	-
3	Escort/ Backing	-	-	-	-	-	-	-	Slow to medium speed impacts with brash ice (X knots)	Slow to medium speed impacts with brash ice (X knots)	Ice driven down by propulsi on, buoyant force (X knots)
4	Support/ Passing through Ridge astern	-	-	-	-	-	-	-	Slow speed milling through ridge (X knots)	Slow speed milling through ridge (X knots)	Slow speed milling through ridge (X knots)
5	Research or Support/ Quick turning using Azimuthing Propulsion	-	-	-	-	Transver se impact with MY floe Lateral speed X knots	Ice sliding down hull	-	Transver se impact with MY floe Lateral speed X knots	Ice sliding down hull	-

9 General Arangement *(1 July 2024)*

Oil fuel tanks, oil tanks, oil residue tanks, oily bilge water tanks, or tanks that will hold hazardous materials are to be internal of the inner shell and double bottom. The distance between the outer and inner shell or double bottom is not to be less than 0.76 m (2.49 ft).

Commentary:

Special consideration should be given to the arrangement and location of tanks. When possible, void tanks should be used between the inner and outer shell for the sides and the outer shell and tank top for the double bottom. Double bottom depth and double side tanks in way of complex hullform or on icebreakers $L < 61$ m (200 ft) may be reduced with justification that the reduction is necessary and unavoidable.

End of Commentary

Commentary:

The hull angles and hullform adopted are at the discretion of the designers and owner/operator, but in general the stem angle (γ in 6-1-2/5.5 FIGURE 2) is not to be greater than 45°, and the waterline angle at the bow (α in 6-1-2/5.5 FIGURE 2) is not to be greater than 40°. α and γ angles exceeding these values should be justified with supporting calculations.

The hull angles (waterline angle, frame angle, buttock angle) are key to performing efficient icebreaking and reducing the ice forces (and pressures). Having a near vertical buttock/stem angle will cause the vessel to break the ice in mostly crushing failure which requires significantly more force than breaking the ice in flexural failure. Similarly, the vessel needs appropriate waterline and frame angles to allow for efficient clearing away of ice from the hull after it has been broken into smaller cusps.

For icebreakers intended to extensively operate in old ice, the icebreaker's mass should be considered.

The use of skegs near the bottom in the bow area or an acceptable alternative are recommended to prevent the bow from riding up too far on ice and/or causing the stern to become submerged. Applying this recommendation should consider the size of the vessel and the hull form. For example, a very large vessel may have too much mass for the ice to support it, and therefore, a skeg is not necessary.

Ice knives should be fitted to protect rudders. Skegs and ice knives where forming part of the hull's watertight envelope should meet the minimum requirements for the given Polar Class hull area or the scenario ice loads, whichever is greater.

End of Commentary

If a transom stern is used, the lower extent is not to go below the upper ice waterline. The scantlings of the transom structures are to comply with the stern area requirements and the applied ice class notation in 6-1-2/7 through 6-1-2/23.

Commentary:

If possible, transom sterns should not be fitted to icebreakers as they can hinder backing in ice.

End of Commentary

11 Structure

Where the critical ice load scenario pressures are greater than the design pressures from 6-1-2/5 for the specified ice class, the Hull Area Factors (AF) are to be scaled to match the pressures from the critical scenarios. Scantlings are to be determined using the methodology specified in 6-1-2/7 through 6-1-2/23 with the higher pressure for each hull area. The pressures applied for the design are to be documented in the ice loads scenario document.

Commentary:

The Polar Class rules use a uniform pressure with a rectangular patch (of specific aspect ratio) for all scantling calculations. The Polar Class rules have been developed with the pressure and patch dimension assumptions and are not easily modified for different ice pressures and patch shapes/sizes.

End of Commentary

The Icebreaker's longitudinal strength is to be assessed using the requirements in 6-1-2/23.9 with $\eta = 0.6$.

13 Machinery

Vessels with the **Icebreaker*** notation are to have sufficient propulsion means to satisfy the speeds in ice specified for the operational profile. The method used to determine the power is to be provided, including any calculations or supporting documents.

Commentary:

There are no minimum powering requirements in the Polar Class rules. It is up to the designer and owner/operator that the vessel has sufficient powering for the hullform in the expected ice and environmental conditions to be able to perform the anticipated mission(s). As with the ice loads, there are many ways to calculate the required propulsion power for the ship including empirical methods, model testing, full scale data from similar ships, or other engineering methods.

Ice interactions with the propeller can cause high loads on the propulsion system that begin and end quickly. The propulsion system design should consider these rapid on and off load cycles with regards to over-speeding, excess torque, overloading, and overheating.

Due to frequent independent operations in remote areas with harsh conditions, it is suggested that Icebreakers have one of the ABS redundancy notations.

End of Commentary

The Polar Class Rules (Section 6-1-3) have several strength and fatigue requirements for the propellers and shafting. These loads are primarily based on the 5 load cases for propeller blades, as well as the blade failure load. The load case areas and loads are defined in 6-1-3/9.5 and 6-1-3/9.7, depending on the propulsion arrangement. These loads cases are to be complied with for the selected ice class. Additional load cases can be developed and submitted if the scenarios indicate the propulsion system loads exceed those required by 6-1-3/9.5 and 6-1-3/9.7. Any additional load cases are to be assessed using the same acceptance criteria specified in 6-1-3/11.5.

Azimuthing propulsors are to meet the requirements of 6-1-3/11.3. See the ABS *Guidance Notes on Ice Load for Azimuthing Propulsors* for developing the ice loads for the azimuthing propulsor bodies and nozzles, if applicable.

15 Steering Systems

Steering systems are to meet the requirements in 6-1-3/23. The design speed used for the rudder holding torque is to be increased where the operational profile for the vessel specifies higher speeds. Assumed turning speeds for relief arrangements are to be in accordance with operational profile but in no case less than the values required in 6-1-3/23.

17 Towing *(1 July 2024)*

For icebreakers intended to provide close tow, escort arrangements for towing are to be provided, including a notch shape in the stern and provision of two chock pipes and two bitts and/or a constant tension towing winch.

Commentary:

Consideration should be given for stern plating and framing to be strengthened to withstand impact loads from escorted ship collisions, as well as the propulsion and steering gear layout and protection from contact with bulbous bows.

End of Commentary

19 Outfitting

Where the liquid in a tank or system is required to remain in a liquid state, the tank or system is to be protected from freezing.

Seawater intakes are to be designed or arranged to prevent blockage by ice ingestion. The seawater intakes are to be fitted with arrangements to enable the crew to clear blockages due to ice ingestion. A recirculation system which provides hot water or steam to the sea chests/bays to prevent the water from freezing may be used.

Commentary:

Icebreakers inherently work in cold air temperature environments. Tanks may freeze if they are not located sufficiently inboard, or if the tank is not equipped with heating elements, agitators, or other means for heating or preventing freezing. Open working decks can cause the crew to become cold and require frequent breaks for warming. Workspaces and decks should be enclosed when possible. For winterization notations and guidance, see the ABS *Guide on Low Temperature Environments*.

Sea chests/bays often become clogged with ice or freeze for icebreaking vessels, which can lead to overheating of the propulsion machinery and potentially lead to a loss of power and steering. Sea chests should be located towards the centerline, ideally in way of the midbody bottom hull area when possible. See the ABS *Guide on Low Temperature Environments* for more information.

End of Commentary

Ice accretion conditions are to be included in the vessel's intact stability if the vessel is intended to operate in an area and time where ice accretion is expected to occur. Means to enable the crew to remove ice accretion is to be provided, and procedures are to be developed for application of the means to remove ice accretion.

Commentary:

Ice accretion conditions in the damage condition should also be considered.

End of Commentary

Vessels assigned the **Icebreaker*** notation and fitted with a heeling system are to be arranged such that when at a draft aligning with the upper ice waterline, the deck edge does not become immersed at an angle of 15° or the maximum achievable heel angle of the system plus 5°, whichever is greater.

If the icebreaker is expected to perform escort operations, the vessel is to be equipped with a manually initiated flashing red light visible from astern to indicate when the ship is stopped. This light is to have a range of visibility of at least two nautical miles, and the horizontal and vertical arcs of visibility are to conform to the stern light specifications required by the International Regulations for Preventing Collisions at Sea.

If the icebreaker is expected to perform escort operations, the vessel is to be equipped with a sound signalling system mounted to face astern to indicate escort and emergency manoeuvres to following ships as described in the International Code of Signals.

If abandonment onto ice is a planned abandonment scenario, the vessel is to have arrangements for evacuation and survival on the ice. Procedures to use these arrangements and enable survival are to be provided on board the vessel.

PART 6

CHAPTER 2

Vessels Intended to Carry Refrigerated Cargoes

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PART 6

CHAPTER 2
Vessels Intended to Carry Refrigerated Cargoes

SECTION 1
General

Note: Text in *italics* is considered necessary as conditions of classification (i.e., compulsory requirements). (See 6-2-1/5.3.)

1 Classification

For details of the scope and condition of classification refer to Part 1A, Chapter 1. However, for cargo or container vessels carrying refrigerated cargo, when specific notation related to this capability is requested by the Owners or builders, the following requirements will also apply.

1.1 Objective *(2024)*

The goals and functional requirements for the topics covered in this chapter are included in the respective sections.

3 Cross-references

Where necessary, applicable requirements in the ABS *Rules for Building and Classing Marine Vessels* have been cross-referenced. For integrated cargo and ballast systems for refrigerated edible bulk liquid tankers, see requirements in 5C-2-3/33.

5 Application

5.1

The requirements of this Chapter are applicable to steel vessels intended to carry refrigerated cargoes such as fruits, vegetables, meat, fish, or other perishable goods in the hold spaces or in the case of edible bulk liquids, in cargo tanks, under controlled temperature conditions and where fitted, also at controlled atmosphere. These vessels, except in the case of the refrigerated edible bulk liquid tankers, may carry cargoes in bulk, break bulk or palletized in the hold spaces or in refrigerated containers of porthole or plug-in types.

5.3

There are a number of requirements in this Chapter which relate to the safety of the vessel and personnel on board and therefore, regardless of the notations referred to in 6-2-1/7, are considered necessary as conditions of classification (i.e., compulsory requirements). These requirements, which are shown in Arial italics, are to be applied for all vessels intended to carry refrigerated cargoes.

5.5

The requirements of this Chapter are applicable to those features that are permanent in nature and can be verified by plan review, calculations, physical survey or other appropriate means.

5.7

The requirements of this Chapter are not applicable to the refrigeration system for a liquefied gas carrier, nor to air conditioning systems or refrigeration systems for provision storage.

7 Class Notations

7.1 Vessels Built Under Survey *(2024)*

Vessels intended for the carriage of refrigerated cargoes, which comply with the requirements of the Rules, and which have been constructed, at the request of the Owners, under survey by the Surveyors, will be distinguished in the *Record* by one of the following optional notations, as appropriate, followed by the date of survey.

✠ **RCC**	Refrigerated Cargo Carrier
✠ **RC(Hold No.)**	Refrigerated Cargo Carrier -Some Holds Only
✠ **RCCC**	Refrigerated Cargo Container Carrier
✠ **IRCC**	Integral Refrigerated Container Carrier
✠ **REBLT**	Refrigerated Edible Bulk Liquid Tankers
✠ **RFC**	Refrigerated Fish Carrier

7.1.1 Vessels Carrying Cargo in Refrigerated Holds, ✠ RCC

Where cargo is carried in refrigerated holds, the *Record* will give the number and state the capacity of the insulated cargo spaces which have been examined, the character of the insulation, a description of the refrigeration machinery and the associated system, the minimum design temperature of each zone attainable with the maximum design ambient and sea water temperature.

The conditions specified in the *Record* will be subject to verification by testing in the presence of Surveyors.

7.1.2 Vessels Carrying refrigerated Cargo in Some of the Cargo Hold(s), ✠ RC(Hold Number(s))

Where there are facilities provided on board the vessel for carriage of refrigerated cargo in some of the cargo hold(s), the *Record* will give the refrigerated cargo hold number(s), the capacity and the characteristics of the insulation, description of the refrigeration machinery and the minimum design temperature attainable with the maximum design ambient and sea water temperatures.

The conditions specified in the *Record* are subject to verification by testing in the presence of Surveyors.

7.1.3 Vessels Carrying Cargo in Refrigerated Containers of Porthole Type, ✠ RCCC

Where cargo is carried in refrigerated containers, individually cooled by the shipboard refrigerated machinery and the associated systems and, where fitted, the associated temperature monitoring and control system, the *Record* will give the number and average design thermal characteristics of the containers, description of the refrigeration machinery and the distribution system for refrigerating the individual containers (porthole type only).

The conditions specified in the *Record* are subject to verification by testing in the presence of Surveyors.

7.1.4 Vessels Carrying Cargo in Refrigerated Containers of Integral Type, ✠ IRCC *(2023)*

Where cargo is carried in refrigerated containers of plug-in or integral types which has its own individually mounted refrigeration machinery, hence requiring shipboard electrical power supply and in some cases the cooling water supply for the condensers and, where fitted, the associated temperature monitoring and control system, the *Record* will give the total number of refrigerated containers on board, the total design load in kW and the type of temperature monitoring and control system installed.

The conditions specified in the *Record* are subject to verification by testing in the presence of Surveyors.

In addition to the requirements of these Rules, compliance with the ABS *Guide for Carriage of Integral Refrigerated Containers On Board Ships* is required to receive the ✠ **IRCC-SP xxx/xx** notation.

7.1.5 Vessels Carrying Edible Liquids in Bulk in Refrigerated Cargo Tanks, ✠ REBLT

Where edible products are carried in bulk in refrigerated cargo tanks cooled by their own shipboard refrigeration machinery and the associated system, the *Record* will give the cubic capacity and the maximum design pressure of the cargo tanks, the minimum permissible design temperature of the cargo, a description of the refrigeration machinery, the maximum design ambient and sea water temperatures.

The conditions specified in the *Record* will be subject to validation by testing in the presence of Surveyors prior to issuance of the certificate.

7.1.6 Vessels Carrying Fish in the Refrigerated Cargo Holds, ✠ RFC

Where fish processing or fish storage vessels are provided with facilities for chilling, cooling, or freezing and/or storage in the refrigerated cargo holds cooled by their own shipboard refrigeration machinery and the associated system, the *Record* will give the number and state capacity of the insulated cargo spaces which have been examined, the character of the insulation, a description of the refrigeration machinery and the associated system, the minimum design temperature of each space attainable with the maximum design ambient and sea water temperature.

The conditions specified in the *Record* will be subject to verification by testing in the presence of Surveyors.

7.3 Vessels Not Built Under Survey

Vessels intended for the carriage of refrigerated cargoes, which have not been constructed under survey by the Surveyors, but which have been subsequently surveyed at the request of the Owners, satisfactorily reported upon by the Surveyor, and which comply with the requirements of this Chapter, will be distinguished in the *Record* by one of the notations listed in 6-2-1/7.1, as appropriate, but the mark ✠ signifying survey during construction will be omitted.

7.5 RMC Notation for Existing vessels

Existing vessels intended for the carriage of refrigerated cargoes, which have not been constructed and installed under ABS Survey, and which do not fully meet the requirements in this Chapter, but which are submitted for classification, will be subject to special classification survey. The refrigerated cargo holds and refrigeration machinery of such vessels are to comply with Part 4, Section 12 of the *Rules for Building and Classing Steel Vessels* (1997 edition). Where found satisfactory and thereafter approved by the Committee, they will be classed and distinguished in the *Record* by symbol **RMC** .

9 Supplemental Optional Notations *(2024)*

9.1 Controlled Atmosphere, ✠ CA *(2024)*

At the request of the Owner or the builder, refrigerated cargo vessels fitted with equipment and systems including the associated safety features which have been constructed and installed for compliance with the requirements of Section 6-2-12 will be distinguished in the ABS *Record* with the notation ✠ **CA** (date of survey).

9.3 Controlled Atmosphere Installation, ✠ CA (INST) *(2024)*

At the request of the Owners or builders, refrigerated cargo vessels fitted with a permanently installed piping system and the associated safety features and which is ready for connection to the portable controlled atmosphere generating equipment which has been constructed and installed for compliance with the requirements of Section 6-2-12 will be distinguished in the ABS *Record* with the notation ✠ **CA (INST)**.

9.5 Fruit Carrier, (F)

At the request of the Owner or the builder, refrigerated cargo or container vessels intended for the carriage of fruit which have been constructed and installed in compliance with the applicable requirements will be distinguished in the *Record* **(F)**.

11 Alternative Designs

11.1

Equipment designed and constructed to alternative national or international standards to those referred to in the Rules will be considered for acceptance based on the requirements of 1A-1-4/7 of the ABS *Rules for Conditions of Classification (Part 1A)*.

11.3 *(2024)*

Where the design of the installation contains new features which have not been addressed in the Rules, these are subject to ABS technical assessment and approval upon receipt of the details such as drawings, data, calculations and, where considered necessary, analysis.

11.5

Refrigerants other than those mentioned in the Rules may be used provided they are considered to be adequate for use in shipboard applications in accordance with national or international standards, international treaties adopted by the government(s) and the flag states or other similar legislation laid down by the flag state.

For the purpose of class, details such as the chemical properties, toxicity, flammability, together with the supporting data are to be submitted for review.

13 Definitions *(2024)*

13.1 Direct Expansion

A refrigeration system, in which the refrigerant expansion occurs through the direct absorption of heat from the primary medium to be cooled.

13.3 Indirect Expansion

A refrigeration system in which a secondary coolant is cooled by the direct expansion of a primary refrigerant and is then circulated to cool the medium which absorbs heat from the space to be cooled.

13.5 Refrigerant

The fluid used for heat transfer in a refrigeration system, which absorbs heat at a low temperature and low pressure of the fluid and rejects heat at a higher temperature and higher pressure of the fluid, usually involving a change of state of the fluid during the process.

13.7 Secondary Coolant

A liquid used for the transmission of heat, without a change of state, and having either no flash point or a flash point above 66°C (150°F).

13.9 Brine

Brine is a term given to secondary coolants which are water solutions of calcium chloride, sodium chloride and magnesium chloride.

13.11 Refrigerating Machinery Spaces

Refrigerating Machinery Spaces are spaces dedicated for housing refrigerating machinery and the associated equipment.

13.13 Refrigeration Unit

A *Refrigeration Unit* is the machinery comprising the compressor, the compressor's driving motor, and a condenser, if fitted, independent of any other refrigeration machinery for provision stores or the air conditioning plant. In indirect refrigeration systems the refrigeration unit also includes a brine or other secondary coolant cooler.

13.15 Refrigeration System

A *Refrigeration System* comprises one or more refrigeration units, together with the piping and ducting system as well as the equipment necessary for cooling the cargo and maintaining it at the required temperature.

13.17 Refrigerated Container

A portable container designed and constructed to a recognized international standard and primarily intended for carrying refrigerated cargo, and which is adequately insulated to reduce heat loss through the boundary walls and made air tight through effective seals.

There are two types of refrigerated containers referred to in this Chapter:

13.17.1 Port Hole Containers

The refrigerated containers where the cargo contained therein is cooled by cold air circulated by the vessel's refrigeration system through flexible connections.

13.17.2 Integrated or Plug-in Containers

The refrigerated containers which are fitted with an individual refrigeration unit either permanently installed or portable and requiring an electrical power supply, and where necessary a cooling water supply from the vessel.

13.19 Controlled Atmosphere

For purposes of the Rules, a *Controlled Atmosphere* is where the oxygen concentration in the cargo space is reduced and the CO_2 concentration adjusted to the required levels by the introduction of high purity nitrogen or other suitable gas. The oxygen and CO_2 concentrations within the cargo space are then monitored and controlled throughout the loaded voyage.

13.21 Refrigerated Edible Bulk Liquid Tankers

Tankers carrying refrigerated edible bulk liquid which is required to be maintained at a pre-specified temperature by means of the refrigeration system fitted on board the vessel.

13.23 Cargo Containment System

The *Cargo Containment System* for the carriage of edible bulk liquid cargoes referred to in 6-2-14/7 may consist of cargo tanks as below:

13.23.1 Integral Tanks

Integral Tanks mean a cargo containment envelope which forms part of ship's hull structure and which may be stressed in the manner and by the same loads which stress the contiguous hull structure and which is normally essential to the structural completeness of the ship's hull.

13.23.2 Independent Tank

An *Independent Tank* means a cargo containment envelope which is not contiguous with, or part of, the hull structure.

13.23.3 Gravity Tank

Gravity Tank means a tank having a design pressure not greater than 0.7 bar gauge at the top of the tank. A gravity tank may be an independent or integral tank.

13.23.4 Pressure Tank

Pressure Tank means a tank having a design pressure greater than 0.7 bar gauge. A pressure tank is to be an independent tank.

13.25 Refrigerated Fish Carrier

Fish processing vessels, fishing vessels, and mother ships of fishing fleet which are provided with facilities for freezing fish and fish products.

PART 6

CHAPTER 2
Vessels Intended to Carry Refrigerated Cargoes

SECTION 2
Plans and Data to be Submitted *(2024)*

The following plans and data are to be submitted:

R: Documents to be reviewed

I: Documentation for information and verification for consistency with related review

1 Hull Construction Drawings *(2024)*

General Arrangement **(R)**

Capacity Plan **(I)**

Midship Section **(R)**

Framing Plan **(R)**

Scantling profile and decks **(R)**

Bottom Construction, floors, girders, etc. **(R)**

Inner bottom plating **(R)**

Shell expansion **(R)**

Deck plans **(R)**

Pillars and girders **(R)**

Watertight and deep tank bulkheads **(R)**

Miscellaneous non-tight bulkheads used as structural supports **(R)**

Shaft tunnel **(R)**

Machinery casings, engine and main auxiliary foundations **(R)**

Fore end construction **(R)**

Aft end construction **(R)**

Stern Frame and rudder **(R)**

Shaft struts **(R)**

Superstructures and deckhouses and their closing appliances **(R)**

Hatches and hatch closing arrangements **(R)**

Side Shell Door - Construction and locking and sealing arrangements **(R)**

Ventilation systems on weather decks **(R)**

Anchor handling arrangements **(R)**

Foundation structure for cranes and other lifting devices **(R)**

Plan of hull showing steel grades **(R)**

Cargo securing manual **(R)**

For stability review:

- Lines and body plan **(I)**
- Hydrostatic curves **(R)**
- Cross curves **(R)**
- Stability information **(R)**

Additional plans for container ships

- Stowage arrangement of containers including stacking loads **(R)**
- Location of container supports and their connection to hull **(R)**

3 Refrigerated Cargo Spaces *(2024)*

Details of insulation installation including density, *K* factor, etc. **(R)**

Details of the fixing arrangements for the load bearing supports of the insulation and linings, and of all other insulation support fittings embedded by the insulation **(R)**

Details of the weld designs for the attachment of the fittings to the ship's structure **(R)**

Proposed arrangements for fixing insulation to the ship's structure **(R)**

Details of the fasteners used for supporting pipework embedded in insulation **(R)**

Cargo space heating arrangements (where fitted) **(R)**

Corrosion protection of the steel structure **(R)**

Temperature gradient calculations **(I)**

5 Refrigeration System and Refrigeration Machinery Spaces *(2024)*

Design pressure and temperature of the refrigeration system **(R)**

Details of the refrigerant and secondary coolant **(I)**

Heat-load calculations and refrigeration capacity, including rate of ventilation of the cargo spaces, where applicable **(I)**

Details of the compressors, prime-mover drive, condensers, receivers, pumps, thermostatic expansion valves, oil recovery equipment, filters and dryers, evaporators and other pressure vessels and heat exchangers **(R)**

Piping diagrams of refrigerant, brine and condenser cooling system **(R)**

Details of the air-coolers, including corrosion protection **(R)**

General arrangement of refrigeration units, indicating location **(I)**

Ventilation details of refrigeration machinery spaces, including ventilation rates **(R)**

Capacity calculations for all the pressure vessel safety relief valves **(R)**

Details of the safety relief devices discharge piping, including design calculations **(R)**

Corrosion protection of the refrigerant and brine pipes **(R)**

Cargo hold defrosting arrangements **(I)**

Drainage and bilge pumping arrangements **(R)**

Location and types of portable fire extinguishers **(R)**

Additional plans and data for the Ammonia refrigeration system:

- Access arrangement to the refrigeration machinery spaces **(R)**
- Details of the emergency ventilation system **(R)**
- Details of the emergency drainage system **(R)**
- Details of the sprinkler system and water screen devices **(R)**
- Fixed ammonia detection system **(R)**
- Details of the personnel safety equipment **(R)**

7 Electrical Systems *(2024)*

Electrical one line wiring diagram for refrigeration machinery **(R)**

Power supply and distribution **(R)**

Arrangements of electrical equipment and cable way in refrigerating machinery spaces and refrigerated cargo holds including cable penetrations of insulated bulkheads and decks **(R)**

Arrangements of thermometers in refrigerated cargo spaces **(R)**

Heat tracing arrangements, where fitted **(I)**

9 Instrumentation, Control and Monitoring Systems *(2024)*

Control and monitoring panels for refrigerating machinery including schematic diagrams, function description, construction plans and outline view **(R)**

Operational description of automatic or remote control and monitoring systems including a list of alarms and displays **(R)**

Computer based systems are to include a block diagram showing system configuration including interface, description of hardware specifications, fail safe features and power supply **(R)**

Control and monitoring **(R)**

Temperature measuring system **(R)**

Refrigerant leakage detection and alarm system **(R)**

O_2 and CO_2 content measuring system **(R)**

Ammonia vapor detection and alarm system **(R)**

11 Cargo Handling Equipment

11.1 Lifting Appliances *(2024)*

Where certification is requested, the drawing submittal is to be in accordance with the ABS *Guide for Certification of Lifting Appliances*.

13 <No Text>

15 Refrigerated Porthole Cargo Container System *(2024)*

Number and overall heat transfer rates of insulated cargo containers to be individually cooled by shipboard refrigeration system **(I)**

Space heating arrangements for cargo cells **(R)**

Details of the air ducting **(I)**

Air circulation rates **(R)**

Details of the flexible coupling, together with means of actuation **(R)**

17 Refrigerated Integral Cargo Container System *(2024)*

Cooling water arrangements **(R)**

Air freshening (ventilation) arrangements for cargo cells **(I)**

19 Controlled Atmosphere *(2024)*

Capacity calculation for the Nitrogen plant **(I)**

Arrangements for controlling the CO_2 in cargo hold **(R)**

Details of CO_2 and Ethylene scrubber **(R)**

Details of compressors and prime-movers **(R)**

Details of the pressure vessels and heat exchangers **(R)**

General arrangement of Nitrogen generation plant, indicating location and access **(R)**

Ventilation details of Nitrogen generator space **(R)**

Piping system, arrangement and details **(R)**

Arrangements to render cargo spaces gas tight; to include details of liquid sealed traps **(R)**

Arrangements for pressure and vacuum relief in cargo spaces **(R)**

Ventilation arrangements, for designated controlled atmosphere spaces, and adjacent spaces **(R)**

Schematic diagram of control and monitoring systems **(R)**

One line electrical wiring diagram and details of the power supply **(R)**

Details of the gas analyzing system **(R)**

A list of alarms and displays **(R)**

Details of the humidification system **(R)**

Details of personnel safety equipment **(R)**

Operations, equipment and procedure manual **(I)**

21 Refrigerated Edible Bulk Liquid Tankers *(2024)*

Design specific gravity of cargo **(I)**

Cargo tanks arrangements and details **(I)**

Cargo tank construction and material details **(R)**

Cargo tank foundations/supports (non-integral tanks) **(R)**

Details of cargo tank coatings **(R)**

Cargo pumping arrangements **(R)**

Cargo tank refrigeration system **(R)**

Cargo tank washing system **(R)**

Nitrogen injection system for cargo tanks (where fitted) **(R)**

Details of inert gas system, if provided **(R)**

23 Refrigerated Fish Carriers *(2024)*

Details of the hull reinforcement (where provided) **(R)**

Details of the cargo spaces as per 6-2-2/3 **(R)**

Details if the refrigeration system and refrigeration machinery spaces as per 6-2-2/5 **(R)**

Details of the refrigerated sea water (RSW) tanks **(R)**

Details of the arrangement for protection of the Ammonia piping in cargo hold (direct expansion systems) **(R)**

25 On Board Tests and Trials *(2024)*

Test schedules for the tests and commissioning trials referred to in Section 6-2-16 **(R)**

PART 6

CHAPTER 2
Vessels Intended to Carry Refrigerated Cargoes

SECTION 3
Hull Construction

Note: Text in *italics* is considered necessary as conditions of classification (i.e., compulsory requirements). (See 6-2-1/5.3)

1 General

1.1 Goals *(2024)*

The vessel structure and equipment covered in this section are to be designed, constructed, operated, and maintained to:

Goal No.	*Goals*
STRU 1	*In the intact condition, have sufficient structural strength to withstand the environmental conditions, loading conditions, and operational loads anticipated during the design life.*
STRU 3.1	*Maintain mechanical properties during extreme temperatures.*
STAB 1	*Have adequate watertight integrity and restoring energy to prevent capsize in an intact condition.*
MAT 1	*The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment..*
CARGO 1	*Enable all cargoes to be stored and secured in such a way that the ship and persons onboard and the environment are not put at risk.*

The goals in the cross-referenced Rules are also to be met.

1.2 Functional Requirements *(2024)*

To achieve the above stated goals, the design, construction, installation, and maintenance are to be in accordance with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
Structure (STRU)	
STRU-FR1	*Scantlings are to have sufficient strength to resist failure and excessive deformation associated with buckling and yielding when subjected to the loads anticipated throughout the service life.*
STRU-FR2	*Avoid structural stress concentrations that may lead to yielding or fatigue crack.*

Functional Requirement No.	*Functional Requirements*
STRU-FR3	Arrangements are to be made for exposed hatch covers of insulated compartments to ensure water ingress is prevented.
STRU-FR4	Have sufficient structural strength to resist failure and excessive deformation associated with buckling and yielding.
STRU-FR5	Adequate longitudinal strength is to be provided to resist bending moments and shear forces associated with vessel loading and wave loads anticipated during the design life
STRU-FR6	Suitable tightness of refrigerated cargo spaces is to be provided.
STRU-FR7	Openings to refrigerated cargo spaces are to be provided with suitable and efficient sealing arrangements.
Stability (STAB)	
STAB-FR1	Be equipped with hull opening securing devices of adequate strength
Materials (MAT)	
MAT-FR1	Materials are to maintain their properties when exposed to the maximum design temperatures anticipated throughout the operational life
MAT-FR2	Materials are to be compatible with liquids, solids, and gases they are expected to encounter during the service life. Properties of the materials or cargoes should not be reduced below that required to meet the design assumptions
Cargo (CARGO)	
CARGO-FR1	Air tightness of structure and ventilation is to be maintained for each cargo space
CARGO-FR2	Contaminated air is to be prevented from entry into the refrigerated cargo spaces.
CARGO-FR3	Supports and fixtures for insulation of refrigerated cargo spaces are to be suitable for their intended purpose.
CARGO-FR4	Stools or other permanent methods for securing cargo within a refrigerated cargo space, and which are welded to the hull, are to be arranged with a thermal break and be flush with the floor

The functional requirements in the cross-referenced Rules are also to be met.

1.3 Compliance *(2024)*

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved, refer to Part 1D, Chapter 2.

1.4 *Applicable Rules*

1.4.1

Vessels intended to carry refrigerated cargo are to comply with the following Rules, as appropriate, for the purposes of obtaining Class:

1.4.1(a) The hull construction and the fire safety arrangements are to be in accordance with the requirements of Part 3, Chapters 2 and 4 of these Rules.

1.4.1(b) Where the vessel is designed primarily for the carriage of containers in holds, or on deck, or both, with structures for that purpose, such as cell guides, pedestals, etc., the requirements of Part 5C, Chapter 5 Part 5C, Chapter 6 are also applicable.

1.4.1(c) Commercial fishing vessels under 61 m (200 ft) in length are to be in accordance with Part 5C, Chapter 18 of these Rules.

1.4.1(d) Vessels intended to operate in areas with low temperatures for long periods are subject to special consideration. ABS offers the notation ***Ice Class*** *followed by an ice class designation, for vessels built in accordance with Part 6, Chapter 1, "Strengthening for Navigation in Ice".*

1.4.2

This Section covers the additional items required for hull construction to obtain the classification notations ✠ ***RCC****, ✠* ***RC (Hold No.)****, ✠* ***RCCC****, ✠* ***IRCC****, ✠* ***REBLT****, and ✠* ***RFC****.*

3 Design Considerations

3.1 *Design Temperatures - Steel Boundary of Refrigerated Cargo Spaces*

3.1.1

Steel grades for plating and associated longitudinals and girders continuously exposed to temperatures below 0°C (32°F) in refrigerated cargo spaces are to be based on the steel design service temperature submitted by the shipyard or Owner. When assessing the steel design service temperature, the temperature of the adjacent, internal, non-refrigerated space may be taken as + 5°C (+ 9°F).

3.1.2

When the shipyard or Owner does not submit a temperature gradient calculation to assess the steel design service temperature, this temperature is to be determined as follows:

3.1.2(a) Un-insulated steel within the refrigerated cargo spaces is at the temperature of the space.

3.1.2(b) Steel insulated within the refrigerated cargo space but un-insulated on other side is at the temperature of the un-insulated side.

3.1.2(c) With steel insulated upon both sides then the following will apply:

Where the temperature difference is less than 30°C (54°F), a mean temperature is to be used and where the temperature difference is greater than 30°C (54°F) the steel temperature is to be specially considered.

3.3 *Avoidance of Notches and Hard Spots in Steel Work*

Unless permitted elsewhere in the Rules, structural members are to be effectively connected to the adjacent structures so as to avoid hard spots, notches and other harmful stress concentrations. See 3-1-2/15.

3.5 Air Tightness of Refrigerated Cargo Spaces

Arrangements are to be made to prevent odors passing into the refrigerated cargo space from an external source, as follows:

3.5.1

Each independent cargo space is to be airtight and of steel construction.

3.5.2

The hatches, access doors, access hatches, bilge well plugs, tank top manhole plugs, etc. fitted in the insulated surfaces must have air-tight joints.

3.5.3

Ventilators are to be fitted with airtight closing appliances.

5 Materials

5.1 General

The materials used in the construction of the vessel are to be manufactured and tested in accordance with the requirements of Part 2, Chapter 1.

5.3 Steel Grades

Steel materials for hull construction are not to be of lower grades than those required for the material class for the particular location, as given in 3-1-2/3. Furthermore, for steel used for the construction of the refrigerated cargo spaces, the grade of steel is also to comply with 6-2-3/5.5, 6-2-3/5.7 and 6-2-3/5.9.

5.5 Toughness of Steel

The steel grade is to be chosen upon the basis of its toughness, measured by an impact test. For details refer to Part 2, Chapter 1, in which the impact test requirements and provision are given for three grades (B, D, E) of normal strength steel. The higher strength steel (H32, H36 and H40) are each subdivided into four grades (A, D, E and F). There is no impact test requirement for Grade A steel of normal strength.

5.7 Areas Exposed to Low Temperatures

The material selection for the following areas of steel work is to be made on the basis of the design service temperature determined in accordance with 6-2-3/3.1.2 and the thickness. The minimum grades of steel to be used for the following are to be in accordance with 6-2-3/5.9:

- *Tween deck plating and longitudinals*
- *Longitudinal and transverse deck girders and deep side shell stringers (i.e., the portion of the tween deck outboard of a centerline hatch)*
- *Shelf plates, including web and face bars (i.e. the hatch covers supports)*
- *The longitudinal bulkhead strakes attached to deck plating and the longitudinal stiffeners on these strakes*
- *Pillars and vertical bulkhead web frames that replace pillars*

See also the requirements of 6-2-3/5.11 for selection of materials for hull structural members other than the above.

5.9 Steel Grades for Areas Exposed to Low Temperature

5.9.1

The following minimum grades of steel are to be used for the areas given in 6-2-3/5.7:

0°C > T ≥ -10°C (32°F > T ≥ 14°F)	
t ≤ 12.5 (0.50)	A
12.5 (0.50) < t ≤ 19.0 (0.75)	B/AH
19.0 (0.75) < t ≤ 51.0 (2.00)	D/DH
-10°C > T ≥ -20°C (14°F > T ≥ -4°F)	
t ≤ 12.5 (0.50)	B/AH
12.5 (0.50) < t ≤ 27.5 (1.08)	D/DH
27.5 (1.08) < t ≤ 51.0 (2.00)	E/EH

-20°C > T ≥ -30°C (-4°F > T ≥ -22°F)	
t ≤ 22.5 (0.89)	*D/DH*
22.5 (0.89) < t ≤ 51.0 (2.00)	*E/EH*

T is design service temperature, in °C (°F)

t is steel thickness, in mm (in.)

5.9.2

Temperature lower than -30°C (-22°F) will be the subject of special consideration.

5.9.3

Steel castings or forgings used in the structure are to meet the same impact test requirements as that for steel plate in the same application.

5.11 *For Other Areas of Hull Construction*

5.11.1

The steel grades for areas other than given in 6-2-3/5.7 are to be as required by other relevant sections of the Rules for Building and Classing Marine Vessels. *These areas include the following:*

- *Exposed main deck plating and stiffening.*
- *Forecastle deck plating and stiffening.*
- *Inner bottom plating and stiffening.*
- *Transverse bulkheads plating and stiffening.*
- *Transverse deck beams, where fitted to every frame.*
- *Shell plating and shell framing.*

5.11.2

Where the design of these areas is of an unusual construction, the material grade will be the subject of special consideration.

7 Hatch Covers

7.1

The scantlings of the hatch covers are to be designed in accordance with the requirements of Section 3-2-15.

7.3

Main hatch covers for insulated compartments are to be provided with double sealing arrangements, as a minimum.

7.5

Exposed hatch covers to an insulated compartment are also to be weathertight in any sea condition and arrangements are to be made to ensure any water ingress is avoided by packing or by efficient drainage leading to the exposed deck, or by an alternative means approved by ABS.

9 *Side Shell Doors*

9.1 *General*

Side shell doors are to be designed in accordance with the applicable requirements of Section 3-2-16. In addition, the following requirements are applicable.

9.1.1

Suitable arrangements are to be made to allow for ship's movement, to ensure that the watertight integrity of the side shell door is maintained in any sea condition.

9.1.2

Adequate structural stiffening is to be fitted at the hull/door sealing interface so that deflections of a local nature are avoided.

9.1.3

The longitudinal strength of the vessel will be subject to special consideration.

The hull girder strength calculations under the combined vertical and horizontal bending moment are to be submitted. The combined longitudinal hull girder stress is to be calculated at the critical points of the continuous longitudinal material e.g.. turn of bilge port and starboard, at the intersection of the intact deck edge and sheerstrake, and at the inboard corner of the deck opening. Alternatively a more comprehensive analysis may be submitted for review. On request, this analysis can be carried out by ABS.

9.1.4

Structural continuity is to be maintained for the remaining longitudinal and transverse members inboard of the opening in the shell and deck.

9.1.5

Each section of a multi-section door is to satisfy the requirements of Section 3-2-16 independently of adjacent sections.

9.1.6

It is to be shown, from the ship's stability book or otherwise, that in conditions of loading or unloading, and when the ship is heeled by cargo or crane movement, or by offset tank weights, that the door edge is not immersed. The door is to have a sill above the uppermost load line of a minimum height of 0.06B. Alternative methods of preventing the ingress of water will be specially considered. Details in this regard are to be submitted for approval.

9.3 *Side Loading Doors, Forming Part of the Deck and Sheer Strake*

Where a side loading door, forming part of the deck and sheerstrake, is fitted, there is an asymmetrical transverse structural section, whereby important longitudinal elements are not continuous at one side (i.e.. the deck stringer plate and sheerstrake). The above requirements in 9.1.1 through 9.1.6 are applicable in addition to the requirements of Section 3-2-16.

11 Insulation Supports and Fixtures within Refrigerated Cargo Spaces

Supports and fixtures for the insulation are to be suitable for their intended purpose, and in accordance with the following requirements:

11.1

All fixing arrangements of brackets, hangers, bolts, studs etc., and of their welded connections are to be capable of withstanding local loads caused by weight and thermal contraction/expansion and vibration.

11.3

The insulation and linings are to be fully supported.

11.5

The linings, side shorings, their supports and fixtures are to be able to withstand the loads imposed by the cargo.

11.7

Studs used for supporting the insulation panels are to be welded to the steel structure.

13 Fixing Arrangements for Cargo Securing Fittings within the Refrigerated Cargo Spaces

13.1

Stools or other permanent methods for securing cargo within a refrigerated cargo space, and which are welded to the hull, are to be arranged with a thermal break.

13.3

Stools are to be flush with the grating top.

15 Sealing of Doors and Access Hatches

Doors and hatches for access to insulated compartments are to be provided with a double sealing arrangement and are to be designed so that they can be opened from both sides.

17 Tests and Inspections

All spaces are to be tested for tightness by either a hose test before insulating the surfaces or a gas or smoke pressure test after insulating the space.

PART 6

CHAPTER 2
Vessels Intended to Carry Refrigerated Cargoes

SECTION 4
Cargo Handling Equipment

1 Optional Certification *(2024)*

The following equipment used on board for loading and unloading cargo may be certified by ABS, upon request by the Owner or Builder, for compliance with the requirements as indicated in 6-2-4/3.1 and 6-2-4/3.3:

- Shipboard cranes.
- Derrick-and-boom cargo gear.

3 Applicable Rules for Cranes, Derrick and Boom Cargo Gear, and Cargo Elevators

3.1 Cranes

A Certification of Lifting Appliances attesting to compliance with Chapter 2, “Guide for Certification of Cranes” of the ABS *Guide for Certification of Lifting Appliances* will be issued at the request of the Owner or Builder upon satisfactory completion of plan review, in-plant survey, installation and testing of the cranes to the satisfaction of the attending Surveyor. Vessels with this Certification will be distinguished in column 5 of the *Record* by a notation **CRC** (Crane Register Certificate) with the number and capacity of cranes.

3.3 Derrick Post and Boom, and Cargo Elevators

For arrangements of derrick post and boom, and cargo elevators, the Owner or Builder may request ABS Cargo Gear Certification in accordance with Chapter 3, “Guide for Certification of Cargo Gear on Merchant Vessels” of the ABS *Guide for Certification of Lifting Appliances*. Appropriate certificates for attachment to the *Register of Cargo Gear*, will be issued following satisfactory compliance with the above requirements.

PART 6

CHAPTER 2
Vessels Intended to Carry Refrigerated Cargoes

SECTION 5
Refrigerated Cargo Spaces

Note: Text in *italics* is considered necessary as conditions of classification (i.e., compulsory requirements). (See 6-2-1/5.3)

1 General

All refrigerated cargo spaces and air cooler rooms are to have access doors, hatches and ladders arranged for easy access and escape.

1.1 Objective (2024)

1.1.1 Goals

The refrigerated cargo spaces covered in this section are to be designed, constructed, installed, operated, and maintained to:

Goal No.	*Goals*
STRU 3.1	maintain mechanical properties during extreme temperatures.
STAB 1	have adequate watertight integrity and restoring energy to prevent capsize in an intact condition.
CARGO 3	be equipped to handle and transfer cargo safely.
MGMT 5.1	design and construct vessel, machinery, and electrical systems to facilitate safe access, ease of inspection, survey, and maintenance.
FIR 3	*reduce the risk of damage caused by fire to the ship, its cargo and the environment.* (SOLAS II-2/Reg 2.1.3)

The goals in the cross-referenced Rules are also to be met.

1.1.2 Functional Requirements

In order to achieve the above stated goals, the design, construction, installation and maintenance of the refrigerated cargo spaces are to be in accordance with the following Functional Requirements.

Functional Requirement No.	*Functional Requirements*
Structure (STRU)	
STRU-FR1	Means for maintaining and controlling the cargo space temperature are to be provided.
STRU-FR2	The grating, insulation, lining, spar deck planking and side shoring are to have sufficient strength to withstand all expected loads.
STRU-FR3	All surfaces in refrigerated cargo spaces are to be protected against corrosion. Openings in refrigerated cargo spaces are to be resistant to moisture.
STRU-FR4	Insulating properties are not to be affected or diminished by coatings/paint, fire, extreme temperatures, and vessel vibrations.
STRU-FR5	All surfaces in refrigerated cargo spaces are to be efficiently insulated to prevent freezing, decay and entry of moisture or water.
Cargo (CARGO)	
CARGO-FR1	Cargo spaces are to be designed to accommodate different types of package cargoes.
CARGO-FR2	Adequate chilled and fresh air circulation around/through the cargo is to be provided.
CARGO-FR3	Minimize the entry of contaminated air into refrigerated cargo space.
CARGO-FR4	Ventilation ducts are to be arranged so that cooling air is distributed evenly throughout the refrigerated cargo spaces during loaded condition.
CARGO-FR5	Provide means to contain and effectively remove leakages.
CARGO-FR6	Arrangements are to be made to prevent cross contamination or leakage of air and water into the refrigerated cargo spaces.
CARGO-FR7	Provide means to protect uninsulated pipes from freezing.
Stability (STAB)	
STAB-FR1	Penetrations through watertight and gas tight bulkheads are to be by methods which maintain the required integrity.
STAB-FR2	Pipes passing through refrigerated cargo spaces are to have suitable strength and to be arranged to prevent mechanical damage
Safety Management (MGMT)	
MGMT-FR1	Provide easy access to bilge and drainage arrangements, deck beneath, and other pipes covered by insulation for operation, inspection and maintenance.
Fire Safety (FIR)	
FIR-FR1	Air pipes from storage tanks containing flammable fluids are not to discharge in refrigerated cargo spaces or air cooler rooms to prevent the ingress of flammable gases from the pipes.

The Functional Requirements in the cross-referenced Rules are also to be met.

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

3 Design Considerations

3.1

Where cargo spaces are intended to carry palletized cargo, the minimum clear height in tween deck cargo spaces is to be consistent throughout to accommodate pallets of a height specified by the Owners/builders and is to include a minimum air gap above the pallets of 100 mm (4 in.) for air circulation.

3.3

For vessels intended to operate in regions where ambient temperatures are expected to be lower than the cargo space temperatures, the owner or builder may install cargo space heating or other means for maintaining cargo space transport temperatures. These systems are to have appropriate controls for maintaining the desired temperature.

3.5

When using either forklift trucks or pallet trucks, the grating, insulation, lining and spar deck planking is to be of sufficient strength to support the weight of a fully loaded truck carrying the heaviest load envisaged during normal loading and unloading. This is to be demonstrated in accordance with tests specified in 6-2-5/17.5.

3.7 Corrosion and Protection

3.7.1 Hull Structure

3.7.1(a) All steel surfaces are to be cleaned of grease and other organic contaminants and are to be abrasive blasted to near white finish (SSPC-SP-10, NACE No.2, SWEDISH SA 2.5) or to an alternative finish in accordance with the paint manufacturers specification, prior to coating. This may be done before erection and welding, in which case special attention is to be given to the preparation of the welded areas.

3.7.1(b) Steel surfaces of refrigerated cargo spaces, behind insulation and including the inside of hatch coamings are to be coated, to a minimum dry film thickness of 150 microns (6 mils). Steel work and fittings, which are to be covered with insulation, are to be similarly cleaned and then coated to prevent corrosion. Where polyurethane foam is applied directly to the steel structure and bulkheads, the surfaces are to be prepared to ensure proper adhesion and resistance to corrosion.

3.7.1(c) Openings in the refrigerated cargo spaces such as the bilge limbers and plugs and other openings to these spaces such as the hatch covers and access doors are to be constructed of moisture resistant material or covered with such material.

3.7.1(d) Where the tank top or bulkhead of an oil storage tank forms part of the refrigerated cargo space walls, the surface of the tank plating is to be coated with an oil impervious coating.

3.7.2 Fittings and Fixtures

Steel bolts, nuts, screws, washers, hangers, and other similar fixtures which support or secure insulation, pipes, meat rails, etc., are to be protected against corrosion by means of galvanizing or other equally effective methods approved by ABS.

3.7.3 Pipes, Ducts and Drip Trays

3.7.3(a) Refrigerant and brine pipes in the refrigerated cargo spaces are to have corrosion protection in accordance with 6-2-6/23.3.

3.7.3(b) All steel ducts and pipes passing through the refrigerated cargo spaces are to be protected against corrosion prior to the application and installation of the insulation.

3.7.3(c) Steel drip trays provided under air coolers and vertical cooling grids are to be galvanized or epoxy coated. Materials other than steel such as plastic or flake glass may be used for the construction of the drip trays, provided the material used is suitable for the intended application and has been approved by ABS.

5 Insulation

5.1

The insulation arrangement, materials, construction and installation are to be in accordance with the approved plans and to the satisfaction of the Surveyors.

5.3

Where the insulation is provided in the form of prefabricated insulating panels, the panels are to be approved by ABS. Inspections by the Surveyors are required during the manufacture of these panels.

5.5

When requested, the manufacturing of the panels referred to in 6-2-5/5.3 is acceptable under the quality assurance program.

5.7 Types

Rockwool, polyurethane, styrofoam, glass fiber or equivalent material may be used for insulation purposes.

5.9 Properties

5.9.1

All insulation material used in the refrigerated cargo spaces is to be of a type which does not produce or absorb paint.

5.9.2

Organic foam is to be fire retardant as established by a recognized fire test procedure such as DIN 4102.B2. Test certificates issued by independent testing laboratories are to be submitted for review.

5.9.3

The insulation material is to be resilient and is not to distort or deform due to the temperatures which will be encountered in service. It is also to withstand shipboard vibrations likely to occur during normal operating conditions.

5.11 Temperature Gradient Calculation

5.11.1

The thickness of insulation over all surfaces is to be in accordance with approved specifications and plans.

5.11.2

Thermal bridges associated with fittings for securing the panels and moisture barriers around the open edges are to be accounted for in the calculations.

5.11.3

Where machinery spaces and other such spaces fitted with heating arrangements such as fuel tanks, etc., are situated adjacent to the refrigerated cargo spaces, the heat transfer calculations are to take this into consideration.

5.13 Installation

5.13.1

The insulation is to be efficiently packed and securely fastened.

5.13.2

Insulation slabs or blocks, where used, are to have the joints staggered and butted as close as possible. If several layers of insulation blocks are employed, these are also to be installed in a similar manner. Any unavoidable gaps between the joints and crevices are to be filled with suitable insulating material.

5.13.3

Panels are to be of sufficient mechanical strength to withstand, without damage, loads due to over or under pressure of the refrigerated cargo spaces resulting from the defrosting of coolers or rapid cooling of the refrigerated cargo space. Alternatively, suitable pressure equalizing devices are to be fitted.

5.13.4

During the installation of the prefabricated insulation panels, the panels are to be butted together such that all joints along the edges and the corners are sealed at the outer and inner sides to form a vapor barrier using an approved sealant. The same method is to be employed at floors, ceiling intersections and the vertical bulkheads.

5.13.5

Provisions are to be made in the design for an effective moisture barrier at the open edges of the panels at the footing, corner intersections, openings for doorways, etc.

5.13.6

Decks, partitions and other structural members which extend into refrigerated cargo spaces from the ship side, machinery spaces, or other such non-refrigerated adjacent spaces, are to be effectively insulated over a length of at least 1 m (3.3 ft.) into the refrigerated cargo space unless temperature gradient calculations prove less carry-over is sufficient.

5.15 Lining

5.15.1

The insulation is to be protected from water and water vapor by suitable lining material such as marine plywood (coated), metallic sheet or other similar material which is impervious to water.

5.15.2

The insulation lining referred to in 6-2-5/5.17.1 is to be installed in such a way as not to allow water to penetrate into the insulation during hosing down of the chambers.

5.15.3

Lining, cooler room screens and structures supporting these are to be of sufficient strength to withstand the loads imposed by either the refrigerated or general cargo in transit.

5.15.4

Where plywood is used it is to be treated against fungi, other microorganisms and dampness.

5.15.5

All timber which is embedded in insulation is to be impregnated under pressure with odorless preservative. All sawn ends and bolt holes are to be treated in situ.

5.15.6 *(2024)*

In order to protect the lining against damage from forklift trucks or pallet jacks, a metallic plate of minimum height 500 mm (1.6 ft.) and thickness of 6 mm (0.24 in.) is to be provided at deck level.

Commentary:

Alternative heights and thicknesses proposed by the Owner/builder with appropriate justification are subject to ABS technical assessment and approval. Other materials such as glass reinforced plastics may be used provided they are demonstrated to the satisfaction of ABS to be of suitable strength and durability.

End of Commentary

5.17 Insulation of Pipes, Ducts and Vent Trunks

5.17.1

To prevent freezing, vent, sounding, overflow and water pipes, are to be insulated from cold surfaces such as the bulkheads and decks and installed so that contact with the warmer surfaces such as the ship side is maintained as much as possible. Where this is impracticable, heat tracing of these pipes is to be fitted.

5.17.2

Ducts and pipes passing through refrigerated cargo spaces are to be efficiently insulated.

5.17.3

Where thermometer tubes are partially inserted into the space being monitored, the portion of the tube external to that space is to be efficiently insulated.

5.19 Penetration of Insulation

5.19.1

Plugs provided for access to manhole covers, bilge suction wells, drains, etc. are to be insulated in accordance with approved plans.

5.19.2

To prevent seepage of water into the tank top insulation, openings for manholes and bilge covers are to be fitted with liquid tight steel coamings. The height of the coaming is not to be less than the insulation. A sealant may be applied at the edges to prevent seepage into the insulation.

5.19.3

Ducts, pipes, and cable penetrations are to be made airtight.

5.19.4

Provisions are to be made in the installation of the insulation to enable inspection during the periodical surveys of the bilge suction pipes, vent and sounding pipes and other similar pipes situated behind the insulation. This may be achieved by installing removable insulation panels or other methods approved by ABS.

7 Stowage and Side Shoring

7.1

Provisions are to be made for the circulation of air between the cargo and the insulation lining surfaces.

7.3

Cooling grids located on vertical surfaces are to be protected by dunnage ribs.

7.5

Side shoring is to be of sufficient strength to withstand the dynamic loads imposed by palletized cargo in transit.

9 Air Circulation and Ventilation

9.1

The required air circulation and fresh air ventilation rates are to be based upon the air volume of empty refrigerated cargo spaces.

9.3

The design of the air circulation system in refrigerated cargo spaces intended for the carriage of fruit is to allow a sufficient flow of chilled air throughout all the stowage space in the loaded condition.

9.5 *(2024)*

For refrigerated cargo spaces fitted with coolers with forced air circulation, the quantity of circulating air for each refrigerated cargo space is to be based on the nature of cargo and design temperature, but is not to be less than 30 air changes per hour. Justification for lower air circulation rates for frozen cargoes are to be submitted to ABS for technical assessment and approval.

9.7

For fruit carriers the cooling fans are to have the capability of running at a minimum of two speeds such that the air circulation rates in the refrigerated holds can be maintained at not less than 45 and 90 air changes per hour.

9.9

Refrigerated cargo spaces intended for carriage of fruit are also to be provided with a fresh air mechanical ventilation system providing at least 2 air changes per hour.

9.11 *(2024)*

Justification for air-circulation and fresh air ventilation rates lower than those stated in 6-2-5/9.5, 6-2-5/9.7 and 6-2-5/9.9, are to be submitted to ABS for technical assessment and approval.

9.13

Each refrigerated cargo space intended for the carriage of fruit is to be provided with its own separate inlet and exhaust vent. The position of the air inlet is to be selected to minimize the possibility of contaminated air entering into any refrigerated cargo space.

9.15

For details of the ventilation when the vessel is engaged in carriage of cargoes other than refrigerated cargoes. Reference is to be made to the requirements contained elsewhere in the Rules.

11 Ducts, Gratings and Spar Decks

11.1

Cooling air from the fan unit is to be evenly distributed at the bottom of the refrigerated cargo spaces.

11.3

The height of the gratings and size and number of ventilation holes are to be appropriate for the air circulation requirements.

11.5

The size and number of ventilation holes in the spar deck planking are to be appropriate for the air circulation requirements.

11.7

Suitable arrangements are to be made to allow for ease of lifting of the gratings to enable cleaning and maintenance of the deck beneath.

11.9 *(2024)*

In each refrigerated cargo space, the grating and associated supports directly underneath the hatch opening and 600 mm (2.0 ft.) beyond are to be designed to withstand impact during loading. Increased grating thickness and/or reduced spacing of the supports is acceptable provided air circulation is not adversely affected. The protection of insulation in gratingless cargo spaces is to be no less effective.

13 Bilge and Drainage Arrangements

13.1

The bilge system for cargo spaces is to be in accordance with 4-6-4/5.5.

13.3

Cooling grids fitted vertically on the refrigerated cargo space sides and air coolers are to be provided with drip trays and drain pipes arranged as follows:

13.3.1

Drain pipes are to be sized to allow drainage without overflowing of the drip trays during defrosting operations, taking into consideration the vessel's motion.

13.3.2

Drainage openings in the drip trays are to be easily accessible for cleaning.

13.3.3

Drain pipes are to have flanged connections near the outlets to allow cleaning in the event of blockage.

13.3.4

Trace heating of the drain pipes and drip trays is to be provided when carrying frozen cargo.

13.5

All refrigerated cargo spaces are to have ample continuous drainage.

13.7

Provision is to be made to prevent air and water from leaking into adjacent refrigerated cargo spaces.

13.9

To prevent air from leaking into adjacent refrigerated cargo spaces, open ended pipes such as drains from each deck space or the drip trays from these spaces are to be fitted with liquid seal traps or non-return vales. These requirements are also applicable to drains underneath the coolers.

13.11

When drains from separate refrigerated cargo spaces join in a common main, the branch lines are to be provided with liquid seal traps to prevent air from leaking into adjacent refrigerated cargo spaces. In *addition, branch lines from lower spaces are to be provided with non-return valves to prevent flow of water from one compartment to another.*

13.13

Liquid seal traps located in areas subject to freezing are to be filled with brine and are to be easily accessible for maintenance purposes.

13.15

Drains from other spaces are not to lead to the bilges of refrigerated cargo spaces.

13.17

Bilge wells where drain pipes are led, and connections to the main bilge system are to be separated from refrigerated cargo spaces by air tight moisture resistant divisions.

15 Pipes Passing Through Refrigerated Cargo Spaces

15.1

Air, sounding and tank filling pipes which pass through insulated spaces are to be arranged as close to the shell and bulkhead structure as possible. Flanged joints are to be kept to a minimum, and where additional supports are necessary, brackets are to be fitted.

15.3

Steel pipes penetrating the tank top in refrigerated cargo spaces are to have a wall thickness of a heavier grade in way of the insulation and the tank top.

15.5

All sounding pipes passing through refrigerated spaces where the temperature may be below 0°C (32°F) are to have an inside diameter of not less than 65 mm (2.6 in.).

15.7

Sounding pipes for oil tanks are not to terminate in refrigerated cargo spaces or air cooler rooms.

17 Tests and Inspections

17.1

The shipyard is to submit the results of the corrosion resistance coating thickness measurement to the attending Surveyor.

17.3

The Surveyor is to verify the adequacy of the seals and traps for each refrigerated cargo space.

17.5

The test required by 6-2-5/3.5 on the insulation and lining is to be carried out in the presence of the attending Surveyor as follows:

A 4 × 4 m (13 × 13 ft.) sample of the cargo floor construction, including insulation, is to be prepared and tested by a fully loaded forklift truck with its heaviest load envisaged during normal loading and unloading operations being driven and maneuvered over the sample. Where cargo operations will not involve forklift trucks, a similar test using a fully loaded pallet truck is to be performed.

17.7

Insulation thickness on pipes, valves, flanges and fittings is to be examined by the attending Surveyor.

17.9

Sample tests performed by the manufacturer to determine the density of the insulating material are to be presented to the Surveyor for verification that the material complies with the design specification.

17.11

Where insulating foam is intended to be applied directly to the ship's structure, the method of application and the procedure are to be approved prior to commencement of the work.

17.13

For prefabricated panels referred to in 6-2-5/5.3 the insulation material is to be in accordance with 6-2-5/17.9.

17.15

For air distribution tests refer to 6-2-16/3.1.3

PART 6

CHAPTER 2
Vessels Intended to Carry Refrigerated Cargoes

SECTION 6
Refrigeration Machinery

Note: Text in *italics* is considered necessary as conditions of classification (i.e., compulsory requirements). (See 6-2-1/5.3)

1 General

1.1 Objective *(2024)*

1.1.1 Goals *(2024)*

The refrigeration machinery covered in this section is be designed, constructed, operated, and maintained to:

Goal No.	*Goals*
SAFE 1.1	Minimize danger to persons on board, the vessel, and surrounding equipment/installations from hazards associated with machinery and systems
MGMT 5-1	Design and construct vessel, machinery, and electrical systems to facilitate safe access, ease of inspection, survey, and maintenance
POW 1	Provide power to enable the machinery/equipment/electrical installation to perform its required functions necessary for the safe operation of the vessel.
AUTO 1	Perform its functions as intended and in a safe manner

Materials are to be suitable for the intended application in accordance with the following goals and support the Tier 1 goals as listed above.

Goal No.	*Goal*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.

The goals in the cross-referenced Rules are also to be met.

1.1.2 Functional Requirements *(2024)*

In order to achieve the above stated goals, the design, construction, and maintenance of the refrigeration machinery is to be in accordance with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
Safety of Personnel (SAFE)	
SAFE-FR1	Refrigeration units for cargo refrigeration are not to be combined with other refrigerating machinery.
SAFE-FR2	Provide protective devices if the equipment can be subjected to a pressure greater than its design pressure.
SAFE-FR3	Withstand the most severe condition of coincident design pressure, temperatures, and loadings.
SAFE-FR4	Sufficient capacity and redundancy to be provided to deal with the cargo onboard reliably.
SAFE-FR5	Equipment and its associated components are to be suitable for the intended service, environmental conditions, and anticipated service life.
SAFE-FR6	During the selection of refrigerant, due regard is to be paid to refrigerant's suitability of intended service i.e. compatibility with the system and equipment materials, solubility of refrigerant in lubricants, toxicity and flammability.
SAFE-FR7	There are to be arrangements to detect the leakage of refrigerant.
SAFE-FR8	Adequate ventilation is to be provided to prevent the accumulation and spread of toxic/ flammable/asphyxiating gases from the refrigeration machinery to other spaces and maintain the atmosphere in the refrigeration machinery space out of the explosive range.
SAFE-FR9	Ventilation of refrigeration machinery space is to be arranged to prevent communication of ventilated air with other ventilation systems for personnel safety.
SAFE-FR10	Provide adequate support to withstand the forces and loads during the anticipated service life.
SAFE-FR11	The pressure relief setting, quantity, installed locations/arrangements and relief flow capacity of the relief devices are to mitigate the effects of overpressure.
SAFE-FR12	The relief discharge location is not to endanger the safety of persons onboard, other equipment/systems and environment.
SAFE-FR13	The pressure relief devices are to be arranged so as not to prevent interference with the flow of air in the event of overpressure.
SAFE-FR14	Provide means to preclude the formation of moisture so as to prevent damage or deterioration of the refrigeration system components and insulation.
SAFE-FR15	The design and arrangement of the refrigerant piping system and equipment are to be suitable for the application with due regard given to the effects of cavitation and flashing.
SAFE-FR16	Provide containment for spillages/leakages.
SAFE-FR17	Accommodation spaces are to be protected from possible hazards due to leakage of refrigerant or fire from refrigeration machinery spaces.
Safety Management (MGMT)	
MGMT-FR1	Provide access for inspection, maintenance, and repair.
MGMT-FR2	Defrosting arrangements are to be provided to remove the build-up of ice.
MGMT-FR3	Provide arrangements to remove or minimize entry of contaminants including oil, dirt and moisture to maintain the refrigeration system clean and dry.
MGMT-FR4	Arrangement/redundancy is to be provided such that operation is not affected in the event of equipment malfunction/repair/maintenance.

Functional Requirement No.	*Functional Requirements*
Power Generation and Distribution (POW)	
POW-FR1	Sufficient capacity and redundancy to be provided to deal with the cargo onboard reliably.
POW-FR2	Equipment is to have sufficient capacity to support all associated shipboard loads during normal operation.
Automation: Control, Monitoring and Safety Systems (AUTO)	
AUTO-FR1	Initiate safety action upon deviation from the defined design/operating parameters.
Materials (MAT)	
MAT-FR1	Initiate safety action upon deviation from the defined design/operating parameters.During the selection of refrigerant, due regard is to be paid to refrigerant's suitability of intended service i.e. compatibility with the system and equipment materials, solubility of refrigerant in lubricants, toxicity and flammability.
MAT-FR2	Impact toughness to be considered for low temperature performance.
MAT-FR3	Toughness at low temperatures to avoid brittle fracture.
MAT-FR4	Materials are to have corrosion and wear resistance appropriate for the operating environment and service life.
MAT-FR5	Materials are to be compatible with medium they are expected to encounter during the service life. Properties of the materials should not be reduced below that required to meet the design assumptions.
MAT-FR6	Avoid galvanic corrosion due to dissimilar materials.
MAT-FR7	Piping penetrations through bulkheads and decks are to be by methods which maintain the required integrity and prevent loss of ductility and increased embrittlement of the hull structure due to low temperatures.

The functional requirements covered in the cross-referenced Rules are also to be met.

1.1.3 Compliance *(2024)*

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

1.3 General Requirements *(2024)*

1.3.1

The location of the refrigeration units and associated equipment such as pumps, coolers, cooling fans and motors, etc. is to be such that sufficient space is available to allow easy access during maintenance and repair.

1.3.2 *(2024)*

The refrigeration units for cargo refrigeration are to be completely independent of any refrigerating machinery associated with air conditioning plants or provision refrigeration installations. A combined system will be subject to ABS technical assessment and approval on an individual basis.

1.3.3

An effective defrosting system suitable for the service conditions and cargo carried is to be installed.

3 Design Considerations

3.1 Design Pressures

3.1.1

The design pressure is the maximum allowable working pressure at which the system can be used. Relief valves in any part of the system are to be set such that the design pressure is not exceeded.

3.1.2

The system is to be designed such that under all normal operating and standstill conditions the design pressure is not exceeded.

3.1.3

The design pressure on the high pressure side of the system is not to be less than the pressure corresponding to the condensing temperature of the refrigerant used, e.g. saturated pressure at 55°C (130°F) for refrigerants with zero or negligible glide. For zeotropic blends with significant glide, the bubble point pressure is to be used (indicated with an asterisk in 6-2-6/3.1.6).

3.1.4

The design pressure of the low pressure side of the system is not to be less than the pressure corresponding to the evaporating temperature of the refrigerant used at the discharge from the expansion valve, e.g. saturated vapor pressure at 45°C (113°F) for refrigerants with zero or negligible glide. For zeotropic blends with significant glide, the bubble point pressure is to be used (indicated with an asterisk in 6-2-6/3.1.6).

3.1.5

Where the method for defrosting is by means of circulating hot refrigerant gas, the design pressure on the low pressure side is to be the same as that on the high pressure side.

3.1.6

The minimum design pressure for the refrigerants listed is to be as follows:

Refrigerant	*High pressure side bar (kgf/cm ^{2}, psi)*	*Low pressure side bar (kgf/cm ^{2}, psi)*
R22	20.5 (20.9, 295)	17.1 (17.4, 250)
R717	22.4 (22.8, 325)	17.9 (18.3, 260)
R134a	13.7 (14.0, 200)	10.5 (10.7, 150)
R404a*	25.0 (25.5, 365)	19.8 (20.2, 285)
R407a*	25.2 (25.7, 365)	19.8 (20.2, 285)
R407b*	26.5 (27.0, 385)	20.9 (21.3, 305)
R407c*	23.9 (24.4, 345)	18.8 (19.2, 275)
R410a	32.8 (33.4, 475)	25.9 (26.4, 285)
R410b	32.5 (33.1, 471)	25.7 (26.2, 375)
R507	25.4 (25.9, 370)	19.9 (20.3, 290)

3.3 Capacity

3.3.1 General

3.3.1(a) At least two refrigeration units are to be provided. The aggregate capacity of the units is to be sufficient to deal adequately with the cargo as received aboard. The ambient conditions for determining the required capacity are to be based on the following conditions:

Sea water temperature	32°C (90°F)
Air temperature	35°C (95°F)
Relative humidity	75%

Where the vessel is intended to operate in regions where the temperature and the relative humidity other than those mentioned above are encountered, alternative conditions will be specially considered upon request from the Owners and/or builders.

3.3.1(b) Capacity of the refrigerating machinery is to be selected taking into account their purpose and service conditions. Where appropriate, allowance is to be made for heat generated by air circulation fans, heat produced by cargo, introduction of fresh air, heat transmission through insulation and heat input from other sources such as insulation, pipes, ducts, tank tops, steel structure, etc.

3.3.1(c) In order to compensate for the deterioration of blown foam insulation over the life of the installation, the calculated transmission heat, based upon the rated insulation performance, is to be increased by 10% prior to inclusion in the capacity calculations.

3.3.1(d) Where refrigerated spaces are served by independent separate refrigeration units, the capacity of the units will be subject to ABS technical assessment and approval.

3.3.2 Fruit Carriers

3.3.2(a) For the purposes of calculations the aggregate capacity of the refrigeration system is to be such that for all the loaded refrigerated cargo spaces, under the conditions specified in 6-2-6/3.3.1, the return air temperature can simultaneously be reduced to a temperature 2°C (1°F) higher than the required steady state delivery air temperature within 24 to 36 hours.

3.3.2(b) A cool down period greater than that stated in 6-2-6/3.3.2(a) above will be specially considered when the vessel is likely to operate under conditions other than those stated in 6-2-6/3.3.1(a) or an alternative cool down period is agreed between the designers/builders and Owners.

3.3.2(c) In the event that one of the refrigeration units becomes non-operational, the capacity of the remaining unit(s) is to be sufficient to achieve and maintain the required delivered air steady state temperature when operating under the design conditions stated in 6-2-6/3.3.1.

3.3.3 Refrigerated Cargo Vessels other than Fruit Carriers

3.3.3(a) For the purposes of calculations the total aggregate capacity of the refrigeration system is to be such that minimum design temperature in all refrigerated cargo holds can be achieved under maximum loads with ambient conditions, as applicable and as specified in 6-2-6/3.3.1

3.3.3(b) The capacity of the refrigeration system is to be sufficient to maintain the minimum design temperature under the conditions, as applicable, specified in 6-2-6/3.3.1, in all refrigerated cargo spaces with one of the Units in standby condition.

3.3.4 Fish Processing Vessels

The aggregate capacity of the refrigeration system is to be in accordance with 6-2-6/3.3.3.

5 Refrigerants and Secondary Coolants

5.1

Refrigerants listed under 6-2-6/3.1.6 are to be used in the refrigeration system of a refrigerated cargo vessel classed with ABS.

5.3

Use of other refrigerants is permitted by ABS subject to approval of the chemical properties, including toxicity, flammability, and compliance with the requirements of 6-2-1/11.5.

5.5

Where it is intended to replace refrigerant in refrigeration system on board existing vessels under ABS Class, their use is subject to the following:

5.5.1

Where substitute refrigerant operates at pressures greater than the system's original design pressure, details are required to be submitted to show the method used, such as calculations followed by hydrostatic tests, such that the integrity of the existing system can withstand higher pressures under all operating and stand still conditions.

5.5.2

For those substitute refrigerants which incorporate a flammable component, precautions are to be taken such that air cannot enter into the system.

5.5.3

The lubricating oil is to be soluble with the substitute refrigerant.

5.5.4

For those lubricating oils which are hygroscopic, the refrigeration system is to be effectively dehydrated before charging.

5.5.5

Poly-glycol lubricating oils are not to be used in systems which previously contained chlorinated refrigerants and mineral oils.

5.5.6

The thermal stability of the lubricating oil is to be compatible with the discharge gas temperature.

5.5.7

The capacity of the pressure relief devices and the diameter and length of the discharge pipes are to comply with 6-2-6/17.15, 6-2-6/17.17 and 6-2-6/17.19

5.5.8

The substitute refrigerant is to be compatible with the materials used in the existing system.

5.5.9

A refrigerant leakage detection system complying with 6-2-10/9 is to be provided in accordance with 6-2-10/9.1.

5.7

Hydrocarbons such as propane, butane, pentane or other similar flammable products are not permitted to be used as refrigerants in shipboard refrigeration systems.

5.9

The use of CFC's as refrigerants in shipboard refrigeration systems is not permitted by various administrations.

5.11 *(2024)*

Solutions of sodium chloride (NaCl), calcium chloride (CaCl), magnesium chloride (MgCl) and water, commonly referred to as brine, can be used as secondary coolant in shipboard refrigeration systems.

Commentary:

The use of other substances as secondary refrigerants may be considered if the flash point of the substance used is greater than 66°C (150°F).

End of Commentary

5.13

Brine concentration is to be maintained to suit the evaporating temperature.

5.15

The refrigerant storage cylinders are to be approved by a nationally recognized agency or other similar authorized body.

7 Materials and Fabrication

7.1 *(2024)*

Materials are to comply with the applicable requirements in Part 2, Chapter 3 and Part 4, or other national recognized standard and in association with an approved design.

7.3 *(2024)*

Materials used for air coolers are to exhibit internal corrosion resistance to the processing medium and withstand external corrosion by the environment. Galvanizing is an alternative for the protection of the external surfaces.

7.5

Ferrous materials for refrigerant piping, valves and fittings with an intended service temperature below -18°C (0°F) are to comply with the requirements of Section 2-3-13 of the ABS *Rules for Materials and Welding (Part 2)* or with other approved specifications, except that:

7.5.1

Impact testing is not required for austenitic stainless steel.

7.5.2

Impact testing is not required for nut and bolt materials.

7.5.3 *(2024)*

Impact testing is not required for the material in 4-4-1-A1/21 TABLE 2 (SI units) or 4-6-2/9.19 TABLE 1 if the intended service temperature is not below -29°C (-20°F), and provided the maximum fiber stress is not more than 40% of the allowable stress indicated in these tables.

7.7

Seamless copper piping and seamless red brass piping, manufactured in accordance with the requirements of Section 2-3-16 or Section 2-3-17 of the ABS *Rules for Materials and Welding (Part 2)*, and seamless or welded copper-nickel piping is acceptable without impact testing.

7.9 *(2024)*

Material for crankshafts, connecting rods, cylinders and cylinder covers, housings, rotors and rotor casings of reciprocating and rotary compressors, as applicable, is to be in accordance with the applicable requirements of this Section and Part 2, Chapter 3. Materials complying with other recognized standards are also allowed in association with an approved design.

7.11

Synthetic materials, such as neoprene, chloroprene, etc., can be used for gaskets, seals, and packing in halocarbon refrigerant systems. Natural rubber is not to be used for applications in contact with the refrigerant.

7.13

Ferritic steel plates used for the fabrication of refrigerant receivers or other low-temperature pressure vessels with an intended service temperature below -18°C (0°F) are to be in accordance with 5C-8-6/4 TABLE 2 (ABS) Provisions for exemptions to the toughness testing for low-stress applications in subsection 6-2-6/7.5 of this Chapter are to be applied.

7.15

Cast iron pipe is not to be used for refrigerant service.

7.17 *(2024)*

The material of pipes, valves and fittings is to be in accordance with Part 2, Chapter 3 and is to be compatible with the refrigerant, the compressor oil, and the combination of the two, as well as the secondary coolant, where applicable.

For service where the fluid is a strong electrolyte such as brine, the materials used within the same system are to be compatible in terms of galvanic potential. Fabrication is to be in accordance with 2-4-2/9.5 of the ABS *Rules for Materials and Welding (Part 2)*, the applicable design standard, and the following:

7.17.1 Ammonia System *(2024)*

Piping is to be black steel (non-galvanized). Seamless pipes and welded pipes are acceptable for use in Ammonia systems. Copper and Zinc is not to be used in systems where they may be exposed to ammonia. Copper-Nickel is considered subject to established practices with evidence provided to ABS for review and approval.

7.17.2 Halocarbon System

Welded or seamless copper, brass or copper-alloy pipes may be used in halocarbon systems. Piping is to be welded or brazed and pipe connections are to be either welded or through brazed flanges. Soldering is not permitted.

Connections to valves, castings, expansion joints, spool pieces and other similar fittings is to be by welding, brazing, or by use of flanges.

Magnesium alloys are not to be used where they are in contact with any halogenated refrigerants (e.g., R22, R134a, etc.).

7.19

Finned piping is acceptable for use in liquid to vapor/gas heat transfer components.

7.21

Materials used for construction of pump components which are exposed to the medium being circulated are to be suitable to withstand the effect of that medium.

9 Location and Access

9.1

The refrigeration machinery are to be located in the main/auxiliary machinery spaces or in a separate dedicated space.

9.3

Spaces containing refrigeration machinery and refrigerant storage cylinders are not to have direct access to accommodation spaces. Doors are to open outwards and those not leading directly to the open deck are to be self-closing.

9.5

Refrigerant storage cylinders are to be properly secured and located in the space containing the refrigeration machinery or a dedicated space which is independently naturally ventilated. Means for closing the vent openings from outside the dedicated space are to be provided.

9.7

Air coolers and fans are to be located in a manner which enables easy access for the maintenance, repair and replacement of equipment with the refrigerated cargo spaces fully loaded.

11 *Ventilation of Refrigeration Machinery Space*

11.1

Spaces containing refrigerating machinery are to be ventilated by means of mechanical ventilation. The ventilation is to be able to provide at least 30 air changes per hour.

11.3

The ventilation ducting of spaces containing refrigerating machinery is not to be connected to the ventilation system serving the accommodation spaces, and the ventilation exhaust is to be led to the weather independently from other ventilation ducting.

11.5

The exhaust air ducts are to be airtight and the exhaust outlet is to be so positioned as to prevent re-circulation to other enclosed spaces.

11.7

Means are to be provided for stopping the ventilation fans and closing the ventilation openings from outside the refrigerated machinery spaces.

13 Compressors

13.1

The crankcase of trunk piston compressors and rotor casing of rotary compressors are to be designed to withstand a pressure equal to the maximum design pressure of the high pressure side of the system.

13.3

Air-cooled compressors are to be designed for an air temperature of at least 45°C (113°F). Water cooled compressors are to be designed for a water temperature of at least 32°C (90°F)

13.5 *(2024)*

Compressors of the positive displacement type over 10 kW (13.4 hp) are to be fitted with a relief valve or a bursting disc so arranged that the discharge is led from the high pressure side to the low pressure side in the event that the discharge valve is inadvertently closed. The capacity of the pressure relief device is to be sufficient to accommodate the discharge from the compressor when operating at full load at the maximum possible suction pressure for the refrigerant used.

Commentary:

Alternatively, discharge from the compressor may be led to the deck, if the outlets are located in accordance with 17.11.

End of Commentary

13.7

Compressor vibration resulting from gas pressure pulses and inertia forces is to be taken into account in the compressor design and mounting arrangement. Acceptable mounting arrangements include resilient rubber mounts, springs, etc.

13.9

The compressor is to be equipped with safety devices to automatically stop the compressor in accordance with 6-2-10/17.7 TABLE 1.

13.11

All compressors are to be equipped with gauges in accordance with 6-2-10/17.7 TABLE 1.

15 Pressure Vessels and Heat Exchangers

15.1 General

Pressure vessels and heat exchangers under refrigerant pressure are to be constructed in accordance with Part 4, Chapter 4.

15.3 Oil Recovery Equipment

Oil separators with automatic drains are to be provided upstream of the evaporator. For compressors which have gas intercoolers, oil separators are also to be provided between the low stage discharge and the inter cooler. Arrangements for recovering oil from surge pots are to be provided.

15.5 Refrigerant Filters and Dryers

15.5.1

Filters are to be provided in the liquid line upstream of the expansion valves and in the gas line on the suction side of the compressor.

15.5.2

Where the solubility of water in the refrigerant is low, dryers are to be provided to maintain the water vapor content below the value at which free water will occur in the low pressure side of the system. The dryers are to be located upstream of the expansion valves.

15.7 Liquid Receivers

15.7.1

The refrigerating system is to be provided with a liquid receiver with shut off valves arranged to accept and capable of holding the complete refrigerant charge of the refrigerating units during servicing or repairs. Where each refrigerating unit is fitted with an individual receiver, the capacity is to be sufficient to hold the charge from that unit.

15.7.2 *(2024)*

Liquid Receivers are to be provided with a means of level indication.

Commentary:

Flat glass type gauge glasses or tubular gauge glasses may be considered acceptable if they are fitted with approved self-closing valve at each end and are adequately protected from a mechanical damage. Details are to be submitted to ABS for technical approval.

End of Commentary

15.9 Expansion Valves

Expansion valves are to be suitable to achieve the required temperature for the refrigerant used.

15.11 Evaporators

Evaporators of the flooded type are to be provided with arrangements for recovering oil.

15.13 Brine Heater

Where arrangements for heating brine are by means of an auxiliary boiler, the capacity of the boiler is to be sufficient such that heating of all refrigerated cargo spaces can be performed simultaneously, whilst supplying other shipboard consumers under normal operating conditions.

17 *Safety Relief Devices*

17.1

Each refrigerant system is to be provided with pressure relief devices set to relieve at a pressure not greater than the design pressure. Where relief valves are fitted, they are to be of a type not affected by back pressure.

17.3

Pressure relief devices are not to be provided with means for isolation from the part of the system they are protecting. However, where overpressure protection is by means of dual pressure relief devices, the isolation arrangement described in 6-2-6/17.7 is acceptable.

17.5

Pressure vessels which contain liquid refrigerant and which may be isolated from the refrigeration system are to be protected by a pressure relief valve or bursting disc set to relieve at a pressure not greater than the design pressure.

17.7

Pressure vessels having an internal gross volume of 0.285 m^3(10 $ft.^3$) or greater are to use dual pressure relief valves or two bursting discs, or a combination thereof. These devices are to be fitted with a three-way valve to permit maintenance of either of the two relief devices without isolating the other. Where pressure relief is to the low pressure side of the refrigeration system, a single pressure relief valve may be used.

17.9

Sections of piping that can be isolated in a liquid full condition are to be provided with pressure relief valves to protect against excessive pressure due to temperature rise.

17.11

Discharge from pressure relief devices is to be led directly to the weather or the low pressure side of the refrigerant system for subsequent relief to the weather. The discharge outlet from these relief devices is to *be led away from ventilation inlets and openings. Prevention against the ingress of water, dirt and debris is to be provided.*

17.13

When the discharge from a pressure relief valve is led to the weather, further protection against loss of refrigerant through leakage is to be provided by means leak detectors located between the outlet and the relief valve.

17.15

The minimum required discharge capacity of the pressure relief device, in terms of air flow, for each pressure vessel is to be determined by the following formula:

$$C = fDL$$

where:

C = *Minimum required discharge capacity of the pressure relief device, in terms of air flow, kg/s (pounds per minute).*

D = *Outside diameter of the pressure vessel, in m (ft.).*

L = *Length of the pressure vessel, in m (ft.).*

f = *Factor applicable to type of refrigerant. The values for f of the more common refrigerants are listed in the following table:*

Refrigerant	***f*** ***metric (US units)***	***f**** ***metric (US units)***
R22	*0.131 (1.6)*	
R134a	*0.131 (1.6)*	
R404a	*0.18 (2.2)*	
R407a		*0.163 (2.0)*
R407b		*0.203 (2.5)*
R407c	*0.131 (1.6)*	
R410a		*0.163 (2.0)*
R410b	*0.197 (2.4)*	
R507		*0.203 (2.5)*
R717	*0.041 (0.5)*	

f - Factor proposed and under consideration.*

17.17

The internal diameter of the discharge pipe from the pressure relief device is not to be less than the outlet of that device. The internal diameter of a common discharge line serving two or more pressure relief devices which may discharge simultaneously is to be based upon the sum of their outlet areas with due allowance for the pressure drop in all downstream sections.

17.19

The maximum length of the discharge pipe serving a pressure relief device is to be determined by the following formula:

$$L = \frac{FP^2 d^5}{C_r^2}$$

where:

F	=	$1.95 \times 10^{-10} (1.88 \times 10^{-10}, 0.5625)$
L	=	*Length of the discharge pipe, m (ft.)*
P	=	*{Set pressure of relief device × 1.1} + 1.0 bar (1.0 kgf/cm^2, 14.7 psi).*
d	=	*Internal diameter of discharge pipe, mm (in.)*
C_r	=	*Rated discharge capacity of pressure relief device, in terms of air flow, kg/s (pounds per minute).*

19 Air Coolers

19.1

The design of the air cooler coils/cooling grids is to be based upon the total heat load and service conditions specified in 6-2-6/3.3 and the air circulation rates specified in 6-2-5/9.

19.3

To minimize the dehydration of fruit cargo and the frosting of air cooler coils/cooling grids, the refrigeration system is to be designed such that under steady state conditions, the inlet temperature of the refrigerant or secondary coolant circulating in the air cooler coils/cooling grids is not greater than 5°C (9°F) below the delivery air temperature for fruit cargoes and 10°C (18°F) below the return air temperature for frozen cargoes.

19.5

For each refrigerated cargo space over 300 m^3 (10,600 ft^3) cooled by air coolers, the air cooler coils are to be divided into at least two independent sections, so that any one of them can be isolated without affecting the operation of the others. Alternatively, at least two independent air coolers are to be fitted.

19.7

A defrosting system is to be installed.

21 Cooling Grids

For each refrigerated cargo space over 300 m^3 (10,600 ft^3) cooled by cooling grids, the cooling grids are to consist of at least two independent sections, so that any one of them can be isolated without affecting operation of the others.

23 Piping Systems

23.1 Design Considerations

23.1.1

Pipes, valves and fittings are to be in accordance with the requirements of Part 4, Chapter 6.

23.1.2

Refrigerant piping is to be designed to resist collapse when subjected to the drying procedure described in 6-2-16/1.3.

23.1.3

Where liquid refrigerant is being pumped near its saturation pressure, the refrigerant pump is to have a sufficient net liquid column above the pump centerline to provide the pressure required to cause liquid flow into the pump suction without flashing.

23.1.4 *(2024)*

Arrangements for preventing slugs of oil or liquid refrigerant entering the compressor suction are to be provided.

Commentary:

Collected oil or liquid refrigerant may be returned to the system by satisfactory means.

End of Commentary

23.1.5

Bulkhead and deck penetrations of refrigerant/secondary coolant pipes whose working temperature is below the normal ambient temperature are to be constructed so that the pipes do not come in direct contact with the steel members of the ship's structure.

23.1.6

Where liquid refrigerant is circulated through the system by pumps, the system is to be provided with a dedicated, readily interchangeable standby pump capable of replacing, without reduction in capacity, any operating pump.

23.1.7

Where secondary coolant is circulated through the system by pumps, the system is to be provided with a dedicated, readily interchangeable standby pump capable of replacing, without reduction in capacity, any operating pump.

23.1.8

Brine tanks are to be preferably of a closed type and have ventilating pipes led to the weather away from ventilation inlets and openings to accommodation spaces. Wire gauze is to be fitted to the ventilating pipe outlets.

23.1.9 *(2024)*

Where open type brine tanks are installed, the compartments in which they are located are to be adequately ventilated to prevent accumulation of objectionable vapor.

Commentary:

Where necessary, the refrigeration units may be interconnected on the discharge and/or suction side to facilitate operation of the individual compressors with each condenser and, where applicable, with each brine cooler.

End of Commentary

23.3 Corrosion Prevention and Insulation

23.3.1

Refrigerant/secondary coolant pipes within refrigerated chambers or embedded in the insulation and all refrigerant/secondary coolant pipes with working temperatures below ambient temperature are to be protected externally against corrosion. Steel pipes are to be galvanized on the outside or protected against corrosion by other equally effective methods approved by ABS.

23.3.2

Brine pipes are not to be galvanized internally.

23.3.3

Pipes welded or threaded in place, such as at pipe and flange connections, are to have their corrosion protection reinstated by an approved method.

23.3.4

All pipes indicated in 6-2-6/23.3, as well as valves and fittings whose working temperature is below the normal ambient temperature are to be effectively insulated. The insulation is to be sufficiently thick to prevent the formation of moisture on the pipe surface at a relative humidity of 90%. The insulation is to be free of discontinuities and is to be protected where there is a danger of damage, and its final layer is to be resistant to moisture penetration.

23.5 Valves and Fittings

23.5.1

Gate valves, ball valves and plug cocks are not to be fitted in the liquid refrigerant circuit unless consideration is given to the expansion of liquid trapped in the valve cavities when the valve or cock is closed.

23.5.2 *(2024)*

Valves in the refrigerant circuit are to be fitted with removable sealing caps or other alternative means to retain any leakage that can pass through valve glands and seals. However, remote controlled valves, or manual valves subject to regular operation, such as manifold valves, are acceptable without the removable caps subject to ABS technical assessment and approval.

23.5.3

Filters, strainers and refrigerant dryers are to be provided with isolation arrangements to enable their cleaning/replacement.

23.5.4

Automatic expansion valves are to be provided with manually operated bypass valves. Alternatively, duplicate automatic expansion valves are acceptable.

25 Tests and Inspections

25.1 Compressor

25.1.1

The Surveyor is to verify the materials used but need not witness the material tests.

25.1.2

The pressure boundary components of the compressor are to be hydrostatically tested in the presence of the attending Surveyors to 1.5 times the design pressure.

25.1.3

In addition to the hydrostatic test specified in 6-2-6/25.1.2, the compressors are to be leak tested in the presence of the attending Surveyor at the design pressure on the LP and HP side. This leak test is to be performed using the mediums referenced in 6-2-6/1.1.

25.1.4 *(2024)*

After completion of the tests referred to in 6-2-6/25.1.2, functional and capacity testing of the compressor is to be carried out in accordance with an approved program at the manufacturer's plant in the presence of the Surveyor. The functional tests are to include recording of the refrigerant used, temperatures, pressures, testing of alarms and shut down, pressure relief devices and vibration measurements such that the limits do not exceed those proposed by the manufacturer and that other features relating to the performance of the equipment are in accordance with the specification. Similarly, during the capacity test, power consumption and the refrigeration loads are to be recorded.

25.3 Pressure Vessels

25.3.1

Pressure vessels including condensers, coolers and heaters under refrigerant pressure are to be hydrostatically tested by the manufacturer to a test pressure equal to 1.5 times the design pressure in the presence of the attending Surveyor. The condenser, heaters and evaporators are to be pressure tested on both tube and shell sides.

25.3.2

Pressure vessels in the refrigerant and the brine system are to be leak tested and the procedure followed is to be in accordance with 6-2-16/1.1.3.

25.5 Piping

25.5.1 *(2024)*

After fabrication (e.g. bending, attachment of flanges and fittings, etc.), all refrigerant and brine pipes are to be subjected to a hydrostatic test pressure at 1.5 times the design pressure in the presence of the attending Surveyor.

Commentary:

The test can be performed pneumatically using a suitable inert gas such as nitrogen.

End of Commentary

25.5.2

The refrigerant and the brine piping is to be leak tested at the design pressure in accordance with the procedures in 6-2-16/1.1.3.

25.5.3

For tests after installation refer to Section 6-2-16.

25.7 Pumps

25.7.1

Refrigerant pumps and brine pumps are to be tested at the manufacturer's plant in the presence of the Surveyor. The pumps are to meet the hydrostatic and capacity test requirements of 4-6-1/7.5.2.

25.7.2

The refrigerant and the brine pumps are to be leak tested at the design pressure in accordance with 6-2-16/1.1.3.

25.9 Relief Devices

The setting of the relief devices is to be verified by the Surveyor.

PART 6

CHAPTER 2
Vessels Intended to Carry Refrigerated Cargoes

SECTION 7
Ancillary Systems

Note: Text in *italics* is considered necessary as conditions of classification (i.e., compulsory requirements). (See 6-2-1/5.3)

1 General *(2024)*

1.1 Objective

1.1.1 Goals

The ancillary systems covered in this section are to be designed, constructed, installed, operated, and maintained to:

Goal No.	*Goals*
CARGO 3	be equipped to handle and transfer cargo safely.
STAB 5	be able to remove accumulated liquids to mitigate the effects of flooding.

The goals covered in the cross-referenced Rules are also to be met.

1.1.2 Functional Requirements

In order to achieve the above stated goals, the design, construction, installation and maintenance of ancillary systems are to be in accordance with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
Cargo (CARGO)	
CARGO-FR1	Provide sufficient capacity and redundancy of cooling water systems to maintain the function of refrigeration unit while operating within the design parameters of the heat exchangers.
CARGO-FR2	Provide means to prevent the water entry from the overboard discharge line.
Stability (STAB)	
STAB-FR1	Provide means of drainage where spillage or leakage is expected during normal operations.

The functional requirements covered in the cross-referenced Rules are also to be met.

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been reviewed and approved by ABS. Refer to Part 1D, Chapter 2.

2 Cooling Water Systems

2.1 Design Considerations

2.1.1

Cooling water pipes, valves and fittings are to be in accordance with the requirements of Part 4, Chapter 6.

2.1.2

The supply of cooling water for condensers is to be available from at least two independent sea connections, one to be preferably on the port and the other on the starboard side.

2.1.3

The maximum cooling water velocity through each condenser is not to exceed manufacturer's recommendations.

2.3 Pumps

At least two independent pumps are to be installed for the supply of cooling water to the refrigeration unit(s), one of which is to act as a standby. The standby pump may be used for other general service duties except oil and bilge systems, provided its capacity is sufficient to simultaneously maintain the required supply of cooling water to the refrigeration unit(s).

2.5 Shell Connections

2.5.1

Shell connections are to be in accordance with the requirements of4-6-2/9.13

2.5.2

If the elevation of the condenser relative to the light water line is such that the manufacturer's recommended back pressure cannot be maintained in the overboard discharge line, then the overboard valve is to be of a spring loaded type.

3 *Bilge and Drainage Systems*

The refrigerating machinery space is to be efficiently drained. Bilge arrangements are to be in accordance with 4-6-4/5

PART 6

CHAPTER 2

Vessels Intended to Carry Refrigerated Cargoes

SECTION 8

Fire Extinguishing Systems and Equipment

Note:

Text in *italics* is considered necessary as conditions of classification (i.e., compulsory requirements). (See 6-2-1/5.3)

1 General *(2024)*

1.1 Objective

1.1.1 Goals

The fire extinguishing systems and equipment covered in this section are to be designed, constructed, operated, and maintained to:

Goal No.	*Goals*
FIR 1	*reduce the risk to life caused by fire (SOLAS II-2).*
FIR 2	*reduce the risk of damage caused by fire to the ship, and the environment (SOLAS II-2).*
FIR 3	detect, *contain, control and suppress fire and explosion in the compartment of origin (SOLAS II-2).*

The goals covered in the cross-referenced Rules are also to be met.

1.1.2 Functional Requirements

In order to achieve the above-stated goals, the design, construction, and maintenance of the fire extinguishing systems and equipment are to be in accordance with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
Fire Safety (FIR)	
FIR-FR1	Provide effective containment and extinction of any fire within space of origin with due regard to the fire growth potential of the protected spaces
FIR-FR2	Provide ready availability and easy accessibility to fire-extinguishing appliances.

The functional requirements covered in the cross-referenced Rules are also to be met

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the prescriptive requirements are complied with or when an alternative arrangement has been reviewed and approved by ABS. Refer to Part 1D, Chapter 2.

2 *Cargo Spaces*

Refrigerated cargo spaces are to be provided with a fixed fire extinguishing system complying with the requirements of 4-7-2/7.2.1. Where gas smothering system is used, the arrangements are to be in accordance with 4-7-3/3

3 *Refrigeration Machinery Spaces*

Where refrigeration machinery is located in a dedicated space, at least two portable fire extinguishers complying with 4-7-3/15 are to be provided in the space. One of the required portable fire extinguishers is to be stowed near the entrance to the space.

5 *Refrigerant Storage Space*

Spaces other than those referred to in 6-2-8/3 above, which contain refrigerant cylinders, are to be provided with at least one portable fire extinguisher complying with 4-7-3/15, which is to be stowed near the entrance to the space.

PART 6

CHAPTER 2

Vessels Intended to Carry Refrigerated Cargoes

SECTION 9

Electrical Systems

1 General

Except as noted herein, compliance with Part 4, Chapter 8, as applicable, is required.

1.1 Objective *(2024)*

1.1.1 Goals

The electrical systems covered in this section is to be designed, constructed, installed, operated, and maintained to:

Goal No.	*Goals*
POW 1	Provide safe and reliable storage and supply of fuel/energy/power.
POW 6	Have fail-safe features that prevent progressive failure in the event of failure of any single component.

The goals in the cross-referenced Rules are also to be met.

1.1.2 Functional Requirements

In order to achieve the above stated goals, the design, construction, installation and maintenance of the electrical systems are to be in accordance with the following functional requirements.

Functional Requirement No.	*Functional Requirements*
Power Generation and Distribution (POW)	
POW-FR1	The cable installation is to maintain the integrity of the refrigerated cargo insulation.
POW-FR2	Electrical equipment installed in refrigerated machinery spaces and refrigerated cargo holds are to be provided with enclosures suitably rated to prevent ingress of water/dust and with protection from mechanical damage.
POW-FR3	Power generation and distribution equipment is to be designed with redundancy to prevent loss of the refrigerating plant and essential/emergency services upon a single failure.
POW-FR4	Provide selective coordination of electrical protective devices to protect the refrigeration plants, isolate faults and keep intact parts running.

The functional requirements in the cross-referenced Rules are also to be met.

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the prescriptive requirements are complied with or when an alternative arrangement has been reviewed and approved by ABS. Refer to Part 1D, Chapter 2.

3 Cable Installation

Cables are not to be installed behind nor imbedded in the insulation. They may, however, pass through such insulation at right angles, provided they are protected by a continuous pipe with a stuffing tube at one end. For deck penetrations these stuffing tubes are to be at the upper end of the pipe and for bulkhead penetrations, on the un-insulated side of the bulkhead.

5 Electrical Installation in Refrigerating Machinery Room and Cargo Hold

5.1

Electrical accessories such as switches, detectors, junction boxes, etc. installed in the refrigerating machinery room are to have IP44 enclosure and all other electrical equipment is to have IP22 enclosure.

5.3

Electrical equipment installed in the cargo holds is to be protected from mechanical damage. All electrical equipment in the cargo holds is to have IP55 enclosure.

5.5

Electrical equipment installed in the ammonia refrigerating machinery spaces is to be in accordance with 6-2-11/13.3.

7 Power Supply *(2024)*

Where the refrigerating plant is electrically driven , the electrical power is to be available from at least two generating sets. The capacity of the generating sets is to be such that, in addition to providing the essential services for propulsion, safety of the ship, enviroment, and services for providing minimum comfortable conditions of habitability as required by 4-8-2/3.1, the following conditions are met:

7.1

Aggregate capacity of the generators is to be sufficient to supply the power to the refrigerating plant(s) mentioned in 6-2-6/3.3.2(a) or 6-2-6/3.3.3(a). Where the vessel is designed for the simultaneous carriage of integral refrigerated containers on deck, the aggregate capacity of the generators is to be sufficient to supply power to the refrigerated cargo spaces mentioned above and all the electrical power sockets for these containers, to enable all modes of operations including cool down.

7.3 *(2024)*

Where, due to operational requirements it is not necessary to supply power simultaneously to all the electrical sockets fitted for the refrigerated containers on deck, alternative aggregate capacity of power supply from the generators to that required in 6-2-9/7.1 can be considered, subject to ABS technical assessment and approval.

7.5

With any one generator out of action the remaining generator(s) are to be capable of supplying sufficient power to the refrigerating plant(s) and/or electrical power sockets in order to achieve and maintain the required steady state temperature in all the loaded cargo spaces and/or containers when operating under the conditions specified in 6-2-6/3.3.1, subject to the applicability of 6-2-9/7.3.

9 Transformer

9.1 *(2024)*

Where the refrigerating plants are supplied by power through transformers or converters, the system is to be so arranged as to ensure continuity of the power supply to the refrigerating plants as follows:

With any one transformer or converter out of action, a standby transformer or converter is to be capable of supplying the power to the refrigerating plants.

Commentary:

Alternatively, the above requirement may be satisfied provided there are alternative arrangements for supplying power to the circuit upon failure of the transformer or converter.

End of Commentary

11 System Design

Coordinated tripping is to be provided between feeder and branch circuit protective devices for refrigerating plants.

13 Testing and Inspection

13.1 Motor Control Centers and Distribution Boards

Motor control centers used for refrigerant plants are to be tested in the presence of the Surveyor in accordance with 4-8-3/5.11.3.

For distribution boards, the tests as per 4-8-3/5.11.3 may be carried out by the manufacturer whose certificate of tests will be acceptable.

13.3 Motors

Motors of 100 kW (135 hp) and over are to be tested in the presence of the Surveyor in accordance with 4-8-3/15 TABLE 3. For motors below 100 kW (135 hp), the tests as per 4-8-3/15 TABLE 3 may be carried out by the manufacturer whose certificates of tests will be acceptable.

13.5 Electrical Installation

Testing of the electrical installation for refrigeration machinery is to be carried out in accordance with 4-8-4/29.

PART 6

CHAPTER 2
Vessels Intended to Carry Refrigerated Cargoes

SECTION 10
Instrumentation, Control and Monitoring

Note:

Text in *italics* is considered necessary as conditions of classification (i.e., compulsory requirements). (See 6-2-1/5.3)

1 General

1.1 Objective *(2024)*

1.1.1 Goals

The instrumentation, control and monitoring systems covered in this section are to be designed, constructed, installed, operated, and maintained to:

Goal No.	*Goals*
AUTO 1	Perform its functions as intended and in a safe manner.
AUTO 2	Indicate the system operational status and alert operators of any essential machinery/systems deviate from its defined design/operating conditions or intended performance.
AUTO 3	Have an alternative means to enable safe operation in the event of an emergency or failure of remote control.
AUTO 4	Provide the equivalent degree of safety and operability from a remote location as those provided by local controls.
AUTO 5	Provide a safety system that will automatically lead machinery controlled to a fail-safe state in response to a fault which may endanger the safety of persons on board, machinery/equipment or the environment.
AUTO 6	Independently perform different functions, such that a single failure in one system will not render the others inoperative.
CARGO 5	Enable monitoring of the cargo and vessel storage, securing, or containment systems.

The goals in the cross-referenced Rules/Regulations are also to be met.

1.1.2 Functional Requirements

In order to achieve the above stated goals, the design, construction, installation and maintenance of the instrumentation, control and monitoring systems are to be in accordance with the following functional requirements.

Functional Requirement No.	*Functional Requirements*
Cargo (CARGO)	
CARGO-FR1	Control and monitoring are to be provided such that the suitable carriage environment for the cargo is maintained during all service conditions.
CARGO-FR2	Quantity, location, and accuracy of sensors are to be selected based on refrigerated space arrangements and specific cargoes.
CARGO-FR3	Provide effective means to detect refrigerant leakage considering capacity of system and volume of associated spaces.
CARGO-FR4	Means are to be provided to automatically alarm and reduce the concentration of refrigerant vapor such that the level of oxygen in the space does not reach IDLH (Immediately Dangerous to Life and Health) levels.
CARGO-FR5	Provide means to initiate alarm from the refrigerated and air-cooled spaces locally.
CARGO-FR6	Temperature of the refrigerated space is to be able to be monitored from outside the space.
CARGO-FR7	CO_2 content is to be effectively monitored and controlled to extend the storage length and flavor of fruits.
Automation: Control, Monitoring and Safety Systems (AUTO)	
AUTO-FR1	Provide display of system parameters and alarms at the control and monitoring stations located at suitable manned locations for the safe operation of the refrigeration equipment/ machinery.
AUTO-FR2	When remote control and monitoring is provided, independent controls and monitoring are to be provided and selectable locally .
AUTO-FR3	Temperature control and monitoring equipment are to be designed with redundancy and independence in order to safeguard against loss of monitoring upon failure of control equipment and vice versa.
AUTO-FR4	Provide means to disable automatic controls for manual control during emergency situations.
AUTO-FR5	Alarm system is to be designed as fail-safe as well as self-monitoring type and be arranged to allow testing.

The functional requirements in the cross-referenced Rules/Regulations are also to be met.

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the prescriptive requirements are complied with or when an alternative arrangement has been reviewed and approved by ABS. Refer to Part 1D, Chapter 2.

1.2

The control and monitoring systems are to be provided such that the selected carriage temperature for the individual cargo spaces is maintained during all service conditions. The monitoring system is to be provided for refrigerating machinery and refrigerated cargo space temperatures.

1.3 *(2024)*

For fruit carriers, the monitoring and control systems are additionally to continuously monitor the CO_2 levels in cargo spaces and to maintain at below the levels selected during all service conditions.

3 Control

3.1

Control, instrumentation and monitoring necessary for operation are to be provided at or in the proximity to the refrigeration machinery, the centralized control and monitoring station of the propulsion machinery, the navigation bridge or other similar spaces.

3.3

Where the refrigeration machinery is remotely controlled from the centralized control and monitoring station of the propulsion machinery, the navigation bridge or other similar spaces, means of independent controls and instrumentation and monitoring necessary for operation are to be provided at or in the proximity to the refrigeration machinery together with means provided locally to disconnect or override associated remote controls.

3.5

See 6-2-10/17.7 TABLE 1 for required displays and alarms.

3.7

The control and monitoring for the temperature of circulating air entering and leaving each air cooler is to be independent from each other.

5 Temperature Measuring Equipment

5.1 Minimum Number of Sensors

The minimum required number of sensors in a refrigerated space is to be determined based on the capacity and geometry of the space, as follows:

4 for up to a 250 m^3 (8,828 $ft.^3$) space.

5 for up to a 400 m^3 (14,124 $ft.^3$) space.

6 for up to a 700 m^3 (24,178 $ft.^3$) space.

7 for up to a 1200 m^3 (42,373 $ft.^3$) space.

8 for up to a 1900 m^3 (67,090 $ft.^3$) space.

10 for up to a 2800 m^3 (98,870 $ft.^3$) space.

5.3 Location of Sensors

In addition to 6-2-10/5.1, in each refrigerated space with forced air circulation through air coolers, at least one sensor is required for the circulating air. See also 6-2-10/3.7.

5.5 Remote Temperature Measurement

5.5.1

Sensors in refrigerated spaces are to be arranged in such a way that temperature reading is possible without entering the spaces.

5.5.2

Each refrigerated cargo space is to be provided with at least two temperature measuring instruments with separate power supply such that the temperature measurement of the space is possible in the event of a fault in any one of the measuring instruments.

5.5.3

Temperature reading devices or similar means are to be fitted for maintaining a log of cargo hold temperature.

5.5.4 *(2024)*

Where temperature measuring systems are supplied by an individual source of power supply, such as transformer, converter or battery, a stand-by source of power is to be provided.

Commentary:

Alternatively, the above requirement can be satisfied provided there are alternative arrangements for supplying power to the circuit upon failure of the transformer, converter or battery.

End of Commentary

5.5.5

Number and arrangement of the remote temperature measuring system sensing elements is to comply with 6-2-10/5.1 and 6-2-10/5.3. The temperature sensing elements are to be permanently connected to their instruments and well protected against damage.

5.7 Accuracy, FSD (Full Scale Deflection) Range

5.7.1

The measuring range of the system is to cover the entire anticipated temperature range plus an additional ±5°C (9°F).

5.7.2

The accuracy of the temperature measuring equipment is to be within ±0.5°C (0.9°F) for frozen cargo and ±0.2°C (0.4°F) for fruit.

5.7.3

Accuracy of instrumentation to a value higher than that stated in 6-2-10/5.7.2 above is required by some Administrations depending on the cargoes carried. Accordingly, due attention is to be given to the requirements of various Port States during the design stages of the temperature monitoring and control systems if it is intended for the vessels to transport cargoes to and from these ports.

7 CO_2 Measuring Equipment

All refrigerated cargo spaces intended for carriage of fruit are to be fitted with permanently installed equipment for indication of CO_2 content. The sensors are to be suitably positioned in the cargo spaces and are to be located away from the fresh air ducts.

9 *Refrigerant Leakage Detection*

9.1

Where the quantity of the refrigerant charge in the largest system exceeds the following per unit volume of the spaces in which it is located, the spaces containing the refrigerating machinery, and in the case of a direct expansion system, the refrigerated cargo spaces, are to be provided with a refrigerant leakage detection system complying with 6-2-10/9.3 and 6-2-10/9.5.

Refrigerant	*Concentration, kg/m ^{3} (lb/ft. ^{3})*
R22	*0.14 (0.009)*
R134a	*0.25 (0.016)*
R404a	*0.48 (0.030)*
R407a	*0.33 (0.021)*
R407b	*0.35 (0.022)*
R407c	*0.35 (0.022)*
R410a	*0.44 (0.028)*
R410b	*0.43 (0.027)*
R507	*0.49 (0.031)*

9.3

The Refrigerant vapor detection system is to give an alarm and start mechanical ventilation in the event of refrigerant concentration exceeding the time weighted average to which personnel may be repeatedly exposed to in the spaces.

9.5 *(2024)*

The refrigerant vapor detection system referenced in 6-2-10/9.3, is also to be arranged to give an alarm and start mechanical ventilation when the refrigerant concentration exceeds a level where oxygen levels in the refrigerant machinery space are below 19.5% by volume.

Commentary:

Alternatively, sensors for monitoring the oxygen level in the machinery space may be fitted and arranged to give an alarm when oxygen levels drop below 19.5%.

End of Commentary

11 Instrumentation and Monitoring

The indications and alarms in accordance with 6-2-10/17.7 TABLE 1 are to be provided at or in the proximity to the refrigeration machinery, the centralized control and monitoring station of the propulsion machinery, the navigation bridge or other similar spaces.

13 *Alarm Call Button*

All refrigerated spaces and air cooler rooms are to be fitted with at least one alarm call button located near the exit.

15 Automatic Controls

15.1 General

Where automatic control is fitted compliance with the following is required, additionally the arrangements are to be in compliance with 1 through 13.

The control systems are to be designed to automatically maintain the selected carriage temperature in the individual cargo spaces and additionally for fruit carriers, the CO_2 level.

15.3 Control and Monitoring

15.3.1

The alarms and the indication as listed in 6-2-10/17.7 TABLE 1 are to be provided at the locations mentioned in 6-2-10/3.1.

15.3.2

Instrumentation and means of independent control and monitoring necessary for operation are to be provided at or in the proximity of the refrigeration machinery.

15.3.3

Adequate arrangements are to be provided to disable the automatic control mode and restore manual control.

15.5 Alarm Systems

15.5.1

Alarm systems are to be of the self-monitoring type and designed so that a fault in the alarm system will cause it to fail to the alarmed condition.

15.5.2

Alarming of other faults that may occur during the acknowledgment process is not to be superseded by such action.

15.5.3

Alarm systems are to be provided with effective means of testing.

15.7 Computer Based Systems *(2024)*

Computer based system where used for control, alarm and monitoring systems associated with refrigerated cargoes are to comply with the requirements in Section 4-9-3.

15.9 Testing of Equipment

Testing of equipment associated with automatic or remote control systems, monitoring systems and computer-based systems is to be in accordance with Section 4-9-9.

For equipment that has been certified by ABS on an individual basis or certified under the ABS Type Approval Program, the tests carried out previously for compliance with Section 4-9-9 are acceptable provided that the equipment being proposed in identical to the one previously tested.

17 Testing after Installation on Board

The following tests are to be carried out to the satisfaction of the Surveyor:

17.1

Local control of the refrigerating machinery is to be demonstrated. This is to include a demonstration of independent manual control and the disconnection or override of the automatic control system.

17.3

Where automatic control or remote control is provided, the ability to control from a remote control station is to be demonstrated. This is to include a demonstration to disable the automatic control mode and restore manual controls.

17.5 *(2024)*

The required alarm control systems and displays are to be verified for compliance with applicable requirements in Section 4-9-10 and satisfactory operation at the predefined set points.

17.7

The following equipment or systems are to be tested:

- The accuracy of the temperature measuring equipment in accordance with 6-2-10/5.7.
- CO_2 measuring system for refrigerated cargo spaces in accordance with 6-2-10/7.
- *Refrigerant leakage detection system in accordance with 6-2-10/9.*
- *Alarm call button in accordance with 6-2-10/13.*

TABLE 1
Instrumentation and Alarms

Item		*Display*	*Alarm*	*Remarks*
Compressor	Automatic stop		Activated	
	Lubricating oil	*Pressure	Low	Automatic stop (Low pressure)
	Driving motors	Running	Stop	
	Available driving motors	Running	Start	For auto start
	Discharge line - Pressure - Temperature - Superheat	*Pressure	High	Automatic stop (High pressure)
		*Temperature	High/Low	Automatic stop (High temp.)
		*Temperature	High	Automatic stop
	Suction line - Pressure - Temperature - Superheat	*Pressure	Low	Automatic stop (Low pressure)
		*Temperature	High	
		*Temperature	Low	Automatic stop (Low temp.)
	Intermediate stage (if fitted)	*Pressure	High	Automatic stop(High pressure)
Brine Lines	Brine pumps	Running	Stop	
	Available pumps	Running	Start	For auto start
	Brine cooler - inlet/ outlet	*Temperature	High (outlet)	
	Pressure line	*Pressure	Low	
	Header tank	*Level	Low	
Condenser	Cooling water pumps	Running	Stop	
	Available cooling water pump	Running	Start	
	Cooling water - inlet	*Temperature		
	Cooling water - outlet	*Temperature	High	
Refrigerant receiver	Level	*Level	High/Low	

Item		*Display*	*Alarm*	*Remarks*
Refrigerating Machinery space	O_2 content (or, excessive refrigerant vapor content)		below 19.5% (excessive)	
Refrigerant leakage	Concentration in Refrigerating machinery space		Leakage (ppm above as per 6-2-10/9.3)	
	Concentration in Refrigerated spaces		Leakage (10 ppm)	Direct system
	Detection system		Failure	
Refrigerated spaces	Temperature measuring	Temperature	Deviation from set point	
	Left/Right hand cooler delivery air/return air	Temperature	Deviation from set point	
	CO_2 content	Percentage	Higher than the set point	For fruit carriers
	Fresh air fan (Full/Half speed)	Stop / Running/ Auto	Failure	
	Ventilation fan (Full/ Half speed)	Stop/Running	Failure	For fruit carriers
Relative Humidity	Percentage		Deviation from set point	
Defrost	Time duration		Disabled	

Note: Those devices marked (*) are to be provided at or in the proximity to the refrigeration machinery.

PART 6

CHAPTER 2

Vessels Intended to Carry Refrigerated Cargoes

SECTION 11

Ammonia Refrigeration System

Note:

Text in *italics* is considered necessary as conditions of classification (i.e., compulsory requirements). (See 6-2-1/5.3)

1 General

1.1 *(2024)*

Refrigerating machinery using ammonia is to be designed, constructed and installed in accordance with the requirements of this Section and other applicable requirements of the Rules.

1.3

Ammonia is to be used as a primary refrigerant in indirect refrigeration systems.

1.5 *(2024)*

Ammonia refrigerant for use in direct expansion systems on-board refrigerated fish carriers is acceptable subject to an ABS technical assessment of all the features necessary for the safety of the installation.

2 Objectives *(2024)*

2.1 Goals

The ammonia refrigeration systems (i.e., refrigerating units and associated equipment) covered in this section are to be designed, constructed, installed, operated, and maintained to:

Goal No.	*Goals*
SAFE 1.1	Minimize danger to persons on board, the vessel, and surrounding equipment/installations from hazards associated with machinery and systems
FIR 1	*Prevent the occurrence of fire and explosion. (SOLAS II-2/Reg 2.1.1)*
EER 1	*Provide means of escape so that persons on board can safely and swiftly escape to a protected place of refuge, muster station, or embarkation station. (SOLAS II-2/Reg 13.1)*

Goal No.	*Goals*
AUTO 2	Indicate the system operational status and alert operators of any essential machinery/systems deviate from its defined design/operating conditions or intended performance
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.

The goals in the cross-referenced Rules are also to be met.

2.3 Functional Requirements

To achieve the above stated goals, the design, construction, installation and maintenance of the ammonia refrigeration system (i.e., refrigerated units and associated equipment) is to be in accordance with the following functional requirements.

Functional Requirement No.	*Functional Requirements*
Safety of Personnel (SAFE)	
SAFE-FR1	Ammonia refrigerating machinery & storage spaces are to be located in a dedicated space with arrangements to prevent spread of ammonia into adjacent spaces due to a leakage.
SAFE-FR2	Provide means operable from outside the ammonia refrigerating machinery spaces to reduce the impact of exposure to ammonia due to a leakage from the spaces.
SAFE-FR3	Accommodation and machinery spaces are to be protected from possible hazards due to ammonia leakage or fire from the ammonia refrigerating machinery spaces and storage spaces.
SAFE-FR4	Adequate ventilation is to be provided to prevent the accumulation of ammonia and the ventilation systems are to be arranged to prevent communication of ventilated air with other ventilation systems for personnel safety.
SAFE-FR5	Ventilation, gas evacuation and other ammonia removal systems are to be operable from safe areas.
SAFE-FR6	Exhaust duct/vent outlets from the ammonia refrigerating machinery spaces are to be arranged such that the discharge of any ammonia do not disperse into other enclosed spaces.
SAFE-FR7	Adequate drainage system for ammonia refrigeration space is to be provided to prevent the build-up on free surfaces and is to be arranged not to contaminate adjacent or other machinery spaces or accommodation spaces.
SAFE-FR8	If water based ammonia removal means are provided, design, arrangements, and capacity are to be suitable for the intended service.
SAFE-FR9	Electrical equipment are to be protected against ingress of foreign objects and liquids based on location of installation.
SAFE-FR10	Sufficient protective safety equipment for crew is to be provided in safe and easily accessible location outside the ammonia refrigerated machinery space and ammonia cylinders storage space to prevent and respond to ammonia related hazards.
SAFE-FR11	Discharge piping connected to the discharge side of safety valves is to be arranged to prevent plugging the pipe.
SAFE-FR12	The discharges are to be terminated in a manner that will prevent both the discharged refrigerant from being sprayed directly on personnel in the vicinity and foreign material or debris from entering the discharge piping.
SAFE-FR13	Ammonia refrigeration system is to be provided with means to maintain a clean condition, free from accumulations of oily dirt, waste, and other debris.

Functional Requirement No.	*Functional Requirements*
SAFE-FR14	Provision shall be made to protect the ammonia pipes from excessive stresses due to thermal movement.
SAFE-FR15	Piping joints are to be such that it minimizes the possibility of Ammonia leakage.
SAFE-FR16	Discharge pipes of cooling sea water from condenser is to be designed such that other systems are not contaminated and do not endanger safety of person onboard, other equipment/systems and environment.
Fire Safety (FIR)	
FIR-FR1 (SAFE)	Provide additional means of ventilation to quickly dissipate large volume of ammonia leakage due to an accident.
FIR-FR2	Electrical installations in hazardous areas are to be restricted to minimize the potential risks that might affect the safety of the ship, persons on board and equipment.
FIR-FR3	Electrical equipment and cables installed in hazardous areas are to be suitable for the environment (gas group and temperature classification) in which they operate.
FIR-FR4	If the electrical equipment is not a certified safe type, means are to be provided to automatically shutdown electrical equipment that poses risk of ignition in case of an ammonia leakage.
Escape, Evacuation Rescue (EER)	
EER-FR1	Redundant means of egress from refrigerating machinery space are to be provided to escape from the spaces to safe spaces in case of an emergency.
Automation: Control, Monitoring and Safety Systems (AUTO)	
AUTO- FR1	Ammonia leakage in the cooling water system is to be measured and notified.
AUTO- FR2	Drains of the refrigerant system are to be monitored and removed effectively.
AUTO- FR3	Provide effective means to detect and notify the leakage of ammonia for immediate actions to maintain a safe environment within the refrigerating machinery space and the spaces where ammonia leakage is expected.
Material (MAT)	
MAT-FR1	All the materials used in ammonia refrigerated systems including machineries, piping, electrical are to be capable of operating in any adverse situation.

The functional requirements covered in the cross-referenced Rules are also to be met.

2.5 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been reviewed and approved by ABS. Refer to Part 1D, Chapter 2.

3 *Design Considerations*

3.1 *Location of Refrigeration Machinery*

3.1.1

Refrigerating units and associated equipment which contain ammonia are to be located in a dedicated space.

3.1.2

The dedicated space referred to in 6-2-11/3.1.1 is to be separated by gastight steel bulkheads and decks from other spaces.

3.3 *Access and Openings*

3.3.1

Access doors to the refrigerated machinery space are to be in accordance with the following requirements:

3.3.1(a) A minimum of two access doors located as far apart as possible are to be provided, one of which is to lead directly to the open deck. Water screens are to be provided above access doors, operable manually from outside the compartment.

3.3.1(b) The access doors are to be gastight and self-closing with no holdback arrangements and are to open outward from the refrigeration machinery space.

3.3.1(c) Access doors are not to open to the accommodation spaces.

3.3.1(d) Where one access is from a Category "A" machinery space, it is to be fitted with double door separation having a minimum space of 1.5 m (4.9 ft) between each door. The doors are to be self-closing and gastight with no holdback arrangements and the space between each door is to be provided with an independent ventilation system, the exhaust from which is to be led to atmosphere. Alternative access arrangements are acceptable provided a similar level of safety is maintained.

3.3.2

Access corridors leading to the refrigerating machinery space are to be ventilated by means of an independent mechanical exhaust system. This is not required if the ventilation system required by 6-2-11/3.5 is also arranged to draw from the access corridors.

3.3.3

Duct, pipe and cable penetrations of bulkheads and decks of the ammonia refrigerating machinery spaces are to be made gastight.

3.5 *Ventilation of the Refrigeration Machinery Space*

The ammonia refrigerating machinery space is to be efficiently ventilated by means of mechanical exhaust ventilation designed in accordance with the following requirements:

3.5.1

The ventilation system is to be independent of other shipboard ventilation systems.

3.5.2

The ventilation system is to be designed for continuous operation.

3.5.3

The capacity of the ventilation system is to be of sufficient capacity for at least 30 air changes per hour based on the total empty volume of the space.

3.5.4

Means are to be provided for stopping the ventilation fans and closing the ventilation openings from a readily accessible position.

3.5.5

Air inlet openings are to be positioned as low as practicable in the spaces being ventilated and exhaust openings as high as practicable that no ammonia accumulates in the space.

3.5.6

Exhaust duct outlets are to be positioned at least 10 m (33 ft.) from air intake openings, openings to accommodation spaces and other enclosed areas, and at least 2 m (6.5 ft.) above the open deck.

3.5.7

Ventilation fans are to be of non-sparking construction in accordance with 4-8-3/11.

3.7 *Emergency Ventilation of Ammonia Refrigeration Machinery Space*

Ammonia refrigerating machinery spaces are to be provided with a mechanical exhaust type gas evacuation system to quickly dissipate a catastrophic leak of ammonia to reduce the risk of fire and explosion. The system is to be designed and constructed in accordance with the following requirements:

3.7.1

The gas evacuation system is to be independent of other shipboard ventilation systems; however, it need not be independent of the ventilation system required in 6-2-11/3.5.

3.7.2

The gas evacuation system is to be arranged to automatically start when the concentration of ammonia in the space exceeds 300 ppm.

3.7.3

The combined capacity of the ventilation and gas evacuation fans is to be based upon the larger of the following:

[A] A volume of 40 air changes per hour based on the total empty volume of the space;

or;

[B] The capacity calculated using the following formula:

$$Q = kG^{0.5}$$

where

k = *0.07 (3.66)*

Q = *minimum combined capacity, in m^3/s (ft^3/s)*

G = *mass of ammonia in the largest refrigerating unit, in kg (lbs)*

3.7.4

The gas evacuation system controls are to be positioned outside of the space.

3.7.5

The exhaust duct outlets are to be positioned at least 10 m (33 ft.) from air intake openings, openings to accommodation spaces and other enclosed areas, and at least 2 m (6.5 ft.) above the open deck. In addition, the vent outlets are to be directed upward and arranged such that the discharge of any ammonia vapors is away from accommodations and other occupied areas.

3.7.6

Gas evacuation fans are to be of non-sparking construction in accordance with 4-8-3/11.

3.9 *Drainage of Ammonia Refrigeration Machinery Space*

3.9.1

The ammonia refrigerating machinery space(s) is to be fitted with an independent bilge system.

3.9.2

The deck plating is to be arranged to facilitate easy cleaning and drying. No other plating above the deck is to be provided.

3.9.3

Where a deluge system (see 6-2-11/3.11) is fitted, the drainage and pumping arrangements are to be such as to prevent the build-up of free surfaces. The drainage system is to be sized to remove not less than 125% of the capacity of the water-spraying system.

3.11 *Deluge System*

Where a water deluge system is fitted, the emergency gas evacuation system in 6-2-11/3.7 may be reduced by 20%. The water deluge system arrangements are to be as follows:

3.11.1

The system is to be independent but may also be used for supply to the water screens required by 6-2-11/3.3.1(a).

3.11.2

The deluge system is to contain fresh water through a pressurized system.

3.11.3

The discharge nozzles in the space(s) protected are to be positioned such that the spray is directed over the entire area containing the Ammonia refrigeration machinery.

3.11.4

The pressurized system is to consist of two pumps, a tank with a capacity to maintain discharge for a period of 30 minutes to all the nozzles simultaneously in the protected space(s), the tank to be fitted with adequate safety relief arrangements, pressure gauge(s), level control and level gauge.

3.11.5

Means are to be provided to automatically maintain the required pressure and the water level in the tank. In the event of low pressure or the low level, an audible alarm is to sound in the refrigeration machinery room, refrigeration cargo control room, if fitted, and the engine room.

3.11.6

The water deluge system is to be arranged to automatically start when the concentration of ammonia in the space exceeds 300 ppm.

3.11.7

The electrical equipment in the Ammonia refrigeration compartment is to be to IP55 enclosure.

3.13 *Storage of Ammonia Cylinders*

3.13.1

A maximum of 140 kg (308 lb) of reserve ammonia may be stored in the refrigerating machinery space. Reserve ammonia in excess of this amount is to be stored in a separate storage space designed and constructed in accordance with the requirements of this Section, unless 6-2-11/3.13.7 is applicable.

3.13.2

Portable steel ammonia storage cylinders satisfying the requirements of 6-2-6/5.15 are to be stowed in an efficiently ventilated dedicated space.

3.13.3

The ammonia storage space is to comply with the requirements of 6-2-11/3.1.2, 6-2-11/3.3.3 and 6-2-11/3.9.

3.13.4

Access doors to the storage space are to be in accordance with 6-2-11/3.3.1, except that two doors are not required.

3.13.5

The storage space is to be provided with a mechanical ventilation system complying with 6-2-11/3.5. Where the storage space is adjacent to the refrigerating machinery space, a common ventilation system servicing both spaces is accepted.

3.13.6

Means for secure stowage and handling of the steel storage cylinders are to be provided.

3.13.7 *(2024)*

Where due to limited space, the provision of a separate storage space is impracticable, alternative solutions such as location of the storage cylinders in the space containing the ammonia refrigeration machinery are acceptable provided that the water deluge system and the leakage detection system is extended to take account of the additional ammonia stored in the space.

5 Materials

5.1

Components in contact with ammonia are not to contain copper, zinc, cadmium or alloys of these materials.

5.3

Components of rubber or plastic materials likely to be exposed to ammonia are not to be used.

5.5

Material for sea water cooled condensers is to be corrosion resistant to sea water.

7 Personnel Safety Equipment

7.1

An eye wash and shower unit are to be provided immediately outside the refrigerating machinery room.

7.3

The following safety equipment is to be provided and stored in a readily accessible protected location outside the refrigerating machinery room and is to be in addition to the equipment required by 4-7-3/15.5:

- At least two sets of ammonia protective clothing, including refrigerant gas mask, helmet, boots and gloves.
- *At least two sets of fireman's outfits complying with 4-7-3/15.5.*
- Two or more power driven air compressors, to recharge breathing apparatus cylinders.

- *One heavy duty adjustable wrench.*
- *Bottles of boric acid, vinegar and eye cups.*

9 *Safety Devices*

9.1

A rupture disc is not to be used in series with the safety relief valve.

9.3

The discharge from safety relief valves on the ammonia side is to be led into the sea below the lightest water line or into the water dump tank near the bottom of the tank.

9.5

Ammonia refrigeration systems are to be provided with automatic air purging devices. The discharge from the purging devices is to be led overboard below the lightest water line or to the water dump tank such that the discharge opening is submerged at all times. Where the connection is lead overboard, the discharge pipe is to be of heavy grade.

9.7

Where condensers are cooled by fresh water which is re-circulated, the fresh water system is to be equipped with pH meters to activate audible and visual alarms in the event of an ammonia leak.

11 Piping Arrangements

11.1

Ammonia pipes are to have provision for expansion and contraction encountered in service. The use of metallic flexible hoses for this purpose will be subject to approval by ABS.

11.3

Where flexible bellows are intended to be used in the ammonia refrigerant system, details and test data to show their suitability for the intended service are to be submitted.

11.5

Joints for piping conveying ammonia are to be butt welded as far as practicable. For pipes up to 25 mm (1 in) nominal diameter, socket welded joints are acceptable. Flanged joints are to be kept to a minimum and precautions are to be taken prior to disconnecting any such joints during repair and maintenance.

11.7

Piping for discharge of cooling sea water from the condenser is to be independent of other sea water piping systems and is to be led directly overboard without passing through accommodations or Category A machinery spaces.

11.9

Oil traps and oil drains are to be provided at the low points of the refrigerant system. Gauge lines and branches to level controls are not to be in locations where oil is likely to accumulate.

11.11

Overboard discharges are to be in accordance with 4-6-2/9.13.

13 Electrical

13.1 General

Except as noted herein, compliance with Section 6-2-9 is required.

13.3 *Equipment and Installation in Hazardous Area*

Ammonia refrigerating machinery spaces and storage spaces are considered hazardous locations. Electrical equipment and wiring are not to be installed in such locations unless essential for operational purposes. Where electrical equipment is installed in the above spaces, the following conditions are to be met:

13.3.1

Electrical equipment operated in the event of ammonia leakage, such as vapor detection and alarm system, is to be intrinsically safe type.

13.3.2

Emergency lighting fixtures of explosion proof type are to be provided in the above spaces. The switches for the lights are to be double pole type and located outside these spaces.

13.3.3

Electrical motors for gas evacuation fans or ventilation fans, if used for the gas evacuation system, are not to be located in the fan ducts or inside the ammonia refrigerating machinery spaces. They are to be located outside the hazardous areas.

13.3.4

For electrical equipment other than those referenced in 6-2-11/13.3.1 and 6-2-11/13.3.2, means are to be provided for automatic de-energizing when the concentration of ammonia vapor in the space exceeds 10,000 ppm.

13.3.5

Cables in these spaces are to be armored and the penetrations are to be through gas tight fittings.

15 Instrumentation, Control and Monitoring

15.1 General

Instrumentation, control and monitoring for the ammonia refrigeration system is to be in accordance with Section 6-2-10 and the following requirements.

15.3 *Ammonia Vapor Detection and Alarm System*

15.3.1

An ammonia vapor detection and alarm system is to be provided for the following locations:

15.3.1(a) The refrigerating machinery spaces; one detector per 36 m^2 (387 ft^2) of the space floor area.

15.3.1(b) One detector in the exhaust duct of the refrigerating machinery space ventilation system.

15.3.1(c) The access corridors leading to the ammonia refrigerating machinery spaces.

15.3.1(d) One detector in the ammonia storage space.

15.3.2

If the concentration of ammonia exceeds 25 ppm, the detectors are to activate audible and visual alarms. In addition, if the concentration of ammonia exceeds 300 ppm, the detectors in the refrigerating machinery space are to stop the refrigerating plant and activate the gas evacuation system.

15.3.3

Additional ammonia vapor detectors set to provide an alarm in a continuously manned space if the ammonia concentration exceeds 500 ppm, are to be provided in the discharge pipes from safety relief valves.

15.3.4

Note that the refrigerant leakage detection system required in 6-2-11/15.3.1 is in lieu of the system required by 6-2-10/9.

15.5 *Instrumentation and Alarms*

The alarms listed in 6-2-11/15.5 TABLE 1 are to be provided at the locations specified in 6-2-10/3.

TABLE 1
Instrumentation and Alarms *(2024)*

<table>
<tr><th>Item</th><th>Location</th><th>Display</th><th>Alarm</th><th>Remarks</th></tr>
<tr><td>Condenser</td><td>Leakage of ammonia into cooling fresh water system</td><td>pH Meter</td><td>Leakage</td><td>Where condensers are cooled by fresh water</td></tr>
<tr><td>Water Dump Tank</td><td>Water Dump Tank</td><td>Level</td><td>Low</td><td>-</td></tr>
<tr><td rowspan="3">Ammonia Vapor Detection</td><td rowspan="2">Locations Mentioned in 5C-18-6/3.15.2.i</td><td>-</td><td>Exceed 25 ppm</td><td>-</td></tr>
<tr><td>-</td><td>Exceed 300 ppm</td><td>Refrigerating Plant Automatic Stop and Activation of Gas Evacuation, Water Screens and Deluge System</td></tr>
<tr><td>Discharge Pipes from Safety Valves</td><td>-</td><td>Exceed 500 ppm</td><td>-</td></tr>
</table>

17 Tests and Inspections

17.1

Gas tightness of openings or doors referred to in 6-2-11/3.3 is to be verified by the attending Surveyor.

17.3

Electrical isolation of the refrigeration equipment at the set limit of 10,000 ppm of ammonia is to be demonstrated.

17.5

Ventilation air changes are to be verified by the attending Surveyor.

17.7

Satisfactory operational test of the emergency ventilation system required by 6-2-11/3.7 is to be verified by the attending Surveyor.

17.9

Ammonia vapor detection and alarm system is to be demonstrated. This is to include a demonstration of the required audible and visual alarms and stopping the refrigerating plant and activation of the gas evacuation system in accordance with 6-2-11/15.3 .

17.11

The required alarms and displays are to be verified for satisfactory operation at the predefined set points.

17.13

Automatic de-energizing of non-intrinsically safe electrical equipment required in 6-2-11/13.3.4 is to be demonstrated in the presence of the Surveyor.

PART 6

CHAPTER 2
Vessels Intended to Carry Refrigerated Cargoes

SECTION 12
Controlled Atmosphere Systems

Note: Text in *italics* is considered necessary as conditions of classification (i.e., compulsory requirements). (See 6-2-1/5.3)

1 General

1.1 *(2024)*

The requirements of this Section are applicable to systems installed on board, either temporary or permanent, for generating nitrogen enriched gases and its supply to the refrigerated cargo spaces and to control the atmosphere in those spaces. Generation and supply of other non-toxic gases for this purpose are subject to ABS technical assessment and approval.

1.3

Portable nitrogen generating equipment intended to serve multiple refrigerated cargo holds is to comply with all the relevant requirements of this Chapter and is to be approved in consideration with the number of specific refrigerated cargo spaces it is intended to serve.

1.5

The nitrogen generating equipment is to be designed, manufactured and installed in accordance with good commercial practice and is to be suitable for intended service conditions including the marine environment. All pressure-retaining components are to comply with the requirements of Part 4, Chapter 4 and Part 4, Chapter 6.

1.7 Objective *(2024)*

1.7.1 Goals

The controlled atmosphere systems covered in this section are to be designed, constructed, operated, and maintained to:

Goal No.	*Goals*
CARGO 1	enable all cargoes be stored and secured in such a way that the ship and persons onboard and the environment are not put at risk.
CARGO 2	enable monitoring of the cargo and vessel storage, securing, or containment systems.
SAFE 1-1	minimize danger to persons on board, the vessel, and surrounding equipment/installations from hazards associated with machinery and systems.

Goal No.	*Goals*
AUTO 2	indicate the system operational status and alert operators of any essential machinery/systems deviate from its defined design/operating conditions or intended performance.
POW 2	provide power to enable the machinery/equipment/electrical installation to perform its required functions necessary for the safe operation of the vessel.

The goals in the cross-referenced Rules/Regulations are also to be met.

1.7.2 Functional Requirements

In order to achieve the above stated goals, the design, construction, and maintenance of the controlled atmosphere systems are to be in accordance with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
Cargo (CARGO)	
CARGO-FR1	Controlled atmosphere environment is to be maintained for the cargo spaces dependent on the type of cargoes carried.
CARGO-FR2	Provide sufficient capacity of the gas generator to maintain suitable carriage environment for the cargo.
CARGO-FR3	Provide sufficient redundancy requirements for the gas generator compressor to minimize malfunction affecting the controlled atmosphere environment in the cargo spaces.
CARGO-FR4	The equipment is to be designed to meet the environmental parameters.
CARGO-FR5	The equipment is to be installed in a space provided with adequate safety provisions.
CARGO-FR6	Provide arrangements to allow the maintenance or removal of devices without impairing the integrity of the pressurized system and affecting operation.
CARGO-FR7	Means are to be provided to stop the supply of nitrogen gas to the refrigerated cargo space.
CARGO-FR8	Piping is to safely contain the fluid media it conveys and be designed, arranged, and protected to minimize chance of mechanical damage.
CARGO-FR9	Provide protective devices if the equipment can be subjected to a pressure greater than its design pressure.
CARGO-FR10	Provide means to prevent inadvertent opening of each cargo space under controlled atmosphere
CARGO-FR11	Provide protective devices if cargo space or compartment can be subjected to a pressure greater than its design pressure or vacuum.
CARGO-FR12	Gas tightness is to be maintained at the boundaries of the gas generator compartment and each cargo space under controlled atmosphere.
CARGO-FR13	Provide means to isolate equipment during malfunction.
CARGO-FR14	Provide means of maintaining humidity level, necessary for the cargoes, which have suitable control, alarm and monitoring.
CARGO-FR15	Information containing guidance for the safe operation of the equipment and system for both normal and anticipated emergency conditions are to be provided.
Safety of Personnel (SAFE)	
SAFE-FR1	Exhaust/discharge arrangements are not to endanger the safety of personnel on board, equipment/systems, and the environment .

Functional Requirement No.	*Functional Requirements*
SAFE-FR2	Suitable ventilation arrangements for compartments adjacent to cargo spaces under controlled atmosphere and cargo spaces with containers under controlled atmosphere are to be provided to maintain a minimum oxygen concentration for human breathing.
SAFE-FR3	Provide appropriate and sufficient protective equipment for the hazards associated with entry into confined spaces.
SAFE-FR4	Provide means to remove contaminants or accumulated water in the system to prevent equipment damage.
SAFE-FR5	Provide means to prevent freezing/condensation to avoid malfunction.
SAFE-FR6	Provide alarms at spaces that may have oxygen deficient atmosphere to warn of hazardous operations.
SAFE-FR7	Bilge and drainage are to be arranged to prevent communication of nitrogen gas between each cargo space.
Automation: Control, Monitoring and Safety Systems (AUTO)	
AUTO-FR1	Permanent means are to be provided to monitor the controlled atmosphere in the cargo spaces and enable sampling to be conducted under all operating conditions.
AUTO-FR2	Provide redundant arrangements for sampling of each cargo space.
AUTO-FR3	Accurate and reliable gas analyzing systems are to be provided for control and/or monitoring.
AUTO-FR4	Provide display of system parameters and alarms at the control and monitoring stations located at suitable manned locations for the safe operation of the controlled atmosphere system equipment/machinery.
AUTO-FR5	Automatic control system is to have independent and separate gas analyzing system from the monitoring system.
Power Generation and Distribution (POW)	
POW-FR1	Sufficient and continuous power is to be supplied to entire controlled atmosphere system and the refrigerating system.
POW-FR2	Provide redundancy and/or reliability in the power supply equipment/systems to minimize malfunction.

The functional requirements in the cross-referenced Rules/Regulations are also to be met.

1.7.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

3 Design Considerations

3.1 *(2024)*

The controlled atmosphere plant is to be able to achieve and maintain the O_2 levels in the designated spaces within a range between 2% and 10% by volume. However, O_2 levels outside this range are acceptable based on specific cargoes carried.

3.3

The controlled atmosphere plant is to be capable of controlling the CO_2 levels in the designated spaces within a specified range by means of nitrogen purge, mechanical scrubbing or other acceptable means.

3.5

Where CO_2 levels are to be controlled by nitrogen purge, the capacity of the nitrogen generator is to take into account the respiration rate of the cargo and the maximum required level of CO_2 which is to be maintained in the designated spaces.

3.7 Capacity

3.7.1

The minimum required nitrogen generator capacity is to be such that the oxygen content in the cargo space can be reduced to a value below 5% within 24 hours after sealing ofthe cargo space or container, in accordance with the following equation:

$$Q = 0.07V$$

where:

Q = Hourly nitrogen generating capacity when delivering nitrogen having a purity of 97%, in m^3 (ft^3), at standard atmospheric conditions of pressure and temperature

V = General cargo carrier: Total empty volume of all cargo spaces which are to be supplied with nitrogen simultaneously, in m^3 (ft^3).

Container carrier: Total empty volume of all containers which are to be supplied with nitrogen simultaneously, in m^3 (ft^3)

General cargo and container carrier: Sum of the volumes calculated above, in m^3 (ft^3).

3.7.2

The required capacity of the nitrogen generator may vary due to variations in types of cargoes, sealing arrangements and other relevant parameters and therefore is to be specified by the designer/Owner. The specified capacity of the system is to be indicated on the submitted plans.

3.9

The nitrogen generator is to be capable of delivering its rated capacity against a back pressure at the cargo space inlet equal to the pressure setting of the PV valve which is protecting that space.

5 Nitrogen Generator Compressor *(2024)*

5.1 *(2024)*

Nitrogen generating systems utilizing compressors are to be provided with two or more compressors and prime movers which together will be capable of delivering the rated capacity. Each compressor is to be sized so that with one compressor out of operation, the system is to be able to maintain the O_2 content in all designated cargo spaces within the range specified in 6-2-12/3.1.

Commentary:

Alternatively, one compressor and prime mover may be accepted if the compressor is capable of delivering the specified capacity, and provided that spares for the compressor and prime mover are carried to enable any failure of the compressor and prime mover to be rectified on board.

End of Commentary

5.3

Materials for crankshafts, connecting rods, cylinders and cylinder covers, housings, rotors and rotor casings of reciprocating and rotary compressors, as applicable, are to be in accordance with the applicable requirements of Part 2, Chapter 3 to other recognized standards will be considered. Material tests need not be witnessed by the Surveyor.

5.5

Air-cooled compressors are to be designed for an air temperature of at least 45°C (113°F). Water-cooled compressors are to be designed for a water temperature of at least 32°C (90°F).

7 Location and Access for Compartments Containing Gas Generating Equipment

7.1

The air compressor and the nitrogen generator may be installed in the engine room or in a separate compartment.

7.3

Where a separate compartment is provided, it is to be:

7.3.1

Treated as 'other machinery spaces' with respect to fire protection,

7.3.2

Positioned outside the cargo area,

7.3.3

Fitted with an independent mechanical extraction ventilation system providing at least six (6) air changes per hour,

7.3.4

Fitted with a low oxygen alarm,

7.3.5

Arranged with no direct access to accommodation spaces, service spaces and control stations

7.5

Where fitted, a nitrogen receiver/buffer tank may be installed either in a dedicated compartment or in the separate compartment containing the air compressor and the generator. Where the nitrogen receiver/buffer tank is installed in an enclosed space, the access is to be arranged only from the open deck and the access door is to open outwards. Permanent ventilation and alarm are to be fitted as in 6-2-12/7.3.3 and 6-2-12/7.3.4 above.

In order to permit maintenance, means of isolation are to be fitted between the generator and the receiver.

7.7

Where the gas generating equipment is located in a container positioned on the open deck, the following requirements are to be met:

7.7.1

The container is to be provided with a mechanical ventilation system of the exhaust type giving at least 6 air changes per hour based on total volume of the container.

7.7.2

The outlets of the ventilation exhaust ducts from the container are to be located such that the exhaust cannot enter enclosed spaces on the vessel.

7.7.3

Means for stopping the ventilation fans and closing all the openings to the gas generator container are to be from outside.

7.7.4

Unrestricted access to the container is to be possible under all loading conditions.

7.7.5

Two portable fire extinguishers complying with 4-7-3/15.2 are to be provided inside the container, of which one is to be stowed near the entrance to the container. Where the compressors are driven by internal combustion engines and the fuel tanks are located inside the container, an approved fixed fire extinguishing system complying with 4-7-3/3 may be required, depending upon the arrangement.

7.7.6

Notices are to be posted to indicate that the container is a dangerous area and may contain a level of oxygen which will cause asphyxiation and will not support human life due to presence of an inert gas.

7.7.7

Means are to be provided for stopping the gas generator from outside of the container.

7.7.8

The container is to be properly secured to the vessel. The container is to be designed considering proper support for the equipment and is to be suitable for the marine environment. Refer to the ABS Guide for Certification of Container Securing Systems*, the ABS* Rules for Certification of Cargo Containers*, and the available certifications contained therein.*

9 Gas and Compressed Air Piping System

9.1 Installation

9.1.1

Where flexible hoses on deck are intended to be used for the supply of nitrogen gas to the refrigerated cargo spaces, they are to be of an approved type complying with the requirements of 4-6-2/5.7. Means are to be provided for protecting these hoses against damage.

9.1.2

Vessels utilizing either portable or fixed nitrogen generating equipment are to be fitted with a permanently installed piping system complying with Part 4, Chapter 6 for the supply and distribution of nitrogen (N_2) gas. A positive closing isolation valve is to be fitted in the gas supply line at the inlet to the refrigerated cargo space. This valve arrangement is to be in accordance with 6-2-12/9.3.1 or 6-2-12/9.3.2.

9.1.3

Exhaust of O_2 and N_2 enriched gases from nitrogen generators are to be led to a safe location in the weather, at least 2 m (6.5 ft) above the open deck and 5 m (16.5 ft) away from ventilation inlets and openings to enclosed spaces

9.1.4

Gas pipes are not to pass through accommodation spaces, ducts or tunnels.

9.1.5

Gas pipes passing through service, machinery and control spaces are to be led through gas tight pipes.

9.3 Valve and Fittings

9.3.1

Each gas inlet line to an individual controlled atmosphere space is to be equipped with two shut-off valves and an intermediate vent valve. Discharge from the vent valve is to be led to a safe location in the weather, at least 2 m (6.5 ft) above the open deck and 5 m (16.5 ft) away from ventilation inlets and openings to enclosed spaces. The shut-off valves are to be provided with arrangements for locking in the closed position.

9.3.2

If a portable nitrogen generating plant is used, the arrangement in 6-2-12/9.3.1 may be dispensed with if it is not possible to supply nitrogen to more than one space at a time. In this case, each permanent gas inlet line is to be equipped with a screw down non return valve provided with arrangements for locking it in the closed position.

9.3.3

Filters are to be provided in the air supply to membrane separators and pressure swing adsorption carbon beds for filtration of oil, debris and water particulate.

11 *Safety Relief Devices*

11.1

Safety relief devices are to be provided in each section of pipe that may be isolated by valves and may build up a pressure in excess of the design pressure. Discharges from relief valves on gas lines are to be led to the weather, at least 2 m (6.5 ft) above the open deck and 5 m (16.5 ft) away from ventilation inlets and openings to enclosed spaces.

11.3

Each air compressor for the nitrogen generating plant is to be provided with a relief valve on the discharge side.

11.5

Pressure vessels with isolating valves are to be equipped with a pressure relief valve set to relieve at a pressure not greater than the design pressure.

13 *Cargo Spaces Under Controlled Atmosphere and Adjacent Spaces*

13.1 *General*

13.1.1

Where the tween-deck spaces within cargo holds are fitted with separate means of maintaining controlled atmosphere conditions, each tween-deck space is to be considered an independent gas tight compartment. For container carriers where the containers stowed under deck are supplied with a low oxygen atmosphere, each container is to be considered a gas tight compartment.

13.1.2

Each cargo space under controlled atmosphere conditions is to be made gas tight as far as practicable. The arrangements are to be such that when cargo space is pressurized with an over pressure of 20 mm of water column, the time taken for a 40% pressure drop is greater than 16 minutes.

13.1.3

Hatch covers and doors to spaces under controlled atmosphere are to be provided with locking arrangements and warning notices informing about the low oxygen atmosphere.

13.1.4

Warning notices are to be posted at all openings to spaces under controlled atmosphere to prevent inadvertent opening while the space is under the controlled atmosphere.

13.3 *Pressure and Vacuum Considerations*

13.3.1

Each cargo space or compartment under controlled atmosphere is to be provided with a pressure and vacuum relief valve (PV valve) to limit the positive and negative pressure below that for which the space is designed.

13.3.2

The pressure relieving capacity of the PV valve is to be such that the pressure in the space does not exceed the design limits referred to in 6-2-12/13.3.1 above, when the gas generating unit is delivering at its maximum capacity to a single cargo space or compartment. Consideration is also to be given to pressure changes caused by defrost cycles.

13.3.3

Outlets of PV valves are to be located at least 2 m (6.5 ft.) above the open deck and 5 m (16.5 ft.) away from air inlets and openings to accommodation spaces, service spaces, machinery spaces and other similar manned spaces.

13.3.4

The PV valves are to be of a type suitable to satisfy the requirements of 6-2-12/13.3.1 and are to be capable of operating at ambient temperatures of 0°C (32°F) or less.

13.3.5 *(2024)*

Arrangements for the protection of cargo spaces or compartments against over or under pressure other than those referred to above are subject to ABS technical assessment and approval .

13.5 *Bilge and Drainage Arrangements*

13.5.1

Liquid sealed traps on drains from cargo spaces, air cooler trays, etc. are to have sufficient liquid head to withstand the design over pressure when the Controlled Atmosphere system is in operation. Ship motions and over pressure of air circulation fans are to be considered when determining the required liquid head.

13.5.2

The liquid in the liquid seal traps is to be of a type that will not freeze or evaporate under any ambient condition.

13.5.3

Spaces under controlled atmosphere are not to have bilge wells or drain tanks common with spaces not intended for controlled atmosphere.

13.5.4

Where it is intended to gain access to the tween-deck spaces referred to in 6-2-12/13.1.1, any open-ended interconnecting pipe work between such spaces is to be arranged to prevent nitrogen gas from escaping from one gas tight space to another.

13.7 *Ventilation*

13.7.1

The ventilation inlets and outlets of cargo spaces under controlled atmosphere are to be provided with positive closing gas tight valves.

13.7.2

All ventilation outlets from spaces under controlled atmosphere are to be located at least 2 m (6.5 ft.) above the open deck and 5 m (16.5 ft.) away from air inlets and openings to accommodation spaces, service spaces, machinery spaces and other similar manned spaces.

13.7.3

Suitable arrangements for gas freeing the spaces under controlled atmosphere conditions are to be provided. Air circulation and ventilation fans may be used for this operation. The ventilation outlets used for gas freeing are to be directed vertically upwards.

13.7.4

Compartments other than tanks, void spaces or other similar areas where personnel do not normally have access, which are adjacent to refrigerated cargo spaces under controlled atmosphere, and other normally accessible spaces containing gas piping where gas leakage may create an oxygen deficient atmosphere, are to be provided with permanent mechanical ventilation systems of the positive pressure type with a capacity of at least 2 air changes per hour based on total volume of the space. The ventilation is to be able to be controlled from outside of the space. The permanent ventilation outlets are to be located in accordance with 6-2-12/13.7.2.

13.7.5

Cargo spaces with containers under controlled atmosphere which are required to be entered by personnel are to be provided with ventilation arrangements which are capable of maintaining a minimum of 19% oxygen (by volume) throughout the space when operating under the conditions specified in 6-2-12/3.5. Ventilation rate calculations are to be based upon a 100% gas leakage rate from the containers into the cargo space. The ventilation is to be able to be controlled from outside of the space. The permanent ventilation outlets are to be in accordance with 6-2-12/13.7.2.

15 Instrumentation, Control and Monitoring

15.1 General

15.1.1

In addition to Section 6-2-10, compliance with the following is required.

15.1.2

Within the specified ranges, the levels of O_2 and CO_2 are to be able to be maintained with an accuracy within ± 0.2%.

15.1.3

A permanently installed monitoring system is to be arranged to display the O_2 and CO_2 content in all spaces under controlled atmosphere. The equipment for measuring CO_2 content may be the same as that required in 6-2-10/7.

15.1.4

Injection of nitrogen and removal of CO_2 may be arranged either manually or automatically.

15.3 *Sampling*

15.3.1

The permanently installed monitoring system is to be provided with independent sampling lines or gas sensors for each cargo space under controlled atmosphere.

15.3.2

Where the sampling lines are connected to a monitoring unit which is located in an enclosed space, that space is to be ventilated at a rate which is at least equivalent to the sampling flow rate.

15.3.3

The exhaust gases from measuring and analysis devices are to be discharged to a safe location on the open deck without creating a back pressure. The exhaust outlets are to be positioned in accordance with 6-2-12/13.7.2.

15.3.4

Sampling line arrangements are to be such as to prevent condensation and freezing of water in the lines under all operating conditions. Inlets of sampling lines are to be provided with filters to prevent dirt and debris entering the lines.

15.3.5

In addition to the sampling line or gas sensor required in 6-2-12/15.3.1, another closeable sampling line is to be provided for each cargo space under controlled atmosphere. This line is to be arranged for attachment of portable O_2 and CO_2 measuring devices as close as possible to the space served.

15.3.6

Portable equipment for measuring O_2 and CO_2 is to be available on board at all times.

15.5 Analyzing

15.5.1

If an automatic control system is installed, gas analyzing equipment independent from the one used by the monitoring system is required. Separate gas sampling lines are to be provided for both systems.

15.5.2

Where a gas monitoring system with sequential analyzing is arranged, the system is to be designed so that each measuring point is analyzed at hourly intervals or other suitable duration specified by the Owner/builder. The instruments are to clearly indicate the space being analyzed. Direct readout of the gas quantity in any space under controlled atmosphere is to be available on demand.

15.5.3

Gas analyzing equipment is to be capable of self calibration and manual calibration with known gases at both zero and full scale. The accuracy of the O_2 analyzers is to be within ± 0.1 % by volume. The accuracy of the CO_2 analyzers is to be within ± 0.25% by volume.

15.7 *Precaution for Low Level of O_2*

15.7.1

The following spaces are to be provided with permanently installed equipment for monitoring O_2 content and be capable of alarming when the O_2 level is low:

15.7.1(a) All normally accessible spaces adjacent to spaces under controlled atmosphere.

15.7.1(b) Cargo spaces not under controlled atmosphere adjacent to spaces under controlled atmosphere and spaces where gas leakage may create an oxygen deficient atmosphere, e.g. spaces containing scrubber units or gas piping.

15.7.1(c) Cargo spaces which contain containers under controlled atmosphere.

15.7.1(d) Ship compartments or containers housing gas generating equipment.

15.7.2

An automatic pre-discharge warning alarm is to be fitted in each space under controlled atmosphere. The alarm is to be arranged to give audible signals continuously for 60 seconds before the gas discharge into that space commences. The alarm may be connected with the O_2 analyzer in a manner that it does not sound if the oxygen level in the space is below 14% by volume.

15.9 *Monitoring and Alarm*

The conditions as per 6-2-12/27.19 TABLE 1 are to be individually alarmed at the manned station for the spaces specified in 6-2-10/3.

17 Electrical

17.1 General

Except as noted herein, compliance with Section 6-2-9 is required.

17.3 Power Supply

17.3.1

Aggregate capacity of the electrical generators is to be sufficient to supply the power simultaneously, to the entire controlled atmosphere system and the refrigerating system referred to in 6-2-9/7.1.

17.3.2

With any one generator out of action, the remaining generator(s) is to be capable of supplying the power to the controlled atmosphere system, excluding standby units, and the refrigerating system referred to in 6-2-9/7.3.

17.3.3

The power for the controlled atmosphere system is to be supplied from the main switchboard by feeders separate from those for other systems.

17.3.4

As an alternative to 6-2-12/17.3.2, an independent generating set providing power for the controlled atmosphere system may be accepted, provided arrangements are made to connect the controlled atmosphere system to the ship service generators, which are to have adequate total capacity to carry the rated load simultaneously of the controlled atmosphere system and the services essential for the propulsion and safety of the ship, services for providing minimum comfortable conditions of habitability and the entire refrigerating system.

17.5 *Cable Penetration*

Cable penetrating the boundaries of the gas generator compartment and spaces under controlled atmosphere are to be arranged gastight by use of cable glands.

19 Ethylene and Carbon Dioxide Scrubbers

19.1

Permanently installed piping complying with Part 4, Chapter 6 is to be provided between the scrubber units and the cargo spaces under controlled atmosphere.

19.3

The piping referred to in 6-2-12/19.1 is to be in accordance with 6-2-12/9.1.4 and 6-2-12/9.1.5.

19.5

Positive closing isolation valves are to be fitted at the connections with the cargo spaces under controlled atmosphere.

19.7

Exhausts from the scrubber units are to be led to a safe location in the weather, at least 2 m (6.5 ft) above the open deck and 5 m (16.5 ft) away from air inlets and openings to accommodation spaces, machinery spaces and other similar manned spaces.

21 Humidification Equipment

Where the cargo space under controlled atmosphere is equipped with a humidification system to control relative humidity of the space, the humidification system is to be in accordance with the following requirements:

21.1

The humidification system is to be capable of increasing the relative humidity in each of the intended cargo spaces up to a level of 90% at the specified space temperatures and maintain the selected level constant within ± 5%.

21.3

The humidification system lines in the refrigerated cargo spaces are to be installed to facilitate ease of drainage and are to be provided with suitable heating arrangements, as applicable.

21.5

Permanently installed equipment for monitoring relative humidity in the cargo spaces is to be provided.

21.7

The deviation of relative humidity from the predetermined set point in each cargo space is to be individually alarmed at the monitoring station.

23 *Personnel Safety Equipment*

23.1

Means are to be provided to re-oxygenate the cargo spaces and compartments prior to gaining entry into the spaces which were under controlled atmosphere conditions. Until the O_2 levels which are considered safe for entry have been achieved, entry into such spaces is to be prevented.

23.3

At least ten portable oxygen monitors with alarms are to be provided on board.

23.5

At least one portable gas analyzer capable of measuring O_2 levels in the atmosphere, is to be provided on board for use prior to entry into the spaces under controlled atmosphere. This portable gas analyzer is in addition to the equipment required in 6-2-12/15.3.6.

23.7

A means of two-way communication is to be provided between the cargo spaces under controlled atmosphere and the nitrogen release control station. If portable radiotelephone apparatus are adopted to comply with this requirement, at least three sets are to be provided on board. This equipment is in addition to the equipment required by SOLAS Chapter III, Regulation 6.

23.9

One set of oxygen resuscitation equipment is to be provided on board.

23.11

Two self-contained breathing apparatus equipped with built in radio communication and lifeline with a belt are to be provided on board together with fully charged spare air bottles with a total free air capacity of 3600 liter (950 US gallons) for each breathing apparatus. This equipment is in addition to the equipment required by SOLAS Chapter II-2, Regulation 17.

25 Operations, Equipment and Procedures Manual

An Operations, Equipment and Procedures Manual is to be available onboard. The manual is to provide the following information:

25.1

General information about controlled atmospheres including explanation such as what is controlled atmosphere, need for controlled atmosphere, method of controlling atmosphere composition, danger associated with oxygen depleted atmosphere, insidious leakage of gas, etc.

25.3

Complete description of the ship's controlled atmosphere installation and diagrammatic arrangements showing the details of the gas tight compartments.

25.5

Procedures for gas freeing of Controlled Atmosphere (CA) spaces, methods of ascertaining adequacy of oxygen prior to entry, methods of communication in CA spaces.

25.7

Procedures for entering the CA spaces after gas freeing.

25.9

Procedures for loading adjacent cargo spaces.

25.11

Procedures prior to starting controlled atmosphere equipment.

25.13

Procedures for opening shut-off valves on nitrogen distribution branch lines and attachment of nitrogen distribution hoses, where applicable.

25.15

Procedures for functional testing portable gas generating unit each time it is placed on board.

25.17

Procedures during the voyage with controlled atmosphere.

25.19

Equipment maintenance procedures and list of spare parts.

25.21

Operation, maintenance and calibration instructions for all types of gas detecting, analyzing and alarming equipment onboard associated with controlled atmosphere system.

25.23

Emergency procedures related to erroneous instrumentation.

25.25

Emergency procedures related to personnel overcome by oxygen deficiency.

25.27

Emergency procedures related to entry using breathing apparatus.

25.29

Instructions for atmosphere testing and gas freeing of spaces without permanent ventilation.

27 Tests and Inspections

27.1

Compressor parts subject to elevated pressure are to be hydrostatically tested at the manufacturer's plant in the presence of the ABS Surveyors to 1.5 times their respective design pressure.

27.3

After completion, functional and capacity testing of the nitrogen generator is to be carried out in accordance with an approved program at the manufacturer's plant in the presence of the Surveyor. The functional tests are to include testing of alarms, shut downs and pressure relief devices. Capacity and quality of the nitrogen produced may alternatively be verified on board, in the presence of the Surveyor.

27.5

Air leakage test for cargo spaces is to be witnessed by the attending Surveyor.

27.7

Sample lines are to be tested for leakage and blockage in the presence of the attending Surveyor.

27.9

The setting of the PV valves is to be verified by the attending Surveyor.

27.11

The accuracy of the levels of O_2 and CO_2 in all spaces under controlled atmosphere is to be verified by the attending Surveyor in accordance with 6-2-12/15.1.2.

27.13

Accuracy ofthe O_2 analyzers and CO_2 analyzers is to be verified by the attending Surveyor in accordance with 6-2-12/15.5.3.

27.15

Low level alarm of O_2 and automatic nitrogen pre-discharge warning alarm are to be demonstrated in accordance with 6-2-12/15.7.

27.17

The required alarms and displays are to be verified for satisfactory operation at the predefined set points.

27.19

The requirements in 6-2-9/13 are to be complied with, as applicable.

TABLE 1
Instrumentation and Alarms

Item		*Display*	*Alarm*	*Remarks*
Compressor	Automatic stop		Activated	
	Lubricating oil	Pressure	Low	Automatic stop (Low pressure)
	Discharge line - Pressure	Pressure	High	Automatic stop (High pressure)
	Suction line - Pressure	Pressure	Low	
O_2 Content	Spaces under controlled atmosphere	Content	Deviation from set point	6-2-12/15.1.3
	Accessible spaces/ cargo spaces adjacent to spaces under C.A.	Content	Low	6-2-12/15.7.1(a) and 6-2-12/15.7.1(b)
	Gas generating compartments	Content	Low	6-2-12/15.7.1(d)
	Gas generating container	Content	Low	6-2-12/15.7.1(d)
	Cargo spaces containing containers under controlled atmosphere	Content	Low	6-2-12/15.7.1(c)
	Accessible spaces containing scrubber units and gas piping	Content	Low	6-2-12/15.7.1(b)
CO_2 Content	Space under controlled atmosphere	Content	Deviation from set point	
Gas Measuring System	Failure		Failure	
	Accuracy		Out of range	
Humidification System	Relative humidity	Relative humidity	Deviation from set point	If humidification system is fitted

PART 6

CHAPTER 2
Vessels Intended to Carry Refrigerated Cargoes

SECTION 13
Refrigerated Cargo Container Carrier

1 General

1.1

Insulated containers are not considered part of the classed installation. However, for installations where the containers are supplied with cooled air from the vessel's refrigeration system, in accordance with 6-2-1/7.1.3 and 6-2-1/7.1.4, the requirements of this Section apply.

1.3

Where requested, insulated containers are to be certified in accordance with the ABS *Rules for Certification of Cargo Containers*.

1.5 Objective *(2024)*

1.5.1 Goals

The refrigerated cargo container carrier covered in this section is to be designed, constructed, operated, and maintained to:

Goal No.	*Goals*
CARGO 1	Enable all cargoes be stored and secured in such a way that the ship and persons onboard and the environment are not put at risk.
CARGO 5	Enable monitoring of the cargo and vessel storage, securing, or containment systems.
AUTO 2	Indicate the system operational status and alert operators of any essential machinery/systems deviate from its defined design/operating conditions or intended performance.

The goals in the cross-referenced Rules/Guides are also to be met.

1.5.2 Functional Requirements

In order to achieve the above stated goals, the design, construction, and maintenance of the refrigerated cargo container carrier are to be in accordance with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
Cargo (CARGO)	
CARGO-FR1	Adequate chilled and fresh air circulation around/through the cargo is to be provided.
CARGO-FR2	Cooling air is to be distributed sufficiently and evenly throughout each container.
CARGO-FR3	Provide means to protect ducts and couplings against moisture, freezing and icing.
CARGO-FR4	Provide arrangements to allow repair or maintenance without affecting operation.
CARGO-FR5	Air circulation and fresh air ventilation are to be designed based on the type of cargo.
Automation: Control, Monitoring and Safety Systems (AUTO)	
AUTO-FR1	Provide means to monitor the quality of air in each air cooler battery.
AUTO-FR2	Provide fixed means, which are protected from damage, to monitor the temperature of delivery and return air ducts.
AUTO-FR3	Provide monitoring of integral refrigeration system at suitable locations.

The functional requirements in the cross-referenced Rules/Guides are also to be met.

1.5.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the applicable prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

3 Porthole Refrigerated Cargo Container Carrier

3.1 Design Considerations

3.1.1

The vessel's refrigeration system is to be designed, constructed and installed in accordance with the requirements of this Section and other applicable requirements.

3.1.2

Where cargo cells are to be insulated, the arrangements are to be in accordance with the applicable requirements of Section 6-2-5.

3.1.3 *(2024)*

Space heating of the cargo cells is subject to ABS technical assessment and approval.

3.1.4

The air circulation and fresh air ventilation system serving the containers is to be based upon the air volume of each empty container connected to the system. Air circulation for each connected container is to be 50 to 70 air changes per hour for fruit cargoes and 30 to 40 air changes per hour for frozen cargoes.

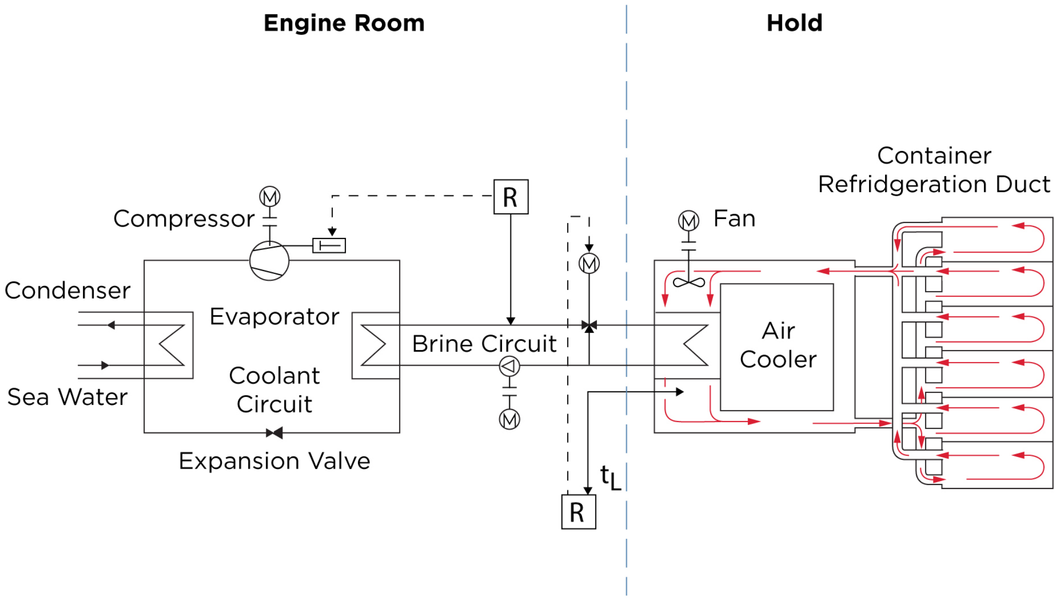
3.1.5

Fresh air ventilation for each container is to be at least two (2) air changes per hour.

3.1.6

Means are to be provided for monitoring CO_2 levels in each air cooler battery.

FIGURE 1
Schematic Representation of Porthole Cargo Refrigeration Plant *(2024)*



3.3 Ducts and Couplings

3.3.1

Ducts, couplings and air cooler casings are to be airtight as established by tests conducted in accordance with 6-2-13/7.

3.3.2

Where a container stack is supplied with cooled air from its own air cooler, the air flow to each connected container is to be within ±5% of the design value.

3.3.3

Insulation installed on the inside of ducts is to be of a type that is not affected by moisture and is resistant to abrasion. The properties required by 6-2-5/5.11 are also applicable.

3.3.4

Where couplings are pneumatically actuated, the compressed air piping, valves and fittings are to be in accordance with Part 4, Chapter 6 and are to be protected against freezing.

3.3.5

The compressed air system referred to in 6-2-13/3.3.4 is to incorporate moisture traps such that the air supply is sufficiently dry to prevent ice formation when cargo cell temperatures are below 0°C (32°F).

3.3.6

In order to protect against icing, the outer surface of the coupling connections is to be insulated.

3.5 Air Coolers *(2024)*

When the total internal volume of all containers connected to a single air cooler exceeds 300 m^3 (10,593 ft^3), the air cooler coils are to be divided into at least two independent sections such that any one of them may be isolated without affecting the operation of the other.

Commentary:

Alternatively, at least two independent air coolers can be fitted.

End of Commentary

3.7 Instrumentation, Control and Monitoring

Except as noted herein, refrigerating machinery plants and machinery spaces are to comply with the requirements in Section 6-2-10.

3.7.1 Temperature Monitoring

3.7.1(a) Delivery and return air ducts for each container are to be fitted with a thermometer. Where a group of containers is being served by one air cooler with common fans, the individual thermometers may be replaced by common thermometers for the delivery air.

3.7.1(b) Remote temperature monitoring of delivery and return air ducts is to comply with the requirements of 6-2-10/5.5.2, 6-2-10/5.5.3 and 6-2-10/5.7 except that the sensors in the delivery air ducts need not be connected to separate measuring instruments if the delivery air temperature is monitored locally.

3.7.1(c) The sensors are to be permanently connected to their instruments and protected against damage**.**

3.7.2 Monitoring

The display and alarms are to be provided in accordance with 6-2-13/3.7.2 TABLE 1, at the locations specified in 6-2-10/3.

TABLE 1
Instrumentation and Alarms

Item	*Display*	*Alarm*
Return air / Delivery air Temperature	Temperature	Deviation from set point
CO_2 Level in each Air Cooler Battery	Content	High

3.9 Electrical

The requirements in Section 6-2-9 are applicable.

3.11 Automatic Control

Where automatic control is provided for refrigerating machinery, compliance with 6-2-10/15, as applicable, is required.

5 Integral Refrigerated Cargo Container Carrier

Note: Please refer to the ABS *Guide for Carriage of Integral Refrigerated Containers On Board Ships*, for additional requirements.

5.1 Design Considerations

5.1.1

Where water-cooled condensers are provided, the cooling water flow rate is to be between 11 and 26 liters per minute.

5.1.2

Cooling water systems are to be in accordance with Section 6-2-7, as applicable.

5.1.3

Cargo cells containing containers are to be provided with sufficient air freshening capability to dissipate metabolic gas such that the cell temperature does not exceed 10°C (18°F) above ambient whilst operating under the conditions specified in 6-2-6/3.3.1.

5.1.4 *(2024)*

Where refrigerated cargo containers are carried in open hatch or hatch less cargo holds of a container vessel, the ventilation, bilge, hold temperature, etc., are subject to ABS technical assessment and approval.

5.3 Instrumentation, Control and Monitoring

Monitoring in accordance with the following 6-2-13/5.3 TABLE 2 is to be provided at a location specified in 6-2-10/3.

TABLE 2
Instrumentation and Displays

Item	*Display*
Power Supply (Monitoring)	Status
Compressor Running	Running
Defrost	Activate
Temperature in range	Temperature

5.5 Electrical

5.5.1

The requirements in Section 6-2-9 and the following are to be complied with.

5.5.2

Receptacles and plugs of different electrical ratings are not to be interchangeable. They are to be in accordance with ISO standard 1496-2 or equipment compatible with ISO standard.

5.7 Automatic Control

Where an automatic control system is provided, compliance with 6-2-10/15 is required.

7 Tests and Inspections

7.1 Porthole Refrigerated Cargo Container Carrier

7.1.1

Measurements are to be carried out in the presence of the attending Surveyor during on-board trials to demonstrate the air circulation and ventilation rates are as per 6-2-13/3.1.4 and 6-2-13/3.1.5.

7.1.2

The air tightness required by 6-2-13/3.3.1 is considered satisfactory when the leakage rate does not exceed 0.5% of the total volumetric flow rate at the design pressure. Tests to establish compliance are to be conducted on the installed system in the presence of the attending Surveyor.

7.1.3

Tests to establish that the cooled air distribution is in compliance with 6-2-13/3.3.2 are to be conducted on the installed system in the presence of the attending Surveyor.

7.1.4

Compressed air lines connected to the coupling actuators referred to in 6-2-13/3.3.4 are to be tested to 1.5 times the design pressure.

7.1.5

The electrical test requirements in 6-2-9/13 are to be complied with.

7.1.6

The alarms and displays required by 6-2-13/3.7 are to be verified for satisfactory operation at pre-defined set points.

7.1.7

In order to simplify shipboard testing, each type of air ducting system with couplings, an air cooler and circulating fans which are completely assembled at the manufacturer's plant is to be tested prior to installation on board in accordance with the following requirements:

7.1.7(a) The test is to be performed in accordance with an approved test program in the presence of the Surveyor.

7.1.7(b) The *k*-values for the duct and cargo cells are to be established as per the requirements of 6-2-16/3.3.3.

7.1.7(c) Air leakage rate for the air distribution duct, couplings and air cooler casings is to be measured.

7.1.7(d) Air distribution in the air ducting system for a stack of containers is to be measured.

7.1.7(e) Air circulating fans are to be tested in accordance with 6-2-16/3.1.1.

7.3 Integral Refrigerated Cargo Container Carrier

7.3.1

The design values required for compliance with 6-2-13/5.1.3 are to be shown on the ventilation fan capacity curve and, by performing on-board trials in the presence of the attending Surveyor, the capacity curve is to be verified at the prevailing ambient conditions.

7.3.2

The electrical test requirements in 6-2-9/13 are to be complied with.

7.3.3

The alarms and displays, where fitted for compliance with 6-2-13/5.3, are to be verified for satisfactory operation at the pre-defined set points.

7.3.4

Cooling water flow rate to the condensers is to be measured for compliance with 6-2-16/1.13.

7.3.5

Air freshening ventilation fans for cargo cells are to be tested in accordance with applicable requirements in 6-2-16/3.1.1.

PART 6

CHAPTER 2
Vessels Intended to Carry Refrigerated Cargoes

SECTION 14
Refrigerated Edible Bulk Liquid Tanker

Note:

Text in *italics* is considered necessary as conditions of classification (i.e., compulsory requirements). (See 6-2-1/5.3)

1 General

1.1

The requirements of this Section are applicable to vessels defined in 6-2-1/13.21 requiring the notation referred to in 6-2-1/7.1.5 for the carriage of refrigerated edible bulk liquids.

1.3

Unless otherwise stated in this Section, the requirements of these Rules are applicable.

1.5

Due regard is to be given to the requirements of the Flag State and the Port State for the carriage and transportation of edible products.

1.7 Objective *(2024)*

1.7.1 Goals

The refrigerated edible bulk liquid tanker covered in this section is to be designed, constructed, installed, operated, and maintained to:

Goal No.	*Goals*
STRU 2	resist structural failure associated with accidental conditions.
CARGO 3	be equipped to handle and transfer cargo safely.
CARGO 5	enable monitoring of the cargo and vessel storage, securing, or containment systems.
STAB 5	be able to remove accumulated liquids to mitigate the effects of flooding.
FIR 1	*prevent the occurrence of fire and explosion. (SOLAS II-2/Reg 2.1.1)*
SAFE 1.1	minimize danger to persons on board, the vessel, and surrounding equipment/installations from hazards associated with machinery and systems.

The goals in the cross-referenced Rules/Regulations are also to be met.

1.7.2 Functional Requirements

In order to achieve the above stated goals, the design, construction, installation and maintenance of the refrigerated edible bulk liquid tanker are to be in accordance with the following functional requirements.

Functional Requirement No.	*Functional Requirements*
Structure (STRU)	
STRU-FR1	Provide arrangements to prevent the independent tanks from floating up during accidental flooding of hold spaces.
STRU-FR2	Vents are to be designed and suitably located to prevent overpressure or under pressure (vacuum) in the cargo tanks during carriage, cargo loading, discharging and ballasting operations.
Cargo (CARGO)	
CARGO-FR1	Provide redundant means of pumping from the cargo tanks in case of failure of any one cargo pump.
CARGO-FR2	Provide protective devices if the system can be subjected to a pressure more than its design pressure.
CARGO-FR3	Cargo pumps other than submersible pumps are to be accessible at all times for maintenance and repair under ordinary operating conditions.
CARGO-FR4	Cargo is to be protected against the leakage of refrigerant.
CARGO-FR5	Provide means to measure the level of liquid in cargo tanks.
CARGO-FR6	Provide means to access and inspect independent tanks in hold spaces.
Stability (STAB)	
STAB-FR1	Provide means to remove accumulated liquids in hold spaces and where high bilge level is expected; hold spaces are to have suitable monitoring and warning devices.
Fire Safety (FIR)	
FIR-FR1	Provide arrangements to prevent dangerous accumulations of explosive mixtures in intact cargo tanks during normal service.
FIR-FR2	Provide sufficient ventilation to minimize the possibility of accumulation of flammable vapors where the accumulation of flammable vapors in cargo tanks or hold spaces is expected.
Safety of Personnel (SAFE)	
SAFE-FR1	Exhaust/discharge arrangements are not to endanger the safety of personnel on board and equipment/systems.

The functional requirements in the cross-referenced Rules/Regulations are also to be met.

1.7.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

3 Design Considerations

The material used is to be in accordance with the requirements of Part 2 and the following:

3.1

Materials used for the construction of the cargo containment, the associated piping, pumps and valves are to be suitable to withstand the design service temperatures, pressures and are to be compatible with the products carried. Materials incompatible with the edible products being carried are not to be used. Details of the materials are to be submitted for review.

3.3 *(2024)*

The use of non-metallic materials for the cargo piping system is subject to ABS technical assessment and approval. Accordingly, relevant details are to be submitted for review.

5 Hull Structure

For design and construction of the hull structure refer to Part 3.

7 *Cargo Containment System*

7.1 *Cargo Tanks*

7.1.1

Cargo tanks, both indepe ndent and integral, are to be designed and constructed in accordance with the applicable requirements in Part 3. Integral tanks are also to comply with the requirements for integral tanks on chemical carriers in 5C-9-4/1.1 and 5C-9-4/1.3.

7.1.2

Independent pressurized tanks referred to in 6-2-1/13.23.4 are to be designed and constructed in accordance with Part 4, Chapter 4, as applicable.

7.1.3

The supports for the independent cargo tank(s) are to be designed in accordance with the requirements of a recognized national or international pressure vessel design code to withstand the static and dynamics loads with liquid full cargo tanks.

7.1.4

The independent cargo tanks are to be fitted with anti-flotation devices, as necessary. The loads on the anti-flotation devices are to assume cargo tanks empty and the hold spaces flooded.

7.1.5

Where the cargo tanks are located in hold spaces, the void spaces are to be made accessible to enable inspection and examination of the containment pressure boundaries and insulation (if fitted).

7.3 *Cargo Tank Protection*

7.3.1

Cargo tanks are to be fitted with pressure/vacuum valves, as applicable, to prevent over- or underpressurization. The discharges from the valves from a cargo tank may be led to another cargo tank provided the cargo tanks are independent of each other and it is not possible to pressurize or vacuum all the tanks simultaneously through a common system. Alternatively the discharge from the cargo tankvalves may be led to the hold bilges.

7.3.2

The setting of the cargo tank pressure/vacuum valve(s) is to be in accordance with 5C-2-3/11.11.2 and 5C-8-1/1.7.1 and the arrangement is to be such that the valve(s) remain connected directly to the cargo tanks at all times except during maintenance and repair.

7.3.3

For cargo tanks fitted with inerting facilities, see 6-2-14/9.5.2.

9 Cargo Loading and Unloading System

9.1 Cargo Piping

9.1.1

A permanently installed cargo loading and unloading system is to be fitted. There are to be a minimum of two pumps capable of taking suction from each cargo tank. Where submersible pumps are used, only one cargo pump per tank may be used provided that an alternative method of pumping cargo is available on board the vessel. This alternative method may be by means of pressurizing the cargo tanks.

9.1.2

Means are to be provided for isolation of each cargo tank in the loading and unloading lines.

9.1.3

Pipes, valves and the fittings in the cargo system are to comply with the requirements of Part 4, Chapter 6.

9.1.4

Cargo loading and unloading lines are to be protected against over pressurization by pressure relief valves. The discharge from the relief valves may be led to the cargo tanks.

9.3 Cargo Pumps

Where the cargo unloading is through cargo pumps other than submersible pumps, they are to be accessible for maintenance and repair.

9.5 *Inert gas system*

Where cargo tanks are provided with facilities to supply inert gas into the vapor spaces, the arrangements are to be in accordance with the following requirements:

9.5.1

The location of the inert gas generating plant or the storage of the reserve inert gas is subject to approval by ABS.

9.5.2

The cargo tanks are to be fitted with pressure/vacuum valves to prevent over or under pressurization. The outlets from the pressure/vacuum valves are to be situated at least 5 m (16.5 ft.) from any openings and air intakes to the accommodation and service spaces.

11 Refrigeration System

11.1

The refrigeration machinery is to comply with the requirements of Section 6-2-6, as applicable.

11.3

Where a direct expansion system is used whereby the refrigerant is circulated through the cooling coils in the cargo tanks, the design of the coils are to be such that there is no possibility of leakage of the refrigerant into the cargo. Details in this regard are to be submitted for review.

11.5

Where an indirect expansion system is used, the secondary coolant is not to be detrimental to the cargo.

13 Ancillary Systems

13.1 Cargo Tank Sounding Arrangements

Cargo tanks are to be provided with means for assessing the liquid levels in the tanks. The system may be a permanently fixed or a temporary arrangement.

13.3 Cargo Tank Ventilation

Means for ventilating the cargo tanks during loading and unloading is to be fitted. For tanks supplied with inert gas refer to 6-2-14/9.5.

13.5 *Hold Space Bilge Arrangement*

13.5.1

A permanently fixed bilge system is to be provided for emptying out the hold space bilges. This system need not be independent of the Bilge system required by Part 4, Chapter 6.

13.5.2

Where the discharge from the cargo tank relief valves is led to the hold bilges, a bilge high level alarm is to be fitted to give an audible and visual alarm in the engine room or the bridge.

13.7 *Hold Space Ventilation Arrangements*

The hold spaces are to be provided with adequate ventilation, where applicable.

15 Tests and Inspections

15.1

Tests and inspections of the refrigerating machinery and associated systems are to be in accordance with 6-2-6/25, as applicable.

15.3

Tests and inspection of the vessel and its machinery, other than the refrigeration machinery, are to be in accordance with applicable Sections of the Rules.

PART 6

CHAPTER 2

Vessels Intended to Carry Refrigerated Cargoes

SECTION 15

Refrigerated Fish Carrier

1 General

1.1

The requirements of this section are applicable to fishing vessels defined in 6-2-1/13.25 requiring the notation referred to in 6-2-1/7.1.6.

1.3

Unless otherwise stated in this Section, these Rules and Part 5C, Chapter 18 are applicable.

1.5

Due regard is to be given to the requirements of the Flag State and Port State for the carriage and transportation of edible products.

1.7 Objective *(2024)*

1.7.1 Goals

The refrigerated fish carrier covered in this section is to be designed, constructed, installed, operated, and maintained to:

Goal No.	*Goals*
STRU 1	in the intact condition, have sufficient structural strength to withstand the environmental conditions, loading conditions, and operational loads anticipated during the design life.
STRU 2	resist structural failure associated with accidental conditions.
CARGO 5	enable monitoring of the cargo and vessel storage, securing, or containment systems.
STAB 5	be able to remove accumulated liquids to mitigate the effects of flooding.

The goals in the cross-referenced Rules/Regulations are also to be met.

1.7.2 Functional Requirements

In order to achieve the above stated goals, the design, construction, installation and maintenance of the refrigerated fish carrier are to be in accordance with the following functional requirements.

Functional Requirement No.	*Functional Requirements*
Structure (STRU)	
STRU-FR1	Provide means to protect vessel shell plating during unloading at sea.
STRU-FR2	Vents are to be designed and suitably located to prevent overpressure or under pressure in the refrigerated sea water (RSW) tanks during carriage, filling and discharging operations.
Cargo (CARGO)	
CARGO-FR1	Provide means to prevent damage to equipment and fittings during cargo operations.
CARGO-FR2	Provide means to measure the level of liquid in the refrigerated sea water tanks.
CARGO-FR3	Provide means to prevent damage of insulation and piping in plate freezers.
CARGO-FR4	Pipes and piping components are to be suitable for the intended service and installed locations.
Stability (STAB)	
STAB-FR1	Provide means to dispose of or clear accumulated liquids in the refrigerated sea water tanks where RWS tank is used for carrying dry fish in bulk.

The functional requirements in the cross-referenced Rules/Regulations are also to be met.

1.7.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

3 Design Considerations

For design considerations. Reference is to be made to the applicable requirements of this Chapter.

5 Materials

The materials used are to be in accordance with the requirements of Part 2 and the applicable sections of this Chapter.

7 Hull Structures

7.1

For design and construction of the hull structure. Refer to the applicable parts of these Rules.

7.3

Where fishing vessels are moored against the mother vessels during unloading at sea, fenders or other similar means for the protection of the shell plating may be required. Where such an arrangement is fitted, the shell plating in way of the protection is to be adequately strengthened.

9 Refrigerated Cargo Spaces

9.1

The refrigerated spaces are to comply with the applicable requirements of Section 6-2-5.

9.3 *(2024)*

Equipment and fittings such as electric lights, etc. are to be suitably protected against damage during loading and unloading of cargo.

11 Refrigeration System

11.1

The refrigeration machinery is to comply with the requirements of Section 6-2-6, as applicable.

11.3

Where an ammonia refrigeration system is used. Reference is to be made to 6-2-11/1.5.

13 Refrigerated Sea Water Tanks (RSW Tank)

13.1

Each RSW tank is to be provided with appropriate venting and sounding arrangements. The arrangements to assess the liquid levels in the tanks may be permanently installed or a temporary arrangement.

13.3

Where cooling coils are used in the tanks using ammonia as the refrigerant. Refer to the requirements of 6-2-15/11.3.

13.5

Where an RSW tank is intended to carry dry fish in bulk, in addition to the requirements for refrigerated spaces, the following arrangements are to be provided:

13.5.1

The tank is to be provided with a bilge well and a permanent connection to the bilge system, unless the tanks are provided with independent bilge systems.

13.5.2

Arrangements are to be made for blanking off sea water piping.

15 Plate Freezers

15.1

Insulation and piping in plate freezers is to be protected from moveable parts of the system.

15.3

Flexible hoses in the system are to be of the armored type suitable for the services intended.

15.5

Piping, including flexible hoses, is to comply with the requirements of 6-2-15/11.1 and 6-2-15/11.3.

17 Tests and Inspections

17.1

The tests and inspections of the refrigeration machinery and associated system is to be in accordance with 6-2-6/25, as applicable.

17.3

Tests and inspection of the vessel and its machinery, other than the refrigeration machinery, are to be in accordance with the applicable Sections of these Rules.

PART 6

CHAPTER 2

Vessels Intended to Carry Refrigerated Cargoes

SECTION 16

Testing *(2024)*

This section includes requirements for testing to verify conformance to Goals and Functional Requirements outlined in the cross referenced sections.

1 On Board Tests After Installation - (Commissioning)

1.1 Piping

1.1.1

All refrigerant and brine piping welded joints are to be hydrostatically tested to a pressure of 1.5 times the respective design pressure. Alternatively, 100 percent nondestructive radiographic or ultrasonic testing of the welded joints may be carried out.

1.1.2

After completion of tests required in 6-2-16/1.1.1, and being completely installed and assembled, but before the application of the insulation, a leak test is to be carried out on the refrigerant and brine systems by use of nitrogen or other suitable gases at pressures not less than the design pressures of the respective systems.

Where defrosting is intended by hot refrigerant gas, the design pressure for the leak test on the low pressure side is to be the same as the high pressure side.

1.1.3

The leak test may be carried out using following methods:

1.1.3(a) By submerging the refrigerant and brine piping and equipment and applying the pressure referred to in 6-2-16/1.1.2.

1.1.3(b) By building up an initial pressure of 0.5 to 1.0 bar (0.5 to 1.0 kgf/cm^2, 7 to 14 psi) in the refrigerant and brine piping systems and checking for leaks at the pressure by either soapy water test, tracer, or detectors. If no leaks are detected or leaks found are dealt with satisfactorily, the pressure is to be increased gradually to the respective design pressures of the systems. The pressure is to be maintained for a predetermined period and pressures deviations are to be recorded.

1.1.3(c) Other alternative effective methods similar to those described above subject to the satisfaction of the attending Surveyor.

1.1.4

Following completion of the above-mentioned tests, the refrigerant piping systems are to be flushed with dry nitrogen to maintain dryness and cleanliness.

1.3

Before charging with refrigerant the entire refrigeration system is to be evacuated using vacuum pumps.

1.5

After completing the pressure tests above, all refrigerant and brine pipes are to be examined under working pressure.

1.7

The refrigeration plant is to be operated to demonstrate its ability to modulate the refrigeration capacity in single and multiple compressor operation, with all possible variations in the cross over connections that can be made with compressors, condensers and evaporators.

1.9

Verify operation of thermostats, solenoid valves, expansion valves, bypass valves, evaporator brine line valves and condenser water regulators and other such similar devices.

1.11

Plant safety valves and other similar safety devices are to be verified for satisfactory operation.

1.13

Cooling water flow rates through the condenser are to be measured to confirm that the velocities do not exceed the maximum design values whilst operating with the main cooling water pump and then the standby pumps.

1.15

The satisfactory operation of the automatic or manual oil refrigerant separation system is to be verified to confirm that separated oil is returned to the compressors, such that the oil levels between the compressors are balanced.

1.17

After initial startup, the refrigeration monitoring system and the automatic control system, where fitted, is to be verified for satisfactory operation.

1.19

Effective operation of the refrigerant leakage detection system is to be demonstrated.

3 Performance Test

3.1 Air Circulation and Fresh Air Ventilation

3.1.1

All fans for air circulation and fresh air ventilation of cargo spaces are to be tested at the full rated speeds of volumetric flow rates referred to in 6-2-5/9. The testing is to include measurements of pressure difference across the fans and power consumption. The anemometer or other similar measuring devices may be situated on the suction side of the cargo hold. These measuring devices are to be calibrated to the satisfaction of the attending Surveyor.

3.1.2

The air circulation distribution pattern in the refrigerated cargo spaces is to be checked.

3.1.3

The air distribution measurement referred to in 6-2-16/3.1.2 is to be carried out to verify the design values specified by the manufacturers and to confirm that there are no areas of insufficient air flow.

3.3 Refrigeration Machinery and Insulation Test

3.3.1 General

The following refrigeration machinery and insulation tests are to verify that the plant has sufficient refrigeration capacity as required by 6-2-6/3.3 relative to the insulation and other heat loads to achieve and maintain the minimum design temperature, which will be the basis of the notations referred to in 6-2-1/7.

3.3.2 Pull Down Test

Upon completion of the commissioning test referred to in 6-2-16/1, all openings to the cargo spaces including the air freshening vents are to be closed.

The refrigerated cargo hold spaces are to be warmed up to ambient atmospheric temperature by means of running air circulation fans and brine pumps, if fitted.

The refrigeration plant is to be started and run at full capacity under automatic control using all compressors and set at maximum design condensing temperature. The refrigeration machinery is to continue to run until the minimum design temperature in all cargo spaces has been achieved. The operation of the refrigeration machinery is to be monitored to confirm satisfactory operation within design parameters.

3.3.3 Heat Balance Test

Upon achieving the minimum design temperature of the refrigerated spaces, after the test specified in 6-2-16/3.3.2, a heat balance test is to be initiated by switching one compressor to manual and remainder switched off and allowing the temperature to stabilize at approximately the minimum design temperature or at least minus 20°C (68°F) and held at these temperatures for a sufficient period of time, generally about 24 hours, to remove the residual heat in the insulation and achieve a balance condition.

The condition is considered to be balanced when the mean temperature in the refrigerated cargo space does not vary by more than ±0.5°C (±1°F) in each hour. The balance condition is to be planned to be achieved during the time of day when the outside temperature is as constant as possible. During the stabilization period, the collection of data is to be taken initially every six (6) hours and every hour for the last six (6) hours.

For this test, at least the following data are to be recorded:

3.3.3(a) The outside temperatures of the shell, bulkheads and decks enclosing the refrigerated cargo spaces.

3.3.3(b) The internal temperatures of the cargo spaces.

3.3.3(c) The suction and discharge pressure of the compressors.

3.3.3(d) The actual voltage and amperage of the compressor electric motor.

3.3.3(e) Heat inputs to the refrigerated spaces from fan motors, lighting fixtures, heat tracing on drain pumps, etc.

3.3.3(f) The rate of cooling water flowing through the condensers.

3.3.3(g) The inlet and outlet temperatures of the condenser cooling water.

3.3.3(h) Upon achieving stabilized temperatures, calculations of the values based on the heat balance test mentioned above are to be carried by the yard/builder and submitted to ABS for review. For these calculations, the air cooler overall heat transfer coefficient at the design conditions is to be taken equal to that measured during the heat balance test. Similarly, the condenser overall heat transfer coefficient at the stated maximum sea water temperature is to be taken equal to that measured during the heat balance test.

3.3.4 Refrigerated Port Hole Type

For container carriers described in 6-2-13/3, a full functional test of all refrigerated cargo spaces may not be required if an operational test equivalent to that described herein is performed on board with at least one cell of containers installed and the following requirements are satisfied:

3.3.4(a) Cooling air to the containers is supplied exclusively by air ducts tested in accordance with 6-2-13/7.

3.3.4(b) The builder demonstrates by calculating, using data obtained during testing described above, to show that the refrigerating machinery has sufficient capacity.

3.3.4(c) It is to be demonstrated that the cell conditioning, if fitted, is sufficient to maintain the cell at a temperature which is in excess of the minimum design temperature of the structural steel.

3.3.5 Insulation Test

After the cargo spaces have been stabilized for the heat balance test in 6-2-16/3.3.3, the outside surfaces of the bulkheads, shell, decks, doors and other opening covers, as well as duct, pipe and cable penetrations are to be checked for excessive condensation or frost indicative of voids and thermal bridges in the insulation.

3.3.6 Temperature Rise Test

For the temperature rise test the refrigerating machinery is to be stopped and all the heat input sources shut off after stabilization as in 6-2-16/3.3.3, and at least the following data are to be recorded once per hour over a six hour period.

3.3.6(a) The outside temperature of the entire shell enclosing the refrigerated cargo space such as ambient, sea water, tanks, engine room.

3.3.6(b) The internal temperature of the cargo space:

i) The test is to be performed at the time of the day when the outside temperature is as constant as possible.

ii) The calculations of the *k* values is to be carried out by the yard/builder and submitted to ABS for review together with a drawing showing precise locations and position of the values recorded for this test.

3.3.7 Defrosting Test

After satisfactory completion of the heat balance test and temperature rise test, the cooler batteries are to be defrosted to demonstrate the ability to completely defrost. The Surveyor to verify that the system for removing defrost water is operating satisfactorily.

3.3.8 Multiple Compartment Temperature Test

Where the design parameter specified requires multiple temperature configurations, a test is to be carried out to demonstrate this capability for the refrigerated spaces.

3.3.9 Heating Capacity Test

Where the design parameter specified requires a heating capacity to be available for the refrigerated compartments, a test is to be carried out to demonstrate the capability of the heating system.

3.3.10 Automatic Control System

Where automatic control systems are fitted, the tests referred to under 6-2-16/3.3.2, 6-2-16/3.3.6, 6-2-16/3.3.7 and 6-2-16/3.3.8 are to be conducted utilizing the control system.

PART 6

CHAPTER 3
Exhaust Emission Abatement

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PART 6

CHAPTER 3
Exhaust Emission Abatement

SECTION 1
General *(2023)*

1 Scope and Application *(2024)*

This Chapter provides guidance and criteria for the design and construction of exhaust emission abatement systems. It covers SO_x scrubbers, Selective Catalytic Reduction (SCR) systems and Exhaust Gas Recirculation (EGR) arrangements, together with Exhaust Emissions Monitoring Systems (EEMS) fitted in conjunction with the aforementioned exhaust emission abatement systems or installed as an alternative Onboard NO_x Verification Procedure in accordance with the Direct Measurement and Monitoring Method of the NO_x Technical Code.

The optional exhaust emission abatement notations detailed under 6-3-1/9.3 through 6-3-1/9.9 will be assigned to a vessel upon request and where the exhaust emission abatement system has been verified to comply with the applicable requirements of this Chapter. Where a notation has not been requested, the exhaust emission abatement system is to comply with the minimum requirements prescribed under 6-3-1/9.11and 6-3-1/13 TABLE 1, and is to be verified by the ABS Surveyor during installation. The plans describing the vessel specific installation as required by 6-3-1/9.11 are to be submitted to ABS Engineering. The installation details included in the ship system plans are acceptable. This is applicable to new construction and existing vessel modifications.

3 General *(2024)*

This Chapter focuses on the safety and reliability aspects of exhaust emission abatement equipment that fall within the scope of traditional Classification requirements and is to be applied to those Exhaust Gas Cleaning (EGC) systems covering SO_x scrubbers, SCR systems, and EGR arrangements. SO_x scrubbers and SCR units are installed downstream of the Fuel Oil Combustion Units (FOCUs) and are secondary after treatment systems. Compatibility of these EGC systems with the FOCU is to be verified as part of the approval process with confirmation from the FOCU equipment manufacturer. A Low Pressure SCR system is one where the SCR reaction chamber and catalysts are integrated after the exhaust gases have passed through the turbocharger. In the case of EGR systems, or SCR systems fitted before an engine turbocharging system (High Pressure SCR), these are primary exhaust emission reduction techniques forming part of the total engine design and as such are to be integrated by the engine designer or a third party under the authorization of the engine designer. Those applicable requirements for EGR and SCR systems contained within this Chapter are supplementary to, and to be applied in association with, the requirements for internal combustion engines under Section 4-2-1.

This Chapter focuses on those systems designed to reduce gaseous exhaust emissions species legislated through the International Maritime Organization (IMO) Annex VI Regulations 13 and 14 for nitrogen oxide (NO_x) emissions from diesel engines and sulfur oxide (SO_x) emissions from all fuel burning equipment on board. Acceptance of a SO_x exhaust gas cleaning system under MARPOL Annex VI, as an alternative means of compliance through Regulation 4, is subject to approval by the flag Administration of the vessel.

The regulatory requirements covering the air emissions performance, testing, statutory certification, and statutory survey aspects are regulated through Annex VI in association with any other applicable IMO Guidelines. The applicable Guidelines for Selective Catalytic Reduction are IMO Resolution MEPC.291(71) – *2017 Guidelines Addressing Additional Aspects to the NOx Technical Code 2008 With Regard to Particular Requirements Related to Marine Diesel Engines Fitted With Selective Catalytic Reduction (SCR) Systems*, adopted 7 July 2017. The applicable Guidelines for SOx exhaust gas cleaning systems are IMO Resolution MEPC.340(77) – *2021 Guidelines for Exhaust Gas Cleaning Systems*, adopted 26 November 2021. This Chapter is intended to cover only the Classification aspects, and the statutory approval can be made by ABS as a separate parallel process in the capacity of a Recognized Organization (RO), when authorized by the flag Administration.

Individual flag Administrations may have in place additional requirements for the operation of EGC systems for vessels operating in their territorial waters, in particular those systems producing a washwater discharge associated with the exhaust gas cleaning process. These requirements may necessitate additional vessel features, performance standards, equipment, reporting and record keeping, or operational practices that are not covered by the IMO regulations or this Chapter. Accordingly, any party selecting an exhaust emission abatement system for a particular vessel is encouraged to verify the need for any additional or specific arrangements to meet the requirements of the vessel flag Administration, coastal state or port Authorities.

5 Objectives *(2024)*

The goals and functional requirements for the topics covered in this chapter are included in the respective sections. Refer to Part 1D, Chapter 2 for information on approval of alternative arrangements.

7 Definitions and Abbreviations

7.1 CO

Carbon Monoxide.

7.3 CO_2

Carbon Dioxide.

7.5 EGC

Exhaust Gas Cleaning.

7.7 EGR

Exhaust Gas Recirculation. The process whereby part of the exhaust gas flow is redirected back to the combustion cylinder of an engine for the purposes of reducing NO_x emissions.

7.9 EEMS *(2024)*

Exhaust Emissions Monitoring System. A system designed for the monitoring of gaseous exhaust emission constituents, primarily for compliance verification of the NO_x and SO_x emissions.

7.11 FOCU *(2024)*

Fuel Oil Combustion Unit. Any engine, boiler, gas turbine, or other fuel oil fired equipment, excluding shipboard incinerators.

7.13 HC

Hydrocarbon.

7.15 MARPOL *(2024)*

The IMO International Convention for the Prevention of Pollution from Ships, 1973, as modified by the 1978 and 1997 Protocols.

7.17 MSDS

Material Safety Data Sheet. Sometimes referred to as Safety Data Sheet (SDS) or Product Safety Data Sheet (PSDS).

7.19 NO_x

Nitrogen Oxides. Predominantly containing NO and NO_2 components and typically calculated as the total weighted emission with mass reference for NO_2 and determined using the relevant test cycles and measurement methods of the IMO NO_x Technical Code or ISO 8178.

7.21 O_2

Oxygen.

7.23 PM

Particulate Matter.

7.25 RO *(2024)*

Recognized Organization. An organization delegated by an Administration to undertake surveys and certification on the Administration's behalf in accordance with the IMO Guidelines adopted by Resolution A.739(18), as amended, and the specifications adopted by IMO Resolution A.789(19), as amended.

7.27 Recognized Standard

An international or national standard acceptable to ABS.

7.29 Rules

The applicable edition of the ABS *Rules for Building and Classing Marine Vessels (Marine Vessel Rules)*.

7.31 SCR *(2024)*

Selective Catalytic Reduction. An exhaust after treatment system whereby the exhaust gases are mixed with a reductant, such as ammonia introduced in a urea/water solution, and passed over a catalyst, such as vanadium, located in the downstream exhaust system for the purposes of reducing NO_x emissions.

A *High Pressure SCR* is an SCR system integrated onto an engine before the exhaust gas passes through the turbo charger.

A *Low Pressure SCR* is an SCR system integrated onto an engine after the exhaust gas passes through the turbo charger.

7.33 SO_x

Sulfur Oxide. All sulfur emissions from fuel oil combustion machinery are caused by the combustion reactions with the sulfur introduced by the fuel which predominately include SO_2 and SO_3 emissions and are typically quantified as SO_2 emissions.

7.35 Urea

The most common reductant source used in SCR applications, where ammonia and deionized water are mixed, typically in 32.5% concentrations for automotive use, commonly known as AUS-32 or Diesel

Exhaust Fluid, and 40% concentration in the marine industry. Where the term "urea" is used in this Chapter, this refers to 40% marine grade urea, commonly known as AUS-40.

9 Classification Notations

9.1 General

The optional vessel notations detailed under 6-3-1/9.3 through 6-3-1/9.9 may be assigned upon request and where single or multi exhaust emission abatement systems are found to comply with the applicable requirements of this Chapter.

9.3 SO_x Scrubbers *(2024)*

Where an exhaust gas cleaning system primarily intended for the reduction of SOx emissions using SO_x scrubber is designed, constructed, and tested in accordance with 6-3-2/2.1, the optional **EGC-SOx (M)** notation may be assigned.

Where an exhaust gas cleaning system primarily intended for the reduction of SO_x emissions using SO_x scrubber is designed, constructed, and tested in accordance with 6-3-2/2.2, the optional**EGC-SO_x** notation may be assigned.

9.5 SCR Systems *(2024)*

Where an exhaust gas cleaning system primarily intended for the reduction of NO_x emissions using Selective Catalytic Reduction catalysts is designed, constructed, and tested in accordance with 6-3-3/2.1, the **EGC-SCR (M)** notation may be assigned.

Where an exhaust gas cleaning system primarily intended for the reduction of NO_x emissions using Selective Catalytic Reduction catalysts is designed, constructed, and tested in accordance with 6-3-2/2.2, the optional**EGC-SCR** notation may be assigned.

9.7 EGR Systems *(2024)*

Where an exhaust gas cleaning system primarily intended for the reduction of NO_x emissions using exhaust gas recirculation is designed, constructed, and tested in accordance with 6-3-4/1 and 6-3-1/13 TABLE 1, the optional **EGC-EGR(M)** notation may be assigned.

Where an exhaust gas cleaning system primarily intended for the reduction of NO_x emissions using exhaust gas recirculation is designed, constructed, and tested in accordance with Section 6-3-4, the optional**EGC-EGR** notation may be assigned. This notation is intended to be applied to those EGR systems that incorporate off-engine systems designed for the removing sulfur by-products from the exhaust gases that originate from the fuel and incorporate water scrubbing and water cleaning systems. Where a water treatment system is incorporated in the EGR system, it is to meet the requirements of IMO Resolution MEPC.307(73) for the discharge of EGR bleed-off water, and as applicable, MEPC.340(77).

The EGR version of the engine is to be approved by incorporation to the existing internal combustion engine approval.

9.9 Exhaust Emission Monitoring Systems *(2024)*

The notation for an exhaust emissions monitoring system will be assigned to a vessel fitted with or without an exhaust emission abatement system. Where a permanently installed exhaust emission monitoring system is designed, constructed, and tested in accordance with Section 6-3-5, the optional**EEMS** notation may be assigned.

9.11 Minimum Requirements for Systems where EGC and EEMS Notations are not Requested *(2024)*

Where a vessel is fitted with an exhaust emission abatement system and the **EGC** and **EEMS** optional vessel notations detailed under 6-3-1/9.3 through 6-3-1/9.9 are not requested, the exhaust emission abatement system is to comply with the minimum requirements prescribed in 6-3-1/13 TABLE 1 and is to be verified by the ABS Surveyor during installation. This is applicable to new construction and existing vessel modifications.

Plans and supporting documentation showing compliance with the minimum requirements in 6-3-1/13 TABLE 1 are to be submitted to ABS Engineering.

11 Operating and Maintenance Instruction Manuals

Detailed instruction manuals covering the operations, safety, and maintenance requirements, and occupational health hazards relevant to the specific exhaust emission abatement unit and associated systems are to be provided on board.

The manuals are to include, but not be limited to, the regular testing and maintenance procedures and schedules for the monitoring systems, safety shut-off systems, and the integrity of backup systems together with identification of the relevant responsible parties.

In addition, there is further guidance regarding the contents of the operating and maintenance manuals in each of the individual Sections of this Chapter. Reference is to be made to the requirements in each Section of this Chapter.

13 Certification

Design review, survey, testing, and the issuance of reports or certificates constitute the certification of machinery, equipment, and systems (see also 4-1-1/3). There is guidance on the certification requirements for machinery, equipment, and systems in each of the applicable individual Sections of this Chapter.

TABLE 1
Minimum Requirements for EGC and EEMS Systems *(2024)*

System	*Reference*
Section 6-3-2 – SO_x Scrubbers	
Exhaust System Bypass	6-3-2/7.9
Configuration and Vessel Integration	6-3-2/7.1.i, 6-3-2/7.3.i
Prevention of Flooding	6-3-2/7.11
Vessel Stability	6-3-2/7.15
Electrical Load Analysis	6-3-2/9.9.2.ii
Piping	6-3-2/11.1.2.ii, 6-3-2/11.1.3, 6-3-2/11.1.4, 6-3-2/11.3
Chemical Treatment Fluid Supply System	6-3-2/11.5 , 6-3-2/11.7
Safety Shutdown System	6-3-2/13.5 , Note 3 of 6-3-2/17 TABLE 2
Section6-3-3 – SCR Systems	
Exhaust System Bypass	6-3-3/7.1.ii
Configuration and Vessel Integration	6-3-3/7.1.ii, 6-3-3/7.3.i
Electrical Load Analysis	6-3-3/9.11.2.ii

System	*Reference*
Piping	6-3-3/11.1.2.ii, 6-3-3/11.1.3.i, 6-3-3/11.1.4
Urea Supply System	6-3-3/11.3
Safety Shutdown System	6-3-3/13.5
Section6-3-4 – EGR Systems	
Configuration and Vessel Integration	6-3-4/7.1.ii, 6-3-4/7.3.i
Prevention of Flooding	6-3-4/7.9
EGR Blowers	6-3-4/9.1.iv
Electrical Load Analysis	6-3-4/9.7.2.ii
Piping	6-3-4/11.1.3, 6-3-4/11.3.1
Chemical Treatment Fluid Supply System	6-3-4/11.5
Safety Shutdown System	6-3-4/13.5, Note 2 of 6-3-4/17.7 TABLE 1
Section6-3-5 – Exhaust Emission Monitoring Systems	
Gases	6-3-5/9.1.i
Piping	6-3-5/9.5.iii

PART 6

CHAPTER 3

Exhaust Emission Abatement

SECTION 2

EGC – SO_x Scrubbers *(2023)*

1 General *(2024)*

This Section provides requirements on the arrangements and system design for exhaust gas cleaning systems designed primarily for the removal of SO_x emissions, or SO_x scrubbers, as they are commonly known. The intent is that these requirements supplement the statutory emissions performance testing, survey, and certification requirements of the applicable IMO Regulations and Guidelines. The applicable Guidelines for SO_x exhaust gas cleaning systems are IMO Resolution MEPC.340(77) – *2021 Guidelines for Exhaust Gas Cleaning Systems*, adopted 26 November 2021. The statutory approval aspects can be made by ABS as a separate parallel process in the capacity of a (RO), when authorized by the flag Administration.

1.1 Objectives *(2024)*

1.1.1 Goals

The SO_x scrubber systems covered in this Section are to be designed, constructed, operated, and maintained to:

Goal No.	*Goal*
STAB 1	have adequate watertight integrity and restoring energy to prevent capsize in an intact condition.
PROP 2	provide redundancy and/or reliability to maintain propulsion.
FIR 1	*prevent the occurrence of fire and explosion.*
ENV 6	prevent and minimize air pollution.
SAFE 1.1	minimize danger to persons on board the vessel, and surrounding equipment/installations from hazards associated with machinery and systems.
MGMT 1	*provide for safe practices in ship operation and a safe working environment.*
MGMT 3	*establish procedures, plans and instruction for operations concerning the safety of the personnel, vessel, and protection of the environment.*
MGMT 5.1	design and construct vessel, machinery, electrical, safety systems to facilitate safe access, ease of inspection, survey and maintenance.
AUTO 1	perform its functions as intended and in a safe manner

Goal No.	*Goal*
AUTO 2	indicate the system operational status and alter operators of any essential machinery/systems deviate from its defined design/operating conditions or intended performance.
AUTO 3	have an alternative means to enable safe operation in the event of an emergency or failure of remote control.
AUTO 4	provide the equivalent degree of safety and operability from a remote location as those provided by local controls.
AUTO 5	provide a safety system that automatically leads machinery controlled to a fail-safe state in response to a fault which may endanger the persons on board, machinery/equipment or environment.

Materials are to be suitable for the intended application in accordance with the following goals and support the Tier 1 goals listed above.

Goal No.	*Goal*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.

The goals in the cross-referenced Rules/Regulations are also to be met.

1.1.2 Functional Requirements

In order to achieve the above stated goals, the design, construction, installation and maintenance of the exhaust gas cleaning system (SO_x scrubbers) are to be in accordance with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
Stability (STAB)	
STAB-FR1	Vessel's stability is to consider effects of the system installation and is to meet necessary criteria.
Materials (MAT)	
MAT-FR1	Chemical Composition to be considered for corrosion resistance, weldability, final mechanical properties.
MAT-FR2	Corrosion resistance to be considered when exposed to different fluids which lead to loss of material.
MAT-FR3	Galvanic compatibility is to be considered when dissimilar metals are connected and come in contact with an electrolytic solution.
Propulsion, Maneuvering, Station Keeping (PROP)	
PROP-FR1	The exhaust emission abatement is to allow continued operation of machinery connected to the system when it is not in operation.
Fire Safety (FIR)	
FIR-FR1	The exhaust emission abatement system is to be arranged to prevent dangerous chemicals from coming in contact with sources of ignition to minimize the risk fire/explosion.
Protection of Environment (ENV)	

Functional Requirement No.	*Functional Requirements*
ENV-FR1	The exhaust emission abatement system is to remove SO_x emitted from the machinery to minimize air pollution.
ENV-FR2	Redundancy is to be provided for exhaust emission abatement equipment to maintain capability of reducing air pollution.
Safety of Personnel (SAFE)	
SAFE-FR1	The exhaust emission abatement system is to be compatible with the connected machinery and their operating parameters.
SAFE-FR2	The exhaust emission abatement system is to be arranged to prevent internal flooding and ingress of water to the connected machinery.
SAFE-FR3	Protective devices compatible with the prospective short circuit current are to be installed in the exhaust emission abatement system circuits to protect the equipment from damage.
SAFE-FR4	The exhaust emission abatement system is to be arranged to prevent the passage of exhaust gas to the machinery space or other equipment for the safety of the crew or to prevent further damage of equipment.
SAFE-FR5	Provide means to protect the crew from the hot surfaces of the exhaust emission abatement system.
SAFE-FR6	Non-metallic piping used in the exhaust emission system is to be designed to minimize the risk of failure due to fire that may lead to flooding.
SAFE-FR7	Chemical treatment system including the tank for dangerous chemicals is to be designed and arranged to contain dangerous chemicals in all expected conditions and prevent leakage/ contact with personnel.
SAFE-FR8	Tanks containing the dangerous chemicals for the exhaust emission abatement system are to be provided with means of confirm the amount of chemical in tanks.
SAFE-FR9	Ventilation of the space with tanks containing dangerous chemicals are to be arranged to extract the dangerous vapors from possible leakage.
SAFE-FR10	Provide suitable equipment to protect the crew from exposure to dangerous chemicals during operation of the exhaust emission abatement system.
SAFE-FR11	Means are to be provided for safe storage and disposal of any exhaust residues associated with the operation of the exhaust emission abatement system.
SAFE-FR12	The exhaust emission abatement system is to be arranged such that a single fault of a component will not lead to a potentially dangerous situation for human safety and/or the vessel.
Safety Management (MGMT)	
MGMT-FR1	Information is to be provided onboard covering the operations, safety and maintenance requirements and occupational health hazards relevant to the exhaust emission abatement system.
MGMT-FR2	The exhaust emission abatement system is to be installed in an accessible location and arranged for ease of inspection and maintenance.
Automation: Control, Monitoring and Safety Systems (AUTO)	
AUTO-FR1	Means are to be provided for visible and audible notifications at manned locations for abnormal conditions of the exhaust emission abatement systems, and the automatic start of the redundant equipment if available, to prevent the further escalation of hazards.

Functional Requirement No.	*Functional Requirements*
AUTO-FR2	Local control and monitoring system for the exhaust emission abatement system is to be provided to enable safe operation, maintenance, and effective control in the event of an emergency or failure of any remote controls.
AUTO-FR3	Alarm, monitoring and control systems are to be provided to facilitate automatic and manual operations, including safe shutdowns, at remote and local locations to allow continued operations.

The functional requirements in the cross-referenced Rules/Regulations are also to be met.

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

2 Notations *(1 July 2023)*

2.1 EGC-SO_x (M)

Vessels complying fully with the statutory emissions performance testing, survey, and certification requirements of the applicable IMO Regulations and Guidelines and the minimum requirements of EGC SO_x scrubbers in 6-3-1/13 TABLE 1 will be assigned the optional **EGC-SOx (M)** notation.

2.2 EGC-SO_x

Vessels complying fully with this section will be assigned the optional **EGC-SOx** notation.

2.3 Notations Not Requested

Where no notation is requested, the SO_x scrubber system is to be verified to be in compliance with the minimum requirements prescribed in 6-3-1/9.11 and 6-3-1/13 TABLE 1 and is to be verified by the ABS Surveyor during installation.

3 Plans and Data to be Submitted *(2024)*

Plans and specifications covering the SO_x scrubber arrangements are to be submitted and are, as applicable, to include:

- General arrangement of the SO_x scrubber installation, layout,and systems
- Documentation detailing the SO_x scrubber specifications
- Analyses demonstrating compatibility of the SO_x scrubber with the fuel oil combustion units (see 6-3-2/7.3)
- Hull plans showing the foundation and attachments to the vessel's structure, including scantlings plans, welding details, and foundation details of principal components
- Documentation detailing the effect on Load Line and Stability of the exhaust emission abatement system (see 6-3-2/7.15)
- Material specifications for the SO_x scrubber unit, pumps, valves, storage/process tanks, residue tanks, piping, distribution systems, separators, and associated components, including a corrosion assessment detailing the corrosive effect of system liquids, vapors, and gases on the materials used in the SO_x scrubber system
- Arrangement and capacity of tanks for storage, chemicals, process washwater, exhaust gas cleaning residues, etc.

- Details of all piping systems, including details of piping and associated components, design pressures, temperatures, insulation, and spill trays, where applicable
- Details of the granulate supply and discharge systems, for dry-type SO_x scrubber systems
- Descriptions and schematic diagrams for the control and monitoring systems, including set points for abnormal conditions and details of the location and positions of exhaust emission monitoring and washwater monitoring systems
- Details of all electrical equipment installed for the SO_x scrubber unit and associated systems, including computer-based systems
- Failure Modes and Effects Analysis (FMEA) to determine possible failures and their effects in the safe operation of the SO_x scrubber (see 6-3-2/13.1)
- Safety shutdown system (see 6-3-2/13.5)
- SO_x scrubber unit FMEA integration test report (see 6-3-2/15)
- Operating and maintenance instruction manuals, including MSDS sheets and details for handling of hazardous and non-hazardous chemicals used in the SO_x scrubber system (see 6-3-2/5)
- Testing procedures during installation and commissioning trials

5 SO_x System Operation and Maintenance Manuals *(2024)*

In accordance with 6-3-1/11, detailed instruction manuals covering the operations, safety, and maintenance requirements and occupational health hazards relevant to the SO_x exhaust emission abatement equipment and associated systems are to be provided on board.

These manuals are to include, but are not limited to, the procedures and schedules for operation, inspection, testing, and maintenance of the SO_x scrubber and associated systems; the regular testing and maintenance procedures for the monitoring systems, safety shutoff systems, and the integrity of backup systems; together with special instructions for the bunkering, storage, and use of hazardous and non-hazardous chemicals that may be used in the SO_x scrubber system and identification of the relevant responsible parties.

The manuals are to be submitted for reference to verify the presence of all the information required by this Section.

7 SO_x System Configuration and Vessel Integration *(2024)*

7.1 General *(2024)*

i) SO_x scrubber systems are to be designed to enable continued operation of the FOCUs at the times the SO_x scrubber system is not in operation, due to, for example, operational selection, equipment failure, or system deterioration through partial blocking/clogging.

ii) The exhaust systems from multiple FOCUs can be led to a common SO_x scrubber unit, sometimes known as an integrated scrubber (see 6-3-2/11.1.3).

iii) The response of the mechanical and electrical systems of the first SO_x scrubber unit in a particular design series is to be demonstrated by the FMEA integration test described in 6-3-2/15.

7.3 Compatibility with Fuel Oil Combustion Units (FOCUs) *(2024)*

i) Installation and operation of a SO_x scrubber system is to be compatible with the FOCUs and is not to cause any adverse effects on the FOCU performance, such as excessive back pressures or high temperatures during operation.

ii) Details are to be submitted demonstrating the exhaust flow compatibility of the SO_x scrubber unit with the connected FOCUs over the whole operational range of the FOCUs. This data is to demonstrate that the operating parameters of the FOCUs do not exceed the approved design limits with the SO_x scrubber system in operation. In the case of integrated scrubbers, this compatibility evaluation is to show that the SO_x scrubber unit is capable of accommodating the maximum combined exhaust flows of all the connected oil burning equipment for the worst-case scenario for that particular ship arrangement and operational profile. SO_x scrubber units that incorporate extractive exhaust fans to maintain the FOCU operating parameters within the approved design limits is subject to ABS technical assessment and approval.

It is to be noted that exhaust emission abatement systems that cause diesel engines to operate outside the exhaust back pressure limits detailed in the approved MARPOL Annex VI NO_x Technical Files can invalidate the emissions certification and will require reapproval of the engine NO_x certification by the Administration or RO responsible for the NO_x certification.

7.5 Redundancy *(2024)*

Redundancy of equipment is to be provided for those rotating and reciprocating components that form part of the SO_x scrubber unit essential supplementary systems, such as pumps, fans, blowers, etc. (see 6-3-2/9.1 and 6-3-2/9.9.3).

Alternative means of compliance or operation to meet this objective is subject to ABS technical assessment and approval. As applicable, documentation is to be submitted demonstrating either that the reliability of the system or component provides continued serviceability of the SO_x scrubber system or that the alternative means of operation provides continued compliance with the statutory environmental requirements, without compromising the vessel propulsion and maneuvering capabilities. Adequate fuel tank capacity for low sulfur fuels, alternative operating modes, or carriage of sufficient spare parts on board are examples of vessel-specific arrangements that will be considered by ABS as meeting this objective and is to be justified with reference to the FMEA required by 6-3-2/13.1.

7.7 Essential Services *(2024)*

For the purposes of design, construction, testing, and survey, SO_x scrubber units and associated components and systems are considered secondary essential services in accordance with 4-8-1/7.3.3.

7.9 Exhaust Bypass *(2024)*

SO_x scrubber units that incorporate a wet washwater scrubbing process are to be capable of being operated without the washwater system in operation, without sustaining thermal damage, or are to be installed with an exhaust bypass arrangement or changeover system of the washwater pump, as applicable, to enable continued operation of the FOCU in the event the SO_x scrubber washwater system is not in operation, either through operational selection or equipment failure. As applicable, evidence of material suitability is to be submitted for dry running of SO_x scrubbers.

SO_x scrubber units serving multiple FOCUs are to be provided with bypass unless arrangements are provided to maintain the function of the FOCUs in the case an SO_x scrubber unit is out of service, and to prevent the return of gas to an idle engine.

A SO_x scrubber unit fitted to single main propulsion engine is to be installed with an exhaust bypass arrangement unless designed for unrestricted flow of exhaust gas and with no risk of causing failure of the main propulsion engine.

When the operation of the engine is affected by back pressure in the SO_x scrubber system and the SO_x scrubber is not designed for dry operation causing possible shutdown of SO_x scrubber unit or reduction in the engine power rating, the bypass of the SO_x scrubber unit is to be arranged for automatic operation.

7.11 Prevention of FOCU Flooding *(2024)*

i) For SO_x scrubber units that incorporate a wet washwater scrubbing process, arrangements are to be provided to prevent the ingress of scrubber washwater into the fuel oil combustion unit under any circumstance. The inlet exhaust piping is to be arranged to prevent direct free flow of washwater back to the FOCU.

ii) Monitoring, alarm, and shutdown arrangements are to be provided to prevent an abnormal rise of washwater level in the scrubber reaction chamber. See 6-3-2/17 TABLE 2.

7.13 Inclinations *(2024)*

SO_x scrubber systems are to be designed for proper operation at the inclination requirements of 4-1-1/7.9.

7.15 Vessel Stability *(1 July 2024)*

i) For those existing ships fitted with an SO_x scrubber system as a retrofit conversion, a revision of the stability calculations is required based on the additional weight of the SO_x scrubber system and increased wind profile. Refer to Table 1 below describing various scenarios and corresponding requirements for inclining test and update of stability information.

TABLE 1 *(1 July 2024)*

Scenario, as calculated by lightweight calculation	*Requirement for Inclining Test*	*Update of Stability Information*
Lightweight change > 2%	Yes	Yes, using new incline result
LCG change > 1% of L_f (either forward or Aft)	Yes	Yes, using new incline result
VCG change > 1%	Yes	Yes, using new incline result
1% < Lightweight change ≤ 2%	No	Yes, using lightweight calculation
0.5% of L_f < LCG Change ≤ 1% of L_f (either forward or Aft)	No	Yes, using lightweight calculation
0.5% < VCG Change ≤ 1%	No	Yes, using lightweight calculation
Lightweight change ≤ 1%	No	No
LCG change ≤ 0.5% of L_f (either forward or Aft)	No	No
VCG change ≤ 0.5%	No	No

i) Documentation detailing the effect on Load Line and Stability of the SO_x scrubber system,in accordance with the guidance in 6-3-2/7.15.i, is to be submitted.

Commentary:

Impact on vessel's stability due to increased windage area is to be investigated and supporting calculations are to be submitted.

L_f is the freeboard length as defined in 3-1-1/3.3.

End of Commentary

7.17 Inspection and Maintenance *(2024)*

SO_x scrubber units are to be arranged for easy inspection and maintenance with at least one inspection port or hatch available for internal inspection and maintenance of the main reaction chamber, and, where applicable, the ability to replace internal components is to be provided.

9 SO_x Scrubber System Equipment *(2024)*

9.1 Pumps/Fans *(2024)*

i) Where provided, SO_x scrubber pumps, essential for the continual operation of the SO_x scrubber system (washwater, circulation, discharge, etc.), are to be tested and certified in accordance with 4-6-1/7.3. This is applicable to SO_x scrubber systems connected to FOCUs rated at 2250 kW (3000 hp) and above or internal combustion engines having cylinders of more than 300 mm (11.8 in.) bore.

ii) Unless alternative means of compliance in accordance with 6-3-2/7.5 are applicable, redundant pumps, essential for the continual operation of the SO_x scrubber system (washwater, circulation, discharge, etc.) are to be provided. There are to be at least two of these essential pumps, and the capacity of the pumps, with any one pump out of service, is to be sufficient for continuous operation of the SO_x scrubber system at full rating. See also 6-3-2/9.9.3.

For vessels fitted with two or more identical SO_x scrubber systems, the provision of a common standby pump (as opposed to individual standby pumps for each SO_x scrubber unit.) (for each essential system) capable of serving all SO_x scrubber units will suffice.

iii) Unless alternative means of compliance in accordance with 6-3-2/7.5 are applicable and where exhaust fans form part of the SO_x scrubber system and are essential for continuous operation of the SO_x scrubber system at full rating, redundancy is to be provided for such fans. The number and power of the fans are be such that if one fan, or a group of fans, is out of service, the capacity of the remaining fan(s) is not to be less than 100% of the total required.

9.3 Exhaust Plume Heaters *(2024)*

i) Where provided, heat exchangers within the exhaust are to be designed, constructed, and certified in accordance with Section 4-4-1.

ii) Where the introduction of hot air to the exit exhaust gases is used on SO_x scrubber systems, the details of this auxiliary system are to be submitted for ABS technical assessment and approval.

9.5 Chemical Treatment System

The specific requirements for chemical treatment system components are given under 6-3-2/11.5.

9.7 Dry Scrubber Consumable Handling Equipment *(2024)*

Unless alternative means of compliance in accordance with 6-3-2/7.5 are applicable, redundancy is to be provided for drive arrangements for the granulate supply and discharge system.

9.9 Electrical System

The electrical system and electrical equipment requirements in this Paragraph are to be applied in association with the requirements of Part 4, Chapter 8.

9.9.1 Electrical Motors and Controllers

Motors and motor controllers of 100 kW (135 hp) and over are to be certified in accordance with 4-8-3/1.5.

9.9.2 Electrical Load Analysis *(2024)*

i) The number and capacity of generators are to be sufficient under normal seagoing conditions with one generator in reserve to carry those loads for essential services and for minimum comfortable conditions of habitability as per 4-8-2/3.1.1.

ii) The electrical loads associated with the SO_x scrubber system are to be included in the electric-plant load analysis required by 4-8-1/5.1.5.

9.9.3 Standby Pump/Fan Arrangements *(2024)*

i) In the event of failure of the essential SO_x scrubber system pumps or fans, the standby pump or fan required by 6-3-2/9.1, where provided, is to be automatically started and put into service. This failure is to be alarmed at the local and remote-control station(s), as applicable.

ii) Where provided, each standby pump or fan is to be fed from separate bus bar sections of the switchboard. In the event of failure of one bus bar section of the switchboard, the standby pump or fan can be fed from another bus bar section.

9.9.4 Circuit Protection Devices and Compatibility *(2024)*

Circuit breakers are to be installed for miscellaneous SO_x scrubber system electrical loads and are to be compatible with the prospective short circuit current level calculated at the switchboards.

11 SO_x Scrubber System Piping *(2024)*

11.1 Exhaust Gas Piping Systems

11.1.1 Exhaust Gas Piping/Scrubber Materials and Installation *(2024)*

i) Exhaust gas piping materials located before the SO_x scrubber unit may be of the same material specification as the standard exhaust gas piping.

ii) The parts and components of the scrubber that are subjected to washwater (e.g., the interior reaction chamber or washwater piping/nozzles, etc.) are to be constructed of corrosion-resistant materials, such as stainless steel, appropriate for the environment.

iii) Exhaust gas piping materials used after the SO_x scrubber unit are to be of a corrosion-resistant material such as stainless steel appropriate for the environment.

iv) The exhaust piping systems for SO_x scrubber systems are to meet the applicable requirements of 4-6-2/9 and 4-6-5/11

v) Exhaust gas piping and piping components constructed of non-metallic materials are to comply with 4-6-2/3 and subject to ABS technical assessment and approval.

11.1.2 Exhaust Gas Piping Valves *(2024)*

i) Valves used in the exhaust system of SO_x scrubber systems are to meet the requirements of 4-6-2/5.11.

Valves located after the scrubber unit are to be constructed of corrosion-resistant materials, such as stainless steel, appropriate for the environment.

ii) Isolation and bypass valves used in SO_x scrubber system exhaust piping systems are to prevent the passage of exhaust gases to other FOCUs or machinery spaces.

Where bypass arrangements for the SO_x scrubber unit are provided, the isolation and bypass valves are to be arranged in an interlocked, fail-safe manner, such that free flow of exhaust gases to the atmosphere is possible at all times, either through the scrubber unit or through the bypass. Bypass valves are to be provided with a local position indicator.

iii) Valves are to be installed in accessible locations, clear of or protected from obstructions, moving equipment, and hot surfaces, to permit regular inspection and maintenance.

11.1.3 Interconnections of Exhaust Gas Piping *(2024)*

Exhaust pipes from internal combustion engines and flue gas pipes from oil- fired boilers are to be routed separately and are not to be interconnected. However, interconnected exhaust piping systems to a common SO_x scrubber unit are accepted subject to the arrangements preventing the passage or leakage of exhaust gases to other equipment or spaces that may then pose a safety risk to that equipment or health risk to the vessel's crew or passengers. The return of exhaust gas between a running FOCU to another stopped, or in operation, FOCU is to be prevented.

The integrated SO_x scrubber system is to be designed not to exceed the back pressure limits specified by the connected engines or boilers. Fans installed for this purpose are to meet the redundancy requirements of 6-3-2/9.1.iii.

11.1.4 Exhaust Gas Scrubber and Scrubber Piping Insulation *(2024)*

Hot surfaces of SO_x scrubber units or their associated equipment or systems likely to make contact with the crew during operation are to be guarded or insulated. Where the surface temperatures will exceed 220°C (428°F) and where any leakage of fuel oil, lubricating oil, or other flammable liquid will come into contact with the SO_x scrubber unit or exhaust pipes, these surfaces are to be insulated with non- combustible materials that are impervious to such liquids. Insulation material not impervious to oil is to be encased in sheet metal cladding or an equivalent impervious sheath.

11.3 Washwater Piping

11.3.1 Piping and Connections *(2024)*

i) Pipes, pipe fittings, and joints are to meet the requirements of these Rules for certification in 4-6-1/7.1, materials in 4-6-2/3, and design in 4-6-2/5.5 and 4-6-2/5.15, subject to the limitations found in 4-6-5/7.3.3 TABLE 3.

Molded non-metallic expansion joints, where used, are to be of an approved type (see 4-6-2/5.8.1).

ii) The piping material for the corrosive scrubber washwater system is to be selected based on the corrosive nature of the liquid.

iii) Pipes and piping components made of thermoplastic or thermosetting plastic materials, with or without reinforcement, used in piping systems are subject to compliance with the requirements of Section 4-6-3. For the purpose of these Rules, "plastic" means both thermoplastic and thermosetting plastic materials, with or without reinforcement, such as polyvinyl chloride (PVC) and fiber reinforced plastics (FRP). Plastic includes synthetic rubber and materials of similar thermo/mechanical properties. Plastic washwater piping is to meet Level 3 fire endurance testing requirements (see 4-6-3/5.11).

iv) Flexible hoses are to comply with the requirements of 4-6-2/5.7.

11.3.2 Remote Control Valves *(2024)*

i) Upon loss of control power, the remote-control valves are to remain in the last ordered position, provided there is a readily accessible means to manually close the valves. Otherwise, they are to be in a failsafe position in accordance with the FMEA.

ii) Remote control valves are to be clearly identified and are to be provided with position indicators at the local and SO_x scrubber system remote control station, as applicable.

iii) Valves are to be installed in accessible locations, clear of or protected from obstructions, moving equipment, and hot surfaces in order to permit regular inspection and maintenance.

11.3.3 Overboard Discharges *(1 July 2024)*

i) Overboard discharges of any SO_x scrubber system are not to be interconnected to other systems.

ii) SO_x scrubber washwater overboard discharge piping is to be designed appropriate for the corrosive washwater. The distance piece between the discharge valve and the shell plating, is to comply with 4-6-2/9.13.3(except as modified in this subsection) and also be made of corrosion resistant material or fitted internally with high corrosive resistance protection material such as super duplex stainless steel sleeves or protected by nickel-chromium alloy cladding layers. The thickness of the distance piece is to be at least 12 mm in cases where complete pipe is made of corrosion resistant steel or 15 mm of mild steel in cases where the inside of the pipe is treated with an anticorrosive coating or fitted with a sleeve of corrosion resistant material. Evidence of suitability for the protection means is to be submitted. Where there is no corrosion protection provided, the distance piece is to be, as far as practicable, of Sch.160 construction.

Alternative arrangements for the SO_x scrubber washwater overboard discharge proven to be of not less effective construction is subject to ABS technical assessment and approval. Arrangements are to be provided to prevent galvanic corrosion due to the use of dissimilar metals. Where a galvanic couple cannot be avoided, coating the stainless steel or using a more noble steel grade is acceptable.

Commentary:

Consideration to the following alternative arrangements or others proven to be of not less effective construction may be given on a case-by-case basis.

- The distance piece is to comply with 4-6-2/9.13.3 and be protected with GRVE lining. Evidence of suitability for the protection means is to be submitted.
- The distance piece is to comply with 4-6-2/9.13.3, but the distance piece is to be of high corrosion resistant material such as super duplex stainless steel.

End of Commentary

iii) The SO_x scrubber washwater overboard discharge is to be located considering the vessel's sea chest inlets, propulsion features, such as thrusters or propellers, or to prevent any discharge of water onto survival craft during abandonment in accordance with SOLAS regulation III/16.8.

iv) Where plastic pipes are permitted to be used for the SO_x scrubber discharge lines, the valves installed on the shell and the pipe connection to the shell are to be metallic. The side shell valves are to be arranged for remote control from outside the space in which the valves are located. See 4-6-3/7.9.

11.5 Chemical Treatment Piping Systems *(2024)*

The requirements for the chemical treatment system detailed in this Subsection are based on the use of solution of sodium hydroxide (NaOH) or calcium hydroxide ($Ca(OH)_2$) that has corrosive properties or are considered to represent a hazard to personnel. For exhaust gas cleaning systems using chemicals other than the above, safety measures are to be taken according to the evaluation of the various risks, in order to eliminate or mitigate the hazards to personnel brought by the use of such exhaust gas cleaning systems, to an extent equivalent to systems complying with the requirements of this Subsection and 6-3-2/11.7.

The requirements detailed below are also based on an arrangement whereby the SO_x scrubber residue tank is also used as an overflow tank for the chemical treatment fluid storage tank. Arrangements that divide these functions into separate tanks may be applied, and in which case, the requirements for the overflow tank are detailed in 6-3-2/11.5 and the requirements for the residue tank in 6-3-2/11.7.

11.5.1 Material for Piping Systems, Chemical Treatment Fluid Storage Tank and SO_x Scrubber Residue/Chemical Treatment Fluid Overflow Tank *(1 July 2024)*

Storage tanks, pipes/piping systems and drip trays for chemical treatment fluids which transfer undiluted chemical treatment fluids are to be of steel or other equivalent material with a melting point above 925°C.

Storage tanks and pipes/piping systems for chemical treatment fluids are to be made with a material compatible with chemical treatment fluids or coated with appropriate anti-corrosion coating.

Commentary:

Several metals are incompatible with the chemical treatment fluids, e.g., NaOH is incompatible with zinc, aluminum, brass or galvanized steel components.

End of Commentary

The material of the SO_x scrubber residue/chemical treatment fluid overflow tank, drip trays, and any other components which may come in contact with the chemical solution or sludge is also to be of a grade of stainless steel or other corrosion-resistant material shown to be appropriate for the application. Aluminum, zinc, brass, or galvanized steel components are not to be used.

11.5.2 Bunkering of Chemical Treatment Fluids *(2024)*

i) The bunker station(s) for chemical treatment fluids is/are to be located on the open deck away from sources of ignition and arranged such that a spill at a bunker station would not result in chemicals contacting or mixing with other incompatible materials.

Alternatively, closed or semi-enclosed bunker stations with the provision of ventilation is subject to ABS technical assessment and approval.

ii) Spill trays, are to be provided with means of drainage to the SO_x scrubber residue/chemical treatment fluid overflow tank.

11.5.3 Arrangement of the Chemical Treatment Fluid Storage Tank and SO_x Scrubber Residue/Chemical Treatment Fluid Overflow Tank *(2024)*

i) The chemical treatment fluid storage and SO_x scrubber residue/chemical treatment fluid overflow tanks are not to be situated where spillage or leakage therefrom can constitute a hazard by falling onto combustibles or heated surfaces. In particular, these tanks are not to be located over boilers or in close proximity to steam piping (supply or return).

ii) The storage tank is to be protected from excessively high or low temperatures applicable to the particular concentration chemical treatment fluids.

Commentary:

Depending on the operational area of the ship, this may necessitate the fitting of heating and/or cooling systems.

End of Commentary

iii) The storage tanks are to have sufficient strength to withstand a pressure corresponding to the maximum height of a fluid column in the overflow pipe, with a minimum of 2.4 m (8 ft) above the top plate taking into consideration the specific density of the treatment fluid.

iv) Where chemical treatment fluid is stored in integral tanks, the following are to be considered during the design and construction:

- These tanks are to be designed and constructed as integral part of the hull (e.g., double bottom, wing tanks).
- These tanks are to be coated with appropriate anti-corrosion coating and are to be segregated by cofferdams, void spaces, pump rooms, empty tanks or other similar spaces so as to not be located adjacent to accommodation, cargo spaces containing cargoes which react with chemical treatment fluids in a hazardous manner as well as any food stores, oil tanks and fresh water tanks.
- These tanks are to be designed and constructed as per the structural requirements applicable to hull and primary support members for a deep tank construction.
- These tanks are to be included in the ship's stability calculation.

11.5.4 Filling, Vents, and Overflows for Chemical Treatment Fluid Tank and SO_x Scrubber Residue/Chemical Treatment Fluid Overflow Tank *(2024)*

i) *Filling*. The chemical treatment fluid storage tank is to be provided with a fill line from the bunker station, and a shutoff valve is to be provided at the bunkering station.

Overflow and/or drains leading to the SO_x scrubber residue/chemical treatment fluid overflow tank are to enter at or near the top of the tank. However, if this arrangement is determined to be impracticable, these lines are to be fitted with a non-return valve at the SO_x scrubber residue/chemical treatment fluid overflow tank.

ii) *Vents*. The chemical treatment fluid storage and SO_x scrubber residue/chemical treatment fluid overflow tanks are to be provided with vent pipes complying with 4-6-4/9, and the outlets are to terminate in a safe location (see 4-6-4/9.3.5(b).ii.) in the weather.

Vents are not to be subject to deterioration due to the concentrations involved, and the arrangement is to be such that the potential source of leakage from the vents does not present any danger to the crew or vessel. Alternatively, the tanks are to be fitted with appropriately sized pressure/vacuum valves.

iii) *Overflow Protection*. Means are to be provided to prevent chemical treatment fluid from spilling or accidently overflowing from the storage and SO_x scrubber residue/chemical treatment fluid overflow tanks. Accordingly, the chemical treatment fluid storage tank is to be fitted with a high level alarm. Alternatively, each storage tank for chemical treatment fluids is to be provided with level monitoring arrangements and high/low level alarms. Further, in all cases, the SO_x scrubber residue/chemical treatment fluid overflow tank is to be fitted with a high level alarm. Other anti-spilling arrangements is subject to ABS technical assessment and approval.

11.5.5 Sounding and Temperature Indication for the Chemical Treatment Fluid Storage and SO_x Scrubber Residue/Chemical Treatment Fluid Overflow Tanks *(2024)*

i) Sounding arrangements are to be provided for the chemical treatment fluid storage and SO_x scrubber residue/chemical treatment fluid overflow tanks and are to comply with the sounding requirements applicable to fuel oil tanks found in 4-6-4/11.3.7.

ii) A sight glass is not to be used unless the materials of construction are compatible with the concentration of the solution involved, it is to be protected from mechanical damage, and the arrangements are equivalent to those found in 4-6-4/11.5.1 (i.e., flat "glass-type", fitted with a self-closing valve at each end).

iii) In addition to local level gauging, the chemical treatment fluid storage and SO_x scrubber residue/chemical treatment fluid overflow tanks are to have remote level gauging indication at the manned control station.

iv) The chemical treatment fluid storage and SO_x scrubber residue/chemical treatment fluid overflow tanks are to be provided with local and remote temperature monitoring arrangements. The remote temperature indication is to be installed at the manned control station. In cases where heating and/or cooling systems are provided, high and/or low temperature alarms or temperature monitoring are also to be provided accordingly.

11.5.6 Spill Trays *(2024)*

i) Those areas of the chemical treatment fluid storage and SO_x scrubber residue/chemical treatment fluid overflow tanks that could result in leakage, locations where leakage from pumps and other associated equipment, which require occasional dismantling for examination or maintenance, and where leakage is normally expected are to be located within spill trays.

Notes:

The following connections are to be screened and fitted with spill trays to prevent the spread of any spillage where they are installed:

- Detachable connections between pipes (flanged connections and mechanical joints, etc.);
- Detachable connections between pipes and equipment such as pumps, strainers, heaters, valves; and
- Detachable connections between equipment mentioned above.

ii) The spill trays are to be fitted with drain pipes which lead to appropriate tanks, such as residue tanks, which are to be fitted with high level alarm, or are to be fitted with alarms for leak detection. In cases where such tank is an integral tank, the requirements of 6-3-2/11.5.3.iv) are to be applied to the tank. Where drainage arrangements are provided, the drain line to the SO_x scrubber residue/chemical treatment fluid overflow tank is to be fitted with a non-return valve.

11.5.7 Miscellaneous Chemical Treatment Fluid Piping Arrangements *(2024)*

i) The chemical treatment fluid piping and venting systems are to be independent of other ship service piping and/or systems.

ii) The chemical treatment fluid piping systems are not to be located in accommodation, service, or control spaces.

iii) Every pipe emanating from a tank containing chemical treatment fluids which, if damaged, would allow chemicals to escape from the tank, is to be provided with a positive closing (quick acting shutoff) valve located directly on the tank. A short length of extra strong pipe (sch 80) connecting the valve to the tank is also acceptable. The valve is not to be of cast iron, although the use of nodular cast iron is permissible, see 4-6-2/3.1.5. The positive closing valve is to be provided with means of closure both locally and from a readily accessible and safe position (even in the event of chemical treatment fluid leakages) outside of the space.

iv) Regardless of design pressure and temperature, piping systems containing chemical treatment fluids only, are to comply with the requirements applicable to Class I piping systems. Pipe joints are to be kept to a minimum. The direct connections of pipe lengths are to be all welded except for necessary flanged connections to valves and other equipment for maintenance in order to minimize risk of leakage.

v) Supply, bunkering and transfer lines for chemical treatment fluid systems are not to be located over, or in close proximity to, boilers, steam piping, exhaust systems, hot surfaces required to be insulated, or other sources of ignition.

11.5.8 Ventilation Arrangements *(1 July 2024)*

i) If a storage tank for chemical treatment fluids is installed in a closed compartment, the area is to be served by an effective mechanical ventilation system of extraction type providing not less than six (6) air changes per hour which is independent from the ventilation system of other spaces. The ventilation system is to be capable of being controlled from outside the compartment. A warning notice requiring the use of such ventilation before entering the compartment is to be provided outside the compartment adjacent to each point of entry.

ii) The requirements specified above also apply to closed compartments normally entered by persons:

- when they are adjacent to the integral storage tank for chemical treatment fluids and there are possible leak points (e.g. manhole, fittings) from these tanks; or
- when the treatment fluid piping systems pass through these compartments, unless the piping system is made of steel or other equivalent material with melting point above 925°C and with fully welded joints

iii) The storage tank located within the engine room is acceptable. In this case, the requirements of 6-3-2/11.5.8.i are to be complied with, except that a separate ventilation system is not required when the general ventilation system for the space is arranged so as to provide an effective movement of air in the vicinity of the storage tank and is maintained in operation continuously except when the storage tank is empty and has been thoroughly ventilated.

iv) Storage tanks for chemical treatment fluids are to be arranged so that they can be safely emptied of the fluids and ventilated by portable or permanent means.

11.5.9 Personnel Protection *(2024)*

For the protection of crew members, the vessel is to have on board personnel protective equipment (PPE) consisting of large aprons, rubber gloves with long sleeves, rubber boots, coveralls of chemical-resistant material, and tight-fitting chemical safety goggles or face shields or both. The protective clothing and equipment is to cover all skin so that no part of the body is left unprotected.

The quantities of PPE carried on board is to be appropriate for the number of personnel engaged in regular handling operations or personnel that may be exposed in the event of a failure of the chemical treatment fluid system; but in no case is there to be less than two sets available on board.

Eyewash and safety showers are to be provided, the location and number of these eyewash stations and safety showers are to be derived from the detailed installation arrangements. As a minimum, the following stations are to be provided:

i) In the vicinity of transfer or treatment pump locations. If there are multiple transfer or treatment pump locations on the same deck, then the acceptance of one eyewash and safety shower station may be considered for acceptance provided that the station is easily accessible from all such pump locations on the same deck is subject to ABS technical assessment and approval.

ii) An eyewash station and safety shower are to be provided in the vicinity of a chemical bunkering station on-deck. If the bunkering connections are located on both port and starboard sides, then two eyewash stations and safety showers are to be provided, one for each side. The acceptance of one eyewash and safety shower station, provided that the station is easily accessible from both port and starboard bunkering stations, is subject to ABS technical assessment and approval.

iii) An eyewash station and safety shower are to be provided in the vicinity of any part of the system where the potential for a person to come into contact with the chemicals exists (e.g., openings such as filling/drainage or system connections/components that require periodic maintenance).

Commentary:

Depending on the specific arrangements (e.g., vessel type, size, layout of deck, machinery space, etc.), consideration may be given so that the personnel protection arrangements required by this section may be shared with those required by 6-3-3/11.3.5 or 6-3-4/11.5.9.

End of Commentary

11.5.10 Safety Notices for the Compartment or at the Location of Tanks Containing Chemical Treatment Fluids *(2024)*

Safety instructions relating to precautions and corrective response actions are to be posted in the compartment containing chemical treatment fluids, and beside the entrance to the compartment. Detailed guidelines given in the Safety Data Sheets are to be followed.

11.7 SO_x Scrubber Residue System *(2024)*

i) The residues generated from the exhaust gas cleaning process are to be stored in a designated residue tank, separate from the engine room sludge tank, and arranged for discharge to appropriate shore reception facilities, in accordance with 4-6-4/5.7.4.

The SO_x scrubber residue tank is to be designed to facilitate cleaning.

Where SO_x scrubber residue tanks used in closed loop, chemical treatment systems are also used as the overflow tank for the chemical treatment fluid storage tank, the additional requirements of 6-3-2/11.5for chemical treatment fluid storage tanks are to be applied.

ii) The material of the SO_x scrubber residue tank is to be selected based on the corrosive nature of the SO_x scrubber residue.

iii) The capacity of the SO_x scrubber residue tank is to be based on the expected residue volumes applicable to the number and type of installed SO_x scrubbers and the maximum period of voyage between ports where SO_x scrubber residue can be discharged. In the absence of precise data, a figure of 30 days is to be used.

iv) The SO_x scrubber residue tank is to be provided with vent pipes complying with 4-6-4/9.

v) The residue tank is to be arranged with a high level alarm.

vi) Sounding arrangements are to be provided for the SO_x scrubber residue tank in accordance with 4-6-4/11.3.7.

vii) For those vessels that do not undertake onboard incineration and collect all engine room sludge for disposal ashore, arrangements utilizing a combined engine room sludge and SO_x scrubber residue tank is subject to ABS technical assessment and approval, and the tank meets the requirements of 6-3-2/11.7.i through 6-3-2/11.7.vi, SO_x scrubber residue record logs satisfy the requirements of MEPC.340(77), and residues are disposed at MARPOL reception facilities.

Combined engine room sludge and SO_x scrubber residue tanks are to be sized to provide the capacity based on the sludge tank capacity requirements of 4-6-4/5.7.3 plus the capacity requirements for SO_x scrubber residue tanks of 6-3-2/11.7.iii.

13 Control, Alarm, and Monitoring System

13.1 General *(2024)*

i) The control system for the SO_x scrubber system can be connected to an integrated control system or a standalone system.

ii) The SO_x scrubber system is to be designed such that a single fault of a component will not lead to a potentially dangerous situation for human safety and/or the vessel.

An FMEA demonstrating the safety system design basis is to be submitted.

iii) Where the EEMS notation is requested, exhaust emissions monitoring systems are to meet the requirements of Section 6-3-5.

13.3 Control and Monitoring System *(2024)*

i) Automatic control, monitoring (including washwater discharge criteria), alarm, and safety functions are to be provided for the SO_x scrubber system so that operations remain within preset parameters for all fuel oil combustion unit(s) and exhaust emission abatement system operating conditions. For vessels with **ABCU**/**ACC**/**ACCU** notations, the alarm and monitoring systems are to be integrated in the vessel's centralized monitoring systems that conform to the requirements for **ABCU**/**ACC**/**ACCU** notations, and in lieu of individual alarms, a summary alarm in the vessel's centralized monitoring system is also acceptable.

ii) The temperatures, pressures, and flows in the SO_x scrubber system and associated systems are to be controlled and monitored as follows:

a) A local control and monitoring system for the SO_x scrubber system is to be provided to enable safe operation, maintenance, and effective control in the event of an emergency or failure of any remote controls.

b) The design of the control system is to provide identification of faults in the equipment, as well as the process system. The control and monitoring systems are to comply with the requirements of 4-9-2/3.1, as applicable.

c) Indications of parameters necessary for the safe and effective operation of the exhaust emission abatement process are to be provided at the local and, as applicable, remote control station(s), as per 6-3-2/17 TABLE 2.

d) The computer-based control systems are to comply with the applicable requirements of Section 4-9-3 as a Category II system based on 4-8-3/15

iii) The power supply arrangements for the control and monitoring system are to meet the requirements of 4-9-2/5.3.

Control and monitoring functions are to be in accordance with 6-3-2/17 TABLE 2.

13.5 Safety Shutdown System

A shutdown system is to be provided. This safety shutdown system is to be based on the following principles:

i) Upon activation of the safety shutdown system, means are to be provided to indicate the parameters causing shutdown and alarms are to be given at the remote control position and at the local control position.

ii) In the event where shutdown by the safety shutdown system is activated, the restart is not to occur automatically, unless after the system is reset.

Safety shutdown is to be automatically activated for the conditions in 6-3-2/17 TABLE 2.

15 FMEA Integration Test

An integration test is to be undertaken on the first SO_x scrubber unit in a particular design series to verify that the operation and response of the complete mechanical and electrical systems are as predicted for all operational modes. The scope of these tests is to be determined based on the FMEA required by 6-3-2/13.1.

17 Surveys During Construction

17.1 General

This Subsection pertains to surveys during fabrication at the manufacturer's facility and installation and testing of SO_x scrubber units on board. For surveys at the manufacturer's facility, the scope of the survey will be confined to only those items that are supplied by the manufacturer.

17.3 Surveys at Manufacturer's Facility

See 6-3-2/17 TABLE 3 for certification requirements of SO_x scrubber units and associated systems. Survey requirements for equipment components and packaged units at the manufacturer's facility are summarized in the relevant sections of the applicable Rules/Guides.

17.5 Surveys During Installation *(2024)*

The following surveys are to be carried out to the satisfaction of the attending Surveyor on the SO_x scrubber unit and associated systems during installation and testing:

i) Inspection and verification that the foundations and attachments of the principal components of the SO_x scrubber unit and associated systems are in accordance with the approved plans and particulars.

ii) Piping systems are to be visually examined and pressure-tested, as required by these Rules. Pressure tests conducted on Class I piping (see 4-6-1/5 TABLE 1) systems should preferably be recorded on test charts for the duration of their tests.

iii) Electrical wiring and connections are to be in accordance with Part 4, Chapter 8 and checked for continuity and proper workmanship.

iv) Instrumentation is to be tested to confirm proper operation as per its predetermined set points.

v) Pressure relief and safety valves installed on the unit are to be tested.

vi) Control system and shutdowns are to be tested for proper operation.

vii) Ventilation arrangements to be examined/tested and confirmed in compliance with the requirements of 6-3-2/11.5.8.

viii) The EGC SO_x scrubber unit is to be checked for proper operation in accordance with the ABS - approved installation test procedure.

17.7 Surveys During Trials

During the initial commissioning trials, the SO_x scrubber unit is to be confirmed for its satisfactory operation, including associated controls, alarms, and shutdowns. The tests are to be conducted in accordance with the testing procedure during sea trials.

TABLE 2
Monitoring and Safety System Functions for SO_x Scrubber Systems *(2024)*

Monitored Parameters (5)	*Display*	*Alarm Activated*	*Automatic SO_x Scrubber Shutdown and Automatic SO_x Scrubber Bypass* (1)
Exhaust fan motors	Running	Stop (2)	-
Exhaust bypass or isolation valves, where provided	Position	-	-
Control-actuating medium of the exhaust bypass or isolation valves, as applicable	Running	Failed	-
Exhaust gas temperature before SO_x scrubber unit	X	High	X (High-High)
Exhaust gas temperature after SO_x scrubber unit	X	High	X (High-High)
Exhaust gas pressure before SO_x scrubber unit	X	High	X (High-High)
Differential pressure across SO_x scrubber unit	X	High	X (High-High) (3)
SO_x scrubber washwater pumps, chemical treatment fluid system pumps or dry system feeder units (6)	Running	Stop (2)	-
SO_x scrubber washwater or chemical treatment fluid system valves (6)	Position	-	-
Control-actuating medium of the SO_x scrubber washwater or chemical treatment fluid system valves (6)	Running	Failed	-

Monitored Parameters (5)	*Display*	*Alarm Activated*	*Automatic SO_x Scrubber Shutdown and Automatic SO_x Scrubber Bypass* (1)
SO_x scrubber system washwater and chemical treatment fluid system supply pressure (6)	X	Low	X (Low-Low)
SO_x scrubber system washwater and chemical treatment fluid system supply temperature (6)	X	High	X (High-High)
Water level in wet SO_x scrubber unit	X	High	X (High-High) (3)
Chemical treatment fluid storage tank temperature (6)	X	Low/High	X (High-High)
Chemical treatment fluid storage tank or dry silo level (6)	X	Low/High	X (Low-Low)
Chemical treatment fluid storage tank spill tray level (6, 7)	-	High	X (High-High) (3, 4)
SO_x scrubber residue tank level (6)	X	High	X (High-High)
Control and safety system power supply	Running	Failed	-
Emergency shutdown	X	X	X

Notes:

1 Automatic bypass of the SO_x scrubber unit is required as defined in 6-3-2/7.9.

2 Failure of essential SO_x scrubber system motors driving pumps, fans or feed systems is to activate the standby units, where fitted (see 6-3-2/9.9.3).

3 Minimum required safety shutdowns for systems where **EGC-SO_x** Notation is not requested. See 6-3-1/13 TABLE 1.

4 Remote closure of the close coupled chemical treatment fluid storage tank valves as required by 6-3-2/11.5.7.iii by reach rods or by electric, hydraulic or pneumatic means is acceptable.

5 As applicable in accordance with the specific SO_x scrubber system design and installation.

6 Chemical treatment fluid requirements are not applicable to open loop scrubbers that do not utilize chemical treatment fluid systems and are not fitted with a SO_x scrubber residue tank.

7 Spill tray level is not required for chemical treatment fluid tanks that have drainage arrangements. See 6-3-2/11.5.6.ii.

TABLE 3
Certification of SO_x Scrubber Systems at the Manufacturer's Facility *(2024)*

This Table has been prepared for guidance only and annotated to agree with the *Marine Vessel Rules*. The list is not to be considered exhaustive; should additional equipment not listed be fitted on board, same will be subject to ABS technical assessment and approval for compliance with the *Marine Vessel Rules*. This list is not to be considered as substitutive or integrative of the content of the *Marine Vessel Rules* and/or other applicable Regulations. In case of conflict between the content of this list and the applicable *Marine Vessel Rules* and other applicable regulations, the latter are to be considered applicable.

Code	*Explanation*
DR	*Design Review* – Design review required.
MS	*Manufacture Survey* – Product is to be surveyed during fabrication stages by the Surveyor.
FS	*Final Survey* – Finished product is to be subject to final hydrostatic, nondestructive, operational testing, or any other required tests, and witnessed by the Surveyor at manufacturer's facility.

Equipment	*DR*	*MS*	*FS*
SO_x scrubber reaction chamber	X	X	X
Exhaust bypass or isolation valves	X	-	-
Exhaust fans/motors (1)	X	-	X
Heat exchangers	X	-	X
Water treatment system	X	-	X
Washwater, chemical treatment fluid system and essential SO_x scrubber system pumps (2)	X	-	X
Washwater, chemical treatment fluid and SO_x scrubber residue associated piping	X	-	-
Control and safety system	X	X	X

Notes:

1 Applicable for motors over 100 kW (135 hp) only. For motors less than 100 kW (135 hp), certification by ABS not required, acceptance based on manufacturer's documentation and guarantee (see 6-3-2/9.9.1).

2 Applicable to pumps fitted to SO_x scrubber systems connected to fuel oil combustion units rated at 2250 kW (3000 hp) and above or internal combustion engines having cylinders of more than 300 mm (11.8 in.) bore (see 6-3-2/9.1.i).

PART 6

CHAPTER 3
Exhaust Emission Abatement

SECTION 3
Selective Catalytic Reduction Systems *(2024)*

1 General *(1 July 2023)*

This Section provides requirements on the arrangements and system design for exhaust emission abatement systems primarily designed for the removal of NO_x emissions using Selective Catalytic Reduction (SCR) systems. The intent is that these requirements supplement the statutory emissions performance testing, survey, and certification requirements of the applicable IMO Regulations and Guidelines. The applicable supplementary Guidelines to MARPOL Annex VI Regulation 13 and the NO_x Technical Code for SCR systems are IMO Resolution MEPC.291(71) – *2017 Guidelines Addressing Additional Aspects of the NO_x Technical Code 2008 With Regard to Particular Requirements Related to Marine Diesel Engines Fitted With Selective Catalytic Reduction (SCR) Systems*, adopted 7 July 2017 and IMO Resolution MEPC.313(74) – *Amendments to the 2017 Guidelines Addressing Additional Aspects to the NOx Technical Code 2008 With Regard to Particular Requirements Related to Marine Diesel Engines Fitted With Selective Catalytic Reduction (SCR) Systems (Resolution MEPC.291(71))*, adopted 17 May 2019. The statutory approval aspects can be made by ABS as a separate parallel process in the capacity of a Recognized Organization (RO) when authorized by the flag Administration.

1.1 Objectives *(2024)*

1.1.1 Goals

The SCR systems covered in this Section are to be designed, constructed, operated, and maintained to:

Goal No.	*Goals*
PROP 2	Provide redundancy and/or reliability to maintain propulsion.
FIR 1	*Prevent the occurrence of fire and explosion. (SOLAS II-2/Reg 2.1.1)*
ENV 6	Prevent and minimize air pollution.
SAFE 1.1	Minimize danger to persons on board the vessel, and surrounding equipment/installations from hazards associated with machinery and systems.
MGMT 1	*Provide for safe practices in ship operation and a safe working environment. (ISM Code 1.2.2.1)*
MGMT 3	*Establish procedures, plans and instruction for operations concerning the safety of the personnel, vessel, and protection of the environment (ISM Code 7)*

Goal No.	*Goals*
MGMT 5.1	Design and construct vessel, machinery, electrical, safety systems to facilitate safe access, ease of inspection, survey and maintenance.
AUTO 1	Perform its functions as intended and in a safe manner
AUTO 2	Indicate the system operational status and alter operators of any essential machinery/systems deviate from its defined design/operating conditions or intended performance.
AUTO 3	Have an alternative means to enable safe operation in the event of an emergency or failure of remote control.
AUTO 4	provide the equivalent degree of safety and operability from a remote location as those provided by local controls.
AUTO 5	Provide a safety system that automatically leads machinery controlled to a fail-safe state in response to a fault which may endanger the persons on board, machinery/equipment or environment.

Materials are to be suitable for the intended application in accordance with the following goals and support the Tier 1 goals listed above.

Goal No.	*Goal*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.

The goals in the cross-referenced Rules/Regulations are also to be met.

1.1.2 Functional Requirements

In order to achieve the above stated goals, the design, construction, installation and maintenance of the Selective Catalytic Reduction Systems are to be in accordance with the following Functional Requirements:

Functional Requirement No.	*Functional Requirements*
Materials (MAT)	
MAT-FR1	Chemical Composition to be considered for corrosion resistance, weldability, final mechanical properties.
MAT-FR2	Corrosion resistance to be considered when exposed to different fluids which lead to loss of material.
Propulsion, Maneuvering, Station Keeping (PROP)	
PROP-FR1	The exhaust emission abatement system is to allow continued operation of engine connected to the system when it is not in operation.
PROP-FR2	Air supply for the exhaust abatement system taken from the propulsion engine starting air system is not to compromise the adequate supply and reserve of starting air.
Fire Safety (FIR)	
FIR-FR1	The exhaust emission abatement system is to be arranged to prevent the dangerous chemicals from coming in contact with sources of ignition to minimize the risk fire/ explosion.
Protection of Environment (ENV)	

Functional Requirement No.	*Functional Requirements*
ENV-FR1	The exhaust emission abatement system is to be arranged to remove NO_x emitted from the engine to minimize air pollution.
ENV-FR2	Redundancy is to be provided for exhaust emission abatement equipment to maintain capability of reducing air pollution.
Safety of Personnel (SAFE)	
SAFE-FR1	The exhaust emission abatement system is to be compatible with the connected engine and their operating parameters.
SAFE-FR2	Protective devices compatible with the prospective short circuit current are to be installed in the exhaust emission abatement system circuits to protect the equipment from damage.
SAFE-FR3	The exhaust emission abatement system is to be arranged to prevent the passage of exhaust gas to the machinery space or other equipment for the safety of the crew or to prevent further damage of equipment.
SAFE-FR4	Provide means to protect the crew from the hot surfaces of the exhaust emission abatement system.
SAFE-FR5	Chemical treatment system including the tank for dangerous chemicals is to be designed and arranged to contain dangerous chemicals in all expected conditions and prevent leakage/ contact with personnel.
SAFE-FR6	Provide means to prevent entry of foreign material that may affect the operation of the exhaust abatement system.
SAFE-FR7	Tanks containing the dangerous chemicals for the exhaust emission abatement system are to be provided with means to measure the temperature and amount of chemical in tanks.
SAFE-FR8	Ventilation of the space with tanks containing dangerous chemicals are to be arranged to extract the dangerous vapors from possible leakage.
SAFE-FR9	Provide suitable equipment to protect the crew from exposure to dangerous chemicals during operation of the exhaust emission abatement system.
SAFE-FR10	The exhaust emission abatement system is to be arranged such that a single fault of a component will not lead to a potentially dangerous situation for human safety and/or the vessel.
Safety Management (MGMT)	
MGMT-FR1	Information is to be provided onboard covering the operations, safety and maintenance requirements and occupational health hazards relevant to the exhaust emission abatement system.
MGMT-FR2	The exhaust emission abatement system is to be installed in accessible location and arranged for ease of inspection and maintenance.
MGMT-FR3 (SAFE)	Provide a notice to warn the crew that the ventilation of the space is required prior to entering spaces with tanks containing dangerous chemicals.
Automation: Control, Monitoring and Safety Systems (AUTO)	
AUTO-FR1	Means are to be provided for visible and audible notifications at manned locations for abnormal or out of boundary conditions of the exhaust emission abatement systems, and the automatic start of the redundant equipment if available, to prevent further escalation of hazards.

Functional Requirement No.	*Functional Requirements*
AUTO-FR2	Local control and monitoring system for the exhaust emission abatement system is to be provided to enable safe operation, maintenance, and effective control in the event of an emergency or failure of any remote controls.
AUTO-FR3	Alarm, monitoring and control systems are to be provided to facilitate automatic and manual operations, including safe shutdowns, at remote and local locations to allow continued operations.

The functional requirements in the cross-referenced Rules/Regulations are also to be met.

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

2 Notations *(1 July 2023)*

2.1 EGC-SCR (M)

Vessels complying fully with the statutory emissions performance testing, survey, and certification requirements of the applicable IMO Regulations and Guidelines and the minimum requirements of EGC SCR Systems in 6-3-1/13 TABLE 1 will be assigned the optional **EGC-SCR (M)** notation.

2.2 EGC-SCR

Vessels complying fully with this section will be assigned the optional **EGC-SCR** notation.

2.3 Notations Not Requested

Where above notations have not been requested, the SCR system is to be verified to be in compliance with the minimum requirements prescribed in 6-3-1/9.11 and 6-3-1/13 TABLE 1 and is to be verified by the ABS Surveyor during installation.

3 Plans and Data to be Submitted *(2024)*

Plans and specifications covering the SCR arrangements are to be submitted and are, as applicable, to

- General arrangement of the SCR installation, layout, and systems
- Documentation detailing the SCR specification, including details of the SCR catalyst reaction chamber and catalysts, reductant specifications, exhaust system components/modifications, mixing arrangements, reductant injection nozzles/injectors, exhaust heaters and soot blowing details
- Analyses demonstrating compatibility of the SCR system with the engine (see 6-3-3/7.3)
- Hull plans showing the foundation and attachments to the vessel's structure including scantlings, welding details, and foundation details of principal components
- Material specifications for the SCR unit, pumps, valves, reductant tanks, piping, distribution systems, filters, and associated components, including a corrosion assessment detailing the corrosive effect of system liquids, vapors, and gases on the materials used in the SCR system
- Arrangement and capacity of reductant storage tanks
- Details of all piping systems, including details of piping and associated components, pumps, reductant dosing systems, air supply systems, design pressures, temperatures, insulation, and spill trays

- Descriptions and schematic diagrams for the control and monitoring systems, including set points for abnormal conditions and details of the location and position at which exhaust emission monitoring probes are to be located
- Details of all electrical equipment installed for the SCR unit and associated systems, including computer-based systems
- Failure Modes and Effects Analysis (FMEA) to determine possible failures and their effects in the safe operation of the SCR system (see 6-3-3/13.1).

  Note: This can be a standalone document, or for those integrated SCR units, incorporated into the engine FMEA required by Appendix 4-2-1-A1.

- Safety shutdown system (see 6-3-3/13.5)
- SCR FMEA integration test report (see 6-3-3/15)
- Operating and maintenance instruction manuals, including MSDS sheets and details for handling of hazardous and non-hazardous chemicals used in the SCR system (see 6-3-3/5)
- Testing procedures during installation and commissioning trials

5 SCR System Operation and Maintenance Manuals *(2024)*

In accordance with 6-3-1/11, detailed instruction manuals are to be provided on board, covering the operations, safety, and maintenance requirements and occupational health hazards relevant to the SCR equipment and associated systems.

These manuals are to include but are not limited to the procedures and schedules for operation, inspection, testing, and maintenance of the SCR and associated systems, the regular testing and maintenance procedures for the monitoring systems, safety shutoff systems, and the integrity of backup systems, together with special instructions for the use of vanadium based catalysts, bunkering, storage, and use of hazardous or non-hazardous chemicals that may be used in the SCR system and identification of the relevant responsible parties.

The manuals may be produced as standalone documents or incorporated within the general engine operation and service manuals required by 4-2-1/1.5.1.

The manuals are to be submitted for reference to verify the presence of all the information required by this Section.

7 SCR System Configuration and Vessel Integration

7.1 General *(2024)*

i) SCR units are installed in the exhaust system of an internal combustion engine, before the exhaust gas economizer, when installed, and as close as possible to the engine due to the relatively high exhaust gas temperatures required by the catalysts for effective NO_x reduction reactions.

An SCR unit installed in place of the conventional exhaust silencer or in parallel with the silencer is acceptable when a bypass configuration is used. See 6-3-3/11.1.3 for exhaust systems from multiple engines connected to a common SCR unit.

For slow speed internal combustion engines with inherently low relative exhaust gas temperatures, this necessitates the integration of the SCR reaction chamber and catalysts before the turbo charger exhaust turbine in a High Pressure SCR arrangement. The SCR catalysts integrated with the engine by close coupling to the engine are acceptable, typically applicable to small high-speed internal combustion engines. In these cases, use of an SCR unit is considered a primary exhaust emission reduction technique that forms part of the total engine design and as such is to be integrated by, or under authorization of, the engine designer. In those instances, the applicable requirements for SCR systems contained within this Section are supplementary to, and to be applied in association with, the requirements for internal combustion engines found in Section 4-2-1. The integration of an SCR system to an already approved internal combustion engine is not considered an engine type defining parameter change as per 4-2-1/13.7.2.

It is to be noted that SCR systems that cause diesel engines to operate outside the exhaust back pressure limits detailed in the approved IMO Annex VI Regulation 13 Technical Files invalidates the emissions certification and will require a re-approval of the engine NO_x certification by the Administration or RO responsible for the original certification.

ii) SCR systems are to be designed to enable continued operation of the engine at the times the SCR system is not in operation, either due to operational selection, equipment failure, or system deterioration through partial blocking/clogging.

All SCR units fitted to single main propulsion engines are to be installed with an exhaust bypass arrangement unless arranged for unrestricted flow of exhaust gas and with no risk of causing failure of the main propulsion engine.

iii) The response of the mechanical and electrical systems of the first SCR unit in a particular design series is to be demonstrated by the FMEA integration test described in 6-3-3/15.

7.3 Compatibility with the Engine *(2024)*

i) Installation and operation of an SCR system is to be compatible with the engine and not to cause any adverse effects on the engine performance such as excessive back pressures or high temperatures during operation.

ii) Details are to be submitted demonstrating the exhaust flow compatibility of the SCR unit with the connected engine over the whole operational range of the engine. This data should demonstrate that the operating parameters of the engine do not exceed the approved design limits with the SCR system in operation. In the case of multi-engine SCR units, this compatibility evaluation is to show that the SCR unit is capable of accommodating the maximum combined exhaust flows of all the connected engines for the worst-case scenario for that particular vessel arrangement and operational profile. SCR units that incorporate extractive exhaust fans or air blowing systems to maintain the engine operating parameters within the approved design limits is subject to ABS technical assessment and approval.

It is to be noted that the normal and limit values for exhaust back pressure of engines fitted with SCR systems, together with other regulatory aspects, are to be detailed in the approved MARPOL Annex VI Technical Files by the Administration or RO responsible for the NO_x certification.

iii) The range of suitable fuels and oils for which the SCR unit is capable of continual operation, in particular with respect to sulfur content or other elements known to cause catalyst clogging, is to be declared by the SCR or engine manufacturer and included in the SCR or engine specification documentation and instruction manuals required by 6-3-3/3 and 6-3-3/5.

Minimum and maximum exhaust gas temperatures, reductant flow rate limits, catalyst limitations or health hazards, or other operating parameters that prohibit or limit SCR operation with the indicated range of suitable fuels and/or sulfur content are to be clearly defined in the manuals.

7.5 Redundancy *(2024)*

Redundancy of equipment is to be provided for those rotating and reciprocating components that form part of the exhaust emission abatement unit essential supplementary systems, such as pumps, fans, blowers, etc. (see 6-3-3/9.1 and 6-3-3/9.11.3).

Alternative means of compliance or operational measures to meet this objective is subject to ABS technical assessment and approval. As applicable, documentation is to be submitted demonstrating that the reliability of the system or component provides continued serviceability of the SCR system,without compromising the vessel propulsion and maneuvering capability. The provision of sufficient spare parts on board is an example of vessel specific arrangements that will be considered during ABS technical assessment as meeting this objective and is to be justified with reference to the FMEA required by 6-3-3/13.1.

7.7 Essential Services

For the purposes of design, construction, testing, and survey, SCR units and associated components and systems are considered secondary essential services in accordance with 4-8-1/7.3.3.

7.9 Inclinations *(2024)*

SCR systems are to be designed for proper operation at the inclination requirements of 4-1-1/7.9.

7.11 Inspection and Maintenance

SCR systems are to be arranged for easy inspection and maintenance with at least one inspection port or hatch available for internal inspection of the main reaction chamber and where applicable the ability to replace internal components is to be provided. Exemptions will be granted to those small SCR units not intended to be dismantled in service and typically integrated with high-speed mass produced internal combustion engines.

9 SCR System Equipment

9.1 Pumps/Fans *(2024)*

i) Unless alternative means of compliance in accordance with 6-3-3/7.5 .are applicable,redundant pumps, essential for the continual operation of the SCR system, are to be provided. There are to be at least two of these essential pumps, and the capacity of the pumps, with any one pump out of service, is to be sufficient for continuous operation of the exhaust emission abatement system at full rating. See also 6-3-3/9.11.3.

For vessels fitted with two or more identical SCR systems, the provision of a common standby pump (for each essential system) capable of serving all SCR units will suffice rather than providing individual standby pumps for each SCR unit.

ii) Unless alternative means of compliance in accordance with 6-3-3/7.5 are applicable and where exhaust fans form part of the SCR system and are essential for continual operation of the exhaust emission abatement system at full rating, redundancy is to be provided for such fans. The number and power of the fans are to be such that if one fan, or a group of fans, is out of service the capacity of the remaining fan(s) is not to be less than 100% of the total required.

9.3 Exhaust Heaters

Where provided, burners and heat exchangers are to be designed, constructed, and certified in accordance with Section 4-4-1. Electrical heating systems are to meet the applicable requirements of Part 4, Chapter 8.

9.5 SCR Reductant System *(2024)*

SCR technologies use an ammonia reductant introduced as an aqueous urea solution into the exhaust stream, prior to the catalyst blocks. For automotive and land-based engine applications, this reductant solution is typically a 32.5% urea solution meeting the ISO 22241 standard (AUS 32). A specific marine engine urea standard utilizing a 40% (AUS 40) urea solution has been developed by ISO (18611 series).

The SCR manufacturer is to detail the specification of the reductant solution(s) appropriate for use with the SCR system and any specific installation considerations that are applicable for storage, handling, and use of the reductant. Urea is not classified as dangerous according to MSDS but can be an eye, skin, and respiratory irritant, and hence there is a need for the provision of appropriate safety features and personal protective equipment.

The key fluid media components of the SCR reductant system comprise reductant storage tank, pumps, filters, dosing units, and injectors with associated control systems. The specific requirements for SCR reductant system components using urea as a reductant are given under6-3-3/11.3.

Arrangements using alternative reductant solutions, such as aqueous ammonia or anhydrous ammonia are subject to ABS technical assessment and approval.

9.7 SCR Reaction Chamber *(2024)*

i) Details of the SCR catalyst specifications, geometry, and fixing arrangements of the catalyst elements in the reaction chamber are to be submitted.

ii) The catalyst elements are to be securely mounted in the reaction chamber to provide effective gas sealing under all operational temperatures to provide effective reaction processes and prevent the passage of unreacted ammonia to the atmosphere.

iii) Access arrangements for the catalyst elements are to provide easy removal and maintenance in service. Sufficient space around the SCR reaction chamber for replacing the catalyst elements is to be provided.

iv) Provision is to be made to indicate that catalyst elements have been removed from the reaction chamber so that reduction injection may be stopped. This can be achieved via the use of a delta pressure sensor, NO_x efficiency monitor, or other acceptable means.

v) Arrangements are to be provided to prevent the blocking or clogging of SCR catalyst elements which could create excessive exhaust back pressures for the connected engine, a reduction in catalyst reaction efficiency, and a fire hazard through soot accumulation. This is to be achieved by control system boundary conditions on reductant injection and by the inclusion of soot blowing arrangements for the catalyst chamber. Details of the soot blowing arrangements, where provided, are to be submitted for review.

The reductant injection strategies are to monitor exhaust temperatures to prevent catalyst breakdown and prevent reductant injection at those operating temperatures and modes that would cause excessive fouling of the catalyst elements by, for example, the formation of ammonia sulfates.

Arrangements are to be such that blocked catalyst elements will not prevent operation of the engine.

vi) Monitoring, alarm, and shutdown arrangements are to be provided to indicate (see 6-3-3/13.3.ii.d):

a) An abnormal pressure rise across the SCR reaction chamber

b) Reductant injection rates above the conversion capability of the catalyst elements

c) Injection of reductant when the engine is not running or there is a fault with the catalyst elements or the associated SCR reductant components or systems

9.9 Pneumatic Systems

i) Details of the pneumatic systems used for reductant injection, soot blowing, and any other associated SCR systems are to be submitted. Pneumaticsystems are to comply with the requirements of 4-6-7/5.

ii) When the air supply for the SCR system is taken from existing vessel infrastructure, it is not to compromise the air start supply and reserve requirements of 4-6-5/9.

9.11 Electrical System

The electrical system and electrical equipment requirements in this Subsection are to be applied in association with the requirements of Part 4, Chapter 8.

9.11.1 Electrical Motors and Controllers

Motors and motor controllers of 100 kW (135 hp) and over are to be certified in accordance with 4-8-3/1.5.

9.11.2 Electrical Load Analysis

i) The number and capacity of generators are to be sufficient under normal sea going conditions with one generator in reserve to carry those loads for essential services and for minimum comfortable conditions of habitability as per 4-8-2/3.1.1.

ii) The electrical loads associated with the SCR system are to be included in the electric-plant load analysis required by 4-8-1/5.1.5.

9.11.3 Standby Pump/Fan Arrangements *(2024)*

i) In the event of failure of the essential SCR system pumps or fans, the standby pump or fan required by 6-3-3/9.1, where provided, is to be automatically started and put into service. This failure is to be alarmed at the local and remote control station(s), as applicable.

ii) Where provided, each standby pump or fan is to be fed from separate bus bar sections of the switchboard. In the event of failure of one bus bar section of the switchboard, the standby pump or fan can fed from the another bus bar section.

9.11.4 Circuit Protection Devices and Compatibility

Circuit breakers are to be installed for miscellaneous SCR system electrical loads and are to be compatible with the prospective short circuit current level calculated at the switchboards.

11 SCR System Piping

11.1 Exhaust Gas Piping Systems

11.1.1 Exhaust Gas Piping/Reaction Chamber Materials and Installation *(2024)*

i) Exhaust gas piping materials located before the reductant injection mixing sections or SCR reaction chamber may be of the same material specification as the standard exhaust gas piping.

ii) The parts and components of the SCR exhaust system and reaction chamber that are subjected to exhaust gas and reductant mixtures are to be constructed of corrosion resistant materials, such as stainless steel, appropriate for the environment.

iii) Details of the exhaust mixers, mixing chambers, reductant nozzles, or injectors are to be submitted. Injection arrangements are to be designed to provide effective mixing of the reductant and exhaust gas.

iv) Non-corrosion-resistant materials may be accepted downstream of the reductant and exhaust gas mixing area if it can be demonstrated that the required mixing of reductant and exhaust gas can reliably be achieved before the area of non-corrosion resistant material.

under all normal operating conditions.

v) The exhaust piping systems for exhaust emission abatement systems are to meet the applicable requirements of 4-6-2/9 and 4-6-5/11.

11.1.2 Exhaust Gas Piping Valves *(2024)*

i) Valves used in the exhaust system of SCR systems are to meet the requirements of 4-6-2/5.11.

ii) The valves are to be constructed of corrosion resistant materials, such as stainless steel, appropriate for the environment.

iii) Isolation and bypass valves used in SCR system exhaust piping systems are to prevent the passage of exhaust gases to other engines or machinery spaces.

Where bypass arrangements for the SCR system are provided, the isolation and bypass valves are to be arranged in an interlocked, fail-safe manner, such that free flow of exhaust gases to atmosphere at all times is possible, either through the SCR system or through the bypass. Bypass valves are to be provided with a local position indicator.

iv) Valves are to be installed in accessible locations, clear of or protected from obstructions, moving equipment, and hot surfaces, in order to permit regular inspection and maintenance.

11.1.3 Interconnections of Exhaust Gas Piping *(2024)*

i) Exhaust pipes from internal combustion engines are to be routed separately and not interconnected. However, interconnected exhaust piping systems to a common SCR unit are accepted subject to the arrangements preventing the passage or leakage of exhaust gases to other equipment or spaces that pose a safety risk to that equipment or health risk to the vessel's crew or passengers. The return of exhaust gas flow from a running engine to another stopped, or in operation, engine is to be prevented.

ii) The combined SCR system is to be designed not to exceed the back pressure limits specified by the connected engines or boilers. Fans installed for this purpose are to meet the redundancy requirements of 6-3-3/9.1.ii

11.1.4 Exhaust Gas Piping and SCR Reaction Chamber Insulation *(2024)*

Hot surfaces of SCR units or their associated equipment or systems likely to make contact with the crew during operation are to be guarded or insulated. Where the surface temperatures will exceed 220°C (428°F) and where any leakage, under pressure or otherwise, of fuel oil, lubricating oil, or other flammable liquid will come into contact with the SCR unit or exhaust pipes, these surfaces are to be insulated with non- combustible materials that are impervious to such liquids. Insulation material not impervious to oil is to be encased in sheet metal cladding or an equivalent impervious sheath.

11.3 Reductant Piping Systems – Urea Solution

The requirements for the reductant piping systems detailed in this Subsection are based on the use of ammonia as a reductant introduced in an aqueous urea solution at 32.5% or 40% concentrations.

11.3.1 Reductant Tank, Piping and Connections *(2024)*

i) Pipe and pipe fittings and joints are to meet the requirements for certification in 4-6-1/7.1, materials in 4-6-2/3, and design in 4-6-2/5.5 and 4-6-2/5.15, subject to the limitations in 4-6-5/7.3.3 TABLE 3.

ii) The reductant piping and venting systems are to be independent of other ship service piping and/or systems.

iii) Reductant piping systems are not to be located in accommodation, service, or control spaces.

iv) Supply, bunkering, and transfer lines for reductant systems, with the exception of those associated with injector equipment, are not to be located over boilers or in close proximity to steam piping, exhaust systems, hot surfaces required to be insulated, or other sources of ignition.

v) The material of the reductant related piping systems, tanks, and other components which come into contact with the reductant solution is to be of a suitable grade of alloyed steel coated with appropriate anti-corrosion coating, non-combustible plastic, or other compatible material established to be suitable for the application. Non-alloyed steels, copper, copper containing alloys, and zinc-coated steels are not to be used for reductant storage or piping systems.

vi) Reductant tanks are to be of steel or other equivalent material with a melting point above 925°C (1697°F). Pipes/piping systems are to be of steel or other equivalent material with melting point above 925°C (1697°F), except downstream of the tank valve, provided this valve is metal seated and arranged as fail- to-closed or with quick closing from a safe position outside the space in the event of fire; in such case, type approved plastic piping is accepted even if it has not passed a fire endurance test.

Notes:

Material requirement "to be of steel or other equivalent material with a melting point above 925°C" is not applicable for integral tanks on FRP vessels such as those listed below, provided that the integral tanks are coated and/or insulated with a self-extinguishing material:

a FRP vessels complying with Regulation 17 of SOLAS Chapter II-2 based on associated IMO guidelines (MSC.1/Circ.1574), and

b FRP vessels exempted from the application of SOLAS e.g., yachts, fast patrol, navy vessels, etc., generally of less than 500 gross tonnage, subject to yacht codes or flag regulations.

vii) Flexible hoses are to comply with the requirements of 4-6-2/5.7.

11.3.2 Filters and Strainers

Filters are to be provided in reductant piping systems to minimize the entry of harmful foreign material that affects operation and closure of regulating valves, dosing valves, or other essential system components. The filters are to be designed to withstand the maximum working pressure of the system.

11.3.3 Arrangement of the Urea Storage Tank *(2024)*

i) The urea storage tank is not to be situated where spillage or leakage from the tank constitutes a hazard by potentially making contact with combustibles or heated surfaces and is to be located in a well-ventilated area away from heat sources.

ii) Locating the urea storage tank within the engine room is acceptable. However, if installed in a separate compartment, the area is to be served by an effective mechanical ventilation system of extraction type providing not less than 6 air changes per hour which is independent from the ventilation system of accommodation, service spaces, or control stations. In addition, if located in a separate compartment, the ventilation system is to be capable of being controlled from outside the compartment. A warning notice requiring the use of such ventilation before entering the compartment is to be provided outside the compartment adjacent to each point of entry.

Alternatively, where a urea storage tank is located within an engine room a separate ventilation system is not required when the general ventilation system for the space is arranged so as to provide an effective movement of air in the vicinity of the storage tank and is to be maintained in operation continuously except when the storage tank is empty and has been thoroughly ventilated.

iii) Where urea-based ammonia solution is stored in integral tanks, the following are to be considered during the design and construction:

a) These tanks are to be designed and constructed as an integral part of the hull, (e.g., double bottom, wing tanks).

b) These tanks are to be coated with appropriate anti-corrosion coating and cannot be located adjacent to fuel oil and freshwater tanks.

iv) The urea storage tank is to be protected from excessively high or low temperatures applicable to the urea concentration of the solution such as those specified in ISO 18611 for AUS 40. Depending on the operational area of the vessel, fitting of heating and/or cooling systems is required. The physical conditions recommended by applicable recognized standards (such as ISO 18611-3) are to be considered to avoid any impairment of the urea solution during storage.

v) Every pipe emanating from a tank containing urea, which, if damaged, would allow urea to escape from the tank, is to be provided with a manual closing valve located directly on the tank. A short length of extra strong pipe (Sch 80) connecting the valve to the tank is also acceptable. The valve is not to be of cast iron, although the use of nodular cast iron is permissible, see 4-6-2/3.1.5.

vi) The urea storage tank is to be provided with vent pipes complying with 4-6-4/9, and the outlets are to terminate in a safe location (see 4-6-4/9.3.5(b).ii.) in the weather and arranged to prevent ingress of water into the urea tank.

The vents are not to be subject to deterioration due to the concentrations involved, and the arrangement is to be such that the potential source of moisture from the vents does not present any danger to the crew or vessel. Alternatively, the tanks are to be fitted with appropriately sized pressure/vacuum valves.

vii) The urea storage tank is to be provided with temperature and level monitoring arrangements. High and low level alarms together with high and low temperature alarms are to be provided (see 6-3-3/13). Urea storage tanks are to be arranged so that they can be emptied of urea and ventilated by means of portable or permanent systems.

viii) The requirements specified in 6-3-3/11.3.3.ii also apply to closed compartments normally entered by persons when they are adjacent to the urea integral tanks and there are possible leak points (e.g., manhole, fittings) from these tanks; or when the urea piping systems pass through these compartments, unless the piping system is made of steel or other equivalent material with melting point above 925°C (1697°F) and with fully welded joints.

11.3.4 Spill Trays

Urea storage tanks with a capacity of 500 liters (132 US gallons) and above are to be located within spill trays fitted with a high level alarm or arranged with a drainage system.

11.3.5 Personnel Protection *(2024)*

For the protection of crew members, the vessel is to have on board suitable personnel protective equipment (PPE) consisting of large aprons, rubber gloves with long sleeves, rubber boots, coveralls of chemical-resistant material, and tight-fitting chemical safety goggles or face shields or both.

The quantities of PPE carried on board is to be appropriate for the number of personnel engaged in regular handling operations or personnel that may be exposed in the event of a failure of the Urea system; but in no case is there to be less than two sets available on board.

Eyewash stations are to be provided. The location and number of these eyewash stations are to be derived from the detailed installation arrangements. As a minimum, the following stations are to be provided:

i) In the vicinity of transfer or treatment pump locations. If there are multiple transfer or treatment pump locations on the same deck, then the acceptance of one eyewash and safety station provided that the station is easily accessible from all such pump locations on the same deck is subject to ABS technical assessment and approval.

ii) An eyewash station and safety shower is to be provided in the vicinity of a chemical bunkering station on- deck. If the bunkering connections are located on both port and starboard sides, then two eyewash stations and safety showers, one for each side, is to be provided. The acceptance of one eyewash and safety shower station, which is easily accessible from both port and starboard bunkering stations, is subject to ABS technical assessment and approval.

iii) An eyewash station and safety shower is to be provided in the vicinity of any part of the system where the potential for a person to come into contact with the chemicals exists (e.g., openings such as filling/drainage or system connections/components that require periodic maintenance).

Depending on the specific arrangements (e.g., vessel type, size, layout of deck, machinery space etc.), consideration may be given so that the personnel protection arrangements required by this section may be shared with those required by6-3-3/11.3.5 or 6-3-4/11.5.9.

11.3.6 Safety Notices for the Compartment or at the Location of Tanks Containing Urea

Safety instructions relating to precautions and corrective response actions are to be posted in the compartment containing urea and beside the entrance to the compartment. Detailed guidelines given in the MSDS are to be followed.

13 Control, Monitoring, and Safety Systems

13.1 General *(2024)*

i) The control system for the SCR system can be connected to an integrated control system or may be a standalone system. Where the SCR control system is integrated in the base engine design, the control system is to be integrated with, or in direct communication with, the engine control system.

ii) The system is to be designed such that a single fault of a component will not lead to a potentially dangerous situation for human safety and/or the vessel.

An FMEA demonstrating the safety system design basis is to be submitted.

iii) Where the optional EEMS notation is requested, exhaust emissions monitoring systems are to meet the requirements of Section 6-3-5.

13.3 Control and Monitoring System *(2024)*

i) Automatic control, monitoring (including washwater discharge criteria), alarm, and safety functions are to be provided for the SCR system so that operations remain within preset parameters for all engine(s) and exhaust emission abatement system operating conditions. For vessels with **ABCU**/**ACC**/**ACCU** notations, the alarm and monitoring systems are to be integrated in the vessel's centralized monitoring systems that conform to the requirements for **ABCU**/**ACC**/**ACCU** notations and in lieu of individual alarms, a summary alarm in the vessel's centralized monitoring systems is also acceptable.

ii) The temperatures, pressures, and flows in the SCR system and associated systems are to be controlled and monitored as follows:

a) A local control and monitoring system for the SCR system is to be provided to enable operation, maintenance, and effective control in the event of an emergency or failure of any remote controls. This may be integrated with the engine control system and/or be a standalone system.

b) The design of the control system is to provide identification of faults in the equipment, as well as the process system. The control and monitoring systems are to comply with the requirements of 4-9-2/3.1, as applicable.

c) Indications of parameters necessary for the safe and effective operation of the exhaust emission abatement process are to be provided at the local and, as applicable, remote control station(s), as per 6-3-3/17.7 TABLE 1.

d) The computer-based control systems are to comply with the applicable requirements of Section 4-9-3 as a Category II system based on 4-8-3/15.

e) Injection of reductant solutions outside the exhaust temperature limits specified by the catalyst manufacturer is to be prohibited by the control system (see 6-3-3/9.7), and controls strategies are to minimize ammonia slip and catalyst breakdown.

iii) The power supply arrangements for the control and monitoring system are to meet the requirements of 4-9-2/5.3.

iv) Control and monitoring functions are to be in accordance with 6-3-3/17.7 TABLE 1.

13.5 Safety Shutdown System *(1 July 2023)*

A shutdown system is to be provided. This safety shutdown system is to be based on the following principles:

i) Upon activation of the safety shutdown system, means are to be provided to indicate parameters causing shutdown and alarms are to be given at the remote control position and at the local control position.

ii) In the event where shutdown by the safety shutdown system is activated, the restart is not to occur automatically, unless after resetting the system.

Safety shutdown is to be automatically activated for the conditions in 6-3-3/TABLE 1.

15 FMEA Integration Test

An integration test is to be undertaken on the first SCR unit in a particular design series to verify that the operation and response of the complete SCR mechanical and electrical systems are as predicted for all operational modes. The scope of these tests is to be determined based on the FMEA required by 6-3-3/13.1.

17 Surveys During Construction

17.1 General

This Subsection pertains to surveys during fabrication at the manufacturer’s facility and installation and testing of SCR units on board. As applicable, these surveys may be incorporated with the certification, shop test, and shipboard tests required by the applicable aspects of 4-2-1/13 and 4-2-1/15. For surveys at the manufacturer’s facility, the scope of the survey will be confined to only those items that are supplied by the manufacturer.

17.3 Surveys at Manufacturer’s Facility

See 6-3-3/17.7 TABLE 2 for certification requirements of SCR units and associated systems. Survey requirements for equipment components and packaged units at the manufacturer’s facility are summarized in the relevant sections of the applicable Rules/Guides.

17.5 Surveys During Installation

The following surveys are to be carried out to the satisfaction of the attending Surveyor on the SCR unit and associated systems during installation and testing:

i) Inspection and verification that the foundations and attachments of the principal components of the SCR unit and associated systems are in accordance with the approved plans and particulars.

ii) Piping systems are to be visually examined and pressure-tested, as required by these Rules. Pressure tests conducted on Class I piping systems (see 4-6-1/5 TABLE 1) are preferably to be recorded on test charts for the duration of their tests.

iii) Electrical wiring and connections are to be in accordance with Part 4, Chapter 8 and checked for continuity and proper workmanship.

iv) Instrumentation is to be tested to confirm proper operation as per its predetermined set points.

v) Pressure relief and safety valves installed on the unit are to be tested.

vi) Control system and shutdowns are to be tested for proper operation.

vii) The SCR unit is to be checked for proper operation in accordance with the ABS approved installation test procedure.

17.7 Surveys During Trials

During the initial commissioning trials, the SCR unit is to be confirmed for its satisfactory operation, including associated controls, alarms, and shutdowns. The tests are to be conducted in accordance with the ABS-approved testing procedure during sea trials.

TABLE 1
Monitoring and Safety System Functions for SCR Systems *(2024)*

Monitored Parameters (4)	*Display*	*Alarm Activated*	*Automatic SCR Shutdown and Automatic SCR Bypass* (1)
Exhaust fan motors	Running	Stop (2)	
Ventilation fans	Running	Stop	
Exhaust bypass or isolation valves, where provided	Position		
Control-actuating medium of the exhaust bypass or isolation valves, as applicable	Running	Failed	
Exhaust gas temperature before SCR chamber	X	High	X (High-High)
Exhaust gas temperature after SCR chamber	X	High	X (High-High)
Differential pressure across SCR chamber	X	High	X (High-High)
Reductant dosing pumps	Running	Stop (2)	
Reductant system supply pressure	X	Low	X (Low-Low)
Reductant storage tank temperature	X	Low/High	X (High-High)
Reductant storage tank level	X	Low/High	X (Low-Low)
Reductant tank spill tray level (3, 6)		High	X (High-High)
Pneumatic supply pressure, injector and soot blowing systems	X	Low	X (Low-Low)
Catalyst temperature or reductant injection out of boundary conditions (5)	X	Low/High	X (High-High)
Control and safety system power supply	Running	Failed	
Emergency Shutdown	X	X	X

Notes:

1 Automatic bypass of the SCR unit is applicable to those SCR units fitted with exhaust gas bypass arrangements (see 6-3-3/7.1.ii).

2 Failure of essential SCR system motors driving pumps or fans is to activate the standby units, where fitted (see 6-3-3/9.11.3).

3 Urea storage tanks of 500 liters (132 US gallons) and above only (see 6-3-3/11.3.4).

4 As applicable, in accordance with the specific SCR system design and installation.

5 See6-3-3/9.7.vi

6 Spill tray level is not required for reductant tanks that have drainage arrangements. See 6-3-3/11.5.4.

TABLE 2
Certification of SCR Systems at the Manufacturer's Facility *(1 July 2023)*

This Table has been prepared for guidance only and annotated to agree with the *Marine Vessel Rules*. The list is not to be considered exhaustive; should additional equipment not listed be fitted on board, same will be subject to special consideration for compliance with the *Marine Vessel Rules*. This list is not to be considered as substitutive or integrative of the content of the *Marine Vessel Rules* and/or other applicable Regulations. In case of conflict between the content of this list and the applicable *Marine Vessel Rules* and other applicable regulations, the latter are to be considered applicable.

Code	*Explanation*
DR	*Design Review* – Design review required.
MS	*Manufacture Survey* – Product is to be surveyed during fabrication stages by the Surveyor.
FS	*Final Survey* – Finished product is to be subject to final hydrostatic, nondestructive, operational testing, or any other required tests, and witnessed by the Surveyor at manufacturer's facility.

Equipment	*DR*	*MS*	*FS*
SCR unit	X	X	X
Exhaust piping	X		
Exhaust bypass or isolation valves	X		
Exhaust fans/motors (1)	X		X
Heat exchangers, burners or heaters	X		X
Reductant system piping	X		
Pneumatic systems	X		
Control and safety system	X	X	X

Notes:

1 Applicable for motors over 100 kW (135 hp) only. For motors less than 100 kW (135 hp), certification by ABS not required, acceptance based on manufacturers documentation and guarantee (see 6-3-3/9.11.1).

PART 6

CHAPTER 3
Exhaust Emission Abatement

SECTION 4
Exhaust Gas Recirculation Systems *(2024)*

1 General *(2024)*

Exhaust Gas Recirculation (EGR) systems fitted for the purposes of reducing internal combustion engine NO_x emissions are considered primary exhaust emission reduction techniques forming part of the total engine design and as such are to be integrated by, or under authorization of, the engine designer. Those applicable requirements for EGR systems contained within this Section are supplementary to, and to be applied in association with, the requirements for internal combustion engines under Section 4-2-1.

Some EGR systems incorporate off-engine systems that are designed to remove sulfur by-products from the exhaust gases that originate from the fuel and incorporate, water scrubbing and water cleaning systems. Other engines incorporate all EGR components within the base engine design and operate with fuels within specified sulfur limits. Where a water treatment system is incorporated in the EGR system, it is to meet the requirements of IMO Resolution MEPC.307(73) for the discharge of EGR bleed-off water, and as applicable, MEPC.340(77). Statutory approval can be made by ABS as a Recognized Organization when authorized by the flag Administration.

Vessels complying fully with this section will be assigned the optional **EGC-EGR** notation. Where this notation has not been requested, the exhaust gas recirculation system is to be verified to be in compliance with the minimum requirements prescribed in 6-3-1/9.11 and6-3-1/13 TABLE 1is to be verified by the ABS Surveyor during installation.

The EGR system, or EGR version of the engine, is to be approved by incorporation into the existing engine approval.

Vessels complying fully with the statutory emissions performance testing, survey, and certification requirements of the applicable IMO Regulations and Guidelines and the minimum requirements of EGC-EGRs in 6-3-1/13 TABLE 1 may be assigned the optional **EGC-EGR (M)** notation.

1.1 Objectives *(2024)*

1.1.1 Goals

The EGR system covered in this Section is to be designed, constructed, operated, and maintained to:

Goal No.	*Goals*
PROP 2	Provide redundancy and/or reliability to maintain propulsion.
ENV 6	Minimize air pollution.
SAFE 1.1	Minimize danger to persons on board the vessel, and surrounding equipment/installations from hazards associated with machinery and systems.
MGMT 1	*Provide for safe practices in ship operation and a safe working environment. (ISM Code 1.2.2.1)*
MGMT 5.1	Design and construct vessel, machinery, electrical, safety systems to facilitate safe access, ease of inspection, survey and maintenance.
AUTO 1	Perform its functions as intended and in a safe manner
AUTO 2	Indicate the system operational status and alter operators of any essential machinery/systems deviate from its defined design/operating conditions or intended performance.
AUTO 3	Have an alternative means to enable safe operation in the event of an emergency or failure of remote control.
AUTO 4	Provide the equivalent degree of safety and operability from a remote location as those provided by local controls.
AUTO 5	Provide a safety system that automatically leads machinery controlled to a fail-safe state in response to a fault which may endanger the persons on board, machinery/equipment or the environment.

Materials are to be suitable for the intended application in accordance with the following goals and support the Tier 1 goals listed above.

Goal No.	*Goal*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.

The goals in the cross-referenced Rules/Regulations are also to be met.

1.1.2 Functional Requirements

In order to achieve the above stated goals, the design, construction, installation and maintenance of the EGR are to be in accordance with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
Materials (MAT)	
MAT-FR1	Chemical Composition to be considered for corrosion resistance, weldability, final mechanical properties.
MAT-FR2	Corrosion resistance to be considered when exposed to different fluids which lead to loss of material.
MAT-FR3	Galvanic compatibility is to be considered when dissimilar metals are connected and come in contact with an electrolytic solution.
Propulsion, Maneuvering, Station Keeping (PROP)	
PROP-FR1	The exhaust emission abatement is to allow continued operation of machinery connected to the system when it is not in operation.

Functional Requirement No.	*Functional Requirements*
Fire Safety (FIR)	
FIR-FR1	The exhaust emission abatement system is to be arranged to prevent dangerous chemicals from coming in contact with sources of ignition to minimize the risk fire/explosion.
Protection of Environment (ENV)	
ENV-FR1	The exhaust emission abatement system is to remove NO_x emitted from the machinery to minimize air pollution.
ENV-FR2	Redundancy is to be provided for exhaust emission abatement equipment to maintain capability of reducing air pollution.
Safety of Personnel (SAFE)	
SAFE-FR1	The exhaust emission abatement system is to be compatible with the connected engine and their operating parameters.
SAFE-FR2	The exhaust emission abatement system is to be arranged to prevent internal flooding and ingress of water to the connected engine.
SAFE-FR3	Protective devices compatible with the prospective short circuit current are to be installed in the exhaust emission abatement system circuits to protect the equipment from damage.
SAFE-FR4	Provide means to protect the crew from the hot surfaces of the exhaust emission abatement system.
SAFE-FR5	Non-metallic piping used in the exhaust emission system is to be designed to minimize the risk of failure due to fire that may lead to flooding.
SAFE-FR6	Chemical treatment system including the tank for dangerous chemicals is to be designed and arranged to contain dangerous chemicals in all expected conditions and prevent leakage/ contact with personnel.
SAFE-FR7	Tanks containing the dangerous chemicals for the exhaust emission abatement system are to be provided with means of confirm the temperature and amount of chemical in tanks.
SAFE-FR8	Ventilation of the space with tanks containing dangerous chemicals are to be arranged to extract the dangerous vapors from possible leakage.
SAFE-FR9	Provide suitable equipment to protect the crew from exposure to dangerous chemicals during operation of the exhaust emission abatement system.
SAFE-FR10	Means are to be provided for safe storage and disposal of any exhaust residues associated with the operation of the exhaust emission abatement system.
SAFE-FR11	The exhaust emission abatement system is to be arranged such that a single fault of a component will not lead to a potentially dangerous situation for human safety and/or the vessel.
Safety Management (MGMT)	
MGMT-FR1	Information is to be provided onboard covering the operations, safety and maintenance requirements and occupational health hazards relevant to the exhaust emission abatement system.
MGMT-FR2	The exhaust emission abatement system is to be installed in an accessible location and arranged for ease of inspection and maintenance.
Automation: Control, Monitoring and Safety Systems (AUTO)	

Functional Requirement No.	*Functional Requirements*
AUTO-FR1	Means are to be provided for visible and audible notifications at manned locations for abnormal conditions of the exhaust emission abatement systems, and the automatic start of the redundant equipment if available, to prevent further escalation of hazards.
AUTO-FR2	Local control and monitoring system for the exhaust emission abatement system is to be provided to enable safe operation, maintenance, and effective control in the event of an emergency or failure of any remote controls.
AUTO-FR3	Alarm, monitoring and control systems are to be provided to facilitate automatic and manual operations, including safe shutdowns, at remote and local locations to allow continued operations.

The functional requirements in the cross-referenced Rules/Regulations are also to be met.

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

3 Plans and Data to be Submitted *(2024)*

Plans and specifications covering the EGR arrangements are to be submitted and are, as applicable, to include:

- General arrangement of the EGR installation, layout,and systems
- Documentation detailing the EGR specification and associated water treatment systems, including details of EGR specific components such as coolers, blowers, valves, etc.
- Hull plans showing the foundation and attachments of accessories to the vessel's structure, including scantlings, welding details, and foundation details of principal components
- Material specifications for the EGR equipment and associated systems, including coolers, blowers, pumps, valves,storage/process tanks, residue tanks, piping, distribution systems, separators, and associated components, including a corrosion assessment detailing the corrosive effect of system liquids, vapors, and gases on the materials used in the EGR system
- Arrangement and capacity of tanks for storage, chemicals, process washwater, exhaust gas cleaning residues, etc.
- Details of all piping systems, including details of piping and associated components, design pressures, temperatures, insulation, and spill trays, where applicable
- Descriptions and schematic diagrams for the control and monitoring systems, including set points for abnormal conditions and details of the location and position at which exhaust emission or EGR rate monitoring and washwater monitoring are to be located
- Details of all electrical equipment installed for the EGR unit and associated systems,including computer-based systems
- Failure Modes and Effects Analysis (FMEA) to determine possible failures and their effects on the operation of the EGR system (see 6-3-4/13.1).

  Note: This can be a standalone document or be incorporated into the engine FMEA required by Appendix 4-2-1-A1.
- Safety shutdown system (see 6-3-4/13.5)
- EGR FMEA integration test report (see 6-3-4/15)

- Operating and maintenance instruction manuals, including MSDS sheets and details for handling of hazardous and non-hazardous chemicals used in the EGR system (see 6-3-4/5)
- Testing procedures during installation and commissioning trials

5 EGR System Operation and Maintenance Manuals *(2024)*

In accordance with 6-3-1/11, detailed instruction manuals are to be provided on board, covering the operations, safety, and maintenance requirements and occupational health hazards relevant to the EGR equipment and associated systems.

These manuals are to include, but are not limited to, the procedures and schedules for operation, inspection, testing, and maintenance of the EGR system and associated systems, the regular testing and maintenance procedures for the monitoring systems, safety shutoff systems, and the integrity of backup systems, together with special instructions for the bunkering, storage, and use of hazardous and non-hazardous chemicals that may be used in the EGR system and identification of the relevant responsible parties.

The manuals can be produced as standalone documents or incorporated within the general engine operation and service manuals required by 4-2-1/1.5.1.

The manuals are to be submitted for reference to verify the presence of all the information required by this Section.

7 EGR System Configuration and Vessel Integration

7.1 General *(2024)*

i) EGR is a NO_x reduction technique where a portion of the exhaust gas, typically up to 40%, is recirculated back into the engine which reduces the amount of excess oxygen within the cylinder and provides gases inert to combustion which act to absorb combustion and heat, and therefore reduce peak in-cylinder temperatures. This is considered a primary exhaust emission reduction technique and as such is to be integrated by, or under authorization of, the engine designer.

Furthermore, the high sulfur content of marine fuels necessitates the use of cleaning processes to be applied to the exhaust gases to avoid engine fouling and corrosion issues, similar to the water treatment systems applied to SO_x scrubbers, and hence those aspects of the EGR system are to comply with the requirements of this Chapter.

The integration of an EGR system to an already approved internal combustion engine is not considered an engine type defining parameter change as per 4-2-1/13.7.2.

ii) EGR systems are to be designed to enable continued operation of the engine at the times the EGR system is not in operation, either through operational selection, equipment failure, or system deterioration through partial blocking/clogging.

iii) The response of the mechanical and electrical systems of the first EGR unit in a particular design series is to be demonstrated by the FMEA integration test of 6-3-4/15.

7.3 Compatibility with the Engine

i) Installation and operation of the EGR system is to be compatible with the engine and is not to cause any adverse effects on engine performance such as excessive back pressures or high temperatures during operation.

ii) The range of suitable fuels for which the EGR system is capable of continual operation, in particular with respect to sulfur content and other fuel elements known to cause fouling issues,is to be declared by the EGR manufacturer and included in the EGR specification documentation and instruction manuals required by 6-3-4/3 and 6-3-4/5.

7.5 Redundancy *(2024)*

Redundancy of equipment is to be provided for those rotating and reciprocating components that form part of the EGR essential supplementary systems, such as pumps, fans, blowers, etc. (see 6-3-4/9.1 and 6-3-4/9.7.3).

Alternative means of compliance or operation to meet this objective is subject to ABS technical assessment and approval. As applicable, documentation is to be submitted demonstrating that the reliability of the system or component provides continued serviceability of the EGR system or the alternative means of operation provides continued compliance with the statutory environmental requirements, without compromising the vessel propulsion and maneuvering capability. The provision of sufficient spare parts on board is an example of vessel specific arrangements that will be considered during ABS technical assessment as meeting this objective and is to be justified with reference to the FMEA required by 6-3-4/13.1.

7.7 Essential Services

For the purposes of design, construction, testing, and survey, EGR units and associated components and systems are considered secondary essential services in accordance with 4-8-1/7.3.3.

7.9 Prevention of Flooding *(2024)*

i) For EGR systems that incorporate a wet washwater scrubbing process, arrangements are to be provided to prevent the ingress of scrubber washwater into the engine under any circumstance.

ii) Monitoring, alarm, and shutdown arrangements are to be provided to prevent an abnormal rise of washwater level in the EGR scrubber unit. See 6-3-4/17.7 TABLE 1.

7.11 Inclinations *(2024)*

EGR systems are to be designed for proper operation at the inclination requirements of 4-1-1/7.9.

9 EGR System Equipment

9.1 Pumps/Blowers *(2024)*

i) Where provided, pumps used in EGR SO_x scrubber washwater, dosing, discharge, etc., systems, essential for the continual operation of the EGR exhaust emission abatement system, are to be tested and certified in accordance with 4-6-1/7.3. This is applicable to exhaust emission abatement systems connected to internal combustion engines rated at 2250 kW (3000 hp) and above or having cylinders of more than 300 mm (11.8 in.) bore.

ii) Unless alternative means of compliance in accordance with 6-3-4/7.5 are applicable, redundant washwater, dosing, discharge, etc., pumps, essential for the continual operation of the EGR water systems, are to be provided. There are to be at least two of these essential pumps, the capacity of the pumps, with any one pump out of service, is to be sufficient for continuous operation of the exhaust emission abatement system at full rating. See also 6-3-4/9.7.3.

For vessels fitted with two or more identical EGR systems, the provision of a common standby pump (for each essential system) capable of serving all EGR units will suffice rather than providing individual standby pumps for each EGR unit.

iii) Unless alternative means of compliance in accordance with 6-3-4/7.5 are applicable and where exhaust fans or blowers form part of the EGR system and are essential for continual operation of the EGR system at full rating, redundancy is to be provided for such fans. The number and power of the fans or blowers should be such that if one unit, or group of units, is out of service the capacity of the remaining units is not to be less than 100% of the total required.

iv) Blowers are to be designed, constructed, and tested in accordance with the applicable requirements for auxiliary blowers of engines in4-2-1/7.9.

9.3 Heat Exchangers/EGR Exhaust Gas Coolers *(2024)*

i) Where provided, heat exchangers are to be designed, constructed, and certified in accordance with Section 4-4-1.

ii) EGR exhaust gas coolers are not subject to 6-3-4/9.3.i Suitability of the cooler materials for the exhaust gases is to be submitted for review.

The coolers are to be hydrostatically tested on the water side to 4 bar (4.1 kgf/cm^2, 57 psi), but not less than 1.5 times the design pressure on the water side, either in the manufacturer's plant or in the presence of the Surveyor, after installation on board the vessel. See also 4-2-1/13.3 for acceptance of manufacturer's certificate.

9.5 Chemical Treatment System

The specific requirements for chemical treatment system components are given in 6-3-4/11.5.

9.7 Electrical System

The electrical system and electrical equipment requirements in this Subsection are to be applied in association with the requirements of Part 4, Chapter 8.

9.7.1 Electrical Motors and Controllers

Motors and motor controllers of 100 kW (135 hp) and over are to be certified in accordance with 4-8-3/1.5.

9.7.2 Electrical Load Analysis

i) The number and capacity of generators are to be sufficient under normal sea going conditions with one generator in reserve to carry those loads for essential services and for minimum comfortable conditions of habitability as required by 4-8-2/3.1.1.

ii) The electrical loads associated with the EGR system are to be included in the electric-plant load analysis required by 4-8-1/5.1.5.

9.7.3 Standby Pump/Fan Arrangements *(2024)*

i) In the event of failure of the essential EGR system pumps or fans/ blowers, the standby pump or fan/blower as required by6-3-4/9.1, where provided, is to be automatically started and put into service. This failure is to be alarmed at the local and remote control station(s), as applicable.

ii) Where provided, each standby pump or fan/blower is to be fed from separate bus bar sections of the switchboard. In the event of failure of one bus bar section of the switchboard, the standby pump or fan can be fed from the another bus bar section.

9.7.4 Circuit Protection Devices and Compatibility

Circuit breakers are to be installed for miscellaneous EGR system electrical loads and are to be compatible with the prospective short circuit current level calculated at the switchboards.

11 EGR System Piping

11.1 Exhaust Gas Piping Systems

11.1.1 Exhaust Gas Piping/Scrubber Materials and Installation *(2024)*

i) Exhaust gas piping materials located before the EGR scrubber, where fitted, may be of the same material specification as the standard engine exhaust gas piping.

ii) The parts and components of the scrubber that are subjected to washwater (e.g., the interior reaction chamber or washwater piping/nozzles, etc.) are to be constructed of corrosion resistant materials, such as stainless steel, appropriate for the environment.

iii) Exhaust gas piping materials used after the EGR unit are to be of a corrosion resistant material such as stainless steel.

11.1.2 Exhaust Gas Piping Valves *(2024)*

i) Valves used in the EGR exhaust system are to meet the requirements of 4-6-2/5.11.

Valves located after the scrubber unit are to be constructed of corrosion-resistant materials, such as stainless steel, appropriate for environment.

ii) The EGR exhaust system valves are to be arranged for automatic position control and position monitoring in association with the EGR control and monitoring system.

iii) Valves are to be installed in accessible locations, clear of or protected from obstructions, moving equipment, and hot surfaces, in order to permit regular inspection and maintenance.

11.1.3 EGR Scrubber and EGR System Insulation

Hot surfaces of EGR systems or their associated equipment or systems likely to come into contact with the crew during operation are to be guarded or insulated. Where the surface temperatures will exceed 220°C (428°F) and where any leakage, under pressure or otherwise, of fuel oil, lubricating oil or other flammable liquid will come into contact with the EGR unit or exhaust pipes, these surfaces are to be suitably insulated with non-combustible materials that are impervious to such liquids. Insulation material not impervious to oil is to be encased in sheet metal cladding or an equivalent impervious sheath.

11.3 Washwater Piping

11.3.1 Piping and Connections *(2024)*

i) Where applicable, the EGR washwater system pipe fittings and joints are to meet the requirements for certification in 4-6-1/7.1, materials in 4-6-2/3 and design in 4-6-2/5.5 and 4-6-2/5.15, subject to the limitations in 4-6-5/7.3.3 TABLE 3.

Molded non-metallic expansion joints, where used, are to be of an approved type (see 4-6-2/5.8.1).

ii) The piping material for the corrosive scrubber washwater system is to be selected based on the corrosive nature of the liquid media.

iii) Pipes and piping components made of thermoplastic or thermosetting plastic materials, with or without reinforcement, used in piping systems are subject to compliance with the requirements of Section 4-6-3. For the purpose of these Rules, "plastic" means both thermoplastic and thermosetting plastic materials, with or without reinforcement, such as polyvinyl chloride (PVC) and fiber reinforced plastics (FRP). Plastic includes synthetic rubber and materials of similar thermo/mechanical properties. Plastic washwater piping is to meet Level 3 fire endurance testing requirements (see 4-6-3/5.11).

iv) Flexible hoses are to comply with the requirements of 4-6-2/5.7.

11.3.2 Remote Control Valves *(2024)*

i) Upon loss of control power, the remote control valves are to remain in the last ordered position, provided there is a readily accessible means to manually close the valves. Otherwise, they are to be in the fail safe position in accordance with the FMEA.

ii) Remote control valves are to be clearly identified and are to be provided with position indicators at the local and EGR system remote control station, as applicable.

iii) Valves are to be installed in accessible locations, clear of or protected from obstructions, moving equipment, and hot surfaces, in order to permit regular inspection and maintenance.

11.3.3 Overboard Discharges *(2024)*

i) Overboard discharges of any EGR system are not to be interconnected to other systems.

ii) Special attention is to be paid to the corrosion resistivity of EGR washwater overboard discharge piping. Where applicable, adequate arrangements are to be provided to prevent galvanic corrosion due to the use of dissimilar metals.

iii) EGR washwater overboard discharge piping is to be designed appropriate for the corrosive washwater. The distance piece between the discharge valve and the shell plating, is to comply with 4-6-2/9.13.3, and be fitted internally with high corrosive resistance protection material such as super duplex stainless steel sleeves. Otherwise, the distance piece is to be at least of Sch.160 construction and is to be protected with an anti-corrosive coating (e.g., epoxy) suitable for the washwater discharges. Evidence of suitability for the protection means is to be submitted.

Alternative arrangements for the EGR washwater overboard discharge proven to be of not less effective construction is subject to ABS technical assessment and approval. Adequate arrangements are to be provided to prevent galvanic corrosion due to the use of dissimilar metals. Where a galvanic couple cannot be avoided, coating the stainless steel or using a more noble steel grade is acceptable.

iv) The EGR washwater overboard discharge is to be located considering the vessel's propulsion features, such as thrusters, propellers or to prevent any discharge of water onto survival craft during abandonment in accordance with SOLAS Reg. III/16.8. As applicable, discharges are to be arranged to enable safe sampling of water discharge plumes.

v) Where plastic pipes are permitted to be used for the EGR washwater discharge lines, the valves installed on the shell and the pipe connection to the shell are to be metallic. The side shell valves are to be arranged for remote control from outside the space in which the valves are located. See 4-6-3/7.9.

11.5 Chemical Treatment Piping Systems *(2024)*

The requirements for the washwater chemical treatment system detailed in this Subsection are based on the use of NaOH in the EGR scrubber water treatment system, as applicable. If other chemicals are to be used, the requirements should be consistent with the intent of the requirements for NaOH and subject to ABS technical assessment and approval.

The requirements detailed below are also based on an arrangement whereby the EGR residue tank is also used as an overflow tank for the NaOH storage tank. Arrangements that divide these functions into separate tanks is acceptable, and in which case, the requirements for the overflow tank are detailed in 6-3-4/11.5 and the requirements for the residue tank in 6-3-4/11.7.

11.5.1 Material for Piping Systems, NaOH Storage Tank, and EGR Residue/NaOH Overflow Tank

The material of the NaOH related piping systems, NaOH storage tank, EGR residue/NaOH overflow tanks, drip trays, and any other components which come into contact with the NaOH solution or sludge is to be of a grade of stainless steel or other corrosion-resistant material shown to be appropriate for the application. Aluminum, zinc, brass, or galvanized steel components are not to be used.

11.5.2 Bunkering of NaOH *(2024)*

i) The bunker station(s) for NaOH is to be located on the open deck away from sources of ignition and arranged such that a spill at a bunker station will not result in NaOH contacting or mixing with other incompatible materials.

Alternatively, closed or semi-enclosed bunker stations with the provision of ventilation is subject to ABS technical assessment and approval.

ii) Spill trays are to be provided with means of drainage to the EGR residue/ NaOH overflow tank.

11.5.3 Arrangement of the NaOH Storage Tank and the EGR Residue/NaOH Overflow Tank *(2024)*

i) The NaOH storage and EGR residue/NaOH overflow tank are not to be situated where spillage or leakage there from can constitute a hazard by falling onto combustibles or heated surfaces. These tanks are not to be located over boilers or in close proximity to steam piping (supply or returns).

ii) Where necessary, the NaOH storage tank is to be provided with an appropriate heating system to prevent freezing.

11.5.4 Filling, Vents, and Overflows for NaOH Tank and EGR Residue/NaOH Overflow Tank *(2024)*

i) *Filling*. The NaOH storage tank is to be provided with a fill line from the bunker station and a shut off valve is to be provided at the bunkering station.

Overflow and/or drains leading to the EGR residue/NaOH overflow tank are to enter at or near the top of the tank. However, if this is determined to be impracticable, these lines are to be fitted with a non-return valve at the EGR residue/NaOH overflow tank.

ii) *Vents*. The NaOH storage and EGR residue/NaOH overflow tanks are to be provided with vent pipes complying with 4-6-4/9, and the outlets are to terminate in a safe location (see 4-6-4/9.3.5(b).ii.) in the weather.

The vents are not to be subject to deterioration due to the concentrations involved, and the arrangement is to be such that the potential source of leakage from the vents does not present any danger to the crew or vessel. Alternatively, the tanks are to be fitted with appropriately sized pressure/vacuum valves.

iii) *Overflow Protection*. Means are to be provided to prevent NaOH from spilling or accidently overflowing from the storage and EGR residue/NaOH overflow tanks. Accordingly, the NaOH storage tank is to be fitted with a high level alarm. Alternatively, the NaOH storage tank may be fitted with an overflow arrangement complying with 4-6-4/9.5.2 and 4-6-4/13.5.4 that is led to the EGR residue/NaOH overflow tank. Further, in all cases, the EGR residue/NaOH overflow tank is to be fitted with a high level alarm. Other anti-spilling arrangements is subject to ABS technical assessment and approval.

11.5.5 Sounding and Temperature Indication for the NaOH Storage and EGR Residue/ NaOH Overflow Tanks

i) Sounding arrangements are to be provided for the NaOH storage and EGR residue/NaOH overflow tanks and are to comply with the sounding requirements applicable to fuel oil tanks of 4-6-4/11.3.7.

ii) A sight glass is not to be used unless the materials of construction are compatible with the concentration of NaOH solution involved, it is to be protected from mechanical damage, and the arrangements are equivalent to that required in 4-6-4/11.5.1 (i.e., flat "glass-type"), fitted with a self-closing valve at each end.

iii) In addition to local level gauging, the NaOH storage and EGR residue/NaOH overflow tanks are to have remote level gauging indication at the manned control station.

iv) The NaOH storage and EGR residue/NaOH overflow tank are to be provided with local and remote temperature monitoring arrangements. The remote temperature indicator is to be installed at the manned control station.

11.5.6 Spill Trays for NaOH Storage and EGR Residue/NaOH Overflow Tanks *(2024)*

i) Those are as of the NaOH storage and EGR residue/NaOH overflow tanks that could result in leakage, locations where leakage from pumps and other associated equipment such as strainers, heaters, flanges, valves, etc., which require occasional dismantling for examination or maintenance, and where leakage is normally expected are to be located within spill trays.

ii) Either drainage arrangements for the spill tray that lead to the dedicated EGR residue/NaOH overflow tank are to be provided or arrangements to activate an alarm in the event of spillage are to be provided. Where drainage arrangements are provided, the drain line to the EGR residue/NaOH overflow tank is to be fitted with a non-return valve.

11.5.7 Miscellaneous NaOH Piping Arrangements *(2024)*

i) The NaOH piping systems are to be independent of other ship service piping and/or systems.

ii) Piping systems for NaOH systems are not to be located in accommodation, service, or control spaces.

iii) Every pipe emanating from a tank containing NaOH, which, if damaged, would allow NaOH to escape from the tank, is to be provided with a positive closing valve located directly on the tank. A short length of extra strong pipe (sch 80) connecting the valve to the tank is also acceptable. The valve not to be of cast iron, although the use of nodular cast iron is permissible, see 4-6-2/3.1.5. The positive closing valve is to be provided with means of closure both locally and from a readily accessible position outside of the space.

iv) Pipe joints are to be kept to a minimum. The direct connections of pipe lengths are to be all welded except for necessary flanged connections to valves and other equipment for maintenance in order to minimize risk of leakage from the pipe lines.

v) Supply, bunkering, and transfer lines for NaOH systems are not to be located over, or in close proximity to, boilers, steam piping, exhaust systems, hot surfaces required to be insulated, or other sources of ignition.

11.5.8 Ventilation Arrangements for NaOH Storage and EGR Residue/NaOH Overflow Tanks *(2024)*

The NaOH storage and EGR residue/NaOH overflow tanks may be located within the engine room or in a separate compartment.

If the tank is installed in a separate compartment, the compartment is to be served by an effective mechanical ventilation system of extraction type providing not less than 6 air changes per hour which is independent from the ventilation system of accommodation, service spaces, or control stations. The ventilation system is to be capable of being controlled from outside the compartment. A warning notice requiring the use of such ventilation before entering the compartment is to be provided outside the compartment adjacent to each point of entry.

Alternatively, where the tank is located within an engine room a separate ventilation system is not required when the general ventilation system for the space is arranged so as to provide an effective movement of air in the vicinity of the storage tank and is to be maintained in operation continuously except when the storage tank is empty and has been thoroughly ventilated.

11.5.9 Personnel Protection *(2024)*

For the protection of crew members, the vessel is to have on board personnel protective equipment (PPE) consisting of large aprons, rubber gloves with long sleeves, rubber boots, coveralls of chemical- resistant material, and tight-fitting chemical safety goggles or face shields or both. The protective clothing and equipment is to cover all skin so that no part of the body is left unprotected.

The quantities of PPE carried on board is to be appropriate for the number of personnel engaged in regular handling operations or that may be exposed in the event of a failure of the NaOH system; but in no case is there to be less than two sets available on board.

Eyewash and safety showers are to be provided, the location and number of these eyewash stations and safety showers are to be derived from the detailed installation arrangements. As a minimum, the following stations are to be provided:

i) In the vicinity of transfer or treatment pump locations. If there are multiple transfer or treatment pump locations on the same deck, then the acceptance of one eyewash and safety shower station provided that the station is easily accessible from all such pump locations on the same deck is subject to ABS technical assessment and approval.

ii) An eyewash station and safety shower is to be provided in the vicinity of a chemical bunkering station on-deck. If the bunkering connections are located on both port and starboard sides, then two eyewash stations and safety showers, one for each side. The acceptance of one eyewash and safety shower station provided that the station is easily accessible from both port and starboard bunkering stations is subject to ABS technical assessment and approval.

iii) An eyewash station and safety shower is to be provided in the vicinity of any part of the system where the potential for a person to come into contact with the chemicals exists (e.g., openings such as filling/drainage or system connections/components that require periodic maintenance).

Depending on the specific arrangements (e.g., vessel type, size, layout of deck, machinery space, etc.), consideration may be given so that the personnel protection arrangements required by this section may be shared with those required by 6-3-2/11.5.9 or 6-3-3/11.3.5.

11.5.10 Safety Notices for the Compartment or at the Location of Tanks Containing NaOH

Safety instructions relating to precautions and corrective response actions are to be posted in the compartment containing NaOH and beside the entrance to the compartment. Detailed guidelines given in the MSDS are to be followed.

11.7 EGR Residue System *(2024)*

i) The residues generated from the exhaust gas cleaning process are to be stored in a designated residue tank, separate from the engine room sludge tank, and arranged for discharge to appropriate shore reception facilities in accordance with 4-6-4/5.7.4.

The EGR residue tank is to be so designed as to facilitate cleaning.

Where EGR residue tanks used in closed loop chemical treatment systems are also used as the overflow tank for the NaOH storage tank, the additional requirements of 6-3-4/11.5 are to be applied.

ii) The material of the EGR residue tank is to be selected based on the corrosive nature of the EGR residue.

iii) The capacity of the EGR residue tank is to be based on the expected residue volumes applicable to the exhaust gas cleaning process and the maximum period of voyage between ports where EGR residue can be discharged. In the absence of precise data, a figure of 30 days is to be used.

iv) The EGR residue tank is to be provided with vent pipes complying with 4-6-4/9.

v) The residue tank is to be arranged with a high level alarm

vi) Sounding arrangements are to be provided for the EGR residue tank in accordance with 4-6-4/11.3.7.

vii) For those vessels that do not undertake on board incineration and collect all engine room sludge for disposal ashore, arrangements utilizing a combined engine room sludge and EGR residue tank are subject to ABS technical assessment and approval, and the tank is to meet the requirements of

6-3-4/11.7.iito 6-3-4/11.7.vi, EGR residue record logs satisfy the requirements of MEPC.340(77), and residues are disposed at MARPOL reception facilities.

Combined engine room sludge and EGR residue tanks are to be sized to provide the capacity based on the sludge tank capacity requirements of 4-6-4/5.7.3 plus the capacity requirements for EGR residue tanks of 6-3-4/11.7.iii

13 Control, Alarm, and Monitoring System

13.1 General *(2024)*

i) The EGR control system is to be integrated with, or in direct communication with, the engine control system. Control systems for associated systems, such as water treatment plants, can be connected to an integrated control system or a standalone system.

ii) The EGR system is to be designed such that a single fault of a component will not lead to a potentially dangerous situation for human safety and/or the vessel.

An FMEA demonstrating the safety system design basis is to be submitted.

iii) Where the optional EEMS notation is requested, exhaust emissions monitoring systems are to meet the requirements of Section 6-3-5.

13.3 Control and Monitoring System *(2024)*

i) Automatic control, monitoring (including washwater discharge criteria), alarm, and safety functions are to be provided for the EGR system so that operations remain within preset parameters for all engine operating conditions. For vessels with **ABCU**/**ACC**/**ACCU** notations, the alarm and monitoring systems are to be integrated in the vessel's centralized monitoring systems that conform to the requirements for **ABCU**/**ACC**/**ACCU** notations and in lieu of individual alarms, a summary alarm in the vessel's centralized monitoring systems is also acceptable.

ii) The temperatures, pressures and flows in the EGR system and associated systems are to be controlled and monitored as follows:

a) A local control and monitoring system for the EGR system is to be provided to enable operation, maintenance, and effective control in the event of an emergency or failure of any remote controls. This may be integrated with the engine control system and/or be a standalone system.

b) The design of the control system is to provide identification of faults in the equipment, as well as the process system. The control and monitoring systems are to comply with the requirements of 4-9-2/3.1, as applicable.

c) Indications of parameters necessary for the safe and effective operation of the exhaust emission abatement process are to be provided at the local and, as applicable, remote control station(s), as per 6-3-4/17.7 TABLE 1.

d) The computer-based control systems are to comply with the applicable requirements of Section 4-9-3 as a Category II system based on 4-8-3/15.

iii) The power supply arrangements for the control and monitoring system are to meet the requirements of 4-9-2/5.3.

Control and monitoring functions are to be in accordance with 6-3-4/17.7 TABLE 1.

13.5 Safety Shutdown System

A shutdown system is to be provided. This safety shutdown system is to be based on the following principles:

i) Upon activation of the safety shutdown system, means are to be provided to indicate the parameters causing shutdown and alarms are to be given at the normal control position and at the local control position.

ii) In the event where shutdown by the safety shutdown system is activated, the restart is not occur automatically, unless after the system is reset.

Safety shutdowns are to be in accordance with 6-3-4/17.7 TABLE 1.

15 FMEA Integration Test

An integration test is to be undertaken on the first EGR unit in a particular design series to verify that the operation and response of the complete EGR mechanical and electrical systems are as predicted for all operational modes. The scope of these tests is to be determined based on the FMEA required by 6-3-4/13.1.

17 Surveys During Construction

17.1 General

This Subsection pertains to surveys during fabrication at the manufacturer's facility and installation and testing of EGR equipment and associated systems on board. These surveys may be incorporated with the certification, shop test, and shipboard tests required by the applicable aspects of 4-2-1/13 and 4-2-1/15. For surveys at the manufacturer's facility, the scope of the survey will be confined to only those items that are supplied by the manufacturer.

17.3 Surveys at Manufacturer's Facility

See 6-3-4/17.7 TABLE 2 for certification requirements of EGR equipment and associated systems. Survey requirements for equipment components and packaged units at the manufacturer's facility are summarized in the relevant sections of the applicable Rules and Guides.

17.5 Surveys During Installation *(2024)*

The following surveys are to be carried out to the satisfaction of the attending Surveyor on the EGR equipment and associated systems during installation and testing:

i) Inspection and verification that the foundations and attachments of the principal components of the EGR equipment and associated systems are in accordance with the approved plans and particulars.

ii) Piping systems are to be visually examined and pressure-tested, as required by these Rules. Pressure tests conducted on Class I piping (see 4-6-1/5 TABLE 1) systems should preferably be recorded on test charts for the duration of their tests.

iii) Electrical wiring and connections are to be in accordance with Part 4, Chapter 8 and checked for continuity and proper workmanship.

iv) Instrumentation is to be tested to confirm proper operation as per its predetermined set points.

v) Pressure relief and safety valves installed on the unit are to be tested.

vi) Control system and shutdowns are to be tested for proper operation.

vii) The EGR system is to be checked for proper operation in accordance with the ABS-approved installation test procedure.

17.7 Surveys During Trials

During the initial commissioning trials, the EGR equipment and associated systems are to be confirmed for their satisfactory operation, including associated controls, alarms, and shutdowns. The tests are to be conducted in accordance with the ABS-approved testing procedure during sea trials.

TABLE 1
Monitoring and Safety System Functions for EGR Systems *(2024)*

Monitored Parameters [4]	*Display*	*Alarm Activated*	*Automatic EGR Shutdown*
EGR exhaust fan/blower motors	Running	Stop [1]	
EGR exhaust bypass, isolation, mixing valves, where provided	Position		
Control-actuating medium of the EGR exhaust bypass, isolation or mixing valves, where provided	Running	Failed	
Exhaust gas temperature before EGR unit	X	High	X (High-High)
Exhaust gas temperature after EGR unit	X	High	X (High-High)
Engine air intake O_2 concentration (or EGR rate)	X	Low/High	X (Low-Low/ High-High)
Differential pressure across EGR scrubber unit or EGR circuit, as applicable	X	High	X (High-High) [2]
EGR washwater pumps, NaOH system pumps	Running	Stop [1]	
EGR washwater or NaOH system valves	Position		
Control-actuating medium of the EGR washwater and NaOH system valves, where provided	Running	Failed	
EGR washwater and NaOH system supply pressure	X	Low	X (Low-Low)
EGR washwater and NaOH system supply temperature	X	High	X (High-High)
Water level in EGR scrubber	X	High	X (High-High) [2]
NaOH Storage/EGR Residue/NaOH Overflow Tank temperature	X	Low/High	X (High-High)
NaOH Storage/EGR Residue/NaOH Overflow Tank level	X	Low/High	X (Low-Low)
NaOH Storage/EGR Residue/NaOH Overflow Tank spill tray level	X	High	X (High-High) [3]
EGR residue tank level	X	High	X (High-High)
Control and safety system power supply	Running	Failed	
Emergency shutdown	X	X	X

Notes:

1 Failure of essential EGR system motors driving pumps, fans or blowers is to activate the standby units, where fitted (see 6-3-4/9.7.3).

2 Safety shutdown are minimum requirements for systems where EGC-EGR Notation is not requested. See 6-3-1/13 TABLE 1.

3 Remote closure of the close coupled NaOH storage tank valves requiredby 6-3-4/11.5.7.iiiby reach rods or by electric, hydraulic or pneumatic means is acceptable.

4 As applicable in accordance with the specific EGR system design and installation.

TABLE 2
Certification of EGR Equipment and Systems at the Manufacturer's Facility
(2024)

This Table has been prepared for guidance only and annotated to agree with the *Marine Vessel Rules*. The list is not to be considered exhaustive; should additional equipment not listed be fitted on board, same will be subject to special consideration for compliance with the *Marine Vessel Rules*. This list is not to be considered as substitutive or integrative of the content of the *Marine Vessel Rules* and/or other applicable Regulations. In case of conflict between the content of this list and the applicable *Marine Vessel Rules* and other applicable regulations, the latter are to be considered applicable.

Code	*Explanation*
DR	*Design Review* – Design review required.
MS	*Manufacture Survey* – Product is to be surveyed during fabrication stages by the Surveyor.
FS	*Final Survey* – Finished product is to be subject to final hydrostatic, nondestructive, operational testing, or any other required tests, and witnessed by the Surveyor at manufacturer's facility.

Equipment	*DR*	*MS*	*FS*
EGR scrubber unit, as applicable	X	X	X
Exhaust piping	X		
Exhaust bypass, isolation or mixing valves	X		
Exhaust fans/blowers (1, 2)	X		X
Heat exchangers (3)	X		X
Water treatment system	X		X
Washwater, NaOH system and essential EGR system pumps (4)	X		X
Washwater, NaOH and EGR residue associated piping	X		
Control and safety system	X	X	X

Notes:

1. Applicable for motorsover 100 kW (135 hp) only. For motors less than 100 kW (135 hp), certification by ABS not required, acceptance based on manufacturer's documentation and guarantee (see 6-3-4/9.7.1).
2. High-speed blowers of 100 kW (135 hp) and over are to be designed, constructed, and certified in accordance with the applicable parts of Section 4-2-2 (see 6-3-4/9.1.iv).
3. For EGR coolers, see 6-3-4/9.3.
4. Applicable to pumps fitted to EGR systems connected to internal combustion engines rated at 2250 kW and above or having cylinders of more than 300 mm (11.8 in.) bore (see 6-3-4/9.1.i).

PART 6

CHAPTER 3
Exhaust Emission Abatement

SECTION 5
Exhaust Emission Monitoring Systems *(2023)*

1 General *(2024)*

This Section provides mandatory and optional requirements related to the arrangements and system design for permanently installed Exhaust Emission Monitoring Systems (EEMS) designed for the monitoring of gaseous exhaust emission constituents, primarily for compliance verification of the NO_x and SO_x emissions. These monitoring systems would, as a minimum, necessitate the measurement of the NO_x, SO_2, and CO_2 gaseous species. Additional exhaust emission measurements for the purposes of fuel efficiency verification, or other gaseous species such as HC, CO, O_2, or exhaust smoke/opacity/PM measurements, not specifically required for compliance verification, are considered optional and reviewed by ABS on a case-by-case basis.

Vessels complying fully with this section will be assigned the optional **EEMS** notation. Where this notation has not been requested, the EEMS is to be verified for compliance with the minimum requirements prescribed in 6-3-1/9.11 and6-3-1/13 TABLE 1and is to be verified by the ABS Surveyor during installation. The intent is that these requirements supplement the statutory specification, calibration, testing, and survey requirements of the applicable IMO Regulations and Guidelines. The applicable IMO requirements are detailed in the MARPOL Annex VI, as amended, and NO_x Technical Code 2008, IMO Resolution MEPC.291(71) as amended by MEPC.313(74) – *2017 Guidelines Addressing Additional Aspects to the NO_x Technical Code 2008 With Regard to Particular Requirements Related to Marine Diesel Engines Fitted With Selective Catalytic Reduction (SCR) Systems*, adopted 7 July 2017 and IMO Resolution MEPC.340(77) – *2021 Guidelines for Exhaust Gas Cleaning Systems*, adopted 26 November 2021. NO_x emissions monitoring systems are installed for the purpose of monitoring exhaust emission abatement systems or for application as an alternative onboard NO_x verification procedure in accordance with the requirements for Direct Measurement and Monitoring Systems of 6.4 and Appendix 8 of the NO_x Technical Code.

The statutory approval aspects can be reviewed and surveyed by ABS as a separate parallel process in the capacity of a Recognized Organization (RO), when authorized by the flag Administrations.

1.1 Objectives *(2024)*

1.1.1 Goals

The EEMS covered in this Section is to be designed, constructed, operated, and maintained to:

Goal No.	*Goals*
PROP 1	Provide redundancy and/or reliability to maintain propulsion.
FIR 1	*Prevent the occurrence of fire and explosion (SOLAS/Reg 2.1.1)*
ENV 6	Minimize air pollution.
SAFE 1.1	Minimize danger to persons on board the vessel, and surrounding equipment/installations from hazards associated with machinery and systems.
MGMT 1	*Provide for safe practices in ship operation and a safe working environment. (ISM Code 1.2.2.1)*
MGMT 3	*Establish procedures, plans and instruction for operations concerning the safety of the personnel, vessel, and protection of the environment (ISM Code 7)*
MGMT 5.1	Design and construct vessel, machinery, electrical, safety systems to facilitate safe access, ease of inspection, survey and maintenance.
AUTO 1	Perform its functions as intended and in a safe manner
AUTO 2	Indicate the system operational status and alter operators of any essential machinery/systems deviate from its defined design/operating conditions or intended performance.
AUTO 3	Have an alternative means to enable safe operation in the event of an emergency or failure of remote control.
AUTO 4	Provide the equivalent degree of safety and operability from a remote location as those provided by local controls.
AUTO 5	Provide a safety system that automatically leads machinery controlled to a fail-safe state in response to a fault which may endanger the persons on board, machinery/equipment or the environment.

The goals in the cross-referenced Rules/Regulations are also to be met.

1.1.2 Functional Requirements

In order to achieve the above stated goals, the design, construction, installation and maintenance of the EEMS is to be in accordance with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
Propulsion, Maneuvering, Station Keeping (PROP)	
PROP-FR1	The EEMS is not to affect the vessel's propulsion.
Fire Safety (FIR)	
FIR-FR1	Provide arrangements for the protection of hot surfaces on the exhaust emission monitoring equipment to prevent fire risks.
Protection of Environment (ENV)	
ENV-FR1	The EEMS is to be calibrated and arranged to monitor gaseous exhaust emission constituents for regulatory compliance and degree of air pollution.
Safety of Personnel (SAFE)	
SAFE-FR1	Provide safety information at locations where crew may come into contact with hazards from gaseous emissions or the EEMS.
SAFE-FR2	The exhaust emission monitoring equipment is to be arranged to protect the crew from the hot surfaces.

Functional Requirement No.	*Functional Requirements*
SAFE-FR3	The alarms of the EEMS are to be self-monitoring and have means of testing to check failures of the system.
SAFE-FR4	The EEMS is to be designed for the anticipated environmental and operating conditions.
Safety Management (MGMT)	
MGMT-FR1	Information is to be provided onboard covering the operations, safety and maintenance requirements and occupational health hazards relevant to the EEMS.
MGMT-FR2	The EEMS is to be installed in an accessible location and arranged for ease of inspection and maintenance.
MGMT-FR3	The components of the EEMS are to be to type tested to withstand fatigue and to be regularly calibrated to ensure proper operation of the EEMS.
Automation: Control, Monitoring and Safety Systems (AUTO)	
AUTO-FR1	The EEMS is to be arranged to automatically record and output data to inform the crew of the operational status of the system.
AUTO-FR2	Means are to be provided for visible and audible notifications at manned locations for abnormal conditions of the EEMS to prevent further escalation of hazards.

The functional requirements in the cross-referenced Rules/Regulations are also to be met.

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

3 Plans and Data to be Submitted *(2024)*

Plans and specifications covering the EEMS arrangements are to be submitted and are, as applicable, to include:

- General arrangement of the EEMS installation, layout,and systems
- Documentation detailing the exhaust emission monitoring equipment and associated system specifications
- Details of the exhaust emission sampling and piping systems, including details of probes, pre-filters, heated lines, air supply arrangements, pure and calibration gas lines, design pressures, temperatures, materials, and insulation
- Descriptions and schematic diagrams for the control and monitoring systems, including set points for abnormal conditions and details of the location and position at which exhaust emissions monitoring probes are to be located
- Details of all electrical equipment installed for the exhaust emission monitoring equipment and associated systems
- Schematic diagrams and operational descriptions of the exhaust emission monitoring equipment and associated systems power supply arrangements
- Electrical one line diagrams depicting type, size, and protection of electrical cables used in the EEMS control and monitoring equipment
- Operating and maintenance instruction manuals
- Testing procedures during installation and commissioning trials

5 EEMS Operation and Maintenance Manuals *(2024)*

In accordance with 6-3-1/11, detailed instruction manuals are to be provided on board, covering the operations, safety, and maintenance requirements and occupational health hazards relevant to the exhaust emission monitoring equipment and associated systems.

These manuals are to include, but are not limited to, the procedures and schedules for operation, inspection, testing, and maintenance of the EEMS together with identification of the relevant responsible parties and special instructions for the health and safety implications of handling and proximity to exhaust gases and the storage and handling of pressurized bottles of pure and calibration gases. Continued serviceability and accuracy of the monitoring system are to be maintained.

The manuals are to be submitted for reference to verify the presence of all the information required by this Section.

7 EEMS *(2024)*

7.1 General *(2024)*

i) Exhaust emissions monitoring systems are installed for the purpose of, but not limited to, verifying compliance with MARPOL Annex VI Regulations 13 and 14 for NO_x or SO_x gaseous emissions and in association with an exhaust emission abatement system.

ii) The optional **EEMS** notation for an exhaust emissions monitoring system can be assigned upon request to a vessel fitted with, or without, an exhaust emission abatement system; see 6-3-1/9.9.

7.3 Inclinations

EEMS are to be designed for proper operation at the inclination requirements of 4-1-1/7.9.

9 Exhaust Emission Monitoring Equipment *(2024)*

9.1 General *(2024)*

i) The system is to be designed taking into account the safety implications related to the handling and proximity of exhaust gases, the measurement equipment, and the storage and use of pressurized pure and calibration gases. Such implications are to be documented in the operation and maintenance manuals and suitable warning notices positioned at the sample points and measurement equipment.

ii) Permanent access platforms are to be installed to enable safe operation and maintenance of the exhaust emission monitoring equipment, as applicable.

9.3 Sample Probes for Gaseous Emissions *(2024)*

i) The gaseous sampling probes are to be positioned to enable sampling of a representative exhaust gas sample after the engine, turbocharger, or exhaust emission abatement system, in accordance with the location and temperature criteria of 5.9.3.1 and 5.9.3.2 of the NO_x Technical Code.

ii) Sample probes are to meet the design requirements of 1.2.1 of Appendix 3 of the NO_x Technical Code.

iii) A sample probe connection flange designed in accordance with Section 5 of Appendix 8 of the NO_x Technical Code and 6-3-5/9.3.i of these Rules is to be provided for each engine required to be monitored.

iv) The sample probe connection flanges are to be installed in accessible locations, clear of or protected from obstructions or moving equipment, to permit regular inspection and maintenance. In order to establish the capability of the sample probe to withstand fatigue, which is likely to occur due to vibrations under operating conditions, each sample probe design is to be vibration tested in accordance with a recognized standard, such as IEC 60068-2-6 for location on engines, as per 4-9-9/15.7 TABLE 1, Item 5, to acceleration ±10.0g.

9.5 Sample Handling *(2024)*

i) Where applicable, pre-filters and heated sample lines are preferably to be installed in accessible locations, clear of or protected from obstructions or moving equipment, in order to permit regular inspection and maintenance.

ii) Pre-filters and heated lines are to meet the design requirements of 1.2.2-5 of Appendix 3 of the NO_x Technical Code.

iii) In order to establish the capability of the pre-filters and sample lines to withstand fatigue, which is likely to occur due to vibrations under operating conditions, each design is to be vibration tested in accordance with a recognized standard, such as IEC 60068-2-6, as per 4-9-9/15.7 TABLE 1, Item 5, to acceleration ±4.0g.

iv) Hot surfaces of pre-filters or heated lines likely to make contact with the crew during operation are to be guarded or insulated. Where the surface temperatures will exceed 220°C (428°F) and where any leakage, under pressure or otherwise, of fuel oil, lubricating oil or other flammable liquid will make contact with the sampling components or exhaust pipes, these surfaces are to be insulated with non-combustible materials that are impervious to such liquids.Insulation material not impervious to oil is to be encased in sheet metal cladding or an equivalent impervious sheath.

9.7 Analyzer Specifications and Calibration

i) The EEMS gaseous analyzers are to be in accordance with the principles and specifications of Appendix 3 of the NO_x Technical Code or else demonstrated as equivalent in accordance with ISO 5725-1 and 5725-2, as permitted by 5.4.2 of the NO_x Technical Code and ISO 8178-1 Section 7, to the satisfaction of ABS.

ii) Calibration of the EEMS analyzers is to be in accordance with Appendix 4 of the NO_x Technical Code or else demonstrated as equivalent to the satisfaction of ABS.

9.9 Data Recording and Processing Device

i) The EEMS is to be capable of recording calibration and emissions monitoring data. This capability may be incorporated within the EEMS control or integrated system.

ii) The data recording device should be capable of preparing data and reports over specified time periods in a readable format capable of being downloaded and printed by the attending Surveyor.

9.11 Pneumatic Systems

i) Where applicable, details of the pneumatic arrangements used for exhaust emission monitoring systems are to be submitted and are to comply with the requirements of 4-9-2/5.7.

ii) Air supply for these systems may be taken from existing vessel infrastructure provided it does not compromise the air start supply and reserve requirements of 4-6-5/9.

11 Monitoring System

11.1 General

The control system for the exhaust emission monitoring system can be connected to an integrated control system or be a standalone system.

11.3 Monitoring System

i) The design of the monitoring system is to provide identification of faults in the equipment, as well as the process system.

ii) The system is to be of a self-monitoring type, and means of testing the alarms are to be provided.

iii) The computer-based monitoring systems are to comply with the applicable requirements of Section 4-9-3 as a Category II system based on 4-8-3/15.

iv) The electronic control equipment is to be performance tested in the presence of the Surveyor or by a recognized testing laboratory, in accordance with the criteria of 4-9-9/15.7 TABLE 1 and 4-9-9/15.7 TABLE 2.

v) The power supply arrangements for the monitoring system are to meet the requirements of 4-9-2/5.3.

Monitoring is to be in accordance with 6-3-5/13.5 TABLE 1.

13 Surveys During Construction

13.1 General

This Subsection pertains to surveys during installation and testing of EEMS units on board.

13.3 Surveys During Installation

The following surveys are to be carried out to the satisfaction of the attending Surveyor on the EEMS unit and associated systems during installation and testing:

i) Piping systems are to be visually examined and pressure-tested as required by these Rules. Pressure tests conducted on Class I piping systems (see 4-6-1/5 TABLE 1) should preferably be recorded on test charts for the duration of their tests.

ii) Electrical wiring and connections are to be in accordance with Part 4, Chapter 8 and checked for continuity and proper workmanship.

iii) Instrumentation is to be tested to confirm proper operation as per its predetermined set points.

iv) Pressure relief and safety valves installed on the unit are to be tested.

v) Control system and alarms are to be tested for proper operation.

vi) The EEMS unit is to be checked for proper operation in accordance with the ABS approved installation test procedure.

13.5 General

This Subsection pertains to surveys during installation and testing of EEMS units on board.

TABLE 1
Monitoring System Functions for EEMS Systems

Monitored Parameters (1)	*Display*	*Alarm Activated*
Analyzer/EEMS power supply	X	Failed
Pneumatic air supply, as applicable		Failed
Exhaust gas sample temperature	X	Low/High
Pre-filter and heated line temperature, as applicable	X	Low/High
Sampling flow rate, as applicable	X	Low
Data logging	X	Failed

Note:

1 As applicable.

PART 6

CHAPTER 4

Low and High Voltage Shore Connection

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PART 6

CHAPTER 4
Low and High Voltage Shore Connection

SECTION 1
General *(2023)*

1 Application *(2024)*

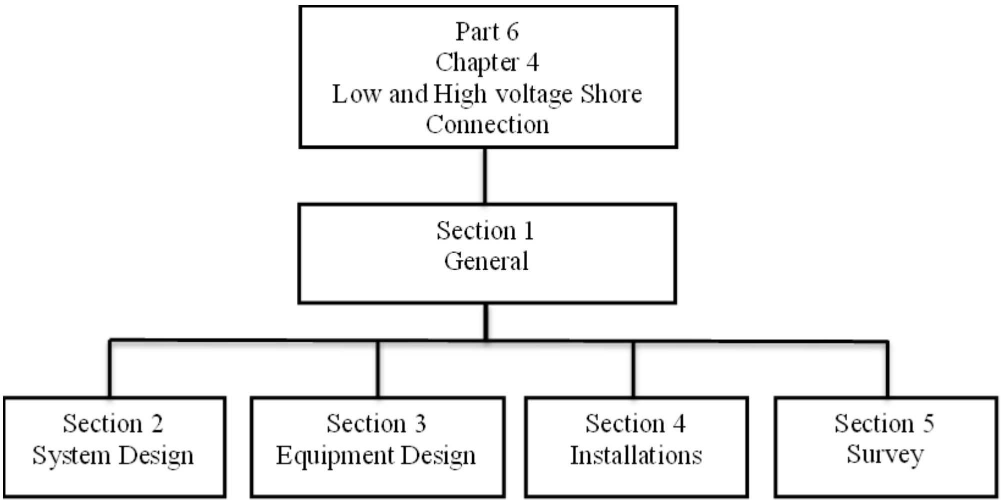
Requirements in this Chapter apply to vessels equipped with a high voltage shore connection system (HVSC) or a low voltage shore connection system (LVSC) designed to power the vessel with the shore power alone, enabling the shipboard generators to be shut down while in port. The installation of a HVSC or LVSC is optional, however if provided, it is to be designed, installed and surveyed in accordance with this Chapter, and when found satisfactory, a classification notation as specified in 6-4-1/5 will be assigned.

Note:

For voltage level definitions, see 6-4-1/9.

The requirements for shore connection system are organized as follows:

FIGURE 1
Oraganization of Shore Connection System Requirements *(2024)*



Section 6-4-1 provides general requirements, describes the notations and provides list of the required submittals and definitions for terms used throughout this chapter.

Section 6-4-2 provides requirements for system design.

Section 6-4-3 provides requirements for equipment design.

Section 6-4-4 provides requirements for shipboard installation.

Section 6-4-5provides requirements for survey.

3 Objectives *(2024)*

The goals and functional requirements for the topics covered in this chapter are included in the respective sections.

The objective of this Chapter is to provide requirements for the design, installation and survey of high voltage shore connection and low voltage shore connection installations. The requirements in this Chapter address:

i) The safety of shipboard and, where applicable, shoreside personnel during the deployment and retrieval of the cable and when making the HV or LV connection.

ii) The safety of shipboard personnel during the period in which the vessel is operating using the established HV or LV shoreside connection.

iii) The safety of the shipboard personnel should the HV or LV connection malfunction.

iv) The safety of crew on board and shoreside staff as applicable at the time of the HV or LV connection and disconnection between the vessel and the shoreside supply.

v) Requirements for the safe storage of the HV or LV equipment and associated connections when not being used.

These objectives are to be achieved by means of the system design, construction of the HV or LV equipment and operating safety procedures.

5 Classification Notation *(2024)*

A vessel with a high voltage shore connection installation which is found to be in compliance with the requirements in this Chapter as indicated in 6-4-1/TABLE 1 will be assigned the mandatory classification notation **HVSC**.

A vessel with a low voltage shore connection installation which is found to be in compliance with the requirements in this Chapter as indicated in 6-4-1/Table 2 will be assigned the classification notation **LVSC.**

A vessel that has been designed for future installation of a high voltage shore connection is eligible for the optional notation **HVSC-Ready**. To be eligible for this notation, the system and equipment do not need to be installed. The requirements are outlined in 6-4-1/TABLE 1.

A vessel that has been designed for future installation of a low voltage shore connection is eligible for the optional notation **LVSC-Ready**. To be eligible for this notation, the system and equipment do not need to be installed. The requirements are outlined in 6-4-1/Table 2.

TABLE 1
Application Section for HVSC *(2024)*

Section	HVSC *Notation*	HVSC-Ready *Notation*
6-4-1/1 - Application	YES	YES
6-4-1/3 - Objectives	YES	YES
6-4-1/5 - Classification Notation	YES	YES
6-4-1/7 - Plans and Data to be Submitted	YES	YES
6-4-1/9 - Definitions	YES	YES
6-4-1/11 - Alternative Arrangements	YES	YES
6-4-1/13 - Maintenance Plan	YES	NO
6-4-1/15 - Operation Manual	YES	NO
6-4-2 - System Design	YES	YES
6-4-3 - Equipment Design	YES	YES (1)
6-4-4 - Installations	YES	NO
6-4-5/1 through6-4-5/7 - Survey	YES	NO

Note:

1 Onboard receiving switchboard, high voltage cables to the onboard receiving switchboard do not need to be installed on board. However, the space and the routing of the cables are to be considered in the design for future installation.

TABLE 2
Application Section for LVSC *(2024)*

Section	LVSC *Notation*	LVSC-Ready *Notation*
6-4-1/1 - Application	YES	YES
6-4-1/3 - Objectives	YES	YES
6-4-1/5 - Classification Notation	YES	YES
6-4-1/7 - Plans and Data to be Submitted	YES	YES
6-4-1/9 - Definitions	YES	YES
6-4-1/11 - Alternative Arrangements	YES	YES
6-4-2 - System Design	YES	YES
6-4-3 - Equipment Design	YES	YES (1)
6-4-3/13 - Cable Management System 6-4-3/15 - Shore Connection Plugs and Receptacles 6-4-3/19 - LV Cables	YES	YES
6-4-4 - Installations 6-4-3/21 - Ship-to-shore Connection and interface equipment	YES	NO
6-4-5/3 - Shore Connection Convertor Equipment	YES	NO

Section	**LVSC** *Notation*	**LVSC-Ready** *Notation*
6-4-1/13 - Maintenance Plan	YES	NO
6-4-1/15 - Operation Manual	YES	NO
6-4-5/9 through6-4-5/13 Survey	YES	NO

Note:

1 Onboard receiving switchboard, low voltage cables to the onboard receiving switchboard do not need to be installed on board. However, the space and the routing of the cables are to be considered in the design for future installation.

7 Plans and Data to be Submitted

7.1 For HVSC *(2024)*

For the **HVSC** notation, the following plans and data are to be submitted for review:

i) One-line diagram showing shipboard elements of the HVSC

ii) Descriptions of Electrical System Grounding philosophy (See6-4-1/9 and 6-4-2/5.5)

iii) Descriptions of instrumentation, monitoring and alarms

iv) Short-circuit current calculations for each shore facility

v) Protection device coordination study for each shore facility

vi) Load analysis

vii) Capacity rating of HVSC installation, including maximum design short-circuit level

viii) Details of shore connection switchboard, including outline view, internal arrangement, dimensions, IP rating, circuit breaker rating, socket rating and schematics

ix) Details of transformer including kVA rating, impedance information and construction details

x) Cable specifications

xi) Details of portions of the ship's main switchboard that are associated with the HVSC interface

xii) Descriptions of the automatic synchronization system for the temporary generator parallel running of ship's generator and the shore power, if fitted

xiii) Descriptions of safety interlocks (See 6-4-2/21)

xiv) Details of the cable management system, if installed

xv) Equipment locations, including the routing of HV cables

xvi) Operation manual as required by 6-4-1/15

For the **HVSC-Ready** notation, plans and data as listed in6-4-1/7.1.i through6-4-1/7.1.xv above are to be submitted, as applicable.

7.3 For LVSC *(2024)*

For the **LVSC** notation, the following plans and data are to be submitted for review:

i) One-line diagram showing shipboard elements of the LVSC

ii) Descriptions of Electrical System Grounding philosophy (See 6-4-1/9 and 6-4-2/5.5)

iii) Descriptions of instrumentation, monitoring and alarms

iv) Short-circuit current calculations for each shore facility *v)* Protection device coordination study for each shore facility

vi) Load analysis

vii) Capacity rating of LVSC installation, including maximum design short-circuit level

viii) Details of shore connection switchboard, including outline view, internal arrangement, dimensions, IP rating, circuit breaker rating, socket rating and schematics

ix) Details of transformer including kVA rating, impedance information and construction details

x) Cable specifications

xi) Details of portions of the ship'smain switchboard that are associated with the LVSC interface

xii) Descriptions of the automatic synchronization system for the temporary generator parallel running of ship's generator and the shore power, if fitted

xiii) Descriptions of safety interlocks (See 6-4-2/21)

xiv) Details of the cable management system, if installed

xv) Equipment locations, including the routing of LV cables

xvi) Operation manual as required by 6-4-1/15

For the **LVSC-Ready** notation, plans and data as listed in 6-4-1/7.3.i through6-4-1/7.3.xv above are to be submitted, as applicable.

9 Definitions *(2024)*

Cable Management System: The cable management system is the ship's interface point with the shore power system. The cable management system is typically composed of flexible HV/LV cables with the plug that extends to the shore power receptacle, cable reel, automatic tension control system with associated control gears, and instrumentation. Shore power is fed to the shore connection switchboard via the cable management system.

Electrical System Grounding Philosophy: The manner in which electrical system is grounded (e.g., ungrounded system, solid neutral grounding system, low impedance neutral grounding system, or high impedance neutral grounding system), including ground potential transformer method. Circuit protection strategy is built around the selected method of system grounding in terms of over voltage prevention, over current prevention or continued operability under single phase grounded condition.

Equipotential Bonding: Provision of electric connections between conductive parts, intended to achieve equipotentiality

High Voltage (HV): For the purpose of this Chapter, the system nominal voltage is considered to be in the range from 1 kV AC to 15 kV AC.

High Voltage Shore Connection (HVSC) Installation: Those onboard systems that are designed to accept high voltage shore power, typically involving incoming power receptacles, shore connection switchboard, step-down transformer or isolation transformer, fixed high voltage power cables, incoming switchboard and associated instrumentation. HVSC is often referred to as *Cold Ironing* or *Alternative Marine Power*.

Low Voltage (LV): Low voltage in this Chapter refers to voltages up to and including 1000 V AC; and 1500 V DC.

Neutral Ground Resistor (NGR): A resistor used in earthing systems to limit maximum ground fault currents to safe levels so that all the electrical equipment in a power system is protected.

Onboard Receiving Switchboard: The receiving switchboard is normally a part of the ship's main switchboard to which the shore power is fed from the shore connection switchboard.

Shore Connection Switchboard: Where no cable management system is provided on board, the shore connection switchboard is normally the ship's interface point with the shore power system. HV/LV shore power is connected to this shore connection switchboard by means of an HV/LV plug and socket arrangement. The shore connection switchboard is provided with a shore power connecting circuit breaker with circuit protection devices.

Shore Facility: Any equipment or group of equipment arranged and installed onshore that is designed to provide power to a vessel either via high voltage connection or low voltage connection and enabling the shipboard generators to be shut down while the vessel is in port.

11 Alternative Arrangements

Alternative arrangements that differ from the specific requirements in this Chapter and that provide an equivalent level of safety may be considered on their technical merits.

13 Maintenance Plan *(2024)*

A maintenance plan is to be developed to establish periodic tests and maintenance procedures for the LVSC and HVSC system. The maintenance plan is to be included in the Operation Manual.

15 Operation Manual *(2024)*

A manual depicting operational procedures for the LV and/or HV shore connection system is to be readily available for the operating crew. The manual is to include, but not limited to, the following:

i) Operating crews' qualification requirements

ii) Shore power compatibility assessment procedures, including acceptable voltage tolerance, frequency and correct phase rotation, the shoreside source impedance for the assessment of prospective short circuit current, and the shoreside neutral grounding method for the assessment of ship's system grounding compatibility (see 6-4-2/5.5)

iii) Operational procedures to establish actions to be taken when the shore power is found not compatible with the shipboard system.

iv) Step-by-step instructions to establish shore connection and disconnection, including equipotential bonding and load transfer

v) Procedures for sending to the shore "permission to close" shoreside LVSC or HVSC circuit breaker (see 6-4-2/21.5)

vi) Emergency shutdown procedures (see 6-4-2/25)

vii) Failure recovery procedures (see 6-4-2/19)

viii) Storage requirements for the LVSC and HVSC equipment (see 6-4-4/7)

ix) LVSC and HVSC system maintenance plan (see 6-4-1/13)

The operation manual is to be readily available for operators at the operating stations.

PART 6

CHAPTER 4
Low and High Voltage Shore Connection

SECTION 2
System Design *(2023)*

1 Objective *(2024)*

1.1 Goals

The LV/HV shore connection installations covered in this section are to be designed, constructed, operated and maintained to:

Goal No.	*Goals*
POW 2	provide power to enable the machinery/equipment/electrical installation to perform its required functions necessary for the safe operation of the vessel.
SAFE 1.1	minimize danger to persons on board, the vessel, and surrounding equipment/installations from hazards associated with machinery and systems.
MGMT 2	have qualified, trained and certified seafarers/crew to maintain safe operations on board the vessel.
AUTO 1	perform its functions as intended and in a safe manner.
AUTO 2	indicate the system operational status and alert operators of any essential machinery/systems deviate from its defined design/operating conditions or intended performance.

The goals in the cross-referenced Rules are also to be met.

1.2 Functional Requirements

In order to achieve the above stated goals, the design, construction, installation and maintenance of the LV/HV shore connection installations are to be in accordance with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
Power Generation and Distribution (POW)	
POW-FR1	Provide means to check shore power compatibility to verify the possibility of connecting the vessel to the shore power supply.
POW-FR2	The shore power source is to be of sufficient capacity to support the connected loads from vessel.
POW-FR3	Provide protection against accidental overvoltage at vessel side.

Functional Requirement No.	*Functional Requirements*
POW-FR4	Provide coordination for protective devices to avoid a blackout condition.
POW-FR5	Provide means to transfer the loads safely between the vessel and the shore side.
Safety of Personnel (SAFE)	
SAFE-FR1	Provide electrical bonding arrangements between the vessel and the shore to reduce the risk of equipment damage and personnel injury.
SAFE-FR2	Provide means to detect ground fault for protection against electrical shock.
SAFE-FR3	Electrical equipment insulation is to be appropriate to system grounding method to reduce the risk of equipment damage.
SAFE-FR4	Provide remote means of operation for LV and/or HV shore connection circuit protective devices to protect the personnel from injury.
SAFE-FR5	Provide means to monitor the activation of emergency shutdown to alert the personnel of any failures.
Safety Management (MGMT)	
MGMT-FR1	Procedures are to be provided for recovery in the event of a shore power failure or emergency shutdown.
MGMT-FR2	Procedures are to be provided for the operation of LV and/or HV plug and socket outlet arrangements for safety.
Automation: Control, Monitoring and Safety Systems (AUTO)	
AUTO-FR1	Provide safety measures to protect the electrical distribution system from harmonics
AUTO-FR2	Provide protection against overload and short circuit conditions to prevent damage to equipment and cables and maintain continuity of power to remaining circuits.
AUTO-FR3	Provide means to monitor all the parameters necessary for safe operation of shore connection.

The functional requirements covered in the cross-referenced rules are also to be met.

1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

2 Shore Power Compatibility *(2024)*

Means to check shore power compatibility (e.g., correct voltage range, frequency and phase rotation) are to be provided at the location from which the LVSC and HVSC circuit breakers are controlled (e.g., at the control station in the engine control room).

3 Capacity *(2024)*

LVSC and/or HVSC installations are to be rated to supply power to the following loads:

i) Normal services required in port

ii) Emergency services

iii) Services needed to support the ship's operations in port

5 Grounding

5.1 Equipotential Bonding *(2024)*

Equipotential bonding between the ship and the shore is to be provided in accordance with IEC 80005-1/6.2.4. An interlock is provided such that the LV and/or HV shore connection cannot be established until the equipotential bonding has been established. The bonding cable can be integrated into the LV and/or HV shore power cable. If the equipotential bonding cable is intended to carry the shipboard ground fault current, the cable size is to be sufficient to carry the design maximum ground fault current.

In order to verify the integrity of the bonding in the shore connection, two different procedures are allowed:

i) Continuous monitoring of the bonding: Verification of the equipotential bonding is to be a part of the safety circuit. Loss of equipotential bonding is to result in the shutdown of the HVSC system, and the ship is to go into ship power restoration mode.

ii) Periodic testing and maintenance of the bonding connections.

Where continuous monitoring of the equipotential bonding is not in place, periodic testing and maintenance of the bonding connections are to be performed by the following procedures:

i) Physical connection points are to be inspected at a frequency not exceeding 12 months.

ii) Shore-side bonding connection resistance is to be measured at a frequency not exceeding 12 months. Results are not to exceed 1Ω.

iii) Ship-side bonding connection resistance is to be measured at a frequency not exceeding 6 months. Results are not to exceed 1Ω.

Measurement methods are vessel specific and are to be documented in Operation Manual.

5.3 Equipotential Bonding Safety Interlock *(2024)*

An interlock arrangement is to be provided such that the loss of equipotential bonding is to result in the disconnection of the LV/HV shore power. See 6-4-2/25.5.i

5.5 System Grounding Compatibility

Arrangements are to be provided so that when the shore connection is established, the resulting system grounding on board is to be compatible with the vessel's original electrical system grounding philosophy (for instance, the shipboard ungrounded power distribution system is to remain ungrounded, or the shipboard high impedance grounding system is to remain high impedance grounded within the design grounding impedance values). Ground fault detection and protection is to remain available after the shore connection has been established. Examples are shown in 6-4-2/5.7 FIGURE 1 through 6-4-2/5.7 FIGURE 4.

5.7 Voltage Rating

The voltage rating of electrical equipment insulation materials is to be appropriate to the system grounding method, taking into consideration the fact that the insulation material will be subjected to $\sqrt{3}$ times higher voltage under single phase ground fault condition.

FIGURE 1
Example for Ungrounded LV Ship's System

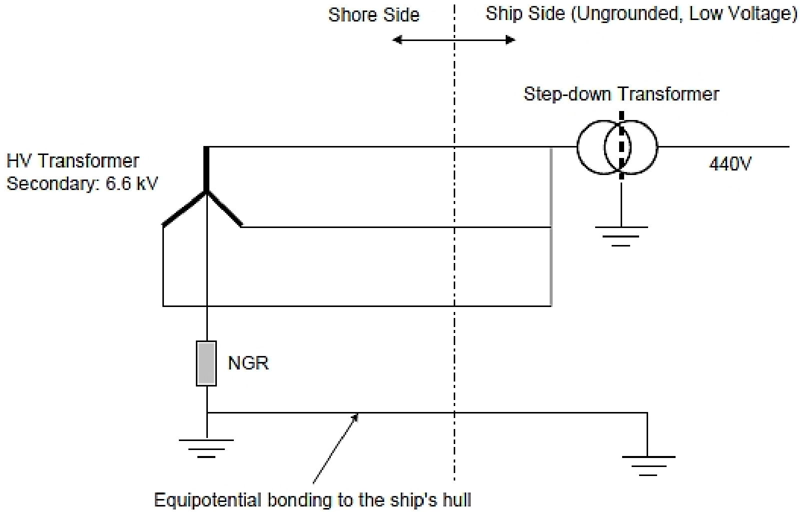


FIGURE 2
Example for Grounded HV Ship's System
(where NGR Value is Compatible with the Ship's Design Ground Current Range, Otherwise 1:1 Isolation Transformer may be Required)

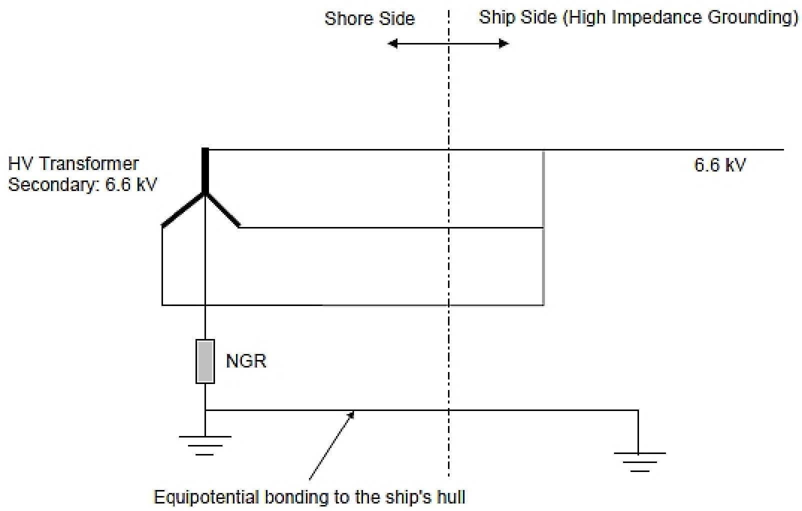


FIGURE 3
Example for Ungrounded Ship's System (e.g., Oil Carriers and Gas Carriers)

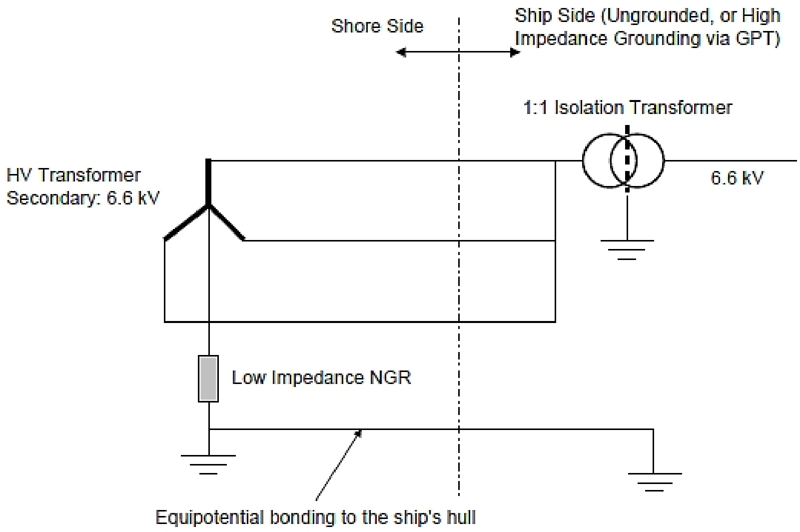
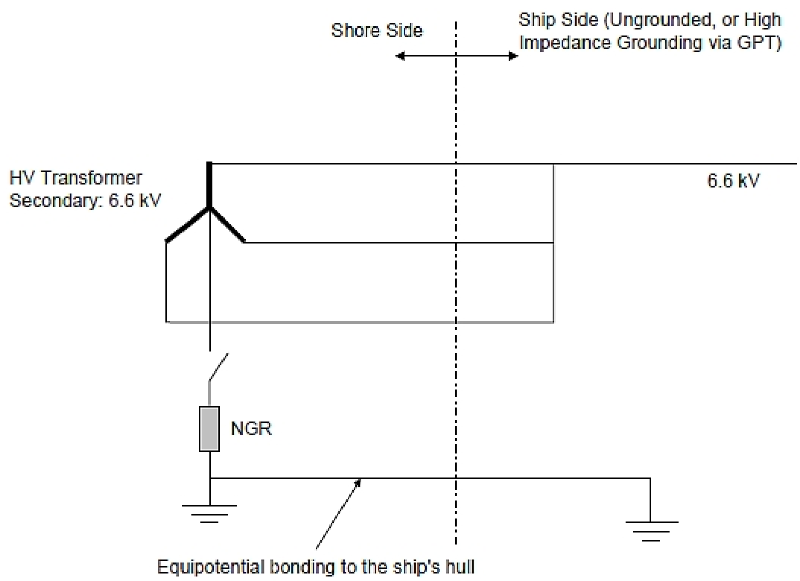


FIGURE 4
Example for Ungrounded Ship's System where Shoreside Option for Ungrounded Neutral is Available (e.g., Oil Carriers and Gas Carriers)



7 Circuit Protection *(2024)*

The LV/HV shore connection switchboard is to be provided with a circuit breaker to protect fixed equipment and cables downstream of the circuit breaker.

9 Short-circuit Level Compatibility *(2024)*

After a shore connection has been established, the prospective short-circuit current level at any point in the ship's power distribution system is not to exceed the short-circuit breaking and making capacities of circuit breakers installed on board. Operational procedures are to be established for assessment of the shoreside impedance, which determines the prospective short-circuit current level after the shore connection has been established. Procedures are to be included in the operation manual.

Commentary:

Alternatively, the prospective short-circuit current level from the HV shore distribution system may be limited by the shore-side system in accordance with IEC 80005-1/4.7.

End of Commentary

11 Overvoltage Protection

Where a step-down transformer is installed on board, the ship's low voltage system is to be protected against accidental overvoltage. This may be achieved by:

i) Direct earthing of the lower voltage system while the shore power is connected

ii) Earthed screen between the primary and the secondary windings of the transformer

13 Protective Device Coordination

The feeder circuit breaker on the main switchboard serving the shore connection is to be coordinated with the generator circuit breakers such that a short-circuit fault in the shore connection circuit will not result in a blackout condition.

15 Protection of Transformer

Transformer, where provided, is to be protected against short-circuit and overload protection in accordance with 4-8-2/9.19. The overload protection device must have time-current protection characteristics consistent with the transformer's thermal damage characteristics.

15.1 LV Shore-to-Ship Electrical Protection System *(2024)*

In addition to the requirements in 6-4-2/15 above, the following are to be taken into account for the LVSC system.

The LV shore-side circuit-breaker on the secondary side of the transformer is to be made to open all insulated poles in the event of the conditions as outlined in 6-4-1/Table 1 below:

TABLE 1
Electrical Protection System Disconnect Conditions

Systems	*Disconnect Conditions*		*A & D*
Electrical Protection System	A1	Current – high (including short-circuit)	X
	A2	Voltage – high and low	X
	A3	Reverse Power	X

Note: [A = Alarm; D = Display; X = Applies]

17 Load Transfer

17.1 Temporary Parallel Running

Where the shipboard generator is intended to run in parallel with the shore power for a short period of time for the purpose of connecting to the shore power or back to ship power without going through a blackout period, the following requirements are to be complied with:

i) Means are to be provided to verify that the incoming voltage is within the range for which the shipboard generator can be adjusted with its automatic voltage regulator (AVR)

ii) Means are to be provided for automatic synchronization

iii) Load transfer is to be automatic

iv) The duration of the temporary parallel running is to be as short as practicable allowing for the safe transfer of the load. In determining the rate of the gradual load transfer, due regard is to be paid to the governor characteristics of shipboard generator in order not to cause excessive voltage drop and frequency dip.

17.3 Load Transfer via Blackout *(2024)*

Where load transfer is executed via blackout (i.e., without temporary generator parallel running), safety interlock arrangements are to be provided so that the circuit breaker for the shore power at the shore connection switchboard cannot be closed while the LV/HV switchboard is live with running shipboard generator(s).

19 Failure Recovery Strategy

In the event of a shore power failure, the shipboard power is automatically restored to an extent that the safe operations of the ship can be maintained. Detailed procedures for the failure recovery are to be included in the operation manual.

21 Safety Interlocks *(2024)*

An interlock, which prevents plugging and unplugging of the LV/HV plug and socket outlet arrangements while they are energized, is to be provided.

21.1 Handling of LV/HV Plug *(2024)*

While the LV/HV shore connection circuit breakers are in the open position, the conductors of the LV/HV supply cables are to be automatically kept earthed by means of an earthing switch. A set of pilot contactors embedded in the LV/HV plug and socket-outlet may be used for this purpose. The earthing switch control is to be designed based on a fail-to-safe concept such that the failure of the control system will not result in the closure of the earthing switch onto the live LV/HV lines.

Note: Earthing by means of manually operated switch is permitted if the details are provided in HVSC or LVSC manual.

21.3 LV and HV Shore Connection Circuit Breakers *(2024)*

Arrangements are to be provided to prevent the closing of the shore connection circuit breaker when any of the following conditions exist:

i) Equipotential bonding is not established

ii) The pilot contact circuit is not established

iii) Emergency shutdown facilities are activated

iv) An error within the LV or HV connection system that could pose an unacceptable risk to the safe supply of shoreside power to the vessel. These errors may occur within the alarm system, whether on board the ship or at the shoreside control position, or within any relevant safety systems including those which monitor system performance.

v) The LV or HV supply is not present

21.5 Closing of Shoreside HVSC Circuit Breaker *(2024)*

Arrangements are to be provided such that the shoreside LVSC or HVSC circuit breaker can be closed after the ship side sends a "permission to close" signal to the shore. Such arrangements may be based on an interlock or visual signal.

23 LVSC and HVSC Circuit Breaker Control *(2024)*

LV or HV shore connection circuit breakers are to be remotely operated away from the LVSC or HVSC equipment. Operational procedures are to be established that state that the attempts to close LV or HV shore connection circuit breakers are to be made only when it has been established that personnel are evacuated from the LV or HV shore connection equipment compartments. The operation manual is to describe these established procedures.

25 LVSC and HVSC Emergency Shutdown *(2024)*

25.1 *(2024)*

In the event of an emergency, the LV and/or HV system is to be provided with means to immediately open the shore connection circuit breaker. These emergency shutdown systems are to be automatically activated.

25.3 *(2024)*

Any of the following conditions are to cause emergency shutdown of the shore power supply:

i) Loss of equipotential bonding

ii) High tension level of LV or HV flexible shore connection cable, or low remaining cable length of cable management system

iii) Shore connection safety circuits fail

iv) The emergency stop button is used (see 6-4-2/25.5)

v) Any attempts to disengage the LV or HV plug while live (this may be achieved by the pilot contactors embedded in the plug and socket such that the pilot contactors disengage before the phase contactors can disengage)

25.5 *(2024)*

Emergency stop buttons that initiate emergency shutdown systems are to be provided:

i) At the remote location from which the LVSC or HVSC circuit breakers are controlled (see 6-4-2/23)

ii) At the shipboard control center for management of the cable and connection and at additional control locations, as applicable and deemed necessary

iii) At the shore connection switchboard

Emergency stop buttons are to be clearly marked so that their method of operation is visible, legible and easily followed. Positioning of the emergency stop buttons and attendant operational instructions should be such as to prevent accidental or inadvertent operation. Once activated, the emergency stop button should require manual action to reset.

Activation of the emergency stop button is to result in a clearly visible visual warning and easily recognizable audible alarm.

25.7

Following the emergency shutdown, the ship's electrical power is to be automatically restored. See 6-4-2/19.

27 Harmonics

Where power converter equipment is provided within the shore connection system in order to obtain desired voltage and/or frequency, the total voltage harmonic distortion of the converter is not to exceed 5 percent at any operating load.

29 Monitoring and Alarm Systems *(2024)*

The following monitoring and alarm systems are to be provided at the location from which the LVSC or HVSC circuit breakers are controlled, and at other strategic locations that are normally manned if deemed necessary:

i) Overtension alarm on LV or HV flexible shore connection cables, or cable management system over-deployment (low remaining cable length) alarm, prior to the emergency shutdown [see 6-4-2/25.3.ii]

ii) The loss of shore power

iii) Emergency shutdown

iv) Manual emergency-stop

v) Safety device activation alarms (e.g., overcurrent, earth fault)

PART 6

CHAPTER 4

Low and High Voltage Shore Connection

SECTION 3

Equipment Design *(2023)*

1 Objectives *(2024)*

1.1 Goals

The LV/HV shore connection installations covered in this section are to be designed, constructed, operated and maintained to:

Goal No.	*Goals*
POW 2	Provide safe and reliable storage and supply of fuel/energy/power.
SAFE 1.1	Minimize danger to persons on board, the vessel, and surrounding equipment/installations from hazards associated with machinery and systems.
MGMT 2	Have qualified, trained and certified seafarers/crew to maintain safe operations on board the vessel.
MGMT 5.1	Design and construct vessel, machinery, and electrical systems to facilitate safe access, ease of inspection, survey, and maintenance.
AUTO 1	Perform its functions as intended and in a safe manner.
AUTO 2	Indicate the system operational status and alert operators of any essential machinery/systems deviate from its defined design/operating conditions or intended performance.

Materials are to be suitable for the intended application in accordance with the following goals and support the Tier 1 goals as listed above.

Goal No.	*Goal*
MAT 1	The selected materials' physical, mechanical, and chemical properties are to meet the design requirements appropriate for the application, operating conditions, and environment.

The goals in the cross-referenced Rules are also to be met.

1.2 Functional Requirements

In order to achieve the above stated goals, the design, construction, installation and maintenance of the LV/HV shore connection installations are to be in accordance with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
Power Generation and Distribution (POW)	
POW-FR1	Provide means to check shore power compatibility to verify the possibility of connecting the vessel to the shore power supply.
POW-FR2	The shore power source is to be of sufficient capacity to support the connected loads from vessel.
POW-FR3	All the electrical components used in connecting the shore power supply to the ship distribution system are to be suitable for the marine environment and rated adequately to support the connected loads.
Safety of Personnel (SAFE)	
SAFE-FR1	Provide enclosure with suitable degree of protection against ingress of foreign objects and liquids based on the location of installation
SAFE-FR2	Provide protection to prevent accidental contact with live parts of the assembly
SAFE-FR3	Provide remote means of operation for HV shore connection circuit protection devices to protect the personnel from injury.
SAFE-FR4	Provide suitable degree of protection against liquids based on location of installation.
SAFE-FR5	Provide measures to prevent hazards and injuries due to high voltage cable penetrations in the accommodation spaces.
SAFE-FR6	Provide means of effective electrical bonding to earth for safe operation of high voltage cables.
SAFE-FR7	Provide suitable marking for high voltage cables, equipment and spaces containing them for easy identification of danger.
Materials (MAT)	
MAT-FR1	Durable, flame-retardant and moisture resistant materials are to be used in the construction so as to withstand the marine environment and maximum ambient temperature without any deterioration.
Safety Management (MGMT)	
MGMT-FR1	Procedures are to be provided for the operation of LV/HV plug and socket outlet arrangements for safety.
MGMT-FR2	Suitable locations and arrangements are to be provided to LV/HV shore connection equipment for safe access for operation, inspection, and maintenance.
Automation: Control, Monitoring and Safety Systems (AUTO)	
AUTO-FR1	Provide means to prevent moisture condensation in the machine when idle
AUTO-FR2	Provide protection against undervoltage and short circuit conditions to prevent damage to equipment and maintain continuity of power to remaining circuits.
AUTO-FR3	Provide instrumentation to monitor and control the shore connection
AUTO-FR4	The circuit protection devices are to be able to withstand the prospective short circuit current values at the point of installation
AUTO-FR5	Provide means to manage cable movements without causing undue stress during shore connection.
AUTO-FR6	Provide protection for the connection cables to maintain continuity of shore power supply.
AUTO-FR7	Provide means to manage cable movements without causing undue stress during shore connection.

The function requirements covered in the cross-referenced rules are also to be met.

1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

2 General *(2024)*

Electrical equipment is to be constructed of durable, flame-retardant, moisture-resistant material, which are not subject to deterioration in the marine environment and at the temperatures to which it is likely to be exposed. The determination of equipment protection class (IP rating) is to be in accordance with4-8-3/15 TABLE 2 for LVSC and4-8-5/3 TABLE 1for HVSC.

3 Protection Against Moisture and Condensation

Means are to be provided to prevent accumulation of moisture and condensation.

5 Air Clearance *(2024)*

Phase-to-phase air clearances and phase-to-earth air clearances between non-insulated parts are to be not less than the minimum, as specified in4-8-3/5.3.2(f) for LVSC and4-8-5/3.7.1(a)Table 1 for HVSC.

Where intermediate values of nominal voltages are accepted, the next highest air clearance is to be observed.

7 Creepage Distance

Creepage distances between live parts and between live parts and earthed metal parts are to be adequate for the nominal voltage of the system, due regard being paid to the comparative tracking index of insulating materials under moist conditions according to the IEC Publication 60112 and to the transient overvoltage developed by switching and fault conditions.

9 Shore Connection Switchboard

9.1 Construction *(2024)*

The shore connection switchboard is to be designed, manufactured and tested in accordance with a recognized standard such as IEC 62271-200 for the HVSC and IEC 61439 for LVSC.

9.3 Circuit Breaker *(2024)*

i) Shore connection HV circuit breaker is to be equipped with under voltage protection (UVP)

ii) The rated short-circuit making capacity of the circuit breaker is not to be less than the prospective peak value of the short-circuit current

iii) The rated short-circuit breaking capacity of the circuit breaker is not to be less than the maximum prospective symmetrical short-circuit current

iv) HV shore connection circuit breaker is to be remotely operated

11 Onboard Receiving Switchboard

11.1 Construction *(2024)*

The onboard receiving switchboard is to be designed, manufactured and tested in accordance with a recognized standard such as IEC 62271-200 for HVSC and IEC 61439 for LVSC.

11.3 Instrumentation

The receiving switchboard is to be equipped with:

i) Voltmeter(s), all three phases, for the shore power and the shipboard power

ii) Phase rotation indicator for the shore power

iii) Frequency meter(s) for the shore power and the shipboard power

iv) Ammeter for the shore power, all three phases

v) Synchronizing device, see 6-4-2/17.1

vi) Short-circuit protection

vii) Overcurrent protection

viii) viii. Earth-fault detection

11.5 Circuit Breaker *(2024)*

i) The rated short-circuit making capacity of the circuit breaker is not to be less than the prospective peak value of the short-circuit current

ii) The rated short-circuit breaking capacity of the circuit breaker is not to be less than the maximum prospective symmetrical short-circuit current

iii) HV shore connection circuit breaker is to be remotely operated

iv) Motor-operated circuit breaker is to be provided for LV shore connection

13 Cable Management System *(2024)*

The cable management system is to allow extending cable and retracting cable without causing undue stress to the cable. The slip ring, where provided, is to be tested in accordance with 6-4-5/5. where cable management system is provided, the cable management system is to be installed according to the following requirements:

i) Be located according to the ship annexes

ii) Be capable of moving the ship-to-shore connection cable, enabling the cable to reach between the socket-outlet and the ship inlet

iii) Be capable of maintaining an optimum length of cable which minimizes slack cable, and prevents the tension limits from being exceeded

iv) Be equipped with a device (e.g., limit switches), independent of its control system to monitor maximum cable tension and maximum cable pay-out

v) Address the risk of submersion by prevention or by the equipment design

vi) Be positioned to prevent interference with ship berthing and mooring systems, including the systems of ships that do not connect to shore power while berthed at the facility

vii) Maintain the bending radius of cables above the minimum bending radius recommended by the manufacturer during deployment, in steady state operation and when stowed.

viii) Be capable of supporting the cables over the entire range of ship draughts and tidal ranges

ix) Be capable of retrieving and stowing the cables once operations are complete

Note:

Where the cable management system employs cable reel(s), the LVSC system rated power is to be based on the operating condition with the maximum number of wraps of cable stowed on the reel that is encountered during normal operations. Where applicable, the cable sizing is to include appropriate de-rating factors. Also, for low voltage cable management, see 4-8-2/7.7.

15 Shore Connection Plugs and Receptacle

15.1 High Voltage Plugs and Receptacles *(2024)*

i) Interlock between the plug and the shore connection circuit breaker is to be provided such that the plug can be disengaged only after the shore connection circuit breaker has been opened. This can achieved by the construction of a plug and socket. An example is shown in 6-4-3/19.1 FIGURE 1.

ii) Plugs and sockets are to be protected from dust, moisture and condensation while not in use. The minimum protection rating of plugs and sockets is to be IP66. An example of the socket is shown in 6-4-3/19.1 FIGURE 1.

15.3 Low Voltage Plugs and Receptacles *(2024)*

The plug, socket-outlet, ship connector and ship inlet is to be in accordance with IEC 60309-1 and IEC 60309-5.

17 Transformer *(2024)*

Where provided, transformers are to comply with the requirements of 4-8-5/3.7.5for HVSC and 4-8-3/7 for LVSC.

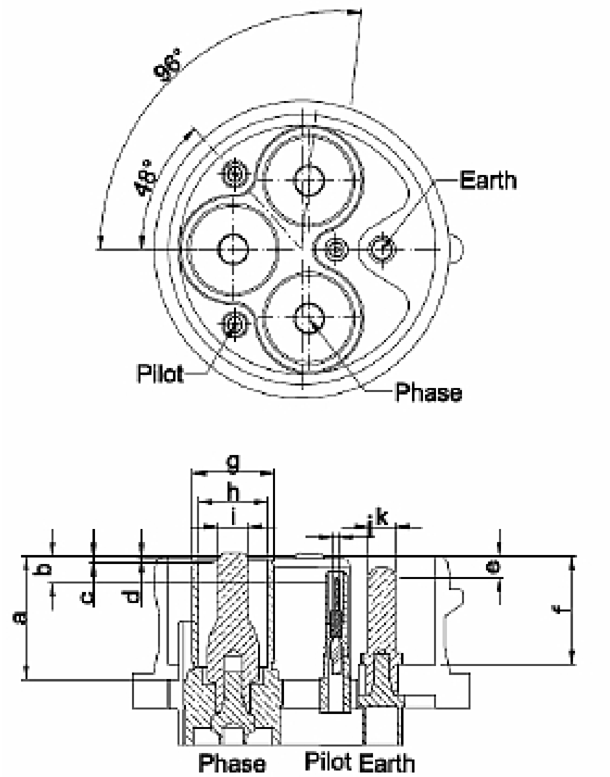
For the determination of the continuous rating of the transformer, the level of harmonics current is to be taken into consideration.

19 LV and HV Cables *(2024)*

19.1 HV Cables *(2024)*

Shipboard fixed HV cables are to be in compliance with IEC 60092-353, 60092-354 or other relevant standards acceptable to ABS. Non-fixed HV cables are to be constructed and tested to recognized standard acceptable to ABS.

FIGURE 1
Example of Plug and Socket, interlock by Pilot Contactor
(The pilot contactor disengages before the phase conductors disengage)



Symbol	Name	Dimension
a	Insulator depth	64
b	Contact pilot	13,8
c	Contact phase	3,4
d	Top insulator	1,4
e	Contact earth	11,1
f	Tounge depth	56
g	Insulator outside Ø	42,5
h	Insulator inside Ø	36,5
i	Phase Ø	16
j	Pilot Ø	3
k	Earth Ø	14
l	Partition phases Ø	72
m	Partition pilots Ø	84
n	Partition earth Ø	105
o	Insulator Ø	119,6
p	Plug inside Ø	140
q	Plug outside Ø	154,5
r	Plug outside + nose	162
s	Partition pilot Ø	36

Note: Image courtesy of CAVOTEC.

19.3 LV Cables *(2024)*

Fixed shipboard LV cables are to comply with 4-8-3/9 and 4-8-4/21.

21 Shore Connection Convertor Equipment *(2024)*

Where provided, converting equipment (transformers, rotating frequency convertors and/or semiconductor convertors) for connecting LV shore supplies to a ship electrical distribution system are to be in accordance with 4-8-3/8.5.

23 Ship-to-shore Connection and Interface Equipment *(2024)*

Where provided, ship-to-shore connection and interface equipment that include standardized LVSC systems, cables, earthing and communications between the ship and shore.

Physical compatibility between ship and shore is to be assumed to be as follows:

i) Ships have the necessary number of inlets according to their maximal power demand while connected to LVSC system

ii) Shore systems have the necessary number of socket-outlets according to the maximal power that can be supplied.

23.1 Main Shore Connection Circuit Breaker

A main shore connection circuit breaker is to be provided on board.

23.3 Ship-to-Shore Connection Cable Installation

Ship-to-shore connection cable installation is to be arranged to provide adequate movement compensation, cable guidance and anchoring/positioning of the cable during normal planned ship-to-shore connection and operating conditions.

23.5 Ship Connector

A ship-side of the connection cable is to be fitted with a ship connector, if a ship inlet will be used on board. Ship-to-shore connection cable extensions are not permitted.

PART 6

CHAPTER 4

Low and High Voltage Shore Connection

SECTION 4

Installations *(2023)*

1 Objectives *(2024)*

1.1 Goals

The LV/HV shore connection installations covered in this section are to be designed, constructed, operated and maintained to:

Goal No.	*Goals*
POW 1	Provide safe and reliable storage and supply of fuel/energy/power.
SAFE 1.1	Minimize danger to persons on board, the vessel, and surrounding equipment/installations from hazards associated with machinery and systems.
MGMT 5.1	Indicate the system operational status and alert operators of any essential machinery/systems deviate from its defined design/operating conditions or intended performance.

The goals in the cross-referenced Rules are also to be met.

1.2 Functional Requirements

In order to achieve the above stated goals, the design, construction, installation and maintenance of the LV/HV shore connection installations are to be in accordance with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
Power Generation and Distribution (POW)	
POW-FR1	Provide safe and reliable storage of removable LVSC/HVSC equipment against physical damage.
Safety of Personnel (SAFE)	
SAFE-FR1	Provide segregation for high voltage equipment and cables to avoid potential electric hazard and injuries
SAFE-FR2	Provide measures to prevent hazards and injuries due to high voltage cable penetrations in the accommodation spaces.
SAFE-FR3	Provide means of effective electrical bonding to earth for safe operation of high voltage cables

Functional Requirement No.	*Functional Requirements*
SAFE-FR4	Provide suitable marking for high voltage cables, equipment and spaces containing them for easy identification of danger
Safety Management (MGMT)	
MGMT-FR1	Suitable locations and arrangements are to be provided to LV/HV shore connection equipment for safe access for operation, inspection, and maintenance.

The functional requirements covered in the cross-referenced rules are also to be met.

1.3 Compliance

A vessel is considered to comply with the goals and functional requirements within the scope of classification when the prescriptive requirements are complied with or when an alternative arrangement has been approved. Refer to Part 1D, Chapter 2.

2 Equipment Locations *(2024)*

i) Access to the LVSC and/or HVSC equipment is to be subject to appropriate controls.

ii) The shore connection switchboard is to be located in a compartment that is sheltered from the weather. LV and/or HV shore cables are to enter this compartment through a temporary opening with weathertight arrangements.

iii) This compartment is not to have any opening(s) within a designated hazardous area.

iv) Ample space around the shore connection switchboard is to be available for the operating crew to freely perform connecting and disconnecting operations.

3 Voltage Segregation

Higher voltage equipment is not to be combined with low voltage equipment in the same enclosure, unless segregation or other suitable measures are taken to provide safe access to lower voltage equipment.

5 HV Cable Installation

5.1 Runs of Cables

In accommodation spaces, high voltage cables are to be run in enclosed cable transit systems.

5.3 Segregation

High voltage cables are not to be installed on the same cable tray for the cables operating at the nominal system voltage of 1 kV or less.

5.5 Installation Arrangements

High voltage cables are to be installed on cable trays or equivalent when they are provided with a continuous metallic sheath or armor which is effectively bonded to earth; otherwise, they are to be installed for their entire length in metallic casings effectively bonded to earth.

5.7 Marking

High voltage cables are to be readily identifiable by suitable marking.

7 LV Cable Installation *(2024)*

LV cable installations are to comply with 4-8-4/21.

9 Storage *(2024)*

Appropriate arrangements are to be provided for storage of removable LVSC and HVSC equipment when not in use. Such storage should take into account issues such as, but not restricted to, temperature, humidity, moisture, condensation, dirt, and dust, and should protect against the likelihood of physical damage to the cable, plugs, sockets, and associated equipment.

PART 6

CHAPTER 4
Low and High Voltage Shore Connection

SECTION 5
Survey *(2024)*

1 HV Switchboard

1.1 Type Test

HV switchboards are to be subjected to an AC withstand voltage test in accordance with 4-8-5/3.13.2 or other relevant national or international standards. A test is to be carried out at the manufacturer's test facility in the presence of the Surveyor.

1.3 Onboard Test

After installation on board, the HV switchboard is to be subjected to an insulation resistance test in accordance with 4-8-5/3.13.1 and 4-8-5/3.13.3 in the presence of the Surveyor.

3 HV Transformer

A transformer is to be tested in accordance with 4-8-5/3.7.5(e). A transformer rated100 kVA and above is to be tested in the presence of Surveyor.

5 HV Cable Reel Slip Ring

5.1 Type Test

A slip ring is to be subjected to an AC withstand voltage test in accordance with 6-4-5/1.1 or other relevant national or international standards. The test is to be carried out at the manufacturer's test facility in the presence of the Surveyor.

5.3 Onboard Test

After installation on board, the HV switchboard is to be subjected to an insulation resistance test in accordance with 6-4-5/1.3.

7 Cable Test After Installation

A voltage withstand test is to be carried out in accordance with 4-8-5/3.13.3 in the presence of the Surveyor.

9 LV Switchboard *(2024)*

9.1 Type Tests

LV switchboards are to be subjected to an AC withstand voltage test in accordance with 4-8-3/5.11.1 or other relevant national or international standards. A test is to be carried out at the manufacturer's test facility in the presence of the Surveyor.

9.3 Onboard Test

After installation on board, the LV switchboard is to be subjected to an insulation resistance test in accordance with 4-8-3/5.11.2 in the presence of the Surveyor.

11 LV Transformer *(2024)*

A transformer is to be tested in accordance with 4-8-3/7.3.5. A transformer rated 100 kVA and above is to be tested in the presence of the Surveyor.

13 LV Cable Slip Ring *(2024)*

13.1 Type Tests

A slip ring is to be subjected to an AC withstand voltage test in accordance with 6-4-5/9.1 above or other relevant national or international standards. The test is to be carried out at the manufacturer's test facility in the presence of the Surveyor.

13.3 Onboard Test

After installation on board, the LV cable slip rings are to be subjected to an insulation resistance test in accordance with 6-4-5/9.3.

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PART 6

CHAPTER 5
Alternative Fuels

SECTION 1
Biofuel *(2024)*

1 General

This section provides guidance and requirements for the utilization of biofuel or biofuel blends as fuel in the combustion units for propulsion and auxiliary systems on board and focuses on the arrangements for the safe use of these fuels.

The requirements specified in these Rules are additional to all other relevant requirements of ABS Rules, Requirements and Guides. The new interim guidance, MEPC.1/Circ.905 *Interim Guidance on the Use of Biofuels under Regulations 26, 27, and 28 of MARPOL Annex VI (DCS and CII),* is also applicable.

2 Scope and Application

Vessels designed, constructed, and operated in compliance with the requirements of this section that burn biofuel blends with up to and including 30% biofuel by volume may be assigned **Biofuel-1** notation.

Vessels designed, constructed, and operated in compliance with the requirements of this section that burn biofuel blends with greater than 30% by volume of biofuel may be assigned **Biofuel-2** notation.

3 Notations

Upon Owner's request, the optional notation **Biofuel-1** or **Biofuel-2** may be granted once the vessel has complied with the requirements of this document, as applicable. See 6-5-1/3 Table 1 below.

Biofuel-1 may be assigned to vessels which use a biofuel blend of up to and including 30% biofuel in compliance with IMO requirements and with subsection 6-5-1/5.i.

Biofuel-2 may be assigned to vessels which use a biofuel blend of greater than 30% biofuel in compliance with IMO requirements and with subsection6-5-1/5.i and 6-5-1/5.ii-6-5-1/5.iv A re-evaluation of emissions may be required if the vessel requires significant changes to its critical NOx technical components to burn biofuels, as per MARPOL Annex VI 18.3.2.2.

All requirements of this Section of the Rules, except those under 6-5-1/5.ii, 6-5-1/5.iii, 6-5-1/5.iv are mandatory even if the optional notations are not selected.

Compliance with applicable requirements of the Marine Vessel Rules and MEPC.1/Circ.795 Rev.8 this section, as applicable, are required, even if the optional notations are not requested.

Table 1

Notation	*Change in NOx Critical Components?*	*Relevant Sections*	*Relevant Interpretations of MEPC.1/Circ.795 Rev.8*
Biofuel-1	No	6-5-1/5.i, 6-5-1/7.1.1, 6-5-1/7.1.2.i	Interpretation 13.1
Biofuel-2	No	6-5-1/5.i through 6-5-1/5.iv, 6-5-1/7.1.1,6-5-1/7.1.2.ii	Interpretation 13.2
	Yes	6-5-1/5.i through 6-5-1/5.iv, 6-5-1/7.1.1, 6-5-1/7.1.2.iii.	Interpretation 13.3

4 Definitions

The definitions provided below are taken from IMO MEPC.1 Circ.795 Revision 8 - Unified Interpretations to MARPOL Annex VI.

Biofuel – a fuel oil derived from biomass.

Commentary:

Fuel oils originating from biomass may include, but are not limited to, fatty acid methyl ester (FAME), biomass to liquid (BTL) fuels, glycerol, straight vegetable oils (SVO), hydrotreated vegetable oil (HVO), hydrotreated renewable diesel, Fischer-Tropsch (FT) diesel, dimethyl ether (DME), bio-methanol, and hydrogenation derived renewable diesel (HDRD).

Biodiesel is a type of biofuel.

End of Commentary

BiofuelBlend- A blend of biofuel with petroleum fuels and is typically expressed as BXXX by the industry. B20 fuel is 20% biofuel and 80% petroleum fuel. B100 is 100% biofuel.

5 Documentation to be Submitted

The following plans, data, and documentation are to be submitted for review, as applicable. The following symbols are used in this Section for the type of review of the documents:

R: Documents to be reviewed.

I: Documentation for information and verification for consistency with related review.

OB: Documents to be furnished on board the vessel.

i) Documentation such as certification, no objection letter, confirmation, or statement of fact from the OEM of the combustion unit (ref. 6-5-1/7.1 below) is to be submitted specifying: (**I, OB**)

a) Type of biofuel(s) intended to be used.

b) The blend ratio(s) and type(s) of blend(s) intended to be used, as well as the specification of the fossil fuel included in the blend(s). The flash point of the fuel blend to be used in combustion is to be provided.

c) The list of approved combustion units and their main destination (auxiliary or propulsion).

d) Any operational limitations, requirements for application, and any additional required maintenance.

ii) Fuel changeover procedures or guidance plans, if necessary (**R, OB**).

iii) Risk Assessment Report as referenced in section 6 (**R, OB**).

iv) Operations and maintenance manuals, including specific biofuel handling procedures (**R, OB**).

v) In-service Inspection Plan including any conditions/limitations and proposed shipboard suitability testing (**R,OB**).

Upon review and approval of the submitted information, ABS issues a review letter of acceptance for Classification purposes and, if applicable, any conditions or limitations of the acceptance.

6 Risk Assessment

A risk assessment is to be conducted to address the additional risks arising from the use of biofuels and biofuel blends. Risks are to be analyzed using acceptable and recognized risk analysis techniques. Risks which cannot be eliminated are to be mitigated to an acceptable level of safety. The risk assessment is to consider, but is not limited to, the following:

i) Fuel characteristics, including viscosity, lubricity, and oxygen levels

ii) Fuel storage degradation induced by temperature, microbials, etc.

iii) Details of the arrangement and material of fuel piping, pipe fittings, and filters appropriate for the specified biofuel or biofuel blend.

iv) Potential and risk of fuel contaminants and degeneration

v) Potential and risk of blockages due to fuel degradation

vi) Bunkering arrangement and systems

vii) Operations, maintenance, and emergency procedures related to the use and storage of biofuels, including fuel sampling procedures.

viii) Engine emissions performance related to NOx emissions compliance by Regulation 13 of MARPOL Annex VI.

7 System Arrangements

All vessel equipment and systems involved in the storage, bunkering, transfer, combustion and delivery of biofuels or biofuel blends are to be designed, operated, and maintained in accordance with the requirements below, as applicable to the use of biofuel or biofuel blend.

Commentary:

Biofuels used in long-term applications and blends with high percentage of biofuels can cause issues that need to be considered. Corrosion of materials due to fuel acidity can affect rubber, copper, brass, lead, tin, and zinc components, including gaskets, rubber hoses, filters, and fuel injectors. Material selection for such components should be considered for the compatibility of the material with the specific fuel or fuel blend used. Biofuel degeneration can also occur when water containing microbials is present in the fuel. Residue from such deterioration may affect filter performance; regular maintenance and cleaning of tanks and filters may be necessary to mitigate these problems. Degeneration may be mitigated by removing water from fuel tanks or with compatible anti-microbial fuel additives. Filters should be maintained when switching from diesel to biofuel, as deposits in the fuel systems can cause clogging. These issues should be addressed in the vessel's operation manual.

End of Commentary

7.1 Combustion Units

7.1.1

This section applies to combustion units as per Part 4.

7.1.2

Engines are to meet the requirements of MARPOL Annex VI:

i) Engines using a biofuel blend of up to and including 30 percent by volume of biofuel are to be certified in accordance with the requirements of MARPOL Annex VI Regulation 13.

ii) Engines using a biofuel blend of more than 30 percent by volume of biofuel that can burn biofuels or biofuel blends without changes to NOx critical components or settings are to meet the requirements of Regulation 18.3.2 of MARPOL Annex VI. An assessment of NOx impacts is not required per 13.2 of Unified Interpretation of the MEPC.1 Circ. 795 Rev 8.

iii) Engines using a biofuel blend of more than 30 percent by volume of biofuel that require changes to critical NOx components or settings to burn biofuels and biofuel blends are to be re-tested to demonstrate compliance with MARPOL Annex VI Regulation 13. The emissions are to be quantified based on Chapter 6 of the NOx Technical Code 2008. For demonstration of compliance with 13.3 of the Unified Interpretation of the MEPC.1 Circ.795 Rev 8 and Regulation 18.3.2.2 of MARPOL Annex VI, and as applicable to possible deviations when undertaking measurements on board, an allowance of 10% of the applicable limit is acceptable.

7.2 Storage Systems

The design, construction and testing of fuel oil tanks are to follow the specifications of Sections 3-2-18 and 4-6-4/13.5, specifically protection from corrosion listed in 3-2-18/5.7 as applicable to the specified biofuel or biofuel blend in use.

7.3 Piping Systems

Fuel oil systems involving biofuels are to be designed in accordance with Sections 4-6-4 and 4-6-5 as applicable.

8 Surveys

8.1 Survey During Construction

8.1.1

The various fuel storage, bunkering, supply systems and equipment are to be examined and verified per applicable requirements in Part 4 of the MVR.

8.1.2

The biofuel system installation is to be tested as indicated in the ABS review letter for shipboard suitability to the satisfaction of the attending surveyor.

8.2 Survey after Installation

8.2.1

In addition, the following are to be verified onboard to the satisfaction of the attending surveyor per subsection 5, "Documentation to be submitted":

i) Certification, no objection letter, confirmation, or statement of fact from the OEM specifying:

a) Type of biofuel(s) intended to be used.

b) The blend ratio(s) and type(s) of blend(s) intended to be used, as well as the specification of the fossil fuel included in the blend(s). The flash point of the fuel blend to be used in combustion is to be provided.

c) The list of approved combustion units and their main destination (auxiliary or propulsion).

d) Any operational limitations, requirements for application, and any additional required maintenance.

ii) Fuel changeover procedures or guidance plans, if necessary.

iii) Any information or documentation requested by the Flag Administration.

iv) Operations and maintenance manuals, including specific biofuel handling procedures.

9 References

The following international standards, guidelines, and recommendations were considered in developing this Notation:

IMO Convention, Resolutions and other Regulations

- IMO *MARPOL 73/78 Annex VI – Regulations for the prevention of air pollution from ships*
- IMO *MEPC.1 Circular 795 Revision 8 – Unified Interpretations to MARPOL Annex VI*
- ISO *Fuel Quality Standard 8216-99:2002*
- ISO *Fuel Quality Standard 8217:2017*
- ASTM *D6751-23a, Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels*
- NOx Technical Code 2008-*Technical Code on Control of Emission of Nitrogen Oxides from Marine Diesel Engines*
- IMO MEPC.1 *Circular 905 – Interim Guidance on the Use of Biofuels under Regulations 26, 27, and 28 of MARPOL Annex VI (DCS and CII).*

PART 6

CHAPTER 6
Ballast Water Treatment

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PART 6

CHAPTER 6
Ballast Water Treatment

SECTION 1
General *(1 July 2024)*

1 Application

The requirements in this Chapter apply to vessels that are designed, equipped and intended to use the treatment method for conducting ballast water management in accordance with Regulation B-3 (as amended) of the "*International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004*" (Convention), the associated International Maritime Organization (IMO) guidelines and national regulations, addressing the use of a ballast water management system. At the request of the owner, a vessel having a ballast water management system (BWMS) installed for conducting ballast water management approved by ABS (see 6-6-1/7.7) and which fully complies with the requirements of this Chapter and the applicable Rules and has been installed under survey by ABS Surveyors, the optional **BWT** or the **BWT+** notation as specified 6-6-1/7.1 and 7.2 may be assigned.

Where a vessel is fitted with a BWMS and the optional **BWT** or **BWT+** notation is not requested, the system is to comply with the minimum requirements prescribed under 6-6-1/7.5 and 6-6-1/Table 1, and is to be verified by the ABS Surveyor during installation.

This Chapter refers to relevant international regulations and guidelines that are considered applicable. While it is the intent of this Chapter to be consistent with the regulations and guidelines, it is recommended that the users refer to the most recent text of those regulations and guidelines.

3 Objective/Scope

IIn accordance with the Convention, a BWMS installed on board a vessel is to be an IMO Member State type-approved and certified system and the installation of this system is to have the prior approval/ acceptance of the vessel's flag Administration. It is recognized that each BWMS is tested, approved and certified in its standard product configuration. However, there are design and engineering issues, as well as special considerations relating to the class requirements that will need to be addressed, as every ship is unique due to its design and operational profile.

The objective of this Chapter is to provide supplementary requirements regarding BWMS. The requirements of this Chapter apply to new or existing vessels.

As indicated in 6-6-1/Figure 1, ballast water treatment is considered one of the accepted ballast water management method for the vessel.

5 IMO Regulations and Guidelines

This Chapter is intended for use in conjunction with the appropriate ABS Rules. BWMS designed and installed in accordance with this Chapter are also to comply, as applicable, with the IMO regulations and guidelines listed below.

- The International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004.
- IMO Resolution MEPC.174(58), "Guidelines for Approval of Ballast Water Management Systems (G8)", adopted on 10 October 2008.
- IMO Resolution MEPC.279(70), "Guidelines for Approval of Ballast Water Management Systems (G8)", adopted 28 October 2016.
- IMO Resolution MEPC.300(72), "Code for Approval of Ballast Water Management Systems", adopted on 13 April 2018.
- IMO Resolution MEPC.169(57) "Procedure for Approval of Ballast Water Management systems that Make Use of Active Substances (G9)", adopted on 4 April 2008.
- IMO Resolution MEPC.127(53), "Guidelines for Ballast Water Management and Development of Ballast Water Management Plans (G4)", adopted on 22 July 2005, as amended by MEPC.306(73), adopted on 26 October 2018.
- IMO Resolution MEPC.209(63), "Guidelines on Design and Construction to Facilitate Sediment Control on Ships (G12)", adopted on 2 March 2012.
- IMO Resolution MEPC.173(58), "Guidelines for Ballast Water Sampling (G2)", adopted on 10 October 2008.

7 Approval of BWMS and Optional BWT or BWT+ Notation

7.1 Systems Installed Under Survey

7.1.1 BWT Notation

Where requested by the Owner, BWMS approved by ABS (see 6-6-1/7.7) and which fully complies with the requirements of this Chapter and the applicable Rules and installed under survey by the ABS Surveyor may be assigned the optional **BWT** notation.

7.1.2 BWT+ Notation

Where requested by the Owner, BWMS approved by ABS (see 6-6-1/7.7) which fully complies with the requirements of this Chapter and the applicable Rules and has been fabricated under survey at the manufacturing facility by the ABS Surveyor may be assigned the optional **BWT+** notation. This survey is to include but is not limited to material tests, assembly verification and operational testing. Similarly, where a vessel is equipped with a BWMS which is composed of several components that are assembled at a shipyard or dockside facility may be assigned the **BWT+** notation, provided the main treatment components of the BWMS which result in the organisms and pathogens becoming ineffective or rendered harmless have been fabricated under survey at the manufacturing facility by the ABS Surveyor. See 6-6-1/7.7 for the requirements of ABS Approval of BWMS.

7.3 Systems Not Installed Under Survey

Vessels equipped with a BWMS where the installation was not conducted under survey by the ABS Surveyor may obtain the optional **BWT** notation, provided that the BWMS and the installation on board the vessel have been determined to fully comply with the with the requirements of this Chapter and the applicable Rules.

The operation of the BWMS is to be demonstrated to the ABS Surveyor by a shipboard function test (6-6-4/7.3), and the specific certification/documentation listed on 6-6-1/Table 4 are to be verified by the ABS Surveyor to confirm that the BWMS is IMO Member State type-approved.

7.5 Minimum Requirements for Systems Where Optional BWT or BWT+ Notation is not Requested

Where a vessel is fitted with BWMS and the optional **BWT** or **BWT+** notation detailed under 6-6-1/7.1 and 7.3 are not requested, the installed system is to be approved by ABS (See 6-6-1/7.7) and to comply with the minimum requirements, applicable for the system and vessel, prescribed in 6-6-1/Table 1 and is to be verified by the ABS Surveyor during installation.

Plans and supporting documentation listed in 6-6-1/Table 3 showing compliance with the minimum requirements in 6-6-1/Table 1 are to be submitted to the ABS Engineering office.

TABLE 1
Minimum Requirements for BWMS where Optional BWT or BWT+ Notation is not Requested

BWMS Requirements	*Reference*
Plans and Documentation	6-6-1/13
System-Related Installation Criteria	6-6-2
Considerations for Oil, Gas and Chemical Carriers	6-6-3

7.7 Approval of BWMS

7.7.1 ABS Approval of BWMS

The acceptability of an IMO Member State type-approved BWMS by ABS is subject to the following requirements:

i) The approval of a BWMS installation is subject to, the exact configuration of the entire system, with each of its components are included in the schematics to plans for the vessel, is the same as identified in the IMO Member State type-approved BWMS.

ii) The approval of a BWMS installation is subject to the ABS approval of the ship plans and operational manuals listed in 6-6-1/Table 3.

iii) The acceptance of any deviation from the IMO Member State type-approved BWMS is subject to the submission of documentation to ABS, issued by the IMO Member State issuing the BWMS Type Approval (TA) or an Recognized Organization (RO) on behalf of the IMO Member State issuing the BWMS Type Approval (TA) with the endorsement of the IMO Member State certifying that the deviation is acceptable within the framework of the original IMO Member State BWMS TA certification. Such certification of acceptance will not be valid if issued by an RO only, in lieu of issuance of certification by an RO on behalf of the IMO Member State issuing the BWMS TA.

7.7.2 ABS Type Approval Program

BWMS and associated components that are IMO Member State type-approved that can be consistently manufactured to the same design and specification can be approved under the ABS Type Approval Program. The ABS Type Approval Program is a voluntary option for the demonstration of compliance of a system or product with the Rules or other recognized standards. The ABS Type Approval Program consists of two components:

i) *Product Design Assessment.* Upon application, the system and components of the BWMS are to be design assessed.

ii) *Manufacturing Assessment.* Upon satisfactory assessment, evaluation of the manufacturing facility and process is to be conducted to confirm its ability to consistently manufacture the main treatment components of the BWMS in accordance with the PDA.

Specific requirements and details regarding the ABS Type Approval Program can be found in 1-1-4/7.7 and Appendix 1-1-A3 of the ABS *Rules for Conditions of Classification (Part 1)*. The configuration of the BWMS is to be confirmed on each vessel, and therefore the ABS Type Approved BWMS does not exempt the submission of the plans and operational manuals listed in 6-6-1/Table 3 for each vessel.

9 Governmental Regulations

Several national Administrations have additional requirements in place pertaining to the management of ballast water for vessels operating in their territorial waters. These requirements can necessitate additional vessel features, performance standards, equipment, reporting and record keeping, which are not included in this section. Owners/operators are to follow the latest national Administration requirements.

9.1 United States Coast Guard Type Approval

In 2012 the United States Coast Guard (USCG.) issued "Federal Register/Vol. 77, No. 57/, March 23, 2012/ Rules and Regulations; 33 CFR Part 151; 46 CFR Part 162 Standards for Living Organisms in Ships" Ballast Water Discharged in U.S. Waters", which states the following:

1) Ships required to meet these USCG ballast water discharge standards are to use a BWMS tested and approved in accordance with 46 CFR 162.060.

2) To comply with USCG regulations, any BWMS utilized, irrespective of certification under the IMO BWM Convention, is required to undergo USCG Type Approval.

3) The USCG regulations include a requirement for the use of existing data generated during testing for approval under the IMO BWM Convention, but the tests and evaluations are to at least be the same or equivalent to those in 46 CFR 162.060. To obtain USCG Type Approval, a BWMS manufacturer is to partner with a USCG-accepted independent laboratory (IL) for all of the required tests and evaluations, even in cases where existing data is to be used. In such a case, the IL would evaluate the existing data to determine if the tests and evaluations meet USCG requirements. For tests and data that have been assessed to not meet USCG requirements, the IL performs all tests and evaluations necessary. Finally, the IL submits a test report asserting that the BWMS has met the USCG requirements, even if the testing and evaluation was performed by another test organization for type approval under the IMO BWM Convention.

11 Definitions

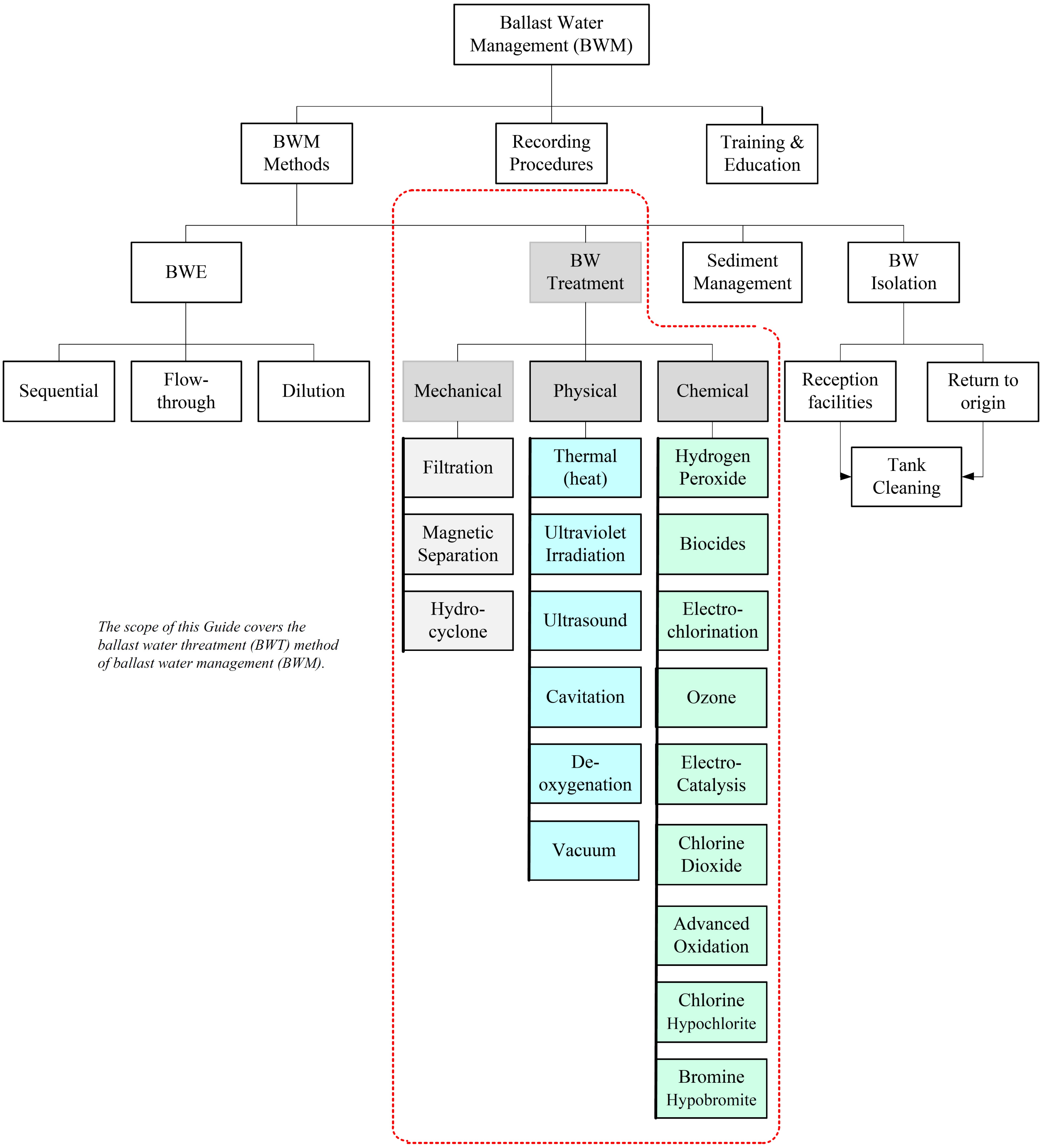
The following definitions are to be applied to the terms used in this section:

- *2008 G8 compliant* means a ballast water management system that was type approved prior to 28 October 2018 and installed on a vessel prior to 28 October 2020 using Guidelines provided in *Resolution MEPC.174(58)*.
- *2016 G8 compliant* indicates a ballast water management system that was type approved after 28 October 2016 using Guidelines provided in either *Resolution MEPC.279(70)* or *Resolution 300(72)*.
- *Administration* is the Government of the State under whose authority the vessel is operating. With respect to a vessel entitled to fly a flag of any State, the Administration is the Government of the State. With respect to floating platforms engaged in exploration and exploitation of the seabed and subsoil thereof adjacent to the coast over which the coastal State exercises sovereign rights for the purposes of exploration and exploitation of its natural resources, including Floating Storage Units (FSUs) and Floating Production Storage and Offloading Units (FPSOs), the Administration is the Government of the Coastal State concerned.
- *Active Substance* means a substance or organism, including a virus or fungus that has general or specific action on or against harmful aquatic organisms and pathogens.

- *Airlock* [in the context of 6-6-2/9.3.2] is a space enclosed by gastight steel bulkheads with two gastight doors spaced not more than 2.5 m apart. The doors are to be self-closing without any hold back arrangements. Air locks are to have mechanical ventilation and are not to be used for other purposes. An audible and visual alarm system to give a warning on both sides of the air lock is to be provided to indicate if more than one door is moved from the closed position. The air lock space is to be monitored for dangerous gas as defined below.
- *Ballast Water* is the water with its suspended matter taken onboard a vessel to control trim, list, draft, stability or stresses of the vessel.
- *Ballast Water Capacity* means the total volumetric capacity of any tanks, spaces or compartments on a vessel used for carrying, loading or discharging ballast water, including any multi-use tank, space or compartment designed to allow carriage of ballast water.
- *Ballast Water Discharge* means the ballast water discharged overboard.
- *Ballast Water Management (BWM)* means mechanical, physical, chemical and biological processes, either singularly or in combination to remove, render harmless, or avoid the uptake or discharge of harmful aquatic organisms and pathogens within the ballast water and associated sediments.
- *Ballast Water Management Plan (BWMP)* is a document describing the ballast water management process and procedures implemented on board individual vessels.
- *Ballast Water Management Room (BWMR)* is any space containing equipment belonging to the Ballast Water Management System. A space containing remote controls for the Ballast Water Management (BWMS) or a space dedicated to the storage of liquid or solid chemicals for BWMS need not be considered as a BWMR.
- *Ballast Water Management System (BWMS)* means any system which processes ballast water such that it meets or exceeds the ballast water discharge performance standard in Regulation D-2 of the Convention. The BWMS includes ballast water treatment equipment, all associated piping arrangements as specified by the manufacturer, control equipment, monitoring equipment and sampling facilities. The categorization of BWMS technologies is given in 6-6-1/Table 1 which is derived from IACS UR M74 Table 1.
- *Biological testing* means sampling ambient ballast water for background and/or treated ballast water being discharged and analyzing samples in accordance with BWM.2/Circ.70 (as amended) to validate compliance during BWMS commissioning.
- *BWMS Code* means *Resolution MEPC.300(72) Code for Approval of Ballast Water Management Systems*. All references to 2016 G8 is to be read to mean references to the BWMS Code after the BWMS Code became effective 13 October 2019.
- *BWMS Code compliant* means a ballast water management system that is type approved after 13 October 2019.
- *Ballast Water Treatment System (BWTS)* is same as BWMS definition above.
- *Ballast Water Tank* is any tank, hold or space used for the carriage of ballast water.
- *Ballast Water Treatment (BWT) Equipment* refers to equipment which mechanically, physically, chemically or biologically processes ballast water, either singularly or in combination, to remove, render harmless or avoid the uptake or discharge of harmful aquatic organisms and pathogens within the ballast water and associated sediments. Ballast water treatment equipment can operate at the uptake or discharge of ballast water, during the voyage, or at a combination of the events.
- *Cargo area* is as defined in following sections : for oil tankers in 5C-2-3/1.3.7; for chemical tankers in 5C-9-1/3.6; for gas carriers in 5C-8-1/2.7; and for offshore support vessels carrying Limited Amounts of Hazardous and Noxious Liquid Substances, in 5D-2-3/5.1.
- *Company* means the Owner of the ship or any other organization or person such as the manager, or the bare boat charter, who has assumed the responsibility for operation of the vessel from the Owner of the vessel and who on assuming such responsibility has agreed to take over all of the duties and responsibilities imposed by the International Safety Management Code.

- *Control Equipment* refers to the installed equipment required to operate and control the ballast water treatment equipment.
- *Convention* means the *International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004*.
- *Electrochlorination* in the context of this Section is same as "Electrolysis" as referenced in IACS UR M74 and F45.
- *Gross Tonnage* is the gross tonnage calculated in accordance with the tonnage measurement regulations contained in Annex I to the *International Convention on Tonnage Measurement for Ships, 1969* or any successor Convention.
- *Harmful Aquatic Organisms and Pathogens* are aquatic organisms or pathogens which, if introduced into the sea, including estuaries, or into fresh water courses, can create hazards to the environment, human health, property or resources, impair biological diversity or interfere with other legitimate uses of such areas.
- *Hazardous Areas* are areas of a ship where flammable or explosive gases or vapors are normally present or likely to be present. The flammable or explosive atmosphere can be expected to exist continuously or intermittently. Hazardous areas are more specifically defined for certain machinery installations, storage spaces and cargo spaces that present hazards, and example Rule citations are given in 4-1-1/1.9.4 . See 6-6-3/3.1.
- *Hazardous or Dangerous gas* means any gas which can develop an atmosphere hazardous to the crew and/or the ship due to flammability, explosivity, toxicity, asphyxiation, corrosivity or reactivity and for which due consideration of the hazards is required. Examples include hydrogen (H2), hydrocarbon gas, oxygen (O_2), carbon dioxide (CO_2), carbon monoxide (CO), ozone (O_3), chlorine (Cl_2) and chlorine dioxide (ClO_2).
- *Monitoring Equipment* refers to the equipment installed for the assessment of the effective operation of the ballast water treatment equipment.
- *Non-hazardous area* is an area which is not a hazardous area as defined above.
- *Preparation* means any commercial formulation containing one or more Active Substances including any additives. This term also includes any Active Substances generated on board for the purposes of ballast water management and any Relevant Chemicals formed in the BWMS that makes use of Active Substances to comply with the Convention.
- *Relevant Chemicals* means transformation or reaction products produced during and after employment of the BWMS in the ballast water or the receiving environment and that can be of concern to the ship's safety, aquatic environment and/or human health.
- *Rules* are the ABS *Rules for Building and Classing of Marine Vessels (Marine Vessel Rules)* and other ABS Rules, as appropriate.
- *Sampling Facilities* refers to the means provided for sampling treated or untreated ballast water.
- *Sediments* are the particulate matter settled out of ballast water.
- *Treatment Rated Capacity (TRC)* is the maximum continuous capacity expressed in cubic meters per hour for which the BWMS is type-approved. It states the amount of ballast water that can be treated per unit time by the BWMS to meet the standard in *Regulation D-2* of the Convention.
- *Type Approval (TA)* refers to the IMO approval and certification regime of BWMS made by an IMO Member State in accordance with the *Convention Guidelines G8, G9 and G10*. An approved BWMS is to have a valid Type Approval Certificate in the proper form and signed by that Member State.
- *Viable Organisms* are organisms and any life stages thereof that are living.

FIGURE 1
Scope of Part 6 Chapter 5



Note:

Taking into consideration future developments of BWMS technologies, some additional technologies can be considered in this Figure 1 by identifying their characteristics in the same manner as for the BWMS Categories 1, 2, 3a, 3b, 3c, 4, 5, 6, 7a, 7b and 8 in 6-6-1/Table 2.

Table 2
Categorization of BWMS Technologies

BMWS' Technology category		*1*	*2*	*3a*	*3b*	*3c*	*4*	*5*	*6*	*7a*	*7b*	*8*
Characteristics		In-line UV or UV + Advanced Oxidation Technology (AOT) or UV + TiO_2 or UV + Plasma	In-line Flocculation	In-line membrane separation and de-oxygenation (injection of N_2 from a N_2 generator)	In-line de-oxygenation (injection of Inert Gas from Inert Gas Generator)	In-line de-oxygenation with Inert Gas Generator	In-line full flow electro-chlorination	In-line side stream electro-chlorination (2)	In-line (stored) chemical injection	In-line side-stream ozone injection without gas/liquid separation tank and without discharge treatment tank	In-line side-stream ozone injection with gas/ liquid separation tank and discharge water treatment tank	In-tank pasteurization and de-oxygenation with N_2 generator
Disinfection when ballasting	Making use of active substance		X			In-tank technology: No treatment when ballasting or deballasting	X	X	X	X	X	In-tank technology: No treatment when ballasting or deballasting
	Full flow of ballast water is passing through the BWMS	X	X	X	X		X				X	

BMWS' Technology category		*1*	*2*	*3a*	*3b*	*3c*	*4*	*5*	*6*	*7a*	*7b*	*8*
	Only a small part of ballast water is passing through the BWMS to generate the active substance							X				
After-treatment when de-ballasting	Full flow of ballast water is passing through the BWMS	X									X	
	Injection of neutralizer						X	X	X	X	X	
	Not required by the Type Approval Certificate issued by the Administration		X	X								
Examples of dangerous (hazardous) gases as defined in 1/13 above			(1)	O_2 N_2	CO_2 CO		H_2 Cl_2	H_2 Cl_2	(1)	O_2 O_3 N_2		O_2 N_2

1) To be investigated for each case based on the result of the IMO (GESAMP) MEPC report for Basic and Final approval in accordance with the G9 Guideline.

2) In-line side stream electrochlorination can also be applied in-tank in circulation mode (no treatment when ballasting or de-ballasting).

Note: Taking into consideration future developments of BWMS technologies, some additional technologies can be considered in this Table 2 by identifying their characteristics in the same manner as for the above BWMS Categories 1, 2, 3a, 3b, 3c, 4, 5, 6, 7a, 7b and 8.

13 Plans and Documentation

13.1 Ship Plans and Operational Manuals

6-6-1/Table 3 below shows the general ship plans and operational manuals that are to be submitted for reviewor information, as applicable. The plans and operational manuals are to be reviewed or filed for information prior to installation. Plans which are to Specific documents that intended to be maintained onboard the ship for presentation to the ABS Surveyor at appropriate surveys are also annotated in the table.

Due to a wide range of treatment systems, ABS can require the submission of additional plans or supporting information as called for by a specific treatment system.

TABLE 3

Type of Ship Plans and Manuals	*Additional Description*	*Submitted for Review (R) or Information (I)*	*Placed Onboard Vessel for Survey (OB)*
General arrangement drawings of the BWMS	Installation arrangement drawings on the ship including location and layout	R	-----
Arrangement and capacity of ballast tanks and pumps		R	-----
Ballast piping system drawings[1][4]	Layout, filling arrangement, and booklet of construction details of piping system	R	-----
Location of ballast water sampling facilities[1]		R	-----
Electrical circuit drawings and main power cable drawings[1]		R	-----
Power calculation document	Electrical load analysis	R	-----
Hazardous area installations and hazardous area plans	For oil, gas and chemical carriers, tank barges or MODUs, as where if applicable	R	-----
Control, monitoring and safety system documentation[1][4]	Where the controls and monitoring of the BWMS have been connected to or integrated with the vessel's control and monitoring system(s)	R	-----
Documentation in accordance with Section 4-9-3 [1][4]	BWMS with computer-based systems	R	-----
Local instrumentation arrangement plan[1]		R	-----
Structural plans	Showing construction details of new BWMR on deck	R	-----
Storage tanks and day tanks containing chemicals and preparations used to treat ballast water	Include complete piping details of filling, drain system, vents, drip trays, and safety precautions, etc.	R	OB

Type of Ship Plans and Manuals	*Additional Description*	*Submitted for Review (R) or Information (I)*	*Placed Onboard Vessel for Survey (OB)*
Safety documentation for hazardous chemicals (1)(4)	In recognized industry format, such as MSDS, CHRIS Code, Cole-Parmer	R	-----
Leakage detection system and safety features associated with the generation of toxic or flammable gases (1)(4)	Safety features include sensor, alarms and shutdown settings, etc. together with proper suitable certification. Schematic plans detailing arrangement and location of sensor are to be provided	R	OB
Safety assessment documentation, where applicable (1)(4)	For BWMS that employs active substances and preparations; include arrangement, handling and safety plans of auxiliary systems for the treatment system, as applicable. See 6-6-2/9.1.2	R	-----
Personnel Protection Equipment arrangements	PPE required by 6-6-2/16	R	OB
Firefighting measures	Verification plans. See 6-6-2/3.1.1ii, 6-6-2/3.4.i and 6-6-2/15	R	OB
Ballast water management plan (BWMP)	BWMP is specific to the ship and in a standard format per *G4 Guidelines* and resolution MEPC.306(73)	R (5)	OB
BWMS operating and safety manual(1)(4)	Manual specific to the actual installation onboard the ship; see 6-6-4/1	R or I (6)	OB
Shipboard function test plan for sea or quay trial(2)	Function test of the installed BWMS at the sea trial or quay trial in the presence of the ABS Surveyor; function test plan per per Regulation E-1 of the *Convention Guidelines*; see 6-6-4/7.3	-----	OB
Ballast water record book	Ballast water record book is to be specific to the ship	-----	S
BWMS maintenance book(3)	BWMS maintenance book is to be specific to the ship and is to include the manufacturer's recommended items, frequencies and methods used for maintenance.	-----	OB

Notes:

1 The BWMS design is to be consistent with the current flag Administration's Type Approval.

2 Shipboard function test plan is to be reviewed for acceptance by the ABS Surveyor prior to commencement of the test.

3 A review by the ABS Surveyor will be carried out to verify that the BWMS maintenance book reflects the manufacturer's recommended items, frequencies and methods used for maintenance. Electronic maintenance records will also be considered acceptable.

4 Including drawings developed by BWMS manufacturer for a specific vessel, as applicable.

5 The BWMP is required in accordance with Regulation B-1 of the Convention and will be reviewed by ABS, when requested. See 6-6-1/17.1.

6 Where the BWT/BWT+ notation is requested, the BWMS operating and safety manual is to be submitted for Review.

13.3 Required Specific Certification and Documentation

In accordance with the Convention, specific certification/documentation listed on 6-6-1/Table 4 are to be retained onboard the vessel for presentation or inspection at appropriate surveys.

TABLE 4

Type of Document for BWMS	*Additional Description*	*Placed Onboard Vessel for Survey (OB)*
Type Approval Certificate of BWMS	*2008 G8 Guidelines*, paragraph 8.1.1 if 2008 G8 compliant. Information for the Certificate is to include main particulars of BWMS, approved application, limiting conditions and others as stipulated in *G8 Guidelines*	OB
	2016 G8 Guidelines or *BWMS Code*, paragraph 8.2.1 if 2016 G8 compliant or BWMS Code compliant. Information for the Certificate is to include main particulars of BWMS, approved application, limiting conditions and others as stipulated in *G8 Guidelines*.	
Results of test analysis for BWMS	Copy of test results showing the effectiveness and ability to meet IMO discharge standards per *2008 G8 Guidelines*, paragraph 6.5.4 if 2008 G8 compliant.	OB
	Copy of test results showing the effectiveness and ability to meet IMO discharge standards per *2016 G8 Guidelines or BWMS Code*, Part 7, paragraph 7.1.8.	
International Ballast Water Management Certificate	In accordance with the Convention Regulation E-2	OB
Documentation verifying IMO Basic Approval of BWMS to *G9 Guidelines*, if applicable	In a suitable format: i.e., Basic Approval application and GESAMP BWWG review report, etc.	---

Type of Document for BWMS	*Additional Description*	*Placed Onboard Vessel for Survey (OB)*
Documentation verifying IMO Final Approval of BWMS to *G9 Guidelines*, if applicable	In a suitable format: i.e., Final Approval application and GESAMP BWWG review report, etc.	---
Statement confirming BWMS type tested in accordance with the environmental testing specifications of the Convention	*2008 G8 Guidelines,* paragraph 8.1.2 if 2008 G8 compliant.	OB
	2016 G8 Guidelines or *BWMS Code*, Part 3, paragraph 3.4 if 2016 G8 compliant or BWMS Code compliant.	---
Equipment manuals for major components of BWMS	*2008 G8 Guidelines,* paragraph 8.1.3 if 2008 G8 compliant; manual should include equipment list and specifications from the BWMS manufacturer	OB
	2016 G8 Guidelines or *BWMS Code,* Part 1, paragraph 1.3.1.3 if 2016 G8 compliant or BWMS Code compliant; manual should include equipment list and specifications from the BWMS manufacturer	
Operations and technical manual	Manual is specific to the ship and approved by the Administration per *2008 G8 Guidelines*, paragraphs 8.1.4 if 2008 G8 compliant.	OB
	If 2016 G8 compliant or BWMS Code compliant, Paragraph 8.2.2; ship-specific not required from the BWMS manufacturer.	
Installation specifications	*2008 G8 Guidelines*, paragraphs 8.1.5 and 5.1.8 if 2008 G8 compliant from the BWMS manufacturer	OB
	2016 G8 Guidelines, or BWMS Code, Part 1, paragraphs 1.3.1.5 and 1.3.1.6 if 2016 G8 compliant or BWMS Code compliant from the BWMS manufacturer	
Installation commissioning procedures	*2008 G8 Guidelines*, paragraph 8.1.6 if 2008 G8 compliant or paragraph 8.2.5 if 2016 G8 compliant or BWMS Code compliant from the BWMS manufacturer	OB
	2016 G8 Guidelines or *BWMS Code*, paragraph 8.2.5 if 2016 G8 compliant or BWMS Code compliant from the BWMS manufacturer	

Type of Document for BWMS	*Additional Description*	*Placed Onboard Vessel for Survey (OB)*
Initial calibration procedures	*2008 G8 Guidelines*, paragraph 8.1.7 if 2008 G8 compliant from the BWMS manufacturer	OB
	2016 G8 Guidelines or *BWMS Code*, Part 1, paragraph 1.3.2.7 if 2016 G8 compliant or BWMS Code compliant from the BWMS manufacturer	
Documentation relating to the environmental and public health effects of the BWMS	*BWM.2/Circ.28,* paragraph 3.1.13.7 and *2008 G8 Guidelines,* Part 1, Paragraph 1.6.4 if 2008 G8 compliant; BWMS manufacturer is to provide information to ship owner	---
	BWM.2/Circ.28, paragraph 3.1.13.7 and *2016 G8 Guidelines* or *BWMS Code,* Part 1, Paragraph 1.6.4 if 2016 G8 compliant or BWMS Code compliant; BWMS manufacturer is to provide information to ship owner	
Documentation relating to the corrosion effects of the BWMS on the ship's tank coatings, steel plating or ballast water system	*BWM.2/Circ.28,* paragraph 3.1.13.2*;* BWMS manufacturer is to provide information to ship owner	---

15 Surveys

The primary function of Surveys is to determine and report on compliance with the applicable ABS Rules for ships and other marine structures.

An initial survey of the BWMS installed (see details in 6-6-4/7.1) is to be carried out and testing witnessed to the satisfaction of the attending surveyor and a shipboard function test (see requirements in 6-6-4/7.3) are required for the issuance of the optional **BWT** or **BWT+** notation.

Surveys after construction are required for retention of the optional **BWT** or **BWT+** notation. See requirements in Subsection 6-6-4/9.

When required by the Administration, biological testing is to be conducted during BWMS commissioning to the satisfaction of the attending surveyor showing treated discharged ballast water is compliant with regulation D-2. Refer to paragraph 8.3.6 of the BWMS Code (commissioning procedures following installation). Refer to 6-6-4/7.5.

17 Record Keeping and Reporting

Record keeping and reporting are to be set up in compliance with the IMO Convention.

17.1 BWMP

17.1.1 General Requirements

Regulation B-1 of the Convention requires all vessels to implement and maintain on board a BWMP approved by the vessel's Flag Administration RO. The BWMP is specific to each vessel and is to be prepared in accordance with the *MEPC.127(53) "Guidelines for ballast water management and development of ballast water management plan (G4)"*, as amended by MEPC.306(73). The plan is to include a detailed description of the actions to be taken to implement the ballast water management requirements and supplemental ballast water management practices.

The BWMP is to be written in the working language of the vessel. If the language used is not English, French or Spanish, a translation into one of these languages is to be made. The plan is to be readily accessible and available for examination upon request by authorities such as port State authorities.

17.1.2 Maintenance of BWMP

The BWMP is to be reviewed periodically by the Owner, operator, ballast water management officer or Master and maintained up to date. Any changes to the provisions of the BWMP are to be submitted for review and approval to the Flag Administration or ABS.

Suitable briefing and training is to be provided to the vessel's crew on changes/updates made to the BWMP, particularly for the changes/updates related to the operational and/or safety aspects of the ballast water management operation.

17.3 Ballast Water Record Book

Vessels are to also have a ship-specific Ballast Water Record Book (Regulation B-2) to record when ballast water is taken on board, circulated or treated for ballast water management purposes, and discharged. It is also used to record when ballast water is discharged to a reception facility and if accidental or other exceptional discharges of ballast water take place.

The ballast water logs are to be maintained onboard the vessel for a minimum of two years after the last entry has been made into the ballast water record book. The record book is to be retained by the Company for a minimum period of three years. The ballast water record book is to be readily available for survey.

An electronic record system or integration of the ballast water logs into another record book is an acceptable alternative to the ballast water record book.

A standard form of the ballast water record book can be found in Appendix II of the Convention.

PART 6

CHAPTER 6
Ballast Water Treatment

SECTION 2
System-Related Installation Criteria *(1 July 2024)*

1 General

In order to minimize the risk associated with the discharge of harmful aquatic invasive species resulting from ballast water transfers, the BWMS is to be effective under the range of typical vessel operating conditions without negatively impacting the safety of shipboard personnel or the vessel or the environment into which the ballast water is discharged. BWMS is to meet international protocols under various environmental conditions, aquatic organisms, flow rates, volumes and retention times. Due to the wide range of factors associated with ballast water treatment, various treatment methods have been developed, or are being developed, for shipboard installation. The IMO Member State Type Approval of a system, however, does not ensure that a given system will work on all vessels or in all situations. The requirements in this Section address the supplementary classification requirements that apply when a BWMS is installed on board a vessel.

1.1 Objective

1.1.1 Goals

The ballast water treatment systems covered in this section are to be designed, constructed, operated and maintained to:

Goal No.	*Goals*
STAB 1	have adequate watertight integrity and restoring energy to prevent capsize in an intact condition.
STAB 2	have adequate subdivision and stability to provide survivability to damage or accidental conditions.
STRU 1	in the intact condition, have sufficient structural strength to withstand the environmental conditions, loading conditions, and operational loads anticipated during the design life.
POW 2	provide power to enable the machinery/equipment/electrical installation to perform its required functions necessary for the safe operation of the vessel.
FIR 1	*prevent the occurrence of fire and explosion.*
FIR 4	detect, *contain, control and suppress or swiftly extinguish a fire in the compartment of origin.*
ENV 8	have provisions in place to control/minimize the introduction of unwanted aquatic organisms and pathogens into the marine environment from ships' ballast waters and sediment discharges.

Goal No.	*Goals*
SAFE 1.1	minimize danger to persons on board, the vessel, and surrounding equipment/installations from hazards associated with machinery and systems.
MGMT 1.1	identify *risks to its ships, personnel and the environment and establish appropriate safeguards.*
MGMT 3	*establish procedures, plans and instructions for operations concerning the safety of the personnel, vessel, and protection of the environment.*
MGMT 4	*establish procedures, plans and instructions for emergency situations concerning the safety of the personnel, vessel, and protection of the environment.*
MGMT 5.1	facilitate safe access, ease of inspection, survey, and maintenance of the vessel, machinery, and electrical systems.
AUTO 1	perform its functions as intended and in a safe manner.
AUTO 2	indicate the system operational status and alert operators of any essential machinery/systems deviate from its defined design/operating conditions or intended performance.
AUTO 3	have an alternative means to enable safe operation in the event of an emergency or failure of remote control.
AUTO 4	provide the equivalent degree of safety and operability from a remote location as those provided by local controls.
AUTO 5	provide a safety system that shall automatically lead machinery controlled to a fail-safe state in response to a fault which may endanger the safety of persons on board, machinery/equipment or environment.
AUTO 6	independently perform different functions, such that a single failure in one system will not render the others inoperative.

Materials are to be suitable for the intended application in accordance with the following goal in support of the Tier 1 Goals as listed above.

Goal No.	*Goal*
MAT 1	The selected materials' physical, mechanical and chemical properties are to meet the design requirements appropriate for the application, operating conditions and environment.

The goals in the cross-referenced Rules/Regulations are also to be met.

1.1.2 Functional Requirements

In order to achieve the above stated goals, the design, construction, installation, and maintenance of the ballast water treatment systems are to be in accordance with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
STABILITY (STAB)	
STAB-FR1	Provide means for piping that is arranged within the assumed damage zone such that the vessel still complies with the applicable damage stability criteria.
STRUCTURE (STRU)	
STRU-FR1 (STAB)	Installation of the system is not to compromise the structural integrity of the vessel and is not to adversely affect the vessel's damage and intact stability.

Functional Requirement No.	*Functional Requirements*
MATERIALS (MAT)	
MAT-FR1	The system is not to not to deteriorate, degrade or reduce the functional life expectancy of the vessel or means or corrosion prevention.
POWER GENERATION & DISTRIBUTION (POW)	
POW-FR1	The vessel is to provide sufficient electrical generating capacity for all operating conditions of the system.
FIRE SAFETY (FIR)	
FIR-FR1	The system is not to compromise and impede the firefighting arrangements on the vessel.
FIR-FR2	Appropriate fire detection, fire alarm, fire extinguishing systems, firefighting equipment capable of extinguishing the type and scale of fire in the space likely occur in association with the system are to be provided.
FIR-FR3 (MGMT)	Special firefighting operational instructions for the system are to be included in the vessel's manuals and notices for the instructions are to be posted in appropriate locations.
FIR-FR4	The firefighting equipment is to be certified for use in the operating environment.
PROTECTION OF ENVIRONMENT (ENV)	
ENV-FR1	The system is to be capable of operating effectively at all conditions meeting the vessel's specification to prevent the transportation of unwanted marine organisms and pathogens between different geographical areas through the vessel's ballast water.
ENV-FR2	The discharge from the BWMS separation system's back wash is not to have an adverse impact on the marine environment.
SAFETY OF PERSONNEL (SAFE)	
SAFE-FR1 (MGMT)	The system is to be accessible at all times and designed for personnel to conduct safe operation, inspection and maintenance.
SAFE-FR2	The system is to be arranged with bypasses or overrides to protect the safety of the vessel and personnel in the event of an emergency.
SAFE-FR3	Piping or tanks is to safely contain the fluid media it conveys and able to withstand the most severe condition of coincident design pressures, temperatures, vibration and loadings.
SAFE-FR4 (AUTO/FIR)	The system is to be arranged to detect the dangerous level of toxic, hazardous and flammable vapor and gas leaked from the system with automatic shutdown and visible/audible notification at manned location to prevent further escalation of hazards.
SAFE-FR5 (FIR)	The system is not to be installed in hazardous areas that may lead to fire and explosions unless the suitable equipment with acceptable countermeasures are provided.
SAFE-FR6 (FIR)	A ventilation system capable of removing toxic, hazardous and flammable vapor and gas leaked from the system is to be provided.
SAFE-FR7	An independent ventilation system of the compartment where the system is installed and other spaces is to be provided.
SAFE-FR8 (AUTO/FIR)	Interlocks are to be provided for automatic shutdown the system during abnormal conditions, failure of equipment, emergency conditions including fire and high concentrations of flammable or toxic gases to prevent further escalation of hazards.

Functional Requirement No.	*Functional Requirements*
SAFE-FR9 (FIR)	Openings of the system or storage area for chemicals used by the system that generate toxic or flammable gas are to considered hazardous suitable equipment with acceptable countermeasures are to be provided.
SAFE-FR10 (MGMT)	Arrangements (controls, instructions, etc.) are to be provided to clean the separation system after each operation.
SAFE-FR11 (ENV)	Adequate containment is to be provided for systems using chemicals.
SAFE-FR12 (FIR)	The piping is to be arranged to prevent excessive surface temperature and also prevent flammable fluid from entering the system.
SAFE-FR13 (FIR)	Acceptable countermeasures are to be provided for openings of compartment where the system is installed or storage area for chemicals to prevent the spread of toxic or flammable gas into other spaces
SAFE-FR14	Suitable personnel protective equipment is to be provided for the protection of the personnel engaging in the servicing, maintenance and repair of the system.
SAFE-FR15 (FIR)	Appropriate life saving equipment is to be provided for use in emergency including fire.
SAFETY MANAGEMENT (MGMT)	
MGMT-FR1 (SAFE)	Notices are to be posted to warn the personnel of dangerous conditions caused by the system.
MGMT-FR2	Detailed assessment is to be conducted when it is determined that the improper operation of the computer-based system may lead to a dangerous situation.
MGMT-FR3 (SAFE)	Detailed assessment is to be conducted to address the risk caused by operation of the system for personnel on board and the vessel.
AUTOMATION (CONTROL, MONITORING AND SAFETY SYSTEMS) (SAFE)	
AUTO-FR1	The automatic shutdowns of the system for safety reasons are to be independent of the control system.
AUTO-FR2 (SAFE)	The system is to be arranged to automatically lead the machinery to a fail-safe state during emergency for the safety of personnel on board and the vessel.
AUTO-FR3	Local instrumentation and controls of the system are to be arranged for ease of operation, maintenance and effective control in the event of an emergency or failure of any remote controls.
AUTO-FR4	The system's instrumentation parameters are to be displayed at remote locations.

The functional requirements in the cross-referenced Rules/Regulations are also to be met.

1.1.3 Compliance

A vessel is considered to comply with the goals and functional requirements when the prescriptive requirements are complied with or when an alternative arrangement has been approved, refer to Part 1D, Chapter 2.

3 Common Criteria

The design and installation of a BWMS is to comply with the following, unless additional measures acceptable to ABS have been provided:

i) The treatment rated capacity (TRC) is to meet the vessel's ballast capacity and normal ballast operations rate. The maximum flow rate at which a BWMS is operated as specified by the IMO Member State Type Approval certificate is to be clearly reflected in the BWMS shipboard operating manual.

ii) Capable of operating at the minimum discharge rate of the ballast pumps or stripping system.

iii) Capable of operating with all connected ballast system pumps and eductors.

iv) Capable of treating all ballast water regardless of tank location, size or structure.

v) Provide for ballast flow to the furthermost tank at maximum capacity stated in the vessel's BWMS specification.

vi) Does not adversely affect any parts, materials, equipment, structures or coatings.

vii) Does not exceed the electrical generating capacity of the shipboard power supply under all anticipated ballasting or de-ballasting operating conditions.

viii) Does not discharge hazardous vapors or byproducts to the atmosphere, other than those considered in the IMO Member State Type Approval.

ix) All parts of the BWMS are to be easily accessible for inspection and maintenance.

x) Have bypasses or overrides to protect the safety of the vessel and personnel in the event of an emergency (See 6-6-2/3.9.9). The arrangement of the bypasses or overrides of the BWMS is to be consistent with the approved Operation Maintenance and Safety Manual by the IMO Member State Type Approval.

xi) Complies with all limitations, requirements, restrictions and conditions identified in the IMO Member State Type Approval certificate.

xii) Where a vacuum or overpressure can occur in the ballast piping or in the ballast tanks due to their height difference or injection of inert gas or nitrogen (N_2), a protection device is to be provided (i.e. P/V valves, P/V breakers, PV breather valves, pressure safety relief valves or high/low pressure alarms). The pressure and vacuum settings of the protection device is not to exceed the design pressure of the ballast piping (BWMS categories 3a and 3b) or ballast tank (BWMS categories 3a, 3b and 3c), as applicable. For BWMS categories 3a, 3b and 3c, the inert gas or nitrogen product enriched air from the inert gas system and from the protection devices installed on the ballast tanks (i.e. P/V valves, P/V breakers or P/V breather valves) are to be discharged to a safe location*(1) & *(2) on the open deck.

Notes:

Safe location needs to address the specific types of discharges separately. Signboards or similar warnings at the discharge areas are to be provided.

Safe location*(1): inert gas or nitrogen product enriched air from:

- in-line (categories 3a and 3b) and in-tank (categories 3c and 8) de-oxygenation BWMS: the protection devices installed on the ballast tanks, nitrogen or inert gas generators, nitrogen buffer tank (if any); or
- in-line ozone injection BWMS (categories 7a and 7b): the oxygen generator.

Safe locations on the open deck are:

- not within 3 m of areas traversed by personnel; and
- not within 6 m of air intakes for machinery (engines and boilers) and all ventilation inlets/outlets.

Safe location*(2): oxygen-enriched air from:

- in-line and in-tank de-oxygenation BWMS (categories 3a and 8): the nitrogen generator; or

- in-line ozone injection BWMS (categories 7a and 7b): the protection devices or vents from oxygen generator, compressed oxygen vessel, the ozone generator and ozone destructor devices.

Safe locations on the open deck are:

- outside of hazardous area;
- not within 3 m of any source of ignition and from deck machinery, which may include anchor windlass and chain locker openings, and equipment which may constitute an ignition hazard;
- not within 3 m of areas traversed by personnel; and
- not within 6 m of air intakes for machinery (engines and boilers) and all ventilation inlets.

xiii) If servicing hazardous ballast tanks and installed in a hazardous area, among the other requirements indicated in this Chapter, the BWMS is to comply with Appendix 6-6-3-A 5. If servicing hazardous ballast tanks and installed in a non-hazardous area, the BWMS is to provided with specifically approved isolation arrangements. See Appendices 6-6-3-A1 through A4 for reference. When it is required to have an automatic shutdown of the BWMS for safety reasons, this is to be initiated by a safety system independent of the BWM control system.

xiv) Where the operating principle of the BWMS (categories 2, 3a, 3b, 3c, 4, 5, 6, 7a, 7b and 8) involves the generation of a dangerous gas, the following requirements are to be satisfied:

- Gas detection equipment is to be fitted in the spaces where dangerous gas could be present, and an audible and visual alarm is to be activated both locally and at the BWMS control station in the event of leakage.

  The gas detectors is to be located as close as possible to the BWMS components where the dangerous gas may accumulate.

  For flammable gases and explosive atmosphere including but not limited to H_2, the construction, testing and performance of the gas detection devices is to be in accordance with IEC 60079-29-1, IEC 60079-29-2, IEC 60079-29-3 and/or IEC 60079-29-4, as applicable.

  Where other hazards are considered like toxicity, asphyxiation, corrosive and reactivity hazards, a recognized standard acceptable to ABS is to be selected with due consideration of the specific gases to be detected and due consideration of the performance of the detection device with regards to the specific atmosphere where it is used.

- The open end of inert gas or nitrogen gas enriched air (BWMS categories 3a, 3b, 3c and 8) or oxygen-enriched air (BWMS categories 3a, 7a, 7b and 8) are to be led to a safe location on open deck (see safe location (1) & (2) in 6-6-2/3.xii above).
- H_2 by-product enriched air vent pipes (BWMS categories 4, 5 and 6) or O_2 enriched air vent pipes (BWMS categories 3a, 7a, 7b and 8) or O_3 piping (BWMS categories 7a and 7b) are not to be routed through accommodation spaces, services spaces and control stations.
- O_2 enriched air vent pipes (BWMS categories 3a, 7a, 7b and 8) are not to be routed through hazardous areas unless it is arranged inside double walled pipes or pipe ducts constructed as the special safeguard for the purpose of 6-6-2/3.9.3.iii Note 1 and provided with suitable gas detection as described in 6-6-2/9.1.1.v and mechanical exhaust ventilation as described in 6-6-2/3.9.3.iii.
- The routing of H_2 by-product enriched air vent pipes (BWMS categories 4, 5 and 6) or O_2 enriched air vent pipes (BWMS categories 3a, 7a, 7b and 8) is to be as short and as straight as possible. When necessary, horizontal portions may be arranged with a minimum slope in accordance with the manufacturer’s recommendation.

3.1 BWMS Locations

3.1.1 General

i) A BWMS can be installed in various locations throughout a vessel. The acceptability of the location and arrangements depends on the type of treatment system, the installation specifications and the type of vessel. Each installation is to be evaluated to verify that potential safety concerns and pollution hazard issues are addressed.

ii) Regardless of the location, all BWMS installations are to be in accordance with all relevant requirements listed in this Chapter and international regulations, standards, guidelines and recommendations.

iii) BWMS equipment enclosures are not to be constructed on weather deck locations that will reduce the navigational bridge visibility below the requirements detailed in Section 3-6-1 and portlight details in 3-2-17/7.

iv) New or retrofitted enclosed deckhouse is to comply with the requirements in Section 3-2-11 for structural requirements and Section 3-2-15 for deck openings.

v) For tankers transporting combustible, corrosive or toxic cargo, the BWMS is to comply with the criteria relevant to the cargo transported and the vessel arrangements as specified in Parts 5A/5B and 5C.

3.1.2 BWMS Located in Non-Hazardous Areas

3.1.2(a) When the BWMS is installed in a non-hazardous space and the BWMS serves non-hazardous ballast tanks, then the BWMS can be installed in the locations indicated in 6-6-2/3.1.2(b), unless prohibited due to the treatment method involved:

3.1.2(b) The BWMS can be installed in the following locations.

i) Machinery space or engine room

ii) Void spaces with or without direct access or adjacent to the machinery room

iii) Dedicated compartment

iv) Other locations subject to ABS technical assessment and approval

3.1.2(c) If the BWMS serves hazardous ballast tanks, the arrangement of the ballast piping cannot permit the ballast water from the ballast tanks to be returned to the non-hazardous space containing the BWMS. See also 6-6-3/7.3 and 5C-2-3/1.7.2.

3.1.2(d) Gas carrier *ballast spaces, including wet duct keels used as ballast piping, and non-hazardous spaces may be connected to a BWMS located in the machinery space*. See 5C-8-3/ 7.5 and 6-6-3/3.iii.

3.1.3 BWMS Located in Hazardous Areas

3.1.3(a) When the BWMS serves ballast tanks that are hazardous, then the BWMS installed in the locations indicated in 6-6-2/3.1.3(b) are acceptable. These spaces are hazardous spaces by virtue of ballast piping originating from hazardous ballast tanks entering such spaces. See 5C-2-3/1.7.2.

3.1.3(b) The BWMS can be installed in the following locations.

i) Void space not adjacent to a cargo tank but with ballast piping, see 6-6-2/3.1.3(a)

ii) Void space adjacent to a cargo tank, see 5C-2-3/1.7.2

iii) Enclosed compartment on the cargo deck

iv) Other locations subject to ABS technical assessment and approval

3.1.3(c) The BWMS may be installed in the pump room of oil or chemical carriers subject to the system configuration, arrangements, locations and isolation arrangements accepted by ABS. See 6-6-2/3.3.2.ii and Section 6-6-3.

3.1.4 Arrangements

The arrangements for the location of the BWMS are to comply with the following compartment criteria.

i) The BWMR is considered to be entered frequently during operation of the BWMS and are to be provided with two escape routes. BWMR, where the maximum travel distance to the door of the compartment is 5 m (10 ft) or less, may be provided with a single escape route. See SOLAS regulations II-2/13.4.2. The travel distance is to be measured from any point normally accessible to the crew during operation of the BWMS, taking into account machinery and equipment within the space.

ii) Watertight integrity of all bulkhead openings and penetrations to be maintained.

iii) Watertight integrity of all deck openings and penetrations to be maintained.

iv) Minimize the extent of bulkhead and deck openings and penetrations.

v) Additional restrictions and requirements apply to installations of BWMS serving ballast tanks of oil and chemical carriers. See Section 6-6-3 for additional details.

3.1.5 BWMS with Treatment Processes that May Create a Hazard

The location of the BWMS with treatment process that may create a hazard will be subject to additional safety measures as required by ABS.

3.3 Ventilation Systems

3.3.1 BWMS Installed in Non-Hazardous Areas

i) Where the BWMS is installed in a machinery space such as an engine room, the equipment is to be located in the proximity of ventilation supply/exhaust duct opening.

ii) Where the BWMS is installed in a separate compartment in a non-hazardous area and does not serve any hazardous ballast tanks, the space is to be fitted with an independent mechanical exhaust ventilation system providing at least six (6) air changes per hour or as specified by the BWMS manufacturer, whichever is greater. See also 6-6-2/3.5 for the ventilation requirements for installations in Steering Gear compartments.

3.3.2 BWMS Installed in Hazardous Areas

The space containing the BWMS that serves hazardous ballast tanks is to comply with the following ventilation requirements or as specified by the BWMS manufacturer, whichever is greater or unless alternative arrangements are specifically approved by ABS:

i) *Separate hazardous compartment other than a cargo pump room*. Where the BWMS with ballast water piping is installed in a separate compartment that is located within a hazardous area and the BWMS treats the ballast water in the ballast tanks that are hazardous, the installation of the BWMS in the separate compartment is to be provided with the following arrangements:

- The compartment is to be considered, a hazardous area without any sources of release (i.e., cargo piping with flanged connections, valves etc.) within the separate compartment. See 5C-2-3/5.3.2(b).
- The ventilation rate of the compartment is to comply with the requirements of 6-6-2/3.3.2.ii.a.

ii) Where the BWMS is installed in a separate compartment, cargo pump room or ballast pump room that is a hazardous area, the ventilation system for the space is to provide:

a) For separate compartment or ballast pump room in a hazardous area:

At least twenty (20) air changes an hour if there are no sources of release (i.e., cargo piping with flanged connections, strainers, etc.) within the space with or without ballast piping. If the detection of gas reaches a maximum of 30% of Lower Flammable Limit (LFL) of the cargo and/or exceeding of the toxicity limit of the involved chemicals or generated gases,* as applicable, the BWMS is to automatically shut down.

b) For oil carriers:

At least twenty (20) air changes per hour if there are sources of release within the space. Where if the detection of gas reaches a maximum of 10% of LFL of the cargo and/or exceeding of the toxicity limit of the involved chemicals or generated gases,* as applicable, the BWMS is to automatically shut down.

c) For chemical carriers:

1) At least thirty (30) air changes per hour if there are sources of release within the space. Where if the detection of gas reaches a maximum of 10% of LFL of the cargo and/or exceeding of the toxicity limit of the involved chemicals or generated gases,* as applicable, the BWMS is to automatically shut down. Such hazardous areas include cargo pump rooms and other compartments specified in 5C-9-12/1.1, with the exemption of chemical cargoes addressed in 5C-9-11/1.2 and 1.3.

2) At least forty five (45) air changes per hour for hazardous cargo pump room spaces containing sources of release of specific chemicals being categorized such that compliance with 5C-9-15/17 in the "Special Requirements (*Column o*)" on the 5C-9-17/2 *Minimum Requirements* Table. Where if the detection of gas reaches a maximum of 10 % of LFL of the cargo and/or exceeding of the toxicity limit of the involved chemicals or generated gases,* as applicable, the BWMS is to automatically shut down. Such hazardous areas include cargo pump rooms and other compartments specified in 5C-9-12/1.1.

Note: * 5C-2-3/25.1.1.iii: *Gas-safe space is a space in which the entry of gases would produce hazards with regard to flammability or toxicity*. Also see 5C-2-3/20, 5C-9-13/2, 5C-8-1/2.24 and 5C-9-21/4.11 and 6-6-3/3.1.

3.3.3 Additional Requirements

The ventilation systems for BWMR containing BWMS of the following types are to be independent of the ventilation systems serving any other spaces:

- BWMS storing, introducing or generating chemical substances
- De-oxygenation, including pasteurization and de-oxygenation (categories 3 and 8)
- Electrochlorination (categories 4 and 5)
- Ozone injection (categories 7a and 7b)

Note:

The above requirements may be reduced if no toxic chemical is stored, and no toxic gas will be generated by the BWMS. The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guidelines) and ''safety hazard" as listed in Section 5C-9-17 are to be considered for this purpose. Chemicals include additives and neutralizers for BWMS.

Notwithstanding the requirements of 6-6-2/3.3.1 and 3.3.2, where the BWMS is installed in a separate compartment and either uses, prepares or stores chemicals or generates gases that are toxic or flammable, the following are to be complied with:

i) The ventilation system is to provide a minimum of thirty (30) air changes per hour, where if the detection of gas reaches a maximum of 10% of the LFL and/or exceeding of the toxicity limit of the involved chemicals or generated gases,* as applicable, the BWMS is to automatically shut down or at an LFL specified by the manufacturer, whichever is more stringent. The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (*G9 Guidelines*) and ''safety hazard'' as listed in Section 5C-9-17 are to be used as references for identifying those cases.

Note: *See Note on 6-6-2/3.3.2.ii.

ii) Where the dangerous gases (as defined in 6-6-1/11) that is generated from the BWMS are heavier than air (e.g. for BWMR containing a nitrogen generator), the exhaust extraction is to be taken from the bottom of the compartment. See 6-6-3/3.1.

iii) The ventilation exhaust for BWMR containing electrochlorination systems (categories 4 and 5) is to be located so as to be able to extract dangerous gases (as defined in 6-6-1/11)that is generated during the electrochlorination process. Due regard is to be paid to the expected quantity and density of such gases when designing the ventilation exhaust.

iv) The following requirements apply to ventilation ducts serving BWMR for ozone-based (categories 7a and 7b) BWMS:

- The part of the ducts located outside of the BWMR is to be made of steel having a thickness of at least 3 mm (0.12 in.) for ducts with a free cross-sectional area of less than 0.075 m2 (0.81 ft2). at least 4 mm (0.16 in.) for ducts with a free cross-sectional area of between 0.075 m2 (0.81 ft2) and 0.45 m2 (4.84 ft2), and at least 5 (0.2 in.) mm for ducts with a free cross-sectional area of over 0.45 m2 (4.84 ft2); and
- The ducts are to be supported and stiffened
- The outside openings of the ducts are to be fitted with protective screens of not more than 13 mm (0.51 in.) square mesh.

v) The ventilation system for BWMR containing ozone-based (categories 7a and 7b) BWMS or ventilation system for hydrogen de-gas arrangement (where provided) as required by 6-6-2/9.5.4 is to be interlocked with the BWMS such that:

- In case of loss of ventilation (primary and secondary), a visual and audible alarm is to be triggered both inside and outside the BWMR and at a manned location. If the ventilation is not restored after a pre-set time, the BWMS is then to be automatically shut down. Any need for cooldown necessary for safe shutdown is to be considered in the shutdown sequence.
- It is not to be possible to start the BWMS without the ventilation running

vi) A mechanical ventilation system is to be provided in enclosed BWMR. Unless specified otherwise in this Section 6-6-2, the ventilation capacity is to provide at least six (6) air changes per hour for BWMS of the flocculation-type (category 2), de-oxygenation including pasteurization and de-oxygenation(categories 3a, 3b, 3c and 8), full flow electrochlorination (category 4) or chemical injection type (category 6); and at least twenty (20) air changes per hour for BWMS of the side-stream electrochlorination (category 5) or ozone injection type (categories 7a and 7b).

3.4 BWMS Installations in Hazardous Areas on the Deck of Oil or Chemical Carriers

This Paragraph details the requirements for installations in hazardous compartments and non-hazardous compartments.

i) When BWMS compartments are installed on the deck of an existing vessel, specific plans are to be submitted to ABS verifying that the arrangements provided for firefighting on the deck of the vessel will not be compromised. The plans for submission are to verify that the firefighting requirements of 3-5-2/3, 3-2-11/11, 5C-8-11, 5C-2-3/27, and Section 4-7-3, and SOLAS regulation II-2/10, as applicable, are unaffected by the installation of BWMS compartments on deck.

ii) For all BWMS compartments a 'Warning Notice' is to be placed outside the entrance of the compartment requiring the start of mechanical ventilation prior to personnel entering the compartment.

iii) An interlock is to be provided for the compartment ventilation such that the electrical power supply to the BWMS cannot be energized while the ventilation is not in operation.

3.4.1 Requirements for Non-hazardous BWMS Compartments in Hazardous Area

When a BWMS is installed in more than one compartment and where some of the components of the BWMS are installed in a separate compartment located in a hazardous area, the interior of the compartment is a non-hazardous BWMS compartment, subject to the provisions of the following arrangements:

i) There are no portions of the BWMS's ballast water piping installed within the compartment.

ii) There are no sources of release (i.e., cargo piping with flanged connections, valves etc.) within the compartment.

iii) The compartment arrangements include separation from the hazardous space by two gastight self-closing doors without hold back arrangements forming an air-lock capable of maintaining an over-pressure.

iv) All ventilation inlets and outlets are routed such that they are located outside of the hazardous area.

v) The overpressure or air flow is to be continuously monitored and so arranged that in the event of a ventilation failure (loss of relative overpressure or loss of air flow) an audible and visual alarm is given at a manned control station and the electrical supply of all equipment (not necessarily of the certified safe type) is to be automatically disconnected.

vi) The mechanical ventilation system is to have at least twenty (20) air changes per hour or as required by the BWMS manufacturer, whichever is greater, that will maintain the separate compartment under a positive pressure relative to the external hazardous area.

vii) The external surface of the floor of the separate compartment is at a height of 2.4 m (8 ft) above the main deck tank top or, alternatively, a cofferdam is installed between the floor of the separate compartment and the main deck tank top with provisions for man entry into the internal cofferdam space for inspection.

viii) Where the external surface of the floor of the separate compartment is at a height of 2.4 m (8 ft) above the main deck tank top, an air lock with two gas-tight doors are not be required.

Note: * For designating compartments on the deck of MODUs, reference is to be made to Section 4-3-6 of the *Offshore Rules*.

3.4.2 Requirements for Hazardous BWMS Compartments

Where a vessel's cargo is a combustible liquid, having a flashpoint at or below 60°C (140°F) (closed cup test), and the ballast water originating from hazardous areas enters into such compartments, and there are no sources of release (i.e., cargo piping with flanged connections, valves, etc.) within the compartment, the interior of the compartment is to be hazardous (Zone 2) and the compartment is subject to the provisions of the following :

i) Mechanical exhaust ventilation is to be provided where the BWMS compartment has the same hazardous zone level as outside (e.g., both Zone 2 outside and inside compartment) or a mechanical supply fan is to be provided to maintain overpressure in the compartment where the BWMS compartment has a lower hazardous zone level than outside (e.g., Zone 1 outside and Zone 2 inside compartment) with at least twenty (20) air changes per hour. See 6-6-2/3.3.2ii.a.

ii) The components of the BWMS and other equipment located in the compartment are to be suitable for hazardous areas.

iii) When a mechanical exhaust ventilation is provided, a spherical volume with a radius of 3 m (10 ft), with the mechanical ventilation exhaust outlet as the center is to be hazardous (Zone 2).

iv) The mechanical or natural ventilation intake is to be located in a non-hazardous area.

v) When a mechanical exhaust ventilation is provided, the intake for the exhaust fan of non-sparking construction is to be from below or near the floor plates and the floor plates are to be of the open grating type to allow the free flow of air.

vi) Where the BWMS compartment has a lower hazardous zone level than outside (e.g., Zone 1 outside and Zone 2 inside compartment), the entrance door is to be of the self-closing type with no hold back arrangements, with a notice “Door to be kept closed at all times”.

vii) An appropriate clearance is to be maintained from the deck with or without a cofferdam. The external surface of the floor of the compartment is to be maintained at a sufficient height above the main deck tank top to facilitate inspection, with provisions for man entry into the internal spaces between the external surface of the floor and the main deck tank top.

viii) The requirements of Appendix 6-6-4-A5 are to be complied with.

Notes:

1 Zone 0 is an area in which an explosive gas atmosphere is present continuously or is present for long periods. See 3.15.1 of IEC 60092-502.

2 Zone 1 is an area in which an explosive gas atmosphere is likely to occur in normal operation. See 3.15.2 of IEC 60092-502.

3 Zone 2 is an area in which an explosive gas atmosphere is not likely to occur in normal operation but, if it does occur, will persist for a short period only. See 3.15.3 of IEC 60092-502.

4 See also Subsection 6-6-3/3.

3.5 BWMS Installations in Steering Gear Compartments

The steering gear compartment on vessels are not to be used for any other purpose other than for which they have been designed.

i) Steering gear compartments are to:

a) Meet the requirements of 4-3-4/1.7. See also SOLAS regulation II-1/29.13.

b) Be provided with access to the emergency fire pump, considering that the emergency fire pump is located in the steering gear room space.

c) Be part of the emergency escape routes on vessels.

ii) If the BWMS cannot be installed in other locations detailed in 6-6-2/3.1, ABS the installation of BWMS in steering gear compartments is acceptable subject to ABS technical assessment and approval. See 6-6-2/Figure 1.

For such cases the following requirements are to be complied with:

a) The BWMS is to be installed in a separate dedicated compartment that can be located within the steering gear compartment.

b) Ballast water piping is not to be routed through this separate compartment or through the other spaces in the steering gear compartment.

c) The location of the compartment is to be such that the items identified in 6-6-2/3.5.i are not compromised under all conditions of operation or failure of the BWMS. Furthermore, the location of the compartment is not to impede the escape routes.

d) The BWMS that can be in this compartment are to be of the non-combustion type and are limited to the following types:

- Stored or prepared chemicals and generated gasses
- Ozone generation/injection (categories 7a and 7b)
- Side stream biocide generation and injection (Electrochlorination systems that generate biocide by using a small slip stream.) (category 5)
- De-oxygenation by nitrogen injection (category 3a)
- Other technologies subject to ABS technical assessment and approval.

e) The small bore process chemical disinfectant, neutralizing chemical, slipstream seawater and freshwater cooling piping entering the separate compartment is acceptable.

f) To prevent liquid spray in case of leakages spraying on to the steering gear and its associated components and/or in to the emergency fire pump space, if applicable, the process liquid and the seawater or fresh water piping as applicable is to be routed from the BWMS compartment through the bulkhead between the BWMS compartment and the engine room.

g) The bulkhead penetration of the BWMS piping between the BWMS compartment and the engine room is to be of an approved type and have the same fire integrity as the division penetrated.

h) Any hazardous gases evolved as part of the BWMS process, such as hydrogen are to comply with 6-6-2/9.5.4.

i) A positive closing stop valve is to be installed in the BWMS compartment in each pipe at the bulkhead penetration between the BWMS compartment and the engine room.

j) The mechanical ventilation for the separate compartment is to be independent from the ventilation system of the steering gear compartment, and/or the ventilation of the emergency fire pump room, except that:

- The ventilation supply can be from the steering gear compartment.
- The ventilation outlet is to be routed to the weather deck.

k) The compartment is to comply with all the applicable sections of this Chapter.

l) For systems that use seawater or freshwater as part of their processes, the separate compartment is to be fitted with a bilge alarm.

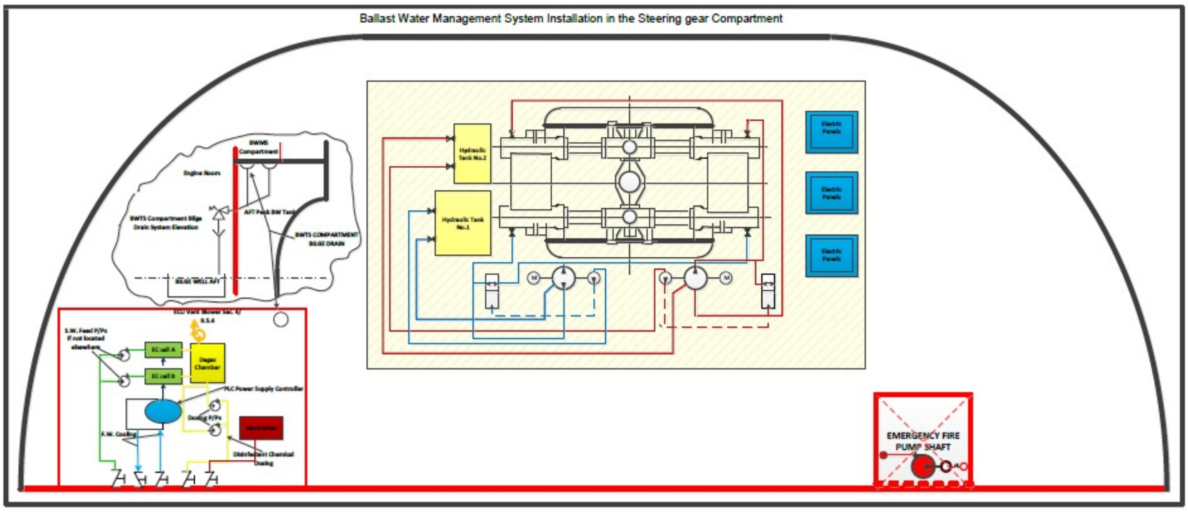
m) Bilge water may be drained in to the main machinery space; all such drains are to be fitted with a valve operable from above the freeboard deck or a quick-acting, self-closing valve. The valve is to be located in an accessible and visible location and preferably in the main machinery spaces. See 4-6-4/3.7.1 and 6-6-2/9.1.1.xii.

n) Gravity drains which terminate in engine room spaces protected by fixed gas extinguishing systems are to be fitted with means to prevent the escape of the extinguishing medium.

o) The separate compartment is to be installed with appropriate fire detection and fire-fighting provisions.

p) Alternative routing of process chemical disinfectant, neutralizing chemical, slipstream seawater and freshwater cooling piping is acceptable subject to ABS technical assessment and approval.

Figure 1
Example of a BWMS Compartment Installed in a Steering Gear Compartment



3.6 Structural Considerations

The treatment unit and related equipment are to be supported and the adjacent structures are to be stiffened as required. Structural considerations are subject to all relevant requirements listed in the Rules, and international regulations, standards, guidelines and recommendations.

The installation of a ballast water management system on a new or existing vessel is not to compromise the integrity of the vessel hull, framing, decks, bulkheads, tank structures, existing equipment foundations or additional structural members. Additionally, the application of a BWMS is not to adversely affect the ballast loading conditions, loading instrumentation, intact stability and damage stability.

Any modification to a vessel's structure, stability or safety considerations as a result of the ballast water treatment equipment is to be designed, constructed and surveyed as indicated in Part 6 Section 5 “Ballast Water Treatment”, Part 3 “Hull Construction and Equipment” and Part 5C “Specific Vessel Types”.

3.7 Corrosion Effects

BWMS is not to deteriorate, degrade or reduce the functional life expectancy of the ballast tank coatings or means of corrosion prevention. Additionally, the treatment method employed is prohibited from resulting in damage, deterioration or degradation to ballast piping and integral joints that are protected against corrosion by means of a coating or lining.

Several official IMO documents address the potential corrosive effects that ballast water management systems may have on the ballast tanks (including coatings) and the ballast system. Shipyards, BWMS manufacturers, owners and operators are to consider and, where appropriate, address the following:

i) The active substances and preparations used for the BWMS as well as the treated ballast water are to be compatible with the coating system (*G9 Guidelines*, Paragraph 3.4) *ii)* Data-set on the corrosivity to the materials or equipment of normal vessel construction are to be provided (*G9 Guidelines*, Paragraph 4.2.1.4)

iii) Application are to include corrosion testing of uncoated substrates and marine epoxy-coated steel; coating in accordance with IMP Performance Standard for Protective Coatings) (*MEPC 59/2/16*, Section 5.1)

iv) Documentation of preliminary assessment of the corrosion effects of the BWMS system (*BWM.2/Circ.28*)

v) Long-term corrosion effects of the treated ballast water on the ballast system and other spaces (Annex to *G8 Guidelines*, Part 1, Paragraph 1.3)

Copies of the documentation relating to the corrosion effects of the BWMS, including the test report or preliminary assessment report, which are a part of the IMO Member State's type-approval documents are to be provided to ABS for reference.

3.9 Ballast System

3.9.1 General

The ballast systems are to provide means of filling, transferring and draining ballast tanks employing a BWMS through the provisions of redundancy, certification of BWMS pumps and remote control, where fitted.

A ballast system design including piping, pumps, valves, and other piping equipment is to comply with all criteria for ballast systems as indicated in Part 6 Chapter 5 and Part 4.

Additional ballast system piping requirements for oil, gas, and chemical carriers, including safety arrangements, are to comply with the relevant sections of Part 5C.

Where the ballast system has a capacity exceeding the treatment rated capacity of an in-line BWMS, an appropriate flow control arrangement is to be provided for the ballast pumps.

BWMS designs and installations on MODUs are to comply with the requirements of Part 6 Chapter 5, the *Offshore Rules* and the IMO *Code for the Construction and Equipment of Mobile Offshore Drilling Units*, as applicable.

3.9.2 Ballast Pumps

Any modification to the existing ballast pumps, installation of new ballast pumps, or installation of booster pumps are to comply with the requirements in 4-6-4/7.3.

3.9.3 Piping Components Materials and Design

i) The materials and design of all BWMS piping components (see definition in 4-6-1/3.5) are subject to the requirements of Sections 4-6-1 and 4-6-2.

  i) The main components of a BWMS, such as filters subjected to or rated at a pressure greater than 6.9 bar as defined in 4-4-1/Table 1 and 4-4-1/Table 2, are required to be 'Unit Certified' to the satisfaction of an ABS Surveyor for all installations.

  ii) Piping and piping components associated with these main BWMS components are to meet the requirements of 4-6-1/Table 1 and 4-6-1/Table 2.

ii) In addition, BWMS piping using miscellaneous nonmetallic components made of thermoplastic or thermosetting plastic material such as polyvinyl chloride (PVC), fiber-reinforced plastic (FRP), etc., are to comply with the requirements of Section 4-6-3. However, the BWMS piping not complying with the fire endurance and flammable spread requirements (4-6-3/5.11 and 4-6-3/5.13) are subject to ABS technical assessment and approval and the additional requirements specified below :

a) The components of the ballast water treatment equipment are to be arranged on a skid. Modular installation design is acceptable, subject to ABS technical assessment and approval.

b) The inlet, outlet and drain pipes connected to the skid-mounted unit are to be made of steel or equivalent materials. However, thermoplastic or thermosetting plastic pipe of approved type and design, which has passed at least the level 3 (L3) fire endurance tests, is acceptable.

c) Depending on the location of the skid-mounted unit within an approved space, local firefighting arrangements and/or a metallic enclosure covering the nonmetallic components can be required at the discretion of ABS.

d) In case of emergencies, remote operable bypasses are to be provided to isolate the nonmetallic piping system on the skid-mounted unit from the rest of the vessel's piping system.

e) For the skid-mounted ballast water treatment equipment installed in hazardous locations, the requirements in this section are applicable in addition to the requirements specified in Section 6-6-3.

f) The requirements of the vessel's Flag Administration for nonmetallic components made of thermoplastic or thermosetting plastic material are to be satisfied.

iii) Where the piping is conveying active substances, by-products or neutralizers that are containing dangerous gas or dangerous liquids, the following requirements apply:

Note:

This requirement is applicable to the injection lines conveying the dangerous gas or dangerous liquids but not applicable to the ballast water lines where the dangerous gas or dangerous liquids are diluted. The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (*G9 Guidelines*) are to be used for assessing the hazards that are to be expected from the media conveyed by the BWMS piping.

a) Irrespective of design pressure and temperature, the piping is to be either of Class I (without special safeguard) or Class II (with special safeguard) as required by 4-6-1/Table 1. The selected materials, the testing of the material, the welding, the non-destructive tests of the welding, the type of connections, the hydrostatic tests and the pressure tests after assembly on-board are to be as required in Section 4-6-2. Mechanical joints, where allowed, are to be selected in accordance with 4-6-2/5.9.

Notes:

i 1 For piping class II with special safeguards conveying dangerous gas such as hydrogen (H_2), oxygen (O_2) or ozone (O_3), the special safeguards are to be either double walled pipes or pipe duct.

ii For piping class II with special safeguards conveying dangerous liquids, other special safeguards like shielding, screening, etc. are acceptable.

iii Plastic pipes can be accepted after ABS technical assessment of the dangerous gas or dangerous liquids conveyed inside. When plastic pipes are accepted, the requirements of 6-6-2/3.9.3.ii above are to be met, as applicable.

b) The length of pipe and the number of connections are to be minimized.

c) Inside double walled space or pipe ducts constructed as the special safeguard for the purpose of Note 1) above are to be equipped with mechanical exhaust ventilation leading to a safe location*[(3) & (4)] on open deck.

Note:

Safe location*[(3)]: hydrogen by-product enriched gas from in-line full flow electrochlorination BWMS (category 4), in-line side-stream electrochlorination BWMS (category 5) and in-line injection BWMS using chemical which is stored onboard (category 6): the hydrogen de-gas arrangement (when provided):

Safe locations on the open deck are: not within 5 m (16.5 ft) of any source of ignition and from deck machinery, which can include anchor windlass and chain locker openings, and equipment which can constitute an ignition hazard; not within 3 m (10 ft) of areas traversed by personnel; and not within 5 m (16.5 ft) of air intakes from non-hazardous enclosed spaces.

The areas on open deck, or semi-enclosed spaces on open deck, within 3 m (10 ft) of the outlets are to be categorized hazardous zone 1 plus an additional 1.5 m (5 ft) surrounding the 3 m (10 ft) hazardous zone 1 is to be categorized hazardous zone 2.

Safe location*[(4)]: For in-line ozone injection BWMS (categories 7a and 7b), vent outlet from O_3 destructor device (ODS) can be considered as oxygen-enriched air provided that: the ODS are duplicated; and the manufacturer justified that the quantity of consumable (activated carbon) used by the ODS is sufficient for the considered life cycle of the BWMS; and ozone detection is arranged in the vicinity of the discharge outlet from the vent outlet of the ODS to alarm the crew in case the ODS is not working.

If one of the above 3 conditions is not fulfilled, the safe location from ODS on open deck are: outside of hazardous area; not within 3 m of any source of ignition; not within 6 m (20 ft) of areas traversed by personnel; and not within 6 m (20 ft) of air intakes for machinery (engines and boilers) and all ventilation inlets.

d) The routing of the piping system is to be kept away from any source of heating, ignition and any other source that could react hazardously with the dangerous gas or liquid conveyed inside. The pipes are to be supported and protected from mechanical damage.

e) Pipes carrying acids are to be arranged so as to avoid any projection on crew in case of a leakage.

3.9.4 Vent Piping

The vent pipe location of a ballast water management system that vents explosive and toxic gases is to comply with the intent of IEC 60092-502 as applicable. A spherical distance within 3 m (10 ft) measured with the vent outlet as the center is to be hazardous.

3.9.5 Ballast Water Sampling Piping

Provision of sampling points are required to maintain operational safety and regulatory compliance of the BWMS. The sampling system is to provide for compliance with Section 5 of the *Resolutions MEPC.173(58) Guidelines for Ballast Water Sampling (G2)*.

Piping is to be arranged such that samples are to be taken from the ballast water discharge piping as close to the point of discharge as feasible. BWMS that employ treatment during discharge operations is to use in-line sampling. Details regarding the sampling facility design as required for compliance are located in Section 5 and Parts 1 and 2 of the *G2 Guidelines*.

3.9.6 Remote Control Valves

Remote control valves, where fitted, are to be arranged so that they will close and remain closed in the event of a loss of control power or emergency shutdown. Alternatively, the remote control valves may remain in the last ordered position upon loss of power, provided that there is a readily accessible manual means to close the valves upon loss of power. Additionally, remote control valves are to be provided with position indicators in the BWMS instrumentation display at the ballast control station.

3.9.7 Damage Stability Consideration

BWMS piping, where installed within zones of the assumed extent of damage under damaged stability conditions, is to comply with 4-6-4/1.5.

3.9.8 Ballast Water Stripping

For BWMS that employ a double passage method (i.e., treating the ballast water both at intake and at discharge), arrangements are to be provided such that, in the ballast stripping operation, the water stripped from the ballast tank can also be routed through all the required treatment equipment and processes identified in the IMO Member State's type-approval for the ballast discharge operation without damaging the BWMS due to sediment and particles in the stripped ballast.

For chemical treatment systems that need to neutralize the residual oxidants in the ballast water before discharge, the driving fluid for any eductor involved in the stripping operation affects the efficacy of the neutralization, depending on where the neutralizer is applied (before or after the eductor) and where the measurements of the TRO (total residual oxidants) level in the ballast system are taken, which can require an adjustment to the amount of neutralizer needed. The effectiveness of the neutralization is to be addressed in the ballast water stripping design and operation.

For oil and chemical carriers, protection measures are to be provided to address the interconnection of piping between the fire/general service pump in the machinery space (non-hazardous space) and the ballast stripping eductor in the cargo pump room (hazardous space). See 6-6-3/7.3.

3.9.9 Bypass Arrangements

Suitable bypass and interlocking arrangements accepted by ABS are to be provided to isolate the BWMS from the ballast system piping such that the ballast system can be operated totally independently from the BWMS in the event of emergency. Any bypass of the BWMS is to activate an alarm, and the bypass event is to be recorded by the BWMS Control Equipment.

3.11 Electrical System

3.11.1 General

Unless specifically stipulated otherwise in this Chapter, the electrical system and electrical equipment are to be in accordance with the applicable electrical requirements of the Rules. The arrangement for placement of electrical equipment in hazardous area are to be in accordance with Appendix 6-6-3-A5.

3.11.2 Electrical Load Analysis

The electrical load of a BWMS is to be such that under all anticipated ballasting or de- ballasting operating conditions, the electrical generating capacity installed on the vessel is to be demonstrated by an electrical load analysis.

3.11.3 Computer-Based Systems

Where a BWMS is installed with a computer-based control system, the computer-based system is to comply with the requirements of Section 4-9-3, 4-9-9/13, 4-9-10/5.1, 4-9-10/5.2, 4-9-13 and 4-9-14. The BWMS belongs to system category II. See 4-9-3/Table 1, 4-9-3/Table 2 and 4-9-3/Table 3.

Changes or upgrades of ABS approved computer-based control systems are to comply with the requirements of 4-9-3/5.1.9.

Where it is determined that improper operation of the computer-based system can result in an unsafe situation with respect to the treatment process, a detailed failure mode and effects analysis (FMEA) is required.

3.13 Instrumentation

3.13.1 Local Instrumentation

Local instrumentation and controls of the BWMS are to be fitted to enable ease of operation, maintenance and control in the event of an emergency or failure of any remote controls. Local instrumentation is to indicate ballast operating conditions and status of the ballast water treatment equipment. For installations where the BWMS equipment that is not located in the same space as the ballast pumps, the operational status of the ballast pumps is to be indicated near the BWMS equipment. The local instrumentation is to include:

i) Ballast pump operational status (e.g., pressure gauge)

ii) BWMS and equipment operational status

iii) Remote control valve, where fitted, position indication

iv) Necessary instrumentation for all BWMS equipment parameters and specific conditions, as applicable

3.13.2 Ballast Control Station Displays

Where remote control stations are fitted, the instrumentation parameters as indicated in 6-6-2/3.13.1.i to 6-6-2/3.13.2.iv and the ballast tank level indications where a tank level gauging system is fitted are to be displayed at the remote control station.

A tank level gauging system, where fitted, is to be capable of measuring the full height of all ballast tanks individually and is to be provided at the ballast control station. Where applicable, the tank level gauging system is to be compatible with the BWMS such that the level gauging system can be integrated with the BWMS.

5 Mechanical Separation Systems

BWMS utilizing mechanical separation are to comply with the following:

i) The maximum pressure loss across the separation system during normal operating conditions is not to prevent or impair the ability of the ballast system to supply the most hydraulically remote ballast tank at an acceptable flow rate identified in the BWMS manual.

ii) The arrangements for back washing, including the flow rate, pressure differential, sizing and routing of the overboard discharge piping, etc., are to be designed such that all wastes will be adequately removed from the separation system when taking into account the maximum static head imposed when the vessel is at its maximum draft.

iii) Arrangements (e.g., controls, procedures, etc.) are to be designed such that the separation system will be back washed and flushed clean upon completion of ballasting operations before the vessel departs the ballasting port.

7 Physical Treatment Systems

The methods of physical treatment used in BWMS include cavitation, thermal (heat), inert gas, ultrasound, and ultraviolet (UV) disinfection. Additional criteria are included, as applicable, within the individual treatment subsection.

7.1 Cavitation and Ultrasound Systems

Any pressure loss across the cavitation or ultrasound treatment system during normal operating conditions is not to prevent or impair the ability of the ballast system to supply the most hydraulically remote ballast tank at an acceptable flow rate identified in the BWMS manual.

When cavitation is the BWMS treatment process (e.g., by use of pressure vacuum reactor working in combination with a vertical ballast water drop line) or part of the BWMS treatment process (e. g., by use of "smart pipe" or "special pipe" in BWMS category 7b or by use of "venturi pipe" in BWMS category 3b or by use other means, the design and the wall thickness or grade of materials or inside coating or surface treatment of the part of the piping where the cavitation is taking place is subject to ABS technical assessment and approval.

7.3 Thermal Systems

The application of thermal (heat) treatment for ballast water management systems is subject to a review of all plans, energy balances, structural considerations and operations. Equipment installed for the application of heat to ballast water is subject to all relevant requirements in the Rules.

7.5 Inert Gas De-oxygenation Systems (category 3a, 3b, 3c and 8)

The design, construction and operational criteria for a BWMS supplying inert gas to ballast tanks are to comply with 5C-2-3/25.43.1(f) to 5C-2-3/25.43.1(l), 5C-2-3/25.43.2(b), 5C-2-3/25.43.2(e) and 5C-2-3/25.43.3. The height of pressure and vacuum valves are to be set in accordance with 4-6-4/9.3.2(a). Where inert gas is injected directly into the ballast piping, equivalent arrangements for safety, monitoring and controls specified in the aforementioned 5C-2-3/25.43 are to be provided, as applicable.

Any interconnections of a shipboard inert gas system and a vendor-supplied inert gas generator intended for ballast treatment is to be subject to ABS technical assessment and approval, and arrangements for isolation, interlocks and controls are to be submitted for review.

Additionally, any pressure loss across the treatment system during normal operating conditions is not to prevent or impair the ability of the ballast system to supply the most hydraulically remote ballast tank at an acceptable flow rate identified in the BWMS manual. Inert gas installed for de-oxygenation BWMS (categories 3a, 3b, 3c and 8) are required to comply with the following requirements :

- 5C-2-3/25.1.1
- 5C-2-3/25.1.2, 5C-2-3/25.7, 5C-2-3/25.13.2 (first paragraph), 5C-2-3/25.25.3, 5C-2-3/25.19.1, 5C-2-3/25.31, 5C-2-3/25.31.1, 5C-2-3/25.31.2, 5C-2-3/25.31.3, 5C-2-3/25.37.1 except 5C-2-3/25.37.1viii), 5C-2-3/25.37.3, 5C-2-3/25.37.4, and 5C-2-3/25.37.8
- 5C-2-3/25.7.1ii), 5C-2-3/25.17, 5C-2-3/25.13.2 (last paragarph), 5C-2-3/25.9, 5C-2-3/25.15, 5C-2-3/25.37.2 except 5C-2-3/25.37.2i)
- 5C-2-3/25.41.3, 5C-2-3/25.41.2(e) and 5C-2-3/25.41.5
- For inert gas systems installed for in-tank de-oxygenation BWMS (category 8): 5C-2-3/25.19, 5C-2-3/25.21 except 5C-2-3/25.21.5, 5C-2-3/25.25.4 and 5C-17/25.21.2(b)

When applying requirements of 5C-2-3/25 to inert-gas based BWMS, the following are to be considered:

- The terms "cargo tank" and "cargo piping" are to be replaced by "ballast water tank" or "ballast water piping" as relevant.
- The term "cargo control room" is to be replaced by "BWMS control station" as relevant.
- Requirements for slop tanks on combination carriers are to be disregarded.
- When applying the requirements of 5C-2-3/25.37.1, the acceptable oxygen content is to be specified by the manufacturer, and the 5% oxygen content in the Rules need not be applied.

In spaces where inert gas generator systems are fitted (categories 3b and 3c) or nitrogen generators are fitted (categories 3a and 8), at least two oxygen sensors (as required by 5C-2-3/25.33) are to be positioned at appropriate locations to alarm when the oxygen level falls below 19%. The alarms are to be both audible and visual and are to be activated: inside the space; at the entry into the space; and inside the BWMS control station.

7.7 Ultraviolet (UV) Disinfection Systems (category 1)

Ultraviolet disinfection BWMS are required to comply with all applicable criteria in the Rules, and international regulations, standards, guidelines and recommendations.

Arrangements are to be provided such that the crew will not be exposed to excessive amounts of UV light during operation, maintenance or repairs of the system. Additionally, the following arrangements are to be provided:

i) A high temperature alarm and a High-High temperature alarm with automatic system shut down

ii) A UV intensity meter

iii) Means to prevent the accumulation of air in the top of the lamp enclosure or treatment chamber

iv) A means to prevent operating the UV lamps without water in the treatment chamber in order to avoid overheating the UV unit. An example of such means include an interlock or an appropriate piping arrangement that maintains a constant flow of water through the treatment chamber to dissipate the heat, etc.

v) Protection of electrical equipment with respect to overcurrent or overvoltage, degree of enclosure, insulation materials and maximum ambient temperatures in accordance with 4-8-3/1 and the manufacturer's specifications.

vi) A document confirming the instrumentation, monitoring and control equipment for all vital parameters such as the UV dose, lamp power, intensity, etc., including the application conditions for effective assessment of the treatment operations, as specified in the IMO Member State's type-approval is to be submitted to ABS.

9 Chemical Treatment/Active Substances Systems

9.1 Prepared Chemical Treatment Systems

9.1.1 General

BWMS employing a chemical treatment are required to comply with all the criteria specified in the Rules, international regulations, standards, Flag Administration criteria, guidelines, recommendations or requirements specified in the chemical manufacturer's Material Safety Data Sheet (MSDS), and local standards involving the discharge of chemical substances. All equipment, piping and components storing, conveying or creating flammable, toxic or corrosive chemicals as provided for, created by or resulting from a BWMS are to be designed, constructed, operated and maintained in accordance with the applicable requirements in Section 4-6-4, and if applicable, criteria established by a vessel's Flag Administration criteria.

These documents, standards, and criteria are to be reviewed and applied in conjunction with the Rules.

When the chemical substances are stored inside integral tanks, the vessel's shell plating is not to form any boundary of the tank.

Tanks containing chemicals are to be segregated from accommodation, service spaces, control stations, machinery spaces not related to the BWMS and from drinking water and stores for human consumption by means of a cofferdam, void space, cargo pump-room, empty tank, oil fuel storage tank, BWMR or other similar space. On-deck stowage of permanently attached deck tanks or installation of independent tanks in otherwise empty hold spaces is considered as satisfying this requirement.

Note:

The requirements in the above paragraph can be reduced when the stored chemicals are neither toxic nor flammable. The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (*G9 Guidelines*) and "safety hazard" as listed in Section 5C-9-17 are to be considered for this purpose. Chemicals include additives and neutralizers for BWMS.

Additionally, the following arrangement/procedures as applicable to the specific chemical treatment system are to be satisfied:

i) Implementation of a safe and secure means of transferring chemical onto the vessel. Such measures include a containment that is impact resistant, leak-proof, airtight, and watertight. Volume, weight, and concentration standards for the chemicals need to be considered.

ii) Design and installation of the containment system for all liquid chemicals that are stored and used are to be such that it prevents any chemicals from escaping under the maximum inclination conditions and to accommodate the type and volume of chemical being used in the event the primary containment barrier fails.

iii) Chemicals provided as a gas are to comply with 4-6-7/7.3 and 4-6-7/7.5.

iv) In addition to 6-6-2/9.1.1.i above, a safe means is to be provided to transfer the stored chemicals into operation.

v) As applicable, an approved gas detection system is to be installed in all spaces housing the chemicals and chemical treatment systems, to provide a safe environment, proper air supply, ventilation, and leakage detection. Alarm levels is subject to ABS technical assessment and approval.

Inside double walled spaces or pipe ducts constructed for the purpose of 6-6-2/3.9.3.iii, sensors are to be provided for the detection of H2 leakages (BWMS categories 4, 5 and 6 when relevant) or O_2 leakages (BWMS categories 7a and 7b) or O_3 leakages (BWMS categories 7a and 7b). The sensors are to activate an alarm at the high level settings and automatic shut-down of the BWMS at the high-high level settings described above and in 6-6-2/7.5 and 6-6-2/9.3.1.

Commentary:

As an alternative to the sensor for the gas detection, an automatic alarm and shut-down of the BWMS in case of loss of the under-pressurization inside the double walled spaces or pipe ducts could be considered. The monitoring can be achieved either by monitoring the pressure inside the double walled spaces or pipe ducts or by monitoring the exhaust fan.

End of Commentary

vi) A high-temperature, a high-pressure alarm and automatic shutdown are to be provided, for any BWMS equipment which are considered unsafe due to an increase in temperature or pressure.

vii) A low pressure alarm and automatic shutdown are to be provided, as applicable.

viii) Chemical level indication, alarms, and automatic shutdown are to be arranged at remote and local control stations.

ix) The system is to be capable of self-monitoring and recording of chemical dosages or treatment intensities.

x) Means to prevent overflowing the ballast tanks and unintentional ballast discharge prior to discharge treatment or at any point during the ballast retention above acceptable residual limits is to be provided. Such measures is not to impair the safety and stability of the vessel under all operating conditions.

xi) All equipment, piping, components and coatings exposed to chemical treatments are to be compatible with the chemical. Chemical treatment is not to induce or accelerate the corrosion of any BWMS or ballast system component.

xii) For BWMS using chemical substances or dangerous gas which are stored on-board for either: storage or preparation of the active substances (categories 2 and 6), or storage or preparation of the neutralizers (categories 4, 5, 6, 7a and 7b), or recycling the wastes produced by the BWMS (category 2), procedures are to be in accordance with the MSDS and BWM.2/Circ.20 "Guidance to ensure safe handling and storage of chemicals and preparations used to treat ballast water and the development of safety procedures for risks to the vessel and crew resulting from the treatment process", and the following measures are to be taken as appropriate:

Dangerous liquids and dangerous gas storage tank air pipes are to be led to a safe location (see Notes in 6-6-2/3.xii) on open deck.

An operation manual containing chemical injection procedures, alarm systems, measures in case of emergency, etc. is to be kept onboard.

Chemical storage tanks and other associated components of the BWMS subject to leakage are to be provided with spill trays or secondary containment system of ample size, large enough to cover the leakage points such as manholes, drain valves, gauge glass, filter, pumps, etc. Drains from such spill trays or chemical dosing sampling/vent piping are not to be led to the engine room or cargo pump room bilges or engine room sludge tanks. When necessary, arrangement is to be provided within the spill trays (or within the secondary containment system) for the detection of dangerous liquid or dangerous gas. The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (*G9 Guideline*) are to be used for this assessment.

xiii) Where applicable "Gas Detection Arrangements" and "Potential Discharge to Ballast Tanks", are to comply with 6-6-2/9.5.6 and 6-6-2/9.5.7.

xiv) Where de-gas arrangements are provided, the control arrangements are to comply with 6-6-2/9.5.4 and 6-6-2/9.5.5.iv.

9.1.2 Safety Assessment

A safety assessment study specific to the BWMS to be installed and the specific type of vessel (chemical carrier, oil carrier, gas carrier, container vessel, bulk carrier, etc.) to address the risk to the vessel and its crew is to be conducted. The scope of the safety assessment is to include at least the following subjects:

9.1.2(a) The scope of the safety assessment is to include at a minimum the following:

i) The loading and storage of chemicals or preparations onto the vessel.

ii) The transfer and application of chemicals or preparations from storage to the BWMS.

iii) The position of the BWMS and associated piping.

iv) Operation of the BWMS, specifically any potential impacts on the vessel's crew.

v) Maintenance of the BWMS and safe work procedures.

vi) Spillages from the BWMS and emergency response plan.

vii) Toxicity of chemicals or gasses associated with the treatment process.

viii) Flammability of chemicals or gasses associated with the treatment process.

9.1.2(b) Specifically, this safety assessment is to address at a minimum the following:

i) Adequacy of the chemical containment system

ii) Ventilation system

iii) Fire protection and extinction of those spaces where the chemicals or preparations are stored, as applicable

iv) Vessel-specific details concerned with the loading of the ballast water treatment chemicals onto the vessel

v) The handling and application of chemicals or preparations into the BWMS

vi) The development of vessel-specific health and safety procedures for the normal operation of the BWMS, and

vii) Procedures to be followed in the event of a spillage on board or crew exposure to the treated ballast water, chemicals or preparations.

The safety assessment is to be undertaken prior to the installation of the BWMS, so that any mitigation measures identified during the assessment study can be applied either prior to or during installation. This safety assessment is to be reviewed by ABS to confirm the adequacy of the proposed arrangements. Relevant information resulting from the safety assessment is to be documented in the vessel's BWMP.

Safety assessments approved by ABS for a specific BWMS installed on a specific type of vessel would be considered in lieu of a safety assessment submission for each BWMS installations on these specific type of vessels.

Additional guidance can be found in the IMO BWM.2/Circ.20, "Guidance to ensure safe handling and storage of chemicals and preparations used to treat ballast water and the development of safety procedures for risks to vessel and crew resulting from the treatment process".

9.3 Ozone Injection Systems (categories 7a and 7b)

9.3.1 Gas Detection

i) Ozone sensors are to be installed in the immediate vicinity of the ozone generating unit and along the route of the ozone piping where ozone gas can accumulate. More specifically:

At least one ozone sensor is to be provided at the vicinity of the discharge outlet to the open deck from the ozone destructors to alarm when the ozone concentration level raises above 0.1 ppm. In addition, at least two ozone sensors are to be positioned in spaces where ozone generators are fitted, spaces where ozone destructors are fitted or spaces where ozone piping is routed, to alarm when the ozone concentration level raises above 0.1 ppm. The ozone sensors are to activate an audible and visual alarm at the following locations:

- inside the space
- at the entry into the space; and
- inside the BWMS control station.

ii) At least two oxygen sensors are to be positioned in spaces where ozone generators are fitted, spaces where ozone destructors are fitted or spaces where ozone piping is routed, to alarm when the oxygen level raises above 23%. The alarms are to be both audible and visual and activated at the following locations:

- inside the space; and
- at the entry into the space; and
- inside the BWMS control station.

9.3.2 Ozone-Based BWMS Installation

i) Ozone-based BWMS (categories 7a and 7b) are to be located in a dedicated compartment, separated from any other space by gastight boundaries. Access to the BWMR from any other enclosed space is to be through airlock only, except if the only access to that space is from the open deck.

A sign is to be affixed on the door providing personnel with a warning that ozone may be present and with the necessary instructions to be followed before entering the room. If the access to the BWMR is from engine room through an airlock, an alarm repeater is provided in the BWMR, which repeats any alarm activated in the engine room.

ii) The construction, installation and routing of the ozone piping is to comply with the manufacturer's recommendations and is not to pass through accommodations or service spaces.

9.3.3 Specific System Arrangements

The arrangements of an ozone-based BWMS (categories 7a and 7b) are to comply with the following:

i) Independent vents from the oxygen receiver safety relief valve and any ozone destructor unit are to be led directly to a place on the open deck where the discharges will not cause a safety or health hazard. See Note on 6-6-2/3.9.3.iii.c.

ii) Arrangements are to be provided to automatically shut down the system, close the remote control valves and stop all pumps under the following conditions:

a) High ambient oxygen concentration (25%);

Note: Audible and visual alarms independent from those specified above are to be activated prior to this shut-down.

b) High ambient ozone concentration (0.2 ppm), when measured from one of the two sensors inside the space. See 6-6-2/9.3.1;

c) The "ozone destructor" (VOD) not being available, if part of the system;

d) Activation of fire alarm in area of installation; and

e) Emergency stop push button pressed.

iii) Permanent warning plates are to be installed near any areas into which the oxygen or ozone could escape.

iv) A Safety Assessment is to be conducted. See the applicable requirements of 4/9.1.2 6- of this Guide.

9.5 Electrochlorination Systems (categories 4 and 5)

9.5.1 Installation Arrangement

Where the electrochlorination unit (ECU) of the BWMS is approved to be installed in hazardous areas, refer to Section 6-6-3 and Appendix 6-6-3-A5.

9.5.2 Piping Arrangements

Arrangements are to be provided such that the ECU chamber is always filled with water to avoid creating an explosive atmosphere in the event of ingress of flammable fluid into the ECU chamber, and also to avoid excessive surface temperature in the event of a water level drop. Placing the ECU at a lower position is an acceptable piping arrangement since it acts asa water trap.

Overflow protection for ballast tanks is to be in accordance with 6-6-2/9.1.1.x.

9.5.3 Ventilation Requirements

Where the ECU is installed in a compartment, other than those hazardous compartments in 6-6-2/9.5.1, the ventilation requirements are to comply with 6-6-2/3.3.1. The BWMS is to be interlocked with the ventilation system so that the ECU cannot be operated unless the ventilation system is in operation. Failure of the ventilation in the vicinity of the ECU is to give an audible and visual alarm at a manned location.

9.5.4 ECU Vents

Exhaust piping vents for any gases generated in the electrochlorination process that is flammable or toxic are to be welded.

The hydrogen de-gas arrangement (when provided) is to be provided with redundant ventilation fans and redundant monitoring of the ventilation system. The ventilation fan is to be certified explosion proof and have spark arrestor to avoid ignition sources to enter the ventilation systems whereas remaining H_2 gas can be present in dangerous concentrations.

9.5.5 Additional Control Arrangements

The following additional control arrangements are to be provided:

i) An interlock arrangement is to be provided such that the ECU cannot be energized if water flow is less than an acceptable flow rate as identified in the BWMS Manual.

ii) Interlocks, with water level or leakage detection, are to be provided so that in the event of a drop in the water level the electrical power to the ECU is shut down.

iii) An independent safety shutdown is to be provided such that excessive temperature or pressure in the ECU shuts down the power supply. This safety shutdown system is to be independent of the control system.

iv) Audible and visual alarms and automatic shut-down of the BWMS are to be arranged for respectively high and high-high levels of H2 concentration. The open end of the hydrogen by-product enriched gas relieving device is to be led to a safe location *(3) on open deck. See 6-6-2/9.5.4.

Note: For *(3) see 6-6-2/3.9.3.iii

v) Notwithstanding the above, at least two independent means of monitoring operation are to be provided for ECU. The monitoring system is to initiate audible and visual alarms and automatic shutdown of the BWMS in the event that an anomaly is detected. See 6-6-2/3.xiv.

Note: If a pressure relief valve is also provided, the vent of this valve is to be led to a safe location on the open deck, as clarified in Note on 6-6-2/3.9.3.iii.c. The valve is to be positioned to remove gas from the ECU.

vi) The arrangements required in items i) through v) are not to have any overrides or bypasses to defeat the intended safety measures.

9.5.6 Gas Detection Arrangements

A fixed hydrogen gas detection system is to be provided in the space housing the ECU and arranged such that the activation of the gas detection alarm will result in an automatic shutdown of all electrical power to the BWMS.

Commentary:

A BWMS of a full flow electrochlorination process (category 4), may preclude the installation of hydrogen gas detection arrangements, subject to:

i The results of the Safety Assessment required in 6-6-2/9.5.8 below, demonstrating that the amount of hydrogen gas generated is far below the threshold values for which the hydrogen gas evolved may be considered as explosive, and.

ii IMO Member State Type Approval has certified installation of the BWMS without the inclusion of hydrogen gas detection arrangements.

End of Commentary

9.5.7 Potential Discharge to Ballast Tanks

The potential of any flammable or toxic gas released into the ballast tanks due to the operation of the electrochlorination system and the associated concentration and volume are to be identified and assessed in the safety assessment. See 6-6-2/9.5.8. Where the concentration and/or volume of any flammable or toxic gases released into the ballast tanks could present a danger to the vessel or a hazard to the crew, arrangements are to be provided for the safety of the vessel and crew (e.g., suitability of level gauging system in tank, venting location and arrangements, etc.).

9.5.8 Safety Assessment

A Safety Assessment is to be conducted. See the applicable requirements of 6-6-2/9.1.2.

11 Combination Treatment

Installation requirements for combination treatments are subject to all criteria and standards for the individual treatment methods applied to the combination treatment.

13 Other Treatment Types

BWMS involving a process other than those specifically addressed in Subsections 6-6-2/5 through 6-6-2/9 above are subject to special consideration ABS technical assessment and approval. See 6-6-2/1.1.3.

15 Special Fire Fighting Equipment and Arrangements

15.1 General

The requirements for fire safety are to be identified by the BWMS manufacturer and are to be based on the following principles:

i) The requirement of fire detection and extinguishing systems and equipment capable of extinguishing the type and scale of fire likely to occur in association with the installed BWMS.

- Where fitted, fixed fire-extinguishing systems are to comply with the relevant requirements of Section 4-7-3.
- BWMR containing equipment related to ozone-based BWMS (categories 7a and 7b) are to be provided with a total-flooding fixed fire extinguishing system installed in category A machinery spaces (See Section 4-7-3) and capable of manual release.
- Where a fixed fire-extinguishing system is provided in the BWMR, it should be compatible with the BWMS and the chemical products that are used, produced or stored in the BWMR. Specific attention is to be paid to potential chemical reactions between the fire extinguishing medium and chemical products used for water treatment. Especially, water-based fire-extinguishing systems is to be avoided in case of sulfuric acid storage.
- For all kinds of BWMS, in case a foam fire extinguishing system is installed in the BWMR, its efficiency is not to be impaired by chemicals used by the BWMS where relevant.
- Where a fixed fire-extinguishing system is installed in the BWMR, automatic shutdown of the BWMS upon release of the fixed fire extinguishing system is to be provided. Any need for

cooldown necessary for safe shutdown of the BWMS to be considered in the shutdown sequence.

- Where BWMS that includes air or O_2 storage is located in a room covered by a fixed gas fire-extinguishing system, air or O_2 storage is to be taken into account for the gas capacity calculation, unless the discharge pipe from safety valves for air or O_2 storage are led directly to outside the room.
- At least one portable fire extinguisher is to be provided, complying with the requirements of Section 4-7-3 and suitable for electrical fires in the BWMR containing UV-type BWMS (category 1).
- A fixed fire detection and fire alarm system complying with the provisions of Section 4-7-3 is to be installed in spaces containing an inert gas generator or an ozone generator (categories 3a, 3b, 3c and 8). A section of fire detectors which covers a control station, a service space or an accommodation space is not to include a BWMR containing equipment related to ozone-based BWMS (categories 7a and 7b).

ii) If installed in a separate compartment, for the application of structural fire protection requirements, the BWMR is to be treated as follows for the purpose of applying the requirements of SOLAS Chapter II-2:

- BWMR containing oil-fired inert gas generators (categories 3b and 3c) are to be treated as machinery spaces of category A
- Other BWMR are to be considered as other machinery spaces and be categorized, depending on the vessel type (10) or (11) according to SOLAS regulation II-2/9.2.2.3 or (7) according to SOLAS regulation II-2/9.2.2.4, II-2/9.2.3 and II-2/9.2.4
- Notwithstanding the above, where a BWMS is located in the cargo area of a tanker as allowed by Section 6-6-3, the BWMR is to be categorized as (8), a cargo pump-room, according to SOLAS regulation II-2/9.2.4.2.2 for determining the extent of fire protection to be provided.

iii) The identification of fire risk of the BWMS, including the active substances or preparations used or generated, and the provisions of effective means to prevent and extinguish fires in the BWMS space is to be submitted for review by ABS.

If BWMS is installed on existing vessels, the BWMS is not to impede the firefighting measures provided for the vessel. Where such special firefighting instructions and/or requirements of the BWMS interferes with the firefighting equipment or system provided in accordance with other Rule requirements, the same is to be clearly identified and subject to ABS technical assessment and approval.

15.3 Recording in the Vessel's Manual

The special firefighting instructions and/or requirements approved by ABS in 4/15.1 above are to be identified in the vessel's operating and safety manuals, and placards indicating the same are to be posted in appropriate locations.

15.5 Spaces Used for the Storage of Chemicals

i) Spaces where the storage of liquid or solid chemicals for BWMS is intended are to be categorized as store-rooms for the purpose of applying the requirements of SOLAS Chapter II-2:

- On passenger vessels carrying more than 36 passengers: "Other spaces in which flammable liquids are stowed" as defined in SOLAS regulation II-2/9.2.2.3.2.2(14), if flammable products are stored; or "Store-rooms, workshops, pantries, etc." as defined in SOLAS regulation II-2/9.2.2.3.2.2(13) otherwise
- On other vessels: "Cargo pump-rooms" as defined in SOLAS regulation II-2/9.2.4.2.2.2(8) if located in the cargo area of a tanker; "Service spaces (low risk)" as defined in SOLAS regulation II-2/9.2.2.4.2.2(5), SOLAS regulation II-2/9.2.3.3.2.2(5) or regulation II-2/9.2.4.2.2.2(5) if the surface area is less than 4 m^2 and if no flammable products are stored;

and "Service spaces (high risk)" as defined in SOLAS regulation II-2/9.2.2.4.2.2(9), SOLAS regulation II-2/9.2.3.3.2.2(9) or regulation II-2/9.2.4.2.2.2(9) otherwise.

Note:

It is understood that only chemical injection (category 6), in-line flocculation (category 2) and technologies using neutralizer injection (categories 4, 5, 6 and 7) requires chemical, neutralizer or additive storage.

ii) Where the chemicals are stored in the same room as the BWMS, this room is to be considered both as a store-room and as a machinery space in line with 6-6-2/15.1.ii.

iii) For BWMS storing, introducing or generating chemicals, the BWMR and chemical substance storage rooms are not to be located in the accommodation area. Any ventilation exhaust or other openings from these rooms are to be located not less than 3 m (10 ft) from entrances, air inlets and openings to accommodation spaces. This requirement need not apply in case the BWMS is located in the engine room.

Note:

The above requirements can be reduced if the BWMS does not use any flammable or toxic chemical substances. The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (*G9 Guidelines*) and "safety hazard" as listed in Section 5C-9-17 are to be considered for this purpose. Chemicals include additives and neutralizers for BWMS.

15.7 Access to/from the BWMR

BWMR containing equipment for BWMS of the following types are to be equipped with tested gastight and self-closing doors without any holding back arrangements:

- BWMS storing, introducing or generating chemical substances
- De-oxygenation based on inert gas generator (categories 3b and 3c)
- Electrochlorination (categories 4 and 5)
- Ozone injection (categories 7a and 7b)

Doors leading to the open deck need however not to be self-closing.

Note:

The above requirements can be reduced if no dangerous gases are generated by the BWMS. The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (*G9 Guidelines*) and "safety hazard" as listed in Section 5C-9-17 are to be considered for this purpose. Chemicals include additives and neutralizers for BWMS.

16 Special Personnel Protective Equipment and Arrangements

i) Personnel protective equipment is to be available onboard for the protection of the crew members who are engaged in the servicing, maintenance and repair of BWMS storing, introducing or generating chemicals, as recommended by the product manufacturers. The protection personnel protective equipment is to consist of large aprons, special gloves with long sleeves, suitable footwear, coveralls of chemical-resistant materials, and tight fitting goggles or face shields or both. The protective clothing and equipment are to cover all skin so that no part of the body is unprotected. This protection equipment is to be provided separately without taking into account equipment required by other mandatory requirements.

ii) Personnel protective equipment is to be kept in easily accessible places and in special lockers. Such equipment is not to be kept within accommodation spaces, with the exception of new, unused equipment and equipment which has not been used since undergoing a thorough cleaning process. Notwithstanding the above, storage rooms for such equipment within accommodation spaces are acceptable if adequately segregated from living spaces such as cabins, passageways, dining rooms, bathrooms, etc.

iii) When a BWMS storing, introducing or generating chemicals is installed on board, clearly marked decontamination showers and an eyewash are to be available in an accessible location in close proximately to the BWMS and the chemical store-room(s).

iv) An emergency escape breathing apparatus (EEBD) is to be provided in the BWMR. This emergency escape breathing apparatus can be one of the EEBDs provided in accordance with the requirements of 4-7-3/15.7. An EEBD need not be required for BWMS of category 1.

v) A personal ozone detector, calibrated as per the manufacturer's specifications, is to be provided for each person engaged in the servicing, maintenance and repair of BWMS utilizing ozone (categories 7a and 7b).

vi) A two-way portable radiotelephone apparatus dedicated for the BWMS service, maintenance and repair is to be provided, in addition to those required by 4-7-3/15.5.2 for fire-fighting purposes. This two-way radiotelephone apparatus is to be clearly identified in order to avoid mix-up with the apparatus intended for fire-fighting operations. Where the BWMS can release explosive gases, this two-way radiotelephone apparatus is to be of a certified safe type suitable for use in zone 1 hazardous areas, as defined in IEC Publication 60079. Where the BWMS stores, utilizes or introduces chemicals, the apparatus is to undergo deep cleaning or de-contamination after use. A two-way portable radiotelephone apparatus need not be required for BWMS of category 1.

Note:

The requirements in i), iii) and vi) above can be reduced if no toxic chemical is used or will be generated by the BWMS. The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (*G9 Guidelines*) and "safety hazard" as listed in Section 5C-9-17 are to be considered for this purpose. Chemicals include additives and neutralizers for BWMS.

PART 6

CHAPTER 6

Ballast Water Treatment

SECTION 3

Consideration for Oil, Gas, and Chemical Carriers *(1 July 2024)*

1 General

The requirements in this Section address the special requirements associated with the treatment of ballast water from tanks located adjacent to cargo tanks or other hazardous areas on oil, gas or chemical carriers and are to be applied in conjunction with the requirements in Part 5C, Chapters 1, 2, 8, 9 and 13, as applicable.

1.1 Objective

1.1.1 Goals

The ballast water treatment systems for oil, gas and chemical carriers covered in this section are to be designed, constructed, operated and maintained to:

Goal No.	*Goals*
FIR 1	*prevent the occurrence of fire and explosion.*
SAFE 1.1	minimize danger to person on board, the vessel, and surrounding equipment/installation from hazards associated with machinery and systems.
MGMT 5.1	facilitate safe access, ease of inspection, survey, and maintenance of vessel, machinery, and electrical systems.
AUTO 5	provide a safety system that shall automatically lead machinery controlled to a fail-safe state in response to a fault which may endanger the safety of persons on board, machinery/equipment or environment.

Materials are to be suitable for the intended application in accordance with the following goal in support of the Tier 1 Goals as listed above.

Goal No.	*Goal*
MAT 1	The selected materials' physical, mechanical and chemical properties are to meet the design requirements appropriate for the application, operating conditions and environment.

The goals in the cross-referenced Rules/Regulations are also to be met.

1.1.2 Functional Requirements

In order to achieve the above stated goals, the design, construction, installation, and maintenance of the ballast water treatment systems for oil, gas and chemical carriers are to be in accordance with the following functional requirements:

Functional Requirement No.	*Functional Requirements*
SAFETY OF PERSONNEL	
SAFE-FR1 (FIR)	Separate systems are to be provided for the hazardous tanks and non-hazardous tanks to prevent flammable vapors entering the non-hazardous areas unless acceptable countermeasures are provided.
SAFE-FR2 (FIR)	The system is not to be installed in hazardous areas that may lead to fire and explosions unless the suitable equipment with acceptable countermeasures are provided.
SAFE-FR3 (AUTO/FIR)	Interlocks are to be provided for automatic shutdown the system during abnormal conditions, failure of equipment, emergency conditions including fire and high concentrations of flammable or toxic gases to prevent further escalation of hazards.
SAFETY MANAGEMENT	
MGMT-FR1 (SAFE)	Detailed assessment is to be conducted to address the risk caused by operation of the system for personnel on board and the vessel.

The functional requirements in the cross-referenced Rules/Regulations are also to be met.

1.1.3 Compliance

A vessel is considered to comply with the Goals and Functional Requirements when the prescriptive requirements are complied with or when an alternative arrangement has been approved, refer to Part 1D Chapter 2.

3 BWMS Equipment Locations and Suitability

i) Two independent BWMS are required, i.e. one for ballast tanks located within the cargo area and the other for ballast tanks located outside cargo area. Specific arrangements where only one single In-line BWMS (categories 1, 2, 3a, 3b, 4, 5, 6, 7a and 7b) can be accepted (refer to Annex I of IACS UR M74).

Note:

When the Fore Peak Tank is ballasted with the piping system serving the other ballast tanks within the cargo area in accordance with IACS UR F44, the ballast water of the Fore Peak tank is to be processed by the BWMS processing the ballast water of the other ballast tanks within the cargo area.

The BWMS, to the extent possible, is to be located in a non-hazardous area.

a) BWMS using ozone generators (categories 7a and 7b) and de-oxygenation BWMS using inert gas generator by treated flue gas from main or auxiliary boilers or gas from an oil or gas-fired gas generator (categories 3b and 3c) are to be located outside the cargo area in accordance with 5C-2-3/25.7.1ii) (this requirement does not apply to nitrogen generator inert gas systems on 5C-2-3 /25.41).

b) In-line full flow electrochlorination BWMS (category 4), in-line side-stream electrochlorination (category 5) and in-line injection BWMS using chemical which is stored onboard (category 6) can be located inside the hazardous areas with due consideration of the requirement of 6-6-3/3.ii below but is not to be located inside the cargo pump room unless it is demonstrated by the BWMS manufacturer that the additional hazards that can be expected from dangerous liquids and dangerous gases stored or evolved from the BWMS (for example H_2 generation):

- do not lead to an upgrade of the hazardous area categorization of the cargo pump room,
- do not react with the cargo vapors expected to be present in the cargo pump room,
- do not impact the performance of the existing fire-fighting systems provided inside the cargo pump room, and
- do not introduce additional hazards inside the cargo pump room such as toxicity hazards that are not addressed by countermeasures approved by ABS.

Notes:

1 In-line full flow electrochlorination BWMS (category 4) is accepted in cargo compressor rooms of liquefied gas carriers and in cargo pump rooms of oil tankers or chemical tankers if the cargo pump room is located above the cargo tank deck.

2 For submerged cargo pumps, the room containing the hydraulic power unit or electric motors is not to be considered as the "cargo pump room".

3 Ballast pump rooms and other pump rooms not containing the cargo pumps are not to be considered as the "cargo pump room".

ii) Electrical equipment installed in hazardous areas is to comply with Appendix 6-6-3-A5 and 4-8-3/13 and 4-8-4/27.3.*

Note: * The application of IEC 60092-502 can be considered for vessels built prior to 1 January 2007, subject to the submission of plans, verifying that the hazardous areas of such vessels, comply in entirety with IEC 60092-502 as a single concept for hazardous area classification for the entire vessel. The combination of IEC 60092-502 with NEC or API standards etc. is not acceptable.

3.1 Definition of Hazardous Areas

Hazardous area:

- Is an area in which an explosive gas atmosphere is, or may be expected to be present, in quantities that require special precautions for the construction, installation and use of electrical equipment.
- When a gas atmosphere is present, consideration is also to be given to the following hazards that may also be present: toxicity, asphyxiation, corrosivity, reactivity and low temperature.
- For the requirements for toxic cargoes see 5C-9-15/12.
- Hazardous Areas (IACS UR M74)

i) Tankers carrying flammable liquids other than liquefied gases having a flashpoint not exceeding 60°C (140°F), for example crude oil, oil products, chemical products. See 4.2 of IEC 60092-502

ii) Cargoes heated to temperatures (T_H) above their flashpoint (FP) and cargoes heated to temperature within 15°C (27°F) of their flashpoint: $T_H \geq$ (FP – 15°C (27°F)). See 4.3.2 of IEC 60092-502

iii) When the concerned ballast tanks are hazardous areas, an extension of hazardous area is to be considered at the outlet of the protection devices: with reference to 4.2.2.9 of IEC 60092-502, the areas on open deck, or semi-enclosed spaces on open deck, within 1.5 m (5 ft) of their outlets are to be categorized hazardous zone 1 and with reference to 4.2.3.1 of IEC 60092-502, an additional 1.5 m (5 ft) surrounding the 1.5 m (5 ft) hazardous zone 1 is to be categorized hazardous zone 2. Any source of ignition such as anchor windlass or opening into chain locker are to be located outside the hazardous areas.

iv) Where products covered by IEC 60092-502 are stored on-board or generated during operation of the BWMS, the requirements of this standard are to be followed in order to: Define hazardous areas and acceptable electrical equipment and define requirements for ventilation systems.

5 Ventilation Requirements

The ventilation systems serving hazardous spaces containing BWMS equipment are to comply with the requirements in 6-6-2/3.3.2.

7 Piping System

7.1 General

The design and installation of the piping system of a BWMS on an oil or chemical carrier are to comply with the applicable requirements in Section 5C-2-3.

7.3 Interconnection Considerations

A piping system serving or having an opening into tanks or spaces that are considered to be hazardous is likewise to be regarded as contaminated is not permitted to enter machinery and other spaces normally containing sources of ignition as indicated in 5C-2-3/1.7.2 due to the potential migration of flammable liquids or vapors from the hazardous area into the non-hazardous area. In association therewith, the following requirements are applicable:

i) Ballast piping serving hazardous ballast tanks is not to enter or be routed through any non-hazardous areas unless specifically approved sampling arrangements are provided. Refer to Appendix 6-6-3-A1.

ii) Ballast piping serving hazardous areas is not to be interconnected with any piping system serving non-hazardous areas unless specifically approved isolation/interconnection arrangements are provided. Refer to Appendices 6-6-3-A2 through A4.

iii) BWMS piping connected to ballast piping serving hazardous areas is not to be routed into non-hazardous areas unless specifically approved isolation/interconnection arrangements are provided. Refer to Appendices 6-6-3-A1 through A4.

iv) Where the ballast water does not need to be treated before it is discharged (except for neutralization), the arrangements for stripping eductors situated in the cargo area using driving water from the machinery spaces are to be provided with specifically approved isolation/interconnection arrangements. Refer to 6-6-3-A4/3, A4/5 or A4/7. See 5C-9-3/5.1 for chemical carriers and 5C-2-3/5.3.2(c) for oil carriers.

v) For BWMS equipment arranged with piping components made of thermoplastic or thermosetting plastic material, it is to comply with the requirements in 6-6-2/3.9.3.ii.

Notes:

1 Sampling lines which are connected to the ballast water piping system serving the tanks in the cargo area and provided for the purpose of ballast water sampling required by the *G2 Guidelines* or for total residual oxidant (TRO) analysis in closed loop system (categories 4, 5, 6, 7a and 7b), are not to be led into a non-hazardous enclosed space outside the cargo area. However, Appendix 6-6-3-A1 provides an acceptable arrangement where the BWMS sampling units are located in a non-hazardous area such as the engine room, which are connected to a ballast piping system serving a treatment unit installed in a hazardous area such as the cargo pump room.

2 Appendix 6-6-3-A2 provides an acceptable arrangement where the BWMS dosing units are located in a non-hazardous area such as the engine room, which serve a ballast system located in a hazardous area such as a cargo pump room. Also refer to Appendix 6-6-3-A3 for an acceptable isolation arrangement of a BWMS dosing piping system (from a non-hazardous compartment to a non-hazardous area routed through a hazardous area).

3 Appendix 6-6-3-A4 provides acceptable arrangements for interconnections of ballast piping where the BWMS is in a non-hazardous area and serves hazardous ballast tanks in the cargo area of tankers. The ballast pumps in these arrangements are to be used only for ballasting or for driving stripping/deballasting eductors located in hazardous areas.

4 Appendix 6-6-3-A5 specifies additional arrangements for the placement of electrical equipment in hazardous areas.

9 Safety Assessment

A Safety assessment study specific to the BWMS to be installed and the specific type of vessel (chemical carrier, oil carrier or gas carrier) to address the risk to the vessel and its crew is to be carried out. The scope of the assessment study is to include at least the following subjects:

i) Equipment locations and hazards associated with the location

ii) System monitoring, control and safety systems

iii) Operational procedures for the BWMS

iv) Maintenance requirements for the BWMS

v) Potential release from the BWMS

vi) Interconnection between piping systems and hazards associated with the BWMS

vii) Vessel operations during ballasting and de-ballasting

viii) Failure modes and safeguards

The safety assessment are to be undertaken prior to the installation of the BWMS, so that any mitigation measures identified during the assessment study can be rectified either prior to or during installation. This safety assessment study is to be reviewed by ABS to confirm the adequacy of the proposed arrangements. Relevant information resulting from this safety assessment is to be documented in the vessel's BWMP.

Safety assessments approved by ABS for a specific BWMS installed on a specific type of vessel would be considered in lieu of a safety assessment submission for each BWMS installations on these specific type of vessels.

PART 6

CHAPTER 6
Ballast Water Treatment

SECTION 3
Appendix 1 - Acceptable Arrangement for Sampling System Piping in Non-Hazardous Area Connected to a BWMS in a Hazardous Area of an Oil or Chemical Tanker *(1 July 2024)*

This Appendix presents an acceptable arrangement for BWMS sampling units located in a non-hazardous area such as the engine room, which are interconnected to a ballast water management system in a hazardous area such as the cargo pump room of an oil tanker or chemical carrier via piping . This arrangement is a protection measure for addressing the migration of hydrocarbon or flammable and/or toxic liquids or vapors from the hazardous ballast system.

The ballast tanks detailed in this Appendix are hazardous if they are adjacent to cargo tanks. The internal diameter of sampling pipes is to be the minimum necessary in order to achieve the functions of the sampling system.

The details of the arrangements are to be as follows:

1) All sample monitoring devices, pumps and other related equipment for the sampling system are to be located within a gas-tight enclosure (e.g., fully enclosed steel cabinet with a gasketed door); non-gasketed doors are not acceptable.

2) The sampling cabinet is to be mounted on the forward bulkhead separating the hazardous and non-hazardous areas (i.e., typically the forward engine room bulkhead), except as permitted in item 12 below.

3) A gas detection device is to be installed in the cabinet and set to initiate an audible and visual alarm locally and at a manned location such as the (e.g., navigation bridge, etc.), upon detection of 30% of the (LFL) lower flammable limit and/or exceeding of toxicity limit of any possible gases involved. Upon an activation of the alarm, all electrical power to the cabinet is to be automatically disconnected. See 5C-9-13/2 and 5C-9-21/4.11 .

Note: When the electrical equipment is of a certified safe type, the automatic disconnection of power supply is not required.

4) A sensor to detect water leakage is to be installed in the cabinet. The sensor is to initiate an audible and visual alarm at a manned location (e.g., navigation bridge, etc.). Upon an activation of the alarm, all electrical power to the cabinet is to be automatically disconnected.

5) The cabinet is to be vented to a non-hazardous area in the weather deck and the vent is to be fitted with a flame screen. The open deck area within 1 m (3 ft) around the natural ventilation outlet is to be hazardous. (See the intent of 4-8-4/27.3.3(a))

6) A positive closing stop valve is to be installed in each sample pipe at the bulkhead penetration on the non-hazardous side of the bulkhead. A warning plate stating "Keep valve closed when not performing measurements" is to be posted near the valves.

7) An automatic fail-closed valve is to be installed in each sample pipe where the pipe enters the cabinet. This valve is to be located within the cabinet and arranged to close upon loss of power or activation of gas detection (item 3) or float level alarms (item 4).

8) A stop valve is to be installed at the connection of the sampling supply line to the ballast piping. A stop/check valve or a combination of a stop (i.e., positive closing) valve and a check (i.e., non-return) valve is to be installed at the connection of the sampling return line to the ballast piping to prevent back flow into the ballast piping.

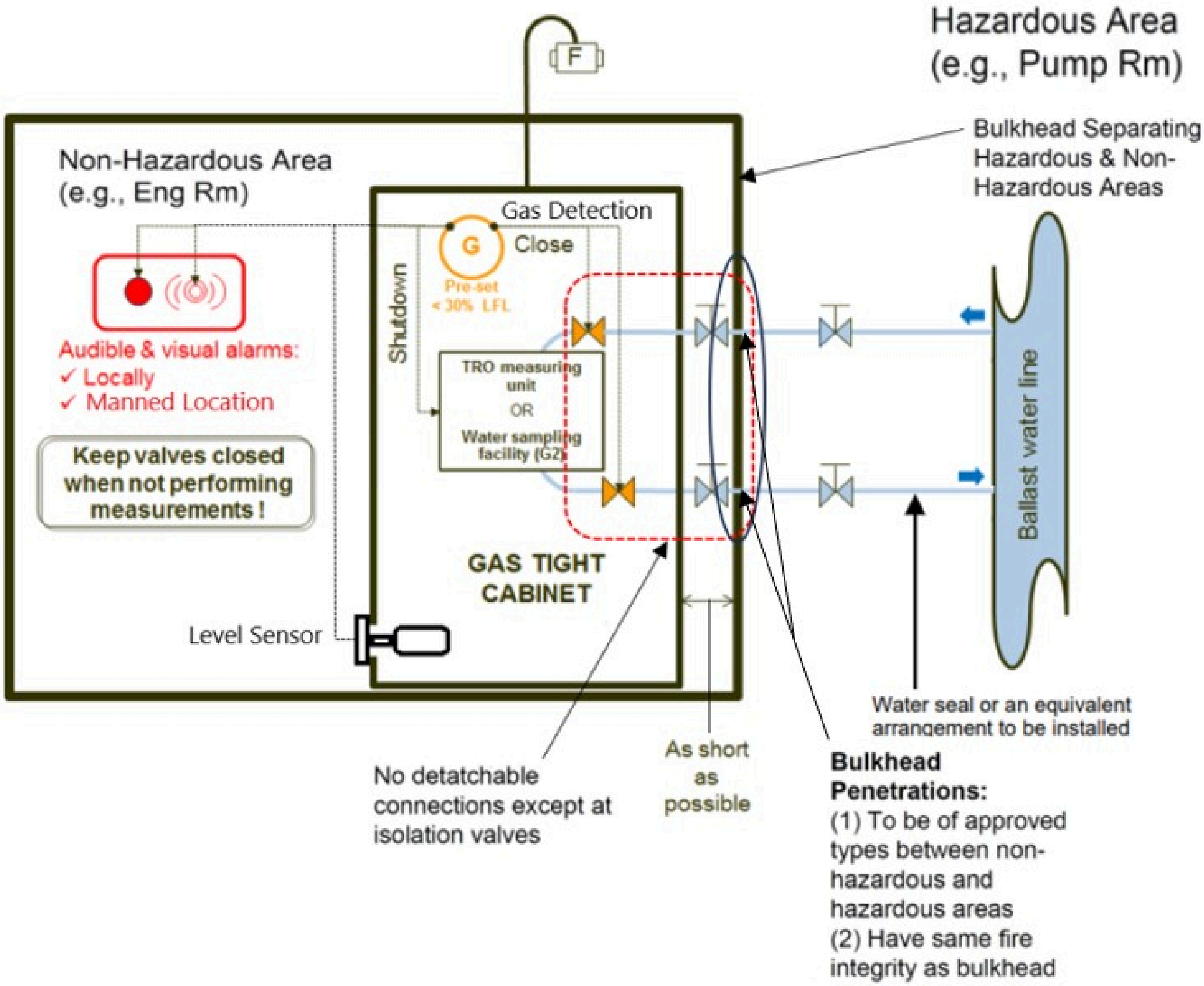
9) Bulkhead penetrations of sampling piping between non-hazardous and hazardous areas are to be of approved types and have the same fire integrity as the division penetrated.

10) The sampling lines are to be routed directly into the sampling cabinet. Where the sampling lines are not routed directly into the sampling cabinet, the arrangements are to be in accordance with item 12 below.

11) Where the cabinet cannot be mounted directly on the forward bulkhead or the sampling piping is not routed directly into the cabinet, the sampling pipes are to be of steel or other equivalent material and without detachable connections, except for the connection points for isolating valves at the bulkhead and the isolation valves within the cabinet. Runs of the sampling pipes within the non-hazardous space are to be as short as possible.

12) Arrangements are to be provided to transfer ballast water drained from sampling systems back to the ballast water system in the hazardous area.

FIGURE 1
Acceptable Interconnection Arrangement of BWMS Sampling System Piping



PART 6

CHAPTER 6
Ballast Water Treatment

SECTION 3
Appendix 2 - Acceptable Isolation Arrangement of a BWMS Dosing System on Oil or Chemical Tankers (From a Non-hazardous Area to a Hazardous Area) *(1 July 2024)*

This Appendix presents an acceptable isolation arrangement of BWMS dosing units located in a nonhazardous area, such as the engine room, which are interconnected to a ballast water system in a hazardous area, such as the cargo pump room, of an oil or chemical carrier via piping. These arrangements are protection measures for addressing migration of hydrocarbon or flammable and/or toxic liquids or vapors from the hazardous ballast systems.

The ballast tanks detailed in this Appendix are hazardous if they are adjacent to cargo tanks. The arrangement details are as follows:

The details of the arrangements are to be as follows:

1) All bulkhead penetrations of the dosing piping between non-hazardous and hazardous areas is to be of an approved type and have the same fire integrity as the division penetrated.

Non-hazardous Area

2) The dosing piping is to pass through the bulkhead separating the non-hazardous and hazardous areas at as high an elevation in the non-hazardous area as possible, below the main deck.

3) A stop/check valve or a combination of a stop (i.e., positive closing) valve and a check (i.e., non-return) valve is to be installed just aft of the bulkhead separating hazardous and non-hazardous areas to prevent back flow into the dosing unit.

4) A system-controlled, fail-closed valve that is closed at all times other than when the dosing system is in operation is to be installed in the dosing line directly behind the stop/check valve required in item 3 above.

5) A reverse flow monitor with an alarm and system shut down is to be fitted in the dosing line.

Hazardous Area

6) A passive in-line water seal shown on 6-6-3-A2/Figure 1 capable of preventing the passage of vapors back through the dosing piping when the system is not operating is to be provided.

Commentary:

Alternatives to the passive in-line water seal may be a loop seal arrangement as in 6-6-3-A4/3, spool piece arrangement as in 6-6-3-A4/5 or a fail-safe actively operated double block and bleed arrangement as in 6-6-3-A4/7, provided it is established that it is:

a Capable of preventing the back flow of vapors against at least a 1.52 m (60 in.) static head,

b Suitable for the service when considering the dosing agent involved (gas, liquid, etc.),

c Operates passively or fail-safe actively, as applicable, and

d The alternative arrangement (loop seal, spool piece or double block and bleed) is to be installed as high as possible in the hazardous area (e.g., pump room) or on the weather deck in the hazardous area.

e Means are to be provided to prevent any liquid seal from freezing where exposed to the weather.

f Where the alternative arrangement (loop seal, spool piece or double block and bleed) is installed on the weather deck, the fail-close valve and the reverse flow monitor in the non-hazardous area (e.g., Engine Rm.) on Items 4 and 5 are not required.

End of Commentary

7) A stop/check valve or a combination of a stop valve and a check valve is to be installed at the connection of the dosing line to the ballast piping.

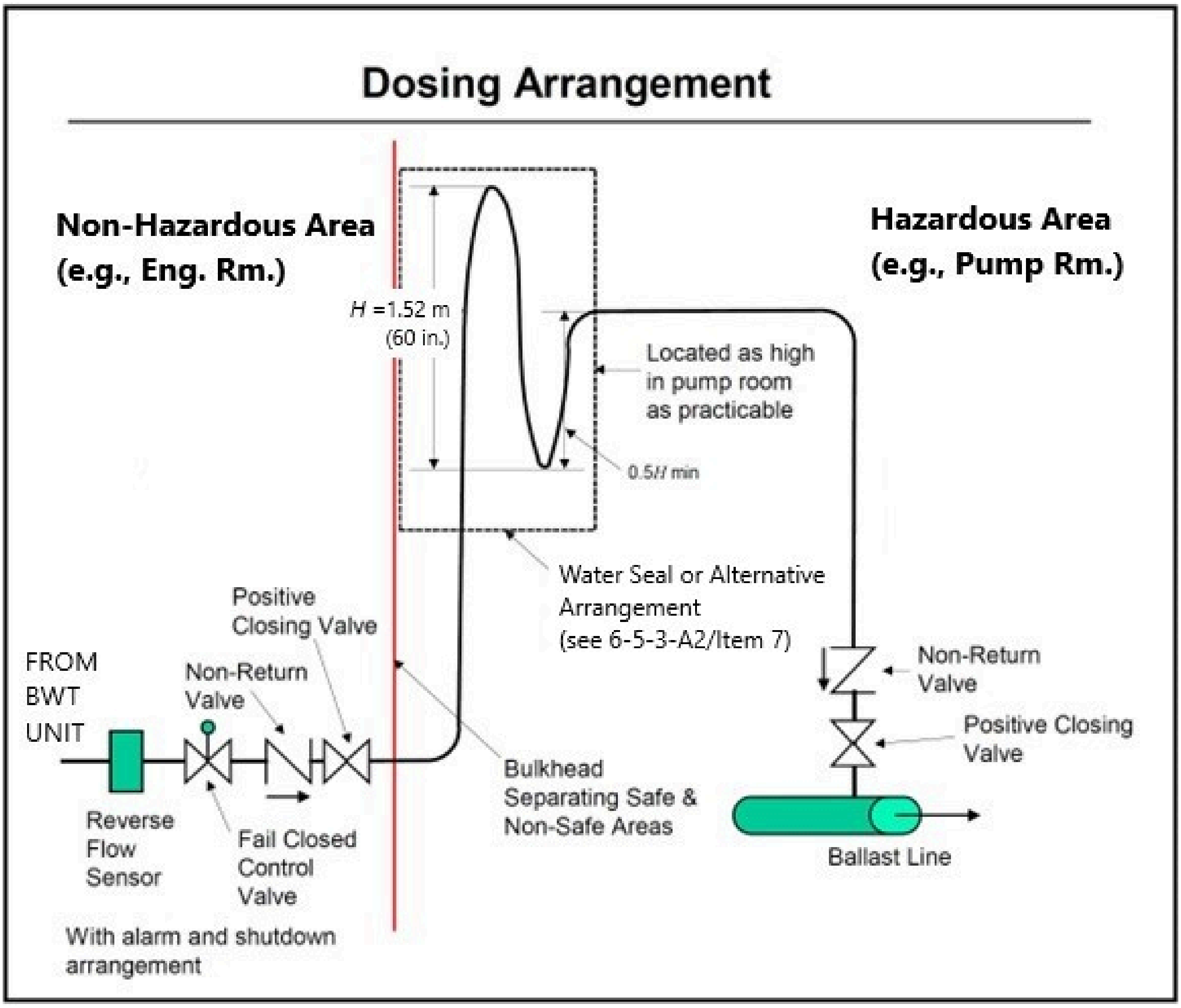
Other devices and arrangements installed in lieu of the water seal are subject to ABS technical assessment and approval.

Notes:

1 Fixed gas detection arrangements are to be provided for ballast tanks. Arrangements are to be provided such that the system-controlled, fail-closed valve at the bulkhead is closed upon detection of 30% of the (LFL) lower flammable limit of hydrocarbon, or other flammable and/or toxic vapors in the ballast tank and upon detection of hydrogen gas in the ballast tanks depending on the BWMS used. See 6-6-3-A5/Item 4.

2 Placards are to be located at all relevant locations indicating "Valves to be closed when the system is not in operation".

FIGURE 1
Acceptable Interconnection Arrangement for BWMS Dosing Piping



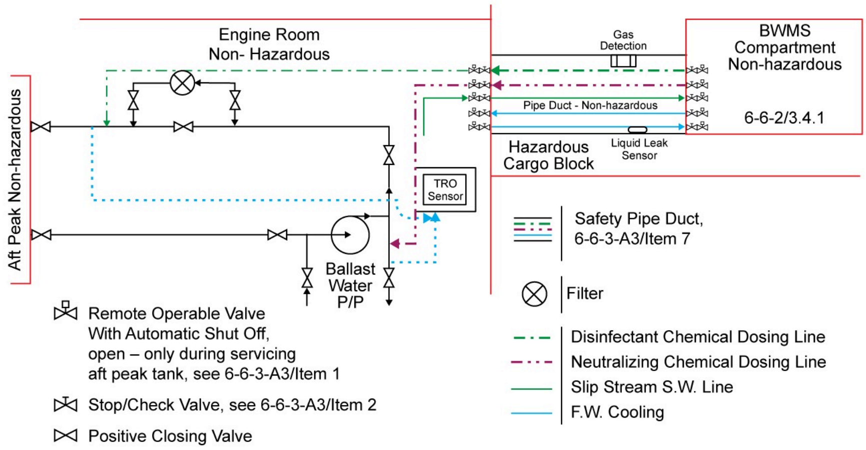
PART 6

CHAPTER 6
Ballast Water Treatment

SECTION 3
Appendix 3 - Acceptable Isolation Arrangement of a BWMS Dosing Piping System on Oil or Chemical Tankers (From a Non-hazardous Compartment to a Non- hazardous Area Routed Through a Hazardous Area) *(1 July 2024)*

This Appendix details acceptable isolation arrangements for a BWMS dosing piping system, routed through a hazardous cargo block area, the BWMS installed in a non-hazardous compartment located in a hazardous cargo block area (6-6-2/3.4.1), serving among other hazardous ballast tanks in the cargo block, a non-hazardous Aft Peak Tank adjoining an engine room. The BWMS located in the non-hazardous compartment may be of the side stream electrochlorination (category 5), chemical injection (category 6) and side stream ozone injection (categories 7a and 7b).

FIGURE 1
BWMS Located in a Non-hazardous Compartment in a Hazardous Cargo Block Servicing Non-hazardous Aft Peak Tanks



Non-hazardous Area (BWMS Compartment and Engine Room)

1) Remote operable valves with automatic shutoff features are to be installed in both the non-hazardous BWMS Compartment (see 6-6-2/3.4.1) and the non-hazardous area (e.g., Engine Rm.)

for the chemical disinfectant, neutralizing chemical, side stream seawater and freshwater cooling piping.

The remote operable valves are to be arranged so that:

a) They remain closed at all times except when Aft Peak Tank ballast and deballast operations are in progress, b) Are to be of the fail safe type with the capability of manual operation with local status indication and remote status indication at the BWMS control station.

2) A stop/check valve or a combination of a positive closing stop valve and a check (i.e., non-return) valve is to be installed in the non-hazardous area at the bulkhead separating hazardous and non-hazardous areas.

3) All bulkhead penetrations by piping between non-hazardous and hazardous areas are to be of an approved type and have the same fire integrity as the division penetrated.

Hazardous Area

4) The chemical disinfectant, neutralizing chemical, side stream sea water cooling and fresh water cooling, (pneumatic piping and instrumentation cabling if required) are to be routed through the safety pipe duct when traversing the hazardous area.

5) The gas tight safety pipe duct is to include sealed inspection openings with gas tight bolted covers to be opened only during gas free conditions.

6) The safety pipe duct is to be installed with gas detection, liquid leakage detection and mechanical ventilation of at least six (6) air changes an hour that will maintain the safety pipe duct under positive pressure relative to the external hazardous area.

7) The gas detection and liquid sensing equipment in Item 6 above are to be of certified safe type. The instrumentation cabling used is to comply with 4-8-4/27.9.

8) The certification of gas detection and liquid sensing equipment required in Item 7 are to be certified for Zone 2 if the safety pipe duct is routed through Zone 2* only. However if sections of the safety pipe duct are routed through Zone 1 areas, then the gas detection and liquid sensing equipment is to certified for Zone 1*.

Note: *For the Zone concept, refer to the "Note" in 6-6-2/3.4.2.

9) The ventilation is to be arranged so as to enable ventilation of the entire length of the pipe duct, the ventilation inlet and outlet are routed such that they are located outside of the hazardous area.

10) The relative overpressure or air flow is to be continuously monitored and so arranged that in the event of a ventilation failure (loss of relative overpressure or loss of air flow) associated with either the safety pipe duct or the non-hazardous compartment housing the BWMS, an audible and visual alarm is given at a manned location with simultaneous automatic shutoff of the BWMS and the closure of the remote operable valves.

11) The automatic shutoff and alarm initiation in Item 10 above is also to be initiated upon detection of 30% (LFL) lower flammable limit of hydrocarbon, or other flammable and/or toxic vapors involved or in the case of liquid leakage detection within the pipe duct.

Alternative Location of Safety Pipe Duct in Non-Hazardous Area

12) If the entire safety pipe duct, including the individual pipe penetrations are routed through non-hazardous areas beyond the boundaries of the designated hazardous areas in IEC 60092-502, the following requirements are not applicable.

a) The ventilation and gas detection in Item 6.

b) Certification of the gas detection and liquid sensing equipment in Items 7 and 8.

c) Continuous monitoring of relative overpressure of air flow in Item 10.

d) Automatic shutoff and alarm upon gas detection in Item 11.

However, automatic shutoff of the BWMS and the remote operable valves in Item 1 is required in case of ventilation failure of the non-hazardous compartment located in the hazardous deck.

Other devices and arrangements in lieu of the arrangements detailed above are subject to ABS technical assessment and approval.

PART 6

CHAPTER 6

Ballast Water Treatment

SECTION 3

Appendix 4 - BWMS in a Non-hazardous Area *(1 July 2024)*

This Appendix presents examples of acceptable arrangements for a BWMS and ballast water pumps installed in an engine room while serving hazardous ballast water tanks of an oil or chemical tanker.

1 General Guidelines for All Installations

1) Ballast piping (except small-bored sampling piping as shown in 6-6-3-A1/Figure 1 and dosing piping in 6-6-3-A2/Figure 1) is not to penetrate the common bulkhead between the non-hazardous area (e.g., Engine Room) and hazardous area (e.g., Pump Room).

2) The ballast water is to flow in one direction only from the non-hazardous area (e.g., Engine Rm.) to the hazardous ballast tanks (i.e., The ballast pumps are only to be used for filling the ballast tanks and/or for driving eductors in the hazardous area to strip/deballast the ballast tanks where the ballast water does not need treatment before it is discharged).

3) The valves to the ballast tanks are to be arranged so that they remain closed at all times except when ballasting or when driving eductors in the hazardous area to strip/deballast ballast tanks where the ballast water does not need treatment before it is discharged. Remote operable valves, where provided, are to be of the fail safe type with the capability of manual operation with an indication of its status locally and remotely at the BWMS control station.

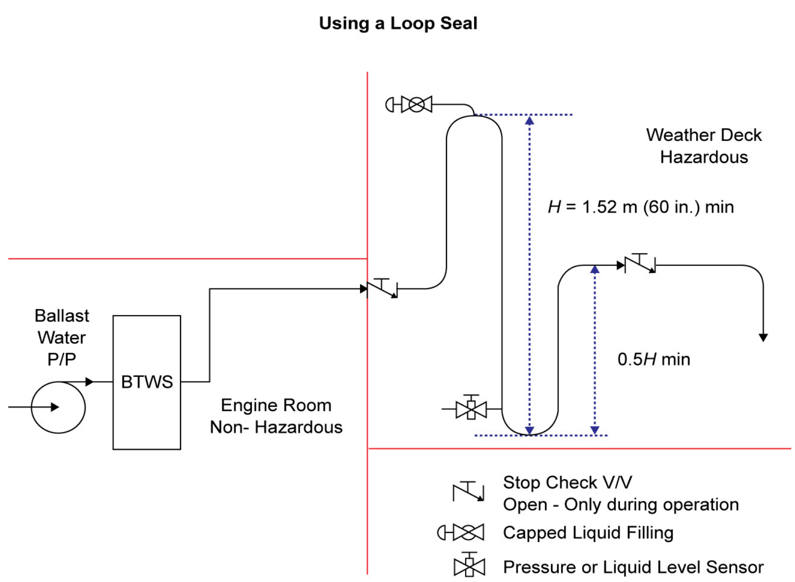
4) The ballast water piping penetrations are to be watertight and of the approved type in accordance with 4-6-2/9.7.1.

5) The ballast tanks are to be fitted with means of detecting hydrocarbon, other flammable and/or toxic vapors, as applicable. See 5C-2-3/19 and 20, 5C-9-13/2 and 5C-9-21/4.11. Automatic shutdown of the BWMS is to be actuated upon detection of 30% (LFL) lower flammable limit of applicable gases and/or toxic vapors involved. See 6-6-3-A5/Item 4.

6) Depending on the type of BWMS used, other additional arrangements may be required at the discretion of ABS.

3 Using a Loop Seal

Figure 1
Loop Seal Arrangement



Hazardous Area (Weather Deck)

1) A stop/check valve or a combination of a positive closing valve and a check valve (i.e., non-return) valve is to be installed where the discharge piping exits the non-hazardous area (e.g., Engine Room). This valve is to be located in the hazardous area just forward of the forward most bulkhead between the hazardous weather deck area and the non-hazardous area.

2) A loop seal of at least 1.52 m (60 in.) height to prevent the passage of vapors from entering the ballast piping in the non-hazardous area(e.g., Engine Rm.) and is to be installed in the hazardous area.

3) In addition to item 2, the loop seal is to be arranged so that the water in the seal is kept free of cargo vapors and liquids through the use of a stop/check valve in the ballast fill line and, if applicable, in the eductor supply line. The stop/check valves in Items 1 and 3 are only to be opened during the BWMS operation.

4) A pressure sensor or liquid level sensor is to be provided at an appropriate location on the loop seal which is to activate an alarm at a manned location if the liquid level column drops below 1.52 m (60 inches).

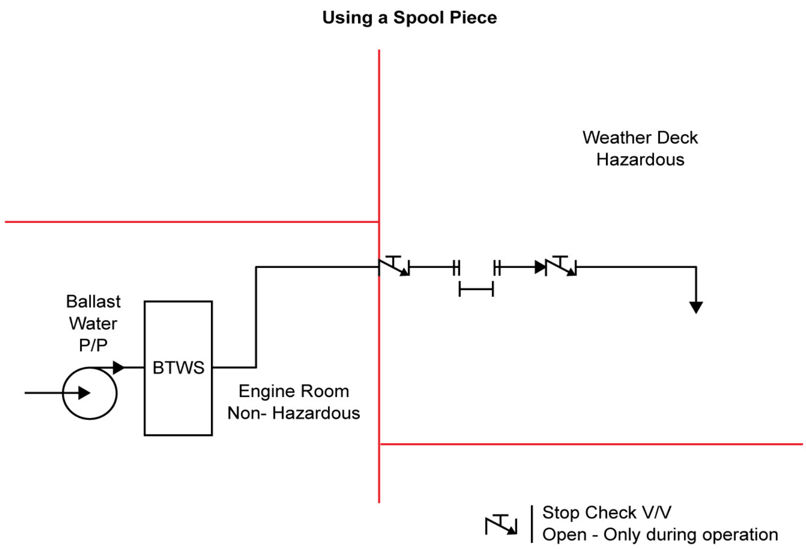
5) Arrangements are to be installed to replenish the water in the loop seal to its normal safe 1.52 m (60 inches) height after a drop in level is detected.

6) The ballast water pump and the BWMS are to be automatically shut down in the case of loss of power, upon detection of 30% lower flammable limit (LFL) of hydrocarbon, or other flammable and/or toxic vapors in the ballast tanks, and upon detection of hydrogen gas in the ballast tanks depending on the BWMS used. See 6-6-3-A5/Item 4.

7) Means are to be provided to prevent any liquid seal from freezing where exposed to the weather.

5 Using a Spool Piece

Figure 2
Spool Piece Arrangement



Hazardous Area (Weather Deck)

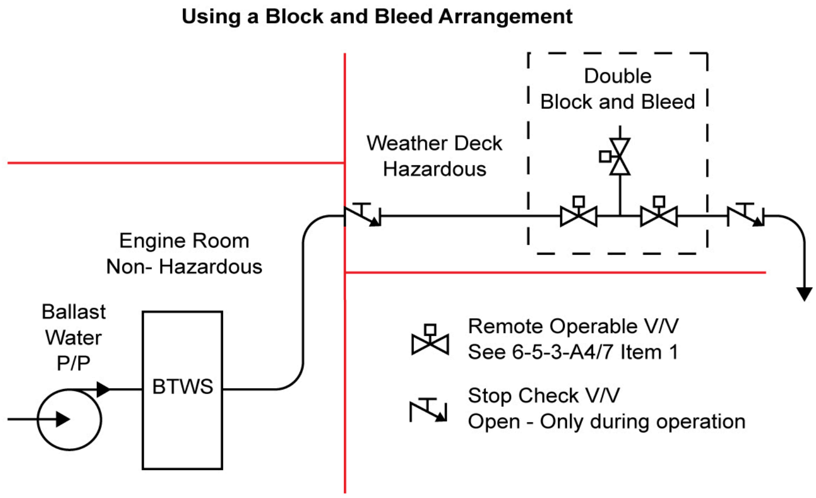
1) A stop/check valve or a combination of a positive closing valve and a check valve (i.e., non-return) valve is to be installed where the discharge piping exits the non-hazardous area (e.g., Engine Room). This valve is to be located in the hazardous area just forward of the forwardmost bulkhead between the hazardous weather deck area and the non-hazardous area.

2) A spool piece is to be removed when the BWT is not in use to prevent the passage of vapors from entering the ballast piping in the non-hazardous area (e.g., Engine Room). Also, a stop/check valve is to be installed in the ballast fill line. The stop/check valves in Items 1 and 2 are only to be opened during the BWMS operation.

3) The ballast water pump and the BWMS are to be automatically shut down in the case of loss of power, upon detection of 30% lower flammable limit (LFL) of hydrocarbon, or other flammable and/or toxic vaporsin the ballast tanks and upon detection of hydrogen gas in the ballast tanks depending on the BWMS used. See 6-6-3-A5/Item 4.

7 Using a Double Block and Bleed Assembly

Figure 3
Block and Bleed Arrangement



1) A stop/check valve or a combination of a positive closing valve and a check valve (i.e., non-return) valve is to be installed where the discharge piping exits the non-hazardous area (e.g., Engine Room). This valve is to be located in the hazardous area just forward of the forwardmost bulkhead between the hazardous weather deck area and the non-hazardous area.

2) In lieu of the loop seal and spool piece arrangement addressed in 6-6-3-A4/3 and 5, respectively, a block and bleed system located on the weather deck (i.e., in the hazardous area). and arranged to automatically go into the “block and bleed" mode when the ballast pump is not in operation, upon loss of power or upon detection of flammable (hydrocarbon, hydrogen, etc.) and/or toxic vapors, in the ballast tanks isan equivalent arrangement for separating the hazardous weather deck area from the non-hazardous areas (e.g. Engine Room).

3) The "block and bleed" valve controls are to comply with the intent of 5C-2-3/25.19.1.

PART 6

CHAPTER 6
Ballast Water Treatment

SECTION 3
Appendix 5 - Additional Arrangements for the Placement of Electrical Equipment in Hazardous Areas (*1 July 2024*)

Additional arrangements for the placement of electrical equipment in hazardous areas in accordance with 6-6-3/3.

i) An interlock is to be provided for disallowing any maintenance on the BWMS when the system is energized.

ii) An interlock is to be provided for the ventilation of the space including the BWMS such that the electrical power supply to the BWMS cannot be energized while the ventilation is not in operation. This also means that in the event of a failure in the ventilation while the BWMS is in operation, the electrical power to the BWMS in the hazardous area is to automatically shut down. Failure of ventilation is to give an audible and visual alarm at a manned location.

iii) Ventilation arrangements are to comply with 6-6-2/3.3.2.

iv) An interlock is to be provided such that any detection of 30% (LFL) lower flammable limit of hydrocarbon gas or other flammable and/or toxic gases associated with the cargo in the Ballast Water Tanks/Ballast Pump Rooms or detection of 10% LFL of hydrocarbon gas or other flammable and/or toxic gases associated with the cargo in the Cargo Pump Room will immediately shut down the BWMS and detection of hydrocarbon (or other flammable and/or toxic) gas to give an audible and visual alarm at a manned location.

v) The circuit feeding the BWMS in the hazardous area is to be monitored continuously for ground faults and is to give an audible and visual alarm at a manned location.

vi) Equipotential bonding is to be provided for the BWMS [i.e., the BWMS is to be earthed to the metal hull (see 5.4 of IEC 60092-502)].

vii) All cables installed in the hazardous area other than those of intrinsically-safe circuits are to be sheathed with a nonmetallic impervious sheath in combination with braiding or other metallic covering.

viii) The failure of pressurization where applicable for certified-safe type components of a BWMS is to result in the shutdown of the power supply of the BWMS. The BWMS shutdown device and power supply are to be located outside the hazardous area.

ix) Alarms, monitoring and interlocks associated with pressurized equipment (i.e., components of the BWMS) are to be periodically tested to confirm correct operation. The inspection and testing methods are to be documented in the BWMS operating manual.

x) An operating manual describing safe operations of the certified-safe type electrical equipment, safe testing and maintenance of the equipment is to be provided. It is to be kept updated and available in a location known to the operating personnel. The operating manual is to include, but not limited to, the following aspects;

1) Any maintenance work on the certified-safe type electrical equipment that may necessarily violate the condition of the safety certification, such as opening of such equipment, is to be carried out while the power supply to the equipment is securely disconnected from the non-hazardous area. Methods to ascertain the disconnection while the maintenance work is on-going is to be described.

2) Inspection and maintenance is to be carried out only by experienced and authorized personnel. Appropriate refresher training is to be given to such personnel on a regular basis.

3) All electrical equipment located in hazardous areas and in the spaces which becomes hazardous on loss of pressurization (pressurized or purged equipment – 'Ex p' on 4-8-3/13.3.4), together with any associated non-hazardous-area apparatus (such as zener safety barriers) required for the protection of the equipment, is to be listed on a schedule. The schedule is to include the following details:

a) Location

b) Zonal classification of location

c) Type of equipment

d) Manufacturer

e) Type reference

f) Test authority and certificate number, or reference and date of manufacturer's declaration

g) Type of protection

h) Apparatus group

i) Temperature class

j) Ambient temperature range for which equipment is suitable

k) Ingress protection (IP) rating

4) Hazardous area equipment certification by a competent, independent testing laboratory that may be subject to acceptance by the flag Administration.

PART 6

CHAPTER 6
Ballast Water Treatment

SECTION 4
Operational Management and Survey Requirements *(1 July 2024)*

1 Operating and Safety Manuals

Detailed operating and safety manuals specific to the actual installation are to be provided on board the vessel as indicated in 6-6-1/Table 3 and key elements of the manuals are to be included in the vessel's BWMP. The manuals are to include the operational, safety and maintenance requirements, as well as occupational health hazards relevant to the ballast water treatment. The manuals are to include an outline of the system design conditions that are to be maintained over the life of the system to comply with the approved design. Details of special tools and gauges required for service or repair are to be provided in the manuals. Additionally, the operating manuals are to include detailed instructions for both local and remote control, procedures in the event of a fault or failure of the system, and troubleshooting procedures.

The operating and safety manuals are to be submitted for review or information to ABS. ABS is not responsible for the operation of the ballast water treatment system.

Any modification made to an existing ballast water treatment system is to be reviewed by ABS. The operating and safety manuals are to be updated accordingly and submitted to ABS for review.

3 BWM Officer

A BWM Officer is to be assigned on board the vessel for the implementation of the BWMP, for verifying that all ballast water handling, treatment and maintenance procedures of the BWMS are followed and for recording and maintaining the appropriate logs and records.

5 Personnel Duties and Training

To assist in the implementation of the BWMP, the vessel's BWM Officer and crew are to be trained in the operation of the installed BWMS and be familiar with the duties assigned and the tasks expected of them. The training is to include the following:

i) General Information

- General nature of ballast water management
- Requirements of the ballast water management convention
- Information on ballast water management and sediment management practices
- General aspects of ballast water exchange
- General aspects of ballast water treatment technologies and approved treatment systems

- General safety considerations
- Documentation requirements – BWMP, ballast water management activity logs, and ballast water record book

ii) Ship-Specific

- Details of the installed BWMS–features, components, system processes, control and monitoring, etc.
- Operating procedures of the BWMS
- Maintenance requirements and procedures as detailed by the BWMS manufacturer
- Safety aspects of the treatment system and safe work procedures employed onboard the vessel
- Emergency response plan and preparedness
- Safety precautions for tank entry for sediment removal
- Procedures for safe handling and packaging of sediment
- Storage of sediment

Information on the designated BWM Officer, personnel duties, and the training records of the crew assigned and engaged in the operation of the ballast water management system are to be included in the vessel's BWMP.

7 Initial Survey

7.1 General

7.1.1 Classification

An initial survey of the BWMS is to be conducted by an ABS Surveyor to verify that the installation of the BWMS including any associated structure, fitting, arrangements and material are in compliance with the requirements on Part 6 Chapter 6, as indicated in the approved drawings/plans.

See 6-6-1/7, 6-6-2/3.11.3 and 4-9-3/9.3.4(b).

7.1.2 Specific Verification of Documentation

7.1.2(a)

The initial survey is also to confirm that the following documentation is on board the vessel (per 2008 *G8 Guidelines*, Paragraph 8.1):

i) A copy of the IMO Member State Type Approval Certificate of the BWMS together with a copy of the original test results for the BWMS

ii) A statement from the IMO Member State, or from a laboratory authorized by the IMO Member State, confirming the electrical and electronic components of the BWMS have been type-tested in accordance with the specification for environmental testing contained in Part 3 of the *G8 Guidelines*

iii) Equipment manuals for the major components of the BWMS

iv) A copy of the operations and technical manual for the BWMS specific to the vessel and approved by the IMO Member State

v) Installation specifications of the BWMS

vi) Installation commissioning procedures of the BWMS

vii) Initial calibration procedures of the BWMS *viii)* A copy of the approved BWMP

ix) Ballast water record book specific to the vessel

7.1.2(b)

The initial survey is also to confirm that the following documentation is on board the vessel (per 2016 *G8 Guidelines*/BWMS Code, paragraph 8.2)

i) for the purpose of information, a copy of the IMO Member State Type Approval Certificate of BWMS the operation, maintenance and safety manual of the BWMS

ii) the operation, maintenace and safety manual of the BWMS

iii) the ballast water management plan of the ship

iv) installation specifications, e.g. installation drawing, Piping and Instrumentation diagrams, etc.; and

v) installation commissioning procedures

7.1.3 Other Items

The initial survey is also to verify the following (per *G8 Guidelines*, Paragraph 8.2 if 2008 *G8 compliant* or paragraph 8.3 if 2016 *G8 compliant* or *BWMS Code* compliant):

i) The BWMS installation has been carried out in accordance with the manufacturer's technical installation specifications.

This verification is to include a consistency check for the entire system layout between:

- The ABS Engineering approved plans
- The vessel's physical layout of the installed piping, piping components and equipment

ii) The BWMS is in conformity with the IMO Member State Type Approval Certificate.

iii) The installation of the complete BWMS has been carried out in accordance with the manufacturer's equipment specifications.

iv) Any operational inlets and outlets are located in the positions indicated on the drawings of the pumping and piping arrangements.

v) The workmanship of the installation is satisfactory and, in particular, that any bulkhead penetrations or penetrations of the ballast system piping are to the relevant approved standards.

vi) The control and monitoring equipment operates correctly in accordance with the manufacturer's technical installation specifications.

7.3 Shipboard Function Test

After installation of the BWMS, a shipboard function test is to be carried out to the Surveyor's satisfaction at the sea or quay trial. Prior to the commencement of the function test, the Surveyor is to be provided with a copy of the Safety Assessment for the BWMS. The function test is to demonstrate the ability of the BWMS installation to operate consistently and continuously during the ship's normal ballast operations at the Treatment Rated Capacity (TRC) in a shipboard test cycle reflecting the manufacturer's specific installation criteria. The normal ballast operational cycles are to include ballasting, de-ballasting and stripping. The duration of each test cycle is to be to the satisfaction of the Surveyor.

In case where the maximum capacity of the ballast pump(s) exceeds the maximum TRC of the BWMS, the maximum allowable flow rate for operating the ballast pump(s) is to be limited not to exceed the maximum TRC. The arrangement of any bypasses or overrides is to be consistent with the approved Operation Maintenance and Safety Manual as noted in 6-6-4/7.1.2.b.ii.

The installation commissioning procedure as noted in 6-6-4/7.1.2.a.vi and 6-6-4/7.1.2.b.v, which is to include at least a recommended test and checkout procedure specific to the installed BWMS, is to be prepared and submitted to the ABS Surveyor for acceptance prior to the testing.

Note:

"This procedure should specify all the checks to be carried out in a functional test by the installation contractor and should provide guidance for the surveyor when carrying out the on board survey of the BWMS and confirming the installation reflects the manufacturer's specific installation criteria"

It is not the purpose of the "Shipboard Function Test" to demonstrate the biological efficacy of the installed BWMS.

7.5 Validating Compliance with Regulation D-2 During BWMS Commissioning

As directed by the vessel flag Administration, biological testing to validate compliance with regulation D-2 may be required for 2008 *G8* compliant BWMS, 2016 *G8* compliant BWMS per paragraph 8.1 of 2016 *G8*, and *BWMS Code* compliant BWMS per paragraph 8.1 of *BWMS Code*.

The MEPC Committee provided guidance for validating compliance of a BWMS with regulation D-2 following installation (refer to *BWM.2/Circ.70 Guidance for the commissioning testing of ballast water management systems*, as amended) and IMO *Resolution A.1140(31), Survey Guidelines Under the Harmonized System of Survey and Certification (HSSC), 2019* (as amended), Annex 4, *Survey Guidelines under the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004*.

"verifying that an operational test of the BWMS was carried out based on the installation commissioning procedures and that documented evidence is provided which shows compliance of the treated discharge ballast water with regulation D-2 through sampling and analysis based on applicable guidelines developed by the Organization"

The company engaged in biological testing for validating compliance is to be an ABS approved Service Provider.

9 Surveys After Construction

This section presents the survey requirements for the retention of the **BWT** or **BWT+** notation.

9.1 Annual Survey

An Annual Survey is to be conducted to retain the **BWT** or **BWT+** notation status. At each Annual Survey, the BWMS is to be examined. See 7-9-26/3.1 of the ABS *Rules for Survey After Construction (Part 7)*.

9.3 Special Periodical Survey

See 7-9-26/3.3 of the ABS *Rules for Survey After Construction (Part 7)*.