RULES
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CHINA CLASSIFICATION SOCIETY

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

AMENDMENTS

2024

Effective from 1 July 2024

Beijing

CHINA CLASSIFICATION SOCIETY

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

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2024

PART ONE PROVISIONS OF CLASSIFICATION

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CHAPTER 2 SCOPE AND CONDITIONS OF CLASSIFICATION

Appendix 1 LIST OF CLASS NOTATIONS FOR SEA-GOING SHIPS

Type Notations① **Table A**

Class notation	Description		Technical requirements②
Geotextiles Layer	Geotextiles layers	Ships provided with special equipment for laying geotextiles, which are engaged in operations of laying soft mattress related to construction of cofferdams on land and floating structure projects under different environmental conditions such as coastal shoals and deep-water harbors	Ch. 17, Pt. 8 of the Rules
Chemical Barge	Chemical Barge	Barges carrying chemicals within holds	~~Rules for Construction and Equipment of Ships Carrying Dangerous Liquid Chemicals in Bulk~~ Ch. 12, Pt. 2 of the Rules
Gas Barge	Gas Barge	Barges carrying liquefied gases within holds	~~Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk~~ Ch. 12, Pt. 2 of the Rules
Woodchip Carrier	Woodchip carriers	Ships ~~specially~~ designed and constructed for the carriage of woodchips. ~~If cargoes are not loaded or unloaded by using a mechanical shovel, a grab of more than 10 tons and other methods which easily damage the structure of the cargo hold, requirements for bulk carriers in SOLAS Chapters II-1, III, IX, XI-1 and XII which are not applicable to the ship type may be dispensed with~~	~~Ch. 8, Pt. 2 of the Rules~~ Guidelines for Hull Structure of Woodchip Carriers
Ferry Passenger Ship	Ferry passenger ships	Ferry carrying more than 12 passengers	Ch. 9, Pt. 2 of the Rules

Cargo and Loading Characteristics Notations **Table D**

Class notation	Description		Technical requirements
SOLAS XII	SOLAS XII bulk cargo loading	The notation is assigned to ships intended to carry dry cargo in bulk, with a configuration different from that defined in 8.1.1.1, Chapter 8, Pt. 2 of the Rules, provided that the requirements of Chapter 37, Pt. 8 of the Rules are satisfied.	Chapter 37, Pt. 8 of the Rules

Special Features Notations **Table E**

Class notation	Description		Technical requirements
ASMW	Operational	The likelihood of different modes of navigation	Sec. 9, Ch. 1, Pt. 2 of the

① For high speed craft complying with the provisions of the Rules for Classification of Sea-going Boats, the suffix (HSC) will be added after the type notation.

② The technical requirements listed in this Table are the basic ones for ships assigned to the notation; in other special cases involving ship types, special consideration is to be given by CCS according to the ship's specific conditions.

Class notation	Description		Technical requirements
	guidance for ships in high sea conditions	safety failures under the combined or separate action of wind and waves is assessed by using methods based on hydrodynamics, to determine sailing conditions that may affect safety and prepare operational guidance for ships in high sea conditions for the master's reference.	Rules

Special Equipment and System Notations **Table G**

Class notation	Description		Technical requirements
HMS(×)	Hull monitoring system	This notation may be assigned when monitoring sensors are installed in the hull monitoring system, but also sensors/ components monitoring other parameters are selected, where within the brackets there will be letters specifying the selected sensors/components and multiple letters are separated by a comma ",". The following sensors/ components may be selected for the hull monitoring system: Gn: Sensor monitoring the global hull strain Dn: Sensor monitoring the local hull strain On: Sensor monitoring the propulsion shaft(s) output An: Sensor monitoring the axial acceleration Mn: Device for monitoring of hull rigid body motions (six degrees of freedom) Pn: Sensor monitoring the transient sea pressure acting on the hull (slamming) Sn: Sensor monitoring the liquid motion pressures in tanks (sloshing) Tn: Sensor monitoring the temperature Bn: Device for monitoring the wave Wn: Wind sensor Nn: Navigation sensors Cn: Online link to loading computer that is continuously up-dating the loading condition Ln: Backup of statistics and triggered monitoring calendars and sending them to CCS on a regular basis Note: n denotes the number of sensors or devices	Ch. 21, Pt. 8 of the Rules
HMS-HSC(×)		This notation may be assigned to the hull monitoring system installed on high speed craft Within the brackets there will be letters specifying the selected sensors/components and multiple letters are separated by a comma ",". The following sensors/ components may be selected for the hull monitoring system: An: Sensor monitoring the axial acceleration Gn: Sensor monitoring the global hull strain Dn: Sensor monitoring the local hull strain Pn: Sensor monitoring the transient sea pressure acting on the hull (slamming) Note: n denotes the number of sensors or devices	
WAP(ROTOR)	Rotor assisted propulsion system	This notation may be assigned to ships provided with the wind-rotor assisted propulsion system	Guidelines for Survey of Marine Wind-Rotor Assisted Propulsion System
RWA	Reduced anchor weight	This notation may be assigned to ships using high holding power anchor or very high holding power anchor to replace ordinary stockless bow anchor, so as to reduce anchor weight	Sec.2, Ch. 3, Pt. 2 of the Rules

Class notation	Description		Technical requirements
PSD	Rotating duct in front of propellers	This notation may be assigned to ships provided with the energy-saving appendages in front of propellers	Sec.8, Ch. 3, Pt. 2 of the Rules
Methanol Bunkering	Methanol bunkering	This notation may be assigned to ships provided with methanol bunkering system	Guidelines for Methanol Bunkering Ships
~~DP-N(CB/CR)~~	~~Closed Bus-Tied DP~~	~~Ships or offshore installations provided with closed bus-tie DP are assigned this notations, among which N should be 2 or 3:~~ ~~Abbrieviated CB and CR implies:~~ ~~CB— Bus bars are closed bus tied, but not ring type;~~ ~~CR— Bus bars are connected as closed ring type.~~ ~~CB,CR could not be assigned simultaneously~~	~~Guidelines for closed bus tie DP~~
DP-N(CBV/CBNV)	DP systems based on closed bus bars	Ships or offshore installations provided with DP systems are assigned this notation, among which N should be 2 or 3: Abbreviated CBV and CBNV imply: CBV— witnessing of closed bus bars on board; CBNV— witnessing of closed bus bars on board is not necessary. CBV,CBNV could not be assigned simultaneously	Guidelines for DP systems based on closed bus bars
OCCS Ready 1	Carbon capture system ready	Design and approval of principle drawings are carried out for OCCS ready ship to ensure that the ship is in compliance with the basic requirements for future installation of OCCS, and that no equipment or systems related to carbon capture systems have actually been installed on board	Guidelines for Shipboard Carbon Capture Systems
OCCS Ready 2		Design and approval of detailed drawings are carried out for OCCS ready ship to ensure that the OCCS ready is in compliance with the relevant requirements, and that no equipment or systems related to carbon capture systems have actually been installed on board	
OCCS Ready 2(X)		On the basis of meeting the requirements of OCCS Ready 2, the OCCS related equipment and systems have actually been installed on board the ship. The symbol X represents one or more suffixes of class notation, with the following specific meanings: ① The hull structures and related supporting structures have been strengthened, represented by the capital letter S; ② The absorption tower, desorption tower and absorbent circulation system have been installed, represented by the capital letter A; ③ The CO_2 compression and liquefaction system has been installed, represented by the capital letter L; ④ The CO_2 storage tanks have been installed, represented by the capital letter T	

Appendix 2 DIAGRAMS OF MANDATORY SHIP TYPES FOR SHIPS HAVING ESP NOTATION

2 Ship Type and Enhanced Survey Programme (ESP) Notations

2.1 Oil tanker

The ship type notation “Oil Tanker”, or equivalent, and the notation “ESP” are to be assigned to sea-going self-propelled ships[①] which are constructed ~~generally~~ with integral cargo tanks and intended primarily to carry oil in bulk. This type notation is to be assigned to tankers of both single and double hull construction, as well as tankers with alternative structural arrangements, e.g. mid-deck designs. Typical midship sections are given in Figure 2.1.

Note: Oil tankers that do not comply with MARPOL I/19 may be subject to International and/or National Regulations requiring phaseout under MARPOL I/20 and/or MARPOL I/21.

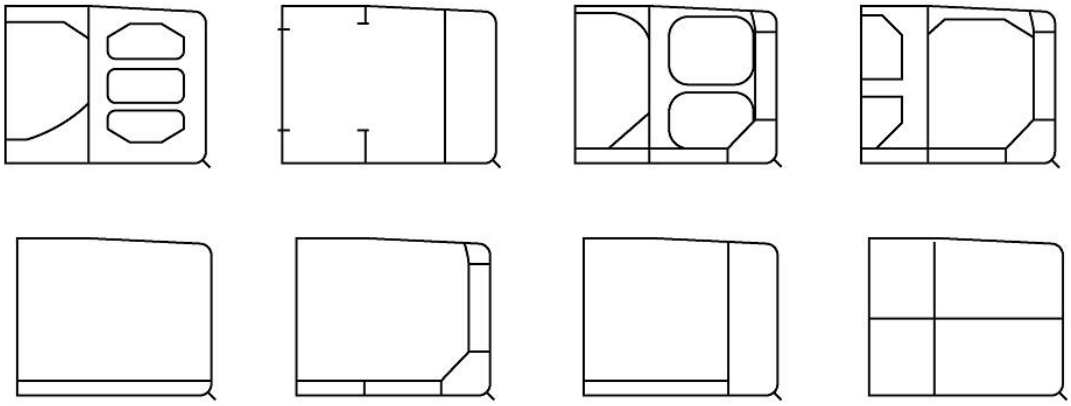

Figure 2.1

[①] Self-propelled ships are ships with mechanical means of propulsion not requiring assistance from another ship during normal operation.

CHAPTER 3 INSPECTIONS OF PRODUCTS

Appendix 1A LIST OF CERTIFICATION REQUIREMENTS FOR CLASSED MARINE PRODUCTS

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
Machinery (including machinery equipment of refrigerated vessels)									
8	Pumps and piping								Refer to Appendix 1D for the additional requirements for pumps and piping included in liquefied natural gas specialized products
8.27	Fume exhaust valve	-	X	-	X	O	-	X	
12	Shafting and propeller								
12.18	Cycloidal steering oar	X	-	-	-	-	-	X	

Appendix 1B LIST OF CERTIFICATION REQUIREMENTS FOR STATUTORY MARINE PRODUCTS①

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
2	Pollution prevention at sea								
2.8	Exhaust cleaning system(scheme A)	X	—	—	X	O	—	X	~~Exhaust cleaning system for scheme A~~ SOx emission compliance certificate
2.9	Exhaust cleaning system(scheme B)	—	—	—	—	—	—	X	To be implemented in accordance with 2.8 of this table for ships flying the flag of China
2.10	Exhaust gas monitoring system	-	X	-	X	O	-	X	For exhaust gas emission monitoring
2.11	Discharge water monitoring system	-	X	-	X	O	-	X	For washwater discharge monitoring
2.9~~12~~	Equipment reducing NO_x emission on board by other equivalent method	X	—	—	X	O	—	X	
2.~~10~~13	Equipment limiting SO_x emission by other technology	X	—	—	X	O	—	X	
2.~~11~~14	NO_x emission of diesel engines of over 130 kW	X	—	—	X	O	—	X	EIAPP certificate
2.~~12~~15	Ballast water management system	X	—	—	X	O	—	X	
2.~~13~~16	Crude oil washing machine	X	—	—	X	O	—	X	
2.~~14~~17	Comminuting and disinfecting system	X	—	—	X	O	—	X	For sewage
~~2.15~~	~~Devices for processing and recording after discharge~~	~~X~~	~~—~~	~~—~~	~~X~~	~~O~~	~~—~~	~~X~~	
3	Fire-resisting material, structure and fire-fighting equipment								
3.32	Helicopter deck foam fire-extinguishing arrangement	X	—	—	X	O	—	X	Foam fire-extinguishing arrangement protecting helicopter deck
~~3.33~~	~~Helicopter land area foam fire-extinguishing arrangement~~	~~X~~	~~—~~	~~—~~	~~X~~	~~O~~	~~—~~	~~X~~	

① If the list is not consistent with the requirements of the flag State Government, the provisions of the flag State Government are to prevail.

Appendix 1C LIST OF CERTIFICATION REQUIREMENTS FOR LIFTING APPLIANCES

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
6	Telescope gangway	X	—	—	—	—	—	X	

Appendix 1E LIST OF CERTIFICATION REQUIREMENTS FOR METHANOL FUEL SYSTEM SPECIALIZED PRODUCTS

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
Independent or portable methanol tank									
1	Independent/portable tank	X	—	—	—	—	X	X	
1.1	Rolled steel	X	—	—	—	—	X	—	
1.2	Forged steel	X	—	—	—	—	X	—	
1.3	Pipes, forgings, castings and fittings (bend, three-way, pipe nipple and tapered pipe, etc.) for methanol piping	X	—	—	—	—	X	—	
1.4	End plate	X	—	—	—	—	X	X[1]	As purchased parts
1.5	Welding consumables	—	X	—	—	—	X	—	
1.6	Fluid well	X	—	—	—	—	—	X[1]	As purchased parts
1.7	Electrical penetrations	—	X	—	X	—	—	X	Air-tight electrical penetrations for submerged pump cables
1.8	Safety valve	X	—	—	X	O	—	X	
Methanol fuel supply and related systems									
2	Methanol main engine fuel supply system								
2.1	Methanol fuel supply unit	X	—	—	—	—	—	X	Applicable to supply in unit mode
2.1.1	Fuel pump	X	—	—	X	O	—	X	Including low pressure pump and high pressure pump etc.
2.1.2	Filter	X	—	—	—	—	—	X	Used for pipes of methanol fuel
2.1.3	Heat exchanger	X	—	X	O	O	—	X	
2.1.4	Electrical control box	X	—	—	—	—	—	X	
2.2	Methanol fuel valve unit	X	—	O	—	—	—	X	
2.2.1	Valve	X	—	—	X	—	—	X	
2.2.2	Filter	X	—	—	—	—	—	X	Used for pipes of methanol fuel
2.2.3	Electrical control box	X	—	—	—	—	—	X	
3	Generator set methanol fuel supply system								
3.1	Methanol low pressure pump unit	X	—	—	—	—	—	X	Applicable to supply in unit mode
3.1.1	Fuel pump	X	—	—	X	O	—	X	Low pressure pump etc.
3.1.2	Heat exchanger	X	—	X	O	O	—	X	
3.1.3	Electrical control box	X	—	—	—	—	—	X	

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
3.2	Methanol fuel valve unit	X	—	O	—	—	—	X	
3.2.1	Valve	X	—	—	X	—	—	X	
3.2.2	Filter	X	—	—	—	—	—	X	Used for pipes of methanol fuel
3.2.3	Pressure vessel	X	—	—	—	—	X	X	Including knock-out drum etc.
3.2.4	Electrical control box	X	—	—	—	—	—	X	
3.3	Methanol fuel pump unit	X	—	—	—	—	—	X	Applicable to supply in unit mode
3.3.1	Fuel pump	X	—	—	X	O	—	X	High pressure pump etc.
3.3.2	Electrical control box	X	—	—	—	—	—	X	
3.4	Seal and control oil pump unit	X	—	—	—	—	—	X	Applicable to supply in unit mode
3.4.1	Oil pump	X	—	—	X	O	—	X	Seal and control oil pump unit etc.
3.4.2	Valve	X	—	—	X	—	—	X	
3.4.3	Filter	X	—	—	—	—	—	X	
4	Methanol boiler fuel supply system								
4.1	Methanol fuel valve unit	X	—	O	—	—	—	X	
4.1.1	Valve	X	—	—	X	—	—	X	
4.1.2	Filter	X	—	—	—	—	—	X	Used for pipes of methanol fuel
4.1.3	Electrical control box	X	—	—	—	—	—	X	
4.1.4	Fuel pump								Used for methanol boiler fuel delivery
5	Methanol bunkering and storage system								
5.1	Bunkering station unit	X	—	—	—	—	—	X	Applicable to supply in unit mode
5.2	Independent/portable tank	X	—	—	—	—	X	X	For certification requirements, refer to independent or portable methanol tank
5.3	Safety valve	X	—	—	X	O	—	X	Used for methanol piping and pressure vessel
5.4	Emergency shut-down valve	X	—	—	X	—	—	X	
5.5	Hydraulic power plant	X	—	—	—	—	—	X	For driving emergency shut-down valve
6	Glycol water system								
6.1	Glycol water system unit	X	—	—	—	—	—	X	Applicable to supply in unit mode

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
6.2	Glycol water circulation pump	X	—	—	X	O	—	X	
6.3	Heat exchanger	X	—	X	O	O	—	X	
6.4	Glycol water balancing vessel	X	—	—	—	—	X	X	Applicable to equipment belonging to pressure vessel
6.5	Electrical control box	X	—	—	—	—	—	X	
7	Nitrogen generator and supply system								
7.1	Nitrogen generator unit	X	—	—	—	—	—	X	Applicable to supply in unit mode
7.2	Nitrogen generator	X	—	—	X	—	—	X	
7.3	Nitrogen tank	X	—	—	—	—	O	X	
7.4	Air compressor	X	—	X	O	O	—	X	
7.5	Electrical control box	X	—	—	—	—	—	X	
8	Piping, valve and fittings								
8.1	Valve	X	—	—	X	—	—	X	Applicable to methanol fuel piping valve
8.2	Pipes, forgings, castings and fittings (bend, three-way, pipe nipple and tapered pipe, etc.) for methanol piping	X	—	—	—	—	X	—	
8.3	Double walled pipe	X	—	—	—	—	—	X	
8.4	Filter	X	—	—	—	—	—	X	Used for pipes of methanol fuel
8.5	Flowmeter	—	X	—	X	—	—	X	Used for pipes of methanol fuel
8.6	Vent mast cap	X	—	—	—	—	—	X	
8.7	Flexible hose assembly	X	—	—	X	O	—	X	Used for pipes of methanol fuel
8.8	Expansion joint and corrugated pipe	X	—	—	X	—	—	X	
8.9	Pressure/vacuum valve	X	—	—	X	—	—	X	Used for ventilation of methanol daily tank
8.10	Fan	X	—	X	O	O	—	X	Used for ventilation of of double walled pipe
Electrical installations and automatic equipment									
9.1	Pressure control and monitoring, alarm system	X	—	—	X	O	—	X	Applicable to inert gas system
9.2	Fuel tank monitoring and control system	X	—	—	X	O	—	X	
9.3	Methanol fuel supply electrical control system	X	—	—	X	O	—	X	Including control, alarm and safety system

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
9.4	Fixed gas detection system	X	—	—	X	O	—	X	Applicable to flammable gas detection, toxic gas detection, oxygen levels detection, chlorine concentration gas detection, carbon dioxide gas detection. Including controller and detector
9.5	Fixed fire detection and fire alarm system	X	—	—	X	O	—	X	The system shall effectively detect methanol flame
9.6	Ship-Shore/Ship Link-System	X	—	—	—	—	—	X	If the product is included in other system , there is no duplicate requirement to hold the certificate
9.7	Emergency shutdown system(ESD)	X	—	—	—	—	—	X	If the product is included in other system , there is no duplicate requirement to hold the certificate

Symbols:

1) C – Marine Products Certificate; E – Equivalent document; W – Manufacturer's document; X – Applicable; — – Not Applicable; O – Optional.

2) DA – Design approval; TA-B – Type approval B; TA-A – Type approval A; WA – Works approval; PA – Plan approval

3)X^1: Inspection is to be carried out according to approved integral product/system (ship, product) drawing.

Appendix 2A LIST OF CERTIFICATION REQUIREMENTS FOR CLASSED MARINE PRODUCT PARTS

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
Machinery (including machinery equipment of refrigerated vessels)									
8	Pumps and piping								
8.27	Fume exhaust valve								
10	Machinery equipment								
10.3	Diesel engine								
10.3.1	Diesel engine (cylinder diameter > 300 mm or single cylinder power >400 kW)								
.29	Other engine-driven pump (oil, water, fuel, bilge water) except for .~~21~~22 and .~~27~~ 28	—	X	—	X	O	—	X	Applicable to engines with power ＞800kW/cyl; W to include hydraulic test;
12	Shafting and propeller								
12.18	Cycloidal steering oar								
.1	Motors (50 kW and over)	X	-	-	X	O	-	X	
.2	Electrical control box (if any)	X	-	-	-	-	-	X	
.3	Main shaft	X	-	-	-	-	X	X	
.4	Bevel gear shaft	X	-	-	-	-	X	X	
.5	Bevel gear	X	-	-	-	-	X	X	
.6	Gear shaft	X	-	-	-	-	X	X	
.7	Blade	X	-	-	-	-	X	X	
.8	Propeller shaft	X	-	-	-	-	X	X	

Appendix 2B LIST OF CERTIFICATION REQUIREMENTS FOR STATUTORY MARINE PRODUCT PARTS

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
2	Pollution prevention at sea								
~~2.8~~	~~Exhaust cleaning system~~								
~~.1~~	~~Exhaust pipe~~	~~—~~	~~X~~	~~—~~	~~—~~	~~—~~	~~X~~	~~—~~	~~Piping of Class III~~
~~.2~~	~~Valve~~	~~X~~	~~—~~	~~—~~	~~X~~	~~O~~	~~—~~	~~X~~	~~Piping of Classes I, II and III over 300 mm~~
~~.3~~	~~Pump (sea water pump and fresh water pump)~~	~~X~~	~~—~~	~~—~~	~~X~~	~~O~~	~~—~~	~~X~~	
~~.4~~	~~Water treatment system (scrubber)~~	~~X~~	~~—~~	~~—~~	~~—~~	~~—~~	~~—~~	~~X~~	
~~.5~~	~~Induced-draft fan/blower~~	~~X~~	~~—~~	~~—~~	~~—~~	~~—~~	~~—~~	~~X~~	
~~.6~~	~~Motors (50 kW and over)~~	~~X~~	~~—~~	~~—~~	~~X~~	~~O~~	~~—~~	~~X~~	
~~.7~~	~~Motors (below 50 kW)~~	~~—~~	~~X~~	~~—~~	~~X~~	~~—~~	~~—~~	~~X~~	
~~.8~~	~~Electrical control box~~	~~X~~	~~—~~	~~—~~	~~—~~	~~—~~	~~—~~	~~X~~	~~The first product is to be subject to type test~~
2.8	Exhaust cleaning system(scheme A)								Exhaust pipe, induced-draft fan/blower, pump, valve, piping, motor, electrical control box etc. used for the system are to be certified in accordance with the requirements of appendix 1A. Water treatment system is to be certified by referring to 10.3.4 of appendix 2A
2.8.1	Scrubber	X	-	-	-	-	-	X	
2.9	Exhaust cleaning system(scheme B)								Exhaust pipe, induced-draft fan/blower, pump, valve, piping, motor, electrical control box etc. used for the system are to be certified in accordance with the requirements of appendix 1A. Water treatment system is to be certified by referring to 10.3.4 of appendix 2A
2.9.1	Scrubber	X	-	-	-	-	-	X	
~~2.15~~	~~Devices for processing and recording after discharge~~								
3	Fire-resisting material, structure and fire-								

	fighting equipment								
3.32	Helicopter ~~platform~~ deck foam fire-extinguishing arrangement								
.1	Low-expansion foam fire-extinguishing medium	—	X	—	—	—	X	—	
.2	Foam storage tank	X	—	—	—	—	X	X	
.3	Proportion mixer	X	—	—	—	—	—	X	
.4	Foam monitor	X	—	—	X	O	—	X	

Appendix 2C LIST OF CERTIFICATION REQUIREMENTS FOR LIFTING APPLIANCE PARTS

No.	Product name	Document		Approval mode				Plan approval	Remark
		C/E	W	DA	TA-B	TA-A	WA	PA	
6	Telescope gangway								
6.1	Main structure								
.1	Aluminium alloy	×	—	—	—	—	×	—	
6.2	Telescopic and amplitude-changing rotary mechanism								
.1	Motors (50 kW and over)	×	—	—	×	0	—	×	
.2	Motors (below 50 kW)	—	×	—	×	—	—	×	
.3	Gear	×	—	—	—	—	×	×[1]	C/E to be provided for forging material
.4	Rack	×	—	—	—	—	—	×	
.5	Guide	×	—	—	—	—	—	×	
.6	Brake	×	—	0	0	—	—	×	
.7	Luffing cylinder	×	—	—	—	—	—	×[1]	
.8	Reduction gearbox	×	—	×	—	—	—	×	
.9	Rotating support	×	—	—	×	0	—	×[1]	C/E to be provided for forging material
.10	Hydraulic motor	×[2]	—	—	—	—	—	×	
6.3	Hydraulic power unit								
.1	Flexible hose assembly, for piping of Classes I and II or more than 50 mm in diameter	×	—	—	×	0	—	×	
.2	Flexible hose assembly: except for above-mentioned	—	×	—	×	—	—	×	
.3	Hydraulic pump	×	—	—	×	0	—	×	
.4	Accumulator	0	×	—	—	—	×	×	<0.7 MPa & 0.1 ~ 0.25 m^3, WA to be provided for W, ≥ 0.7 MPa or ≥ 0.25 m^3, C/E to be provided
.5	Motors (50 kW and over)	×	—	—	×	0	—	×	
.6	Motors (below 50 kW)	—	×	—	×	—	—	×	
.7	Electrical control box	×	—	—	—	—	—	×	
6.4	Winch (where applicable)								
.1	Winch	×	—	—	—	—	—	×	

CHAPTER 4 SURVEY DURING CONSTRUCTION[①]

Section 2 SURVEYS AND TESTS

4.2.1 General requirements

4.2.1.6 Unless otherwise specified, the survey of all watertight cable transits installed on all ships contracted for construction on or after the effective date of the amendments is to comply with the requirements of Appendix 3 of this Chapter.

[①] The requirements for initial classification surveys of ships under construction are given in 5.14.2 of Section 14 of Chapter 5.

CHAPTER 5 SURVEY AFTER CONSTRUCTION

Section 1 GENERAL PROVISIONS

5.1.5 Definitions

5.1.5.2 The following definitions are added for oil tankers in addition to those in 5.1.5.1 of this Chapter:

(3) An **oil tanker** is a ship which is constructed primarily to carry oil in bulk in cargo tanks forming an integral part of the ship's hull, and including ship types such as combination carriers (Ore/Oil ships etc.) but excluding ships carrying oil in independent tanks not part of the ship's hull such as asphalt carriers.

(~~3~~4) A **double hull oil tanker** is a ship which is constructed primarily for the carriage of oil in bulk, which has the cargo tanks forming an integral part of the ship's hull and is protected by a double hull which extends for the entire length of the cargo area, consisting of double sides and double bottom spaces for the carriage of water ballast or void spaces.

5.1.5.3 The following definitions are added for bulk carriers in addition to those in 5.1.5.1 of this Chapter:

(3) **Ballast tank:**

① A **ballast tank of a bulk carrier** is a tank which is used ~~solely~~ primarily for salt water ballast, or, where applicable, a space which is used for both cargo and salt ballast will be treated as a ballast tank when substantial corrosion has been found in that space.

② A **ballast tank of a double skin bulk carrier** is a tank which is used ~~solely~~ primarily for salt water ballast, or, where applicable, a space which is used for both cargo and salt ballast will be treated as a ballast tank when substantial corrosion has been found in that space. A double side tank is to be considered as a separate tank even if it is in connection to either the topside tank or the hopper side tank.

5.1.7 Documentation on board

5.1.7.3 Supporting documents

(1) The following additional documentation is to be available on board:

① survey programme as required by 5.1.6.5 until such time as the special survey or intermediate survey, as applicable, has been completed;

② main structural plans of cargo/cargo oil and ballast tanks (for CSR ships these plans are to include for each structural element both the as-built and renewal thickness. Any thickness for voluntary addition is also to be clearly indicated on the plans. The midship section plan to be supplied on board the ship is to include the minimum allowable hull girder sectional properties for the hold/ tank transverse section in all cargo holds/tanks);

③ previous repair history;

④ cargo and ballast history;

⑤ inspection by ship's personnel with reference to:

a. structural deterioration in general;

b. leakages in bulkheads and piping;

c. condition of coating or corrosion protection, if any;

d. a guidance for reporting is shown in paragraph 2, Appendix 12 of this Chapter;

⑥ extent of use of inert gas plant and tank cleaning procedures (for oil tankers and chemical tankers);

⑦ any other information that will help identify suspect areas and/or critical structural areas requiring inspection;

⑧ Cable Transit Seal Systems Register, the owner is to maintain the Register to record any disruption (repair, modification or opening out and closing) to a cable transit or to record the installation of a new cable transit.

5.1.8 Reporting and evaluation of survey

5.1.8.4 An executive hull summary (see Appendix 11 of this Chapter) is to be summarized and developed by the survey unit completing the enhanced survey, and upon verification and endorsement by CCS authorized person, the executive hull summary is to be issued to the owner and placed on board the ship for reference at future surveys.

5.1.18 Remote Inspection Techniques (RIT)①

5.1.18.1 The RIT is to provide the information normally obtained from a close-up survey. RIT surveys are to be carried out in accordance with the requirements given here-in and the requirements of IACS Recommendation 42 'Guidelines for Use of Remote Inspection Techniques for surveys'. These considerations are to be included in the proposals for use of a RIT which are to be submitted in advance of the survey so that satisfactory arrangements can be agreed with CCS.

5.1.18.2 The equipment and procedure for observing and reporting the survey using a RIT are to be discussed and agreed with the parties involved prior to the RIT survey, and suitable time is to be allowed to set-up, calibrate and test all equipment beforehand.

5.1.18.3 When using a RIT as an alternative to close-up survey, if not carried out by CCS itself, it is to be conducted by a firm approved as a service supplier according to Appendix 8 of this Chapter and is to be witnessed by an attending surveyor of CCS.

5.1.18.4 The structure to be examined using a RIT is to be sufficiently clean to permit meaningful examination. Visibility is to be sufficient to allow for a meaningful examination. CCS is to be satisfied with the methods of orientation on the structure.

5.1.18.5 The Surveyor is to be satisfied with the method of data presentation including pictorial representation, and a good two-way communication between the Surveyor and RIT operator is to be provided.

5.1.18.6 If the RIT reveals damage or deterioration that requires attention, the Surveyor may require traditional survey to be undertaken without the use of a RIT.

Section 6 ADDITIONAL REQUIREMENTS FOR HULL AND EQUIPMENT SURVEYS OF OIL TANKERS

5.6.4 Special surveys

5.6.4.5 Extent of tank testing

(1) The minimum requirements for ballast tank testing are given in (3) of this paragraph and Table 5.6.4.5(1); the minimum requirements for cargo tank testing are given in (4) of this paragraph and Table 5.6.4.5(1). Cargo tank testing carried out by the ship's crew under the direction of the Master may be accepted by the Surveyor provided the following conditions are complied with:

① a tank testing procedure, specifying fill heights, tanks being filled and bulkheads being tested, has been submitted by the Owner and reviewed by CCS prior to the testing being carried out;

② the tank testing is carried out prior to overall survey or close-up survey;

③ the tank testing is carried out within the special survey window and not more than 3 months prior to the date on which the overall or close up survey is completed;

②④ there is no record of leakage, distortion or substantial corrosion that would affect the structural integrity of the tank;

~~③ the tank testing has been satisfactorily carried out within a special survey window not more than 3 months prior to the date of the survey on which the overall or close-up survey is completed;~~

④⑤ the satisfactory results of the testing is recorded in the ship's logbook;

⑤⑥ the internal and external condition of the tanks and associated structure are found satisfactory by the Surveyor at the time of the overall and close-up survey.

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① Remote Inspection Techniques (RIT) is ~~not applicable to surveys of oil tankers and bulk carriers~~ applicable to survey of ships specified in Sections 4, 5, 8 and 16 of this Chapter.

Section 7 ADDITIONAL REQUIREMENTS FOR HULL AND EQUIPMENT SURVEYS OF BULK CARRIERS

5.7.2 Annual surveys

5.7.2.9 Examination of double-side skin void spaces for bulk carriers exceeding 20 years of age and of 150 m in length and upwards

(1) Examination of double-side skin void spaces, for bulk carriers exceeding 20 years of age and of 150 m in length and upwards, are to be carried out as required by 5.7.4.2(4) and 5.7.3.4(1) of this Section. When considered necessary by the Administration, or when extensive corrosion exists, thickness measurements are to be carried out. If the results of these thickness measurements indicate that substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with Table 5.7.4.5(2)②a～d of this Section. These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

(2) For ships built under the IACS Common Structural Rules, the annual thickness gauging may be omitted where a protective coating has been applied in accordance with the coating manufacturer's requirements and is maintained in good condition.

5.7.3 Intermediate surveys

5.7.3.2 Bulk carriers 5 to 10 years of age

① Ballast tanks

a. For tanks used for water ballast, an overall survey of representative spaces selected by the Surveyor is to be carried out. The selection is to include fore and aft peak tanks and a number of other tanks, taking into account the total number and type of ballast tanks. If such overall survey reveals no visible structural defects, the examination may be limited to verification that the corrosion prevention system remains efficient.

b. Where ~~POOR coating~~ a hard coating is found to be in less than GOOD condition, corrosion or other structural defects are found in water ballast tanks or where a hard protective coating was not applied from the time of construction, the examination is to be extended to other ballast tanks of the same type.

c. In ballast tanks other than double bottom tanks, where a hard protective coating is found ~~in POOR~~ to be in less than GOOD condition and it is not renewed, or where a soft or semi-hard coating has been applied, or where a hard protective coating was not applied from the time of construction, the tanks in question are to be examined and thickness measurements carried out as considered necessary at annual intervals. When such breakdown of hard protective coating is found in ballast double bottom tanks, or where a soft or semi-hard coating has been applied, or where a hard protective coating has not been applied, the tanks in question may be examined at annual intervals. When considered necessary by the Surveyor, or where extensive corrosion exists, thickness measurements are to be carried out.

5.7.4 Special surveys

5.7.4.2 ~~Tank~~ Space protection

(1) Where provided, the condition of the corrosion prevention system of ballast tanks is to be examined. For ballast tanks, excluding double bottom tanks, where a hard protective coating is found ~~in POOR~~ to be in less than GOOD condition and it is not renewed, where a soft or semi-hard coating has been applied, or where a hard protective coating has not been applied from the time of construction, the tanks in question are to be examined at annual intervals. Thickness measurements are to be carried out as deemed necessary by the Surveyor.

(2) When such breakdown of hard protective coating is found in water ballast double bottom tanks and it is not renewed, where a soft or semi-hard coating has been applied, or where a hard protective coating has not been applied from the time of construction, the tanks in question may be examined at annual intervals.

When considered necessary by the surveyor, or where extensive corrosion exists, thickness measurements are to be carried out.
(3) Where a hard protective coating is provided in cargo holds and is found in GOOD condition, the extent of close-up surveys and thickness measurements may be specially considered.
(4) For double-side skin void spaces bounding cargo holds for bulk carriers exceeding 20 years of age and of 150 m in length and upwards, where provided, the condition of the corrosion prevention system of void spaces is to be examined. Where a hard protective coating is found to be in POOR condition, and it is not renewed, or where a soft or semi-hard coating has been applied, or where a hard protective coating has not been applied from the time of construction, the void spaces in question are to be examined at annual intervals. Thickness measurements are to be carried out as deemed necessary by the surveyor.

Section 12 SURVEYS OF PROPELLER SHAFTS AND TUBE SHAFTS

5.12.2 Oil lubricated shafts or closed loop system fresh water lubricated shafts (closed system)
5.12.2.1 Shaft survey methods
(1) Method 1
The survey is to consist of:
③ for flanged connection:
a. whenever the coupling bolts of any type of flange-connected shaft are removed or the flange radius is made accessible in connection with overhaul, repairs or when deemed necessary by the Surveyor, the coupling bolts and flange radius are to be examined by means of an approved surface crack-detection method.

(2) Method 2
The survey is to consist of:
② for flanged connection:
a. a. whenever the coupling bolts of any type of flange-connected shaft are removed or the flange radius is made accessible in connection with overhaul, repairs or when deemed necessary by the Surveyor, the coupling bolts and flange radius are to be examined by means of an approved surface crack-detection method.

5.12.3 Water lubricated shafts (open systems)
5.12.3.1 Shaft Survey Methods
(1) Method 4
The survey is to consist of:
③ for flanged connection:
a. a. whenever the coupling bolts of any type of flange-connected shaft are removed or the flange radius is made accessible in connection with overhaul, repairs or when deemed necessary by the Surveyor, the coupling bolts and flange radius are to be examined by means of an approved surface crack-detection method.

5.12.4 Survey related to notation SCM
5.12.4.1 For ships which are assigned the notation SCM in accordance with Appendix 14 “Guidelines for Screwshaft Condition Monitoring System” of this Chapter, if they are found satisfactory at a survey of the items specified in 5.12.4.3, ~~and~~ 5.12.4.4 or 5.12.4.5, it may be not necessary to consider items related to the drawing of oil lubricated screwshaft for examination ~~may not be necessary~~ when the examination is carried out in accordance with 5.12.2.1(1) or 5.12.3.1(1), ~~but~~ and the interval of drawing may be extended to a maximum period not exceeding 15 years for water lubricated screwshaft.
5.12.4.2 Notwithstanding the notation SCM, the survey is to comply with 5.12.2.1(1) or 5.12.3.1(1).
5.12.4.4 For closed water-lubricated propeller shafts, the shaft condition monitoring (SCM) is to be verified during each annual survey of the ship, covering:

(1) propeller shaft condition records, including alarm records, examination and maintenance records, lubricating water sampling / testing records and closed cycle lubricating water consumption records;
(2) confirmation that lubricating water samples have been submitted to a laboratory analysis organization complying with international standards (e.g. ISO/IEC 17025) or accepted by CCS complying with equivalent standards at least once every 6 months for analysis and test of the samples; the water quality parameters include at least:

① chloride content;
② PH value;
③ content of bearing particles.

(3) verification that water quality analysis report issued by the analysis organization, together with a qualification certificate of the organization and a conclusion on the condition and suitability of the water, are kept on board; the Surveyor is to verify a water quality analysis report from the last 6 months;
(4) examination and confirmation that the lubricating water supply system (including pumping and water filters/separators), alarm system and shaft starting interlock are in normal condition.

5.12.4.5 For open water-lubricated propeller shafts, the SCM is to be verified during the annual survey, covering:
(1) propeller shaft condition records, including alarm records, examination and maintenance records, lubricating water sampling / testing records, etc.;
(2) confirmation that the ship has developed procedures for sampling and testing supply water and is provided with the testing kit. Lubricating water is sampled at least once every 6 months to test the size of particles in the supply water so as to confirm that the water complies with the design requirements of the manufacturer. The ship can also submit the water samples to a laboratory analysis organization complying with international standards (e.g. ISO/IEC 17025) or accepted by CCS complying with equivalent standards for analysis and test. In the absence of procedures for sampling and testing supply water or records for sampling and testing, there is to be other equivalent means to prove that the supply water system is in a satisfactory working condition, and specific equivalent means may be referred to 1.3.2.5, Appendix 14 Guidelines for Screwshaft Condition Monitoring System of this Chapter.
(3) Check the supply water treatment system (including pumping and filtration or separation units), alarm system and shaft starting interlock, and confirm that they are in normal condition.

Section 14 INITIAL CLASSIFICATION SURVEYS OF SHIPS CONSTRUCTED NOT UNDER THE SUPERVISION OF CCS

5.14.3 Initial classification surveys of ships after construction

5.14.3.1 Initial classification surveys of ships which have been surveyed by the Societies accepted by CCS
(1) Initial classification surveys of ships which have been certified by the Societies accepted by CCS:

④ In addition to the items corresponding to ship's age and losing class status, the extent of surveys is to include the following:

a. Hull:

(c) For ships of 10 years of age and above but less than 20 years of age, the survey is to include an Annual Survey and inspection of a representative number of ballast spaces and cargo spaces, except for:

For oil tankers (including product carriers), chemical carriers of 10 years of age and above but less than 15 years of age, in lieu of an internal inspection of cargo tanks without internal stiffening and framing, inspections of surrounding ballast tank(s) and void spaces and deck structure, are to be applied.

Appendix 1 CRITERIA FOR RENEWAL OF HULL STRUCTURAL MEMBERS

This Appendix does not apply to the ships constructed in accordance with Common Structural Rules① and CCS Rules for Structures of Container Ships.

2 Criteria for local strength

2.9 For Polar Class ships, steel renewal is required where the shell plating corrosion/abrasion additions within the ice-strengthened hull areas is greater than the value specified in Table 13.2.11.2, Chapter 13, PART EIGHT of the Rules minus 0.5 mm.

① PART NINE or TEN of the Rules (2012 version) and its 2013 and 2014 amendments or PART NINE of the Rules (2015 version) and its subsequent versions (including amendments).

Appendix 8 PROCEDURAL REQUIREMENTS FOR SERVICE SUPPLIERS

3. Definitions

3.3 Agent: A person or company authorized to act for or to represent a manufacturer or approved / recognized service supplier.

6. Certification

6.1 Upon satisfactory completion of both the audit of the supplier and the demonstration test, as applicable, CCS may issue a certificate of approval stating that the supplier's service operation system has been found to be satisfactory and that the results of services performed in accordance with that system may be accepted and utilised by CCS Surveyors in making decisions affecting classification or statutory certification, as relevant. The certificate is to clearly state the type and scope of services and any limitations or restrictions imposed including type of equipment and/or names of manufacturers of equipment where this is a limiting restraint. The supplier may also be included in CCS record of approved service suppliers.

Annex 1
Special Requirements for Various Categories of Service Suppliers

13. Firms engaged in maintenance, thorough examination, operational testing, overhaul and repair of lifeboats and rescue boats, launching appliances and release gear

13.3 Certification of personnel

13.3.2 The education for initial certification of personnel should be documented and address, as a minimum:

— causes of lifeboat and rescue boat accidents;

14. Firms engaged in measurements of noise level onboard ships

14.4 Equipment

14.4.4 Calibration

Sound Calibrator and sound level meter are to be verified at least every two years by a national Standard laboratory or a competent laboratory accredited according to ISO/IEC 17025~~(2005)~~:2017, as amended. A record with a complete description of the equipment used is to be kept, including a calibration log.

Appendix 11 ESP SURVEY REPORTING PRINCIPLES

Report 1

EXECUTIVE HULL SUMMARY

A) General particulars:	– Refer to previous page
B) Report review:	– Where and how survey was done
C) Close-up survey:	– Extent (which tanks)
D) Cargo & ballast piping system	– Examined
	– Operationally tested
E) Thickness measurements:	– Reference to thickness measurement report
	– Summary of where measured
	– Separate form indicating the tanks/areas with substantial corrosion, and corresponding
	* Thickness diminution
	* Corrosion pattern
F) Tank protection	Separate form indicating:
	– Location of coating
	– If coating condition less than "GOOD" is given, extended annual surveys are to be introduced. This is to be noted in part ~~H~~ I) of the Executive Hull Summary.
G) Repairs:	– Identification of tanks/areas
H) Condition of class:	
I) Memoranda:	– Acceptable defects
	– Any points of attention for future surveys, e.g. for suspect areas
	– Examination of ballast tanks at annual surveys~~Extended annual/intermediate survey~~ due to coating breakdown
J) Evaluation results of the ship's longitudinal strength (for oil tankers of 130 m in length and upwards and of over 10 years of age)	
K) Conclusion	– Statement on evaluation/verification of survey report

TANK PROTECTION

1) Tank Nos.	2) Tank protection	3) Coating condition	Remarks

Remarks:
1) All segregated ballast tanks and combined cargo/ballast tanks to be listed.
2) C = Coating; NP = No Protection.
3) Coating condition according to the following standard:
GOOD condition with only minor spot rusting;
FAIR condition with local breakdown at edges of stiffeners and weld connections and/or light rusting over 20% or more of areas under consideration, but less than as defined for POOR condition;
POOR condition with general breakdown of coating over 20% or more of areas or hard scale at 10% or more of areas under consideration.

For ballast tanks, if ~~If~~ coating condition less than "GOOD" is given, ~~extended annual surveys are to be introduced~~ tanks are to be examined at annual surveys. This is to be noted in part I) of the Executive Hull Summary.

Report 2

EXECUTIVE HULL SUMMARY

A) General particulars:	–	Refer to previous page
B) Report review:	–	Where and how survey was done
C) Close-up survey:	–	Extent (which tanks)
D) Thickness measurements:	–	Reference to thickness measurement report
	–	Summary of where measured
	–	Separate form indicating the tanks/areas with substantial corrosion, and corresponding
	*	Thickness diminution
	*	Corrosion pattern
E) Tank/hold/double-side skin void space Protection	Separate form indicating:	
	–	Location of coating
	–	If coating condition "POOR" is given, extended annual surveys are to be introduced. This is to be noted in part ~~G~~ H) of the Executive Hull Summary.
F) Repairs:	–	Identification of tanks/areas
G) Condition of class:		
H) Memoranda:	–	Acceptable defects
	–	Any points of attention for future surveys, e.g. for suspect areas
	–	~~Extended annual/intermediate survey~~ Examination of ballast tanks and double-side skin void spaces at annual surveys due to coating breakdown
I) Conclusion	–	Statement on evaluation/verification of survey report

~~TANK~~SPACE PROTECTION

1) Tank/hold/void Nos.	2) Tank/hold/void protection	3) Coating condition	Remarks

Remarks:
1) All ballast tanks, ~~and~~ cargo holds and double-side skin void spaces to be listed.
2) C = Coating; NP = No Protection
3) Coating condition according to the following standard:

GOOD condition with only minor spot rusting;
FAIR condition with local breakdown at edges of stiffeners and weld connections and/or light rusting over 20% or more of areas under consideration, but less than as defined for POOR condition;
POOR condition with general breakdown of coating over 20% or more of areas or hard scale at 10% or more of areas under consideration.

For ballast tanks, if ~~If~~ coating condition less than "GOOD" ~~"POOR"~~ is given, ~~extended annual surveys are to be introduced~~ tanks are to be examined at annual surveys. This is to be noted in part H) of the Executive Hull Summary.
For double-side skin void spaces on bulk carriers exceeding 20 years of age and of 150 m in length and upwards, if coating condition POOR is given, those voids are to be examined at annual surveys. This is to be noted in part H of Executive Hull Summary.

Appendix 12 GUIDELINES FOR TECHNICAL ASSESSMENT IN CONJUNCTION WITH PLANNING FOR ENHANCED SURVEYS AND OWNER'S INSPECTION REPORT

1 Guidelines for technical assessment in conjunction with planning for enhanced surveys

1.1 Introduction

These guidelines contain information and suggestions concerning technical assessments, which may be of use in conjunction with the planning of enhanced special surveys of oil tankers, bulk carriers and chemical tankers. See 5.1.6.5(5) of this Chapter①.The guidelines are a recommended tool which may be invoked at the discretion of CCS, when considered necessary and appropriate, in conjunction with the preparation of the required survey programme.

1.2 Purpose and principles

1.2.4 Aspects to be considered

1.2.4.2 Technical assessments of the relative risks of susceptibility to damage or deterioration of various structural elements and areas are to be judged and decided on the basis of recognized principles and practices, such as may be found in publications of Tanker Structure Cooperative Forum (TSCF), (Refs.2 and 3)② and Bulk Carriers-Guidelines for Surveys, Assessment and Repair of Hull Structure (IACS), (Ref. 4).

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① Ref.1: See Sections ~~6, 7 and~~ 8 of this Chapter for ~~hull survey of oil tankers/~~chemical tankers~~/bulk carriers~~. IACS Rec 96 Double Hull Oil Tankers – Guidelines for Surveys, Assessment and Repair of Hull Structures, 2019.

② Ref.2: TSCF Guidance Manual for the Inspection and Condition Assessment of Tanker Structures (1986), TSCF Guidelines for the Inspection and Maintenance of Double Hull Tanker Structures (1995); Ref.3: TSCF Condition Evaluation and Maintenance of Tanker Structures (1992), TSCF Guidance Manual for Tanker Structures (1997), Rec 76 IACS Guidelines for Surveys, Assessment and Repair of Hull Structure – Bulk Carriers, 2007.

Appendix 14 GUIDELINES FOR SCREWSHAFT CONDITION MONITORING SYSTEM

1 General Provision

1.1 General requirements

1.1.3 Requirements for the analysis organization and its personnel

1.1.3.3 A lubricating water analysis organization carrying out water-lubricated screwshaft condition monitoring system is to comply with International Standards for Laboratory Approval (e.g. ISO/IEC 17025) or equivalent standards accepted by CCS. The analysis organization is to submit qualification certificate to the ship owner.

1.3 Water-lubricated screwshaft condition monitoring system

1.3.2 Technical requirements for condition monitoring system

1.3.2.1 The screwshaft is to either be made of corrosion resistant material or protected with a corrosion resistant protective liner or coating approved by CCS (i.e. shaft body is covered by paint between two bearing liners to prevent water corrosion). Where a protective liner and/or coating is used, the ship owner must submit measures for condition examination and evaluation (e.g. at stern tube opening or fitted with endoscope), which are to be approved by CCS.

1.3.2.3 A maximum permitted weardown of the bearing and the weardown at which it is recommended to carry out an inspection and maintenance are to be established, and equipment measuring bearing clearance is to be fitted. When the ship is docking or subject to in-water survey, bearing weardown or clearance is to be measured and the conditions of wear of protective shaft liner and integrity of coating are to be examined. The results are to be recorded and retained on board.

1.3.2.4 For open water lubrication system, ~~T~~the ship is to be fitted with water supply processing system. The lubricating water supply is to be filtered, separated and purified, ~~at least removing floating particles with diameter greater than 120 μm~~ so as to ensure compliance with design requirements of the manufacturer. ~~The water supply pumps, filters and separators are to be easy for maintenance and replacement.~~ The water supply pump, filters and separators are to be duplicated and as a standby to each other, match the lubrication water flow required by the design and have sufficient redundancy to ensure that the lubrication water flow requirements can be met even when filters and separators are slightly clogged. The above equipment is to be easy for maintenance and replacement, and means are to be provided to prevent impurities such as suspended particles from entering the lubrication water of the stern tube during maintenance. The system is to be provided with sampling openings which are readily accessible, and the selected samples are to reflect the condition of processed water supply before entering stern tube. Samples are to be taken under service condition.

1.3.2.5 The ship owner is to establish sampling procedure, appoint special person to collect water supply samples regularly at intervals not exceeding six months. The analysis organization mentioned in 1.1.3.3 is to carry out water sample detection and analysis according to detection technology and water sample analysis index allowance provided by the manufacturer, and analysis records are to be kept on board ship. For open water lubrication system, sampling is to be carried out at least once every 6 months, and the size of suspending particles are to be detected each time as a minimum. In the absence of procedures for sampling or records for sampling and testing, equivalent means including but not limited to the followings may be taken:

① during the annual survey and tube shaft survey as a minimum, the supply water treatment system is to be inspected, the maintenance record and alarm record are to be checked, and the monitoring and alarm equipment is to be confirmed ~~to confirm that it is~~ in a satisfactory working condition; or

② online monitoring of the diameter of the floating particles in the supply water, and providing the alarm function when standard is exceeded .

For closed water lubrication system, sampling is to be carried out at least once every 6 months, and ~~in addition to the size of suspending particles,~~ chloride content, PH value as well as bearing material particles

content are to be detected each time as a minimum.[①]

3 Oil-lubricated Screwshaft Condition Monitoring Procedures

3.2 Analysis of lubricating oil samples

3.2.3 Determination of reference values for parameters of lubricating oil analysis

3.2.3.3 In the quantitative spectrum or ferrographic analysis, the following interim criteria are to be used for reference:

Viscosity (at 40℃)	at least 70 m^2/s
Water	maximum 1~~0.5~~%
Copper	maximum 50 ppm
Iron	maximum 30 ppm
Tin	maximum 10 ppm
Nickel	maximum 10 ppm
Chromium	maximum 10 ppm
~~Stibium~~	~~maximum 10 ppm~~
Silicon	maximum 40 ppm
Sodium	maximum 80~~50~~ ppm
Lead	maximum 10~~40~~ ppm
Chlorine content in water	maximum 70ppm ((ingress of salt water)
Magnesium	maximum 30ppm

In addition, the gradient values of spectrum readings are to be controlled.

[①] Refer to IACS Rec 143 Recommended procedure for the determination of contents of metals and other contaminants in a closed fresh water system lubricated stern tube.

Appendix 16 GUIDELINES FOR SURVEY OF PLANNED MAINTENANCE SCHEME(PMS)FOR MACHINERY

1 General

1.2 Scope

1.2.3 PMS considers surveys to be carried out on the basis of intervals between overhauls recommended by manufacturers, documented operator's experience and a condition monitoring system, where fitted.

1.2.~~3~~4 For a ship which is subject to survey of PMS, any other survey items necessary for maintaining its class is not to be canceled and changed, and the items not included in survey of PMS are to be surveyed in compliance with Chapter 5 of this PART.

CHINA CLASSIFICATION SOCIETY

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

AMENDMENTS

2024

PART TWO HULL

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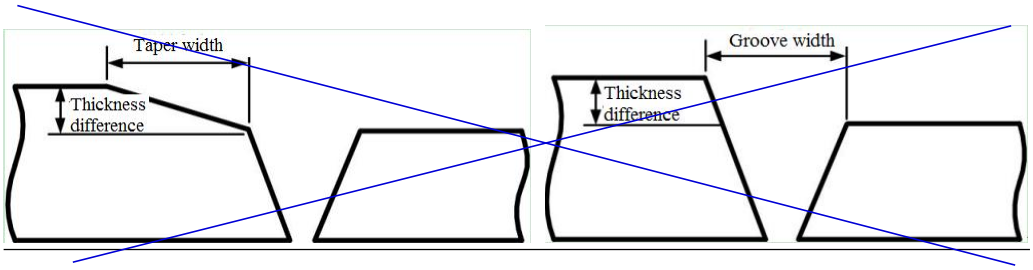
CHAPTER 1 GENERAL

Section 4 WELDING DESIGN FOR HULL STRUCTURES

1.4.3 Butt, lap and slot welds

1.4.3.1 Where plates of different thicknesses are to be butt welded and the difference in thickness of one side is less than or equal to 4 mm, the transition may be achieved within the width of the weld. Where the difference in thickness of one side is greater than 4 mm, the edge of the thicker plate is to be tapered so as to ensure a uniform transition with the weld. The width ~~of taper~~ is not to be less than 3 times the difference in thickness of one side, and the difference in height of the two sides of the groove d is not to be greater than 4 mm, as shown in Figure 1.4.3.1(1). Where ~~the difference in thickness is more than 4 mm and~~ the groove width is not less than 3 times the difference in thickness of one side, taper may not be necessary and the transition may be achieved within the width of the weld, as shown in Figure 1.4.3.1(2).



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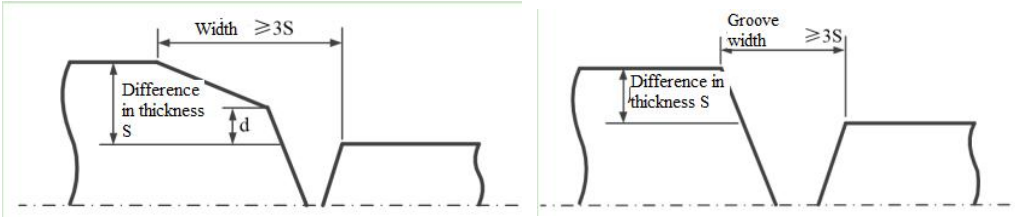

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Figure 1.4.3.1 Butt welding of steel plates of different thickness

Section 7 FORE DECK FITTINGS

1.7.2 Strength and securing of small hatches on the exposed fore deck

1.7.2.1 The provisions of this Section apply to the strength of, and securing devices for, small hatches fitted on the exposed deck over the forward 0.25 *L* ,where the height of the exposed deck in way of the hatch is less than 0.1 *L* or 22 m above the summer load waterline, whichever is the lesser, for all ships of 80 m or over in length. This regulation does not apply to small hatches on container ship giving access to a cargo hold which comply with UI LL64 except the requirement of clauses 4 & 5. Such hatch covers are considered non-weathertight regardless of whether it is actually weathertight or not. However, for scantlings of small hatches, the strength requirements in

1.7.2.4-1.7.2.7 of this Section could be applied instead of clause 6 of UI LL64.

Section 9 INTACT STABILITY

1.9.1 General requirements

1.9.1.6 Ships applying for the ASMW notation are to comply with the provisions of 1.9.7 of this Section.

1.9.3 Plans and documents

1.9.3.1 The following plans and documents are to be submitted for approval or confirmation:

(1) Stability calculations for loading conditions or loading manual;

(2) Curves or table of allowable height of center of gravity or allowable initial metacentric height;

(3) Coordinates of opening of flooding angles and curves or table of flooding angles;

(4) Stability information for carriage of grain (capacity of fully and partially filled compartments, curves or table of assumed volumetric heeling moment, curves or table of maximum permissible heeling moment) and stability calculations for loading conditions or loading manual (if applicable);

(5) Operational guidance for ships in high sea conditions (may be included in the loading manual) (if applicable).

1.9.3.2 The following plans and documents are to be submitted for information:

(1) General arrangement;

(2) Lines and offsets;

(3) Hydrostatic curves or table;

(4) Stability cross curves or table;

(5) Capacity curves or table;

(6) Arrangement of bilge keels;

(7) Plan of subdivision draught and load line marks;

(8) Auxiliary calculations for windage area and moment of area, crowding of all passengers towards one side, icing, etc.;

(9) Cross-sectional area (if applicable);

(10) Approved inclining test report or light ship survey report;

(11) Assessment calculations of operational guidance for ships in high sea conditions (if applicable).

1.9.3.3 The above information may be reduced as appropriate for ships of which the intact stability has been approved, except for those of which service has been changed.

1.9.7 Operational guidance for ships in high sea conditions

1.9.7.1 Hydrodynamic-based methods are to be used to analyze the performance and characteristics of the ship, assess the sailing conditions that may affect safety, and prepare operational guidance for ships in potential high sea conditions for the master's reference.

1.9.7.2 Due to the influences of environmental conditions, the ship's own state, human factors and other factors, operating the ship according to the ship's operational guidance in high sea conditions cannot ensure that the ship can completely avoid loss of stability, excessive movement

and capsizing accidents when sailing in adverse sea conditions, nor can the master be released from the responsibility of the ship's navigation safety.

1.9.7.3 The likelihood of different modes of navigation safety failures under the combined or separate action of wind and waves is to be assessed, and operational guidance for ships in high sea conditions is to be developed accordingly. Modes of navigation safety failures that are to be assessed include:

(1) excessive roll or excessive acceleration caused by parametric rolling;

(2) excessive roll or excessive acceleration caused by synchronous rolling motion during navigation;

(3) loss of stability caused by pure loss of stability;

(4) excessive roll/capsizing or insufficient stability caused by the combined action of wind and waves in the dead ship condition.

1.9.7.4 Navigation safety assessments are to be carried out for typical loading conditions in sailing conditions as a minimum and operational guidance for ships in high sea conditions is to be developed.

1.9.7.5 The level 2 criteria for parametric rolling in IMO MSC.1/Circ.1627 is to be used to calculate the amplitude of parametric rolling and the resultant lateral acceleration at the bridge when the ship is sailing at typical speed in head waves and following waves. Operational guidance for ships in high sea conditions is to include sailing and sea conditions where the calculated roll amplitude is greater than 25° or lateral acceleration is greater than 4.64 m/s^2.

1.9.7.6 The level 2 criteria for pure loss of stability in IMO MSC.1/Circ.1627 is to be used to calculate the vulnerability index of ship's pure loss of stability. Operational guidance for ships in high sea conditions is to include sea conditions with a calculated vulnerability index of 1.0.

1.9.7.7 The potential flow theory is to be used to calculate the amplitude of parametric rolling and the resultant lateral acceleration at the bridge when the ship is sailing at typical speed in typical waves. Operational guidance for ships in high sea conditions is to include sailing and sea conditions where the calculated roll amplitude is greater than 25° or lateral acceleration is greater than 4.64 m/s^2.

1.9.7.8 The meteorological criteria of the International Code for Intact Stability, 2008, adopted by IMO resolution MSC.267(85), is to be used to calculate the steady wind speed value (beam wind) that meets the requirements of the meteorological criteria, assuming that the ship is in a dead ship condition and that the roll angle caused by wave action is 25°. Operational guidance for ships in high sea conditions is to include the steady wind speed value (beam wind).

1.9.7.9 The potential flow theory is to be used to calculate the amplitude of parametric rolling and the resultant lateral acceleration at the bridge when the ship is in the dead ship conditions in typical waves. Operational guidance for ships in high sea conditions is to include sailing and sea conditions where the calculated roll amplitude is greater than 25° or lateral acceleration is greater than 4.64 m/s^2.

1.9.7.10 Other numerical simulations or model tests may be used as alternatives to navigation safety assessment subject to CCS agreement.

1.9.7.11 Operational guidance for ships in high sea conditions is to be provided in a loading manual or onboard computer-based system in a simple and clear form.

CHAPTER 2 HULL STRUCTURES

Section 1 GENERAL PROVISIONS

2.1.1 Application

2.1.1.1 This Chapter applies mainly to dry cargo ships. If not covered in this Chapter, the requirements of Chapter 1 of this PART are to be complied with.

2.1.1.2 This Chapter applies to the basic structural configuration of a multi-deck or a single deck hull which includes a double bottom, or a single bottom arrangement, and with the hatch openings of normal dimensions.

2.1.1.3 Longitudinal framing is in general to be adopted at the strength deck outside the line of openings and at the bottom.

2.1.1.4 For ships with self-unloading system, such system is to meet the relevant requirements of CCS Rules for Lifting Appliances of Ships and Offshore Installations.

2.1.2 Class notations

2.1.2.1 General dry cargo ships complying with the requirements of this Chapter will be assigned the class notation General Dry Cargo Ship.

2.1.2.2 Ships which have been strengthened for heavy cargoes and comply with the requirements of Section 22 of this Chapter will be assigned the class notation Strengthened for Heavy Cargoes.

2.1.2.3 Ships which have been strengthened for grabs and comply with the requirements of Section 23 of this Chapter will be assigned the class notation Grab*(X).

2.1.2.4 Ships which comply with the requirements of Section 14, Chapter 8 of this PART will be assigned the class notation Double Side Skin.

~~**2.1.4 Additional requirements for dry cargo ships occasionally carrying bulk cargo**~~

~~2.1.4.1 For dry cargo ships occasionally carrying bulk cargo, the hull structure within the cargo region is to comply with the following requirements, in addition to the requirements of this Chapter:~~

~~(1) the strength of bottom framing is to comply with the requirements of Section 2, Chapter 8 of this PART;~~

~~(2) the strength of watertight bulkhead is to comply with the requirements of Section 4, Chapter 8 of this PART;~~

~~(3) the loading manual and loading instruments are to comply with the requirements of Section 7, Chapter 8 of this PART;~~

~~(4) where the load line length L_L is 100 m and above, double side skin structure is to be provided and is to comply with the requirements of Section 14, Chapter 8 of this PART.~~

Section 17 SUPERSTRUCTURES AND DECKHOUSES

2.17.3 End bulkheads of superstructures and boundary bulkheads of deckhouses

2.17.3.1 The thickness t of end bulkhead plating of superstructures and boundary bulkhead

plating of deckhouses is not to be less than:

$$t = 3s\sqrt{hK} \quad \text{mm}$$

The minimum thickness of the plate, t_{min}, is to comply with the following requirements:

If $L_1 \geq 65$ m: $t = (0.01L_1 + 5.0)\sqrt{K}$ mm, for lowest tier

$t = (0.01L_1 + 4.0)\sqrt{K}$ mm, for upper tiers, and not less than 5 mm

If $L_1 < 65$ m: $t_{min} = 5.0$ mm, for the lowest unprotected front

$t_{min} = 4.0$ mm for all other cases

where: s — spacing of stiffeners, in m;

h — design pressure head, in m, to be calculated according to 2.17.2 of this Section;

L_1 — length of ship, in m, L_1 need not be taken greater than 300 m;

K — material factor.

Section 20 HATCHWAYS AND HATCH COVERS

2.20.1 General requirements

2.20.1.1 In addition to the requirements of this Section, exposed hatchways and hatch covers are to comply with the relevant requirements of the Amendments to Annex I to Annex B of the Protocol of 1988 Relating to the International Convention on Load Lines, 1966.

2.20.1.2 The structural scantlings of non-exposed hatch covers may be determined according to the relevant requirements of this Section, depending on their structural configuration and with only permissible cargo loads being taken into account.

2.20.1.3 The scantlings of steel hatch covers for deep tanks may be determined according to the relevant requirements of this Section and depending on the position of hatch covers, but in no case are to be less than those required in Section 13 of this Chapter for deep tank deck and its framing.

2.20.1.4 Where wheeled vehicles are to be stowed on hatch covers or used for cargo handling, the scantlings of hatch covers are also to comply with the requirements for vehicle deck in Section 21 of this Chapter.

2.20.1.5 The scantlings of hatch covers used as helicopter deck are also to comply with the requirements for helicopter decks in Section 18 of this Chapter.

2.20.1.6 Except as otherwise provided, the width of the attached plating of hatch cover stiffeners and girders is to be determined according to 1.2.2 of Section 2, Chapter 1 of this PART. However, the areas of stiffeners are not to be included in the area of the attached plating of girders.

2.20.1.7 For the hatch covers on the lower deck within cargo holds, the strength is to be checked according to the requirements of 2.20.3.

2.20.1.8 Height of hatch coamings

(1) at Position 1, the height is not to be less than 600 mm;

(2) at Position 2, the height is not to be less than 450 mm;

(3) for ships provided with steel weathertight hatch covers, with the consent of the flag State Administration, the height of hatch coamings may be suitably reduced provided that efficient measures have been taken and that the safety of the ship is not impaired;

(4) for hatchways on unexposed freeboard decks or exposed superstructure decks, hatchway coamings with a suitable height may be provided depending upon the position of the hatchways and the protection necessitated by such hatchways.

2.20.1.9 Hatch cover types

(1) Single skin cover

A hatch cover made of steel or equivalent material that is designed to comply with ICLL Regulation 16. The cover has continuous top and side plating, but is open underneath with the stiffening structure exposed. The cover is to be weathertight and fitted with gaskets and clamping devices unless specifically exempted from such fittings.

(2) Double skin cover

A hatch cover as above but with continuous bottom plating such that all the stiffening structure and internals are protected from the environment.

(3) Pontoon type cover

A special type of portable cover, secured weathertight by tarpaulins and battening devices. Such covers are to be designed in accordance with ICLL Regulation 15.

Note: Modern designs of lift-away hatch covers are in many cases called pontoon covers. This definition does not fit to the (3) above. Modern lift-away hatch covers are to fall into one of the two categories of single skin covers and double skin covers.

2.20.2 Weathertight steel hatch covers

2.20.2.1 General requirements

(1) These requirements apply to all ships except CSR bulk carriers, ~~other than bulk carriers, self-unloading bulk carriers, ore carriers and combination carriers as defined in Appendix 2, Chapter 2 of PART ONE of the Rules,~~ and are for all cargo hatch covers and coamings on exposed decks. As specified in this Section, parts of the requirements are for some specific ship types as categorized below:

- Type-1 ships, including all ships except bulk carriers, self-unloading bulk carriers, ore carriers and combination carriers, as defined in Appendix 2, Chapter 2 of PART ONE.
- Type-2 ships, including all bulk carriers, self-unloading bulk carriers, ore carriers and combination carriers, as defined in Appendix 2, Chapter 2 of PART ONE.

(2) The strength requirements are applicable to hatch covers and hatch coamings of stiffened plate construction and their closing arrangements.

(3) These requirements are applicable to hatch covers and coamings made of steel. The materials of hatch covers and hatch coamings are to meet the relevant requirements of Section 3, Chapter 1 of this PART. The material class I is to be applied for top plate, bottom plate and primary supporting members of hatch covers. Equivalent materials and novel designs subject to approval by CCS.

(4) Primary supporting members and secondary stiffeners of hatch covers are to be continuous over the breadth and length of hatch covers, as far as practical. When this is impractical, sniped end connections are not to be used and appropriate arrangements are to be adopted to provide sufficient load carrying capacity.

The spacing of primary supporting members parallel to the direction of secondary stiffeners is not to exceed 1/3 of the span of primary supporting member. When strength calculation is carried out by FE analysis using plane strain or shell elements, this requirement may be relaxed appropriately.

Secondary stiffeners of hatch coamings are to be continuous over the breadth and length of hatch coamings.

(5) Unless stipulated otherwise, the thickness t in these requirements is net thickness.

The net thicknesses are the member thicknesses necessary to obtain the minimum net scantlings required by 2.20.2.3 to 2.20.2.6 and 2.20.2.8 of this Section.

The required gross thickness is obtained by adding the corrosion addition t_s, given in 2.20.2.10 of this Section, to the net thickness t_s.

Strength calculations using ~~grillage analysis or~~ FEM are to be performed with net scantlings.

2.20.2.2 Hatch cover and coaming load model

The structural strength evaluation of hatch covers and hatch coamings is to be carried out using the design loads defined as follows:

Definitions:

L = length of ship, in m;

L_L = load line length, in m;

x = longitudinal distance measured from midpoint of structural member to the aft end of L or L_L, in m;

D_{min} = the least moulded depth, in m, as defined in Regulation 3 of ICLL Annex I;

h_N = standard superstructure height, in m, to be calculated as follows:

$$h_N = 1.05 + 0.01L_L \text{, and} 1.8 \le h_N \le 2.3 .$$

(1) Vertical weather design load

The pressure p_H, in kN/m², on the hatch cover panel is given by ICLL. This may be taken from Table 2.20.2.2(1). The vertical weather design load is not to be combined with cargo loads in 2.20.2.2(3) and (4).

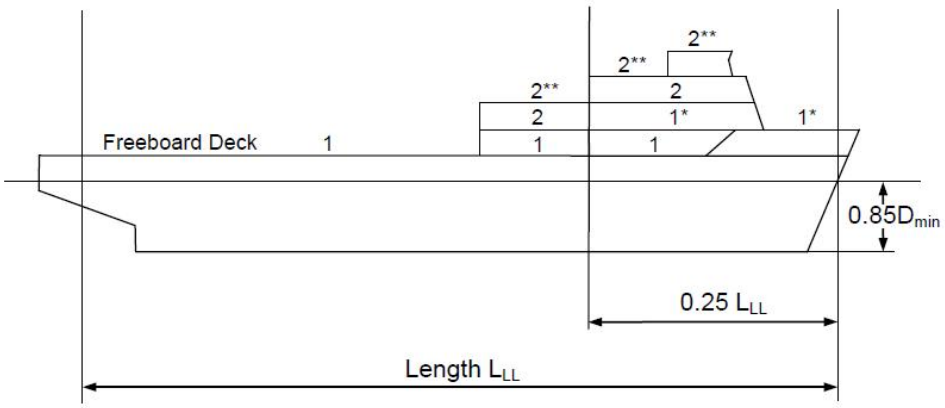
For Position 1 and Position 2, see Figure 2.20.2.2(1).

Where an increased freeboard is assigned, the design load for hatch covers on the actual freeboard deck may be as required for a superstructure deck, provided that the summer freeboard is such that the resulting draught will not be greater than that corresponding to the minimum freeboard calculated from an assumed freeboard deck situated at a distance at least equal to the standard superstructure height h_N below the actual freeboard deck, see Figure 2.20.2.2(2).

Vertical Design Load p_H of Weather Deck Hatches **Table 2.20.2.2(1)**

<table>
<tr><td rowspan="2">Position</td><td colspan="2">Vertical design load p_H , kN/m²</td></tr>
<tr><td>$\frac{x}{L_L} \le 0.75$</td><td>$0.75 < \frac{x}{L_L} \le 1.0$</td></tr>
<tr><td rowspan="5">1</td><td colspan="2">For $24\text{m} \le L_L \le 100\text{m}$</td></tr>
<tr><td rowspan="2">$\frac{9.81}{76}(1.5L_L + 116)$</td><td>On freeboard deck: $\frac{9.81}{76}\left[(4.28L_L + 28)\frac{x}{L_L} - 1.71L_L + 95\right]$</td></tr>
<tr><td>Upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck: $\frac{9.81}{76}(1.5L_L + 116)$</td></tr>
<tr><td colspan="2">For L_L>100 m</td></tr>
<tr><td>9.81×3.5</td><td>On freeboard deck for type B ships according to ICLL: $9.81\left[(0.0296L_1 + 3.04)\frac{x}{L_L} - 0.0222L_1 + 1.22\right]$</td></tr>
</table>

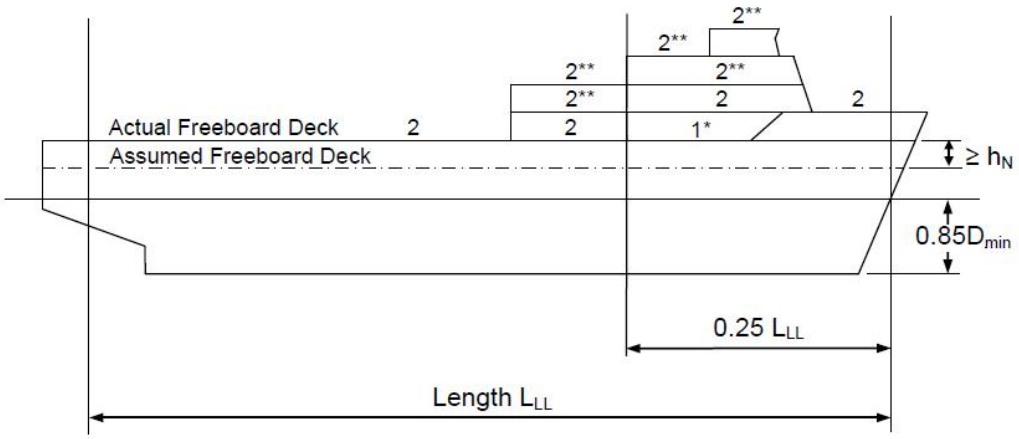
		On freeboard deck for ships with less freeboard than type B according to ICLL: $9.81\left[(0.1452L_1-8.52)\frac{x}{L_L}-0.1089L_1+9.89\right]$ $L_1=L_L$, but not more than 340 m
		Upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck: 9.81×3.5
2	For $24\text{ m}\le L_L\le100\text{ m}$	
	$\frac{9.81}{76}(1.1L_L+87.6)$	
	For $L_L>100$ m	
	9.81×2.6	
	Upon exposed superstructure decks located at least one superstructure standard height above the lowest Position 2 deck: 9.81×2.1	



* — reduced load upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck;

** — reduced load upon exposed superstructure decks of vessels with L_L > 100 m located at least one superstructure standard height above the lowest Position 2 deck.

Figure 2.20.2.2(1) Positions 1 and 2



*— reduced load upon exposed superstructure decks located at least one superstructure standard height above the freeboard deck;

** — reduced load upon exposed superstructure decks of vessels with L_L > 100 m located at least one superstructure standard height above the lowest Position 2 deck.

Figure 2.20.2.2(2) Positions 1 and 2 for an Increased Freeboard

(2) Horizontal weather design load

① General horizontal weather design load

The horizontal weather design load p_A, in kN/m^2, for determining the scantlings of outer edge girders (skirt plates) of weather deck hatch covers and of hatch coamings is to be calculated by the following formula:

$$p_A = ac(bfc_L - z) \quad \text{kN/m}^2$$

where: $f = \frac{L}{25} + 4.1$, for $L < 90$ m;

$f = 10.75 - \left(\frac{300 - L}{100}\right)^{1.5}$, for $90\text{m} \le L < 300\text{m}$;

$f = 10.75$, for $300\text{m} \le L < 350\text{m}$;

$f = 10.75 - \left(\frac{L - 350}{150}\right)^{1.5}$, for $350\text{m} \le L \le 500\text{m}$;

$c_L = \sqrt{\frac{L}{90}}$, for $L < 90$ m;

$c_L = 1$, for $L \ge 90\text{m}$;

$a = 20 + \frac{L_1}{12}$, for unprotected front coamings and hatch cover skirt plates;

$a = 10 + \frac{L_1}{12}$, for unprotected front coamings and hatch cover skirt plates, where the distance from the actual freeboard deck to the summer load line exceeds the minimum non-corrected tabular freeboard according to ICLL by at least one standard superstructure height;

$a = 5 + \frac{L_1}{15}$, for side and protected front coamings and hatch cover skirt plates;

$a = 7 + \frac{L_1}{100} - \frac{8x'}{L}$, for aft ends of coamings and aft hatch cover skirt plates abaft amidships;

$a = 5 + \frac{L_1}{100} - \frac{4x'}{L}$, for aft ends of coamings and aft hatch cover skirt plates forward of amidships;

L_1=L, but need not be taken as greater than 300 m;

$b = 1.0 + \left(\frac{\frac{x'}{L} - 0.45}{C_b + 0.2}\right)^2$, for $\frac{x'}{L} < 0.45$;

$b = 1.0 + 1.5\left(\frac{\frac{x'}{L} - 0.45}{C_b + 0.2}\right)^2$, for $\frac{x'}{L} \ge 0.45$;

C_b — block coefficient, $0.6 \le C_b \le 0.8$, when determining scantlings of aft ends of coamings and aft hatch cover skirt plates forward of amidships, C_b need not be taken less than 0.8;

x' — distance in m, between the transverse coaming or hatch cover skirt plate considered and aft end of the length L . For side coamings or side hatch cover skirt plates, the side is to be subdivided into parts of approximately equal length, not exceeding 0.15 L each, and "x" is to be taken as the distance between aft end of the length L and the centre of each part considered;

z — vertical distance, in m, from the summer load line to the midpoint of stiffener span, or to the middle of the plate field;

$c = 0.3 + 0.7\frac{b'}{B'}$, the $\frac{b'}{B'}$ is not to be less than 0.25;

b' — breadth of coaming, in m, at the position considered;

B' —actual maximum breadth of ship, in m, on the exposed weather deck at the position considered.

The horizontal design load is not to be taken less than the minimum values given in Table 2.20.2.2(2).

Minimum Horizontal Design Load P_{Amin} **Table 2.20.2.2(2)**

L	P_{Amin} kN/m²	
	Unprotected fronts	elsewhere
≤ 50m	30	15
> 50m < 250m	$25+\frac{L}{10}$	$12.5+\frac{L}{20}$
≥ 250m	50	25

~~Note: The horizontal weather design load need not be included in the direct strength calculation of the hatch cover, unless it is utilized for the design of substructures of horizontal support according to 2.20.2.9(2)③.~~

② Horizontal weather design load applicable to coamings of Type-2 ships

The pressure P_{coam}, in kN/m², on the No. 1 forward transverse hatch coaming is given by:

$P_{coam} = 220$ kN/m², when a forecastle is fitted in accordance with Section 13, Chapter 8 of this PART;

$P_{coam} = 290$ kN/m² in the other cases;

The pressure P_{coam}, in kN/m² , on the other coamings is given by:

$P_{coam} = 220$ kN/m²

Note: The horizontal weather design loads p_A and P_{coam} need not be included in the direct strength calculation of the hatch cover, unless it is utilized for the design of substructures of horizontal support according to 2.20.2.9(2)③.

(3) Cargo loads

① Distributed loads

The uniform cargo load on hatch covers due to cargo loads p_L, resulting from heave and pitch (i.e. ship in upright condition) is to be determined according to the following formula:

$$p_L = p_C(1 + a_V) \quad \text{kN/m}^2$$

where: P_C — uniform cargo load, in kN/m²;

a_V — vertical acceleration addition as follows:

$a_V = Fm$;

$F = \dfrac{0.11v_0}{\sqrt{L}}$;

$m = m_0 - 5(m_0 - 1)\dfrac{x}{L}$ for $0 \le \dfrac{x}{L} \le 0.2$;

$m = 1.0$ for $0.2 < \dfrac{x}{L} \le 0.7$;

$m = 1 + \dfrac{m_0 + 1}{0.3}\left[\dfrac{x}{L} - 0.7\right]$ for $0.7 < \dfrac{x}{L} \le 1.0$;

$m_0 = 1.5 + F$;

v_0 — maximum speed at summer load line draught, is not to be taken less than $\sqrt{L}$, in kn.

② Point loads

The load P, in kN, due to a concentrated force P_S, in kN, except for container load, resulting from heave and pitch (i.e. ship in upright condition) is to be determined as follows:

$$P = P_S(1 + a_V) \quad \text{kN}$$

where: P_S — point force, in kN;

a_V — vertical acceleration addition.

(4) Container loads

① The loads defined in ② ~~and~~ to ④ are to be applied where containers are stowed on the hatch cover.

② Corner loads for ship in upright condition

The load P, in kN, applied at each corner of a container stack, and resulting from heave and pitch (i.e. ship in upright condition) is to be determined as follows:

$$P = 9.81\frac{M}{4}(1 + a_V) \quad \text{kN}$$

where: a_V — vertical acceleration addition according to (3)①;

M — maximum designed mass of container stack, in t.

③ Corner loads for ship in heel condition

Where containers are stowed on hatch covers, the loads due to heave, pitch and the ship's rolling motion are to be determined as follows (see Figure 2.20.2.2(4)):

$$A_z = 9.81\frac{M}{2}(1 + a_V)\left(0.45 - 0.42\frac{h_m}{b}\right) \quad \text{kN}$$

$$B_z = 9.81\frac{M}{2}(1 + a_V)\left(0.45 + 0.42\frac{h_m}{b}\right) \quad \text{kN}$$

$$B_y = 2.4M \quad \text{kN}$$

where:

a_V — vertical acceleration addition according to 2.20.2.2(3);

M — maximum designed mass of container stack, in t;

h_m — designed height of centre of gravity of stack above hatch cover top, in m, may be calculated as weighted mean value of the stack, where the centre of gravity of each tier is assumed to be located at the centre of each container, $= \sum(z_i \cdot W_i)/M$;

z_i — distance from hatch cover top to the centre of *i*th container, in m;

W_i — mass of *i*th container, in t;

b — distance between foot points, in m;

A_z, B_z — support forces in *z*-direction at the forward and aft stack corners;

B_y — support forces in *y*-direction at the forward and aft stack corners.

~~Note: When strength of the hatch cover structure is assessed by grillage analysis according to 2.20.2.4, h_m and z_i need to be taken above the hatch cover supports. Forces B_y need not be considered in this case.~~

Values of A_z and B_z applied for the hatch cover strength evaluation are to be shown in the drawings of the hatch covers.

Note: It is recommended that container loads as calculated above are considered as limit for foot point loads of container stacks in the calculations of cargo securing (container lashing).

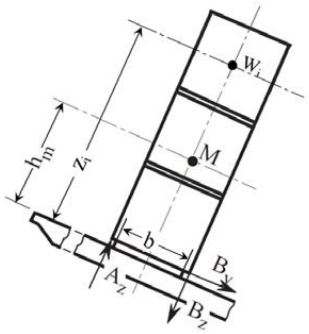


Figure 2.20.2.2(4)

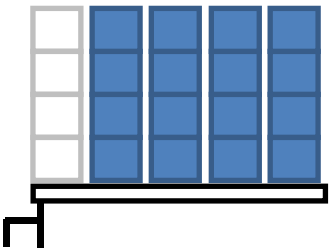
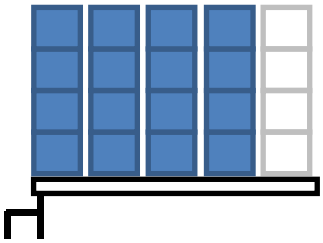
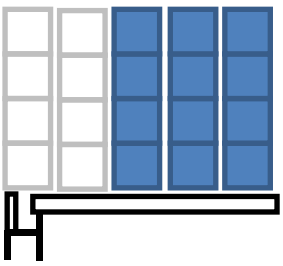
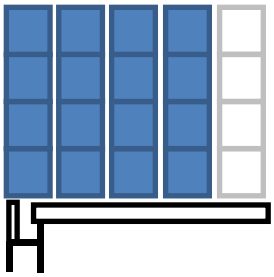
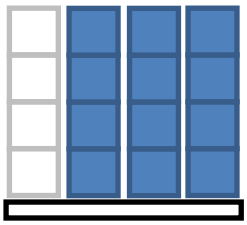
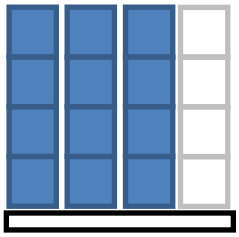
④ Load cases with partial loading

The load cases in ② and ③ above are also to be considered for partial non-homogeneous loading which may occur in practice, e.g. where specified container stack places are empty. For each hatch cover, the heel directions, as shown in Table 2.20.2.2(4), are to be considered. The load case of partial loading of container hatch covers may be evaluated using a simplified approach, where the hatch cover is loaded without the outermost stacks that are located completely on the hatch cover. If there are additional stacks that are supported partially by the hatch cover and partially by container stanchions then the loads from these stacks may be neglected, refer to Table 2.20.2.2(4) Partial loading of container hatch covers.

In addition, the case where only the stack places supported partially by the hatch cover and partially by container stanchions are left empty is to be assessed in order to consider the maximum loads in the vertical hatch cover supports.

It may be necessary to also consider partial load cases where more or different container stack places are left empty. Therefore, CCS may require that additional partial load cases other than those in Table 2.20.2.2(4) be considered.

Partial loading of container hatch covers **Table 2.20.2.2(4)**

Heel direction	←	→
Hatch covers supported by the longitudinal hatch coaming with all container stacks located completely on the hatch cover		
Hatch covers supported by the longitudinal hatch coaming with the outermost container stack supported partially by the hatch cover and partially by container stanchions		
Hatch covers not supported by the longitudinal hatch coaming (center hatch covers)		

⑤ Mixed stowage of 20’ and 40’ containers on hatch cover

In the case of mixed stowage (20'+40' container combined stack), the foot point forces at the fore and aft end of the hatch cover are not to be higher than resulting from the design stack weight for 40’ containers, and the foot point forces at the middle of the cover are not to be higher than resulting from the design stack weight for 20’ containers.

(5) Hatch covers, which in addition to the loads according to (1) to (4) above are loaded in the ship’s transverse direction by forces due to elastic deformations of the ship’s hull, are to be designed such that the sum of stresses does not exceed the allowable value given in 2.20.2.5.

2.20.2.3 The net structural scantling of weathertight steel hatch covers is to be in compliance with the following requirements:

(1) Local net plate thickness

The local net plate thickness of the hatch cover top plating is not to be less than that obtained from the following formulae, and not less than 6 mm:

$$t = 15.8 F_p s \sqrt{\frac{p}{0.95 R_{eH}}} \quad \text{mm}$$

$$t = 10 s \quad \text{mm}$$

where: F_p — factor for combined membrane and bending response, calculated as follows:

$F_p = 1.5$ in general;

$F_p = 1.9 \frac{\sigma}{\sigma_a}$ for $\frac{\sigma}{\sigma_a} \geq 0.8$ for the attached plate flange of primary supporting members;

s — stiffener spacing, in mm;

p — pressure p_H and p_L, calculated according to 2.20.2.2 of this Section, in kN/m^2;

σ — maximum normal stress of hatch cover top plating, in N/mm^2, determined according to Figure 2.20.2.3;

σ_a ~~$=0.8R_{eH}$~~ permissible stress, see Table 2.20.2.5, in N/mm^2;

R_{eH} — yield stress of materials, in N/mm^2.

For flange plates under compression, the buckling strength requirements of 2.20.2.6 of this Section are to be complied with.

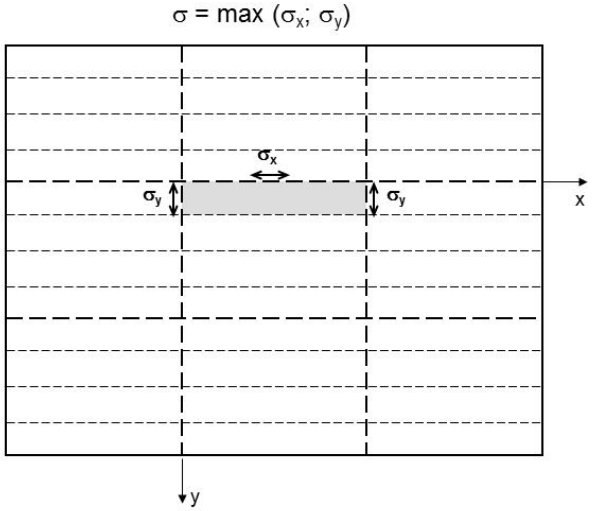


Figure 2.20.2.3

① The local net plate thickness of hatch covers for wheel loading is also to meet the relevant requirements of Section 21 of this Chapter.

② The local net plate thickness of lower plating of double skin hatch covers and box girders are to comply with the following requirements:

The thickness to fulfill the strength requirements is to be obtained from the calculation according to 2.20.2.4 under consideration of allowable stresses according to 2.20.2.5 of this Section. When the lower plating is taken into account as a strength member of the hatch cover, the net thickness, in mm, of lower plating is to be taken not less than 5 mm. When project cargo is intended to be carried on a hatch cover, the net thickness is not to be less than:

$$t = 6.5s \times 10^{-3} \text{ mm}$$

where: s — stiffener spacing, in mm.

When the lower plating is not considered as a strength member of the hatch cover, the thickness of the lower plating is not to be less than 5 mm.

Note:

Project cargo means especially large or bulky cargo lashed to the hatch cover. Examples are parts of cranes or wind power stations, turbines, etc. Cargoes that may be considered as uniformly distributed over the hatch cover, e.g. timber, pipes or steel coils need not to be considered as project cargo.

(2) The stiffeners of hatch covers are to comply with the following requirements:

The net section modulus Z ~~W~~ and net shear area A_{shr} of uniformly loaded hatch cover stiffeners constrained at both ends are not to be less than:

— $W=\frac{104}{R_{eH}}spl^2$ ~~cm³, for design load according to 2.20.2.2(1);~~

— $W=\frac{93}{R_{eH}}spl^2$ ~~cm³, for design loads according to 2.20.2.2(3)①;~~

— $A_s=\frac{10.8}{R_{eH}}spl$ ~~cm², for design load according to 2.20.2.2(1);~~

— $A_s=\frac{9.6}{R_{eH}}spl$ ~~cm²~~, ~~for design loads according to 2.20.2.2(3)①~~

$$Z = \frac{psl^2}{f_{bc}\sigma_a} \text{ cm}^3$$

$$A_{shr} = \frac{8.7psl}{\sigma_a}10^{-3} \text{ cm}^2$$

where: l — secondary stiffener ~~s~~span, in m, to be taken as the spacing of primary supporting members or the distance between a primary supporting member and the edge support, as applicable. When brackets are fitted at both ends of all stiffener spans, the secondary stiffener span may be reduced by an amount equal to 2/3 of the minimum brackets arm length, but not greater than 10% of the unsupported span, for each bracket;

s — spacing of stiffeners, in mm;

p — p_H and p_L, to be calculated according to 2.20.2.2 of this Section, in kN/m²;

f_{bc} — boundary coefficient of stiffener, taken equal to:

f_{bc} = 8, in the case of stiffener simply supported at both ends or simply supported at one end and clamped at the other end

f_{bc} = 12, in the case of stiffener clamped at both ends.

σ_a ~~R_{eH}~~ — allowable stress as defined in Table 2.20.2.5~~yield stress of materials~~, in N/mm².

For secondary stiffeners of lower plating of double skin hatch covers, requirements mentioned above are not applied due to the absence of lateral loads. For double skin hatch covers of holds designed for ballast or liquid cargo, the stiffeners on lower plating are to be strengthened according to CCS requirements.

The net thickness, in mm, of the stiffener (except U-beams/trapeze stiffeners) web is not to be less than 4 mm.

The net section modulus of secondary stiffeners is to be determined based on an attached plate width assumed equal to the stiffener spacing.

~~For flat bar secondary stiffeners and buckling stiffeners, the ratio of h/t_w is to be not greater than $15k^{0.5}$, where h is height of the stiffener, t_w is net thickness of the stiffener, $k = 235/R_{eH}$.~~

Stiffeners parallel to primary supporting members ~~and arranged within the effective breadth according to 2.20.2.4 of this Section~~ are to be continuous at crossing primary supporting members, and may be considered for calculations regarding cross-sectional properties of primary members.

It is to be verified that the combined stress of those stiffeners induced by the bending of primary supporting members and lateral pressures does not exceed the allowable stresses according to 2.20.2.5 of this Section. When the lower plating is not taken into account as a strength member of the hatch cover, the requirements of this paragraph are not necessary for the stiffeners of lower plating.

For hatch cover stiffeners under compression, sufficient safety against lateral and torsional buckling according to 2.20.2.6 of this Section is to be verified.

For hatch covers subject to wheel loading, the relevant requirements of Section 21 of this Chapter are to be complied with. For hatch covers subject to point loads, stiffener scantlings are to be determined by direct calculations under consideration of the allowable stresses as required in 2.20.2.5 of this Section.

(3) The net scantlings of primary supporting members are to comply with the following requirements:

① Scantlings of primary supporting members are to be obtained from direct calculations according to 2.20.2.4 under consideration of allowable stresses according to 2.20.2.5 of this Section.

For all components of primary supporting members sufficient safety against buckling is to be verified according to 2.20.2.6 of this Section. For biaxially compressed flange plates, the buckling strength is to be verified within the effective width according to 2.20.2.6(3)② of this Section.

The net thickness, in mm, of webs of primary supporting members is not to be less than:

$$t = 6.5s \times 10^{-3} \quad \text{mm}$$

$$t = 5 \quad \text{mm}$$

where: s — spacing of stiffeners, in mm.

② The net scantlings of edge girders are to comply with the following requirements:

Scantlings of edge girders are to be verified according to 2.20.2.4 under consideration of allowable stresses according to 2.20.2.5 of this Section.

The net thickness of the outer edge girders exposed to wash of seawater is not to be less than the largest of the following values:

$$t = 0.0158s\sqrt{\frac{p_A}{0.95R_{eH}}} \quad \text{mm}$$

$$t = 8.5s \times 10^{-3} \quad \text{mm}$$

$$t = 6 \quad \text{mm}$$

where: S — spacing of stiffeners, in mm;

P_A — horizontal weather design pressure, calculated according to 2.20.2.2 of this Section, in kN/m^2;

~~R_{eH} — yield stress of material, in N/mm^2.~~

For the required moment of inertia of edge girders, refer to 2.20.2.9(1)④.

~~The stiffness of edge girders is to be sufficient to maintain adequate packing line pressure between securing devices. The moment of inertia of edge girders is not to be less than:~~

$$I = 6qs_{SD}^4 \quad \text{cm}^4$$

~~where: q — packing line pressure, in N/mm, taken as minimum of 5 N/mm;~~

~~s_{SD} spacing of securing devices, in m.~~

2.20.2.4 Strength calculation

The stresses in hatch covers are to be determined by FE analysis.

The stress calculation model in this section is to be used for both yielding and buckling strength assessments in accordance with 2.20.2.5 and 2.20.2.6, respectively.

The net scantlings as defined in 2.20.2.1(5) are to be used.

~~Strength calculation for hatch covers may be carried out using grillage analysis or FEM. Double skin hatch covers or hatch covers with box girders are to be assessed using FEM, refer to (2) below.~~

~~(1) Effective cross-sectional properties for calculation by grillage analysis~~

~~Cross-sectional properties are to be determined considering the effective breadth. Cross-sectional areas of secondary stiffeners parallel to the primary supporting member under consideration within the effective breadth are to be taken into account, as shown in Figure 2.20.2.6(2) of this Section.~~

~~The effective breadth e_m of plating of primary supporting members is to be determined according to Table 2.20.2.4(1), considering the type of loading. Special calculations may be required for determining the effective breadth of one-sided or non-symmetrical flanges.~~

~~The effective cross-sectional area of plates is not to be less than that of the face plate.~~

~~For flange plates under compression with secondary stiffeners perpendicular to the web of the primary supporting member, the effective width is to be determined according to 2.20.2.6(3)② of this Section.~~

~~**Effective Breadth e_m of Plating of Primary Supporting Members Table 2.20.2.4(1)**~~

~~l/e~~	~~0~~	~~1~~	~~2~~	~~3~~	~~4~~	~~5~~	~~6~~	~~7~~	~~≥ 8~~
~~e_{m1}/e~~	~~0~~	~~0.36~~	~~0.64~~	~~0.82~~	~~0.91~~	~~0.96~~	~~0.98~~	~~1.00~~	~~1.00~~
~~e_{m2}/e~~	~~0~~	~~0.20~~	~~0.37~~	~~0.52~~	~~0.65~~	~~0.75~~	~~0.84~~	~~0.89~~	~~0.90~~

~~e_{m1} is to be applied where primary supporting members are loaded by uniformly distributed loads or else by not less than 6 equally spaced single loads;~~

~~e_{m2} is to be applied where primary supporting members are loaded by 3 or less single loads.~~

~~Intermediate values may be obtained by direct interpolation.~~

~~l : length of zero-points of bending moment curve:~~

~~$l = l_0$ for simply supported primary supporting members;~~

~~$l = 0.6 \cdot l_0$ for primary supporting members with both ends constrained;~~

~~where l_0 is the unsupported length of the primary supporting members.~~

~~e : width of plating supported, measured from centre to centre of the adjacent unsupported fields.~~

(~~2~~1) General requirements for FEM calculations

For strength calculations of hatch covers by means of finite elements, the cover geometry is to be idealized as realistically as possible. ~~Element size is to be appropriate to account for effective breadth.~~ In no case element width is to be larger than stiffener spacing. In way of force transfer points and cutouts the mesh has to be refined where applicable. ~~The ratio of element length to width is not to exceed 4.~~

The element height of webs of primary supporting members is not to exceed one-third of the web height. ~~Stiffeners and supporting plates against pressure loads have to be included in the idealization. Stiffeners may be modelled using shell elements, plane stress elements or beam elements.~~ Stiffeners, which support plates subjected to lateral pressure loads, are to be included in

the FE model idealization. Stiffeners may be modelled by using beam elements, or shell/plate elements. Buckling stiffeners may be disregarded for the stress calculation.

Hatch covers fitted with U-type stiffeners as shown in Figure 2.20.2.4(1) are to be assessed by means of FE analysis.The geometry of the U-type stiffeners is to be accurately modelled using shell/plate elements. Nodal points are to be properly placed on the intersections between the webs of a U-type stiffener and the hatch cover plate, and between the webs and flange of the U-type stiffener.

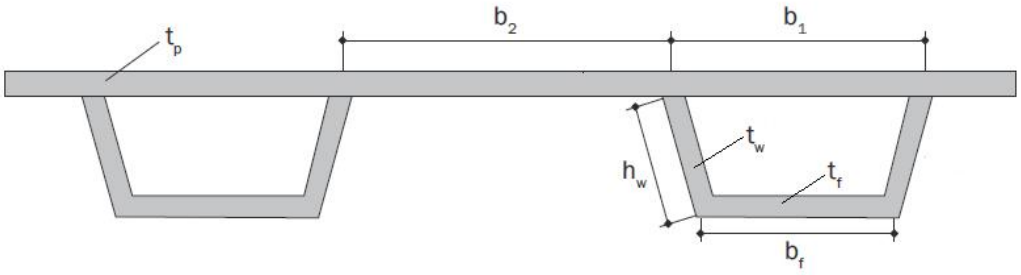


Figure 2.20.2.4(1) Example of hatch cover fitted with U-type stiffeners

① A right-handed coordinate system is to be used with:
the *x*-axis measured in the longitudinal direction, positive forward;
the *y*-axis measured in the transverse direction, positive to port from the centerline;
the *z*-axis measured in the vertical direction, position upward.

② The FEM is to be performed with net scantlings.

③ The finite element model is to be limited as follows:

(a) for symmetry of the hatch cover girders, loads and supporting boundary conditions about only the x-axis or y-axis, it may be limited to a half of the hatch cover for check;

(b) for non-symmetry of hatch cover girders, loads or supporting boundary conditions about any of the axes, the whole hatch cover may be taken for strength evaluation, see Figure 2.20.2.4(~~1~~2).

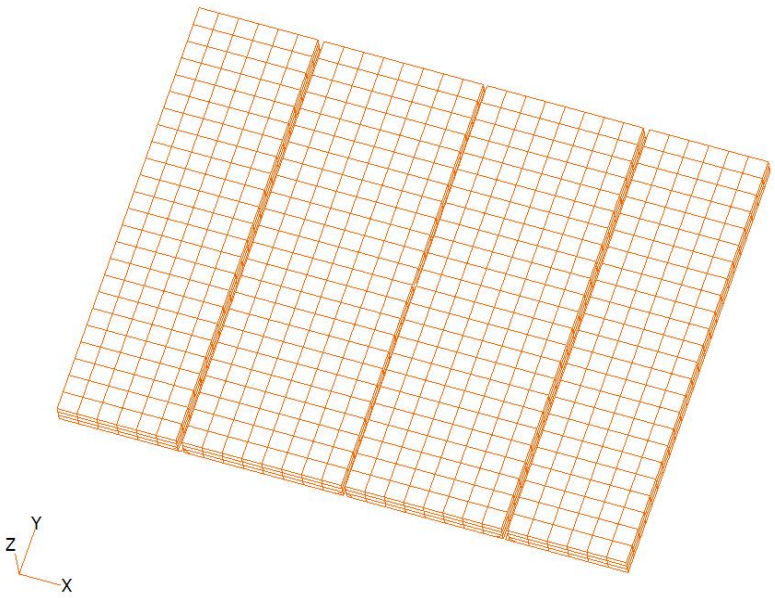


Figure 2.20.2.4(~~1~~2) Finite Element Hatch Cover Model

④ The model element is to comply with the following requirements:

(a) all plating, including girders and stiffeners, is to be represented by the finite element model;

(b) all plating, such as top plates, bottom plates, brackets, and girder webs, face plates of primary supporting members is to modeled using plate elements, triangular elements are to be avoided where possible;

(c) all stiffeners are to be modeled using beam, rod or plate elements.

⑤ The element mesh size is to be controlled as follows:

(a) the mesh size is not to be greater than the spacing of stiffeners;

(b) the girders are to be represented by at least 3 elements in the depth;

(c) triangular and distorted quadrilateral elements with corner angles less than 60 degrees and greater than 120 degrees are to be avoided.

⑥ Boundary conditions are to be determined as follows:

(a) for symmetry of the hatch cover girders and loads about the ~~x-axis~~xz-plane, the longitudinal displacement of nodes in the symmetric plane and the rotations about the y and z axes are to be taken as 0 respectively, i.e. $\delta_x = \theta_y = \theta_z = 0$, as shown in Figure 2.20.2.4(~~2~~3);

(b) for symmetry of the hatch cover girders and loads about the ~~y-axis~~yz-plane, the transverse displacement of nodes in the symmetric plane and rotation about the x and z axes are to be taken as 0 respectively i.e. $\delta_y = \theta_x = \theta_z = 0$, as shown in Figure 2.20.2.4(~~2~~3);

(c) boundary nodes in way of bearing pads on the hatch coamings are generally to be fixed against displacement in the z direction, i.e. $\delta_z = 0$;

(d) lifting stoppers are to be fixed against displacements in the direction determined by the stoppers;

(e) hinges in folding type hatch covers are to be represented as rigid links which tie together displacements in the z direction.

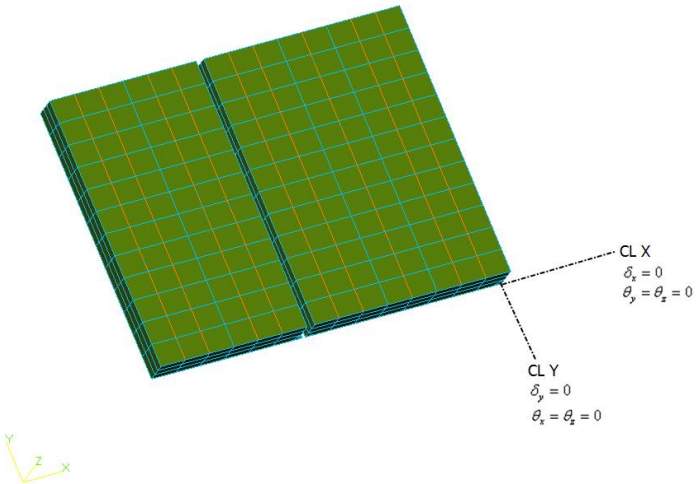


Figure 2.20.2.4(~~2~~3) Boundary Conditions of Hatch Cover Model

2.20.2.5 Yield strength and deflection criteria of hatch cover structures

(1) Allowable stresses

~~The equivalent stress σ_V in steel hatch cover structures related to the net thickness is not to exceed $0.8R_{eH}$, where R_{eH} is the minimum yield stress, in N/mm^2, of the material. For design loads according to 2.20.2.2(2) to (6) of this Section, the equivalent stress σ_V related to the net thickness is not to exceed 0.9 R_{eH} when the stresses are analysed by means of FEM.~~

~~For steels with a yield stress of 390 N/mm^2, it is taken as 368 N/mm^2 for calculation.~~

~~For grillage analysis, the equivalent stress may be taken as follows:~~

$$\sigma_V = \sqrt{\sigma^2 + 3\tau^2} \quad \text{N/mm}^2$$

~~where: σ — normal stress, in N/mm^2;~~

~~τ — shear stress, in N/mm^2.~~

All hatch cover structures are to comply with the following formulae:

$\sigma_{vm} \le \sigma_a$, for shell element;

$\sigma_{axial} \le \sigma_a$, for rod or beam elements.

where: σ_a ——allowable stress in Table 2.20.2.5;

R_{eH} ——yield stress of the material;

σ_{vm} ——~~For FEM calculations,~~ the equivalent stress may be taken as follows:

$$\sigma_{vm} = \sqrt{\sigma_x^2 - \sigma_x \cdot \sigma_y + \sigma_y^2 + 3\tau^2} \quad \text{N/mm}^2$$

where: σ_x — normal stress, in N/mm^2, in x-direction;

σ_y — normal stress, in N/mm^2, in y-direction;

τ — shear stress, in N/mm^2, in the x-y plane;

σ_{axial} —axial stress in rod or beam elements, in N/mm^2.

In case of FEM calculations using shell ~~or plane strain~~ elements, the stresses are to be read from the centre of the individual element. It is to be observed that, in particular, at flanges of unsymmetrical girders, the evaluation of stress from element centre may lead to non-conservative results. Thus, a sufficiently fine mesh is to be applied in these cases or, the stress at the element edges is not to exceed the allowable stress. Where shell elements are used, the stresses are to be evaluated at the mid plane of the element.

For steels with a yield stress of 390 N/mm^2, it is taken as 368 N/mm^2 for calculation.

Stress concentrations are to be evaluated according to the actual conditions.

Allowable stress **Table 2.20.2.5**

Members of	Subject to	σ_a, in N/mm^2
Hatch cover structure	External pressure, as defined in 2.20.2.2(1)	$0.80R_{eH}$
	Other loads, as defined in 2.20.2.2(2)~(5)	$0.90R_{eH}$ for static+dynamic load case $0.72R_{eH}$ for static load case

(2) Deflection

The vertical deflection of primary supporting members due to the load stipulated in 2.20.2.2 of this Section is to be not more than 0.0056 l_g, where l_g is the greatest span of primary supporting member.

Note: Where containers are arranged on hatch covers and mixed stowage is allowed, i.e., a 40'-container stowed on top of two 20'-containers, particular attention is to be paid to the deflections of hatch covers. Further the possible contact of deflected hatch covers with cargo in hold has to be considered.

2.20.2.6 Buckling strength of hatch cover structures

(1) General

Buckling strength of all hatch cover structures is to be checked. Buckling assessments are to be performed in compliance with the requirements in Appendix 5.

The net scantlings as defined in 2.20.2.1(5) are to be used for buckling check.

(2) Slenderness requirements

The slenderness requirements are to be in accordance with those specified in Section 2 of Appendix 5.

The slenderness requirements need not be applied to the lower boundary of double skin hatch covers unless the cargo hold is designed for carriage of ballast or liquid cargo.

The breadth of the primary supporting member flange is to be not less than 40% of their depth for laterally unsupported spans greater than 3.0 m. Tripping brackets attached to the flange may be considered as a lateral support for primary supporting members.

(3) Buckling requirements

① These requirements apply to the buckling assessment of hatch cover structures subjected to compressive and shear stresses and lateral pressures. The buckling assessment is to be performed for the following structural elements:

- Stiffened and unstiffened panels, including curved panels and panels stiffened with U-type stiffeners.
- Web panels of primary supporting members in way of opening.

The buckling strength assessment of coaming parts is to be done according to this paragraph.

For rule application, the panel types and assessment methods, the applied lateral pressure and stresses, safety factors and buckling check criteria are defined in 2.20.2.6(3)②-2.20.2.6(3)⑤, respectively. The procedure and detailed requirements for buckling assessment are given in Sec4 of Appendix 5, including idealization of irregular plate panels, definition of reference stresses and buckling criteria.

Unless otherwise specified, the symbols used in 2.20.2.6(3) are defined in Appendix 5.

② Panel types and assessment methods

The plate panel of a hatch cover structure is to be modelled as stiffened panel (SP) or unstiffened panel (UP) as defined in 4.2, Section 4 of Appendix 5. Assessment Method A (-A) and Method B (-B) as defined in 1.3, Section 1 of Appendix 5 are to be used in accordance with Table 2.20.2.6(3)①, Figure 2.20.2.6(3)① and Figure 2.20.2.6(3)②. For a web panel with opening, the procedure for opening should be used for its buckling assessment.

For a hatch cover fitted with U-type stiffeners, the additional buckling assessment requirements specific for panels with U-type stiffeners in 5.2.5, Section 5 of Appendix 5 are also to be followed.

Structural members and assessment methods Table 2.20.2.6(3)①

Structural elements	Assessment method[(1)(2)]	Normal panel definition
Hatch cover top/bottom plating structures, see Figure 2.20.2.6(3)①		
Hatch cover top/bottom plating	SP-A	Length: between transverse girders Width: between longitudinal girders
Irregularly stiffened panels	UP-B	Plate between local stiffeners/PSM
Hatch cover web panels of primary supporting members, see Figure 2.20.2.6(3)②		
Web of transverse/longitudinal girder (single skin type)	UP-B	Plate between local stiffeners/face plate/PSM
Web of transverse/longitudinal girder (double skin type)	SP-B[(3)]	Length: between PSM Width: full web depth
Web panel with opening	Procedure for opening	Plate between local stiffeners/face plate/PSM
Irregularly stiffened panels	UP-B	Plate between local stiffeners/face plate/PSM
Note 1: SP and UP stand for stiffened and unstiffened panel respectively. Note 2: A and B stand for Method A and Method B respectively. Note 3: In case that the buckling carlings/brackets are irregularly arranged in the web of transverse/longitudinal girder, UP-B method may be used.		

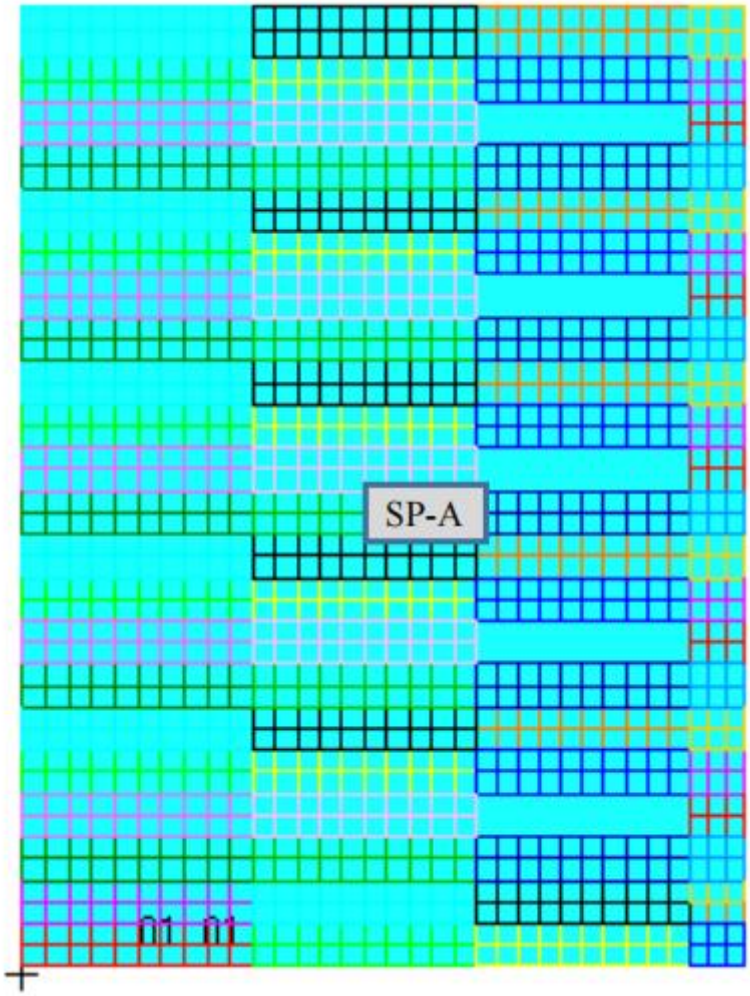


Figure 2.20.2.6(3)①

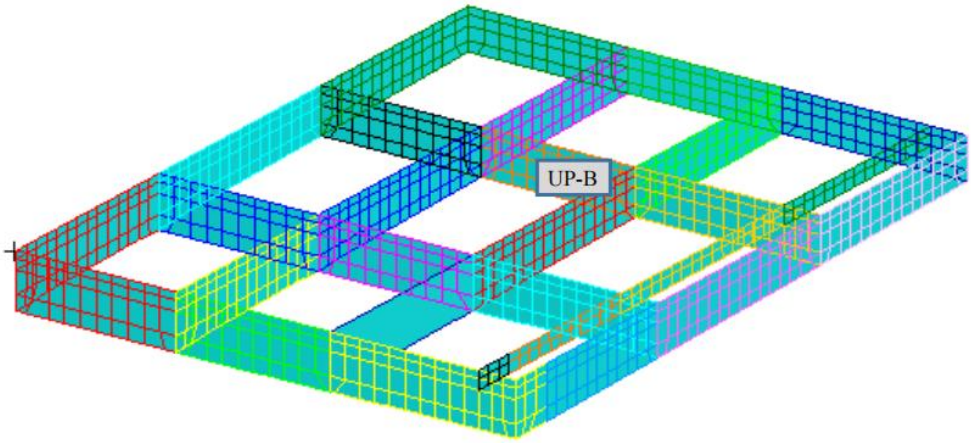


Fig. 2.20.2.6(3)②

③ Applied lateral pressure and stresses

The buckling assessment of hatch covers is based on the lateral pressure as defined in 2.1 and 2.2, and stresses obtained from FE analysis, refer to 2.20.2.4.

④ Safety factors

For all hatch cover structural members, safety factor S=1.0 is to be applied to both of the plating and stiffener buckling capacity formulas as defined in 5.2.2, Section 5 of Appendix 5 and 5.2.3, Section 5 of Appendix 5, respectively.

⑤ Buckling acceptance criteria

A structural member is considered to have an acceptable buckling strength if it satisfies the following criterion:

$$\eta_{act} \leq \eta_{all}$$

where: η_{act}——Buckling utilisation factor based on the applied stress, as defined in 1.3.2.2, Section 1 of Appendix 5 and Section 4 of Appendix 5, and calculated per Section 5 of Appendix 5.

η_{all}——Allowable buckling utilisation factor, taken as given in Table 2.20.2.6(3)⑤.

Allowable buckling utilisation factors Table 2.20.2.6(3)⑤

Structural component	Subject to	η_{all}, allowable buckling utilisation factor
Plates and stiffeners Web of PSM	External pressure, as defined in 2.20.2.2(1)	0.80
	Other loads, as defined in 2.20.2.2(2)~(5)	0.90 for static+dynamic load case 0.72 for static load case

2.20.2.7 Details of hatch covers

(1) Container foundation on hatch covers

Container foundations on hatch covers are to be in compliance with the relevant requirements of Appendix 1 of Chapter 7 of this PART. The calculated stresses of substructures of container foundations under cargo and container loads according to 2.20.2.2 of this Section are to comply with the requirements of 2.20.2.5 of this Section.

(2) Weathertightness

In addition to the following requirements, the hatch covers are also to meet the relevant requirements of IACS REC14.

① Packing material (general)

The packing material is to be suitable for all expected service conditions of the ship and is to be compatible with the cargoes to be transported. The packing material is to be selected with regard to dimensions and elasticity in such a way that expected deformations may be carried. Forces are to be carried by the steel structure only.

The packings are to be compressed so as to give the necessary tightness effect for all expected operating conditions. Special consideration is to be given to the packing arrangement in ships with large relative movements between hatch covers and coamings or between hatch cover sections.

② Dispensation of weathertight gaskets

For hatch covers of cargo holds intended solely for the transport of containers, upon request by the Owner and subject to compliance with the following conditions, the fitting of weathertight gaskets according to 2.20.2.7(2) may be dispensed with:

- The hatchway coamings are to be not less than 600 mm in height.
- For weather deck hatch covers located above a depth $H(x)$, $H(x)$ is to comply with the

following criterion:

$$H(x) \geq T_{fb} + f_b + h \qquad \text{m}$$

where: T_{fb} — draught, in m, corresponding to the assigned summer load line;

f_b — minimum required freeboard, in m, determined in accordance with ICLL Regulation 28 as modified by further regulations as applicable;

$$h = 4.6 \text{ m} \qquad \text{for } \frac{x}{L_L} \leq 0.75;$$

$$h = 6.9 \text{ m} \qquad \text{for } \frac{x}{L_L} > 0.75.$$

- Labyrinths, gutter bars or equivalents are to be fitted proximate to the edges of each panel in way of the coamings. The clear profile of these openings is to be kept as small as possible.
- Where a hatch is covered by several hatch cover panels, the clear opening of the gap in between the panels is to be not wider than 50 mm.
- The labyrinths and gaps between hatch cover panels are to be considered as unprotected openings with respect to the requirements of intact and damage stability calculations.
- With regard to drainage of cargo holds and the necessary fire-fighting system, refer to the relevant requirements of Chapter 6, PART EIGHT of the Rules.
- Bilge alarms are to be provided in each hold fitted with non-weathertight covers.
- Furthermore, Chapter 3 of IMO MSC/Circ.1087 is to be complied with for the storage and segregation of containers carrying dangerous goods.

③ Cross-joint of multi-panel covers are to be provided with efficient drainage arrangements.

2.20.2.8 Hatch coamings are to comply with the following requirements:

(1) The net thickness of weather deck hatch coamings is not to be less than the larger of the following values:

- For Type-1 ships:

$$t = 0.0142 s \sqrt{\frac{p_A}{0.95 R_{eH}}} \qquad \text{mm}$$

$$t = 6 + \frac{L_1}{100} \qquad \text{mm}$$

- For Type-2 ships:

$$t = 0.016 s \sqrt{\frac{p_{coam}}{0.95 R_{eH}}} \quad \text{mm}$$

$$t_{min} = 9.5 \quad \text{mm}$$

where: s — stiffener spacing, in m;

P_A — horizontal weather design load, in kN/m^2, to be calculated according to 2.20.2.2(2) ① of this Section;

p_{coam} — horizontal weather design load, in kN/m^2, to be calculated according to 2.20.2.2(2) ② of this Section;

~~R_{eH} — yield stress of material, in N/mm^2;~~

$L_1 = L$, but need not be taken as greater than 300 m.

The continuous longitudinal hatch coamings within 0.4L amidships are also to comply with the relevant requirements of Section 2 of this Chapter.

(2) The stiffeners of hatch coaming are to meet the following requirements:

The stiffeners are to be continuous at the coaming stays.

For stiffeners with both ends constrained, the net section modulus ~~W~~ Z and net shear area A_{shr}, calculated on the basis of net thickness, are not to be less than:

- For Type-1 ships:

$$W = \frac{83sl^2 p_A}{R_{eH}} \text{ ~~cm}^3\text{~~}$$

$$A_s = \frac{10sl\ p_A}{R_{eH}} \text{ ~~cm}^2\text{~~}$$

$$Z = \frac{p_A sl^2}{f_{bc} R_{eH}} \text{ cm}^3$$

$$A_{shr} = \frac{p_A sl^2}{R_{eH}} 10^{-2} \text{ cm}^2$$

where: f_{bc} =12 in general
= 8 for the end spans of stiffeners sniped at the coaming corners

l —stiffener span, in m, to be taken as the spacing of coaming stays;

s — stiffener spacing, in m;

P_A — horizontal weather design load, in kN/m^2, to be calculated according to 2.20.2.2(2)① of this Section;

~~R_{eH} — yield stress of material, in N/mm^2.~~

For sniped stiffeners of coaming at hatch corners, section modulus and shear area at the fixed support have to be increased by 35%. The gross thickness of the coaming plate at the sniped stiffener end is not to be less than:

$$t = 19.6\sqrt{\frac{p_A s(l - 0.5s)}{R_{eH}}} \quad \text{mm}$$

- For Type-2 ships:

$$Z = 1.21\frac{p_{coam} sl^2}{f_{bc} c_p R_{eH}}$$

where: f_{bc} —16 in general
12 for the end spans of stiffeners sniped at the coaming corners

l —stiffener span, in m, to be taken as the spacing of coaming stays;

s — stiffener spacing, in mm;

P_A — horizontal weather design load, in kN/m^2, to be calculated according to 2.20.2.2(2)① of this Section;

p_{coam} — horizontal weather design load, in kN/m^2, to be calculated according to 2.20.2.2(2)② of this Section;

c_p — ratio of the plastic section modulus to the elastic section modulus of the stiffeners with an attached plate breadth, in mm, equal to $40t$, where t is the plate net thickness

c_p — 1.16 in the absence of more precise evaluation

The horizontal stiffeners of continuous longitudinal hatch coamings within 0.4L amidships are also to comply with the relevant requirements of Section 2 of this Chapter.

(3) Coaming stays are to be designed for the loads transmitted through them and are to comply with the following requirements, in addition to the allowable stresses stipulated in 2.20.2.5 of this Section.

① Coaming stay section modulus and web thickness

At the connection with deck, the net section modulus ~~W~~Z, in cm^3, and the gross thickness t_w, in mm, of the coaming stays designed as beams with flange (examples 1 and 2 are shown in Figure 2.20.2.8(3)) are to be taken not less than:

$$W = \frac{526eh_s^2 p_A}{R_{eH}} \text{ ~~cm}^3$$

$$t_w = \frac{2}{R_{eH}} \cdot \frac{e \cdot h_s \cdot p_A}{h_W} + t_s \text{ ~~mm}$$

$$Z = \frac{Ps_c H_c^2}{1.9R_{eH}} \text{ cm}^3$$

$$t_w = \frac{2Ps_c H_c}{hR_{eH}} \text{ mm}$$

where: H_C ~~e~~ — stay height, in m ~~spacing of coaming stays, in m~~;

s_c ~~h_s~~ — stay spacing, in mm ~~height of coaming stays, in m~~;

h ~~h_w~~ — stay depth, in mm, at the connection with the deck ~~web height of coaming stay at its lower end, in m~~;

p ~~t_s~~ — pressure on coaming, in kN/m^2 , taken as p_A defined in 2.20.2.2(2)① in general and as p_{coam} defined in 2.20.2.2(2)② for Type-2 ships ~~corrosion addition, in mm, according to 2.20.2.10 of this Section;~~

~~P_A~~ — ~~horizontal weather design load, in kN/m^2, to be calculated according to 2.20.2.2(2) of this Section~~.

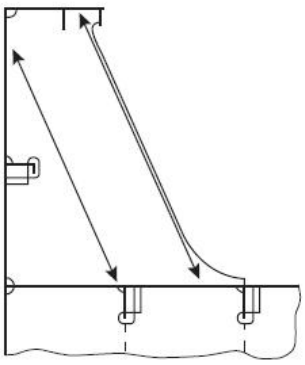
For other designs of coaming stays, such as those shown in Figure 2.20.2.8(3), examples 3 and 4, the stresses are to be determined through a grillage analysis or FEM. The calculated stresses are to comply with the permissible stresses according to 2.20.2.5 of this Section.

Coaming stays are to be supported by appropriate substructures. Face plates may only be included in the calculation of section modulus of coaming stays if an appropriate substructure is provided and welding provides an adequate joint.

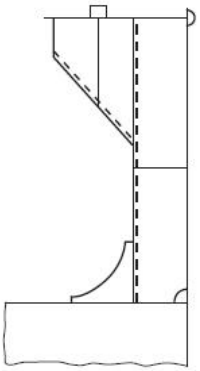
Webs are to be connected to the deck by fillet welds on both sides with a throat thickness of not less than 0.44t_w.

For Type-2 ships, toes of stay webs are to be connected to the deck plating with full or partial penetration double bevel welds extending over a distance not less than 15% of the stay width. For

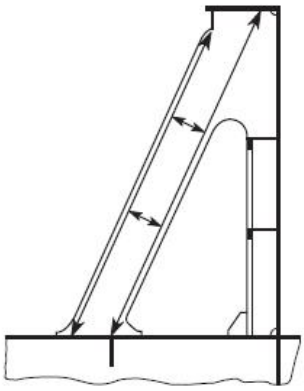
other ship types the ~~The~~ size of welding for toes of webs at the lower end of coaming stays is to comply with the relevant requirements of Chapter 1 of this PART.



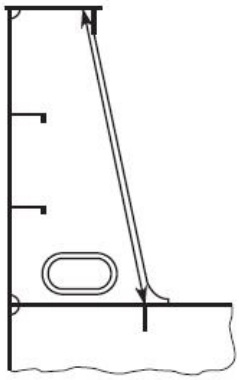
Example 1



Example 2



Example 3



Example 4

Figure 2.20.2.8(3) Examples of coaming stays

② For coaming stays, which transfer friction forces at hatch cover supports, fatigue strength is to be considered.

(4) The hatch coaming is also to comply with the following requirements:

① Hatch coamings which are part of the longitudinal hull structure are to be designed according to the relevant requirements of Section 2 of this Chapter.

② For structural members welded to coamings and for cutouts in the top of coamings, sufficient fatigue strength is to be verified.

③ Longitudinal hatch coamings with a length exceeding 0.1*L* are to be provided with tapered brackets or equivalent transitions and a corresponding substructure at both ends. At the end of the brackets, they are to be connected to the deck by full penetration welds of minimum 300 mm in length.

④ The local details are to be designed to transfer the loads on the hatch covers to the hatch coamings, and, through them, to the deck structures below. Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions. Structures under deck are to be checked against the load transmitted by the stays. Unless otherwise stated, welding and material are to comply with the relevant requirements of CCS.

⑤ On ships carrying cargo on deck, such as timber, coal or coke, the stays are to be spaced not more than 1.5 m apart.

⑥ Coaming plates are to extend to the lower edge of the deck beams or hatch side girders are to be fitted that extend to the lower edge of the deck beams. Extended coaming plates and hatch side girders are to be flanged or fitted with face bars or half-round bars. See Figure 2.20.2.8(4).

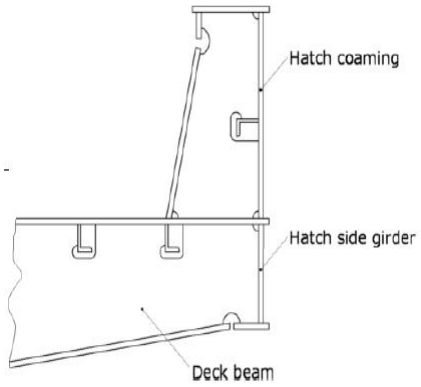


Figure 2.20.2.8(4) Example for the Extension of Coaming Plates

⑦ Drainage arrangement at the coaming is to comply with the following requirements:

If drain channels are provided inside the line of gasket by means of a gutter bar or vertical extension of the hatch side and end coaming, drain openings are to be provided at appropriate positions of the drain channels.

Drain openings in hatch coamings are to be arranged with sufficient distance to areas of stress concentration (e.g. hatch covers, transitions to crane posts).

Drain openings are to be arranged at the ends of drain channels and are to be provided with non-return valves to prevent ingress of water from outside. It is unacceptable to connect fire hoses to the drain openings for this purpose.

If a continuous outer steel contact between cover and ship structure is arranged, drainage from the space between the steel contact and the gasket is also to be provided.

2.20.2.9 Closing arrangements of weathertight steel hatch covers

(1) Securing arrangements

① General requirements

Securing devices between cover and coaming and at cross-joints are to be installed to provide weathertightness. Sufficient packing line pressure is to be maintained. Securing devices are to be appropriate to bridge displacements between cover and coaming due to hull deformations.

Securing devices are to be of reliable construction and effectively attached to the hatchway coamings, decks or covers. Individual securing devices on each cover are to have approximately the same stiffness characteristics. According to the requirements of 2.20.2.3(3)② of this Section, a sufficient number of securing devices is to be provided at each side of the hatch cover, including that consisting of several parts.

The materials of stoppers, securing devices and their welding are to comply with the relevant requirements of CCS Rules for Materials and Welding. Specifications of the materials are to be shown in the drawings of the hatch covers.

② Rod cleats

Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

③ Hydraulic cleats

Where hydraulic cleating is adopted, a positive means is to be provided so that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

④ Cross-sectional area of the securing devices

The gross cross-sectional area of the securing devices is not to be less than:

$$A = 0.28 q S_{SD} k_l \qquad \text{cm}^2$$

where: q —packing line pressure, in N/mm, minimum 5 N/mm;

S_{SD} — spacing between securing devices, in m, not to be taken less than 2 m;

$k_l = (\frac{235}{R_{eH}})^e$;

R_{eH} — the minimum yield stress of material, in N/mm^2, but not to be taken greater than $0.7 R_m$;

R_m — tensile strength of material, in N/mm^2;

e =0.75 for $R_{eH} > 235$ N/mm^2;

e =1.00 for $R_{eH} \le 235$ N/mm^2.

Rods or bolts are to have a gross diameter not less than 19 mm for hatchways exceeding 5m^2 in area.

Securing devices of special design in which significant bending or shear stresses occur may be designed as anti-lifting devices according to 2.20.2.9(1)⑤. The design load is taken as the packing line pressure q multiplied by the spacing S_{SD} between securing devices.

⑤ Anti-lifting devices

The securing devices of hatch covers, on which cargo is to be lashed, are to be designed for the lifting forces resulting from loads according to 2.20.2.2(4) of this Section, refer to Figure 2.20.2.9(1). Unsymmetrical loadings, which may occur in practice, are to be considered. Under these loadings the equivalent stress in the securing devices is not to exceed:

$$\sigma_V = \frac{150}{k_l} \qquad \text{N/mm}^2$$

where: k_l — as in 2.20.2.9(1)④.

Note: The partial load cases given in Table 2.20.2.2(4) may not cover all unsymmetrical loadings, critical for hatch cover lifting.

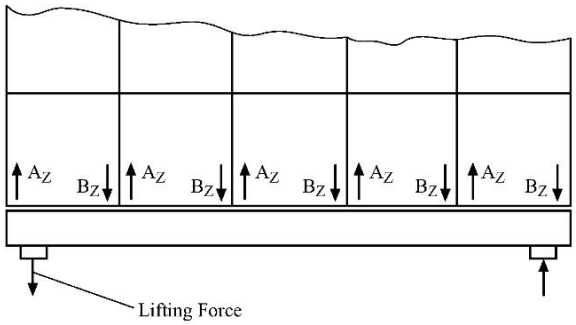


Figure 2.20.2.9(1) Lifting Forces at a Hatch Cover

The anti-lifting devices may be dispensed with according to the following requirements:

In the absence of hatch cover lifting under loads arising from the ship's rolling motion, securing devices for hatch covers may be omitted. In such cases, it is to be proven by means of grillage or finite element analysis that an equilibrium condition is achieved using compression only boundary elements for the vertical hatch cover supports. If securing devices are omitted, transverse cover guides are to be effective up to a height h_E, as shown in Figure 2.20.2.9(2), where h_E is not to be less than:

$$h_E = 1.75(2se + d^2)^{0.5} - 0.75d \quad \text{mm}$$

$$h_{E\min} = \text{height of the cover edge plate} + 150 \quad \text{mm}$$

where: e — largest distance from the inner edge of the transverse cover guide to the end of the cover edge plate, in mm;

s — total clearance within the transverse cover guide, with $10 \le s \le 40$, in mm;

d — distance between upper edge of transverse stopper and hatch cover support, in mm.

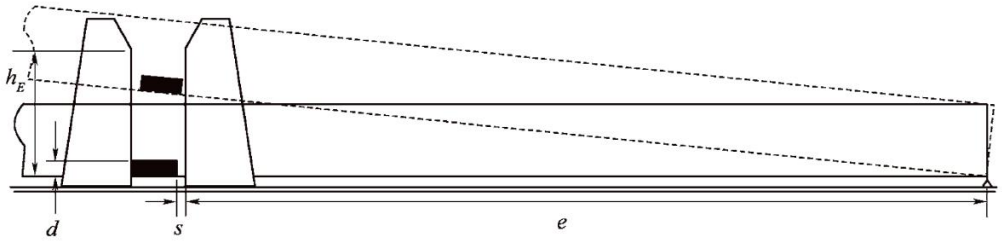


Figure 2.20.2.9(2) Height of Transverse Cover Guide

The transverse cover guides and their substructure are to be dimensioned in accordance with the transverse loads acting at a height h_E.

(2) Hatch cover supports, stoppers and supporting structures

① Horizontal mass forces

For the design of hatch cover supports, the horizontal mass force is to be taken as follows:

$$F_h = ma$$

where: F_h— horizontal mass force, in kN;

$a_X = 0.2g$ in longitudinal direction;

$a_Y = 0.5g$ in transverse direction;

m— sum of mass of cargo lashed on the hatch cover and mass of hatch cover.

The accelerations in longitudinal direction and in transverse direction need not be considered as acting simultaneously.

② Hatch cover supports

For the transmission of the support forces resulting from the load cases specified in 2.20.2.2 of this Section and of the horizontal mass forces specified in (2)①, supports are to be provided which are to be designed such that the nominal surface pressures in general do not exceed the values obtained from the following formula:

$$p_{n\max} = dp_n \qquad \text{N/mm}^2$$

where: d = 3.75-0.015L;

$d_{\max} = 3.0$;

$d_{\min} = 1.0$, in general;

$d_{\min} = 2.0$, for partial loading conditions, see 2.20.2.2(5);

P_n — Allowable nominal surface pressure, see Table 2.20.2.9(2).

Allowable Nominal Surface Pressure P_n Table 2.20.2.9(2)

Support material	P_n (N/mm^2) when loaded by	
	Vertical force	Horizontal force (on stoppers)
Hull structural steel	25	40
Hardened steel	35	50
Lower friction materials	50	—

For metallic supporting surfaces not subjected to relative displacements, the following nominal surface pressure applies:

$$p_{n\max} = 3p_n \qquad \text{N/mm}^2$$

Note: When the maker of vertical hatch cover support material can provide proof that the material is sufficient for the increased surface pressure, not only statically but under dynamic conditions including relative motion for adequate number of cycles, permissible nominal surface pressure may be relaxed at the discretion of CCS. However, realistic long term distribution of spectra for vertical loads and relative horizontal motion is to be assumed and agreed with CCS.

Drawings of the supports are to be submitted for approval. In the drawings of supports, the permitted maximum pressure given by the material manufacturer is to be indicated.

Where large relative displacements of the supporting surfaces are to be expected, the use of material having low friction properties is recommended.

The substructures of the supports are to be of such a design that a uniform pressure distribution is achieved.

Irrespective of the arrangement of stoppers, the supports are to be able to transmit the following force P_h in the longitudinal and transverse direction:

$$P_h = \mu \cdot \frac{P_V}{\sqrt{d}}$$

where: P_V — vertical supporting force;

μ — frictional coefficient;

μ = 0.5 steel to steel.

For non-metallic, low-friction support materials on steel, the friction coefficient μ may be reduced but not to be less than 0.35 and it is to be submitted to CCS for approval.

Supports as well as the adjacent structures and substructures are to be designed such that the allowable stresses in 2.20.2.5 of this Section are not exceeded.

For substructures and adjacent structures of supports subjected to horizontal forces P_h, a fatigue strength is to be considered.

③ Hatch cover stoppers

Hatch covers are to be sufficiently secured against horizontal shifting. Stoppers are to be provided for hatch covers on which cargo is carried.

The greater of the loads resulting from 2.20.2.2(2) of this Section and 2.20.2.9(2)① is to be applied for the dimensioning of the stoppers and their substructures.

The allowable stress in stoppers and their substructures, in the cover, and of the coamings is to be determined according to 2.20.2.5 of this Section and in addition, the requirements in 2.20.2.9(2)② are to be taken into consideration.

Specifically for Type-2 ships, the following additional requirements are to be complied with:

Hatch covers are to be effectively secured, by means of stoppers, against the transverse forces arising from a pressure of 175 kN/m^2.

With the exclusion of No.1 hatch cover, hatch covers are to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 175 kN/m^2.

No. 1 hatch cover is to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 230 kN/m^2.

This pressure may be reduced to 175 kN/m^2 when a forecastle is fitted in accordance with Section 13, Chapter 8 of this PART.

The equivalent stress in stoppers and their supporting structures, and calculated in the throat of the stopper welds is not to exceed the allowable value of 0.8R_{eH}.

2.20.2.10 Corrosion addition and steel renewal

(1) Corrosion addition for hatch covers and hatch coamings

For scantlings of hatch cover components, the general corrosion additions t_S, as shown in Table 2.20.2.10, is required.

Corrosion Addition t_S for Hatch Covers and Hatch Coamings **Table 2.20.2.10**

Application	Structure	t_S[mm]
Weather deck hatches of container ships, car carriers, paper carriers	Hatch covers	1.0
	Hatch coamings	1.5 for $t \le 10$

Application	Structure	t_S[mm]
and passenger vessels		$\frac{0.1t}{\sqrt{K}}+0.5$, but not greater than 3, for $t>10$
Weather deck cargo hatches of Type-2 ships	Hatch covers in general	2.0
	Top and bottom plating of double skin hatch covers	2.0
	Internal structure of double skin hatch covers	1.5
	Hatch coamings and coaming stays	1.5
Weather deck hatches of all other ships	Hatch covers in general	2.0
	Weather exposed plating and bottom plating of double skin hatch covers	1.5
	Internal structure of double skin hatch covers and closed box girders	1.0
	Hatch coamings not part of the longitudinal hull structure	1.5
	Hatch coamings part of the longitudinal hull structure	1.5 for $t \le 10$
		$\frac{0.1t}{\sqrt{K}}+0.5$, but not greater than 3, for $t>10$
	Coaming stays and stiffeners	1.5

Notes:

t: net thickness of hatch coaming required by the Rules.

K: material factor.

(2) Steel renewal

Steel renewal is required where the gauged thickness is less than t_{net} + 0.5 mm for

- single skin hatch covers,
- the plating of double skin hatch covers, and
- coaming structures the corrosion additions t_S of which are given in Table 2.20.2.10.

Coating is to be maintained in GOOD condition, as defined in 5.1.5.1(15), Chapter 5 of PART ONE of the Rules.

For internal structure of double skin hatch covers, thickness gauging is required when hatch cover top or bottom plating renewal is to be carried out or when it is deemed necessary by CCS surveyor, on the basis of the plating corrosion or deformation. In these cases, steel renewal for the internal structures is to be required where the gauged thickness is less than t_{net}.

For corrosion addition t_S = 1.0 mm, the thickness for steel renewal is t_{net} and coating or annual gauging may be used for substitution of renewal when gauged thickness is between t_{net} and t_{net} + 0.5 mm.

For coaming structures, the corrosion additions t_S of which are not given in Table 2.20.2.10, steel renewal and coating or annual gauging are to be in accordance with the relevant requirements of CCS.

2.20.3 Steel pontoon covers

2.20.3.1 The design load of steel pontoon covers is to comply with the following requirements:

(1) The design load of vertical exposed hatch covers is to be calculated according to Table 2.20.2.2(1) of this Section.

(2) The permissible cargo load p on hatch covers is to be specified by the Owner or designer and included in the loading manual, complying with the following requirements:

① The permissible cargo load p for 'tween deck hatch covers is not to be less than:

$$p = 7.06h \qquad \text{kN/m}^2$$

where: h — the vertical distance, in m, measured from the hatch cover to the underside of hatch cover stiffeners on deck above.

This requirement does not apply to multi-purpose ships of which the 'tween deck hatch covers are used as 'tween deck, see Figure 2.20.3.1(2) of this Section.

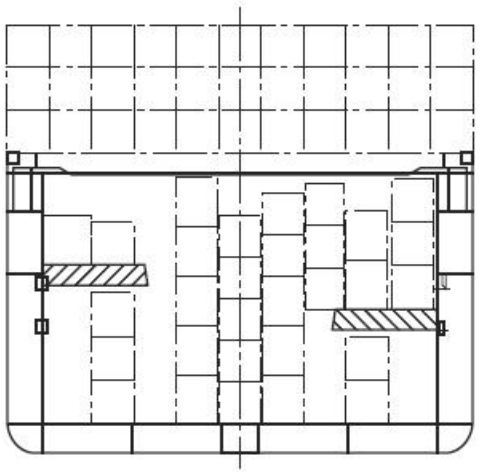


Figure 2.20.3.1(2)

② The permissible cargo load p for hatch covers in the accommodation spaces is not to be less than 12.7 kN/m^2.

2.20.3.2 The local scantlings of hatch covers are to comply with the following requirements:

(1) The thickness t of the top plating of steel hatch covers is not to be less than that obtained from the following formula:

~~$t = 10s$~~ $t = 0.01s$ mm, but in no case to be less than 6 mm.

where: s— spacing of stiffeners, in mm.

(2) The scantlings of stiffeners and girders of steel pontoon covers are to comply with the following requirements:

① Where the uniformly distributed design load of vertical exposed hatch covers is applied, the section modulus W and the section moment of inertia I of stiffeners are not to be less than:

~~$W = 0.782Kspl^2$~~ $W = 7.82Kspl^2 \times 10^{-4}$ cm^3

~~$I = 1.44spl^3$~~ $I = 1.44spl^3 \times 10^{-3}$ cm^4

where: p— vertical weather design load, in kN/m^2;

s— spacing of stiffeners, in mm;

l— span of stiffener, in m;

K—material factor.

② Where the uniformly distributed cargo load is applied, the section modulus W and the section moment of inertia I of stiffeners are not to be less than:

~~$W = 1.064Kspl^2$~~ $W = 1.064Kspl^2 \times 10^{-3}$ cm^3

~~$I = 1.8spl^3$~~ $I = 1.8spl^3 \times 10^{-3}$ cm^4

where: p—permissible cargo load, in kN/m^2;

s—spacing of stiffeners, in mm;

l—span of stiffener, in m;

K—material factor.

③ Where the ends of stiffeners are effectively bracketed or continuous, the values of section modulus and moment of inertia may be reduced respectively by 33% and 80% than those obtained from ① or ②.

④ The scantlings of girders of steel pontoon covers are to be determined by direct calculations. Where steel pontoon covers are subject to uniformly distributed loading and girders are fitted in one direction only, however, the scantlings of girders may also be determined according to ① and ②.

~~(3) The scantlings of stiffeners and girders with variable cross-section are to comply with the following requirements:~~

~~① The section modulus at the mid-span of stiffener and girder with a variable cross-section (see Figure 2.20.3.2(3)) is to be not less than the greater of the values obtained from the following formulae:~~

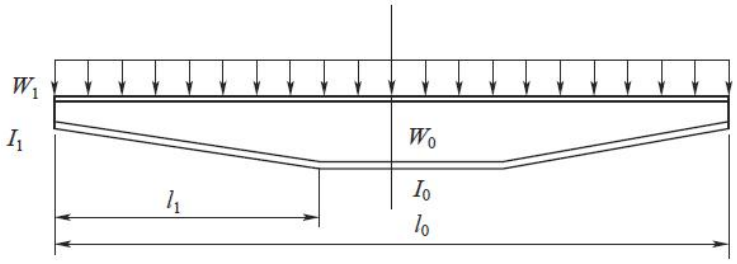
~~$W = W_{es}$ cm^3~~

~~$W = \left(1 + \frac{3.2\alpha - \gamma - 0.8}{7\gamma + 0.4}\right) W_{cs}$ cm^3~~

~~where: W_{es} — section modulus, in cm^3, for a constant cross-section, complying with this Section;~~

~~$\alpha = \frac{l_1}{l_0}$, where l_0 is span, in m, l_1 is length of the variable cross-section, in m;~~

~~$\gamma = \frac{W_1}{W_0}$, where W_0 is section modulus at mid-span, in cm^3, W_1 is section modulus at ends, in cm^3.~~



~~**Figure 2.20.3.2(3)**~~

② The section moment of inertia I at the mid-span of stiffener and girder with a variable cross-section is not to be less than the greater of the values obtained, from the following formulae:

$$I = I_{cs} \quad \text{cm}^4$$

$$I = \left(1 + \frac{8\alpha^3(1-\beta)}{0.2+3\sqrt{\beta}}\right) I_{cs} \quad \text{cm}^4$$

where: I_{cs} moment of inertia, in cm^4, for a constant cross-section, complying with this Section;

$\alpha = \frac{l_1}{l_0}$, where l_0 is span, in m, l_1 is length of the variable cross-section, in m;

$\beta = \frac{I_1}{I_0}$, where I_0 is section moment of inertia at mid-span, in cm^4; I_1 is section moment of inertia at ends, in cm^4.

③ The web depth of the stiffeners and girders at ends is not to be less than 2/5 of that at the mid-span, and is in no case to be less than 150 mm and the section modulus of the stiffeners and girders at ends is not to be less than 35% of that at the mid-span.

2.20.3.3 The direct strength calculation of steel pontoon covers is to be in compliance with the requirements of 2.20.2.4 of this Section.

2.20.3.4 Yield strength and deformation criteria of steel hatch covers of steel pontoon covers

The yield strength and deflection of steel pontoon covers are to meet the requirements of Table 2.20.3.4.

Steel Pontoon Covers **Table 2.20.3.4**

Load	Allowable positive stress [σ] (N/mm^2)	Allowable deflection (m)
Vertical weather design load	0.70R_{eH}	0.0049 l
Loads other than vertical weather design load	0.65R_{eH}	0.0044 l

2.20.3.5 The buckling strength of steel pontoon covers is to meet the requirements of Table 2.20.3.5.

Table 2.20.3.5

Structural member		Criteria
Top panels of hatch covers	Girders fitted in uni-axial direction	The normal stress of top panels in compression of girders is not to exceed 0.8 times the critical buckling stress σ_c, σ_c may be calculated according to 8.11.3.6(1), Section 11, Chapter 8 of this PART2.20.3.5(1)
	Girders fitted in bi-axial directions	Biaxial compressive stress of top panels, when calculated by means of finite plate element model, is to be in accordance with the relevant requirements in 2.20.2.6(1) of this Section
Girder webs		The shear stress of girder web panels is not to exceed 0.8 times the critical shear buckling stress τ_c, τ_c may be calculated according 8.11.3.6(3), Section 11, Chapter 8 of this PART2.20.3.5(3)
Stiffeners parallel to girders		The normal stress of attached plating of stiffeners in compression of girders parallel to stiffeners is not to exceed 0.8 times the critical buckling stress σ_c, σ_c may be calculated according to 8.11.3.6(2), Section 11, Chapter 8 of this PART2.20.3.5(2)

(1) Hatch cover plating critical stress

The compressive stress σ in the hatch cover plate panels, induced by the bending of primary supporting members parallel to the direction of secondary stiffeners, is not to exceed 0.8 times the

critical buckling stress σ_{c1}, to be evaluated as defined below:

$$\sigma_{c1} = \sigma_{E1} \quad \text{for } \sigma_{E1} \le \frac{R_{eH}}{2}$$

$$\sigma_{c1} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E1}}\right) \quad \text{for } \sigma_{E1} > \frac{R_{eH}}{2}$$

where: R_{eH} — yield stress of the material, in N/mm^2;

$\sigma_{E1} = 3.6E\left(\frac{t}{1000s}\right)^2$, in N/mm^2;

E — modulus of elasticity, in N/mm^2, = 2.06×10^5 for steel;

t — net thickness of plate panel, in mm;

s — spacing of secondary stiffeners, in m.

The mean compressive stress σ in each of the hatch cover plate panels, induced by the bending of primary supporting members perpendicular to the direction of secondary stiffeners, is not to exceed 0.8 times the critical buckling stress σ_{c2}, to be evaluated as defined below:

$$\sigma_{c2} = \sigma_{E2} \quad \text{for } \sigma_{E2} \le \frac{R_{eH}}{2}$$

$$\sigma_{c2} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E2}}\right) \quad \text{for } \sigma_{E2} > \frac{R_{eH}}{2}$$

where: R_{eH} — yield stress of the material, in N/mm^2;

$\sigma_{E2} = 0.9mE\left(\frac{t}{1000s_s}\right)^2$, in N/mm^2;

$m = c\left[1 + \left(\frac{s_s}{l_s}\right)^2\right]^2 \frac{2.1}{\psi + 1.1}$

E — modulus of elasticity, in N/mm^2, = 2.06×10^5 for steel;

t — net thickness of plate panel, in mm;

s_s — length of the shorter side of the plate panel, in m;

l_s — length of the longer side of the plate panel, in m;

ψ — ratio between smallest and largest compressive stress;

c = 1.3 when plating is stiffened by primary supporting members;

c = 1.21 when plating is stiffened by secondary stiffeners of angle or T type;

c = 1.1 when plating is stiffened by secondary stiffeners of bulb type;

c = 1.05 when plating is stiffened by flat bar.

(2) Hatch cover secondary stiffeners critical stress

The compressive stress σ in the top flange of secondary stiffeners, induced by the bending of primary supporting members parallel to the direction of secondary stiffeners, is not to exceed 0.8

times the critical buckling stress σ_{cs}, to be evaluated as defined below:

$$\sigma_{CS} = \sigma_{ES} \quad \text{for} \quad \sigma_{ES} \le \frac{R_{eH}}{2}$$

$$\sigma_{cs} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{ES}}\right) \quad \text{for} \quad \sigma_{ES} > \frac{R_{eH}}{2}$$

where: R_{eH} — yield stress of the material, in N/mm^2;

σ_{ES} — ideal elastic buckling stress of the secondary stiffener, in N/mm^2,

= minimum between σ_{E3} and σ_{E4};

σ_{E3} = $\frac{0.001EI_a}{Al^2}$, in N/mm^2;

E — modulus of elasticity, in N/mm^2, = 2.06×10^5 for steel;

I_a — moment of inertia of the secondary stiffener, in cm^4, including a top flange equal to the spacing of secondary stiffeners;

A — cross-sectional area of the secondary stiffener, in cm^2, including a top flange equal to the spacing of secondary stiffeners;

l — span of the secondary stiffener, in m;

σ_{E4} = $\frac{\pi^2 EI_w}{10^4 I_p l^2}\left(m^2 + \frac{K}{m^2}\right) + 0.385E\frac{I_t}{I_p}$, N/mm^2;

K = $\frac{Cl^4}{\pi^4 EI_w} \times 10^6$;

m — number of half waves, given by Table 2.20.3.5(2);

I_w — sectorial moment of inertia of the secondary stiffener about its connection with the plating, in cm^6:

$I_w = \frac{h_w^3 t_w^3}{36} \times 10^{-6}$, for flat bar secondary stiffeners;

$I_w = \frac{t_f b_f^3 h_w^2}{12} \times 10^{-6}$, for "Tee" secondary stiffeners;

$I_w = \frac{b_f^3 h_w^2}{12(b_f + h_w)^2}[t_f(b_f^2 + 2b_f h_w + 4h_w^2) + 3t_w b_f h_w] \times 10^{-6}$, for angles and bulb secondary stiffeners;

I_p — polar moment of inertia of the secondary stiffener about its connection with the plating, in cm^4:

$I_p = \frac{h_w^3 t_w}{3} \times 10^{-4}$, for flat bar secondary stiffeners;

$I_p = (\frac{h_w^3 t_w}{3} + h_w^2 b_f t_f) \times 10^{-4}$, for flanged secondary stiffeners;

I_t — St Venant's moment of inertia of the secondary stiffener without top flange, in cm^4:

$I_t = \frac{h_w t_w^3}{3} \times 10^{-4}$, for flat bar secondary stiffeners;

$I_t = \frac{1}{3}[h_w t_w^3 + b_f t_f^3 (1 - 0.63\frac{t_f}{b_f})] \times 10^{-4}$, for flanged secondary stiffeners;

h_w — web height of the secondary stiffener, in mm;

t_w — web net thickness of the secondary stiffener, in mm;

b_f — width of the secondary stiffener bottom flange, in mm;

t_f — net thickness of the secondary stiffener bottom flange, in mm;

s — spacing of secondary stiffeners, in m;

C — spring stiffness exerted by the hatch cover top plating, calculated by the following formula:

$$C = \frac{k_p E t_p^3}{3s(1 + \frac{1.33 k_p h_w t_p^3}{1000 s t_w^3})} \times 10^{-3};$$

$k_p = 1 - \eta_p$, to be taken not less than zero; for flanged secondary stiffeners, k_p need not be taken as less than 0.1;

$\eta_p = \frac{\sigma}{\sigma_{E1}}$;

σ — compressive stress of flanges of primary supporting members;

σ_{E1} — as given in 2.20.3.5(1);

t_p — net thickness of the hatch cover plate panel, in mm.

Number of Half Waves (*m* value) **Table 2.20.3.5(2)**

K	$0 < K \leq 4$	$4 < K \leq 36$	$36 < K \leq 144$	$(m-1)^2 < K \leq m^2(m+1)^2$
m	1	2	3	m

(3) Web panels of hatch cover primary supporting members critical stress

This check is to be carried out for the web panels of primary supporting members, formed by web stiffeners or by the crossing with other primary supporting members, the face plate (or the bottom cover plate) or the attached top cover plate.

The shear stress τ in the hatch cover primary supporting member web panels is not to exceed 0.8 times the critical buckling stress τ_c, to be evaluated as defined below:

$$\tau_c = \tau_E \quad \text{for } \tau_E \leq \frac{\tau_F}{2}$$

$$\tau_c = \tau_F \left(1 - \frac{\tau_F}{4\tau_E}\right) \quad \text{for } \tau_E > \frac{\tau_F}{2}$$

where: $\tau_F = \frac{R_{eH}}{\sqrt{3}}$ N/mm^2;

R_{eH} — yield stress of the material, in N/mm^2;

$\tau_E = 0.9 k_t E \left[\frac{t_{pr,n}}{1000d}\right]^2$ N/mm^2;

E — modulus of elasticity, in N/mm^2, = 2.06×10^5 for steel;

$t_{pr,n}$ — net thickness of primary supporting member, in mm;

$k_t = 5.35 + 4.0\left(\frac{d}{a}\right)^2$;

a — greater dimension of web panel of primary supporting member, in m;

d — smaller dimension of web panel of primary supporting member, in m.

For primary supporting members parallel to the direction of secondary stiffeners, the actual dimensions of the panels are to be considered.

For primary supporting members perpendicular to the direction of secondary stiffeners or for hatch covers built without secondary stiffeners, a presumed square panel of dimension d is to be taken for the determination of the stress τ_c. In such a case, the average shear stress τ between the values calculated at the ends of this panel is to be considered.

2.20.3.6 Steel pontoon covers are to be provided with tarpaulins and securing devices in accordance with the following requirements:

(1) At least two layers of tarpaulin in good condition are to be provided for each hatchway in exposed freeboard and superstructure decks.

(2) Tarpaulins are to be free from jute, and the minimum weight in unit area of the material before treatment is to be:

0.65 kg/mm^2, if the material is tarred;

0.65 kg/mm^2, if the material is chemically dressed;

0.55 kg/mm^2, if the material is dressed with black oil.

(3) Cleats are to be welded to the hatch coamings or the horizontal stiffeners, and the cleats are to be so set as to fit the taper of the wedges. The width of cleats is not to be less than 65 mm, and the cleats are to be spaced not more than 600 mm from centre to centre. The first and last cleats along each side or end are to be arranged not more than 150 mm from the hatch covers.

(4) Wedges are to be of tough wood. They are to have a taper of not more than 1 in 6 and are not to be less than 13 mm in thickness at the point.

(5) For all hatchways situated in exposed freeboard and superstructure decks, steel bars or other equivalent means are to be provided in order to efficiently secure each section of hatch covers after the tarpaulins are battened down. Hatch covers of more than 1.5 m in length are to be secured by at least two such securing appliances.

(6) For all hatchways situated in other exposed positions, ring bolts or other fittings for lashings are to be provided.

2.20.3.7 The hatch coamings of steel pontoon covers are to comply with the following requirements:

(1) Construction of exposed hatch coamings

① The thickness t of hatch coamings is not to be less than that obtained from the following formula:

$$t = 0.05L + 6.5 \quad \text{mm}$$

where: L— length of ship, in m, need not be greater than 90 m.

② Coamings of 600 mm or more in height are to be stiffened on their upper edges or at about 250 mm below the upper edge by a horizontal bulb flat or equivalent strength member. The web depth of the horizontal bulb flat is not to be less than 180 mm, and an additional support is to be afforded by fitting vertical stays or brackets from the bulb flat to the deck at intervals of not more than 3 m. The web depth of the stiffeners or brackets is to be not less than that of the horizontal bulb flat and they are to be flanged or fitted with a face plate. Where the coamings are more than 900 mm in height, the spacing of the above-mentioned stays or brackets is to be suitably reduced. Where the coamings are equal to or more than 1,200 mm in height, an additional horizontal bulb flat or equivalent strength member is to be fitted in way of half height of the coaming. Where the coamings are subject to loaded containers, the hatch coamings and their supporting members are to be strengthened correspondingly.

③ Where no face plate is fitted, the upper edges of coamings are to be stiffened by half round bars or other rolled bars to ensure the rigidity of coamings and the smoothness of their upper edges.

④ Where the deck plating does not extend inside the coamings, the coamings at the corners of hatchways are to be rounded. For openings within 0.5L amidships, the radius of the rounded corner is to comply with the requirements of 2.4.4 of this Chapter.

If the deck plating extends inside the coamings, the coamings at the corners of hatchways may be square provided that the corners of deck openings are in compliance with the requirements of 2.4.4 of this Chapter and that the longitudinal coamings at hatch corners are extended in the form of a tapered bracket.

⑤ Extension brackets or rails arranged approximately in line with the cargo hatch side

coamings and intended for the stowage of steel covers are not to be welded to a deckhouse or masthouse, unless upon calculation it shows that the hatch coamings may be used as longitudinal strength members of the hull.

⑥ Where the exposed hatch coamings act as deck girders, they are also to comply with the relevant requirements of 2.8.8 of this Chapter.

(2) Where the 'tween deck hatch coamings act as deck girders, they are also to comply with the relevant requirements of 2.8.8 of this Chapter.

2.20.4 Hatch covers with portable beams

2.20.4.1 The design load of hatch covers with portable beams is to comply with the following requirements:

(1) The vertical weather design load of exposed hatch covers is to comply with Table 2.20.2.2(1) of this Section.

(2) The permissible cargo load on hatch covers is to comply with the requirements of 2.20.3.1(2) of this Section.

2.20.4.2 Hatch covers with portable beams are to be in compliance with the following requirements:

(1) Hatch covers with portable beams, where the cover is made of steel, are to meet the requirements of 2.20.3.2(1) of this Section; where the cover is made of wood, the thickness t is not to be less than that obtained from the following formula:

$$t = 40S \quad \text{mm, but in no case to be less than 60 mm}$$

where: S— spacing of portable hatch beams, in m.

Where the design load exceeds 18.4 kN/m^2, the thickness of wood covers is to be increased in direct proportion to the load.

Both ends of wood hatch covers are to be protected by encircling galvanized steel bands, about 65 mm wide and 3 mm thick, efficiently secured.

(2) Where the vertical design load is applied, the exposed hatch covers with portable beams are to comply with the following requirements:

① The section modulus W and the section moment of inertia I of the portable beams are not to be less than:

$$W = 0.782\,KSpl^2 \quad \text{cm}^3$$
$$I = 1.44\,Spl^3 \quad \text{cm}^4$$

where:

p — vertical weather design load, in kN/m^2, to be calculated according to 2.20.4.1 of this Section;

S — spacing of portable beams, in m;

l — span of portable beam, in m;

K — material factor.

② The ends of web plates are to be doubled, or inserts fitted for at least 180 mm along length of web.

③ The portable beams are to be stiffened at their upper and lower edges by continuous face plates. The width of the upper face plate is to be sufficient to provide a bearing surface of not less than 65 mm for hatch covers, and a vertical flat bar with a height of 50 mm is to be arranged on the upper face plate.

④ Carriers or sockets are to provide means for the efficient fitting and securing of portable hatch beams. The width of bearing surface is at least to be 75 mm.

⑤ The section modulus W and the section moment of inertia I of stiffeners of steel covers are not to be less than:

$$W = 0.664Kspl^2 \quad \text{cm}^3$$
$$I = 1.13spl^3 \quad \text{cm}^4$$

where:

p — vertical weather design load, in kN/m^2, to be calculated according to 2.20.4.1 of this Section;

l — span of stiffener, in m;

s — spacing of stiffeners, in m;

K — material factor.

(3) Where the uniformly distributed cargo load is applied, the hatch covers with portable beams are to comply with the following requirements:

① The section modulus W and the section moment of inertia I of portable beams are not to be less than:

$$W = 1.064KSpl^2 \quad \text{cm}^3$$
$$I = 1.8Spl^3 \quad \text{cm}^4$$

where:

p — permissible cargo load, in kN/m^2;

S — spacing of portable beams, in m;

l — span of portable beam, in m;

K — material factor.

② Portable beams are also to comply with the requirements of 2.20.4.2(2)② to ④.

③ The section modulus W and the section moment of inertia I of portable beams are not to be less than:

$$W=1.064Kspl^2 \quad \text{cm}^3$$
$$I=1.8spl^3 \quad \text{cm}^4$$

where:

p — permissible cargo load, in kN/m^2;

l — span of portable beam, in m;

s — spacing of portable beams, in m;

K — material factor.

(4) The scantling of stiffeners and girders with a variable cross-section for hatch covers with portable beams are to comply with the requirements of 2.20.3.2(3) of this Section.

2.20.4.3 The direct strength calculation of hatch covers with portable beams is to comply with the requirements of 2.20.2.4 of this Section.

2.20.4.4 The yield strength and deformation of hatch covers with portable beams is to comply with the requirements of 2.20.3.4 of this Section.

2.20.4.5 The buckling strength of hatch covers with portable beams is to comply with the requirements of 2.20.3.5 of this Section.

2.20.4.6 The closing appliances of hatch covers with portable beams are to comply with the requirements of 2.20.3.6 of this Section.

2.20.4.7 The hatch coamings of hatch covers with portable beams are to comply with the

requirements of 2.20.3.7 of this Section.

2.20.5 Miscellaneous openings

2.20.5.1 Miscellaneous openings are to comply with the requirements of 1.12.7 of Chapter 1 of this PART.

2.20.5.2 Small hatchways on exposed decks are also to comply with the following requirements:

(1) The height of coamings of small hatchways is to comply with the requirements of 2.20.1.8 of this Section. The thickness of the coamings is not to be less than the minimum thickness as required in this Chapter for the deck inside the line of openings for that position, or 11 mm, whichever is the lesser;

(2) Small hatchways are to be provided with steel weathertight hatch covers and reliable securing devices. The means of securing are to be such that weathertightness can be maintained in any condition. The thickness of the hatch covers is not to be less than the minimum thickness required by this Chapter for the deck inside the line of openings for that position, or 8 mm, whichever is the lesser;

(3) Strength and securing of small hatches on the exposed fore deck are also to comply with the relevant requirements of Section 7, Chapter 1 of this PART.

A new appendix is added as follows:

Appendix 5 BUCKLING STRENGTH ASSESSMENT OF SHIP STRUCTURAL ELEMENTS

SECTION 1 APPLICATION AND DEFINITIONS

Abbreviation

EPP —— Elementary plate panel, as defined in [1.2.3.1];

PSM —— Primary supporting member;

SP —— Stiffened panel, as defined in [1.2.3.3];

UP —— Unstiffened panel, as defined in[1.2.3.3].

1.1 Application

1.2

1.1.1 General Requirements

1.1.1.1 Relevant unified requirements concerning strength of ships

This Appendix establishes a general buckling assessment procedure as illustrated in Figure 1.1.1.1, and is to be applied in conjunction with Section 20 of Chapter 2 for hatch cover structures. The Section 20 of Chapter 2 is referred to as Relevant UR-S hereafter in this Appendix.

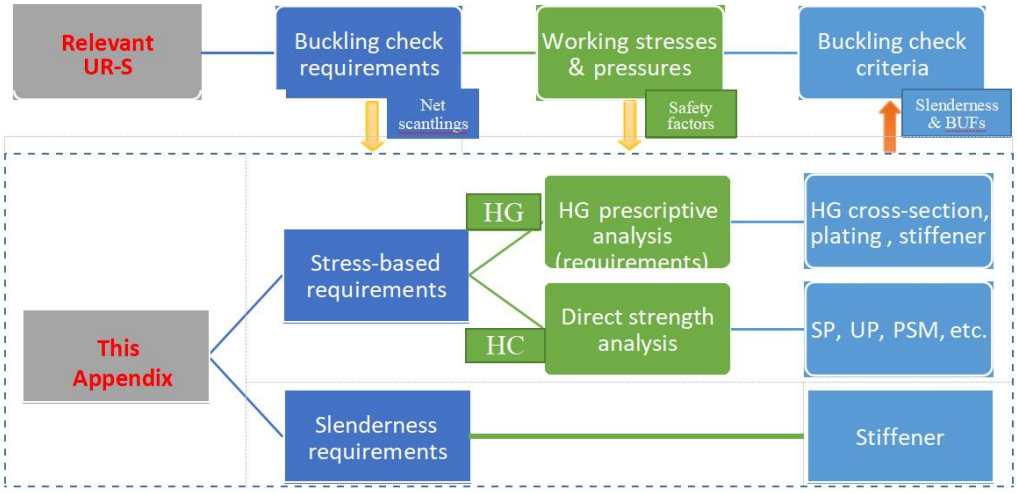


Figure 1.1.1.1 Overview of applying this UR in conjunction with Relevant UR-S

1.1.2 Application of this Appendix

1.1.2.1 Sections of this Appendix and application description

The buckling checks are to be performed according to:

(1) Section 1 for general definitions regarding buckling capacity, allowable buckling utilisation factors and buckling check criteria.

(2) Section 2 for the slenderness requirements of longitudinal and transverse stiffeners.

(3) Section 3 for the prescriptive buckling requirements of plates, longitudinal and transverse stiffeners, primary supporting members and other structures subject to hull girder stresses.

(4) Section 4 for direct strength analysis (usually by finite element method) buckling requirements of hatch cover structural members including plates, stiffeners and primary supporting members.

(5) Section 5 for the determination of buckling capacities of plate panels, stiffeners, primary supporting members and column structures.

1.1.2.2 Buckling assessment with this Appendix

For the buckling assessment of a ship hull girder, a hatch cover or other structural components, the slenderness requirements as defined in Section 2 and the buckling requirements as defined in Section 3 or Section 4 are to be checked as per the requirements of the applicable Relevant UR-S.

1.1.2.3 Alternative methods

This Appendix contains the general methods for the determination of buckling capacities of plate panels, stiffeners, primary supporting members, and columns. For special cases not covered in this Appendix, such as a whole plate structure with stiffeners in two directions (i.e., a stiffened panel with both primary and secondary stiffeners), other more advanced methods, such as finite element analysis methods, can be used with the consent of CCS.

1.2 Terminology and Assumptions

1.2.1 Buckling

1.2.1.1 Buckling strength

Buckling strength or capacity refers to the strength of a structure under in-plane compressions and/or shear and lateral load. Buckling strength with consideration of the buckling behaviour in [1.2.1.2] gives a lower bound estimate of ultimate capacity, or the maximum load a structural member can carry without suffering major permanent set.

For each structural member, its buckling strength is to be taken as corresponding to the most unfavourable or critical buckling mode.

1.2.1.2 Buckling behaviour

Buckling strength assessment takes into account both elastic buckling and post-buckling behaviours. Post-buckling can consider the internal redistribution of loads depending on the load situation, slenderness and type of structure. Such as for the buckling assessment of plates, generally its positive elastic post-buckling effect can be utilized.

As such, for slender structures, the calculated buckling strength is typically higher than the ideal elastic buckling stress (minimum eigenvalue). Accepting elastic buckling of slender plate panels implies that large elastic deflections and reduced in-plane stiffness may occur at higher buckling utilisation levels.

1.2.2 Net Scantling Approach

1.2.2.1 General requirements

Unless otherwise specified, all the scantling requirements, including slenderness requirements, in this Appendix are based on net scantlings obtained by removing full corrosion addition t_c from the gross offered thicknesses.

1.2.2.2 Corrosion addition

Corrosion addition t_c referred to in this Appendix is defined in the Relevant UR-S.

1.2.2.3 Stress calculation models

The structural models used for the calculation of stresses to be applied for buckling assessment, which are usually based on net scantlings, are defined in the Relevant UR-S.

1.2.3 Structural Idealisation

1.2.3.1 Elementary plate panel (EPP)

An elementary plate panel (EPP) is the unstiffened part of the plating between stiffeners and/or primary supporting members. The plate panel length, *a*, and breadth, *b*, of the EPP are defined respectively as the longest and shortest plate edges, as shown in Figure 1.2.3.1.

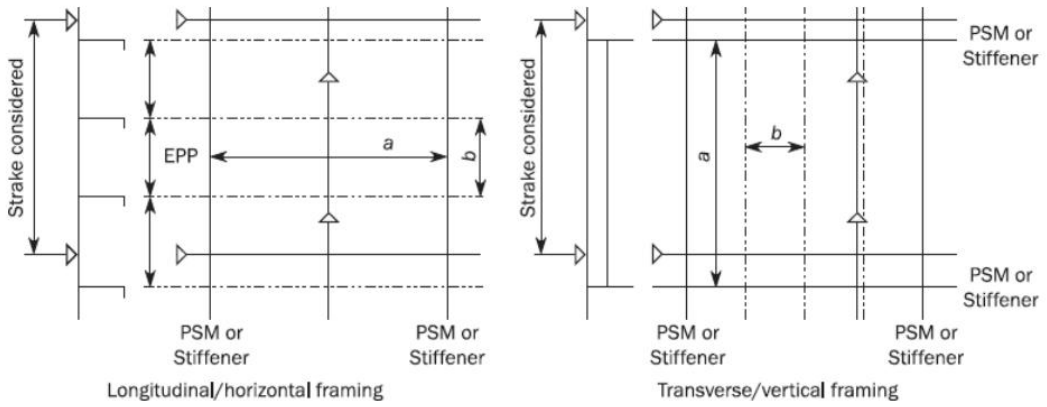


Figure 1.2.3.1 Elementary plate panel (EPP) definition

1.2.3.2 Standard types of stiffeners

Definitions of the cross-sectional dimensions of typical stiffener types are shown in Figure 1.2.3.2(1), which are flat bars, bulb flats, angles, L2 and T bars. If applicable, other types of stiffeners can be idealized to one of the typical types in Figure 1.2.3.2(1) for buckling check. For the U-type stiffener which is usually fitted in some hatch covers, the definition of its cross-sectional dimensions is shown in Figure 1.2.3.2(2).

Unless otherwise specified, the full span or full length *l*, in mm, of a stiffener is to be used for buckling check, which equals to the spacing between primary supporting members.

Symbolic dimensions of the cross-sections are as below:

b_1 —— Width of the attached plate enclosed by the U-type stiffener, in mm, as shown in Figure 1.2.3.2(2);

b_2 —— Width of the attached plate between adjacent U-type stiffeners, in mm, as shown in Figure 1.2.3.2(2);

b_f —— Width of the flange or face plate of the stiffener, in mm, as shown in Figure 1.2.3.2(1) and Figure 1.2.3.2(2);

$b_{f\text{-}out}$ —— Maximum distance, in mm, from mid thickness of the web to the flange edge, in mm, as shown in Figure 1.2.3.2(1);

d_f —— Breadth of the extended part of the flange for L2profiles, in mm, as shown in Figure 1.2.3.2(1);

e_f —— Distance from attached plating to centre of flange, in mm, as shown in Figure 1.2.3.2(1). For its detailed definition, refer to Section 5, Symbols;

h_w —— Depth of stiffener web, in mm, as shown in Figure 1.2.3.2(1) and Figure 1.2.3.2(2);

t_f —— Net flange thickness, in mm;

t_p —— Net thickness of plate, in mm;

t_w —— Net web thickness, in mm.

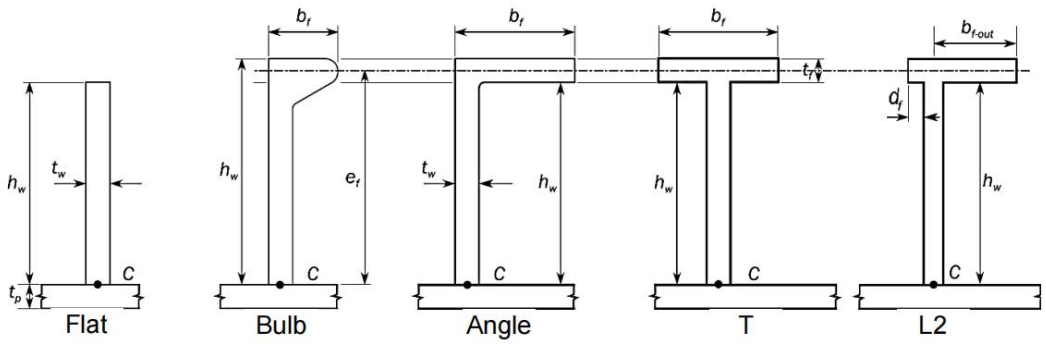


Figure 1.2.3.2(1) Dimensions of typical stiffener cross sections

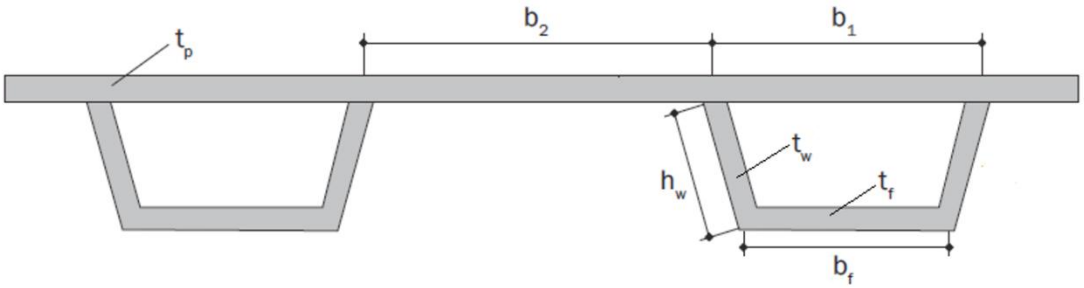


Figure 1.2.3.2(2) Dimensions of a U-type stiffener cross section

1.2.3.3 Stiffened panel (SP) and unstiffened panel (UP)

For a panel with relatively strong interactive effect between the stiffener and its attached plate, each stiffener with its attached plate as a whole is to be modelled as a stiffened panel (SP), so as to be able to consider both of its local and global buckling modes.

However, for an EPP, if its buckling strength can be checked without considering its interactive effect with stiffeners fitted along its edges, it is to be modelled as an unstiffened panel (UP).

1.2.4 Sign Convention

1.2.4.1 Stresses

In this Appendix, compressive and shear stresses are to be taken as positive, tension stresses are to be taken as negative.

1.3 Assessment Methods and Acceptance Criteria

1.3.1 Assessment Methods

1.3.1.1 Method A and Method B

The buckling assessment is to be carried out according to one of the following two methods taking into account different boundary condition types:

(1) Method A: All the edges of the EPP are forced to remain straight (but free to move in the in-plane directions) due to the surrounding structure/neighbouring plates.

(2) Method B: The edges of the EPP are not forced to remain straight due to low in-plane stiffness at the edges and/or no surrounding structure/neighbouring plates.

1.3.1.2 SP-A, SP-B, UP-A and UP-B models

For the buckling assessment of the stiffened panel (SP) and unstiffened panel (UP) structural

models defined in [1.2.3.3], with application of either Method A or Method B for the plate buckling assessment, the following four buckling assessment models are established:

(1) SP-A: a stiffened panel with application of Method A.

(2) SP-B: a stiffened panel with application of Method B.

(3) UP-A: an unstiffened panel with application of Method A.

(4) UP-B: an unstiffened panel with application of Method B.

1.3.2 Buckling Utilisation Factor

1.3.2.1 The utilisation factor, η, is defined as the ratio between the applied loads and the corresponding buckling capacity.

1.3.2.2 For combined loads, the utilisation factor, η_{act}, is to be defined as the ratio of the applied equivalent stress and the corresponding buckling capacity, as shown in Figure 1.3.2.2, and is to be taken as:

$$\eta_{act} = \frac{W_{act}}{W_U} = \frac{1}{\gamma_c}$$

where:

W_{act} —— Equivalent applied stress. The actual applied stresses are given in Section 3 and Section 4 respectively for buckling assessment by prescriptive and direct strength analysis;

W_U —— Equivalent buckling capacity. For plates and stiffeners, their respective buckling or ultimate capacities are given in Section 5;

γ_c —— Stress multiplier factor at failure.

For each typical failure mode, the corresponding buckling capacity of the panel is calculated by applying the actual stress combination and then increasing or decreasing the stresses proportionally until collapse occurs, i.e., when the increased or decreased stresses are on a buckling strength interaction curve or surface.

Figure 1.3.2.2 illustrates the buckling capacity and the buckling utilisation factor of a structural member subject to σ_x and σ_y stresses.

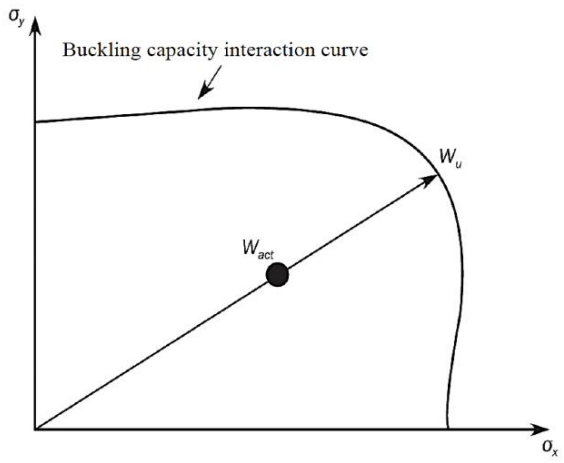


Figure 1.3.2.2 Illustration of buckling capacity and buckling utilisation factor

1.3.3 Allowable Buckling Utilisation Factor

1.3.3.1 The allowable buckling utilisation factor η_{all} is to be taken according to the Relevant UR-S.

1.3.4 Buckling Acceptance Criteria

1.3.4.1 A structural member is considered to have an acceptable buckling strength if it satisfies the following criterion:

$$\eta_{act} \leq \eta_{all}$$

where:

η_{act} —— Buckling utilisation factor based on the applied stress, defined in [1.3.2.2];

η_{all} —— Allowable buckling utilisation factor, as defined in [1.3.3.1].

SECTION 2 SLENDERNESS REQUIREMENTS

Symbols

For symbols not defined in this section, refer to Section 1, [1.2.3.2].

R_{eH} —— Specified minimum yield stress of the structural member being considered, in N/mm^2.

2.1 General Requirements

2.1.1 Introduction

2.1.1.1 The stiffener elements except for U-type stiffeners are to comply with the applicable slenderness and proportion requirements given in this Section.

2.2 Stiffeners

2.2.1 Proportions of Stiffeners

2.2.1.1 Net thickness of all stiffener types

The net thickness of stiffeners is to satisfy the following criteria:

(1) Stiffener web plate:

$$t_w \geq \frac{h_w}{C_w}\sqrt{\frac{R_{eH}}{235}}$$

(2) Flange:

$$t_f \geq \frac{b_{f-out}}{C_f}\sqrt{\frac{R_{eH}}{235}}$$

where:

C_w, C_f —— Slenderness coefficients given in Table 2.2.1.1.

Slenderness coefficient Table 2.2.1.1

Type of Stiffener	C_w	C_f
Anble and L2 bars	75	12
T-bars	75	12
Bulb flats	45	-
Flat bars	22	-

If requirement b) is not fulfilled, the effective free flange outstand, in mm, used in strength assessment including the calculation of actual net section modulus, is to be taken as:

$$b_{f-out-max} = C_f t_f \sqrt{\frac{235}{R_{eH}}}$$

For built-up profile where the relevant yielding strength for the web of built-up profile without the edge stiffener is acceptable, as an alternative the web can be assessed according to the web requirements of Angle and L2 bars in Table 2.2.1.1, and the edge stiffener can be assessed as a flat bar stiffener according to [2.2.1.1]. The requirement to flange in [2.2.1.2] shall still apply.

2.2.1.2 Net dimensions of angle and T-bars

The total flange breadth, b_f, in mm, for angle and T-bars is to satisfy the following criterion:

$$b_f \geq 0.2h_w$$

2.3 Primary Supporting Members

2.3.1 Proportions and Stiffness

2.3.1.1 Proportions of web plate and flange

The scantlings of webs and flanges of primary supporting members are to comply with the relevant requirements of [4.1], Section 2, Chapter 8, PART NINE of the Rules.

SECTION 3 BUCKLING REQUIREMENTS FOR HULL GIRDER PRESCRIPTIVE ANALYSIS

Symbols

η_{all} : Allowable buckling utilisation factor, as defined in Section 1, [1.3.3.1].

LCP：Load calculation point, as defined in [3.1.2.1].

3.1 General Requirements

3.1.1 Introduction

3.1.1.1 This Section applies to plate panels including plane and curved plate panels, stiffeners and corrugation of longitudinal corrugated bulkheads subject to hull girder compression and shear stresses.

3.1.1.2 The ship longitudinal extent where the buckling check is performed for structural elements subject to hull girder stresses is to be in accordance with the Relevant UR-S.

3.1.1.3 Design load sets: The buckling check is to be performed for all design load sets corresponding to the design loading conditions defined in the Relevant UR-S with the most unfavourable pressure combinations.

For each design load set, for all static and dynamic load cases, the lateral pressure is to be

determined at the load calculation point defined in [3.1.2.1], and is to be applied together with the hull girder stress combinations defined in the Relevant UR-S.

3.1.2 Definitions

3.1.2.1 Load calculation point

The load calculation points (LCP) for both elementary plate panels (EPP) and stiffeners are defined as follows:

(1) LCP for hull girder stresses of EPP

The hull girder stresses for EPP are to be calculated at the load calculation points defined in Table 3.1.2.1.

Load calculation points (LCP) coordinates for plate buckling assessment Table 3.1.2.1

LCP coordinates	**Hull girder bending stress**		**Hull girder shear stress**
	Non horizontal plating	**Horizontal plating**	
x coordinate	Mid-length of the EPP		
y coordinate	Both upper and lower ends of the EPP (points A1 and A2 in Figure 3.1.2.1(1))	Outboard and inboard ends of the EPP (points A1 and A2 in Figure 3.1.2.1(1))	Mid-point of EPP (point B in Figure 3.1.2.1(1))
z coordinate	Corresponding to *x* and *y* values		

(2) LCP for hull girder stresses of longitudinal stiffeners

The hull girder stresses for longitudinal stiffeners are to be calculated at the following load calculation point:

- at the mid length of the considered stiffener;
- at the intersection point between the stiffener and its attached plate.

(3) LCP for pressure of horizontal stiffeners

The load calculation point for the pressure is located at:

- middle of the full length, *l*, of the considered stiffener;
- the intersection point between the stiffener and its attached plate.

(4) LCP for pressure of non-horizontal stiffeners

The lateral pressure, *P* is to be calculated as the maximum between the value obtained at middle of the full length, *l*, and the value obtained from the following formulae:

$P = \frac{p_U + p_L}{2}$, when the upper end of the vertical stiffener is below the lowest zero pressure level;

$P = \frac{l_1}{l}\frac{p_L}{2}$, when the upper end of the vertical stiffener is at or above the lowest zero pressure level.

where: l_1 —— Distance, in m, between the lower end of vertical stiffener and the lowest zero pressure level;

p_U, p_L ——Lateral pressure at the upper and lower end of the vertical stiffener span, *l*, respectively.

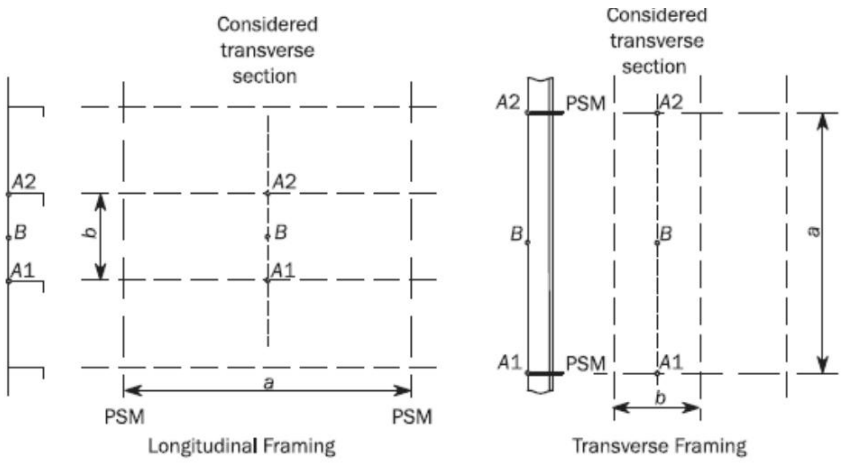


Figure 3.1.2.1(1) LCP for plate buckling assessment (PSM means the primary supporting members)

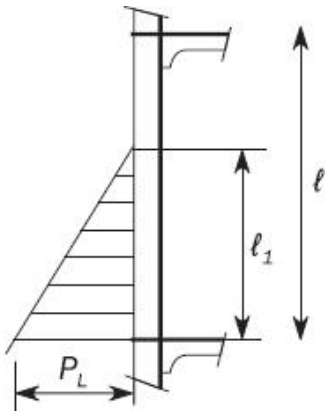


Figure 3.1.2.1(2) Definition of pressure for vertical stiffeners

3.1.3 Equivalent plate panels

3.1.3.1 Longitudinal stiffening with varying plate thickness

In longitudinal stiffening arrangement, when the plate thickness varies over the width b, of a plate panel (EPP), the buckling check is to be performed for an equivalent plate panel width,combined with the smaller plate thickness, t_1. The width of this equivalent plate panel, b_{eq}, in mm, is defined by the following formula:

$$b_{eq} = l_1 + l_2 (\frac{t_1}{t_2})^{1.5}$$

where: l_1——Width of the part of the plate panel with the smaller plate thickness, t_1, in mm, as defined in Figure 3.1.3.1;

l_2—— Width of the part of the plate panel with the greater plate thickness, t_2, in mm, as defined in Figure 3.1.3.1.

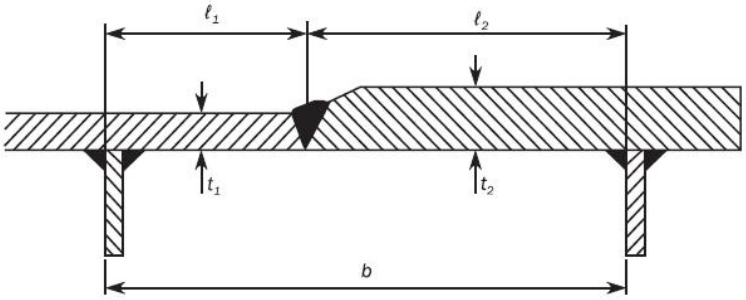


Figure 3.1.3.1 Plate thickness change over the width

3.1.3.2 Transverse stiffening with varying plate thickness

In transverse stiffening arrangement, when an EPP is made with different thicknesses, the buckling check of the plate and stiffeners is to be made for each thickness considered constant on the EPP, the stresses and pressures being estimated for the EPP at the LCP.

3.1.3.3 Plate panel with different materials

When the plate panel is made of different materials, the minimum yield strength is to be used for the buckling assessment.

3.2 Buckling Criteria

3.2.1 Overall Stiffened Panel

3.2.1.1 The buckling strength of overall stiffened panels is to satisfy the following criterion:

$$\eta_{overall} \leq \eta_{all}$$

where: $\eta_{overall}$ ——Maximum overall buckling utilisation factor as defined in Section 5, [5.2.1].

3.2.2 Plates

3.2.2.1 The buckling strength of elementary plate panels is to satisfy the following criterion:

$$\eta_{plate} \leq \eta_{all}$$

where: η_{plate} ——Maximum plate buckling utilisation factor as defined in Section 5, [5.2.2] where SP-A model is to be used.

For the determination of η_{plate} of the vertically stiffened side shell plating of single side skin bulk carrier between hopper and topside tanks, the cases 12 and 16 of Section 5, Table 3 corresponding to the shorter edge of the plate panel clamped are to be considered together with a mean σ_y stress and $\varphi_y = 1$.

3.2.3 Stiffeners

3.2.3.1 The buckling strength of stiffeners or of side frames of single side skin bulk carriers is to satisfy the following criterion:

$$\eta_{stiffener} \leq \eta_{all}$$

where: $\eta_{stiffener}$ ——Maximum stiffener buckling utilisation factor as defined in Section 5, [5.2.3].

Note 1: This buckling check can only be fulfilled when the overall stiffened panel buckling check, as defined in [3.2.1], is satisfied.

Note 2: The buckling check of the stiffeners is only applicable to the stiffeners fitted along the long edge of the buckling panel.

3.2.4 Vertically Corrugated Longitudinal Bulkheads

3.2.4.1 The shear buckling strength of vertically corrugated longitudinal bulkheads is to satisfy the following criterion:

$$\eta_{shear} \leq \eta_{all}$$

where: η_{shear} —— Maximum shear buckling utilisation factor, defined as

$$\eta_{shear} = \frac{\tau_{bhd}}{\tau_c} ;$$

τ_{bhd} ——Shear stress, in N/mm^2, in the bulkhead taken as the hull girder shear stress defined in the Relevant UR-S;

τ_c —— Shear critical stress, in N/mm^2, as defined in Section 5, [2.2.3].

3.2.5 Horizontally Corrugated Longitudinal Bulkheads

3.2.5.1 Each corrugation unit within the extension of half flange, web and half flange (i.e. single corrugation as shown in grey in Figure 3.2.5.1) is to satisfy the following criterion:

$$\eta_{column} \leq \eta_{all}$$

where: η_{column} —— Overall column buckling utilisation factor, as defined in Section 5, [5.3.1].

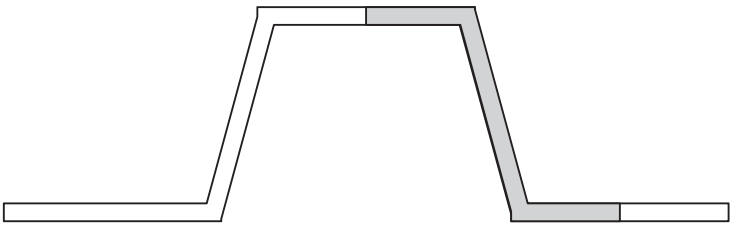


Figure 3.2.5.1 Single corrugation

SECTION 4 BUCKLING REQUIREMENTS FOR DIRECT STRENGTH ANALYSIS OF HATCH COVERS

Symbols

R_{eH_P}——Yield stress of the plate panel, as defined in [4.2.1.3];

R_{eH_S}——Yield stress of the stiffener, as defined in [4.2.1.3];

α—— Aspect ratio of the plate panel as defined in the Symbol list of Section 5;

η_{all} ——Allowable buckling utilisation factor, as defined in Section 1, [1.3.3.1].

4.1 General Requirements

4.1.1 Introduction

4.1.1.1 The requirements of this Section apply to the buckling assessment of hatch cover structural members based on direct strength analysis (usually by finite element method) and subjected to normal stress, shear stress and lateral pressure.

4.1.1.2 All structural elements in the direct strength analysis carried out according to the Relevant UR-S are to be assessed individually. The buckling checks are to be performed for the following structural elements:

- Stiffened and unstiffened panels.
- Web plate in way of openings.

4.2 Stiffened and Unstiffened Panels

4.2.1 General Requirements

4.2.1.1 The plate panel of a hatch cover structure is to be modelled as stiffened panel or unstiffened panel, with either Method A or Method B as defined in Section 1, [1.3.1.1] to be used for the calculation of the plate buckling capacity, which in combination is also equivalent to use the buckling assessment models defined in Section 1, [1.3.1.2].

4.2.1.2 Average thickness of plate panel

For FE analysis, where the plate thickness along a plate panel is not constant, the panel used for the buckling assessment is to be modelled with a weighted average thickness taken as:

$$t_{avr} = \frac{\sum_1^n A_i t_i}{\sum_1^n A_i}$$

where: A_i——Area of the i-th plate element;

t_i ——Net thickness of the i-th plate element;

n ——Number of finite elements defining the buckling plate panel.

4.2.1.3 Yield stress of the plate panel and stiffener

The panel yield stress R_{eH_P} is taken as the minimum value of the specified yield stresses of the elements within the plate panel.

The stiffener yield stress R_{eH_S} is taken as the minimum value of the specified yield stress of the elements within the stiffener.

4.2.2 Stiffened Panels

4.2.2.1 For a stiffened panel (SP), each stiffener with attached plate is to be idealized as a stiffened panel model of the extent defined in the Relevant UR-S.

4.2.2.2 If the stiffener properties or stiffener spacing varies within the stiffened panel, the calculations are to be performed separately for all configurations of the panels, i.e. for each stiffener and plate between the stiffeners. Plate thickness, stiffener properties and stiffener spacing at the considered location are to be assumed for the whole panel.

4.2.2.3 The buckling check of the stiffeners of stiffened panels is only applicable to the stiffeners fitted along the longer side edges of the buckling panel.

4.2.3 Unstiffened Panels

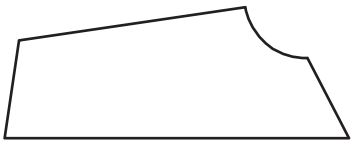
4.2.3.1 Irregular plate panel

In way of web frames, horizontal girders and brackets, the geometry of the panel (i.e. plate bounded by web stiffeners/face plate) may not have a rectangular shape. In this case, an equivalent rectangular panel is to be defined according to [4.2.3.2] for irregular geometry and [4.2.3.3] for triangular geometry and to comply with buckling assessment.

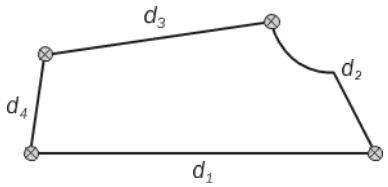
4.2.3.2 Equivalent EPP of an unstiffened panel with irregular geometry

Unstiffened panels with irregular geometry are to be idealised to equivalent panels for plate buckling assessment according to the following procedure:

(1) The four corners closest to a right angle, 90 deg, in the bounding polygon for the plate are identified.



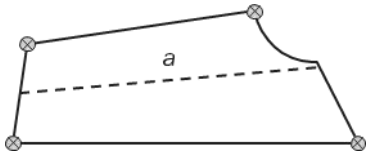
(2) The distances along the plate bounding polygon between the corners are calculated, i.e. the sum of all the straight-line segments between the end points.



(3) The pair of opposite edges with the smallest total length is identified, i.e. minimum of $d_1 + d_3$ and $d_2 + d_4$.

(4) A line joins the middle points of the chosen opposite edges (i.e. a mid-point is defined as the point at half the distance from one end). This line defines the longitudinal direction for the capacity model. The length of the line defines the length of the capacity model, a,

measured from one end point.



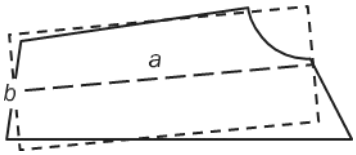
(5) The length of shorter side, b, in mm, is to be taken as:

$$b = \frac{A}{a}$$

where:

A —— Area of the plate in mm^2;

a —— Length defined in (4), in mm.

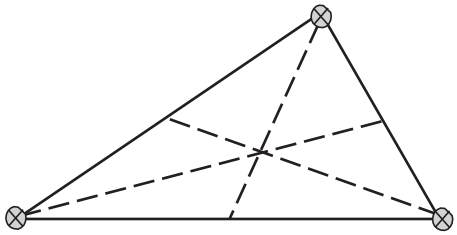


(6) The stresses from the direct strength analysis are to be transformed into the local coordinate system of the equivalent rectangular panel. These stresses are to be used for the buckling assessment.

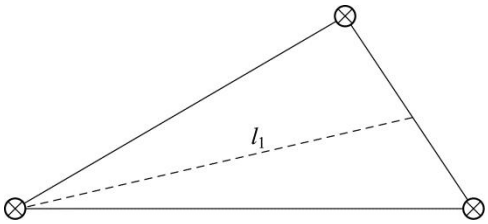
4.2.3.3 Modeling of an unstiffened plate panel with triangular geometry

Unstiffened panels with triangular geometry are to be idealised to equivalent panels for plate buckling assessment according to the following procedure:

(1) Medians are constructed as shown below:



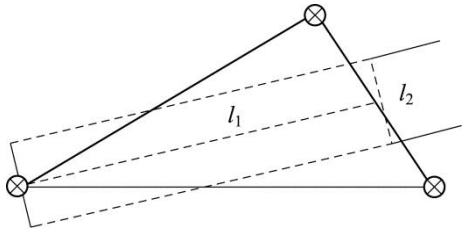
(2) The longest median is identified. This median the length of which is l_1, in mm, defines the longitudinal direction for the capacity model.



(3) The width of the model, l_2, in mm, is to be taken as:

$$l_2 = \frac{A}{l_1}$$

where: A —— Area of the plate, in mm^2.



(4) The lengths of shorter side, b, and of the longer side, a, in mm, of the equivalent rectangular plate panel are to be taken as:

$$b = \frac{l_2}{C_{tri}}$$

$$a = l_1 C_{tri}$$

where: $C_{tri} = 0.4\frac{l_2}{l_1} + 0.6$

(5) The stresses from the direct strength analysis are to be transformed into the local coordinate system of the equivalent rectangular panel and are to be used for the buckling assessment of the equivalent rectangular panel.

4.2.4 Reference Stress

4.2.4.1 The stress distribution is to be taken from the direct strength analysis according to the Relevant UR-S and applied to the buckling model.

4.2.4.2 For FE analysis, the reference stresses are to be calculated using the stress-based reference stresses as defined in Section 6.

4.2.5 Lateral Pressure

4.2.5.1 The lateral pressure applied to the direct strength analysis is also to be applied to the buckling assessment.

4.2.5.2 Where the lateral pressure is not constant over a buckling panel defined by a number of finite plate elements, an average lateral pressure, in N/mm^2, is calculated using the following formula:

$$P_{avr} = \frac{\sum_1^n A_i P_i}{\sum_1^n A_i}$$

where:

A_i—— Area of the i-th plate element, in mm^2;

P_i—— Lateral pressure of the i-th plate element, in N/mm^2;

n—— Number of the finite elements in the buckling panel.

4.2.6 Buckling Criteria

4.2.6.1 UP-A

The compressive buckling strength of UP-A is to satisfy the following criterion:

$$\eta_{UP-A} \leq \eta_{all}$$

where: η_{UP-A} —— Maximum buckling utilisation factor of plate, calculated according to Method A as defined in Section 5, [5.2.2].

4.2.6.2 UP-B

The compressive buckling strength of UP-B is to satisfy the following criterion:

$$\eta_{UP-B} \leq \eta_{all}$$

where: η_{UP-B} —— Maximum buckling utilisation factor of plate, calculated according to Method B as defined in Section 5, [5.2.2].

4.2.6.3 SP-A

The compressive buckling strength of SP-A is to satisfy the following criterion:

$$\eta_{SP-A} \leq \eta_{all}$$

where: $\eta_{SP\text{-}A}$—— Buckling utilisation factor of the stiffened panel, taken as the maximum of the buckling utilisation factors calculated as below:

- The overall stiffened panel buckling utilisaiton factor $\eta_{overall}$ as defined in Section 5, [5.2.1];
- The plate buckling utilisation factor η_{plate} calculated according to Method A as defined in Section 5 [5.2.2];
- The stiffener buckling utilisation factor $\eta_{stiffener}$ as defined in Section 5, [5.2.3] considering separately the properties (thickness, dimensions), the pressures defined in [4.2.5.2] and the reference stresses of each EPP at both sides of the stiffener.

Note 1: The stiffener buckling strength check can only be fulfilled when the overall stiffened panel capacity check, as defined in Section 5, [5.2.1], is satisfied.

4.2.6.4 SP-B

The compressive buckling strength of SP-B is to satisfy the following criterion:

$$\eta_{SP-B} \leq \eta_{all}$$

where: $\eta_{SP\text{-}B}$—— Buckling utilisation factor of the stiffened panel, taken as the maximum of the buckling utilisation factors calculated as below:

- The overall stiffened panel buckling utilisation factor $\eta_{overall}$ as defined in Section 5, [5.2.1];
- The plate buckling utilisation η_{plate} calculated according to Method B as defined in Section 5, [5.2.2];
- The stiffener buckling utilisation factor $\eta_{stiffener}$ as defined in Section 5, [5.2.3] considering separately the properties (thickness, dimensions), the pressures defined in [4.2.5.2] and the reference stresses of each EPP at both sides of the stiffener.

Note 1: The stiffener buckling strength check can only be fulfilled when the overall stiffened panel capacity check, as defined in Section 5, [5.2.1], is satisfied.

4.2.6.5 Web plate in way of openings

The web plate of primary supporting members with openings is to satisfy the following criterion:

$$\eta_{opening} \leq \eta_{all}$$

where: $\eta_{opening}$—— Maximum web plate utilisation factor in way of openings, calculated with the definition in Section 1, [1.3.2.2] and the stress multiplier factor at

failure γ_c which can be calculated following the requirements in Section 5, [5.2.4].

SECTION 5 BUCKLING CAPACITY

Symbols

A_p —— Net sectional area of the stiffener attached plating, in mm^2, taken as:

$A_p = st_p$;

A_s —— Net sectional area of the stiffener without attached plating, in mm^2;

a —— Length of the longer side of the plate panel, in mm;

b —— Length of the shorter side of the plate panel, in mm;

b_{eff} —— Effective width of the attached plating of a stiffener, in mm, as defined in [5.2.3.5];

b_{eff1} —— Effective width of the attached plating of a stiffener, in mm, without the shear lag effective taken as:

(1) For $\sigma_x > 0$,

① For prescriptive assessment:

$$b_{eff1} = \frac{C_{x1}b_1 + C_{x2}b_2}{2}$$

② For FE analysis:

$$b_{eff1} = C_x b$$

(2) For $\sigma_x \leq 0$,

$$b_{eff1} = b;$$

b_f —— Breadth of the stiffener flange, in mm;

b_1, b_2 —— Width of plate panel on each side of the considered stiffener, in mm. For stiffened panels fitted with U-type stiffeners, b_1 and b_2 are as defined in Section 1, Figure 1.2.3.2(2);

C_{x1}, C_{x2} —— Reduction factor defined in Table 5.2.2.3 calculated for the EPP1 and EPP2 on each side of the considered stiffener according to case 1;

d —— Length of the side parallel to the cylindrical axis of the cylinder corresponding to the curved plate panel as shown in Table 5.2.2.6, in mm;

e_f —— Distance from attached plating to center of flange, in mm, as shown in Section 1, Figure 1.2.3.2(1), to be taken as:

$e_f = h_w$ for flat bar profile

$e_f = h_w - 0.5t_f$ for bulb profile

$e_f = h_w + 0.5t_f$ for angle, L2 and T profiles.

F_{long} —— Coefficient defined in [5.2.2.4];

F_{tran} —— Coefficient defined in [5.2.2.5];

h_w —— Depth of stiffener web, in mm, as shown in Section 1, Figure 1.2.3.2(1);

l —— Span, in mm, of stiffener equal to spacing between primary supporting members of span of side frame equal to the distance between the hopper tank and top wing tank in way of the side shell;

R —— Radius of curved plate panel, in mm;

R_{eH_P} —— Specified minimum yield stress of the plate, in N/mm^2;

R_{eH_S} —— Specified minimum yield stress of the stiffener, N/mm^2;

S —— Partial safety factor, unless otherwise specified in the Relevant UR-S, to be taken as 1.0;

t_p —— Net thickness of plate panel, in mm;

t_w —— Net stiffener web thickness, in mm;

t_f —— Net flange thickness, in mm;

x-axis —— Local axis of a rectangular buckling panel parallel to its long edge;

y-axis —— Local axis of a rectangular buckling panel perpendicular to its long edge;

α —— Aspect ratio of the plate panel, defined in Table 5.2.2.3, to be taken as: $\alpha = \frac{a}{b}$;

β —— Coefficient taken as: $\beta = \frac{1-\psi}{\alpha}$;

ω —— Coefficient taken as: $\omega = min\,(3, \alpha)$;

σ_x —— Normal stress applied on the edge along *x*-axis of the buckling panel, in N/mm^2;

σ_y —— Normal stress applied on the edge along *y*-axis of the buckling panel, in N/mm^2;

σ_1 —— Maximum normal stress along a panel edge, in N/mm^2;

σ_2 —— Minimum normal stress along a panel edge, in N/mm^2;

σ_E —— Elastic buckling reference stress, in N/mm^2, to be taken as:

(1) For the application of the limit state of plane plate panels according to [5.2.2.1]:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{b}\right)^2$$

(2) For the application of the limit state of curved plate panels according to [5.2.2.6]:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{d}\right)^2;$$

τ —— Applied shear stress, in N/mm^2;

τ_c —— Buckling strength in shear, in N/mm^2;

ψ —— Edge stress ratio to be taken as: $\psi = \frac{\sigma_2}{\sigma_1}$;

γ —— Stress multiplier factor acting on loads. When the factor is such that the loads reach the interaction formulae, $\gamma = \gamma_c$;

γ_c —— Stress multiplier factor at failure;

γ_{GEB} —— Stress multiplier factor of global elastic buckling capacity.

5.1 General Requirements

5.1.1 Introduction

5.1.1.1 This Section contains the methods for determination of the buckling capacities of plate panels, stiffeners, primary supporting members and columns.

5.1.1.2 For the application of this Section, the stresses σ_x, σ_y and τ applied on the structural members are defined in:

(1) Section 3 for hull girder prescriptive buckling requirements.

(2) Section 4 for direct strength analysis buckling requirements of hatch covers.

5.1.1.3 Buckling capacity

The buckling capacity is calculated by applying the actual stress combination and then increasing or decreasing the stresses proportionally until the interaction formulae defined in [5.2.1.1], [5.2.2.1] and [5.2.3.4] of this Section are equal to 1.0, respectively.

5.1.1.4 Buckling utilisation factor

The buckling utilisation factor of the structural member is equal to the highest utilisation factor obtained for the different buckling modes.

5.1.1.5 Lateral pressure

The lateral pressure is to be applied and considered as constant for the calculation of buckling capacities as defined in [5.1.1.3].

5.2 Buckling Capacity of Plate Panels

5.2.1 Overall Stiffened Panels

5.2.1.1 The elastic stiffened panel limit state is based on the following interaction formula, which sets a precondition for the buckling check of stiffeners in accordance with [5.2.3.4]:

$$\frac{\gamma_c}{\gamma_{GEB}} = 1$$

with the corresponding buckling utilisation factor defined as:

$$\eta_{overall} = \frac{1}{\gamma_c}$$

where: the stress multiplier factor of global elastic buckling capacity, γ_{GEB}, are to be calculated based on the following formulae:

$\gamma_{GEB} = \gamma_{GEB,bi+\tau}$ for $\tau \neq 0$ and ($\sigma_x > 0$ or $\sigma_y > 0$) ;

$\gamma_{GEB} = \gamma_{GEB,bi}$ for $\tau = 0$ and ($\sigma_x > 0$ or $\sigma_y > 0$) ;

$\gamma_{GEB} = \gamma_{GEB,\tau}$ for $\tau \neq 0$ and ($\sigma_x \leq 0$ or $\sigma_y \leq 0$) .

where: $\gamma_{GEB,bi+\tau}$, $\gamma_{GEB,bi}$ and $\gamma_{GEB,\tau}$ are stress multiplier factors of the global elastic buckling capacity for different load combinations as defined in [5.2.1.2], [5.2.1.3] and [5.2.1.4], respectively. For the calculation of $\gamma_{GEB,bi+\tau}$, $\gamma_{GEB,bi}$ and $\gamma_{GEB,\tau}$, neither σ_x nor σ_y are to be taken less than 0.

σ_x, σ_y —— Applied normal stress to the plate panel, in N/mm^2, to be taken as defined in [5.2.2.7];

τ —— Applied shear stress, in N/mm^2, to be taken as defined in [5.2.2.7].

5.2.1.2 The stress multiplier factor $\gamma_{GEB,bi}$ for the stiffened panel subjected to biaxial loads is taken as:

$$\gamma_{GEB,bi} = \frac{\pi^2}{L_{B1}^2 L_{B2}^2} \frac{\left[D_{11}L_{B2}^4 + 2(D_{12}+D_{33})n^2 L_{B1}^2 L_{B2}^2 + n^4 D_{22} L_{B1}^4\right]}{L_{B2}^2 N_x + n^2 L_{B1}^2 N_y}$$

where:

N_x—— Load per unit length applied on the edge along *x*-axis of the stiffened panel, in N/mm, taken as

$N_x = \sigma_{x,av}(A_p + A_s)/s$

For stiffened panels fitted with U-type stiffeners, stiffener spacing *s* is taken as:

$s = b_1 + b_2$

Where b_1 and b_2 are as defined in Figure 5.3.1.4;

N_y—— Load per unit length applied on the edge along *y*-axis of the stiffened panel, in 方 N/mm, taken as:

$N_y = c\sigma_y t_p$;

L_{B1}—— Stiffener span, in mm, distance between primary supporting members, i.e.

$L_{B1} = l$;

L_{B2}—— Width of stiffened panel between stiffened panels, in mm, taken as 6 times of the stiffer spacing, i.e. $L_{B2} = 6s$;

n—— Number of half waves along the direction perpendicular to the stiffener axis. The factor $\gamma_{GEB,bi}$ is to be taken as the smallest value larger than 0.

c—— Factor taking into account the normal stress distribution in the panel boundaries acting perpendicular to the stiffener's axis:

$c = 0.5(1+\Psi)$ for $0 \leq \Psi \leq 1$;

$c = \frac{1}{2(1-\Psi)}$ for $\Psi < 0$;

Ψ—— Edge stress ratio for case 2 according to Table 5.3.1.3;

$\sigma_{x,av}$—— Average stress, in MPa, for both plate and stiffener after Poisson correction, taken as:

$\sigma_{x,av} = \sigma_x - \nu c\sigma_y A_s/(A_p + A_s) \geq 0$ for $\sigma_x > 0$ and $\sigma_y > 0$

$\sigma_{x,av} = \sigma_x$ for $\sigma_x \leq 0$ or $\sigma_y \leq 0$;

$D_{11}, D_{12}, D_{22}, D_{33}$ —— Bending stiffness coefficients, in N·mm, of the stiffened panel, defined in general as:

$$\left.\begin{aligned} D_{11} &= \frac{EI_{eff}10^4}{s} \\ D_{12} &= \frac{Et_p^3\nu}{12(1-\nu^2)} \\ D_{22} &= \frac{Et_p^3}{12(1-\nu^2)} \\ D_{33} &= \frac{Et_p^3}{12(1+\nu)} \end{aligned}\right\}$$

For stiffened panels fitted with U-type stiffeners, D_{12} and D_{22} are defined as:

$$D_{22} = \frac{Et_p^3}{12(1-\nu^2)}\left[1.2 + 4.8 \times Min\left(1.0,\ \frac{b_1^2}{h_w(b_1+b_2)}\right) \times Min\left(1.0, \left(\frac{t_w}{t_p}\right)^3\right)\right]$$

$$D_{12} = \nu D_{22}$$

h_w—— Breadth of U-type stiffener web as defined in Figure 5.3.1.4;

I_{eff}——Moment of inertia, in cm^4, of the stiffener including the effective width of the attached plating, same as I defined in [5.2.3.4].

5.2.1.3 The stress multiplier factor $\gamma_{GEB,\tau}$, for the stiffened panel subjected to pure shear load is taken as:

$$\gamma_{GEB,\tau} = \frac{\sqrt[4]{D_{11}^3 D_{22}}}{(L_{B1}/2)^2 N_{xy}}\left[8.125 + 5.64\sqrt{\frac{(D_{12}+D_{33})^2}{D_{11}D_{22}}} - 0.6\frac{(D_{12}+D_{33})^2}{D_{11}D_{22}}\right] \quad \text{for } D_{11}D_{22} \geq (D_{12}+D_{33})^2$$

$$\gamma_{GEB,\tau} = \frac{\sqrt{2D_{11}(D_{12}+D_{33})}}{(L_{B1}/2)^2 N_{xy}}\left[8.3 + 1.525\frac{D_{11}D_{22}}{(D_{12}+D_{33})^2} - 0.493\frac{D_{11}^2 D_{22}^2}{(D_{12}+D_{33})^4}\right] \quad \text{for } D_{11}D_{22} < (D_{12}+D_{33})^2$$

where: $N_{xy} = \tau t_p$

5.2.1.4 The stress multiplier factor$\gamma_{GEB,bi+\tau}$, for the stiffened panel subjected to combined loads is taken as:

$$\gamma_{GEB,bi+\tau} = \frac{1}{2}{\gamma_{GEB,\tau}}^2\left[-\frac{1}{\gamma_{GEB,bi}} + \sqrt{\frac{1}{{\gamma_{GEB,bi}}^2} + 4\frac{1}{{\gamma_{GEB,\tau}}^2}}\right]$$

where: $\gamma_{GEB,bi}$ and $\gamma_{GEB,\tau}$ are as defined in [5.2.1.2] and [5.2.1.3], respectively.

5.2.2 Plates

5.2.2.1 Plate limit state

The plate limit state is based on the following interaction formulae:

$$\left(\frac{\gamma_{c1}\sigma_x S}{\sigma_{cx}}\right)^{e_0} - B\left(\frac{\gamma_{c1}\sigma_x S}{\sigma_{cx}}\right)^{\frac{e_0}{2}}\left(\frac{\gamma_{c1}\sigma_y S}{\sigma_{cy}}\right)^{\frac{e_0}{2}} + \left(\frac{\gamma_{c1}\sigma_y S}{\sigma_{cy}}\right)^{e_0} + \left(\frac{\gamma_{c1}|\tau|S}{\tau_c}\right)^{e_0} = 1$$

$$\left(\frac{\gamma_{c2}\sigma_x S}{\sigma_{cx}}\right)^{\frac{2}{\beta_p^{0.25}}} + \left(\frac{\gamma_{c2}|\tau|S}{\tau_c}\right)^{\frac{2}{\beta_p^{0.25}}} = 1 \text{ for } \sigma_x \geq 0$$

$$\left(\frac{\gamma_{c3}\sigma_y S}{\sigma_{cy}}\right)^{\frac{2}{\beta_p^{0.25}}} + \left(\frac{\gamma_{c3}|\tau|S}{\tau_c}\right)^{\frac{2}{\beta_p^{0.25}}} = 1 \text{ for } \sigma_y \geq 0$$

$$\frac{\gamma_{c4}|\tau|S}{\tau_c} = 1$$

with:

$$\gamma_c = Min\,(\gamma_{c1}, \gamma_{c2}, \gamma_{c3}, \gamma_{c4})$$

and the corresponding buckling utilisation factor defined as:

$$\eta_{plate} = \frac{1}{\gamma_c}$$

where:

σ_x, σ_y—— Applied normal stress to the plate panel, in N/mm^2, to be taken as defined in [5.2.2.7];

τ —— Applied shear stress to the plate panel, in N/mm^2;

σ_{cx}—— Ultimate buckling stress, in N/mm^2, in direction parallel to the longer edge of the buckling panel as defined in [5.2.2.3];

σ_{cy}—— Ultimate buckling stress, in N/mm^2, in direction parallel to the shorter edge of the buckling panel as defined in [5.2.2.3];

τ_c—— Ultimate buckling shear stress, in N/mm^2, as defined in [5.2.2.3];

$\gamma_{c1}, \gamma_{c2}, \gamma_{c3}, \gamma_{c4}$ Stress multiplier factors at failure for each of the above different limit states. γ_{c2} and γ_{c3} are only to be considered when $\sigma_x \geq 0$ and $\sigma_y \geq 0$ respectively.

B—— Coefficient given in Table 5.2.2.1;

e_0—— Coefficient given in Table 5.2.2.1;

Plate slenderness parameter taken as:

β_p—— $\beta_p = \frac{b}{t_p}\sqrt{\frac{R_{eH_P}}{E}}$.

Definition of coefficients of B and e_0 Table 5.2.2.1

Applied stress	$\boldsymbol{B}$	$\boldsymbol{e_0}$
$\sigma_x \geq 0$ and $\sigma_y \geq 0$	$0.7 - 0.3\,\beta_p/\alpha^2$	$2/\beta_p^{0.25}$
$\sigma_x < 0$ or $\sigma_y < 0$	1.0	2.0

5.2.2.2 Reference degree of slenderness

The reference degree of slenderness is to be taken as:

$$\lambda = \sqrt{\frac{R_{eH_P}}{K\sigma_E}}$$

where: K——Buckling factor, as defined in Table 5.2.2.3 and Table 5.2.2.6.

5.2.2.3 Ultimate buckling stresses

The ultimate buckling stresses of plate panels, in N/mm^2, are to be taken as:

$$\sigma_{cx} = C_x R_{eH_P}$$

$$\sigma_{cy} = C_y R_{eH_P}$$

The ultimate buckling stress of plate panels subject to shear, in N/mm^2, is to be taken as:

$$\tau_c = C_\tau \frac{R_{eH_P}}{\sqrt{3}}$$

Where: C_x, C_y, C_τ ——Reduction factors, as defined in Table 5.2.2.3.

For the 1st Equation of [5.2.2.1], when $\sigma_x < 0$ or $\sigma_y < 0$, the reduction factors are to be taken as :

$$C_x = C_y = C_\tau = 1$$

For other cases:

(1) For SP-A and UP-A, C_y is calculated according to Table 5.2.2.3 by using

$$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

(2) For SP-B and UP-B, C_y is calculated according to Table 5.2.2.3 by using

$$c_1 = 1$$

(3) For vertically stiffened single side skin of bulk carrier, C_y is calculated according to Table 5.2.2.3 by using

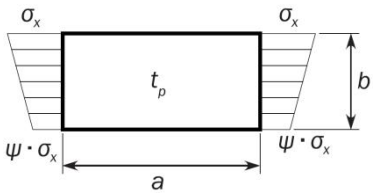
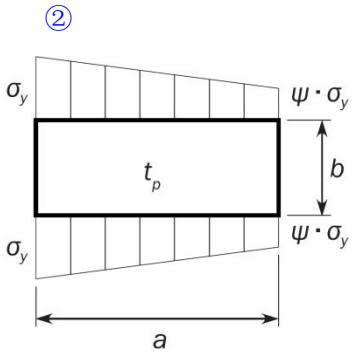
$$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

(4) For corrugation of corrugated bulkheads, Cy is calculated according to Table 5.2.2.3 by using

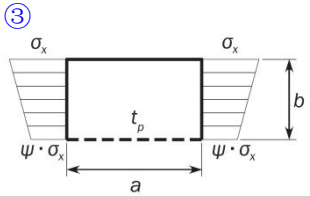
$$c_1 = \left(1 - \frac{1}{\alpha}\right) \geq 0$$

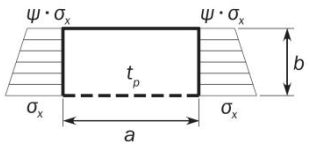
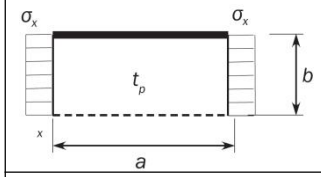
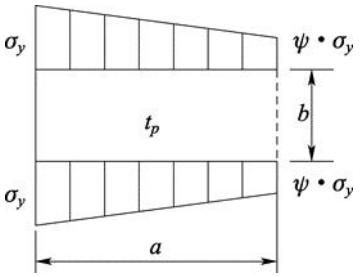
The boundary conditions for plates are to be considered as simply supported, see cases in ①, ② and ⑮ of Table 5.2.2.3. If the boundary conditions differ significantly from simple suppoet, a more appropriate boundary condition can be applied according to the different cases of Table 5.2.2.3 with the consent of CCS.

Buckling factor and reduction factor plane plate panels — Table 5.2.2.3

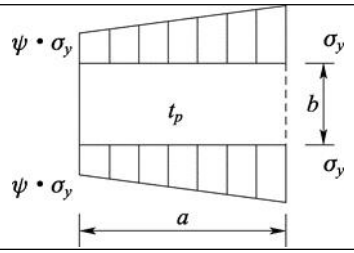
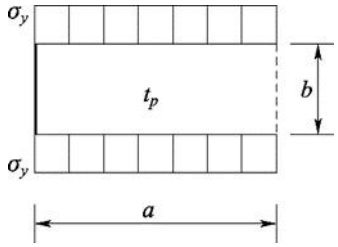
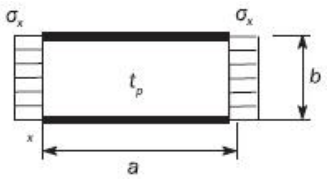
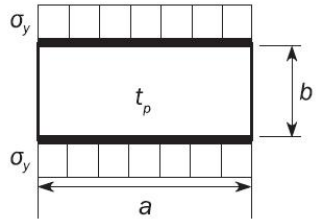
Case	Stress ratio ψ	Aspect ratio α	Buckling factor K	Reduction factor C
① 	$1\geq\psi\geq 0$	$K_x = F_{long}\dfrac{8.4}{\psi+1.1}$		When $\sigma_x \leq 0$, $C_x = 1$; When $\sigma_x > 0$, $C_x = 1$ for $\lambda \leq \lambda_c$ $C_x = c\left(\frac{1}{\lambda}-\frac{0.22}{\lambda^2}\right)$ for $\lambda > \lambda_c$ where: $c = (1.25-0.12\psi)\leq 1.25$ $\lambda_c = \dfrac{c}{2}\left(1+\sqrt{1-\dfrac{0.88}{c}}\right)$
	$0>\psi>-1$	$K_x = F_{long}[7.63-\psi(6.26-10\psi)]$		
	$\psi\leq -1$	$K_x = F_{long}\left[5.975(1-\psi)^2\right]$		
② 	$1\geq\psi\geq 0$	$K_y = F_{tran}\dfrac{2\left(1+\frac{1}{\alpha^2}\right)^2}{1+\psi+\frac{(1-\psi)}{100}\left(\frac{2.4}{\alpha^2}+6.9f_1\right)}$		When $\sigma_y \leq 0$, $C_y = 1$; When $\sigma_y > 0$: $C_y = c\left(\dfrac{1}{\lambda}-\dfrac{R+F^2(H-R)}{\lambda^2}\right)$ where: $c = (1.25-0.12\psi)\leq 1.25$ $R = \lambda\left(1-\dfrac{\lambda}{c}\right)$ for $\lambda < \lambda c$ $R = 0.22$ for $\lambda \geq \lambda c$
		$\alpha \leq 6$	$f_1 = (1-\psi)(\alpha-1)$	
		$\alpha > 6$	$f_1 = 0.6(1-\frac{6\psi}{\alpha})(\alpha+\frac{14}{\alpha})$ but not greater than $14.5-\dfrac{0.35}{\alpha^2}$	

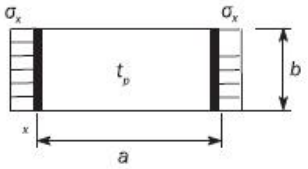
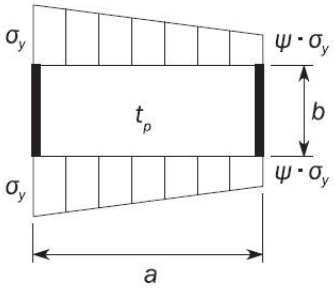
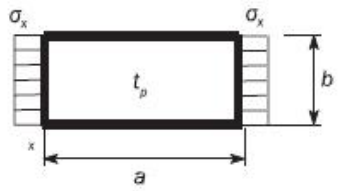
<table>
<tr>
<td></td>
<td>$1-\frac{4\alpha}{3} \le \psi < 0$</td>
<td colspan="2">$K_y = \frac{200F_{tran}\left(1+\beta^2\right)^2}{(1-f_3)(100+2.4\beta^2+6.9f_1+23f_2)}$</td>
<td rowspan="5">$\lambda_c = 0.5c(1+\sqrt{1-0.88/c})$
$F = \left(1-\left(\frac{K}{0.91}-1\right)\Big/\lambda_p^2\right)c_1 \ge 0$
$\lambda_p^2 = \lambda^2 - 0.5$ for $1 \le \lambda_p^2 \le 3$
c_1 as defined in 5.1.1.3.
$H = \lambda - \frac{2\lambda}{c(T+\sqrt{T^2-4})} \ge R$
$T = \lambda + \frac{14}{15\lambda} + \frac{1}{3}$</td>
</tr>
<tr>
<td></td>
<td>$\alpha > 6(1-\psi)$</td>
<td>$f_1 = 0.6(\frac{1}{\beta}+14\beta)$
but not greater than
$14.5-0.35\beta^2$
$f_2 = f_3 = 0$</td>
</tr>
<tr>
<td></td>
<td>$3(1-\psi) \le \alpha \le 6(1-\psi)$</td>
<td>$f_1 = \frac{1}{\beta}-1$
$f_2 = f_3 = 0$</td>
</tr>
<tr>
<td></td>
<td>$1.5(1-\psi) \le \alpha < 3(1-\psi)$</td>
<td>$f_1 = \frac{1}{\beta}-(2-\omega\beta)^4-9(\omega\beta-1)(\frac{2}{3}-\beta)$
$f_2 = f_3 = 0$</td>
</tr>
<tr>
<td></td>
<td>$1-\psi \le \alpha < 1.5(1-\psi)$</td>
<td>For $\alpha > 1.5$,
$f_1 = 2\left(\frac{1}{\beta}-16\left(1-\frac{\omega}{3}\right)^4\right)(\frac{1}{\beta}-1)$
$f_2 = 3\beta-2$; $f_3 = 0$
For $\alpha \le 1.5$,
$f_1 = 2\left(\frac{1.5}{1-\psi}-1\right)\left(\frac{1}{\beta}-1\right)$</td>
</tr>
</table>

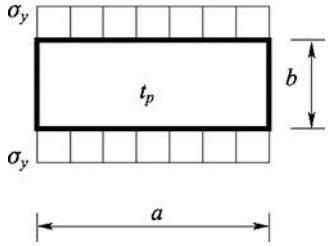
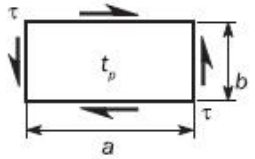
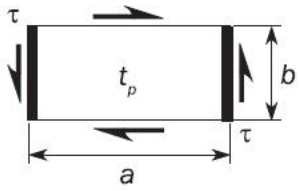
			$f_2 = \frac{\psi(1-16f_4^2)}{1-\alpha}$; $f_3 = 0$ $f_4 = [1.5 - Min(1.5;\alpha)]^2$	
		$0.75(1-\psi) \le \alpha < (1-\psi)$	$f_1 = 0$ $f_2 = 1 + 2.31(\beta-1) - 48\left(\frac{4}{3} - \beta\right) f_4^2$ $f_3 = 3f_4(\beta-1)\left(\frac{f_4}{1.81} - \frac{\alpha-1}{1.31}\right)$ $f_4 = [1.5 - \mathrm{Min}(1.5;\alpha)]^2$	
	$\psi < 1 - \frac{4\alpha}{3}$	$K_y = 5.972F_{tran}\frac{\beta^2}{1-f_3}$ where, $f_3 = f_5\left(\frac{f_5}{1.81} + \frac{1+3\psi}{5.24}\right)$ $f_5 = \frac{9}{16}[1 + Max(-1;\psi)]^2$		
③  	$1 \ge \psi \ge 0$	$K_x = \frac{4(0.425 + 1/\alpha^2)}{3\psi + 1}$		For UP-A: $C_x = 1$ for $\lambda \le 0.75$ $C_x = \frac{0.75}{\lambda}$ for $\lambda > 0.75$ For UP-B:
	$0 > \psi > -1$	$K_x = 4(0.425 + 1/\alpha^2)(1+\psi)$ $-5\psi(1-3.42\psi)$		

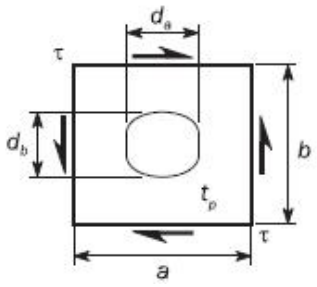
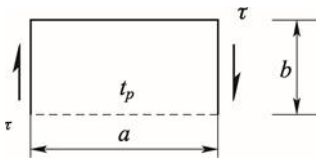
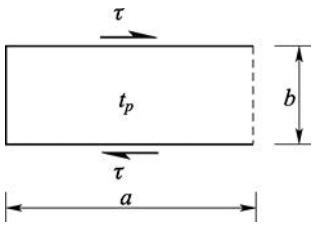
<table>
<tr>
<td>④
</td>
<td>$1 \geq \psi \geq -1$</td>
<td colspan="2">$K_x = \left(0.425 + \frac{1}{\alpha^2}\right)\frac{3-\psi}{2}$</td>
<td rowspan="3">$C_x = 1$ for $\lambda \leq 0.7$
$C_x = \frac{1}{\lambda^2+0.51}$ for $\lambda > 0.7$</td>
</tr>
<tr>
<td rowspan="2">⑤
</td>
<td rowspan="2">-</td>
<td>$\alpha \geq 1.64$</td>
<td>$K_x = 1.28$</td>
</tr>
<tr>
<td>$\alpha < 1.64$</td>
<td>$K_x = \frac{1}{\alpha^2} + 0.56 + 0.13\alpha^2$</td>
</tr>
<tr>
<td rowspan="2">⑥
</td>
<td>$1 \geq \psi \geq 0$</td>
<td colspan="2">$K_y = \frac{4(0.425+\alpha^2)}{(3\psi+1)\alpha^2}$</td>
<td rowspan="3">For UP-A:
$C_y = 1$ for $\lambda \leq 0.75$
$C_y = \frac{0.75}{\lambda}$ for $\lambda > 0.75$

For UP-B:
$C_y = 1$ for $\lambda \leq 0.7$
$C_y = \frac{1}{\lambda^2+0.51}$ for $\lambda > 0.7$</td>
</tr>
<tr>
<td>$0 > \psi \geq -1$</td>
<td colspan="2">$K_y = 4\left(0.425+\alpha^2\right)(1+\psi)\frac{1}{\alpha^2} - 5\psi(1-3.42\psi)\frac{1}{\alpha^2}$</td>
</tr>
<tr>
<td>⑦</td>
<td>$1 \geq \psi \geq -1$</td>
<td colspan="2">$K_y = \left(0.425+\alpha^2\right)\frac{3-\psi}{2\alpha^2}$</td>
</tr>
</table>

			
⑧ 	--	$K_y = 1 + \frac{0.56}{\alpha^2} + \frac{0.13}{\alpha^4}$	
⑨ 	—	$K_x = 6.97$	$C_x = 1$ for $\lambda \leq 0.83$ $C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
⑩ 	—	$K_y = 4 + \frac{2.07}{\alpha^2} + \frac{0.67}{\alpha^4}$	$C_y = 1$ for $\lambda \leq 0.83$ $C_y = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$

⑪ 	—	$\alpha \geq 4$	$K_x = 4$	$C_x = 1$ for $\lambda \leq 0.83$ $C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
		$\alpha < 4$	$K_x = 4 + 2.74\left[\frac{4-\alpha}{3}\right]^4$	
⑫ 	-	K_y = K_y determined as per case ②		For $\alpha < 2$, $C_y = C_{y2}$; For $\alpha \geq 2$, $C_y = \left(1.06 + \frac{1}{10\alpha}\right)C_{y2}$; where, C_{y2}: C_y determined as per case ②
⑬ 	—	$\alpha \geq 4$	$K_x = 6.97$	$C_x = 1$ for $\lambda \leq 0.83$ $C_x = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
		$\alpha < 4$	$K_x = 6.97 + 3.1\left[\frac{4-\alpha}{3}\right]^4$	
⑭	—	$K_y = \frac{6.97}{\alpha^2} + \frac{3.1}{\alpha^4}\left(\frac{4-1/\alpha}{3}\right)^4$		

			$C_y = 1$ for $\lambda \leq 0.83$ $C_y = 1.13\left(\frac{1}{\lambda} - \frac{0.22}{\lambda^2}\right)$ for $\lambda > 0.83$
⑮ 	—	$K_\tau = \sqrt{3}\left[5.34 + \frac{4}{\alpha^2}\right]$	$C_\tau = 1$ for $\lambda \leq 0.84$ $C_\tau = \frac{0.84}{\lambda}$ for $\lambda > 0.84$
⑯ 	—	$K_\tau = \sqrt{3}\left[5.34 + \text{Max}\left[\frac{4}{\alpha^2}; \frac{7.15}{\alpha^{2.5}}\right]\right]$	
⑰	—	$K_\tau = K_{\tau case15} r$ $K_{\tau case15}$: K_τ according to case ⑮ r = opening reduction factor taken as $r = \left(1 - \frac{d_a}{a}\right)\left(1 - \frac{d_b}{b}\right)$	

		with $\frac{d_a}{a} \le 0.7$ *and* $\frac{d_b}{b} \le 0.7$	
⑱ 	—	$K_\tau = \sqrt{3}\left(0.6 + \frac{4}{\alpha^2}\right)$	
⑲ 	—	$K_\tau = 8$	$C_\tau = 1$ for $\lambda \le 0.84$ $C_\tau = \frac{0.84}{\lambda}$ for $\lambda > 0.84$
Edge boundary conditions：- - - - - - - - - - - - Plate edge free; ———————Plate edge simply supported; ▬▬▬ Plate edge clamped.			
Note (1): Cases listed are general cases. Each stress component (σ_x, σ_y) is to be understood in local coordinates.			

5.2.2.4 Correction factor F_{long}

The correction factor F_{long} depending on the edge stiffener types on the longer side of the buckling panel is defined in Table 5.2.2.4. An average value of F_{long} is to be used for plate panels having different edge stiffeners. For stiffener types other than those mentioned in Table 5.2.2.4, the value of c is to be agreed by CCS. In such a case, value of c higher than those mentioned in Table 5.2.2.4 can be used, provided it is verified by buckling strength check of panel using non-linear FE analysis and deemed appropriate by CCS.

Correction factor F_{long} Table 5.2.2.4

<table>
<tr><th colspan="3">Structural element types</th><th>F_{long}</th><th>c</th></tr>
<tr><td colspan="3">Unstiffened Panel</td><td>1.0</td><td>N/A</td></tr>
<tr><td rowspan="6">Stiffened Panel</td><td colspan="2">Stiffener not fixed at both ends</td><td>1.0</td><td>N/A</td></tr>
<tr><td rowspan="5">Stiffener fixed at both ends</td><td>Flat bar(1)</td><td rowspan="4">$F_{long} = c + 1 \ for \ \frac{t_w}{t_p} > 1$
$F_{long} = c\left(\frac{t_w}{t_p}\right)^3 + 1 \ for \ \frac{t_w}{t_p} \le 1$</td><td>0.10</td></tr>
<tr><td>Bulb profile</td><td>0.30</td></tr>
<tr><td>Angle profile</td><td>0.40</td></tr>
<tr><td>T profile</td><td>0.30</td></tr>
<tr><td>Girder of high rigidity (e.g. bottom transverse)</td><td>1.4</td><td>N/A</td></tr>
<tr><td>U-type profile fitted on hatch cover(2)</td><td>(1) Plate on which the U-type profile is fitted, including EPP b_1 and EPP b_2:
● For $b_2 < b_1$: F_{long}=1;
● For $b_2 \ge b_1$:
$F_{long} = \left(1.55 - 0.55\frac{b_1}{b_2}\right)\left[1 + c\left(\frac{t_w}{t_p}\right)^3\right]$
(2)Other plates of the U-type profile:
F_{long}=1</td><td>0.2</td></tr>
<tr><td colspan="5">Notes:
(1) t_w is the net web thickness, in mm, without the correction defined in [5.4.3.5] of this Section.
(2) b_1, b_2 and t_w are defined in Section 1, Figure 1.2.3.2(2).</td></tr>
</table>

5.2.2.5 Correction factor F_{tran}

The correction factor F_{tran} is to be taken as:

(1) For transversely frame EPP of single side skin bulk carrier, between the hopper and top wing tank:

① $F_{tran} = 1.25$ when the two adjacent frames are supported by one tripping bracket fitted in way of the adjacent plate panels;

② $F_{tran} = 1.33$ when the two adjacent frames are supported by two tripping brackets each fitted in way of the adjacent plate panels.

③ $F_{tran} = 1.15$ elsewhere.

(2) For the attached plate of a U-type stiffener fitted on a hatch cover:

$$F_{tran} = \text{Max}\left(3 - 0.08(F_{tran0} - 6)^2, 1.0\right) \le 2.25$$

where:

$$F_{tran0} = \text{Min}\left(\frac{b_2}{b_1} + \frac{6b_2^2}{\pi^2 h_w (b_1 + b_2)}\left(\frac{t_w}{t_p}\right)^3, 6\right) \qquad \text{for EPP } b_2;$$

$$F_{tran0} = \text{Min}\left(\frac{b_1}{b_2} + \frac{6b_1^2}{\pi^2 h_w (b_2 + b_1)}\left(\frac{t_w}{t_p}\right)^3, 6\right) \qquad \text{for EPP } b_1.$$

with b_1, b_2 and h_w as defined in Figure 1.2.3.2(2) of this Section.

Coefficient F defined in Case 2 of Table 5.2.2.3 is to be replaced by the following formula:

$$F = \left[1 - \left(\frac{K_y}{0.91F_{tran}} - 1\right) / \lambda_p^2\right] c_1 \ge 0$$

(3) For other cases, the correction factor F_{tran} is to be taken as 1.0.

5.2.2.6 Curved plate panels

This requirement for curved plate limit state is applicable when $R/t_p \le 2500$. Otherwise, the requirement for plate limit state given in [5.2.2.1] of this Section is applicable.

The curved plate limit state is based on the following interaction formula:

$$\left(\frac{\gamma_c \sigma_{ax} S}{C_{ax} R_{eH_P}}\right)^{1.25} - 0.5 \cdot \left(\frac{\gamma_c \sigma_{ax} S}{C_{ax} R_{eH_P}}\right)\left(\frac{\gamma_c \sigma_{tg} S}{C_{tg} R_{eH_P}}\right) + \left(\frac{\gamma_c \sigma_{tg} S}{C_{tg} R_{eH_P}}\right)^{1.25} + \left(\frac{\gamma_c \tau \sqrt{3} S}{C_\tau R_{eH_P}}\right)^2 = 1.0$$

With the corresponding buckling utilisation factor defined as:

$$\eta_{curved_plate} = \frac{1}{\gamma_c}$$

where:

σ_{ax}—— Applied axial stress to the cylinder corresponding to the curved plate panel, in N/mm^2. In case of tensile axial stresses, $\sigma_{ax} = 0$;

σ_{tg}—— Applied tangential stress to the cylinder corresponding to the curved plate panel, in N/mm^2. In case of tensile tangential stresses, $\sigma_{tg} = 0$;

C_{ax}, C_{tg}, C_τ —— Buckling reduction factor of the curved plate panel, as defined in Table 5.2.2.6.

The stress multiplier factor, γ_c, of the curved plate panel need not be taken less than the stress multiplier factor, γ_c, for the expanded plane panel according to [5.3.1.1] of this Section.

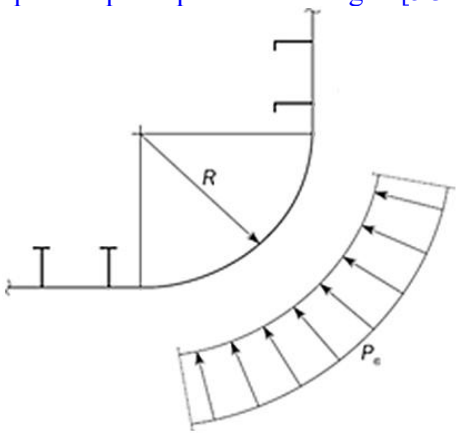
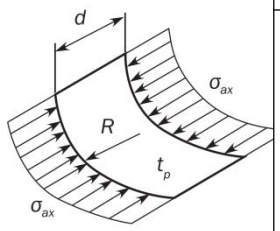
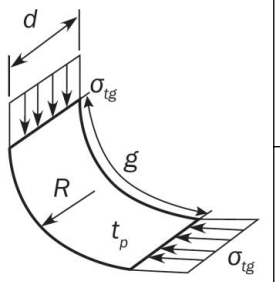
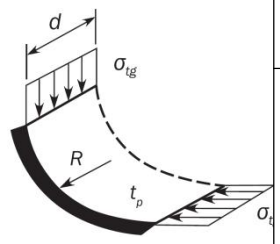
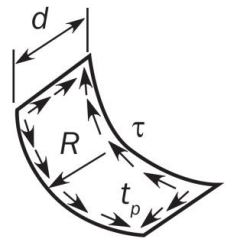


Figure 5.2.2.6 Transverse stiffened bilge plating

Buckling factor and reduction factor for curved plate panel with $R/t_p \le 2500$

Table 5.2.2.6

Case	Aspect ratio	Buckling factor K	Reduction factor C
1 	$\frac{d}{R} \le 0.5\sqrt{\frac{R}{t_p}}$	$K = 1 + \frac{2}{3}\frac{d^2}{Rt_p}$	For general application $C_{ax} = 1$ for $\lambda \le 0.25$ $C_{ax} = 1.233 - 0.933\lambda$ for $0.25 < \lambda \le 1$ $C_{ax} = 0.3/\lambda^2$ for $1 < \lambda \le 1.5$ $C_{ax} = 0.2/\lambda^2$ for $\lambda > 1.5$ For curved single fields, e.g. bilge strake, which are bounded by plane panels as shown in Figure 5.3.1.6: $C_{ax} = \frac{0.65}{\lambda^2} \le 1.0$
	$\frac{d}{R} > 0.5\sqrt{\frac{R}{t_p}}$	$K = 0.267\frac{d^2}{Rt_p}\left[3 - \frac{d}{R}\sqrt{\frac{t_p}{R}}\right]$ $\ge 0.4\frac{d^2}{Rt_p}$	
2 	$\frac{d}{R} \le 1.63\sqrt{\frac{R}{t_p}}$	$K = \frac{d}{\sqrt{Rt_p}} + 3\frac{(Rt_p)^{0.175}}{d^{0.35}}$	For general application: $C_{tg} = 1$ for $\lambda \le 0.4$ $C_{tg} = 1.274 - 0.686\lambda$ for $0.4 < \lambda \le 1.2$ $C_{tg} = \frac{0.65}{\lambda^2}$ for $\lambda > 1.2$ For curved single fields, e.g. bilge strake, which are bounded by plane panels as shown in Figure 5.3.1.6: $C_{tg} = \frac{0.8}{\lambda^2} \le 1.0$
	$\frac{d}{R} > 1.63\sqrt{\frac{R}{t_p}}$	$K = 0.3\frac{d^2}{R^2} + 2.25\left(\frac{R^2}{dt_p}\right)^2$	
3 	$\frac{d}{R} \le \sqrt{\frac{R}{t_p}}$	$K = \frac{0.6d}{\sqrt{Rt_p}} + \frac{\sqrt{Rt_p}}{d} - 0.3\frac{Rt_p}{d^2}$	As in load case 2
	$\frac{d}{R} > \sqrt{\frac{R}{t_p}}$	$K = 0.3\frac{d^2}{R^2} + 0.291\left(\frac{R^2}{dt_p}\right)^2$	
4 	$\frac{d}{R} \le 8.7\sqrt{\frac{R}{t_p}}$	$K = \sqrt{3}\sqrt{28.3 + \frac{0.67d^3}{R^{1.5}t_p^{1.5}}}$	$C_\tau = 1$ for $\lambda \le 0.4$; $C_\tau = 1.274 - 0.686\lambda$, for $0.4 < \lambda \le 1.2$; $C_\tau = \frac{0.65}{\lambda^2}$ for $\lambda > 1.2$
	$\frac{d}{R} > 8.7\sqrt{\frac{R}{t_p}}$	$K = \sqrt{3}\frac{0.28d^2}{R\sqrt{Rt_p}}$	
Explanations for boundary conditions - - - - - - - - - - - - Plate edge free; ———— Plate edge simply supported; ▬▬▬ Plate edge clamped.			

5.2.2.7 Applied normal and shear stresses to plate panels

The normal stress, σ_x and σ_y, in N/mm^2, to be applied for the overall stiffened panel capacity and the plate panel capacity calculations as given in [5.2.1.1] and [5.2.2.1] respectively, are to be taken as follows:

(1) For FE analysis, the reference stresses as defined in Section 4, [4.2.4];

(2) For prescriptive assessment of the overall stiffened panel capacity and the plate panel capacity, the axial or transverse compressive stresses calculated according to the Relevant UR-S, at load calculation points of the considered stiffener or the considered elementary plate panel, as defined in (1) and (2) of Section 3, [3.1.2.1] respectively. However, in case of transverse stiffening arrangement, the transverse compressive stress used for the assessment of the overall stiffened

panel capacity is to be taken as the compressive stress calculated at load calculation points of the stiffener attached plating, as defined in (1) of Section 3, [3.1.2.1].

(3) For grillage analysis where the stresses are obtained based on beam theory, the stresses taken as:

$$\sigma_x = \frac{\sigma_{xb} + \nu\sigma_{yb}}{1 - \nu^2}$$

$$\sigma_y = \frac{\sigma_{yb} + \nu\sigma_{xb}}{1 - \nu^2}$$

where:

σ_{xb}, σ_{yb} —— Stress, in N/mm^2, from grillage beam analysis respectively along x and y axis of the plate attached to the PSN web.

The shear stress, τ, in N/mm^2, to be applied for the overall stiffened panel capacity and the plate panel capacity calculations as given in [5.2.1.1] and [5.2.2.1] respectively, are to be taken as follows:

① For FE analysis, the reference shear stresses as defined in Section 4, [4.2.4];

② For prescriptive assessment of the plate panel buckling capacity, the shear stresses calculated according to the Relevant UR-S, at load calculation points of the considered elementary plate panel, as defined in (1) of Section 3, [3.1.2.1];

③ For prescriptive assessment of the overall elastic stiffened panel buckling capacity, the shear stresses calculated according to the Relevant UR-S, at the following load calculation point:

(a) At the middle of the full span, l, of the considered stiffener;

(b) At the intersection point between the stiffener and its attached plating.

(4) For grillage beam analysis, $\tau = 0$ in the plate attached to the PSM web.

5.2.3 Stiffeners

5.2.3.1 Buckling modes

The following buckling modes are to be checked:

(1) Stiffener induced failure (*SI*);

(2) Associated plate induced failure (*PI*).

5.2.3.2 Web thickness of flat bar

For accounting the decrease of the stiffness due to local lateral deformation, the effective web thickness of flat bat stiffener, in mm, is to be used in [5.2.1] and [5.2.3.4] for the calculation of the net sectional area, A_s, the net section modulus, Z, and the moment of inertia, I, of the stiffener and is taken as:

$$t_{w_red} = t_w \left(1 - \frac{2\pi^2}{3}\left(\frac{h_w}{s}\right)^2 \left(1 - \frac{b_{eff1}}{s}\right)\right)$$

5.2.3.3 Idealisation of bulb profile

Bulb profiles are to be considered as equivalent angle profiles. The net dimensions of the equivalent built-up section are to be obtained from the following formulae:

$$h_w = h_w^{'} - \frac{h_w^{'}}{9.2} + 2$$

$$b_f = \alpha\left(t_w^{'} + \frac{h_w^{'}}{6.7} - 2\right)$$

$$t_f = \frac{h_w^{'}}{9.2} - 2$$

$$t_w = t_w^{'}$$

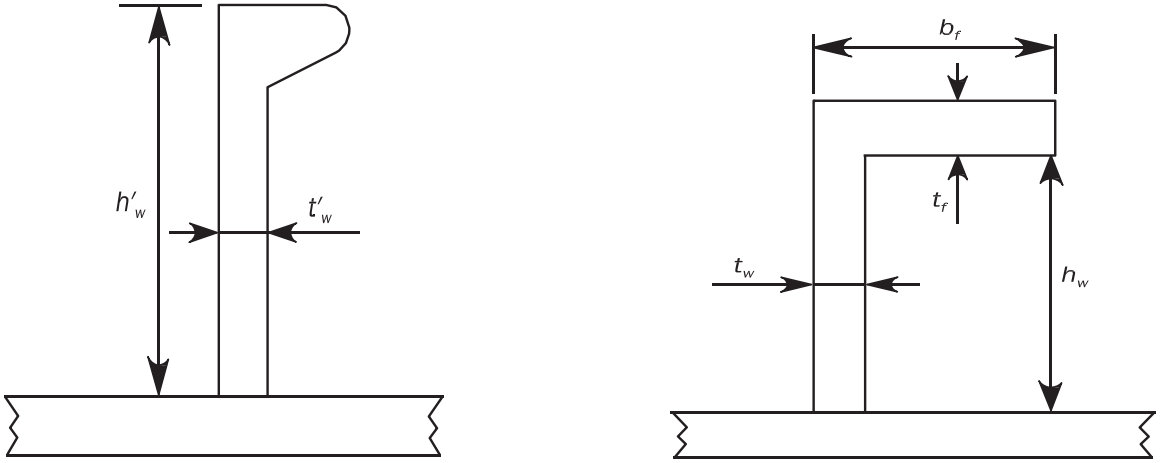
where: $h_w^{'}, t_w^{'}$——Net height and thickness of a bulb section, in mm, as shown in

Figure 5.2.3.3;

α ——Coefficient equal to:

$$\alpha = 1.1 + \frac{(120 - h_w')^2}{3000} \quad \text{for } h_w' \le 120$$

$$\alpha = 1.0 \quad \text{for } h_w' > 120.$$



Bulb flat **Equivalent angle bar**

Figure 5.2.3.3 Idealisation of bulb stiffener

5.2.3.4 Ultimate buckling capacity

When $\sigma_a + \sigma_b + \sigma_w > 0$ while initially setting γ = 1, the ultimate buckling capacity for stiffeners is to be checked according to the following interaction formula:

$$\frac{\gamma_c \sigma_a + \sigma_b + \sigma_w}{R_{eH}} S = 1$$

with the corresponding buckling utilisation factor defined as:

$$\eta_{stiffener} = \frac{1}{\gamma_c}$$

where:

σ_a —— Effective axial stress, in N/mm^2, at mid span of the stiffener, acting on the stiffener with its attached plating

$$\sigma_a = \sigma_x \frac{st_p + A_s}{b_{eff1} t_p + A_s} \quad .$$

σ_x —— Nominal axial stress, in N/mm^2, acting on the stiffener with its attached plating:

(1) For FE analysis, σ_x is the FE corrected stress as defined in [5.2.3.6] in the attached plating in the direction of the stiffener axis;

(2) For prescriptive assessment, σ_x is the axial stress, in N/mm^2, calculated according to Section 3, [3.2.2.1] at load calculation point of the stiffener, as defined in Section 3, [3.1.2.1];

(3) For grillage beam analysis, σ_x is the stress acting along the *x*-axis of the attached buckling panel.

R_{eH} —— Specified minimum yield stress of the material, in N/mm^2:

(1) $R_{eH} = R_{eH_S}$ for stiffener induced failure *(SI)*;

(2) $R_{eH} = R_{eH_P}$ for plate induced failure *(PI)*.

σ_b —— Bending stress in the stiffeners, in N/mm^2:

$\sigma_b = \frac{M_0 + M_1 + M_2}{1000Z}$.

Z —— Net section modulus of stiffener, including effective width of attached plating according to [5.2.3.5], to be taken as:

(1) The section modulus calculated at the top of stiffener flange for stiffener

induced failure *(SI)*;

(2) The section modulus calculated at the bottom of attached plating for plate induced failure *(PI)*.

M_2 —— Bending moment, in N·mm, due to eccentricity of sniped stiffeners, to be taken as:

(1) $M_2 = 0$ for continuous stiffeners;

(2) $M_2 = C_{snip} w_{na} \gamma \sigma_x (A_p + A_s)$ for stiffeners sniped at one or both ends.

C_{snip} —— Coefficient to account for the end effect of the stiffener sniped at one or both ends, to be taken as:

(1) $C_{snip} = -1.2$ for stiffener induced failure *(SI)*;

(2) $C_{snip} = 1.2$ for plate induced failure (*PI*).

σ_w —— Stress due to torsion, in N/mm^2, as defined in [5.4.4.4].

M_1 —— Bending moment, in N·mm, due to the lateral load, *P,* taken as follows:

(1) $M_1 = C_i \frac{|P| s l^2}{24 \times 10^3}$ for continuous stiffener;

(2) $M_1 = C_i \frac{|P| s l^2}{8 \times 10^3}$ for sniped stiffener at both ends;

(3) $M_1 = C_i \frac{|P| s l^2}{14.2 \times 10^3}$ for stiffener sniped at one end and continuous at the other end.

P —— Lateral load, in kN/m^2:

(1) For FE analysis， P is the average pressure as defined in Section 4, [4.2.5.2] in the attached plating;

(2) For prescriptive assessment, P is the static pressure calculated at load calculation point of the stiffener, as defined in Section 3, [3.1.2.1].

C_i —— Pressure coefficient:

(1) $C_i = C_{SI}$ for stiffener induced failure (*SI);*

(2) $C_i = C_{PI}$ for plate induced failure (*PI).*

C_{PI} —— Plate induced failure pressure coefficient:

(1) $C_{PI} = 1$ if the lateral pressure is applied on the side opposite to the stiffener;

(2) $C_{PI} = -1$ if the lateral pressure is applied on the same side as the stiffener.

C_{SI} —— Stiffener induced failure pressure coefficient:

(1) $C_{SI} = -1$ if the lateral pressure is applied on the side opposite to the stiffener;

(2) $C_{SI} = 1$ if the lateral pressure is applied on the same side as the stiffener.

M_0 —— Bending moment, in Nmm, due to the lateral deformation w of stiffener:

$$M_0 = F_E C_{sl} \frac{\gamma}{\gamma_{GEB} - \gamma} w_0 \text{ with precondition } \gamma_{GEB} - \gamma > 0.$$

γ_{GEB} —— Stress multiplier factor of global elastic buckling capacity as defined in [5.2.1].

F_E —— Ideal elastic buckling force of the stiffener, in N:

$$F_E = \left(\frac{\pi}{l}\right)^2 EI \times 10^4.$$

I —— Moment of inertia, in cm^4, of the stiffener including effective width of attached plating. I is to comply with the following requirement:

$$I \geq \frac{s t_p^3}{12 \times 10^4}.$$

t_p —— Net thickness of plate, in mm, to be taken as:

(1) For prescriptive requirements: the mean thickness of the two attached plating panels;

(2) For FE analysis, the thickness of the considered EPP on one side of the stiffener.

C_{sl} —— Deformation reduction factor to account for global slenderness, to be taken as:

(1) $C_{sl} = 1 - \frac{1}{12}\lambda_G^4$ for $\lambda_G \leq 1.56$;

(2) $C_{sl} = 3/\lambda_G^4$ for $\lambda_G > 1.56$.

λ_G —— The reference degree of global slenderness of the stiffened panel, to be taken as:

$$\lambda_G = \sqrt{\frac{\gamma_{ReH}}{\gamma_{GEB}}}$$

where: $\gamma_{ReH} = \frac{\text{Min}\,(R_{eH_P},\ R_{eH_S})}{\sqrt{\sigma_{x,av}^2+\sigma_y^2-\sigma_{x,av}\sigma_y+3\tau^2}}$.

$\sigma_{x,av}$ —— Average stress for both plate and stiffener as defined in [5.2.1.2].

σ_y —— Applied transverse stress to the plate panel as defined in [5.2.1.1].

τ —— Applied shear stress to the plate panel as defined in [5.2.1.1].

w_0 —— Assumed imperfection, in mm, to be taken as:

$$w_0 = l/1000;$$

σ_w —— Stress due to torsional deformation, in N/mm^2, to be taken as:

(1) For stiffener induce failure (*SI*)

① For $\sigma_a > 0$:

$$\sigma_w = Ey_w e_f \Phi_0 \left(\frac{m_{tor}\pi}{l_{tor}}\right)^2 \left(\frac{1}{1-\frac{\gamma\sigma_a}{\sigma_{ET}}} - 1\right) \text{ with precondition } \sigma_{ET} - \gamma\sigma_a > 0$$

② For $\sigma_a \le 0$:

$$\sigma_w = 0$$

(2) For plate induced failure (*PI*)

$$\sigma_w = 0$$

y_w —— Distance, in mm, from centroid of stiffener cross section to the free edge of stiffener flange, to be taken as:

(1) $y_w = \frac{t_w}{2}$ for flat bar;

(2) $y_w = b_f - \frac{h_w t_w^2 + t_f b_f^2}{2A_s}$ for angle and bulb profiles;

(3) $y_w = b_{f-out} + 0.5t_w - \frac{h_w t_w^2 + t_f(b_f^2 - 2b_f d_f)}{2A_s}$ for L2 profile;

(4) $y_w = \frac{b_f}{2}$ for T profile.

Φ_0 —— Coefficient taken as:

$$\Phi_0 = \frac{l_{tor}}{m_{tor}h_w} \times 10^{-4}.$$

σ_{ET} —— Reference stress for torsional buckling, in N/mm^2, to be taken as:

$$\sigma_{ET} = \frac{E}{I_p}\left[\left(\frac{m_{tor}\pi}{l_{tor}}\right)^2 I_\omega \times 10^2 + \frac{1}{2(1+\nu)} I_T + \left(\frac{l_{tor}}{m_{tor}\pi}\right)^2 \varepsilon \times 10^{-4}\right] .$$

I_p —— Net polar moment of inertia of the stiffener defined in Table 5.4.4.4, in cm^4, about point *C* as shown in Section 1 Figure 1.2.3.2, as defined in Table 5.2.3.4.

I_T —— Net St. Venant's moment of inertia of the stiffener, in cm^4, as defined in Table 5.2.3.4.

I_ω —— Net sectional moment of inertia of the stiffener, in cm^6, about point *C* as shown in Section 1, Figure 1.2.3.2(1), as shown in Table 5.2.3.4.

l_{tor} —— Stiffener span, in mm, distance equal to spacing between primary supporting members, i.e. $l_{tor} = l$. When the stiffener is supported by tripping brackets, l_{tor} is to be taken as the maximum spacing between the adjacent primary supporting members and fitted tripping brackets.

m_{tor} —— Number of half waves, taken as a positive integer so as to give smallest reference stress for torsional buckling.

ε —— Degree of fixation, to be taken as:

$\varepsilon = \left(\frac{3b}{t_p^3} + \frac{2h_w}{t_w^3}\right)^{-1}$ for bulb, angle, L2 and T profiles;

$\varepsilon = \left(\frac{t_p^3}{3b}\right)$ for flat bars.

A_w —— Net web area, in mm^2;

A_f —— Net flange area, in mm^2.

Moment of inertia **Table 5.2.3.4**

Cross section characteristics	Flat bars	Bulb, angle, L2 and T profiles
I_p	$\frac{h_w^3 t_w}{3\times 10^4}$	$\left(\frac{A_w(e_f-0.5t_f)^2}{3}+A_f e_f^2\right)\times 10^{-4}$
I_T	$\frac{h_w t_w^3}{3\times 10^4}\left(1-0.63\frac{t_w}{h_w}\right)$	$\frac{(e_f-0.5t_f)t_w^3}{3\times 10^4}\left(1-0.63\frac{t_w}{e_f-0.5t_f}\right)+\frac{b_f t_f^3}{3\times 10^4}\left(1-0.63\frac{t_f}{b_f}\right)$
I_ω	$\frac{h_w^3 t_w^3}{36\times 10^6}$	For bulb, angle and L2 profiles: $\frac{A_f^3+A_w^3}{36\times 10^6}+\frac{e_f^2}{10^6}\left(\frac{A_f b_f^2+A_w t_w^2}{3}-\frac{(A_f b_f+A_w t_w)^2}{4(A_f+A_w)}\right)$ For T profile: $\frac{b_f^3 t_f e_f^3}{12\times 10^6}$

Notes:
(1) t_w is the net web thickness, in mm. t_{w_red} as defined in [5.2.3.2] is not to be used in this Table;
(2) d_f is to be taken as 0 for bulb and angle profiles.

5.2.3.5 Effective width of attached plating

The effective width of attached plating of stiffeners, b_{eff} in mm, is to be taken as:

(1) For $\sigma_x > 0$:

① For FE analysis,

$$b_{eff} = Min\,(C_x b, \chi_s s)$$

② For prescriptive assessment,

$$b_{eff} = Min\left(\frac{C_{x1}b_1 + C_{x2}b_2}{2}, \chi_s s\right)$$

(2) For $\sigma_x \le 0$:

$$b_{eff} = \chi_s s$$

where: χ_s —— Effective width coefficient to be taken as:

① $\chi_s = \frac{1.12}{1+\frac{1.75}{\left(\frac{\ell_{eff}}{s}\right)^{1.6}}} \le 1.0$ for $\frac{\ell_{eff}}{s} \ge 1$

② $\chi_s = 0.407\frac{\ell_{eff}}{s}$ for $\frac{\ell_{eff}}{s} < 1.$

ℓ_{eff}—— Effective length of the stiffener, in mm, taken as:

(1) $\ell_{eff} = \frac{l}{\sqrt{3}}$ for stiffener fixed at both ends;

(2) $\ell_{eff} = 0.75l$ for stiffener simply supported at one end and fixed a the other.

(3) $\ell_{eff} = l$ for stiffener simply supported at both ends.

5.2.3.6 FE corrected stresses for stiffener capacity

When the reference stresses σ_x and σ_y obtained by FE analysis according to Section 4, [4.2.4] are both compressive, σ_x is to be corrected according to the following formulae:

(1) If $\sigma_x < \nu\sigma_y$

$$\sigma_{xcor} = 0$$

(2) If $\sigma_x \ge \nu\sigma_y$

$$\sigma_{xcor} = \sigma_x - \nu\sigma_y$$

5.2.4 Primary Supporting Members

5.2.4.1 Web plate in way of openings

The web plate of primary supporting members with openings is to be assessed for buckling based on the combined axial compressive and shear stresses.

The web plate adjacent to the opening on both sides is to be considered as individual unstiffened plate panels as shown in Table 5.2.4.1.

The interaction formulae of [5.2.2.1] are to be used with:

$$\sigma_x = \sigma_{av}$$

$$\sigma_y = 0$$

$$\tau = \tau_{av}$$

where: σ_{av} —— Weighted average compressive stress, in N/mm^2, in the area of web plate being considered, i.e. *P1, P2* and *P3* as shown in Table 5.2.4.1.

For the application of Table 5.2.4.1, the weighted average shear stress is to be taken as:

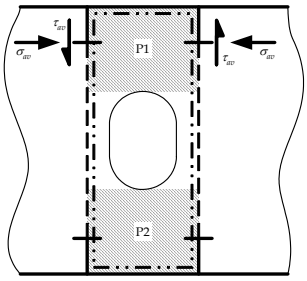
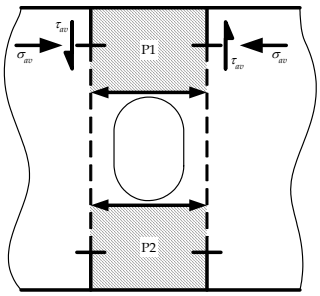
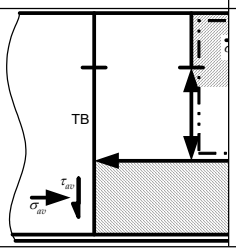
(1) Opening modelled in primary supporting members:

τ_{av} —— Weighted average compressive stress, in N/mm^2, in the area of web plate being considered, i.e. *P1, P2* and *P3* as shown in Table 5.2.4.1.

(2) Opening not modelled in primary supporting members:

τ_{av} —— Weighted average shear stress, in N/mm^2, given in Table 5.2.4.1.

Buckling reduction factors of web plate in way of openings Table 5.2.4.1

Configuration (1)		C_x, C_y	C_τ	
			Opening modelled in PSM	**Opening not modelled in PSM**
(a) Without edge reinforcements (2)		Separate reduction factors are to be applied to areas *P1* and *P2* using case ③ or case ⑥ in Table 5.2.2.3, with edge stress ratio: ψ=1.0	Separate reduction factors are to be applied to areas *P1* and *P2* using case ⑱ or case ⑲ in Table 5.2.2.3.	When case ⑰ of Table 5.2.2.3 is applicable: A common reduction factor is to be applied to areas *P1* and *P2* using case ⑰ with: $\tau_{av} = \tau_{av}(web)$; When case ⑰ of Table 5.2.2.3 is not applicable: Separate reduction factors are to be applied to areas *P1* and *P2* using case ⑱ or case ⑲ with: $\tau_{av} = \tau_{av}(web)h/(h-h_0)$
(b) With edge reinforcement		Separate reduction factors are to be applied for areas *P1* and *P2* using C_x for case ① or C_y for case ② in Table 5.2.2.3 with stress ratio: ψ=1.0.	Separate reduction factors are to be applied for areas *P1* and *P2* using case ⑮ in Table 5.2.2.3.	Separate reduction factors are to be applied to areas *P1* and *P2* using case ⑮ in Table 5.2.2.3 with: $\tau_{av} = \tau_{av}(web)h/(h-h_0)$
(c) Example of hole in web		Panels *P1* and *P2* are to be evaluated in accordance with (a). Panel *P3* is to be evaluated in accordance with (b).		
where:				

Configuration (1)	C_x, C_y	C_τ	
		Opening modelled in PSM	Opening not modelled in PSM
h —— Height, in m, of the web of the primary supporting member in way of the opening; h_0 —— Height, in m, of the opening measured in the depth of the web; τ_{av} (web) —— Weighted average shear stress, in N/mm^2, over the web height of the primary supporting member. Note (1) Web panels to be considered for buckling in way of openings are shown shaded and numbered *P1*, *P2*, etc. Note (2) For a PSM web panel with opening and without edge reinforcements as shown in configuration (a), the applicable buckling assessment method depends on its specific boundary conditions. If one of the long edges along the face plate or along the attached plating is not subject to "inline support", i.e. the edge is free to pull in, Method B should be applied. In other cases, typically such as when the short plate edge is attached to the plate flanges, Method A is applicable.			

5.2.4.2 Reduction factors of web plate in way of openings

The reduction factors, C_x or C_y in combnaiton with C_τ of the plate panel(s) of the web adjacent to the opening is to be taken as shown in Table 5.2.4.1.

5.2.4.3 The equivalent plate panel of web plate of primary supporting members crossed by perpendicular stiffeners is to be idealised as shown in Figure 5.2.4.3.

The correction of panel breadth is applicable also for other slot configurations provided that the web or collar plate is attached to at least one side of the passing stiffener.

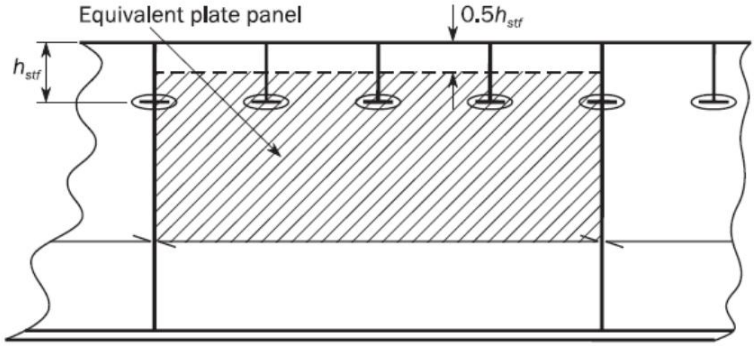


Figure 5.2.4.3 PMS web plate idealisation

5.2.5 Stiffened Panels with U-type Stiffeners

5.2.5.1 Local plate buckling

For stiffened panels with U-type stiffeners, local plate buckling is to be checked for each of the plate panels EPP b_1, b_2, b_f and h_w (see Section 1, Figure 1.2.3.2(2)) separately as follows:

(1) The attached plate panels EPP b_1, b_2 are to be assessed using SP-A model, where in the calculation of buckling factors K_x as defined in Case ① of Table 5.2.2.3, the correction factor F_{long} for U-type stiffeners as defined in Table 5.2.2.4 is to be used; and in the calculation of K_y as defined in Case ② of Table, the F_{tran} for U-type stiffeners as defined in [5.2.2.5] is to be used.

(2) The face plate and web plate panels EPP b_f and h_w are to be assessed using UP-B model with $F_{long} = 1$ and $F_{tran} = 1$.

5.2.5.2 Overall stiffened panel buckling and stiffener buckling

For a stiffened panel with U-type stiffeners, the overall buckling capacity and ultimate capacity of the stiffeners are to be checked with warping stress σ_w = 0, and with bending moment of inertia including effective width of attached plating being calculated based on the following assumptions:

(1) The two web panels of a U-type stiffener are to be taken as perpendicular to the attached plate with thickness equal to t_w and height equal to the distance between the attached plate and the face plate of the stiffener.

(2) Effective width of the attached plating b_{eff}, taken as the sum of the b_{eff} calculated for EPP, b_1 and b_2 respectively according to SP-A model.

(3) Effective width of the attached plating of a stiffener without shear lag effect, b_{eff1}, taken as

the sum of the b_{eff1} calculated for the EPP, b_1 and b_2 respectively.

5.3 Buckling capacity of column structures

5.3.1 Column Buckling of Corrugations

5.3.1.1 Buckling utilisation factor

The column buckling utilisation factor, η, for axially compressed corrugations is to be taken as:

$$\eta_{column} = \frac{\sigma_{av}}{\sigma_{cr}}$$

where: σ_{av} —— Average axial compressive stress in the member, in N/mm^2;

σ_{cr} —— Minimum critical buckling stress, in N/mm^2, taken as:

① $\sigma_{cr} = \sigma_E$ for $\sigma_E \leq 0.5R_{eH_S}$

② $\sigma_{cr} = \left(1 - \frac{R_{eH_S}}{4\sigma_E}\right) R_{eH_S}$ for $\sigma_E > 0.5R_{eH_S}$;

σ_E —— Elastic column compressive buckling stress, in N/mm^2, according to [5.3.1.2];

R_{eH_S} —— Specified minimum yield stress of the considered member, in N/mm^2. For built-up members, the lowest specified minimum yield stress is to be used.

5.3.1.2 Elastic column buckling stress

The elastic compressive column buckling stress, σ_E, in N/mm^2 of members subject to axial compression is to be taken as:

$$\sigma_E = \pi^2 E f_{end} \frac{I}{A l_{pill}^2} \times 10^{-4}$$

where: I —— Net moment of inertia about the weakest axis of the cross section, in cm^4;

A —— Net cross-sectional area of the member, in cm^2;

l_{pill} —— Unsupported length of the member, in m;

f_{end} —— End constraint factor, corresponding to simply supported ends is to be applied except for fixed end support to be used in way of stool with width exceeding 2 times the depth of the corrugation, taken as:

- $f_{end} = 1.0$ where both ends are simply supported;
- $f_{end} = 2.0$ where one end is simply supported and the other end is fixed;
- $f_{end} = 4.0$ where both ends are fixed.

SECTION 6 STRESS BASED REFERENCE STRESSES

Symbols

a —— Length, in mm, of the longer side of the plate panel as defined in Section 5;

b —— Length, in mm, of the shorter side of the plate panel as defined in Section 5;

A_i —— Area, in mm2, of the i-th plate element of the buckling panel;

n —— Number of plate elements in the buckling panel;

σ_{xi} —— Actual stress, in N/mm^2, at the centroid of the *i*-th plate element in *x* direction, applied along the shorter edge of the buckling panel;

σ_{yi} —— Actual stress, in N/mm^2, at the centroid of the *i*-th plate element in *y* direction, applied along the longer edge of the buckling panel;

ψ —— Edge stress ratio as defined in Section 5;

τ_i —— Actual membrane shear stress, in N/mm^2, at the centroid of the *i*-th plate element of the buckling panel.

6.1 Stress Based Method

6.1.1 Introduction

6.1.1.1 This Section provides a method to determine stress distribution along edges of the considered buckling panel by second-order polynomial curve, by linear distribution using least square method and by weighted average approach. The reference stress is the stress components at centre of plate element transferred into the local system of the considered buckling panel.

6.1.1.2 Definition

A regular panel is a plate panel of rectangular shape. An irregular panel is plate panel which is not regular, as detailed in Section 4, [4.2.3.1].

6.1.2 Stress Application

6.1.2.1 Regular panel

The reference stresses are to be taken as defined in [6.2.1] for a regular panel when the following conditions are satisfied:

- At least, one plate element centre is located in each third part of the long edge *a* of a regular panel; and
- This element center is located at a distance in the panel local *x* direction not less than *a*/4 to at least one of the element centers in the adjacent third part of the panel.

Otherwise, the reference stresses are to be taken as defined in [6.2.2] for an irregular panel.

6.1.2.2 Irregular panel and curved panel

The reference stresses of an irregular panel or of a curved panel are to be taken as defined in [6.2.2].

6.2 Reference Stresses

6.2.1 Regular Panel

6.2.1.1 Longitudinal stress

The longitudinal stress σ_x applied on the shorter edge of the buckling panel is to be calculated as follows:

For plate buckling assessment, the distribution of $\sigma_x(x)$ is assumed as second order polynomial curve as:

$$\sigma_x = Cx^2 + Dx + E$$

The best fitting curve $\sigma_x(x)$ is to be obtained by minimising the square error Π considering the area of each element as a weighting factor:

$$\Pi = \sum_{i=1}^{n} A_i\left[\sigma_{xi} - (Cx_i^2 + Dx_i + E)\right]^2$$

The unknown coefficients *C*, *D* and *E* is yield zero first derivatives, $\partial\Pi$ with respect to *C*, *D* and *E*, respectively.

$$\begin{cases} \dfrac{\partial \Pi}{\partial C} = 2\displaystyle\sum_{i=1}^{n} A_i x_i^2\left[\sigma_{xi} - \left(Cx_i^2 + Dx_i + E\right)\right] = 0 \\ \dfrac{\partial \Pi}{\partial D} = 2\displaystyle\sum_{i=1}^{n} A_i x_i\left[\sigma_{xi} - \left(Cx_i^2 + Dx_i + E\right)\right] = 0 \\ \dfrac{\partial \Pi}{\partial E} = 2\displaystyle\sum_{i=1}^{n} A_i\left[\sigma_{xi} - \left(Cx_i^2 + Dx_i + E\right)\right] = 0 \end{cases}$$

The unknown coefficients *C*, *D* and *E* can be obtained by solving the 3 above equations.

$$\sigma_{x1} = \frac{1}{b}\int_0^b \sigma_x(x)dx = \frac{b^2}{3}C + \frac{b}{2}D + E$$

$$\sigma_{x2} = \frac{1}{b}\int_{a-b}^{a} \sigma_x(x)dx = \left(a^2 - ab + \frac{b^2}{3}\right)C + \left(a - \frac{b}{2}\right)D + E$$

If $-\frac{D}{2C} < \frac{b}{2}$ or $-\frac{D}{2C} > a - \frac{b}{2}$, , σ_{x3} is to be ignored. Otherwise, σ_{x3} is taken as:

$$\sigma_{x3} = \frac{1}{b}\int_{x_{min}}^{x_{max}} \sigma_x(x)dx = \frac{b^2}{12}C - \frac{D^2}{4C} + E$$

where: $x_{min} = -\frac{b}{2} - \frac{D}{2C}$

$$x_{max} = \frac{b}{2} - \frac{D}{2C}$$

The longitudinal stress is to be taken as:

$$\sigma_x = Max\,(\,\sigma_{x1}, \sigma_{x2}, \sigma_{x3})\ ;$$

The edge stress ratio is to be taken as:

$$\psi_x = 1$$

For overall stiffened panel buckling and stiffener buckling assessments, the longitudinal stress σ_x applied on the shorter edge of the attached plate is to be taken as:

$$\sigma_x = \frac{\sum_{i=1}^{n} A_i \sigma_{xi}}{\sum_{i=1}^{n} A_i}$$

The edge stress ratio ψ_x for the stress σ_x is equal to 1.0.

6.2.1.2 Transverse stress

The transverse stress σ_y applied along the longer edges of the buckling panel is to be calculated by extrapolation of the transverse stresses of all elements up to the shorter edges of the considered buckling panel.

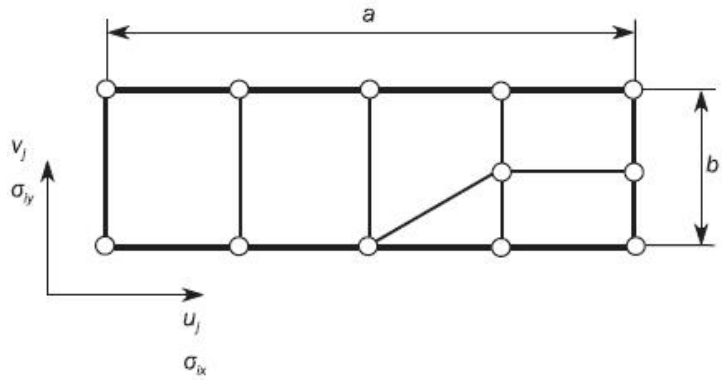


Figure 6.2.1.2 Buckling panel

The distribution of $\sigma_y(x)$ is assumed as straight line. Therefore:

$$\sigma_y(x) = A + Bx$$

The best fitting curve $\sigma_y(x)$ is to be obtained by the least square method minimising the square error Π considering area of each element as a weighting factor.

$$\Pi = \sum_{i=1}^{n} A_i \left[\sigma_{yi} - (A + Bx_i)\right]^2$$

The unknown coefficients A and B 应 is to be yield zero first partial derivatives, $\partial\Pi$ with respect to A and B, respectively.

$$\frac{\partial \Pi}{\partial A} = 2\sum_{i=1}^{n} A_i \left[\sigma_{yi} - (A + Bx_i)\right] = 0$$

$$\frac{\partial \Pi}{\partial B} = 2\sum_{i=1}^{n} A_i x_i \left[\sigma_{yi} - (A + Bx_i)\right] = 0$$

The unknown coefficients A and B are obtained by solving the 2 above equations and are given as follow:

$$A = \frac{\left(\sum_{i=1}^{n} A_i \sigma_{yi}\right)\left(\sum_{i=1}^{n} A_i x_i^2\right) - \left(\sum_{i=1}^{n} A_i x_i\right)\left(\sum_{i=1}^{n} A_i x_i \sigma_{yi}\right)}{\left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} A_i x_i^2\right) - \left(\sum_{i=1}^{n} A_i x_i\right)^2}$$

$$B = \frac{\left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} A_i x_i \sigma_{yi}\right) - \left(\sum_{i=1}^{n} A_i x_i\right)\left(\sum_{i=1}^{n} A_i \sigma_{yi}\right)}{\left(\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} A_i x_i^2\right) - \left(\sum_{i=1}^{n} A_i x_i\right)^2}$$

The transverse stress is to be taken as:

$$\sigma_y = max\,(\,A, A + Ba)$$

The edge stress ratio is to be taken as:

$$\psi_y = \frac{min\,(A, A + Ba)}{max\,(A, A + Ba)} \quad \text{for} \quad \sigma_y > 0$$

$$\psi_y = 1 \quad \text{for} \quad \sigma_y \leq 0.$$

6.2.1.3 Shear stress

The shear stress τ is to be calculated using a weighted average approach, and is to be taken as:

$$\tau = \frac{\sum_{i=1}^{n} A_i \tau_i}{\sum_{i=1}^{n} A_i}$$

6.2.2 Irregular Panel and Curved Panel

6.2.2.1 Reference stresses

The longitudinal, transverse and shear stresses are to be calculated using a weighted average approach. They are to be taken as:

$$\sigma_x = \frac{\sum_{i=1}^{n} A_i \sigma_{xi}}{\sum_{i=1}^{n} A_i}$$

$$\sigma_y = \frac{\sum_{i=1}^{n} A_i \sigma_{yi}}{\sum_{i=1}^{n} A_i}$$

$$\tau = \frac{\sum_{i=1}^{n} A_i \tau_i}{\sum_{i=1}^{n} A_i}$$

The edge stress ratios are to be taken as:

$$\psi_x = 1;$$

$$\psi_y = 1.$$

CHAPTER 3 EQUIPMENT AND OUTFITS

Section 1 RUDDERS

3.1.1 General requirements

3.1.1.1 Basic assumptions

(1) This Section applies to ordinary profile rudders, and to some enhanced profile rudders with special arrangements for increasing the rudder force. Rudders not conforming to the profile types included in this Section will be subject to special consideration.

(2) This section applies to rudders made of steel. Rudders made of material different from steel will be subject to special consideration.

3.1.1.2 Design considerations

(1) Effective means are to be provided for supporting the weight of the rudder without excessive bearing pressure, e.g. by a rudder carrier attached to the upper part of the rudder stock. The hull structure in way of the rudder carrier is to be suitably strengthened.

(2) Suitable arrangements are to be provided to prevent the rudder from lifting.

(3) In rudder trunks which are open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the ~~deepest waterline~~waterline at scantling draught (without trim), two separate watertight seals /stuffing boxes are to be provided.

3.1.1.4 Welding and design details

(3) Welds in the rudder side plating subjected to significant stresses from rudder bending and welds between plates and heavy pieces (solid parts in forged or cast steel or very thick plating) are to be made as full penetration welds. In way of highly stressed areas e.g. cut-out of semi-spade rudder and upper part of spade rudder, cast or welding on ribs is to be arranged. Two sided full penetration welding is normally to be arranged. Where back welding is impossible welding is to be performed against ceramic backing bars or equivalent. Steel backing bars may be used and are to be continuously welded on one side to the ~~heavy piece~~bevelled edge, see Figure 3.1.1.4(3). The bevel angle is to be at least 15° for one sided welding.

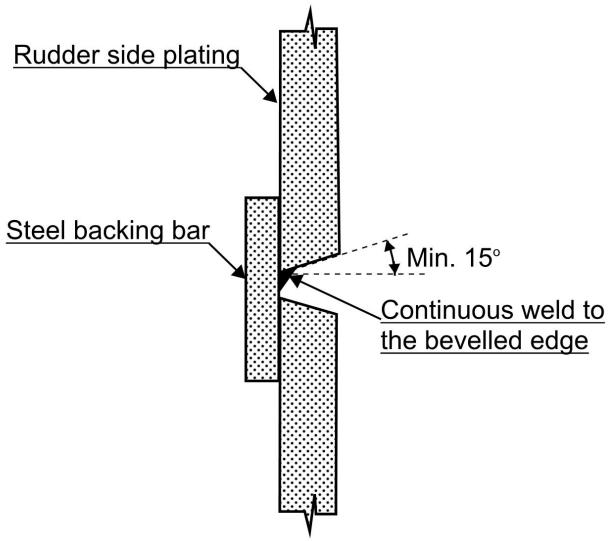


Figure 3.1.1.4(3) Use of steel backing bar in way of full penetration welding of rudder side plating

3.1.2 Rudder force and rudder torque

3.1.2.1 Rudder blades without cut-outs

(1) The rudder force C_R upon which the rudder scantlings are to be based is to be determined from

the following formula:

$$C_R = 132 K_1 K_2 K_3 A V^2 \quad \text{N}$$

where: C_R — rudder force, in N;
A — area of rudder blade, in m^2;
V — maximum service speed (knots). When the speed is less than 10 knots, V is to be replaced by the following:
$V_{min} = (V + 20) / 3$
For the astern condition the maximum astern speed V_{astern} (the greatest speed which the ship is designed to maintain in service at sea at the deepest sea-going draught) is to be used, however, in no case less than:
$V_{astern} = 0.5\ V$;

3.1.4 Rudder stock scantlings

3.1.4.2 Rudder stock scantlings due to combined loads

If the rudder stock is subjected to combined torque and bending, the equivalent stress in the rudder stock is not to exceed $118 / K$ N/mm^2.

K — material factor for the rudder stock as given in 3.1.1.3(5).

The equivalent stress σ_c is to be determined by the formula:

$$\sigma_c = \sqrt{\sigma_b^2 + 3\tau_t^2} \quad \text{N/mm}^2$$

where: bending stress: $\sigma_b = \frac{10.2M}{d_c^3} \times 10^3$ N/mm^2;

torsional stress: $\tau_t = \frac{5.1Q_R}{d_c^3} \times 10^3$ N/mm^2.

The rudder stock diameter d_c is therefore not to be less than:

$$d_c = d_t \sqrt[6]{1 + \frac{4}{3}\left(\frac{M}{Q_R}\right)^2} \quad \text{mm}$$

where: M — bending moment, in N·m, at the station of the rudder stock considered.
For a spade rudder with trunk extending inside the rudder, the rudder stock scantlings are to be checked against the two cases defined in 2.2, Appendix 1 of this Chapter.

3.1.5 Rudder blade

3.1.5.2 Rudder plating

The thickness t of the rudder side, top and bottom plating is not to be less than:

$$t = 5.5 s \beta \sqrt{K} \sqrt{d + C_R 10^{-4} / A} + 2.5 \quad \text{mm}$$

where: d — ~~summer loadline~~ scantling draught, in m;
C_R — rudder force, in N, according to 3.1.2.1 of this Section;
A — rudder area, in m^2;

$\beta = \sqrt{1.1 - 0.5(\frac{s}{b})^2}$ max. 1.00 if $\frac{b}{s} \geq 2.5$;

s — smallest unsupported width of plating, in m;
b — greatest unsupported width of plating, in m;
K — material factor for the rudder plating as given in 3.1.1.3(2).

3.1.6 Rudder stock couplings

3.1.6.4 Cone couplings with special arrangements for mounting and dismounting the couplings

(2) Push-up pressure

The push-up pressure is not to be less than the greater of the two following values:

$$p_{req1} = \frac{2Q_F \times 10^3}{d_m^2 l \pi \mu_0} \quad \text{N/mm}$$

$$^{2}\ p_{req2} = \frac{6M_c \times 10^3}{l^2 d_m} \quad \text{N/mm}^2$$

where: Q_F — design yield moment of rudder stock, as defined in 3.1.6.3(2) of this Section, in N·m;

d_m — mean cone diameter, in mm, see Figure 3.1.6.3(a);

l — coupling length, in mm;

μ_0 — frictional coefficient, equal to 0.15;

~~M_b~~ M_c — bending moment in rudder stock at the top of the cone coupling (e.g. in case of spade rudders), in N·m.

For spade rudder with trunk extending inside the rudder, the coupling is to be checked against the two cases defined in 2.2, Appendix 1 of this Chapter

It has to be proved by the designer that the push-up pressure does not exceed the permissible surface pressure in the cone. The permissible surface pressure ~~p_{perm}~~, in N/mm², is to be determined by the following formula:

$$p_{perm} = \frac{0.95R_{eH}(1-\alpha^2)}{\sqrt{3+\alpha^4}} - p_b \quad \text{N/mm}^2 \quad \text{N/mm}^2$$

where: $p_b = \frac{3.5M_c \times 10^3}{d_m l^2} \quad \text{N/mm}^2$;

R_{eH} — specified minimum yield stress of the material of the gudgeon, in N/mm²;

$\alpha = \frac{d_m}{d_a}$;

d_m — diameter, in mm, see Figure 3.1.6.3(a);

d_a — outer diameter of the gudgeon, see Figure 3.1.6.3(a), in mm, to be not less than $1.25d_0$, see Figure 3.1.6.3(a) and Figure 3.1.6.3(b)(the least diameter is to be considered).

3.1.7 Pintles

3.1.7.2 Couplings

(2) Push-up pressure for pintle

The required push-up pressure for pintle in case of dry fitting, in N/mm², is to be determined by p_{req1} as given below.

The required push-up pressure for pintle in case of oil injection fitting, in N/mm², is to be determined by the maximum pressure of p_{req1} and p_{req2} as given below:

~~The required push-up pressure for pintle p_{req}, in N/mm², is to be determined by the following formula:~~

$$p_{req} = 0.4\frac{B_1 d_0}{d_m^2 l} \quad \text{N/mm}^2$$

$$p_{req2} = \frac{6M_{bp}}{l^2 d_m} \times 10^3 \quad \text{N/mm}^2$$

where: B_1 — Supporting force in the pintle, in N;

d_0 — Pintle diameter, in mm, see Figure 3.1.6.3(a).

M_{bp} ——bending moment in the pintle cone coupling to be determined by:

$$M_{bp} = Bl_a \quad \text{Nm}$$

l_a ——length between middle of pintle-bearing and top of contact surface between cone coupling and pintle, see Figure 3.1.7.2.

The push up length Δl_1 is to be calculated similarly as in 3.1.6.4(3) of this Section, using required push-up pressure and properties for the pintle.

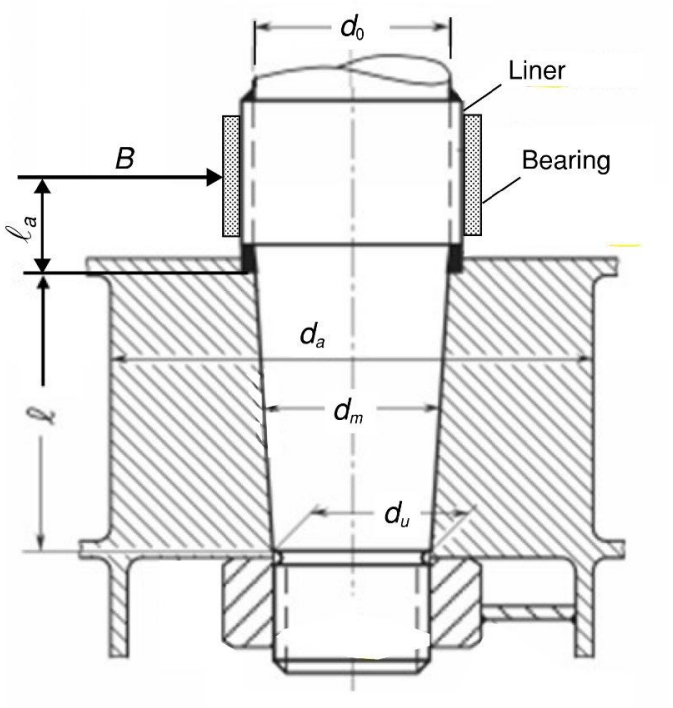


Figure 3.1.7.2 Pintle cone coupling indicating l_a

3.1.8 Rudder stock bearing, rudder shaft bearing and pintle bearing

3.1.8.1 Liners and bushes

(1) Rudder stock bearing

Liners and bushes are to be fitted in way of bearings. For rudder stocks and pintles having diameter less than 200 mm, liners in way of bushes may be provided optionally. The minimum thickness of liners and bushes t_{min} is to be equal to:

- t_{min} = 8 mm for metallic materials and synthetic material;
- t_{min} = 22 mm for lignum material.

(2) Pintle bearing

The thickness of any liner or bush t, in mm, is not to be less than the minimum thickness defined in 3.1.8.1(1) and the following value:

$$t = 0.01\sqrt{B}$$

where: B— relevant bearing force, in N.

3.1.9 Strength of rudder horns and rudder trunk

3.1.9.2 Rudder trunk

The requirements in this paragraph apply to trunk configurations which are extended below stern frame and arranged in such a way that the trunk is stressed by forces due to rudder action.

(1) Materials, welding and connection to hull

The steel used for the rudder trunk is to be of weldable quality, with a carbon content not exceeding 0.23% on ladle analysis or a carbon equivalent C_{EQ} not exceeding 0.41%.

Plating materials for rudder trunks are in general not to be of lower grades than corresponding to class II as defined in Section 3, Chapter 1 of this PART.

The weld at the connection between the rudder trunk and the shell or the bottom of the skeg is to be full penetration.

For rudder trunks extending below shell or skeg, the ~~The~~ fillet shoulder radius r, in mm (see Figure 3.1.9.2) is to be as large as practicable and to comply with the following formulae:

$r = 0.1 d_c / K$, without being less than:

r =60 mm when σ = 40/ K N/mm^2

r = 30 mm when σ <40/ K N/mm^2

where: d_c — rudder stock diameter axis as defined in 3.1.4.2;

σ — bending stress in the rudder trunk, in N/mm^2;

K — material factor for the rudder trunk as given in 3.1.1.3(2) or 3.1.1.3(5) of this Section.

The radius may be obtained by grinding. If disk grinding is carried out, score marks are to be avoided in the direction of the weld. The radius is to be checked with a template for accuracy. Four profiles at least are to be checked. A report is to be submitted to the Surveyor.

Rudder trunks comprising of materials other than steel are to be specially considered by CCS.

Section 2 ANCHORING AND MOORING EQUIPMENT

3.2.1 Equipment number

3.2.1.1 The anchoring equipment for sea-going ships are to be provided in accordance with Tables 3.2.1.1(1) and 3.2.1.1(2), based on the ship type and service area as well as the equipment number derived from 3.2.1.2 of this Section. Requirements of this Section for the number, length and breaking loads of towlines and mooring lines are only as guidance.

For non-self-propelled ships engaged in special work, of which an increased mass of anchors is required by the owner and anchoring operations are carried out by means of other appliances, chain cables may be provided in accordance with the rule requirements for the mass of anchors only.

The requirement for the anchoring equipment in this Section is intended for temporary mooring of a vessel within a harbour or sheltered area when the vessel is awaiting berth, tide, etc.

The equipment is therefore not designed to hold a ship off fully exposed coasts in rough weather or to stop a ship which is moving or drifting. In this condition the loads on the anchoring equipment increase to such a degree that its components may be damaged or lost owing to the high energy forces generated, particularly in large ships.

The anchoring equipment presently required in this Section is designed to hold a ship in good holding ground in conditions such as to avoid dragging of the anchor. In poor holding ground the holding power of the anchors will be significantly reduced.

The Equipment Numeral (EN) formula for anchoring equipment required in this Section is based on an assumed maximum current speed of 2.5 m/sec, maximum wind speed of 25 m/sec and a minimum scope of chain cable between 6 and 10, the scope being the ratio between length of chain paid out and water depth. For ships with an equipment length greater than 135 m, alternatively the required anchoring equipment can be considered applicable to a maximum current speed of 1.54 m/s, a maximum wind speed of 11 m/s and waves with maximum significant height of 2 m.

It is assumed that under normal circumstances a ship will use only one bow anchor and chain cable at a time.

Manufacture of anchors and anchor chain cables is to be in accordance with the relevant requirements of CCS Rules for Materials and Welding.

The bower anchor is to be connected with its chain cable, arranged onboard the ship and ready for use.

In addition to planned anchoring for normal operations, anchoring equipment is also important for ship safety in emergency situations such as loss of maneuverability, unscheduled repairs and other unexpected situations.

3.2.1.2 The equipment number N is to be obtained from the following formula:

$$N = \Delta^{\frac{2}{3}} + 2(Bh + S_{fun}) + \frac{A}{10}$$

where: Δ — moulded displacement, in t, to the summer load waterline;

B — moulded breadth, in m;

h — effective height, in m, from the summer load waterline to the top of the uppermost house, i.e.:

$$h = a + \Sigma\, h_i$$

where: a — vertical distance at hull side, in m, measured from the summer load

waterline amidships to the upper deck;

h_i — height at the centreline, in m, of each tier of houses having a breadth greater than $B/4$; for the lowest tier h_1 is to be measured at centreline from the upper deck or from a notional deck line where there is local discontinuity in the upper deck, see Figure 3.2.1.1(1);

A — area, in m², in profile view of the hull, within the length of the vessel, and of superstructures and deckhouses and funnels above the summer load waterline, which are within the length of the vessel, and also having a breadth greater than $B/4$. The side projected area of the funnel is considered in A when A_{FS} is greater than zero. In this case, the side projected area of the funnel should be calculated between the upper deck, or notional deck line where there is local discontinuity in the upper deck, and the effective height h_F;

S_{fun} — effective front projected area of the funnel, in m², defined as:

$$S_{fun} = A_{FS} - S_{shield}$$

where: A_{FS}— front projected area of the funnel, in m² , calculated between the upper deck at centreline, or notional deck line where there is local discontinuity in the upper deck, and the effective height h_F. A_{FS} is taken equal to zero if the funnel breadth is less than or equal to $B/4$ at all elevations along the funnel height;

h_F— effective height of the funnel, in m, measured from the upper deck at centreline, or notional deck line where there is local discontinuity in the upper deck, and the top of the funnel. The top of the funnel may be taken at the level where the funnel breadth reaches B/4;

S_{shield} — the section of front projected area A_{FS}, in m², which is shielded by all deck houses having breadth greater than $B/4$. If there are more than one shielded section, the individual shielded sections i.e $S_{shield1}$, $S_{shield\ 2}$ etc as shown in Figure 3.2.1.2(3) to be added together. To determine S_{shield}, the deckhouse breadth is assumed B for all deck houses having breadth greater than $B/4$ as shown for $S_{shield1}$, $S_{shield2}$ in Figure 3.2.1.2(3).

When several funnels are fitted on the ship, the above parameters are taken as follows:

h_F— effective height of the funnel, in m, measured from the upper deck, or notional deck line where there is local discontinuity in the upper deck, and the top of the highest funnel. The top of the highest funnel may be taken at the level where the sum of each funnel breadth reaches $B/4$;

A_{FS} — sum of the front projected area of each funnel, in m², calculated between the upper deck, or notional deck line where there is local discontinuity in the upper deck, and the effective height h_F. A_{FS} is to be taken equal to zero if the sum of each funnel breadth is less than or
equal to $B/4$ at all elevations along the funnels height;

A — Side projected area, in m², of the hull, superstructures, houses and funnels above the Summer Load waterline which are within the length of the ship. The total side projected area of the funnels is to be considered in the side projected area of the ship, A, when A_{FS} is greater than zero. The shielding effect of funnels in transverse direction may be considered in

the total side projected area, i.e., when the side projected areas of two or more funnels fully or partially overlap, the overlapped area needs only to be counted once.

The equipment number of tugs is to be determined by the following formula:

$$N = \Delta^{\frac{2}{3}} + 2(aB + \sum b_i\ h_i\ ) + \frac{A}{10}$$

where: a, B and h_i — same as defined above;

b_i — breadth, in m, of superstructures or of deckhouses of each tier having a breadth greater than $B/4$.

For tugs under 45 m in length intended for towing service only, one anchor may be used onboard provided that the second anchor and its relevant chain cable holds readily available to be installed. In case of loss of anchor, the tug is to remain in port until replace anchor equipment is installed onboard.

In the calculation of h and A, sheer and trim are to be ignored, i.e. h is the sum of freeboard amidships plus the height (at centreline) of each tier of houses having a breadth greater than B/4.

Screens and bulwarks more than 1.5 m in height are to be regarded as parts of superstructures or deckhouses.

Screens and bulwarks more than 1.5 m in height are to be regarded as parts of superstructures or deckhouses.

If a house having a breadth greater than $B/4$ is above a house with a breadth of $B/4$ or less then the wide house is to be included but the narrow house ignored.

The height of the hatch coamings and that of any deck cargo, such as containers, may be disregarded when determining h and A. With regard to determining A, when a bulwark is more than 1.5 m high, the area shown as A_2 in Figure 3.2.1.2(2) is to be included in A. The total length of chain given in Table 3.2.1.1(2) is to be divided in approximately equal parts between the two bower anchors.

For ships of length less than 90 m, alternative methodology using direct force calculation for anchoring equipment described in Appendix 3 of this Chapter may be used.

Equipment Required **Table 3.2.1.1(1)**

Ship type	Required equipment
Cargo ships, bulk carriers, oil tankers, trailing suction dredgers, ferries, etc.	Using N
Tugs	Using N
Offshore supply ships	Using N, but the chain cables are to be selected 2 grades above N
Manned barges	Using N
Unmanned barges	Using N, but only one bower anchor is required, and 0.5 times the length of chain cables required for N may be provided
Floating cranes, floating pile drivers or other similar workboats	Using N, but side projections of the crane, pile driver, etc., are to be considered for N. If the anchors used comply with the requirements of this Table, they may be used in lieu of bower anchors. ~~Where wires are substituted for chain cables(irrespective of ship length), anchor weight is at least to be increased by 25%, the length of the wires is not to be less than 1.5 times that of the required chain cables and the breaking strength of the wires is to be equal to that of the required chain cables. Anchor winches used as an alternative to windlasses are to satisfy the requirements of Section 2, Chapter 13, PART THREE of the Rules (except for requirements for cable lifters and chain stoppers). For the arrangement of winches, rope guides are to be provided and testing is to be carried out in accordance with the requirements of 13.2.6, Chapter 13, PART THREE of the Rules. A short length of chain cables is to be fitted between the anchor and the wire, having a length of 12.5 m or equal to the distance from the anchor in the stowed position to the winch, whichever is the lesser, and a swivel is to be fitted at the connection between the wire and the chain cable~~

3.2.2 Anchors

3.2.2.4 When high holding power anchors are used as bower anchors, the mass of each such anchor may be 75% of the mass given in Table 3.2.1.1(2) of this Section for ordinary stockless bower anchors. When super high holding power anchors of the proven holding power are used as bower anchors, the mass of each such anchor may be reduced to not less than 50% of the mass required for ordinary stockless anchors in Table 3.2.1.1(2) of this Section. See specific requirements of Section 1, Chapter 10 of PART ONE of CCS Rules for Materials and Welding. Where high holding power anchors or very high holding power anchors are used as bower anchors, leading to the reduction in the mass of anchors, the notation RWA may be assigned.

3.2.3 Chain cables

3.2.3.1 For ships with *N* less than 90, chain cables may be substituted by studless chains of equivalent proof-load.

3.2.3.2 Wire rope may be used in place of chain cable on ships ~~with less than 40 m in length and~~ subject to the following conditions:

(1) with less than 90 m in length and which will need an anchor for emergency purposes, i.e., not intended to use their anchor in normal temporary anchoring operation, or

(2) with the anchoring equipment used for positioning with a minimum of 4 points anchoring, e.g., for cable or pipe laying.

(3) for anchors used for operation of floating cranes, floating pile drivers or other similar workboats as specified in Table 3.2.1.1(1).

3.2.3.3 Use of wire rope in place of chain cable is subject to the following conditions:

(1) The wire ropes are to have a total length equal to 1.5 times the corresponding length of stud link chain cables required in Table 3.2.1.1(2), and a minimum breaking load equal to that given for the corresponding stud link chain cable of Grade CCS 1.

(2) The anchor weight shall be increased by 25 % compared to anchor associated with chain cable according to Table 3.2.1.1(2).

(3) A short length of chain cable is to be fitted between the wire rope and the anchor, having a length equal to 12.5 m or the distance from the anchor in the stowed position to the winch, whichever is the lesser.

(~~3~~4) All surfaces being in contact with the wire need to be rounded with a radius of not less than 10 times the wire rope diameter (including stem).

(5) Steel wire shall be selected to fit for purpose based on the manufacturer recommendation and shall be provided with guidance for maintenance and inspection.

3.2.3.~~3~~4 A swivel is to be provided to the chain cables at the outboard end to which the anchor is connected.

3.2.3.~~4~~5 The inboard end of the chain cables is to be secured to the hull structure and so arranged that they will be capable of being immediately released from a position easily accessible outside the chain locker.

3.2.3.~~5~~6 Grade CCS 1 material having a tensile stress of less than 400 N/mm² is not to be used in association with high holding power anchors. Grade CCS 3 material is to be used only for chains of 20.5 mm or more in diameter.

3.2.3.~~6~~7 The total length of chain given in Table 3.2.1.1(2) is to be divided in approximately equal parts between the two bower anchors.

3.2.4 Towlines and mooring lines

3.2.4.1 The number, length and breaking loads of mooring lines are to be marked on the mooring arrangement plan of the ship. The towlines listed in Table 3.2.1.1(2) are provided on board for the tug or for the use by other ships towing the ship. The lateral projected area of deck cargoes as given ~~in the loading manual~~ by the ship nominal capacity condition is to be taken into account during the calculation of equipment number for selection of towing lines. As an alternative method to 3.2.4, the number and strength of mooring lines may be determined by means of direct mooring analysis of Appendix 2 of this Chapter.

Section 7 SUPPORT STRUCTURE FOR DECK EQUIPMENT

3.7.3 Supporting structure for cranes, derricks and lifting masts

Permissible Stress Table 3.7.43.12

Type of element	Permissible stress
Grillage	Direct stress: $[\sigma]=0.67R_{eH}$ Shear stress: $[\tau]=0.39R_{eH}$
Plate element	Equivalent stress: $[\sigma_e]=0.80R_{eH}$

where: R_{eH} – yield stress of material, in N/mm^2.

Section 8 ENERGY-SAVING APPENDAGES IN FRONT OF PROPELLERS

3.8.1 General

3.8.1.1 The provisions in this Section is optional and apply to energy-saving appendages installed onboard in front of propellers. Ships applying for notation PSD are to comply with the provisions of this Chapter.

Appendix 1 GUIDELINES FOR CALCULATION OF BENDING MOMENT AND SHEAR FORCE DISTRIBUTION

2 The Forces on Rudder–Rudder Stock

2.1 Spade rudder

Data for the analysis

l_{10} – l_{30} = lengths of the individual girders of the system, in m;

I_{10} – I_{30} = moments of inertia of these girders, in cm^4.

Load of rudder body P_R:

$$P_R = C_R / (l_{10}10^3) \qquad \text{kN/m}$$

Moments and forces

The moments and forces may be determined by the following formulae:

$$M_b = C_R(l_{20} + (l_{10}(2c_1 + c_2)/3(c_1 + c_2)\,)) \qquad \text{Nm}$$

$$B_3 = \frac{M_b}{l_{30}} \qquad \text{N}$$

$$B_2 = C_R + B_3 \qquad \text{N}$$

where: C_R — rudder force, in N.

The maximum moment, M_e, in top of the cone coupling as shown in Figure 2.1 is applicable for the connection between the rudder and the rudder stock.

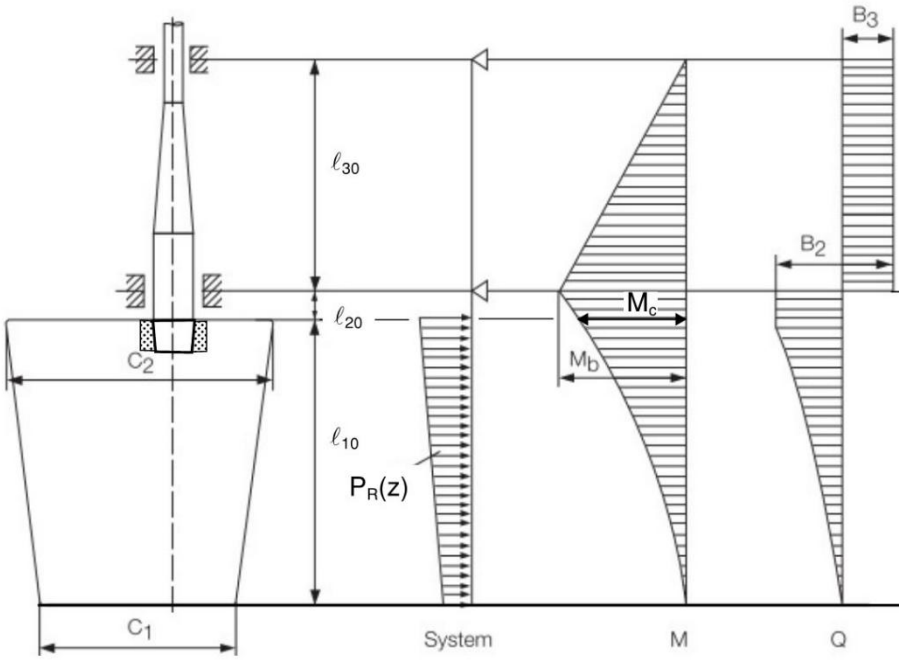


Figure 2.1 Spade rudder

2.2 Spade rudder with trunk

Data for the analysis

l_{10} – l_{30} = lengths of the individual girders of the system, in m;

I_{10} – I_{30} = moments of inertia of these girders, in cm^4.

Load of rudder body P_R:

$$P_R = C_R / ((l_{10} + l_{20})10^3) \qquad \text{kN/m}$$

Moments and forces

For a spade rudders with ~~rudders trunks the moments~~with trunk extending inside the rudder, ~~in N·m, and forces, in N, may be determined by the following formulae:~~the strength is be checked against the following two cases, and the moments and forces for the two cases defined above may be determined according to Figure 2.2(1) and 2.2(2), respectively.

(1) pressure applied on the entire rudder area;

Full rudder force $C_R = C_{R1} + C_{R2}$

total rudder torque $Q_R = Q_{R1} + Q_{R2}$

rudders stock bending moment $M_b = M_{CR2} - M_{CR1}$

(2) pressure applied only on rudder area below the middle of neck bearing.

Rudder force C_{R2} corresponding to rudder torque Q_{R2} acting at rudder blade area A_2 with rudders stock bending moment $M_b = M_{CR2}$

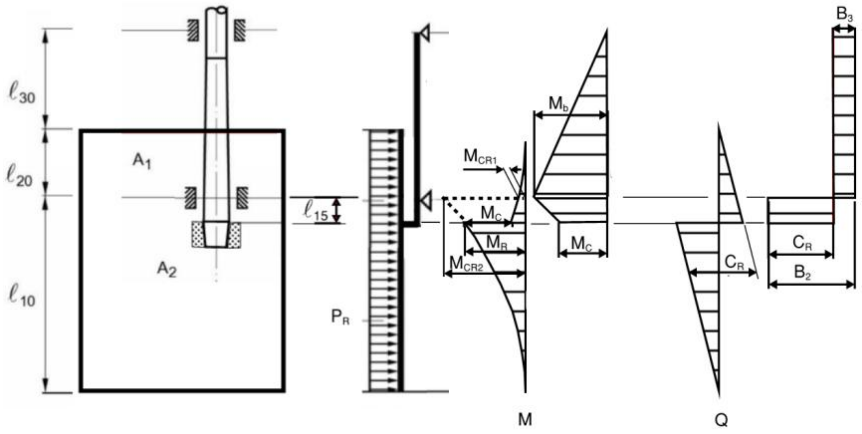


Figure 2.2(1)

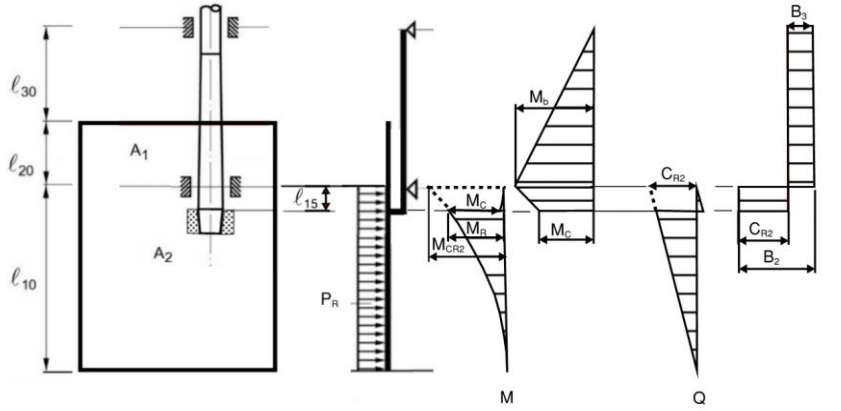


Figure 2.2(2)

~~M_R is the greatest of the following values:~~

$$M_{CR1} = C_{R1}(CG_{1Z} - l_{10}) \qquad \text{Nm}$$

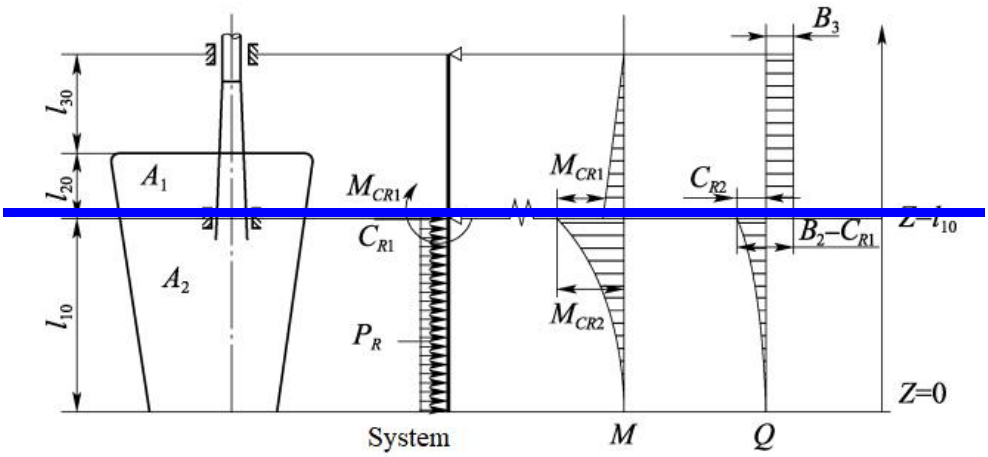
$$M_{CR2} = C_{R2}(l_{10} - CG_{2Z}) \qquad \text{Nm}$$

where: C_{R1}: rudder force over the rudder blade area A_1;
C_{R2}: rudder force over the rudder blade area A_2;
CG_{1Z}: vertical position of the centre of gravity of the rudder blade area A_1;
CG_{2Z}: vertical position of the centre of gravity of the rudder blade area A_2;

$$C_R = C_{R1} + C_{R2} \qquad \text{N}$$

$$B_3 = (M_{CR2} - M_{CR1}) / (l_{20} + l_{30}) \qquad \text{N}$$

$$B_2 = C_R + B_3 \qquad \text{N}$$



~~Figure 2.2 Spade rudder with trunk~~

A new Appendix 3 is added as follows:

Appendix 3 DIRECT FORCE CALCULATION FOR ANCHORING EQUIPMENT

1 General

1.1 As an alternative to the prescriptive approach described in 3.2.1.2 of this Chapter direct force calculation may be performed to determine the necessary anchoring equipment for monohull ships with length less than 90 m.

2 Total force F_{EN}

2.1 The total force (static + dynamic) F_{EN}, in kN, induced by wind and current acting on monohull in anchoring condition as defined in A1.1 may be calculated as follows:

$$F_{EN} = 2(F_{SLPH} + F_{SH} + F_{SS})$$

where: F_{SLPH} ——Static force on wetted part of the hull due to current;

F_{SH} ——Static force on hull due to wind;

F_{SS} ——Static force on superstructures due to wind.

2.1.1 Calculation of F_{SLPH}

Static force on wetted part of the hull due to current F_{SLPH}, in kN, is defined according to the following formula:

$$F_{SLPH} = \frac{1}{2}\rho C_f S_m V_e^2 10^{-3}$$

where: ρ ——Water density, equal to 1025kg/m^3;

C_f ——Coefficient equal to:

$$C_f = (1+k)\frac{0.075}{(\log R_e - 2)^2}$$

where: R_e ——Reynolds number equal to:

$$R_e = \frac{(V_c L_{WL})}{1.054 \cdot 10^{-6}}$$

k ——Coefficient equal to:

$$k = 0.017 + 20\frac{C_{bWL}}{L_{WL}^2 T^{-0.5} B_{WL}^{-1.5}}$$

C_{bWL} ——block coefficient at waterline equal to:

$$C_{bWL} = \frac{\Delta}{1.025 L_{WL} B_{WL} T}$$

where: Δ ——Moulded displacement at waterline, in m^3;

S_m ——Total wetted surface of the part of the hull under draught, in m^2. The value of S_m is to be given by the Designer. When this value is not available, S_m may be taken equal to $6 \cdot \Delta^{2/3}$;

V_c ——Speed of the current, in m/s.

2.1.2 Calculation of F_{SH}

Static force on hull due to wind F_{SH}, in kN, is defined according to the following formula:

$$F_{SH} = \frac{1}{2}\rho(C_{hfr} S_{hfr} + 0.02 S_{hlat}) V_W^2 10^{-3}$$

where: ρ ——Air density, equal to 1.22kg/m^3;

V_W ——Speed of the wind, in m/s;

S_{hfr} ——Front surface of hull and bulwark if any, in m^2, projected on a vertical plane of the ship situated aft of the aft end of the ship and perpendicular to the longitudinal axis of the ship;

S_{hlat} ——Partial lateral surface of one single side of the hull and bulwark if any, in m^2, through the overall length of the ship, projected on a vertical plane parallel to the longitudinal axis of the ship and delimited according to Figure 2.1.2. In Figure 2.1.2, B is the breadth of the hull, in m.

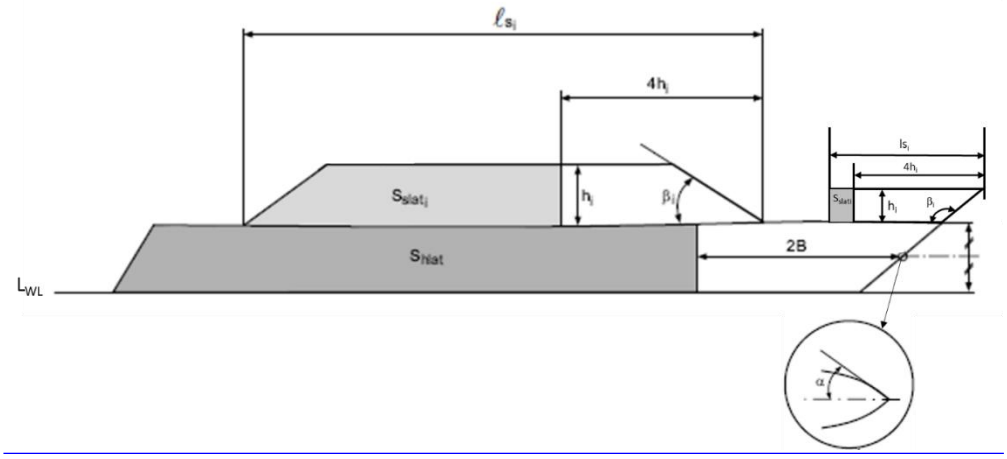


Figure 2.1.2

C_{hfr} ——Coefficient equal to $0.8\sin\alpha$, with α defined in Figure 2.1.2;

The upper part of the hull is the part extending from side to side to the uppermost continuous deck extending over the ship length.

2.1.3 Calculation of F_{SS}

(1) General case

Static force on superstructures and deckhouses due to wind F_{SS}, in kN, is defined according to the following formula:

$$F_{SS} = \frac{1}{2}\rho\sum(C_{sfr_i}S_{sfr_i} + 0.08S_{slat_i})V_W^2 10^{-3}$$

where: ρ ——Air density, equal to 1.22kg/m^3;

V_W ——Speed of the wind, in m/s;

S_{sfr_i} ——Front surface of tier i (superstructure or deckhouse, including bulwark if any), in m^2, projected on a vertical plane of the ship situated aft of the aft end of the ship and perpendicular to the longitudinal axis of the ship;

S_{slat_i} ——Partial lateral surface of one single side of tier i (superstructure or deckhouse, including bulwark if any), in m^2, projected on a vertical plane parallel to the longitudinal axis of the ship and delimited according to Figure 2.1.2. When $4h_i \geq l_{si}$, S_{slat_i} is to be taken equal to 0;

C_{sfr_i} ——Coefficient equal to $0.8\sin\beta_i$, with β_i defined in Figure 2.1.2 without being greater than 90°;

(2) Superstructures in the forward part of the ship

When superstructures are located in the front of the hull with front and side walls of superstructures in the continuity of the side shell, the static force induced by wind applied on these superstructures F_{SS}, in KN, is defined as the sum of the forces applied to each superstructure tier according to the following formula:

$$F_{SS} = \frac{1}{2}\rho\sum(C_{hfr_i}S_{hfr_i} + 0.08S_{slat_i})V_W^2 10^{-3}$$

where: S_{hfr_i} ——Front surface of tier i of the superstructure, in m^2, projected on a vertical plane of the ship situated aft of the aft end of the ship and perpendicular to the longitudinal axis of the ship

C_{hfr_i} ——Coefficient equal to $0.8\sin\alpha_s$, with α_s defined in Figure 2.1.2 and measured at mid height of the superstructure tier located in the front of the hull.

The static force is to be added to the static force calculated for the other superstructures and deckhouses according to 2.1.3(1) of this Appendix.

3 Anchor mass

3.1 The individual mass of anchor, in kg, is to be at least equal to:

for ordinary anchor: $P = (F_{EN}/7)\cdot 10^2$

for high holding power anchor: $P = (F_{EN}/10)\cdot 10^2$

for very high holding power: $P = (F_{EN}/15)\cdot 10^2$

4 Chain cable

4.1 Stud link chain cable scantling

Chain cable diameters are to be based on the minimum breaking load BL and proof load PL of

steel grades.

	CCS Grade 1	CCS Grade 2	CCS Grade 3
BL	$6F_{EN}$	$6.8F_{EN}$	$7.5F_{EN}$
PL	0.7BL		

The chain cable scantling is to be consistent with the mass of the associated anchor. In case the anchor on board is heavier by more than 7% from the mass calculated in 3.1 of this Appendix, the value of F_{EN} to take into account for the calculation of *BL* and *PL* is to be deduced from the actual mass of the anchor according to the formulae in 3.1 of this Appendix.

4.2 Length of individual chain cable

The length of chain cable L_{ec}, in m, linked to each anchor is to be at least equal to:

when P<180, $L_{ec} = 30\ln(P) - 42$

when P≥180, L_{ec} to be selected according to Table 3.2.1.1(2) of this Chapter.

where: P: Anchor weight, in kg, defined in 3.1 of this Appendix for an ordinary anchor according to the considered case.

CHAPTER 4 STRENGTHENING FOR NAVIGATION IN ICE

Section 1 GENERAL PROVISIONS

4.1.1 General requirements

4.1.1.2 Ships, which comply with the requirements of Section 2 of this Chapter, may be assigned an appropriate ice class notation in accordance with 4.2.1.2, Section 2 of this Chapter; ships, which comply the requirements of Section 3 of this Chapter, may be assigned the notation of Ice Class B.

Table 4.1.1.2

Applicable ice navigation waters	Ice class	Requirements in corresponding chapters of the Rules	Additional requirements for ships having icebreaking capability	Additional provisions for ice-breakers
Polar open sea	PC1 ~ PC7	Sections 1 ~ 2, Chapter 13 of PART EIGHT	–	Sections 1 ~ 2, Chapter 13 of PART EIGHT
Baltic or other sea areas with similar ice conditions in winter	B1*, B1 ~ B3	Section 2, Chapter 4 of PART TWO	Chapter 9 of PART EIGHT	–
Drift ice sea areas other than large stationary ice such as for coastal ice condition in northern part of China in winter	B	Section 3, Chapter 4 of PART TWO	–	–

4.1.1.4 The equivalence between ice strengthening requirements for B1*, B1, B2, B3 and B of CCS and the ice classes of Finnish-Swedish Ice Class Rules ~~2017~~ (FSICR) is given in Table 4.1.1.4.

Table 4.1.1.4

CCS	FSICR
B1*	IA Super
B1	IA
B2	IB
B3	IC
B	II

~~Note: In fact, the requirements for class B are higher than those for II.~~

Section 2 ICE STRENGTHENING FOR CLASSES B1*, B1, B2 AND B3

4.2.1 General requirements

4.2.1.4 The sides of ship, to which the class notation of B1*, B1, B2 or B3 is assigned, are to be provided with a warning triangle and with an ice class draught mark at the maximum permissible ice class draught amidships (see Figure 4.2.1.4) when the upper ice waterline (UIWL) is lower than the fresh water load line in summer.

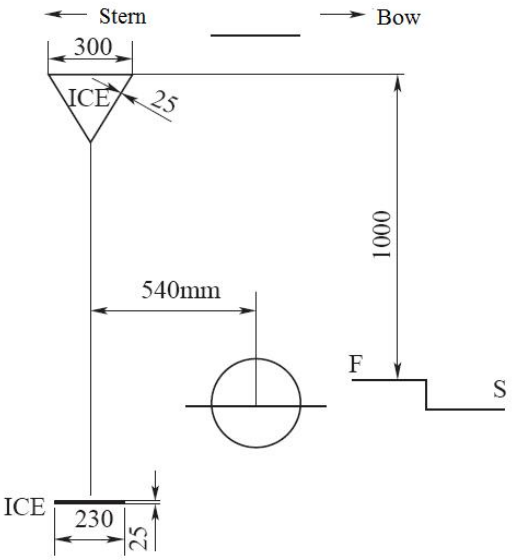


Figure 4.2.1.4 Warning Triangle and Maximum Ice Class Draught Mark (Starboard)

CHAPTER 8 BULK CARRIERS

Section 1 GENERAL PROVISIONS

8.1.1 Application

8.1.1.1 Bulk carriers are ships provided with single deck, double bottom, topside tank and hopper tank, and intended primarily to carry dry cargo in bulk, not including ore carriers.

8.1.1.2 This Chapter applies to bulk carriers as defined in 8.1.1.1 above, with the exception of those complying with 8.1.1.3 below.

8.1.1.3 CSR bulk carriers are to comply with the requirements in PART NINE of the Rules. ~~Wood chip carriers specifically designed and constructed for carrying wood chips are to comply with the requirements of CCS Guidelines for Hull Structure of Wood Chip Carriers.~~

8.1.1.4 Those not covered in this Chapter are to comply with the relevant requirements of Chapter 2 of this PART.

~~8.1.1.5 The structural arrangement of bulk carriers of 20,000 gross tonnage and over is to comply with the requirements for means of access for inspections in Section 12, Chapter 1 of this PART.~~

8.1.1.~~6~~ 5 The requirements of 8.11.5 of this Chapter are not applicable to self-unloading bulk carriers.

8.1.4 Direct strength calculation and fatigue strength assessment for hull structure

8.1.4.1 For bulk carriers of 150 m or over in length, direct calculation is to be carried out for the strength of primary structural members (both longitudinal and transverse) within cargo area in accordance with the requirements of Appendix 1 of this Chapter.

8.1.4.2 For bulk carriers of 150 m or over in length, the fatigue strength check is to be carried out for the following structural members in the cargo area in accordance with CCS Guidelines for Fatigue Strength of Ship Structure:

(1) connections of longitudinals (bottom, side, deck and inner shell) to transverse web frames;
(2) connections of longitudinals (bottom, side, deck and inner shell) to transverse bulkheads;
(3) connections of hopper tanks or inner shell to inner bottoms;
(4) connections of inner bottoms to lower stool ~~sloping~~ side plates;
(5) connections of corrugated transverse bulkheads to lower stool top plates;
(6) connections of corrugated transverse bulkheads to upper stool sloping plates;
(7) connections of frames to top side tanks and hopper tanks of single hull bulk carriers.

Section 11 is amended as follows:

Section 11 EVALUATION OF SCANTLINGS OF HATCH COVERS OF CARGO HOLDS

8.11.1 General requirements

8.11.1.1 This Section applies to bulk carriers, ore carriers and combination carriers. If hatch covers of cargo holds are to comply with the relevant requirements of 2.20.2, Chapter 2 of this PART.

Section 14 DOUBLE SIDE STRUCTURES

8.14.1 General requirements

8.14.1.1 This Section applies to the double side skin construction within the cargo area of bulk carriers.

8.14.1.2 Manholes are to be provided in transverse webs and horizontal girders. The manholes may either be round or elliptical. The long axis of an elliptical manhole is to be vertical to or along the length of the ship. Except access openings, the holes in upper and lower adjacent horizontal

girders are not to be on the same vertical line. The manhole edges are to be strengthened.

8.14.2 Structural arrangements of double side skin

8.14.2.1 Where ~~Double~~ double side skin is ~~to be~~ provided ~~throughout~~ in the cargo area, ~~and~~ the inner shell is to extend as far forward and aft as practicable at the fore and aft ends of the cargo hold and is to be effectively connected and tapered to the structures there. Supporting members within the inner shell are to be provided in double side skin instead of one side of the cargo hold.

CHAPTER 9 ROLL ON-ROLL OFF SHIPS, PASSENGER SHIPS, RO-RO PASSENGER SHIPS AND FERRIES

Section 1 GENERAL PROVISIONS

9.1.1 Application

9.1.1.1 This Chapter applies to roll on-roll off ships, passenger ships, ro-ro passenger ships and ferries defined as follows:

(1) A roll on-roll off ship is a ship specially designed and constructed for the carriage of vehicles, and cargo in pallet form or in containers, and loaded/unloaded by wheeled vehicles;

(2) A passenger ship is a ship which carries more than twelve passengers;

(3) Ro-ro passenger ship means a passenger ship with ro-ro cargo spaces or special category spaces;

(4) Ferries are the ships specially designed for the carriage of passengers (without sleeping berths) and/or vehicles engaged on regular voyages between two sides of straits or islands. Ferries carrying more than 12 passengers are ferry passenger ships.

9.1.2 Class notations

9.1.2.1 Ships complying with the requirements of this Chapter will be eligible to be assigned one of the following class notations:

(1) Roll on-roll off ships: ~~Ro/Ro~~ RO-RO Ship;

(2) Passenger ships: Passenger Ship;

(3) Ro-ro passenger ships carrying only road vehicles: ~~Ro/Ro~~ RO-RO Passenger Ship;

(4) Ro-ro passenger ships carrying railway vehicles: Train/~~Ro/Ro~~ RO-RO Passenger Ship;

(5) Ferries: Ferry;

(6) Ferry Passenger Ship.

A new Section 8 is added as follows:

Section 8 EXTERNAL GLASS BALUSTRADES

9.8.1 General

9.8.1.1 The requirements of this Section apply solely to external glass balustrades. External glass balustrades are barriers constructed with glass that are used on exposed decks.

9.8.1.2 Glass balustrades, in lieu of bulwark or guard rails (see Section 19, Chapter 2 of this PART), may be accepted on exposed decks above position 2 specified in 1.1.2.22, Section 1, Chapter 1 of this PART, except on mooring deck and in way of lifeboats and life rafts and embarkation stations.

9.8.1.3 Glass is to be manufactured in accordance with a recognized National or International Standard.

9.8.1.4 The detailed arrangement, applicable loads and structural strength calculations are to be submitted to CCS.

9.8.2 Arrangement requirements

9.8.2.1 External glass balustrades are to be not less than 1 m in height.

9.8.2.2 In general, openings (e.g. the gaps between panels or the gap between the deck and the bottom of a panel) are not to be greater than 76 mm unless required for water freeing.

9.8.2.3 If a well is formed, the necessary drainage port is to be provided. Openings for water freeing are not to be greater than 230 mm.

9.8.3 Design pressure

9.8.3.1 For the lowest weather deck, the minimum design pressure P_w of glass balustrades is to be calculated as follows:

$$P_w=9.81h, \text{ kN/m}^2$$

where: h——head in 2.17.2, Section 17, Chapter 2 of this PART.

9.8.3.2 For higher exposed decks, the minimum design pressure P_w of glass balustrades is to be calculated as follows:
(1) Below 1.7C m above the scantling draught, P_w=5kN/m^2, where C is the coefficient as specified in 2.2.3.1, Section 2, Chapter 2 of this PART;
(2) For other locations, P_w=2.5kN/m^2.

9.8.4 Minimum scantling requirements

9.8.4.1 External glass balustrades using monolithic glass are to comply with the following requirements:
(1) Minimum thickness of glass is not to be less than 6 mm;
(2) Top rail is required, with a minimum section modulus of 17 cm^3;
(3) Stanchions is to be fitted, not more than 1.5 m apart, with minimum section modulus of 20 cm^3.

9.8.4.2 External glass balustrades using laminated glass are to comply with the following requirements:
(1) Minimum thickness for each glass pane is not to be less than 4 mm;
(2) Top rail is required, with a minimum section modulus of 17 cm^3;
(3) Stanchions is to be fitted, not more than 1.5 m apart, with minimum section modulus of 20 cm^3.

9.8.4.3 The section modulus requirements in 9.8.4.1 and 9.8.4.2 above are based on steel. For other metallic materials, equivalent section modulus is to be calculated.

9.8.4.4 The glass panes are to be supported at minimum two opposite sides by metallic mounting frames. The glass panes can be fixed to the metal frame by mechanical means or adhesive. If the metal mounting frames are connected to the stanchion by bolts, there is to be no less than two force bolts on one side.

9.8.4.5 The overlap between the glass panes and metallic frames is not to be less than 10 mm or b/75 mm, whichever is greater, but not more than 20 mm, b is the breadth of the glass pane, in mm.

9.8.4.6 In public areas, laminated glass panes are required for external glass balustrades.

9.8.5 Glass thickness

9.8.5.1 For monolithic toughened glass, the thickness is to be less than the value obtained from the following formula:

$$t = b\sqrt{\beta P} / 200 \quad \text{mm}$$

where: b ——length of the shorter side of the glass, in mm;
P ——load for calculation, $P = 0.5Pw$, in kN/m^2;
P_w——design pressure, in kN/m^2, see 9.8.3 of this Section;
β ——coefficient, to be taken as follows:
1) glass with firm support on all sides:

$$\beta = 0.54A_R - 0.078A_R^2 - 0.17 \quad \text{for} \quad A_R \le 3.6$$

$$\beta = 0.7645 \quad \text{for} \quad A_R > 3.6$$

2) glass with firm support on two sides only:

$$\beta = 0.7645$$

where: A_R ——aspect ratio of rectangle window, to be taken as follows

$$A_R = a / b$$

a ——length of the longer side of the glass, in mm;
b ——length of the shorter side of the glass, in mm.

9.8.5.2 For laminated toughened glass, the equivalent thickness is to be less than the value obtained from 9.8.5.1. The equivalent thickness is calculated according to the following formula:

$$t_e = \sqrt{\sum_{i=1}^{n} t_i^2} \quad \text{mm}$$

where: n —number of glass layers;
t_i —thickness of the ith layer glass.

9.8.6 Balustrade stanchions

9.8.6.1 For balustrade stanchions below $1.7C$ m above the scantling draught, the section modulus W at the bottom is not to be less than:

$$W = 655\frac{PSl^2}{R_{eH}} \quad \text{cm}^3$$

where: S ——distance between stanchions, in m;

l ——height of the stanchion, in m;

P ——load for calculation, $P = Pw$, in kN/m^2;

P_w——design pressure, in kN/m^2, see 9.8.3 of this Section;

R_{eH}——yield stress of material, in N/mm^2.

9.8.6.2 For balustrade stanchions below $1.7C$ m above the scantling draught, the shear area A at the bottom is not to be less than:

$$A = 22.7\frac{PSl}{R_{eH}} \quad \text{cm}^2$$

where: S ——distance between stanchions, in m;

l ——height of the stanchion, in m;

P ——load for calculation, $P = Pw$, in kN/m^2;

R_{eH}——yield stress of material, in N/mm^2.

CHAPTER 12 BARGES

Section 1 GENERAL PROVISIONS

12.1.1 Application

12.1.1.1 The barges defined in this Chapter are non-self-propelled ships pushed or towed by other ships and divided into the following types:

(1) Barges carrying general dry cargo in cargo holds;

(2) Barges carrying cargo oil in cargo tanks;

(3) Shipborne barges carrying general dry cargo in cargo holds and carried on board a barge carrier;

(4) Specially designed pontoons for the carriage of cargo on deck;

(5) Barges dedicated to transporting marine engineering jacket structure and landing jacket into water by the stern for launching of jacket;

(6) Barges carrying chemicals in cargo tanks;

(7) Barges carrying liquefied gas in cargo tanks.

12.1.1.2 Where not covered by this Chapter, barges carrying cargo oil in bulk in cargo tanks are to comply with the relevant requirements of Chapter 5 or 6 of this PART according to its structural configuration; barges carrying chemicals in cargo tanks are to comply with the relevant requirements of Chapter A4, PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk; barges carrying liquefied gas in cargo tanks are to comply with the relevant requirements of Appendices 1 and 2, PART TWO of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gas in Bulk and other barges are to comply with the relevant requirements of Chapter 2 of this PART.

12.1.1.3 For pontoons regarded as one of offshore floating facilities, the structure may be in accordance with the requirements of this Chapter for pontoon barges.

12.1.2 Class notations

12.1.2.1 Barges complying with the requirements of this Chapter are eligible to be assigned one of the following class notations:

(1) Barges: the notation Barge is to be assigned to the barges as defined in 12.1.1.1(1);

(2) Oil barges: the notation Oil Barge is to be assigned to the barges as defined in 12.1.1.1(2);

(3) Shipborne barges: the notation Shipborne Barge is to be assigned to the barges as defined in 12.1.1.1(3);

(4) Pontoon barges: the notation Pontoon Barge is to be assigned to the barges as defined in 12.1.1.1(4);

(5) Launch Barge: the notation Launch Barge is to be assigned to the barges as defined in 12.1.1.1(5);

(6) Chemical Barge: the notation Chemical Barge is to be assigned to the barges as defined in 12.1.1.1(6);

(7) Gas Barge: the notation Gas Barge is to be assigned to the barges as defined in 12.1.1.1(7).

CHAPTER 20 MEMBRANE TANK LIQUEFIED GAS CARRIERS

Appendix 3 CALCULATION OF TEMPERATURE FIELD AND THERMAL STRESS

3 CALCULATION OF TEMPERATURE FIELD OF HULL

3.1 General requirements

3.1.1 The calculation results of temperature field of this Section may be used as reference for determination of hull steel grades, analysis of structural thermal stress and calculation of ~~thermal~~ daily boil off rate of cargo containment systems.

3.2 Mode of heat transfer

3.2.1 For the calculation of hull temperature field, the following modes of heat transfer are assumed:

(1) convective heat transfer between plates of hull structure and air within tanks;

(2) convective heat transfer between plates of hull structure and external air, taking into account forced convective heat exchange for any wind speed;

(3) convective heat transfer between plates of hull structure and sea water;

(4) radiation heat transfer between plates of hull structure and external environment;

(5) radiation heat transfer between shell plating and inner hull plating (when the temperature field is used for calculation of nominal ~~thermal~~ daily Boil Off Rate).

3.3 Calculation conditions

3.3.1 For different calculation purposes, the external conditions for calculation of hull temperature field are as follows:

(1) for the calculation of temperature distribution of hull structure and determination of steel grades where the primary insulation completely fails and the low-temperature cargo directly acts on the inner surface of secondary insulation;

(2) for the assessment of the efficiency of cargo containment systems of membrane tank liquefied gas carriers and calculation of nominal ~~thermal~~ daily Boil Off Rate (detailed calculation methods are given in Appendix 3B of this Chapter) where equator condition is considered (see Table 3.3.2), primary and secondary insulations are complete and low-temperature cargo directly acts on the inner surface of primary insulation;

(3) other calculation purposes deemed necessary by CCS or the owner.

CHINA CLASSIFICATION SOCIETY

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

AMENDMENTS

2024

PART THREE MACHINERY INSTALLATIONS

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CHAPTER 2 PUMPING AND PIPING SYSTEMS

Section 6 PUMPS, VALVES AND FITTINGS

2.6.2 Valves and fittings

2.6.2.5 Indicators are to be provided to show the open and closing condition of the valves, unless this can be observed in some other way; for remotely controlled valves, the remote control position is also to show the open and closing condition of the valve.

Section 8 ARRANGEMENT

2.8.1 Piping arrangement

2.8.1.3 The pipe piercing the collision bulkhead below the freeboard deck (bulkhead deck for passenger ships) is to be fitted with a ~~screw-down~~ remotely controlled valve~~, unless the use of other valves are agreed by the Administration,~~ capable of being operated from above the freeboard deck (bulkhead deck for passenger ships)~~, and the valve chest is to be secured at the bulkhead inside the forepeak and means being provided for indicating whether the valve is open or shut~~. The valve is to be normally closed. If the remote control system should fail during operation of the valve, the valve is to close automatically or be capable of being closed manually from a position above the freeboard deck (bulkhead deck for passenger ships).

~~For cargo ships, the above pipes may be provided with butterfly valves capable of being operated from above freeboard decks, supported as appropriate by valve seats or flanges.~~

The above-mentioned valves ~~may~~ are to be fitted on the forward or after side of the collision bulkhead provided that ~~the valves are readily accessible under all service conditions and~~ the space in which they are located is not a cargo space~~, and it is not necessary to fit an operating device above the freeboard deck~~.

All valves are to be of steel, bronze or other approved ductile material. Valves of ordinary cast iron or similar material are not acceptable.

CHAPTER 3 SHIP'S PIPING AND VENTILATING SYSTEMS

Section 12 ADDITIONAL REQUIREMENTS TO WATER LEVEL DETECTION AND DEWATERING OF FORWARD SPACES OF BULK CARRIERS

3.12.4 Dewatering system

3.12.4.1 On bulk carriers, the means for drainage and pumping ballast tanks forward of the collision bulkhead, and bilges of dry spaces any part of which extends forward of the foremost cargo hold (excluding dry spaces the volume of which does not exceed 0.1% of the ship's maximum displacement volume and the chain locker), are to be capable of being brought into operation from a readily accessible enclosed space, the location of which is accessible from the navigation bridge or propulsion machinery control position without traversing exposed freeboard or superstructure decks. Where pipes serving such tanks or bilges pierce the collision bulkhead, ~~as an alternative to the valve control specified in 2.8.1.3 of this PART, valve operation by means of remotely operated actuators may be accepted, provided that the location of such valve controls complies with this regulation~~ the remote control position of valves specified in 2.8.1.3 of this PART is to comply with the requirements of this regulation.

The detailed arrangements of dewatering system are to satisfy following requirements:

(1) The enclosed spaces which are required to control dewatering system are to be accessible from the navigation bridge or propulsion machinery control position without traversing exposed freeboard or superstructure decks. A position which is accessible via an under deck passage, a pipe trunk or other similar means of access is not accepted.

(2) The dewatering arrangements are to be such that any accumulated water can be drained directly by a pump or ejector.

(3) Where the piping arrangements for dewatering closed dry spaces are connected to the piping arrangements for the drainage of water ballast tanks, two non-return valves are to be provided to prevent the ingress of water into dry spaces. One of these non-return valves is to be fitted with shut-off isolation arrangement. The non-return valves are to be located in readily accessible positions. The valve operation is to comply with all the requirements of this paragraph.

(4) The valve is not to move from the demanded position in the case of failure of the control system power or actuator power.

(5) Positive indication is to be provided at the remote control station to show that the valve is fully open or closed.

(6) Bilge wells are to be provided with gratings or strainers that will prevent blockage of the dewatering system with debris.

(7) The dewatering arrangements are to be such that when they are in operation, other systems essential for the safety of the ship including fire-fighting and bilge systems remain available and ready for immediate use. The systems for normal operation of electric power supplies, propulsion and steering are not to be affected by the operation of the dewatering systems. It must also be possible to immediately start fire pumps and have a ready available supply of fire-fighting water and to be able to configure and use bilge system for any compartment when the dewatering system is in operation.

(8) The enclosure of electrical equipment for the dewatering system installed in any of the forward dry spaces are to provide protection to IPX8① for a water head equal to the height of the space in which the electrical equipment is installed for a time duration of at least 24 h.

~~(9) Local hand powered valve operation from above the freeboard deck as specified in 2.8.1.3, Chapter 2 of this PART is required. An acceptable alternative to such arrangement may be remotely operated actuators on the condition that all provisions in 3.12.4.1 of this Section are met.~~

① See IEC Publication 60529.

CHAPTER 5 PIPING SYSTEM FOR OIL TANKERS

Section 1 GENERAL PROVISIONS

5.1.7 Earthing of cargo oil pipes

5.1.7.1 Earthing and bonding of cargo tanks and piping systems for the control of static electricity is to comply with the requirements in 1.3.4.11~~2~~ of PART FOUR of the Rules.

CHAPTER 9 DIESEL ENGINES

Section 1 GENERAL PROVISIONS

9.1.12 Plans and documents

9.1.12.1 The following engine plans and documents are to be submitted for approval:

No.	Item
1	Bedplate and crankcase of welded design, with welding details and welding instructions[1,2]
2	Thrust bearing bedplate of welded design, with welding details and welding instructions[1]
3	Bedplate/oil sump welding drawings[1]
4	Frame/framebox/gearbox of welded design, with welding details and instructions[1,2]
5	Frame/framebox/gearbox, with welding drawings[1,2]
6	Crankshaft, details, each cylinder No.
7	Crankshaft, assembly, each cylinder No.
8	Crankshaft calculations (for each cylinder configuration) according to Appendix 3 of this Chapter
9	Thrust shaft or intermediate shaft (if integral with engine)
10	Shaft coupling bolts
11	Material specifications of main parts (see Table 9.2.2.1) with information on non-destructive material tests and pressure tests[3]
12	Schematic layout or other equivalent documents on the engine of starting air system, fuel oil system, lubricating oil system, cooling water system, hydraulic system (including hydraulic system for valve lift), control and safety system
13	Shielding of high pressure fuel pipes, assembly[4]
14	Construction and strength of accumulators (for electronically controlled engine)
15	Arrangement and details of the crankcase explosion relief valve (see 9.7.4)[5]
16	Calculation results for crankcase explosion relief valves (see 9.7.4)
17	Details of the type test program and the type test report[7]
18	High pressure parts for fuel oil injection system[6]
19	Oil mist detection and/or alternative alarm arrangements (see 9.7.6 and 9.7.7)
20	Details of mechanical joints of piping systems (see 2.5.3, Chapter 2 of this PART)
21	Documentation verifying compliance with inclination limits (see 1.2.1, Chapter 1 of this PART)
22	Documents as required in ~~1.1.3.2~~ Section 6, Chapter ~~1~~ 2, PART SEVEN of the Rules, as applicable

Section 2 INSPECTION, TEST AND CERTIFICATION OF DIESEL ENGINE PARTS

9.2.2 Inspection, test and certification

Summary of inspection, test and certification of diesel engine parts **Table 9.2.2.1**

Item	Parts [5)]	Material properties [1)]	Non-destructive examination [2)]	Hydraulic testing	Dimensional inspection (including surface condition)	Visual inspection (surveyor)	Applicable to engines
1	Welded bedplate	CC+M	UT+MT/PT			VT(fit-up and post-welding)	All
2	Bearing transverse girders (cast steel)	CC+M	UT+MT/PT			VT	All
3	Welded frame box	CC+M	UT+MT/PT			VT(fit-up and post-welding)	All
4	Cylinder block (cast iron)			X[4)]			>400 kW/cyl

Item	Parts [5]	Material properties [1]	Non-destructive examination [2]	Hydraulic testing	Dimensional inspection (including surface condition)	Visual inspection (surveyor)	Applicable to engines
5	Welded cylinder frames	CC+M	UT+MT/PT			VT(fit-up and post-welding)	CH
6	Engine block (grey cast iron)			X[4]			>400 kW/cyl
7	Engine block (nodular graphite cast iron)	M		X[4]			>400 kW/cyl
8	Cylinder liner	CC+M		X[4]			D>300mm
9	Cylinder head (cast iron)			X			D>300mm
10	Cylinder head (cast steel)	CC+M	UT+MT/PT	X		VT	D>300mm
11	Forged cylinder head	CC+M	UT+MT/PT	X		VT	D>300mm
12	Piston crown (cast steel)	CC+M	UT+MT/PT			VT	D>400mm
13	Forged piston crown	CC+M	UT+MT/PT			VT	D>400mm
14	Crankshaft: made in one piece	CC+M	UT+MT/PT		X	VT (random, of fillets and oil bores)	All
15	Semi-built crankshaft (Crank throw, forged main journal and journals with flange)	CC+M	UT+MT/PT		X	VT (random, of fillets and shrink fittings)	All
16	Exhaust gas valve cage			X			CH
17	Piston rod	CC+M	UT+MT/PT			VT (random)	D>400mm CH
18	Cross head	CC+M	UT+MT/PT			VT (random)	CH
19	Connecting rod with cap	CC+M	UT+MT/PT		X	VT (random, of all surfaces, in particular those shot peened)	All
20	Coupling bolts for crankshaft	CC+M	UT+MT/PT		X	VT (random, of interference fit)	All
21	Bolts and studs for main bearings and cylinder heads	CC+M	UT+MT/PT				D>300mm
22	Bolts and studs for connecting rods	CC+M	UT+MT/PT		X (thread making)		D>300mm
23	Tie rod	CC+M	UT+MT/PT		X (thread making)	VT (random)	CH
24	High pressure fuel injection pump body	CC+M		X			All
25	High pressure fuel injection valves (only for not autofretted)			X			All
26	High pressure fuel injection pipes including common fuel rail	CC+M		X for those that are not autofretted			All
27	High pressure common servo oil system	CC+M		X			All
28	Cooler, both sides [3]	CC+M		X			D>300mm

Item	Parts [5)]	Material properties [1)]	Non-destructive examination [2)]	Hydraulic testing	Dimensional inspection (including surface condition)	Visual inspection (surveyor)	Applicable to engines
29	Accumulator	CC+M		X			All engines with accumulators with a capacity of >0.5 l
30	Piping, pumps, actuators, etc. for hydraulic drive of valves, if applicable	CC+M		X			>800 kW/cyl
31	Engine driven pumps (oil, water, fuel, bilge) other than pumps referred to in item 24 and 30			X			>800 kW/cyl
32	Bearings for main, crosshead, and crankpin	CC	UT (full contact between basic material and bearing metal)		X		>800 kW/cyl

Notes:
(1) Material properties include chemical composition and mechanical properties, and also surface treatment such as surface hardening (hardness, depth and extent), peening and rolling (extent and applied force).
(2) Non-destructive examination means e.g. ultrasonic testing, crack detection by MT or PT. When certain NDE method on the finished component is impractical (for example UT for items 10/11), the NDE method can be performed at earlier appropriate stages in the production of the component, see 3.1.5.2, PART ONE of the Rules.
(3) Charge air coolers need only be tested on the water side.
(4) Hydraulic testing is also required for those parts filled with cooling water and having the function of containing the water which is in contact with the cylinder or cylinder liner.
(5) Material certification requirements for pumps and piping components are dependent on the operating pressure and temperature. The certification requirements for relevant components are to comply with the requirements of Chapter 3, PART ONE of the Rules.

Section 6 SCAVENGING AND SUPERCHARGING ARRANGEMENTS

9.6.10 Containment

9.6.10.4 Containment tests are to be performed at ~~working temperature~~ a temperature which is not lower than the maximum allowable temperature of the turbocharger to be specified by the manufacturer.

9.6.10.5 Manufacturers are to determine whether cases more critical than those defined in 9.6.10.3 and 9.6.10.4 exist with respect to containment safety. Where such a case is identified, evidence of containment safety is also to be provided for that case.

9.6.10.~~5~~6 A numerical analysis ~~(~~simulation~~)~~ such as Finite Element Method (FEM) of sufficient containment integrity of the casing based on calculations by means of a simulation model may be accepted in lieu of the practical containment test, provided that:
(1) the numerical simulation model has been tested and its suitability/accuracy has been proven by direct comparison between calculation results and the practical containment test for a reference application (reference containment test). This test is to be performed at least once by the manufacturer for acceptance of the numerical simulation method in lieu of tests;
(2) the corresponding numerical simulation for the containment is performed for the same speeds as specified for the containment test;
(3) material properties for high-speed deformations are to be applied in the numeric simulation. The correlation between normal properties and the properties at the pertinent deformation speed are to be substantiated;
(4) the design of the turbocharger regarding geometry and kinematics is similar to the

turbocharger that was used for the reference containment test. In general, totally new designs will call for a new reference containment test.

Note: A generic range means a series of turbocharger which are of the same design, but scaled to each other.

9.6.10.7 In cases where a totally new design is adopted for a turbocharger for which an application for type approval certification has been requested, new reference containment tests are to be performed.

Note: Totally new design means the principal differences between a new turbocharger and previous ones are related to geometry and kinematics. The turbochargers are to be regarded as having a totally new design if the structure and/or material of the turbocharger casings are changed, or any of, but not limited to, the following items is changed from the previous design.

(1) Maximum permissible exhaust gas temperature;
(2) Number of bearings;
(3) Number of turbine blades;
(4) Number of turbine wheels and/or compressor wheels;
(5) Direction of inlet air and/or exhaust gas (e.g., axial flow orientation, radial flow orientation);
(6) Type of the turbocharger drive (e.g., axial turbine type, radial turbine type, mixed flow turbine type).

9.6.11 Type testing

9.6.11.2 Turbochargers for the low, medium, and high-speed engines are to be subjected to at least 500 load cycles at the limits of operation. This test may be waived if the turbocharger together with the engine is subjected to this kind of low cycle testing, see Appendix 4 of this Chapter.

9.6.12 Certification

9.6.12.2 For category C, this is to be verified by means of periodic product audits of Alternative Certification Scheme (ACS, see Section 10, Chapter 3, PART ONE of the Rules).

Appendix 3 APPRAISAL OF CRANKSHAFT STRENGTH OF DIESEL ENGINES

Annex I Guidance for Evaluation of Fatigue Tests of Crankshafts

4 Full size testing

4.3 Use of results and crankshaft acceptability

In order to combine tested bending and torsion fatigue strength results in calculation of crankshaft acceptability, see 2.8 of this Appendix, the Gough-Pollard approach and the maximum principal equivalent stress formulation can be applied for the following cases:

~~Related to~~ At the crankpin ~~diameter~~ fillet:

$$Q = \left(\sqrt{\left(\frac{\sigma_{BH} + \sigma_{add}}{\sigma_{DWCT}} \right)^2 + \left(\frac{\tau_H}{\tau_{DWCT}} \right)^2} \right)^{-1}$$

~~$$Q = \left(\sqrt{\left(\frac{\sigma_{BH}}{\sigma_{DWCT}} \right)^2 + \left(\frac{\tau_H}{\tau_{DWCT}} \right)^2} \right)^{-1}$$~~

where:

σ_{DWCT}— fatigue strength by bending testing;

τ_{DWCT}— fatigue strength by torsion testing.

For other parameters see this Appendix.

Related to crankpin oil bore:

$$Q = \frac{\sigma_{DWOT}}{\sigma_v}$$

where:

σ_{DWOT}—fatigue strength by means of largest principal stress from torsion testing;

$$\sigma_v = \pm \frac{1}{3} \sigma_{BO} \left[1 + 2 \sqrt{1 + \frac{9}{4} \left(\frac{\sigma_{TO}}{\sigma_{BO}} \right)^2} \right], \quad \text{MPa}$$

~~Related to~~ At the journal ~~diameter~~ fillet:

$$Q = \left(\sqrt{\left(\frac{\sigma_{BG} + \sigma_{add}}{\sigma_{DWJT}} \right)^2 + \left(\frac{\tau_G}{\tau_{DWJT}} \right)^2} \right)^{-1}$$

~~$$Q = \left(\sqrt{\left(\frac{\sigma_{BG}}{\sigma_{DWJT}} \right)^2 + \left(\frac{\tau_G}{\tau_{DWJT}} \right)^2} \right)^{-1}$$~~

where:

σ_{DWJT}— fatigue strength by bending testing;

τ_{DWJT}— fatigue strength by torsion testing.

For other parameters see this Appendix.

In case increase in fatigue strength due to the surface treatment is considered to be similar between the above cases, it is sufficient to test only the most critical location according to the

calculation where the surface treatment had not been taken into account.

Appendix 9 TYPE TESTING PROCEDURE OF EXPLOSION RELIEF DEVICES FOR COMBUSTION AIR INLET AND EXHAUST GAS MANIFOLDS OF I.C. ENGINES USING GAS AS FUEL

1 Scope

1.1 This Appendix specifies testing procedure for explosion relief devices for combustion air inlet manifold and exhaust gas manifold of internal combustion engines using gas as fuel.

2 Definitions

2.1 Definitions addressing gas as fuel as given in Appendix 1 Safety of Low Pressure Gas Fuel Engines of this Chapter, apply.

2.2 Explosion relief device (ERD) means a device to protect a component against a determined overpressure in the event of a gas explosion. The device is fitted with a flame arrester and may be a valve, a rupture disc or other, as applicable.

3 Documents

3.1 Prior to testing, the following documentation for the ERD shall be submitted for approval:

(1) drawings (sectional drawings, details, assembly etc.);

(2) specification data sheet including operating conditions and design limits such as:

① maximum permissible operating pressure, resulting from maximum charging air or exhaust gas back pressure;

② maximum permissible operating temperature, resulting from maximum charging air or exhaust gas temperature;

③ static opening pressure, resulting from maximum charging air or exhaust gas back pressure;

④ maximum explosion pressure, i.e. maximum pressure that the device can withstand;

⑤ geometric relief area;

(3) product marking;

(4) installation and operation manual;

(5) test program;

(6) specification of test vessel.

4 Tests

4.1 Test specimens

4.1.1 The ERD used for the explosion test is to be selected from the manufacturer's production line by CCS:

(1) as a finished certified component itself, or

(2) on samples taken from earlier stages in the production of the component, when applicable.

4.1.2 If necessary, an additional ERD may need to be selected for the demonstration of the opening pressure. The selected ERD has to be clearly marked.

4.1.3 If applicable, the selected ERD shall be representative for the type range and operating conditions, for example:

(1) kind of ERD (valve, rupture disc, etc.);

(2) mounting orientation (vertical, horizontal);

(3) design of ERD (e.g., spring design, sealing);

(4) design of flame arrester;

(5) ERD intended to be fitted to the air inlet or exhaust gas manifold of an engine having a turbocharger with characteristics as per the testing conditions in 4.3.2 of this Appendix.

4.1.4 The selection of the representative ERD is subject to approval by the CCS.

4.2 Demonstration of opening pressure

The ERD which has been selected is to be subjected to a pressure test at the manufacturer's works to demonstrate that the static opening pressure is kept within the manufacturer's specification and that the ERD is air tight at the maximum permissible operating pressure for at least 30 seconds.

4.3 Explosion test

4.3.1 Test facility

4.3.1.1 The test facilities are to be accredited to a national or international standard, e.g. ISO/IEC 17025, and are to be acceptable to the CCS.

4.3.1.2 The test facilities are to be equipped so that they can perform and record explosion testing in accordance with this procedure.

4.3.1.3 The test facilities are to have equipment for controlling and measuring a methane gas concentration within a test vessel to an accuracy of ±0.1%.

4.3.1.4 The test facilities are to be capable of effective point-located ignition of a methane/air mixture.

4.3.1.5 The test facility arrangements are to be capable of measuring and recording the pressure changes throughout an explosion test at a frequency recognizing the speed of the events during an explosion (10 kHz or above).

4.3.1.6 The explosion test (Para 4.3.5 of this Appendix) is to be documented by high speed (250 frames/s or above) video recording. The video recording shall be provided with a time stamp.

4.3.2 Test vessel

4.3.2.1 The test vessel is a simplified model of the air inlet or exhaust gas manifold. The free area of the connected turbo charger (compressor or turbine wheel) is to be considered.

4.3.2.2 The test vessel shall comply with the following requirements:

(1) The shape of the test vessel is to correspond to a pipe with $L/D \geq 10$.

(2) The test vessel is to be equipped with a rupture disc at one front end to simulate the turbo charger. The relief area of the rupture disc shall be in relationship to the test vessel diameter based on turbocharger manufacturer data for an equivalent free area of compressor or turbine wheel. The opening pressure shall be ± 10% of the static opening pressure of the ERD.

(3) The volume of the test vessel is to comply with the specific relief area of the ERD of 700 cm^2/m^3 ± 15%.

(4) The test vessel is to be provided with all necessary flanges and connection to mount the ERD in the intended position, to mount a rupture disc as turbo charger simulation, to connect the Methane-air mixture supply and the measurement equipment.

(5) The ignition is to be made at the middle of the test vessel.

(6) The test vessel is to be designed to verify a homogeneous air / methane mixture inside the vessel.

(7) The test vessel is to have connections for measuring the pressure in the test vessel in at least two positions, one at the ERD and the other at the test vessel center.

(8) The test vessel is to have a design pressure of not less than the maximum explosion pressure of a stoichiometric air / methane mixture at test conditions in Para 4.3.6 of this Appendix.

(9) The test vessel configuration is subject to approval by CCS.

4.3.2.3 Typical test vessel configurations:

As shown in Figures 4.3.2.3(1) to 4.3.2.3(3), all test vessel configurations to be equipped with a rupture disc (1) (turbo charger simulation) at one front end. The ignition is in the centre of the test vessel (↯). The pressure sensors are mounted at the valve flanges (p1) and at the test vessel centre (p2). The measuring of the methane concentration to verify a homogeneous air / methane mixture can be performed at both ends of the test vessel, e.g. (c1) and (c2).



Figure 4.3.2.3(1) Configuration without ERD (flanges for ERDs closed (2))



Figure 4.3.2.3(2)　Configuration with ERD (3) mounted at the front end of the test vessel

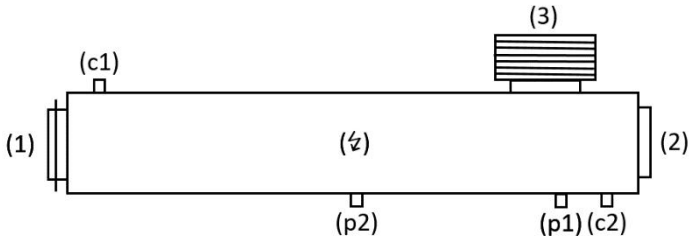

Figure 4.3.2.3(3)　Configuration with ERD (3) mounted on top of the test vessel

4.3.3　Explosion test process

4.3.3.1　The explosion testing is to be performed in two stages according to 4.3.4 and 4.3.5 of this Appendix for each ERD that is required to be approved as type tested.

4.3.3.2　The explosion testing is to be witnessed by a Society surveyor.

4.3.3.3　Calibration records for the instrumentation used to collect data are to be presented to, and reviewed by, the attending surveyor.

4.3.4　Reference test – Explosion test without ERD

4.3.4.1　Two explosion tests are to be carried out in the test vessel without ERD. The test vessel configuration is shown in Figure 4.3.2.3(1) of this Appendix.

4.3.4.2　The aim of this test is to establish a reference pressure level in the test vessel which can be used for determination of the capability of a relief valve in terms of pressure relief.

4.3.5　ERD test – Explosion test with ERD

4.3.5.1　Two explosion tests are to be carried out in the test vessel with the same ERD at the required position. If the ERD is a rupture disc with flame arrester, the rupture disc shall be replaced.

4.3.5.2　If shielding arrangements to deflect the emission of explosion combustion products at the ERD are intended, the ERD are to be tested with the shielding arrangements fitted. The test vessel configuration is shown in Figure 4.3.2.3(2) or 4.3.2.3(3).

4.3.6　Explosion test method

4.3.6.1　The test conditions shall comply with the intended use of the ERD, such as:

(1) pipe diameter;

(2) operating pressure;

(3) operating temperature;

(4) installation orientation.

4.3.6.2　All explosion tests are to be carried out using an air and methane mixture with a volumetric methane concentration of 9.5% ± 0.5%. A homogeneous air / methane mixture inside the test vessel is to be verified. The concentration of methane shall not differ by more than 0.5%.

4.3.6.3　The initial pressure in the test vessel is to be the specified maximum operating pressure of the ERD.

4.3.6.4　The initial temperature in the test vessel is to be the specified maximum operating temperature of the ERD.

4.3.6.5　If the initial pressure and/or initial temperature deviate from the design limits, the ERD manufacturer shall prove the acceptability of this deviation either using standards or generally applicable calculation methods.

4.3.6.6　The ignition is to be made using an explosive charge of 50 - 100 Joule.

4.3.6.7　Successive explosion testing to establish an ERD functionality is to be carried out as quickly as possible during stable weather conditions.

4.3.6.8　The pressure rise and decay during all explosion testing is to be recorded.

4.3.6.9 The effect of an ERD in terms of pressure relief following an explosion is ascertained from maximum pressure recorded at the centre of the test vessel during the two stages. The pressure relief within the test vessel due to the installation of an ERD is the difference between average pressure of the two explosions of the reference test (4.3.4 of this Appendix) and the average of the two explosions of the ERD test (4.3.5 of this Appendix).
4.3.6.10 For acceptance of correct functioning of the flame arrester, there is to be no indication of flame or combustion outside of the ERD during its testing (4.3.5 of this Appendix). This is to be monitored by a high-speed video camera (4.3.1 of this Appendix), for which ambient light conditions are to be considered to maximise the potential for flame/combustion detection. The use of a dark, ideally matt finish, background and an avoidance of direct light onto the video camera monitored area are recommended.
4.3.6.11 After each ERD test (4.3.5 of this Appendix), the external condition of the flame arrester to be examined for signs of damage and/or deformation that may affect the operation of the ERD.

4.4 Check of ERD components

4.4.1 After completing the explosion tests, the ERDs are to be dismantled and the condition of all components are to be ascertained and documented.

5 Test report

5.1 A complete test report has to be submitted to CCS for:
(1) the demonstration of opening pressure (4.2 of this Appendix);
(2) the explosion test (4.3 of this Appendix).
5.2 The reports shall include respective information according to the requirements in 4 of this Appendix, as applicable:
(1) test specimens;
(2) test facility, including measuring equipment and test vessel;
(3) measuring results (pressures, temperatures, flame velocities, volumetric methane concentration, ambient conditions etc.);
(4) video documentation of explosion tests;
(5) photo documentation of ERD components.

6 Assessment

6.1 To verify compliance with this requirement the assessment has to address the following:
6.1.1 Function and mechanical integrity of the ERD.
(1) After dismantling of the ERD, the flame arrester shall not show signs of damage or any deformation that may affect the operation of the ERD.
(2) If a valve is used any indication of valve sticking or uneven opening during the explosion that may affect subsequent operation of the valve has to be considered.
(3) The mechanical integrity of the ERD is proven up to a maximum explosion pressure (as average of the two explosions) of the ERD tests in 4.3.5 of this Appendix.
6.1.2 The functioning of the flame arresters is considered satisfactory if there is no indication of flame or combustion outside the ERD during the explosion tests.

7 Approval

7.1 The approval of an ERD is at the discretion of individual classification societies based on the appraisal of plans and particulars and the test report of type testing.
7.2 The type approval is valid only for an ERD fitted to the air inlet or exhaust gas manifold of an engine having a turbocharger with compressor or turbine wheel characteristics corresponding to those required in 4.3.2 of this Appendix for the test vessel rupture disc in terms of free area.

Appendix 10 SAFETY OF METHANOL/ETHANOL FUEL ENGINES

1 General Requirements

1.1 Application and scope

1.1.1 This Appendix applies to engines supplied with methanol/ethanol as fuel. This Appendix only specifies relevant requirements for the use of methanol/ethanol fuel, and in addition, methanol/ethanol fuel engines are to comply with relevant provisions of this Chapter.

1.1.2 Methanol/ethanol fuel engines can be either dual fuel engines or methanol/ethanol fuel only engines. Methanol/ethanol fuel can be introduced as follows:

(1) cylinder air inlet channel port; or

(2) cylinder direct injection.

The methanol/ethanol and air mixture in the cylinder can be ignited by the combustion of a certain amount of fuel (pilot injection) or by extraneous ignition (sparking plug).

1.1.3 This Appendix covers the following applications, but is not limited to:

(1) mechanical propulsion;

(2) generating sets intended for main propulsion and auxiliary applications;

(3) single engine or multi-engine installations.

1.1.4 For fuel only engines, applicable requirements of this Appendix can be determined in consultation with CCS.

1.2 Definitions

(1) Dual fuel engine means an engine that can burn methanol/ethanol as fuel simultaneously with liquid diesel fuel, either as pilot oil or bigger amount of liquid diesel fuel (methanol/ethanol mode), and also has the capability of running on liquid diesel fuel oil only (Diesel mode).

(2) Fuel only engine means an engine capable of operating on methanol/ethanol fuel only and not able to switch over to oil fuel operation.

(3) Methanol/ethanol fuel engine means either a methanol/ethanol fuel only engine or a dual fuel engine.

(4) Pilot fuel means the fuel oil that is injected into the cylinder to ignite the methanol/ethanol and air mixture on dual fuel engines.

(5) Methanol/ethanol fuel valve unit is a set of valves and fittings used to control the methanol/ethanol fuel supply to each engine, which is used to control or adjust the methanol/ethanol fuel supply before the engine.

(6) Recognized standards mean applicable international or national standards acceptable to CCS or standards laid down and maintained by an organisation which complies with the standards adopted by IMO and which are recognized by the Classification Society.

(7) Safety Concept is a document describing the safety philosophy with regard to methanol/ethanol as fuel. It describes how risks associated with this type of fuel are controlled under reasonably foreseeable abnormal conditions as well as possible failure scenarios and their control measures.

Note: A detailed evaluation regarding the hazard potential of injury from a possible explosion is to be carried out and reflected in the safety concept of the engine.

1.3 Plans and documents

1.3.1 The following plans and documents are to be submitted for approval with regard to the approval of gas fuel engines, in addition to those required in 9.1.12.1 of this Chapter :

No.	Plans and documents
(1)	Schematic layout or other equivalent documents of methanol/ethanol fuel system on the engine
(2)	Methanol/ethanol piping system (including double-walled arrangement where applicable)
(3)	Parts for methanol/ethanol admission system②
(4)	Arrangement of explosion relief valves (crankcase①, charge air manifold, exhaust gas manifold) as applicable
(5)	List of certified safe equipment and evidence of relevant certification
(6)	Schematic layout or other equivalent documents of fuel oil system (main and pilot fuel systems) on the

	engine (only for dual fuel engine)
(7)	Shielding of high pressure fuel pipes for pilot fuel system, assembly (only for dual fuel engine)
(8)	High pressure parts for pilot fuel oil injection system② (only for dual fuel engine)
(9)	Ignition system (only for fuel only engine)

Note:

① If required by 9.1.12 of this Chapter.
② The documentation to contain specification of pressures, pipe dimensions and materials.

1.3.2 The following plans and documents are to be submitted for information with regard to the approval of methanol/ethanol fuel engines, in addition to those required in 9.1.12.2 of this Chapter:

No.	Plans and documents
(1)	Safety concept
(2)	Report of the risk analysis①
(3)	Methanol/ethanol specification
(4)	Other plans and documents as deemed necessary by CCS

Note:
① see 1.4 of this Appendix.

1.4 Risk analysis

1.4.1 The risk analysis is to address:

(1) a failure or malfunction of any system or component involved in the methanol/ethanol operation of the engine;

(2) a fuel leakage downstream of the methanol/ethanol valve unit;

(3) the safety of the engine in case of emergency shutdown or blackout, when running on methanol/ethanol;

(4) the inter-actions between the methanol/ethanol fuel system and the engine.

Note: With regard to the scope of the risk analysis it shall be noted that failures in systems external to the engine, such as fuel storage or fuel gas supply systems, may require action from the engine control and monitoring system in the event of an alarm or fault condition. Conversely failures in these external systems may, from the vessel perspective, require additional safety actions from those required by the engine limited risk analysis.

1.4.2 The risk analysis is to be carried out in accordance with international standard ISO 31010: Risk management - Risk assessment techniques, or other recognized standards.

The required analysis is to be based on the single failure concept, which means that only one failure needs to be considered at the same time. Both detectable and non-detectable failures are to be considered. Consequences failures, i.e. failures of any component directly caused by a single failure of another component, are also to be considered.

1.4.3 The risk analysis is to:

(1) Identify all the possible failures in the concerned equipment and systems which could lead:

① to the presence of methanol/ethanol in components or locations not designed for such purpose, and/or

② to ignition, fire or explosion.

(2) Evaluate the consequences.

(3) Where necessary, identify the failure detection method.

(4) Where the risk cannot be eliminated, identify the corrective measures, e.g. in the system design such as redundancies or safety devices, monitoring or alarm provisions which permit restricted operation of the system; in the system operation, such as initiation of the redundancy or activation of an alternative mode of operation.

The results of the risk analysis are to be documented.

1.4.4 The risk analysis required for engines is to cover at least the following equipment and systems

(1) failure of the methanol/ethanol-related systems or components, in particular methanol/ethanol piping and cylinder methanol/ethanol supply valves etc. Failures of the methanol/ethanol supply components not located directly on the engine, are not to be considered in the analysis;

(2) failure of the ignition system (oil fuel pilot injection or sparking plugs);

(3) failure of the methanol/ethanol combustion or abnormal combustion (misfiring, knocking);

(4) failure of the engine monitoring, control and safety systems;

Note: Where engines incorporate electronic control systems, a failure mode and effects analysis (FMEA) is to be

carried out in accordance with 9.1.12.2(23) and Note 5 of this Chapter.
(5) changes of operating modes for dual fuel engines, including fuel oil mode, methanol/ethanol fuel mode and other working mode;
(6) hazard potential for crankcase methanol/ethanol fuel accumulation, for engines where the space below the piston is in direct communication with the crankcase.

2 Design Requirements

2.1 General principles

2.1.1 The manufacturer is to declare the methanol/ethanol fuel for the engine.
2.1.2 Components containing or likely to contain methanol/ethanol are to be designed to:
(1) minimise the risk of fire and explosion so as to demonstrate an appropriate level of safety commensurate with that of an oil-fuelled engine;
(2) mitigate the consequences of a possible explosion to a level providing a tolerable degree of residual risk, due to the strength of the component(s) to withstand the overpressure due to the ignition of leaked methanol/ethanol in the most severe condition or the fitting of suitable pressure relief devices of an approved type.
Note:
① Discharge from pressure relief devices is to prevent the passage of flame to the machinery space and be arranged such that the discharge does not endanger personnel or damage other engine components or systems.
② Relief devices are to be fitted with a flame arrester.

2.2 Design requirements

2.2.1 A means is to be provided to monitor and detect poor combustion or misfiring in the engine. In the event that it is detected, continued operation may be allowed, provided that the fuel supply to the concerned cylinder is shut off and provided that the operation of the engine with one cylinder cut-off is acceptable with respect to torsional vibrations.
Engine components through which methanol/ethanol fuel may flow are to be effectively sealed to prevent leakage of fuel into the machinery space.
2.2.2 Engine-mounted methanol/ethanol pipes are to be designed in accordance with the methanol/ethanol pipe requirements (e.g. wall thickness, allowable stress, material, pipe manufacture and connection etc.) in Chapter 3 of CCS Guidelines for Ships Using Methanol/Ethanol Fuel and the arrangement is to satisfy the following requirements:
(1) Pipes and equipment containing methanol/ethanol fuel are defined as hazardous area Zone 0. The space between the methanol/ethanol fuel piping and the wall of the outer pipe or duct is defined as hazardous area Zone 1.
(2) Methanol/ethanol fuel fuel piping is to be arranged for gas freeing and purging.
(3) The arrangement and installation of methanol/ethanol fuel piping are to provide the necessary flexibility to accommodate the sway or vibration of the engine and prevent fatigue damage at the connection between the piping and the engine.
2.2.3 Charge air system on the engine
(1) The charge air system on the engine is to be designed in accordance with 2.1.2 above.
(2) In case of a single engine installation, the engine is to be capable of operating at sufficient load to maintain power to essential consumers after opening of the pressure relief devices caused by an explosion event. Sufficient power for propulsion capability is to be maintained.
Note: Load reduction is to be considered on a case by case basis, depending on engine configuration (single or multiple) and relief mechanism (self-closing valve or bursting disk).
2.2.4 Exhaust system on the engine
(1) The exhaust gas system on the engine is to be designed in accordance with 2.1.2 above.
(2) In case of a single engine installation, the engine is to be capable of operating at sufficient load to maintain power to essential consumers after opening of the pressure relief devices caused by an explosion event. Sufficient power for propulsion capability is to be maintained.
(3) Each methanol/ethanol engine is to be provided with independent exhaust system.
2.2.5 For engines where the space below the piston is in direct communication with the crankcase, protection of crankcase is also to comply with the following requirements:
(1) Detailed assessment is to be carried out to hazard potential for crankcase gas accumulation.
(2) For maintenance purposes, a connection, or other means, are to be provided for crankcase inerting and ventilating and gas concentration measuring.

2.2.6 Control, monitoring, alarm and safety systems

(1) The engine control system is to be independent and separate from the safety system.

(2) The methanol/ethanol supply valves are to be controlled by the engine control system or by the engine methanol/ethanol demand.

(3) Combustion is to be monitored on an individual cylinder basis.

(4) If monitoring of combustion for each individual cylinder is not practicable due to engine size and design, common combustion monitoring may be accepted.

(5) Unless the risk analysis required by 1.4 of this Appendix proves otherwise, the monitoring and safety system functions for dual fuel or fuel only engines are to be provided in accordance with Table 1 of this Appendix in addition to the general monitoring and safety system functions given by the Rules.

Note: For dual fuel engines, Table 1 applies only to the methanol/ethanol mode.

Monitoring and Safety System Functions for Methanol/Ethanol Fuel Engines

Table 1

Parameter	Alarm	Automatic activation of the engine block valve	Automatic switching over to oil fuel mode①	Engine shutdown
Abnormal pressures in the methanol/ethanol fuel supply line	×	×	×	×⑤
Methanol/ethanol fuel supply systems - malfunction	×	×	×	×⑤
Pilot fuel injection or spark ignition systems - malfunction	×	×②	×	×②⑤
Exhaust gas temperature after each cylinder - high	×	×②	×	×②⑤
Exhaust gas temperature after each cylinder, deviation from average – low③	×	×②	×	×②⑤
Cylinder pressure or ignition - failure, including misfiring, knocking and unstable combustion	×	×②④	×④	×②④⑤
Oil mist concentration in crankcase or bearing temperature⑥ - high	×	×		×
Pressure in the crankcase – high④ (for engines where the space below the piston is in direct communication with the crankcase)	×	×	×	
Engine stops - any cause	×	×		
Failure of the control-actuating medium of the methanol/ethanol fuel block valve	×	×	×	

Symbol: × Applicable

Note:

① Dual fuel engine only, when running in methanol/ethanol mode.

② For fuel only engines, the block valve and the engine shutdown may not be activated in case of specific failures affecting only one cylinder, provided that the concerned cylinder can be individually shutoff and the safe operation of the engine in such conditions is demonstrated by the risk analysis.

③ Required only if necessary for the detection of misfiring.

④ In the case where the failure can be corrected by an automatic mitigation action, only the alarm may be activated. If the failure persists after a given time, the safety actions are to be activated.

⑤ Fuel only engine only.

⑥ Where required by 9.7.6 of this Chapter.

3 Specific Design Requirements

3.1 Dual fuel engines

3.1.1 The maximum continuous power that a dual fuel engine can develop in methanol/ethanol

mode may be lower than the approved MCR of the engine (i.e. in oil fuel mode), depending in particular on the methanol/ethanol quality. This maximum power available in methanol/ethanol mode and the corresponding conditions are to be stated by the engine manufacturer and demonstrated during the type test. The 110% load tests are not required in the methanol/ethanol mode of dual fuel engines when 4.1.4, 4.2.1 and 4.3 of this Appendix are implemented in accordance with the provisions in 1.3 of Appendix 4, 2.3 and 3.4 of Appendix 6 of this Chapter.

3.1.2 Dual fuel engines are to be arranged to use either oil fuel or methanol/ethanol fuel for the main fuel charge and with pilot oil fuel for ignition. The engines are to be arranged for rapid changeover from methanol/ethanol use to fuel oil use. In the case of changeover to either fuel supply, the engines are to be capable of continuous operation using the alternative fuel supply without interruption to the power supply.

Changeover to methanol/ethanol fuel operation is to be only possible at a power level and under conditions where it can be done with acceptable reliability and safety as demonstrated through testing.

Changeover from methanol/ethanol fuel operation mode to oil fuel operation mode is to be possible at all situations and power levels.

The changeover process itself from and to methanol/ethanol operation is to be automatic but manual interruption is to be possible in all cases.

In case of shut-off of the methanol/ethanol supply, the engines are to be capable of continuous operation by oil fuel only.

3.1.3 Methanol/ethanol supply to the combustion chamber is not to be possible without operation of the pilot oil injection.

Note: Pilot injection is to be monitored for example by fuel oil pressure and combustion parameters.

3.1.4 In case of an emergency stop or a normal stop, the methanol/ethanol fuel is to be automatically shut off not later than the ignition source. It is not to be possible to shut off the ignition source without first or simultaneously closing the fuel supply to each cylinder or to the complete engine.

3.2 Fuel only engines

3.2.1 In case of ignition failure of the ignition system, the engine is to be shut down except if this failure is limited to one cylinder, subject to immediate shut off of the cylinder methanol/ethanol supply and provided that the safe operation of the engine is substantiated by the risk analysis and by tests.

3.2.2 In case of an emergency stop or a normal stop, the methanol/ethanol fuel is to be automatically shut off not later than the ignition source. It is not to be possible to shut off the ignition source without first or simultaneously closing the fuel supply to each cylinder or to the complete engine.

4 Type Testing, Factory Acceptance Tests and Shipboard Trials

4.1 Type Testing

4.1.1 Type approval of dual fuel and fuel only engines is to be carried out in accordance with 9.10.1 and 9.10.2 of this Chapter, taking into account the additional requirements below.

4.1.2 In addition to the criteria given in 9.1.2.1(1) of this Chapter, the type of engine is defined by the following:

(1) methanol/ethanol admission method (direct cylinder injection, cylinder intake channel injection etc.);

(2) methanol/ethanol supply valve operation (mechanical or electronically controlled);

(3) ignition system (pilot injection, spark ignition etc.);

(4) ignition system (mechanical or electronically controlled).

4.1.3 In addition to the safety precautions mentioned in 1.2, Appendix 4 of this Chapter, measures to verify that methanol/ethanol fuel piping on engine is gas tight and liquid tight are to be carried out prior to start-up of the engine.

4.1.4 The type testing of the engine is to be carried out in accordance with 1.3, Appendix 4 of this Chapter.

For dual fuel engines, the load tests are to be carried out in methanol/ethanol mode at the different percentages of the maximum power available in methanol/ethanol mode (see 3.1.1 of this

Appendix).

4.1.5 In addition to the measurements and records required in 1.4, Appendix 4 of this Chapter, the following engine data are to be measured and recorded:

(1) Each fuel index for methanol/ethanol and diesel as applicable (or equivalent reading).

(2) Methanol/ethanol pressure and temperature at the inlet of the methanol/ethanol manifold.

Additional measurements may be required in connection with the design assessment.

4.1.6 In addition to internal tests required in 2.1, Appendix 4 of this Chapter, the following conditions are to be tested:

(1) dual fuel engines are to run the load points in both methanol/ethanol and diesel modes (with and without pilot injection in service) as found applicable for the engine type.

(2) for dual fuel engines, switch over between methanol/ethanol and diesel modes are to be tested at different loads.

4.1.7 Witnessed tests are to be carried out in accordance with 2.2, Appendix 4 of this Chapter. The following requirements are to be considered:

(1) The following test conditions are to be considered for dual fuel engine during the load test:

① All load points must be run in both methanol/ethanol and diesel modes that apply for the engine type as defined by the engine designer. This also applies to the overspeed test.

(2) The following items are to be carried out for functional test:

① For dual fuel engines, the lowest specified speed is to be verified in diesel mode and methanol/ethanol mode.

② For dual fuel engines, switch over between methanol/ethanol and diesel modes are to be tested at different loads.

③ The efficiency of the ventilation arrangement of the double walled piping system is to be verified.

④ Simulation of a methanol/ethanol leakage in way of a cylinder methanol/ethanol supply valve.

Engines intended to produce electrical power are to be tested as follows:

① Capability to take sudden load and loss of load in accordance with the provisions of 9.7.10.1 of this Chapter.

Notes:

1. For dual fuel engines, switchover to oil fuel during the test is acceptable.

2. Application of electrical load in more than 2 load steps can be permitted in the conditions stated in 9.7.10.1 of this Chapter.

(3) Fuel only and dual fuel engines are to undergo integration tests to verify that the response of the complete mechanical, hydraulic and electronic engine system is as predicted for all intended operational modes. The scope of these tests is to be agreed with CCS for selected cases based on the risk analysis, and is at least to include the following incidents:

① Failure of ignition (spark ignition or pilot injection systems), both for one cylinder unit and common system failure;

② Failure of a cylinder methanol/ethanol supply valve;

③ Failure of the combustion (to be detected by e.g. misfiring, knocking, exhaust temperature deviation, etc.);

④ Abnormal methanol/ethanol pressure;

⑤ Abnormal methanol/ethanol temperature*.

Note*: This test may be carried out using a simulation signal of the temperature.

4.1.8 Component inspection is to be carried out in accordance with the provisions of 2.3, Appendix 4 of this Chapter. The components to be inspected after the test run are to include also:

(1) methanol/ethanol supply valve;

(2) pilot fuel injection valve/spark igniter.

4.2 Factory acceptance test

4.2.1 Factory acceptance tests are to be carried out in accordance with Appendix 6 of this Chapter, taking into account the additional requirements below.

For dual fuel engines, the load tests referred to in 2.3, Appendix 6 of this Chapter are to be carried out in methanol/ethanol mode at the different percentages of the maximum power available in methanol/ethanol mode (see 3.1.1 of this Appendix).

4.2.2 In addition to the safety precautions mentioned in 1.1, Appendix 6 of this Chapter , measures to verify that methanol/ethanol fuel piping on engine is gas tight and liquid tight are to be carried out prior to start-up of the engine.

4.2.3 In addition to the records required in 2.2, Appendix 6 of this Chapter, the following engine data are to be recorded:

(1) Fuel index, both methanol/ethanol and diesel as applicable (or equivalent reading);

(2) Methanol/ethanol pressure and temperature at the inlet of the methanol/ethanol manifold.

4.2.4 Test loads for various engine applications are given in 2.3, Appendix 6 of this Chapter. Dual fuel engines are to be tested in both diesel and methanol/ethanol pressure and temperature at the inlet of the methanol/ethanol manifold mode as found applicable. In addition the scope of the trials may be expanded depending on the engine application, service experience, or other relevant reasons.

4.2.5 Methanol/ethanol fuel engines are to undergo integration tests to verify that the response of the complete mechanical, hydraulic and electronic engine system is as predicted for all intended operational modes.

The scope of these tests is to be agreed with CCS for selected cases based on the risk analysis, and is at least to include the following incidents:

① Failure of ignition (spark ignition or pilot injection systems), both for one cylinder unit and common system failure;

② Failure of a cylinder methanol/ethanol supply valve;

③ Failure of the combustion (to be detected by e.g. misfiring, knocking, exhaust temperature deviation, etc.);

④ Abnormal methanol/ethanol pressure;

⑤ Abnormal methanol/ethanol temperature.

Note: The above tests may be carried out using simulation or other alternative methods, subject to special consideration by CCS.

4.3 Shipboard trials

4.3.1 Shipboard trials are to be carried out in accordance with the provisions of Appendix 6 of this Chapter. For dual fuel engines, the test loads are to be carried out in all operating modes (methanol/ethanol mode, diesel mode, etc.). For dual fuel engines, when load tests specified in 3.4, Appendix 6 of this Chapter are carried out in methanol/ethanol mode, test loads are taken as each percentage of the maximum output power in methanol/ethanol mode (see 3.1.1 of this Appendix).

CHAPTER 10 TRANSMISSION GEARING

Appendix 1 APPRAISAL OF GEAR STRENGTH

Values of K_1 **Table 1.5.3.3**

Accuracy grades①						
Gear type	3	4	5	6	7	8
spur gears	2.1	3.9	7.5	14.9	26.8	39.1
helical gears	1.9	3.5	6.7	13.3	23.9	34.8

① The accuracy grades are to be according to ISO 1328-~~2~~1:2013. In case of mating gears with different accuracy grades, the grade corresponding to the lower accuracy is to be used.

CHAPTER 12 SHAFT VIBRATION AND ALIGNMENT

Section 2 TORSIONAL VIBRATION

12.2.4 Additional requirements for generators

12.2.4.1 In the case of alternating current generators, the resultant vibration amplitudes at the rotor are not to exceed 3.5° electrical degrees under rated load working conditions. Where the inverter provided with rectification can ensure the output of stable power supply to the grid for normal use, the electrical degree is not limited to 3.5°.

Section 3 AXIAL VIBRATION

12.3.1 General requirements

12.3.1.2 Documents of axial vibration characteristics of the ~~large-sized~~ slow-speed two-stroke diesel engine direct propulsion shafting systems and of the turbine propulsion shafting systems are to be submitted for approval.

CHAPTER 14 STRENGTHENING FOR NAVIGATION IN ICE

Section 1 GENERAL PROVISIONS

14.1.1 General requirements

14.1.1.3 The strengthening requirements for ice notations B1*, B1, B2 and B3 correspond respectively to the relevant provisions in the Finish-Swedish Ice Class Rules, ~~2017~~2021, as follows:

B1* — IA Super;
B1 — IA;
B2 — IB;
B3 — IC.

Section 2 PROPULSION MACHINERY

14.2.5 Design loads

14.2.5.3 Torsional design loads

(3) Design torque for non-resonant shaft lines

~~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 speed (bollard condition), the following estimation of the maximum torque can be used.~~

If there is no bladed secondary torsional resonance within a speed range of 20% above or below the maximum operating speed under bollard conditions (i.e., the nominal speed n_n at maximum sustained power free running without ice) and within the usual speed range, the maximum response torque estimated by the equation below can be used.

Directly coupled two stroke diesel engines without flexible coupling

$$Q_{peak} = Q_{e\max} + Q_{\text{vib}} + Q_{\max}\frac{I_e}{I_t} \qquad \text{kNm}$$

and other plants

$$Q_{peak} = Q_{e\max} + Q_{\max}\frac{I_e}{I_t} \qquad \text{kNm}$$

where all the torques and the inertia moments are to be converted to equivalent values at the rotation speed of the component being examined.

If the maximum torque Q_{emax} is unknown, it is to be taken from Table 14.2.5.3(3):

(4) Design torque for shaft lines having resonances

~~If there is 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)~~ If there is bladed secondary torsional resonance within a speed range of 20% above or below the maximum operating speed under bollard conditions (i.e., the nominal speed n_n at maximum sustained power free running without ice) and within the usual speed range, 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.

1. Time domain calculation for estimated milling sequence excitation
2. 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.

14.2.6 Design

14.2.6.2 Propeller blade

(3) Fatigue design of propeller blade

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 is to be calculated and the acceptability criterion for fatigue should be fulfilled as given in this paragraph. The equivalent stress cycles are specified as 1×10^8.

For materials with a two-slope SN curve (see Figure 14.2.6.2(3)-1), if the following criterion is fulfilled, fatigue calculations according to this Chapter are not required:

$$\sigma_{\exp} \geq B_1 \cdot \sigma_{ref2}^{B_2} \cdot \log\left(N_{ice}\right)^{B_3}$$

where coefficients B_1, B_2 and B_3 for open and ducted propellers are given in the Table 14.2.6.2(3).

Values of B_1, B_2 and B_3 **Table 14.2.6.2(3)**

Coefficient	Open propeller	Ducted propeller
B_1	~~0.00246~~0.00328	~~0.00167~~0.00223
B_2	~~0.947~~1.0076	~~0.956~~1.0071
B_3	2.101	~~2.470~~2.471

CHINA CLASSIFICATION SOCIETY

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

AMENDMENTS

2024

PART FOUR ELECTRICAL INSTALLATIONS

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CHAPTER 2 ELECTRICAL INSTALLATIONS IN SHIPS

Section 17 ADDITIONAL REQUIREMENTS FOR SHIPS CARRYING VEHICLES WITH FUEL IN THEIR TANKS FOR THEIR OWN PROPULSION

2.17.2 Carriage of vehicles in special category spaces above the bulkhead deck of passenger ships and in closed ro-ro spaces and closed vehicle spaces (with not less than 10 air changes per hour) of passenger ships and cargo ships

2.17.3 Carriage of vehicles in special category spaces below the bulkhead deck of passenger ships and in closed ro-ro spaces and closed vehicle spaces (with less than 10 air changes per hour) of passenger ships and cargo ships

2.17.4 Carriage of vehicles ~~in cargo spaces of passenger ships and cargo ships~~ in cargo spaces other than vehicle, special category or ro-ro spaces

2.17.4.1 ~~Where vehicles are carried in cargo spaces of passenger ships, the electrical equipment fitted within such spaces and their exhaust ventilation trunking are to be of certified safe type.~~ On all ships, when vehicles with fuel in their tanks for their own propulsion are carried in cargo spaces other than vehicle, special category or ro-ro spaces, the requirements of SOLAS regulation II-2/20.2.1.2 are to be complied with.

~~2.17.4.2 Where vehicles are carried in cargo spaces of cargo ships, the electrical equipment fitted within such spaces and their exhaust ventilation trunking are to be of certified safe type. For spaces with not less than 10 air changes per hour and other than those within a height of 450 mm above the vehicle deck or vehicle platform, where electrical equipment other than that of certified safe type is fitted, the enclosure of which is to be of at least IP55 type.~~

2.17.5.1 For the electrical equipment fitted in the area, the degrees of protection by enclosures are to comply with the relevant requirements of Table 1.3.2.2 of this PART.

Section 18 ADDITIONAL REQUIREMENTS FOR SHIPS CARRYING DANGEROUS GOODS

2.18.3.4 Where ammonium nitrate (UN1942) and ammonium nitrate fertilizer (UN2067) of class 5.1, ammonium nitrate fertilizer (UN2071) of class 9, ammonium nitrate-based fertilizer and ammonium nitrate-based fertilizer MHB ~~(non-hazardous)~~ are to be carried, all electrical equipment, other than that of ~~intrinsically~~ certified safe type, in hazardous areas are to be electrically disconnected from the power source in accordance with the requirements of 2.18.8.1.

2.18.5.1 Where solid dangerous goods in bulk (solid dangerous goods capable of creating explosive gas atmosphere) and MHB are to be carried, electrical equipment of certified safe type installed in hazardous areas are to be in compliance with the minimum requirements of Table 2.18.5.1.

Characteristics of Electrical Equipment for Use in Hazardous Areas (Example)

Table 2.18.5.1

Dangerous goods	IMO class	Dominant risk①	Protection against explosive dust atmosphere	Protection against explosive gas atmosphere	
			Degree of protection	Explosion group	Temperature class
Aluminium ferrosilicon powder UN1395	4.3	H_2	—	IIC	T2
Aluminium silicon powder	4.3	H_2	—	IIC	T2

uncoated UN1398					
Aluminium smelting by-products or Aluminium remelting by-products UN3170	4.3	H2	—	IIC	T2
Aluminium smelting/remelting by-products, processed	MHB(WF and/or WT and/or CR)	H2	—	IIC	T1
Ammonium nitrate UN1942	5.1	~~Combustible~~ —	—	~~Intrinsically safe equipment~~ —	T4
Ammonium nitrate based fertilizer UN2067	5.1	~~Combustible~~ —	—	~~Intrinsically safe equipment~~ —	T4
Ammonium nitrate based fertilizer UN2071	9	—	—	~~Intrinsically safe equipment~~ —	T4
Ammonium nitrate based fertilizer ~~(non-hazardous)~~	-	—	—	~~Intrinsically safe equipment~~ —	T4
Ammonium nitrate-based fertilizer MHB	MHB(OH)	—	—	—	T4
Brown coal briquettes	MHB (CB and/or SH)	Dust, methane	IP55	IIA	T4
Coal	MHB (CB and/or SH and/or WF and/or CR)	Dust, methane	IP55	IIA	T4
Direct reduced iron (A)	MHB (SH and/or WF)	H_2	—	IIC	T2
Direct reduced iron (B)	MHB (SH and/or WF)	H_2	—	IIC	T2
Direct reduced iron (C)	MHB (SH and/or WF)	H_2	—	IIC	T2
Ferrophosphorus (including briquettes)	MHB (WF and/or WT)	H_2	—	IIC	T1
Ferrosilicon, with at least 25% but less than 30% silicon, or 90% or more silicon (including briquettes)	MHB (WF and/or WT)	H_2	—	IIC	T1
Ferrosilicon UN1408, with 30% or more but less than 90% silicon(including briquettes)	4.3	H_2	—	IIC	T1
Iron oxide, spent or sponge iron, spent UN1376	4.2	Dust	IP55	IIA	T2
Seed cake, containing vegetable oil UN1386	4.2	Hexane	—	IIA	T3
Seed cake UN2217	4.2	Hexane	—	IIA	T3
Seed cakes and other residues of processed oily vegetables	MHB (SH)	Dust	IP55	IIA	T3
Silicomanganese (low-carbon)	MHB(WF and/or WT and/or TX)	H_2	—	IIC	T1
Solidified fuels recycled from paper and plastics	MHB (SH)	Combustible	IP55	—	T3
Sugarcane biomass pellets	MHB(CB and/or WF and/or WT and/or OH)	Combustible, dust	IP55	IIA	T3
Sulphur UN1350 (crushed lump and coarse grained)	4.1	Combustible, dust	IP55	—	T4
Zinc Ashes UN1435	4.3	H_2	—	IIC	T2

Wood torrefied	MHB(CB and/or SH and/or CR)	Combustible, dust	IP55	—	T3
Wood pellets, containing additives and/or binders	MHB(WF)	Dust	IP55	—	T3
Wood pellets, not containing any additives and/or binders	MHB(OH)	Dust	IP55	—	T3

Note: ① The term "risk" relates only to the risk of explosion due to dangerous goods and electrical appliances.

Section 19 ~~ADDITIONAL REQUIREMENTS FOR BULK CARRIERS~~ DETECTION OF WATER INGRESS IN CARGO HOLDS

2.19.1 Application

2.19.1.1 This Section applies to all bulk carriers, ~~and~~ single hold cargo ships other than bulk carriers and multiple hold cargo ships other than bulk carriers and tankers of 500 gross tonnage and upwards engaged on international voyages. Bulk carriers mentioned in this Section are bulk carriers as defined in SOLAS Chapter XII.

2.19.2 Water level detector system

2.19.2.1 Water level detectors installed in cargo holds, ballast tanks and dry spaces are to comply with the relevant requirements of acceptable standards① in addition to the provisions of this Section, and are to be subject to type approval.

2.19.2.2 All bulk carriers to which this Section is applicable are to be fitted with water level detectors and the following requirements are to be satisfied:

(1) Audible and visual alarms are to be given in each cargo hold, one when the water level above the inner bottom in any hold reaches a height of 0.5 m and another at a height not less than 15% of the depth of the cargo hold but not more than 2.0 m. On bulk carriers to which SOLAS regulation XII/9.2 applies, detectors with only the latter alarm need be installed. ~~The water level detectors are to be fitted in compliance with the provisions of 2.19.2.11 of this section.~~ For cargo holds which are used for water ballast, an alarm overriding device may be installed. The audible and visual alarms are to clearly discriminate between the two different water levels detected in each hold.

~~2.19.2.3~~(2) In any ballast tank forward of the collision bulkhead required by SOLAS regulation II-1/1~~1~~2, an audible and visual alarm is to be given when the liquid in the tank reaches a level not exceeding 10% of the tank capacity. An alarm overriding device may be installed to be activated when the tank is in use.

~~2.19.2.4~~(3) In any dry or void space other than a chain cable locker, any part of which extends forward of the foremost cargo hold, an audible and visual alarm is to be given at a water level of 0.1 m above the deck. Such alarms need not be provided in enclosed spaces the volume of which does not exceed 0.1% of the ship's maximum displacement volume.

2.19.2.3 Single hold cargo ships having a length of less than 80 m and a single cargo hold below the freeboard deck or cargo holds below the freeboard deck which are not separated by at least one bulkhead made watertight up to that deck are to be fitted in such space or spaces with water level detectors, which are to give an audible and visual alarm at the navigation bridge when the water level above the inner bottom in the cargo hold reaches a height of not less than 0.3 m, and another when such level reaches not more than 15% of the mean depth of the cargo hold. The audible and visual alarms are to clearly discriminate between the two different water levels detected in each hold. The water level detectors required by this paragraph need not be fitted in ships having watertight side compartments each side of the cargo hold length extending vertically at least from inner bottom to freeboard deck.

2.19.2.4 Multiple hold cargo ships other than bulk carriers and tankers are to be fitted with water level detectors in each cargo hold intended for dry cargoes. Water level detectors are not required for cargo holds located entirely above the freeboard deck. The following requirements are to be satisfied:

(1) Giving audible and visual alarms at the navigation bridge, one when the water level above the bottom of the cargo hold reaches a height of not less than 0.3 m, and another at a height not less than 15% of the depth of the cargo hold but not more than 2 m. For cargo holds which are occasionally used for water

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① See resolution MSC.188(79)/Rev.2 adopted by IMO – ~~Performance Standards for Water Level Detectors on Bulk Carriers and Single Hold Cargo Ships Other than Bulk Carriers~~ Performance standards for water level detectors on ships subject to SOLAS regulations II-1/25, II-1/25-1 and XII/12.

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ballast, an alarm overriding device may be installed. The visual alarms are to clearly discriminate between the two different water levels detected in each hold.

(2) As an alternative to the water level detector at a height of not less than 0.3 m as per (1) of this paragraph, a bilge level sensor serving the bilge pumping arrangements required by SOLAS regulation II-1/35-1 and installed in the cargo hold bilge wells or other suitable location is considered acceptable, subject to:

① the fitting of the bilge level sensor at a height of not less than 0.3 m at the aft end of the cargo hold;

② the bilge level sensor giving audible and visual alarm at the navigation bridge which is clearly distinctive from the alarm given by the other water level detector fitted in the cargo hold.

2.19.2.5 The audible and visual alarms specified in 2.19.2.2 to 2.19.2.4 are to be located on the navigation bridge.

2.19.2.6 Detection equipment is to be suitably corrosion resistant for all intended cargoes. Detection equipment includes the sensor and any filter and protection arrangements for the detector installed in cargo holds and other spaces.

Equipment which is to be used in refrigerated cargo spaces is to satisfy the requirements of a suitable industry standard covering the relevant service temperatures.

2.19.2.7 Detection equipment is to be electrical equipment of a certified safe type complying with the requirements of 1.3.3.1, Chapter 1 of this PART. The explosion groups and temperature classes are determined in accordance with carried cargoes. The part of the water level detector system which has circuitry in the cargo area is to be of an intrinsically safe type and explosion protection type ~~complying with ib class~~ as specified in acceptable standards①. Where a ship is designed only for the carriage of cargoes that cannot create a combustible or explosive atmosphere, then the requirement for ~~intrinsically safe circuitry~~ electrical equipment of certified safe type may not be mandatory provided that this is specified in the operation manual of the water level detector system, the ship's cargo book and the certificate relating to the carriage of specially identified cargoes.

2.19.2.8 ~~Where intrinsically safe equipment is installed in cargo spaces, it is to be of a certified safe type complying with 1.3.3.1 of this PART. The explosion group and the maximum surface temperature of the equipment are to be appropriate for the combustible dust and/or explosive gas likely to be encountered.~~ Where the characteristics of the dust and gas are unknown, the explosion group of electrical equipment used in dust and/or gas hazardous space is not to be lower than IIIC and/or IIC ~~the explosion group is not to be lower than IIC~~ and the temperature class is to be T6 ~~or the maximum surface temperature is not to exceed 85℃~~.

2.19.2.9 The electrical power supply for the water level detector system is to comply with the following:

(1) It is to be supplied from two independent sources of electrical power:

① the main source of electrical power and the emergency source of electrical power; or

② the main source of electrical power, and a continuously charged dedicated accumulator battery of which the arrangement, location and endurance for power supply (18 h) are equivalent to those of the emergency source of electrical power. The battery may be an internal battery of the water level detector system;

(2) The changeover of supply from one source of electrical power to another need not be integrated into the water level detector system;

(3) Failure of any of the two electrical power supplies is to be indicated by an alarm. ~~Failure of the primary electrical power supply is to be indicated by an alarm. Where batteries are used for the secondary power supply, failure alarms for both power supplies are to be provided.~~

2.19.2.10 The degree of protection provided by enclosures for electrical components installed in cargo holds, ballast tanks and dry spaces are to satisfy the requirements of IP 68.

2.19.2.11 Where the cargo hold is used as water ballast, sensors provided in the hold are to be suitable for the maximum pressure that might occur in the hold.

2.19.3 Installation requirements for water level detectors

2.19.3.1 ~~Installation requirements for water level detectors (1)~~ The sensors are to be located in a protected position that is in communication with the specified part of the cargo hold (usually the aft part) such that the position of the sensor detects the level that is representative of the levels in the actual hold space. These sensors are to be located either as close to the centerline as practicable, or at both the port and starboard sides of the cargo hold.

~~For ships the keels of which are laid on or after 1 July 2004, t~~The sensors are to be placed at a distance not exceeding 1 corrugation spacing or 1 bulkhead vertical stiffener spacing from the centerline, otherwise

① See IEC publication 60079.

sensors are to be located at both the port and starboard sides of the cargo hold.
~~For ships the keels of which are laid before 1 July 2004, the sensors are to be placed at a distance not exceeding or equal to *B*/6 (*B* being breadth of the ship) from the centerline, otherwise sensors are to be located at both the port and starboard sides of the cargo hold.~~
2.19.3.2 The sensors are to be located at the specified height. These heights are to be measured from the upper surface of the inner bottom. For bilge level sensors in 2.19.2.4(2) of this Section, if the bottom of the bilge well is below the upper surface of the inner bottom, the heights of those sensors are to be measured from the bottom of the bilge well.
2.19.3.3 When a lining or insulation is fitted, if the lining or insulation is not constructed to a watertight standard, then the height is to be measured from the upper surface of the inner bottom. If the lining or insulation is tested as watertight, then the heights may be measured from the upper surface of the lining/insulation.
2.19.3.4~~(2)~~ The detector installation is not to inhibit the use of any sounding pipe or other water level gauging device for cargo holds or other spaces.
2.19.3.5~~(3)~~ Detectors and equipment are to be installed where they are accessible for survey, maintenance and repair.
2.19.3.6~~(4)~~ Any filter element fitted to detectors is to be capable of being cleaned before loading.
2.19.3.7~~(5)~~ Electrical cables and any associated equipment installed in cargo holds are to be protected from damage by cargoes or mechanical handling equipment associated with bulk carrier operations, such as in tubes of robust construction or in similar protected locations.
2.19.3.8~~(6)~~ Any change/modification to the ship's structure, electrical systems or piping systems that involves cutting and/or welding are to be approved by CCS prior to commencement of work.

CHAPTER 3 CONSTRUCTION AND TESTING OF ELECTRICAL EQUIPMENT

Section 2 ROTATING MACHINES

3.2.9.3 Items for type and routine tests of the electrical machines are to be in compliance with Table 3.2.9.3. Test requirements may differ for shaft generators, special purpose machines and machines of novel construction.

Items for Type and Routine Tests of Electric Machines **Table 3.2.9.3**

No	Tests	AC Generators		Motors	
		Type test①	Routine test②	Type test①	Routine test②
1	Examination of the technical documentation, as appropriate and visual inspection	×	×	×	×
2	Insulation resistance measurement	×	×	×	×
3	Winding resistance measurement	×	×	×	×
4	Verification of the voltage regulation system	×	×③		
5	Rated load test and temperature rise measurements	×		×	
6	Overload/overcurrent test	×	×④	×	×④
7	Verification of steady short circuit conditions⑤	×			
8	Overspeed test	×	×	×⑥	×⑥
9	Dielectric strength test	×	×	×	×
10	No-load test	×	×	×	×
11	Verification of degree of protection	×		×	
12	Verification of bearings	×	×	×	×

Notes: ① Type tests on prototype machine or tests on at least the first batch of machines.
② The report of machines routine tested is to contain the manufacturer's serial number of the machine which has been type tested and the test result~~, the certificate number of type approval and the test result~~.
③ Only functional test of voltage regulator system.
④ Only applicable for machines of essential services rated above 100 kW.
⑤ Verification of steady short circuit condition applies to synchronous generators only.
⑥ Not applicable for squirrel cage motors.

Section 3 SWITCHGEAR ASSEMBLIES

3.3.5.4 Where circuit breakers are operated by a power operating device, a hand operated mechanism is to be provided to operate the circuit breaker in case of failure of the electrical driven gear ~~and is to be operated at the front of panels.~~ For AC main switchboard of less than 1 kV in rated voltage, the generator circuit breaker is to be operated at the front of panels without opening the panel.

Section 6 POWER AND LIGHTING TRANSFORMERS

3.6.6.1 Performance tests (winding resistance measurement, voltage ratio measurement and check of phase displacement, short-circuit impedance and load loss measurement, no-load loss and no-load current measurement, etc.) are to to be carried out to all transformers at the manufacturer and in addition to the tests in 3.6.6.2 to 3.6.6.~~5~~6 of this Section as a minimum, relevant tests are to be carried out in accordance with the requirements of IEC 60076 series publication and equivalent standards ~~are at least to be carried out~~

~~to all transformers at the manufacturer~~. However, the test required in 3.6.6.2 may only be carried out to the first product for batch products of the same type and specification.

~~3.6.6.6 Voltage regulation test: Transformers are to be subjected to voltage regulation test and the requirements of 3.6.3.1 of this Section are to be complied with. If the test is impracticable at the manufacturer, it may be waived, subject to agreement of CCS.~~
~~3.6.6.7 Short-circuit test: Short-circuit test is to be carried out as necessary and in accordance with the requirements of 3.6.5.1 of this Section.~~

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PART FIVE REFRIGERATED CARGO INSTALLATIONS

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CHAPTER 2 REFRIGERATING PLANT

Section 4 CONTROL, ALARM AND SAFETY SYSTEMS

2.4.3 Safety

2.4.3.1 The refrigerating plant is to be provided with safety systems to automatically shut down the compressors in the following events:

(2) excessively high pressure at the delivery side of compressors ~~and excessively high pressure in condensers~~;

Section 6 SAFETY DEVICES

2.6.1 Relief valves and safety valves

2.6.1.4 All pressure vessels or other components of refrigerant systems which could become filled with liquid refrigerant and isolated are to be provided with safety discs and / or relief valves, the discharge being led to a safe place above deck. When the safety disc is fitted in front of the relief valve, the back of the safety disc is to be provided with a bulwark to ensure the function of the relief valve. When the safety disc is fitted behind the relief valve, a pressure gauge indicating the intermediate pressure is to be fitted between the relief valve and the safety disc.

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PART SIX FIRE PROTECTION, DETECTION AND EXTINCTION

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CHAPTER 2 FIRE EXTINCTION SYSTEMS

Section 2 FIXED GAS FIRE-EXTINGUISHING SYSTEMS

2.2.1 General requirements

2.2.1.3 ~~Stations~~ Storage rooms of extinguishing medium used for all fixed gas fire-extinguishing systems are to comply with the following requirements:

(1) ~~Stations~~ Storage rooms of extinguishing medium are to be used only for the storage of containers and other components and parts of the systems.

(2) ~~Stations~~ Storage rooms of extinguishing medium are to be provided with direct communications to the bridge or control station.

(3) The key to the ~~container storage rooms or control stations~~ storage rooms of extinguishing medium is to be stowed in a box with glass cover which is to be situated in an easily accessible and conspicuous position near the door.

(4) In each s~~tation~~ storage room of extinguishing medium there is to be displayed a clear and permanent schematic diagram showing the arrangement of the containers, manifold, piping and fittings relating to the release of extinguishing medium, together with the concise instructions for the operation of the system.

CHAPTER 3 FIRE SAFETY MEASURES

Section 4 MISCELLANEOUS

~~**3.4.12 Fire testing of flexible pipes**~~

~~3.4.12.1 Flexible pipes with end attachments which are required to be of fire-resisting materials, are to be subject to a fire for 30 min at a temperature of 800°C, while water at the maximum service pressure is circulated inside the pipe. The temperature of the water at the outlet is not to be less than 80°C. No leak should be recorded during or after the test.~~

~~3.4.12.2 An alternative to that required in 3.4.12.1 is to fire test the flexible pipe with flowing water at a pressure of at least 0.5 MPa and subsequent pressure test to twice the design pressure.~~

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PART SEVEN AUTOMATION SYSTEMS

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CHAPTER 2 BASIC REQUIREMENTS

Section 6 COMPUTER BASED SYSTEMS

The whole section is replaced by the following:

2.6.1 General requirements

2.6.1.1 This Section applies to design, construction, commissioning and maintenance of computer-based systems where they depend on software for the proper achievement of their functions. This Section applies to systems which provide control, alarm, monitoring, safety, or internal vessel communication functions that are subject to classification requirements. This Section does not apply to computer-based systems that are covered by statutory regulations, e.g. loading instruments/ stability computer[①] and radio communication and navigation equipment covered by SOLAS chapters IV and V.

2.6.1.2 Computer based systems are, in addition to satisfying the requirements of this Section, to satisfy relevant requirements in the Guidelines for Type Approval Test of Electric and Electronic Products and the class notation Cyber Security (P) in the Guidelines for Ship Cyber Security.

2.6.1.3 The following standards may be used for the development of hardware/software of computer based systems:

(1) IEC 61508 Functional safety of electrical/electronic/programmable electronic safety-related systems;

(2) ISO/IEC/IEEE 12207 Systems and software engineering – Software life cycle processes;

(3) ISO 9001 Quality Management Systems – Requirements;

(4) ISO/IEC/IEEE 90003 Software engineering - Guidelines for the application of ISO 9001:2015 to computer software;

(5) IEC 60092-504 Electrical installations in ships - Part 504: Special features - Control and instrumentation;

(6) ISO/IEC 25000 Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - Guide to SQuaRE;

(7) ISO/IEC 25041 Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - Evaluation guide for developers, acquirers and independent evaluators;

(8) IEC 61511 Functional safety - Safety instrumented systems for the process industry sector;

(9) ISO/IEC/IEEE 15288 Systems and software engineering - System life cycle process;

(10) ISO 10007 Quality management – Guidelines for configuration management;

(11) ISO 24060 Ships and marine technology - Ship software logging system for operational technology.

Other standards accepted by CCS may also be considered.

2.6.2 Definitions

2.6.2.1 For the purpose of this Section:

(1) Black-box description: A description of a system's functionality and behaviour and performance as observed from outside the system in question.

(2) Black-box test methods: Verification of the functionality, performance, and robustness of a system, sub-system or component by only manipulating the inputs and observing the outputs. This does not require any knowledge of the system's inner workings and focuses only on the observable behaviour of the system/component under test in order to achieve the desired level of verification.

(3) Computer-based system(CBS): A programmable electronic device, or interoperable set of programmable electronic devices, organized to achieve one or more specified purposes such as collection, processing, maintenance, use, sharing, dissemination, or disposition of information. CBSs onboard include IT and OT systems. A CBS may be a combination of subsystems connected via network. Onboard CBSs may be connected directly or via public means of communications (e.g. Internet) to ashore CBSs, other vessels' CBSs and/or other facilities.

(4) Failure mode description: A document describing the effects due to failures in the system, not failures in the equipment supported by the system. The following aspects shall be covered:

① list of failures which are subject to assessment, with

② description of the system response to each of the above failures

③ comments to the consequence of each of these failures.

(5) Parameterization: To configure and tune system and software functionality by changing parameters. It

① Refer to the requirements of Appendix 1 and Appendix 2 of Chapter 2, PART TWO of the Rules.

does not usually require-computer programming and is normally done by the system supplier or a service provider, not the operator or end-user.

(6) Programmable device: Physical component where software is installed.

(7) Robustness:The ability to respond to abnormal inputs and conditions.

(8) Simulation test: Monitoring, control, or safety system testing where the equipment under control is partly or fully replaced with simulation tools, or where parts of the communication network and lines are replaced with simulation tools.

(9) Software component: A standalone piece of code that provides specific and closely coupled functionality.

(10) Software master files: The computer-files that constitutes the original source of the software. For custom made software this may be readable source- code files, and for COTS software it may be different forms of binary files.

(11) Software-structure: Overview of how the different software components interact and is commonly referred to as the Software Architecture, or Software Hierarchy.

(12) Sub-system: Identifiable part of a system, which may perform a specific function or set of functions.

(13) System: A combination of components, equipment and logic which has a defined purpose, functionality, and performance. In the context of this Section, a specific system is delivered by one system supplier.

(14) System of systems: A system which is made up of several systems In the context of this Section, the system of systems encompasses all monitoring, control and safety systems delivered from the Shipyard as a part of a vessel.

(15) Owner:The organization or person which orders the vessel in the construction phase or the organization which owns or manages the vessel in service. In the context of this Section this is a defined role with specific responsibilities.

(16) Supplier: A generic term used for any organisation or person that is a contracted or a subcontracted provider of services, system components, or software.

(17) Service supplier: A person or company, not employed by an IACS Member, who at the request of an equipment manufacturer, shipyard, vessel's owner or other client acts in connection with inspection work and provides services for a ship or a mobile offshore unit such as measurements, tests or maintenance of safety systems and equipment, the results of which are used by surveyors in making decisions affecting classification or statutory certification and services.

(18) System supplier: An organisation or person that is contracted or a subcontracted provider of system components or software under the coordination of the Systems integrator. In the context of this Section this is a defined role with specific responsibilities.

(19) Systems integrator: Single organization or a person coordinating interaction between suppliers of systems and sub-systems on all stages of life cycle of computer-based systems in order to integrate them into a verified vessel-wide system of systems and to provide proper operation and maintenance of the computer based systems. In the context of this Section this is a defined role with specific responsibilities. During the design and delivery phase the Shipyard is the default Systems integrator, during operations phase the Owner is the default.

(20) Vessel: Ship or offshore unit where the computer-based system is to be installed.

2.6.3 Approval of system and components

2.6.3.1 Computer-based systems that are necessary to accomplish vessel-functions of category II or category III shall be delivered with a vessel-specific Society certificate. The objective of the vessel-specific system certification is to confirm that design and manufacturing of the system has been completed and that the system complies with applicable rules of the classification Society. Vessel-specific system certification consist of two main verification activities:

(1) Assessment of vessel-specific documentation (see documents listed in Table 2.6.4.1(1));

(2) Survey and testing of the system to be delivered to the vessel.

CCS may accept Alternative Certification Scheme (ACS) provided that the requirements are met, and that the system is provided with a vessel-specific certificate.

2.6.3.2 Computer-based systems that are routinely manufactured and include standardized software functions may be type approved in accordance with specified rules of CCS. The type approval consist of two main verification activities:

(1) Assessment of type-specific documentation, including documents listed in Table 2.6.4.1(1) and other documents required to apply for CCS type approval;

(2) Survey and testing of the standardized functions.

Type approval will normally not yield exemption from vessel-specific system certification since

vessel-specific functions, parameter configurations and installation elements demand vessel specific verification.

2.6.4 Plans and documents

2.6.4.1 Plans and documents are to be submitted to CCS in accordance with the requirements of Tables 2.6.4.1(1) and 2.6.4.1(2) for computer based systems. Items in Table 2.6.4.1(3) are to be witnessed and surveyed by CCS surveyors.

Plans and documents to be submitted by system supplier Table 2.6.4.1(1)

No.	Name of plan	System category		
		Category I	Category II	Category III
1	Quality plan	—	①	①
2	System description	①(if necessary)	Ⓐ	Ⓐ
3	Environmental compliance testing report	①(if necessary)	①	①
4	Software testing report	—	①(if necessary)	①(if necessary)
5	System testing report	—	①(if necessary)	①(if necessary)
6	FAT program	—	Ⓐ	Ⓐ
7	FAT report	—	①	①
8	Additional FAT documents (e.g. user manuals)	—	①(if necessary)	①(if necessary)
9	Change management procedure	—	①	①

Plans and documents to be submitted by system integrator Table 2.6.4.1(2)

No.	Name of plan	System category		
		Category I	Category II	Category III
1	Quality plan	—	①	①
2	List of system category	Ⓐ	Ⓐ	Ⓐ
3	Risk assessment report	Ⓐ(if necessary)	Ⓐ(if necessary)	Ⓐ(if necessary)
4	Vessel's system-architecture description	①	①	①
5	SAT program	—	Ⓐ	Ⓐ
6	SAT report	—	①	①
7	SOST program	—	Ⓐ	Ⓐ
8	SOST report	—	①	①
9	Software change management procedure	—	①	①

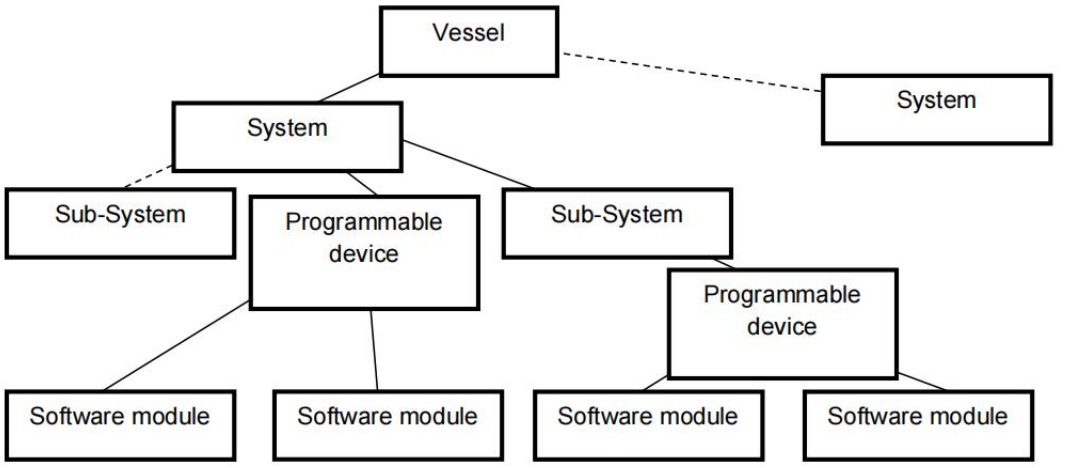
Items to be witnessed or surveyed by surveyors Table 2.6.4.1(3)

No.	Item	Responsible	System category		
			Category I	Category II	Category III
1	FAT	System supplier	—	Ⓦ	Ⓦ
2	SAT	System integrator	—	Ⓦ	Ⓦ
3	SOST	System integrator	—	Ⓦ	Ⓦ
4	Verification of changes	System integrator	—	Ⓦ	Ⓦ

Note: The meanings of symbols used in the Table are as follows:
Ⓐ Submitted to CCS for approval; ① Provided to CCS for information; Ⓦ To be witnessed or surveyed by CCS surveyors.

2.6.5 Structure and category of computer based system

2.6.5.1 The hierarchy and relationships of a typical computer based system are as shown in Figure 2.6.5.1.



Note: Dashed lines show non-developed branches of diagram

Figure 2.6.5.1 Illustrative System Hierarchy

2.6.5.2 The categorization of a system is based on the potential severity of the consequences if the system serving the function fails. Table 2.6.5.2 provides the definitions of the categories.

System categories **Table 2.6.5.2**

Category	Failure effects	Typical System functionality
I	Those systems, failure of which will not lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment.	- Monitoring, informational and administrative functions
II	Those systems, failure of which could eventually lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment.	- Vessel alarm, monitoring and control functions which are necessary to maintain the vessel in its normal operational and habitable conditions
III	Those systems, failure of which could immediately lead to dangerous or catastrophic situations for human safety, safety of the vessel and/or threat to the environment.	- Control functions for maintaining the vessel's propulsion and steering - Vessel safety functions

2.6.5.3 Category I systems are normally not subject to verification by CCS, as failure of these systems shall not lead to dangerous situations. However, information pertinent to category I systems shall be required upon request to determine the correct category or ensure that they do not influence the operation of systems in category II and category III. The category of a system shall always be evaluated in the context of the specific vessel in question; thus, the categorization of a system may vary from one vessel to the next. This means that the examples of categories below are given as guidance only, and the systems are not exhaustive.

(1) Category I systems:

① Fuel monitoring system;

② Maintenance support system;

③ Diagnostics and troubleshooting system;

④ Closed circuit television;

⑤ Cabin security, entertainment system;

⑥ Fish detection system.

(2) Category II systems:

① Fuel oil treatment system;

② Alarm monitoring and safety systems for propulsion and auxiliary machinery;

③ Inert gas system;

④ Control, monitoring and safety system for cargo containment system;

⑤ Monitoring and safety system.

(3) Category III systems:

① Propulsion control system;

② Steering gear control system;

③ Electric power system (including power management system);

④ Dynamic positioning system (DP 2 and DP 3).

2.6.6 Requirements on development and certification of computer-based system

2.6.6.1 A global top-down approach shall be undertaken in the design and development of both hardware and software and the integration in sub-systems, systems, and system of systems, spanning the complete system lifecycle. This approach shall be based on the standards as listed herein or other standards recognized by CCS.

2.6.6.2 Systems integrators and system suppliers shall, in the development of computer-based systems for category II and category III, comply to a recognised quality standard such as ISO 9001; also incorporating principles of IEC/ISO 90003. The quality system is certified as compliant to a recognized standard by an organisation with accreditation under a national accreditation scheme or CCS confirms compliance to a standard through a specific assessment of the quality system. The quality system shall as a minimum include the following topics in Table 2.6.6.2:

Quality system **Table 2.6.6.2**

Area		Role	
No.	Topic	System supplier	System integrator
1	Responsibilities and competency of the staff	x	x
2	The complete lifecycle of delivered software and of associated hardware	x	x
3	Specific procedure for unique identification of a computer-based system, its components and versions	x	
4	Creation and update of the vessel's system architecture		x
5	Organization set in place for acquisition of software and related hardware from suppliers	x	x
6	Organization set in place for software code writing and verification	x	
7	Organization set in place for system validation before integration in the vessel	x	
8	Specific procedure for conducting and approving of systems at FAT and SAT	x	x
9	Creation and update of system documentation	x	
10	Specific procedure for software modification and installation on board the vessel, including interactions with shipyard and owner	x	x
11	Specific procedures for verification of software code	x	
12	Procedures for integrating systems with other systems and testing of the system of systems for the vessel	x	x
13	Procedures for managing changes to software and configurations before FAT	x	
14	Procedures for managing and documenting changes to software and configurations after FAT	x	x
15	Checkpoints for the organization's own follow-up of adherence to the quality system	x	x

2.6.7 Requirements on the system supplier

2.6.7.1 The system supplier shall define a quality plan (No.1 in Table 2.6.4.1(1)) and document that the quality management system is applied for the design, construction, delivery, and maintenance of the specific system to be delivered. All applicable items described in Table 2.6.6.2 (for the system supplier role) shall be demonstrated to exist and being followed, as relevant.

2.6.7.2 A method for unique identification of a system, its different software components and different revisions of the same software component shall be applied. The method shall be applied throughout the lifecycle of the system and the software. The documentation of the method is typically a part of the quality management system. Technical requirements for unique identification of systems and software are given in 2.6.11.1 of this Section.

2.6.7.3 The system's specification and design shall be determined and documented in a system description (No.2 in Table 2.6.4.1(1)). In addition to serve as a specification for the detailed design and implementation, the purpose of the system description is to document that the entire system-delivery is according to the specifications and in compliance with applicable rules and regulations. The system description shall contain information of the following:

(1) Purpose and main functions, including any safety aspects;

(2) System category as defined;

(3) Key performance characteristics;

(4) Compliance with the technical requirements and CCS rules;

(5) User interfaces/mimics;

(6) Communication and Interface aspects: Identification and description of interfaces to other vessel systems;

(7) Hardware-arrangement related aspects:

① Network-architecture/topology, including all network components like switches, routers, gateways, firewalls etc.;

② Internal structure with regards to all interfaces and hardware nodes in the system (e.g. operator stations, displays, computers, programmable devices, sensors, actuators, I/O modules etc.);

③ I/O allocation (mapping of field devices to channel, communication link, hardware unit, logic function);

④ Power supply arrangement;

⑤ Failure mode description.

2.6.7.4 Evidence of environmental type testing (No.3 in Table 2.6.4.1(1)) according to CCS Guidelines for Type Approval Test of Electric and Electronic Products regarding hardware elements included in the system and sub-systems shall be submitted to CCS.

2.6.7.5 The software created, changed, or configured for the delivery project shall be developed and have the quality assurance activities assessed according to the selected standard(s) as described in the quality plan. The quality assurance activities may be performed on several levels of the software -structure and shall include both custom-made software and configured components (e.g. software libraries) as appropriate. For components in systems of Category II and III, the scope, purpose, and results of all performed reviews, analyses, tests, and other verification activities shall be documented in test reports (No.4 in Table 2.6.4.1(1)).

The verification of the software shall as a minimum verify the following aspects based on black-box methods[①]:

(1) Correctness, completeness and consistency of any parameterization and configuration of software components;

(2) Intended functionality;

(3) Intended robustness.

2.6.7.6 The system shall as far as practicable be tested before the FAT. The main purpose of the system test is for the system supplier to verify that the entire system delivery is according to the specifications, approved documentation and in compliance with applicable rules and regulations; and further, that the system is completed and ready for the FAT. Faults are to be simulated as realistically as possible to demonstrate appropriate system fault detection and system response. Some of the testing may be performed by utilizing simulators and replica hardware. The test-environment shall be documented, including a description of any simulators, emulators, test-stubs, test-management tools, or other tools affecting the test environment and its limitations. Test cases and test results shall be documented in test programs and test reports (No.5 in Table 2.6.4.1(1)) respectively. The testing shall at least verify the following aspects of the system:

(1) Functionality;

(2) Effect of faults and failures (including diagnostic functions, detection, alerts response);

(3) Performance;

(4) Integration between software and hardware components;

(5) Human-machine interfaces;

(6) Interfaces to other systems.

2.6.7.7 A factory acceptance test (FAT) shall be arranged for the system in question. The main purpose of the FAT is to demonstrate to CCS that the system is completed and compliant with applicable classification

① Some of the methods utilized in this activity are sometimes referred to as "software unit test" or "developer test" and may also include verification methods like code-reviews and static- or dynamic code analysis.

rules, thus enabling issuance of a Society Certificate for the system. The FAT test program (No.6 in Table 2.6.4.1(1)) shall cover a representative selection of the test items from the internal system test (described in 2.6.7.6 of this Section), including normal system functionality and response to failures. For category II and III systems, network testing to verify the network resilience requirements in 2.6.11.2 of this Section shall be performed. If agreed by all parties, the network testing may be performed as a part of the system test onboard the vessel. The FAT shall as a rule be performed with the project specific software operating on the actual hardware components to be installed on board, with necessary means for simulation of functions and failure responses, however other solutions such as replica hardware or simulated hardware (emulators) may be agreed with CCS. For each test-case it shall be noted if the test passed or failed, and the test-results shall be documented in a test report (No.7 in Table 2.6.4.1(1)). The test report shall also contain a list of the software (including software versions) that were installed in the system when the test was executed①.

2.6.7.8 The initial installation and subsequent updates of the software components of the system shall be done according to a management of change procedure which has been agreed between the system supplier and the systems integrator. The management of change procedure shall comply with the requirements in 2.6.10 of this Section. Cyber security measures shall be observed as described in CCS Guidelines for Ship Cyber Security.

2.6.8 Requirements on the systems integrator

2.6.8.1 For the purposes of this Section, the Shipyard is considered as the systems integrator in the development and delivery phase unless another organization or person is explicitly appointed by the Shipyard.

2.6.8.2 The systems integrator shall define a quality plan (No.1 in Table 2.6.4.2(1)) and document that the quality management system is applied for the installation, integration, completion, and maintenance of the systems to be installed on board. All applicable items described in Table 2.6.6.2 (for the systems integrator role) shall be demonstrated to exist and being followed, as relevant.

2.6.8.3 For each system delivery to a particular vessel, it shall be decided which category the system falls under based on the failure effects of the system (as defined in 2.6.5.2 of this Section). The category for a specific system must be conveyed to the relevant system supplier. CCS may decide that a risk-assessment② (No.3 in Table 2.6.4.1(2)) is needed to verify the proper system category.

2.6.8.4 The system of systems (SoS) shall be specified and documented (No.4 in Table 2.6.4.1(2)). This architecture specification provides the basis for category determination and development of the different integrated systems by allocating functionality to individual systems and by identifying the main interfaces between the systems③. It shall also serve as a basis for the testing of the integrated systems on the vessel level (see 2.6.8.6 of this Section).

The vessel's system architecture shall at least contain description of:

(1)Overview of the total systems architecture (the system of systems);

(2)Each system's purpose and main functionality;

(3)Communication and interface aspects between different systems.

2.6.8.5 A system acceptance test shall be arranged onboard the vessel. The main purpose of the system acceptance test (SAT) is to verify the system functionality, after installation and integration with the applicable machinery/electrical/process systems on board including possible interfaces with other control and monitoring systems. For each test-case it shall be noted if the test passed or failed, and the test-results shall be documented in a test report (No.6 in Table 2.6.4.1(2)). The test report shall also contain a list of the software (including software versions) that were installed in the system when the test was executed.

2.6.8.6 Integration tests shall be conducted after installation and integration of the different systems in its final environment on board④. The purpose of the tests is to verify the functionality of the complete installation (system of systems) including all interfaces and inter-dependencies in compliance with requirements and specifications. The testing shall at least verify the following aspects of the system of systems:

(1) The overall functionality of the interacting systems as a whole;

---

① For complex systems there may be a large difference in scope between the "Internal system testing before FAT" activity and the FAT, while for some systems the scope may be identical.

② IEC/ISO31010 "Risk management - Risk assessment techniques" may be used as guidance in order to determine method of risk assessment.

③ See network topology in CCS Guidelines for Ship Cyber Security.

④ For complex systems there may be a large difference in scope between the "System acceptance test (SAT) onboard the vessel" activity and the SOST, while for some systems the scope may be overlapping or identical. It is possible to combine the two activities into one when the test scope is similar.

(2) Failure response between systems;
(3) Performance;
(4) Human-machine interfaces;
(5) Interfaces between the different systems.
2.6.8.7 The systems integrator shall follow procedures for management of change (No.9 in Table 2.6.4.1(2)) to the system as described in 2.6.10 of this Section.

2.6.9 Requirements on maintenance of computer-based systems

2.6.9.1 For the purposes of this Section, the vessel owner is considered to be the systems integrator in the operations phase unless another organization or person is explicitly appointed by the owner. Accordingly, CCS shall in a timely manner be informed by the owner about the appointed systems integrator which is responsible for implementing any changes to the systems in conjunction with system supplier(s).
2.6.9.2 The systems integrator shall ensure that necessary procedures for software and hardware change management exist on board, and that any software modification/upgrade are performed according to the procedure(s). For details about change management please see paragraph 2.6.10 of this Section.
2.6.9.3 Changes to computer-based systems in the operational phase shall be recorded. The records shall contain information about the relevant software versions and other relevant information as described in 2.6.10.9 of this Section.
2.6.9.4 The system supplier shall follow procedures for maintenance of the system including procedures for management of change as described in 2.6.10 of this Section.
2.6.9.5 The system supplier shall make sure that the planned changes to a system have passed relevant in-house tests before the change is made to systems on board.

2.6.10 Management of change

2.6.10.1 The management of change process shall be coordinated and agreed between the relevant stakeholders along the different stages of the lifecycle of the computer-based system①. If changes are required to a system after it has been approved by applicable stakeholders (typically the systems integrator and CCS at FAT) the modifications shall follow defined change management procedures.
2.6.10.2 The change management procedures cover both hardware and software. After FAT, the system supplier shall manage all changes to the system in accordance with the procedure. Examples could be qualification of new versions of acquired software, new hardware, modified control logic, changes to configurable parameters. The procedure(s) shall at least describe the activities listed in 2.6.10.3 to 2.6.10.10 of this Section.
2.6.10.3 The system supplier shall make sure that each system and software version is uniquely identifiable, see 2.6.7.2 of this Section.
2.6.10.4 There shall be defined mechanisms for handling of the files that constitutes the master-files for a software component. Personnel authorities shall be clearly defined along with the tools and mechanisms used to ensure the integrity of the master files.
2.6.10.5 It shall be clearly defined how to perform backup and restoration of the software components of a computer-based system onboard the vessel.
2.6.10.6 Before a change to the system is made, an impact analysis shall be performed in order to determine to what extent the change activities shall be performed. The analysis shall:
(1) Determine the criticality of the change.
(2) Determine the impact on existing documentation.
(3) Determine the needed verification and test activities.
(4) Determine the need to inform other stakeholders about the change.
(5) Determine the need to obtain approval from other stakeholders (e.g. CCS and or Owner) before the change is made.
2.6.10.7 When maintenance includes installation of new versions of the software in the system, it shall be possible to perform a rollback of the software to the previous installed version with the purpose of returning the system to a known, stable state. Roll-backs shall be documented and analysed to find and eliminate the root cause.
2.6.10.8 To the largest degree practically possible, modifications shall be verified before being installed onboard. After installation, the modification(s) shall be verified onboard according to a documented

① Typically, the management of change address at least three different stages: Development and internal verification before FAT, involving the system supplier and sub-suppliers; From FAT to handover of the vessel to the owner, involving the system supplier, the systems integrator, CCS, and the owner; In operation, involving the system supplier, service suppliers, the owner, and CCS.

verification program containing:
(1) Verification that the new functionalities and/or improvements have had the intended effect.
(2) Regression test to verify that the modification has not had any negative effects on functionality or capabilities that was not expected to be affected.
2.6.10.9 Changes to systems and software shall be documented in change records to allow for visibility and traceability of the changes. The change records shall contain at least the following items:
(1) The purpose for a change;
(2) A description of the changes and modifications;
(3) The main conclusions from the impact analysis (see 2.6.10.6 of this Section);
(4) The identity and version of any new system or software version(s) (see 2.6.10.3 of this Section);
(5) Test reports or tests summaries (see 2.6.10.8 of this Section).
2.6.10.10 Documentation of the changes to software may be recorded in the planned maintenance system (PMS), in a software registry or equivalent.
2.6.10.11 During in operation (vessel in service) phase, the verification by CCS regarding the management of change in operation is generally performed during the annual survey of the vessel. Procedures for management of change and relevant change records shall be made available at the time of survey. In the cases where the change requires approval from CCS up front, the relevant procedures and documentation for the change in question may be verified at that time. During newbuilding, the verification of management of change in the newbuilding phase is divided into two:
(1) Procedures are verified as a part of the verification of the quality management system (Table 2.6.6.2);
(2) Project specific implementation of the procedures are verified during FAT and after FAT.

2.6.11 Technical requirements on computer-based systems

2.6.11.1 The system shall provide means to identify its name, version, identifier, and manufacturer. It is recommended that the system can automatically report the status of its software to a ship software logging system (SSLS) as specified in the international standard ISO 24060.
2.6.11.2 Loss of a data link shall be specifically addressed in risk assessment analysis/FMEA, including:
(1) A single failure in data link shall not cause loss of vessel- functions of category III. Any effect of such failures shall meet the principle of fail-to-safe for the vesselfunction(s) being served.
(2) For vessel-functions of category II and III, any loss of functionality in the remote control system shall be compensated for by local/manual means.
(3) The data link shall have means to prevent or cope with excessive communication rates.
(4) Data links shall be self-checking, detecting failures or performance issues on the link itself and data communication failures on nodes connected to the link.
(5) Detected failures shall initiate an alarm.
2.6.11.3 Category III systems shall not use wireless data links unless specifically considered by CCS on the basis of an engineering analysis carried out in accordance with an International or National Standard acceptable to CCS.
2.6.11.4 Other categories of systems may use wireless data links with the following requirements:
(1) Recognised international wireless communication system protocols shall be employed, incorporating:
① Message integrity. Fault prevention, detection, diagnosis, and correction so that the received message is not corrupted or altered when compared to the transmitted message.
② Configuration and device authentication. Shall only permit connection of devices that are included in the system design.
③ Message encryption. Protection of the confidentiality and or criticality of the data content.
④ Security management. Protection of network assets, prevention of unauthorized access to network assets.
(2) The internal wireless system within the vessel shall comply with the radio frequency and power level requirements of International Telecommunication Union and flag state requirements.
(3) Consideration should be given to system operation in the event of port state and local regulations that pertain to the use of radio-frequency transmission prohibiting the operation of a wireless data communication link due to frequency and power level restrictions.
(4) For wireless data communication equipment, tests during harbour and sea trials are to be conducted to demonstrate that radio-frequency transmission does not cause failure of any equipment and does not self-fail as a result of electromagnetic interference during expected operating conditions.
2.6.11.5 The implementation of the technical requirements provided in 2.6.11 of this Section is verified as part of the system description, FAT and SAT described above.

CHINA CLASSIFICATION SOCIETY

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

AMENDMENTS

2024

PART EIGHT ADDITIONAL REQUIREMENTS

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CHAPTER 6 ADDITIONAL REQUIREMENTS FOR OPEN-TOP CONTAINER SHIPS

Section 1 OPEN-TOP CONTAINER SHIPS ENGAGED IN UNRESTRICTED SERVICE

6.1.13 Segregation of dangerous goods

6.1.13.1 The segregation of dangerous goods for open-top container holds is to comply with Table 6.1.13.1 instead of the table of segregation of freight containers on board container ships contained in section ~~15.3.2~~ 7.4.3.3 of the IMDG Code.

CHAPTER 10 ADDITIONAL REQUIREMENTS FOR PETROLEUM ASPHALT CARRIERS

Section 2 CONSTRUCTION AND ARRANGEMENT OF SHIP

10.2.1.3 For asphalt carriers fitted with independent tanks and also with the single bottom of which is longitudinally framed and double sides of which are longitudinally framed, the following requirements are to be complied with:

(4) side framing: for ~~longitudinally framed~~ double side framing, where the side tanks are used as ballast tanks, the inner hull structure, watertight diaphragms and stiffeners are also to comply with the deep tank requirements of Section 13, PART TWO of the Rules.

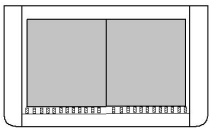
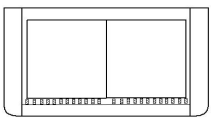
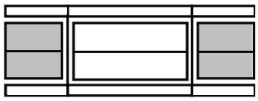
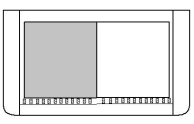
Appendix 1 DIRECT CALCULATION OF STRUCTURAL STRENGTH OF ASPHALT CARRIERS FITTED WITH INDEPENDENT CARGO TANKS

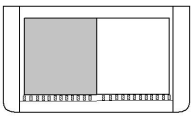
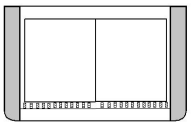
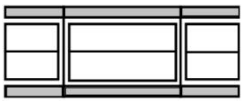
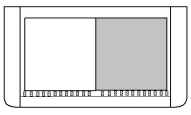
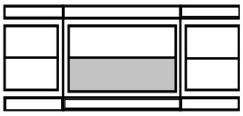
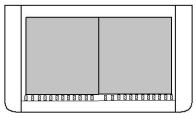
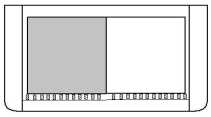
3 Loads and conditions

3.2 Calculation conditions

3.2.1 The tank structural assessment is to be carried out according to the applicable conditions in Table 3.2.1. For conditions LC3, LC4, LC6 and LC8, where the centerline bulkhead has asymmetrical structure, cargo tanks at port and starboard sides are to be calculated separately for separate loading modes.

Assessment Conditions of Cargo Tank Structure **Table 3.2.1**

<table>
<tr><td colspan="6">Seagoing conditions</td></tr>
<tr><td>Condition</td><td>Draught</td><td>Bending moment</td><td>External pressure</td><td>Internal pressure</td><td colspan="2">Pattern of loading</td></tr>
<tr><td>LC1</td><td>d</td><td>$\overline{M_s + M_w}$</td><td>P_e</td><td>P_i</td><td></td><td></td></tr>
<tr><td colspan="7">External pressure: $P_e = P_{hs} + P_{hd}$, according to 1.5.3, Chapter 1 of PART TWO of the Rules
Internal pressure: $P_i = \rho g(h + 2.5 f_r)$, according to 1.5.5, Chapter 1 of PART TWO of the Rules</td></tr>
<tr><td>Condition</td><td>Draught</td><td>Bending moment</td><td>External pressure</td><td>Internal pressure</td><td colspan="2">Pattern of loading</td></tr>
<tr><td>LC2</td><td>d</td><td>$\overline{M_s + M_w}$</td><td>P_e</td><td>P_i</td><td></td><td></td></tr>
<tr><td colspan="7">External pressure: $P_e = P_{hs} + P_{hd}$, according to 1.5.3, Chapter 1 of PART TWO of the Rules
Internal pressure: $P_i = \rho g(h + 2.5 f_r)$, according to 1.5.5, Chapter 1 of PART TWO of the Rules</td></tr>
<tr><td>Condition</td><td>Draught</td><td>Bending moment</td><td>External pressure</td><td>Internal pressure</td><td colspan="2">Pattern of loading</td></tr>
<tr><td>LC3</td><td>d</td><td>$\overline{M_s + M_w}$</td><td>P_e</td><td>P_i</td><td></td><td></td></tr>
<tr><td colspan="7">External pressure: $P_e = P_{hs} + P_{hd}$, according to 1.5.3, Chapter 1 of PART TWO of the Rules
Internal pressure: $P_i = \rho g(h + 2.5 f_r)$, according to 1.5.5, Chapter 1 of PART TWO of the Rules</td></tr>
</table>

Condition	Draught	Bending moment	External pressure	Internal pressure	Pattern of loading	
LC4	d	$\overline{M_s + M_w}$	P_e	P_i		
External pressure: $P_e = P_{hs} + P_{hd}$, according to 1.5.3, Chapter 1 of PART TWO of the Rules Internal pressure: $P_i = \rho(g + 0.5a_v)(h + 25f_r)$, where a_v is according to 1.5.2.2(8), Chapter 1 of PART TWO of the Rules						
Condition	Draught	Bending moment	External pressure	Internal pressure	Pattern of loading	
LC5	d_b	$\overline{M_s + M_w}$	P_e	P_i		
External pressure: $P_e = P_{hs}$, according to 1.5.3, Chapter 1 of PART TWO of the Rules Loading pressure: $P_i = \rho g(h + 2.5f_r)$, according to 1.5.5, Chapter 1 of PART TWO of the Rules						
Harbour conditions						
Condition	Draught	Bending moment	External pressure	Internal pressure	Pattern of loading	
LC6	0.35D	$\overline{M_{sp}}$	P_e	P_i		
External pressure: $P_e = P_{hs}$, according to 1.5.3, Chapter 1 of PART TWO of the Rules Internal pressure: $P_i = \rho g(h + 2.5f_r)$, according to 1.5.5, Chapter 1 of PART TWO of the Rules						
Condition	Draught	Bending moment	External pressure	Internal pressure	Pattern of loading	
LC7	0.35D	$\overline{M_{sp}}$	P_e	P_i		
External pressure: $P_e = P_{hs}$, according to 1.5.3, Chapter 1 of PART TWO of the Rules Internal pressure: $P_i = \rho g(h + 2.5f_r)$, according to 1.5.5, Chapter 1 of PART TWO of the Rules						
Condition	Draught	Bending moment	External pressure	Internal pressure	Pattern of loading	
LC8	0.25D	$\overline{M_{sp}}$	P_e	P_i		
External pressure: $P_e = P_{hs}$, according to 1.5.3, Chapter 1 of PART TWO of the Rules Internal pressure: $P_i = \rho g(h + 2.5f_r)$, according to 1.5.5, Chapter 1 of PART TWO of the Rules						
Note: For conditions LC3, LC4, LC6 and LC8, where the centerline bulkhead has asymmetrical structure, cargo tanks at port and starboard sides are to be calculated separately for separate loading modes.						

CHAPTER 13 ADDITIONAL REQUIREMENTS FOR POLAR CLASS SHIPS

Section 1 GENERAL REQUIREMENTS FOR POLAR CLASS SHIPS

13.1.1 Application

13.1.1.3 Ships which are assigned a Polar Class notation and complying with the relevant requirements of Sections 2 and 3 of this Chapter may be given the additional notation “Icebreaker”. “Icebreaker" refers to any ship 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, and having a class certificate endorsed with this notation.

13.1.3 Upper and lower ice waterlines

13.1.3.1 The upper and lower ice waterlines upon which the design of the vessel has been based are to be indicated in the classification certificate. The upper ice waterline (UIWL) is to be defined by the maximum draughts fore, amidships and aft. The lower ice waterline (LIWL) is to be defined by the minimum draughts fore, amidships and aft.

13.1.3.2 The lower ice waterline (LIWL) is to be determined with due regard to the ship’s ice-going capability in the ballast loading conditions. The propeller is to be fully submerged at the lower ice waterline (LIWL).

13.1.3.3 When the upper ice waterline (UIWL) is lower than the summer fresh water loadline draught, an ice class draught mark is to be provided in accordance with the requirements of 4.2.1.4, Section 2, Chapter 4, PART TWO of the Rules.

Section 2 STRUCTURAL REQUIREMENTS

13.2.1 Application and definitions

13.2.1.2 The length L_{UI} is the distance, in m, measured horizontally from the fore side of thestem at the intersection with the upper ice waterline (UIWL) to the after side of the rudder post, or the centre of the rudder stock if there is no 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.

13.2.1.3 The ship displacement D_{UI} is the displacement, in kt, 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.

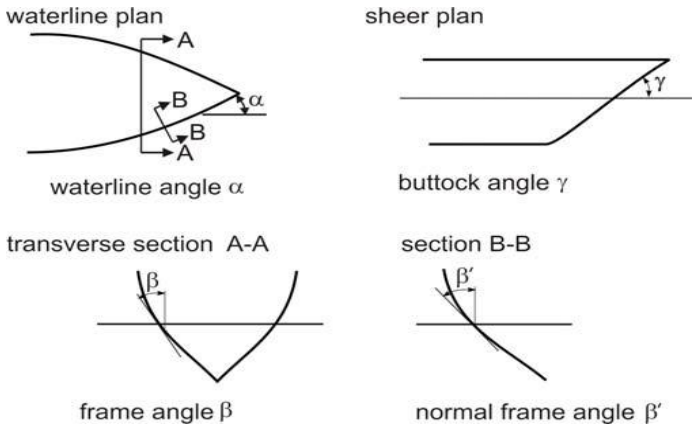
13.2.2.2 The upper ice waterline (UIWL) and lower ice waterline (LIWL) are as defined in 13.1.3.

13.2.2.4 Figure 13.2.2.1 notwithstanding, the aft boundary of the bow region need not be more than 0.45 L_{UI} aft of the fore side of the stem at the intersection with the upper ice waterline (UIWL).

13.2.2.7 Figure 13.2.2.1 notwithstanding, for ships assigned the additional notation “Icebreaker”, 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.

(1) Bow area

① 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 (fa). The hull angles are defined in Figure 13.2.3.2.



Notes: β' — normal frame angle at upper ice waterline [°];

α — upper ice waterline angle [°];

γ — buttock angle at upper ice waterline (angle of buttock line measured from horizontal) [°];

$\tan(\beta) = \tan(\alpha)/\tan(\gamma)$;

$\tan(\beta') = \tan(\beta)\cdot\cos(\alpha)$.

13.2.3.4 Pressure within the design load patch

(2) 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 Table 13.2.3.4 are used to account for the pressure concentration on localized structural members.

Peak Pressure Factors **Table 13.2.3.4**

Structural member		Peak pressure factor (PPF_i)
Plating	Transversely-framed	$PPF_p = (1.8 - s) \geq 1.2$
	Longitudinally-framed	$PPF_p = (2.2 - 1.2\,s) \geq 1.5$
Frames in transverse framing systems	With load distributing stringers	$PPF_t = (1.6 - s) \geq 1.0$
	With no load distributing stringers	$PPF_t = (1.8 - s) \geq 1.2$
Frames in bottom structures		$PPF_s = 1.0$
Load carrying stringers Side ~~and bottom~~ longitudinals Web frames		$PPF_s = 1.0$, if $S_w \geq 0.5w$ $PPF_s = 2.0 - 2.0\,S_w/w$, if $S_w < (0.5w)$

where: s — frame or longitudinal spacing, in m;

S_w — web frame spacing, in m;

w — ice load patch width, in m.

13.2.3.5 Hull area factors

(3) Due to their increased manoeuvrability, ships having propulsion arrangements with azimuthing (geared and podded) thrusters are to have ~~specially considered~~ stern ice belt (S_i) and stern lower (S_l) hull area factors *AF* listed in Table 13.2.3.5(3).

(4) For ships assigned the additional notation “Icebreaker”, the area factor (*AF*) for each hull area is listed in Table 13.2.3.5(4)-1. For propulsion arrangements with azimuthing (geared and podded) thrusters, the area factor (*AF*) for each hull area is listed in Table 13.2.3.5(4)-2.

Hull Area Factors **Table 13.2.3.5(3)**

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*)	Ice belt	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*)	Ice belt	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*)	Ice belt	S_i	0.90	0.85	0.80	0.75	0.65	0.55	0.50
	Lower	S_l	0.60	0.55	0.50	0.45	0.45	0.40	0.40
	Bottom	S_b	0.35	0.30	0.30	0.25	0.15	**	**

Notes: * — See 13.2.3.1(3).
** — Indicates that strengthening for ice loads is not necessary.

Hull Area Factors (*AF*) for ships with additional notation "Icebreaker" **Table 13.2.3.5(4)-1**

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*)	Ice belt	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*)	Ice belt	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*)	Ice belt	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

Hull Area Factors (*AF*) for ships with additional notation "Icebreaker" **Table 13.2.3.5(4)-2**

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*)	Ice belt	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*)	Ice belt	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*)	Ice belt	S_i	0.95	0.90	0.80	0.80	0.80	0.80	0.80
	Lower	S_l	0.70	0.65	0.60	0.60	0.60	0.60	0.60
	Bottom	S_b	0.35	0.30	0.30	0.30	0.30	0.30	0.30

13.2.4.2 The thickness of shell plating required to resist the design ice load, t_{net}, depends on the orientation of the framing.

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

$$t_{net} = 500s[(AF \cdot PPF_p \cdot P_{avg})/R_{eH}]^{0.5}/[1+s/(2b)] \quad \text{mm}$$

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

$$t_{net} = 500s[(AF \cdot PPF_p \cdot P_{avg})/R_{eH}]^{0.5}/[1+s/(2l)] \quad \text{mm}$$

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

$$t_{net} = 500s[(AF \cdot PPF_p \cdot P_{avg})/R_{eH}]^{0.5} \cdot [2b/s-(b/s)^2]^{0.5}/[1+s/(2l)] \quad \text{mm}$$

In the case of obliquely-framed plating ($70° > \Omega > 20°$), linear interpolation is to be used.

where: Ω — smallest angle between the chord of the waterline and the line of the first level framing, [°], illustrated in Figure 13.2.4.2;

s — transverse frame spacing in transversely-framed ships or longitudinal frame spacing in longitudinally-framed ships, in m;

AF — hull area factor from Table 13.2.3.5(1) or Table 13.2.3.5(4);

PPF_p — peak pressure factor from Table 13.2.3.4;

P_{avg} — average patch pressure according to 13.2.3.4, in MPa;

R_{eH} — yield stress of the material, in N/mm^2;

b — height of design load patch, in m, where b is to be taken not greater than ($l - s/4$) in the case of determination of the net thickness for transversely-framed plating;

l — distance between frame supports, in mm, i.e. equal to the frame span as given in 13.2.5.5, but not reduced for any fitted end brackets. When a load-distributing stringer is fitted, the length l need not be taken larger than the distance from the stringer to the most distant frame support.

13.2.5.2 The term "framing member" refers to transverse and longitudinal local frames, load-carrying stringers and web frames in the areas of the hull exposed to ice pressure, see Figure 13.2.2.1. Where load-distributing stringers have been fitted, they are generally fitted at or near the midpoint of the span of the frame, and web height of stringers is not to be less than 0.8 times the web height of the frame ~~the arrangement and scantlings of these are to be in accordance with the applicable requirements of Chapter 6, PART NINE of the Rules~~.

13.2.5.7 The actual net effective shear area, A_w, of a transverse or longitudinal local frame is given by:

$$A_w = h\, t_{wn} \sin\varphi_w / 100 \qquad \text{cm}^2$$

where: h — height of stiffener, in mm, see Figure 13.2.5.7;

t_{wn} — net web thickness, in mm:

$t_{wn} = t_w - t_c$

where: t_w —as-built web thickness, in mm, see Figure 13.2.5.7;

t_c —corrosion deduction to be subtracted from the web and flange thickness, in mm, as specified in 13.2.11.3 ~~PART TWO of the Rules, but not less than t_s as required by 13.2.11.3~~;

φ_w — smallest angle between shell plate and stiffener web, [°], measured at the midspan of the stiffener, see Figure 13.2.5.7. The angle φ_w may be taken as 90° provided the smallest angle is not less than 75°.

13.2.9.2 Framing members for which it is not practicable to meet the requirements of 13.2.9.1 (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 ensure the structural stability of the framing member. The minimum net web thickness for these framing members is given by:

$$t_{wn} = 2.63 \times 10^{-3} c_1 \sqrt{R_{eH} / (5.34 + 4(c_1 / c_2)^2)} \qquad \text{mm}$$

where: $c_1 = h_w - 0.8h$, in mm;

where: h_w—web height of stringer / web frame, in mm, see Figure 13.2.9.2;

h — height of framing member penetrating the member under consideration (0 if no such framing member), in mm, see Figure 13.2.9.2;

c_2 — spacing between supporting structure oriented perpendicular to the member under consideration, in mm, see Figure 13.2.9.2;

R_{eH} — yield stress of the material, in N/mm^2.

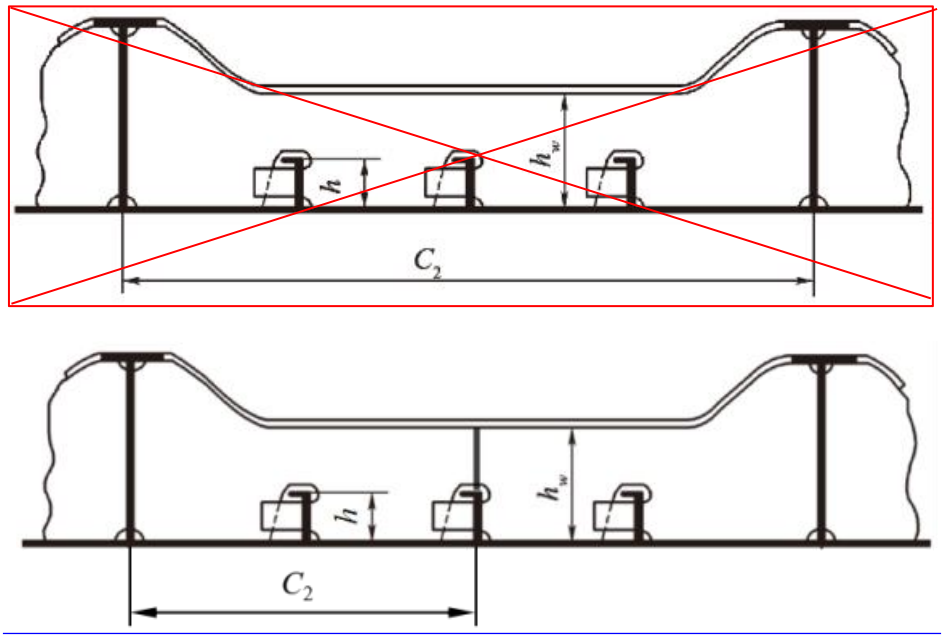


Figure 13.2.9.2 Parameter Definition for Web Stiffening

13.2.12.4 Steel grades for all weather exposed plating of hull structures and appendages situated above the level of 0.3 m below the lower ice waterline (LIWL), as shown in Figure 13.2.12.3, are to be not less than that given in Table 13.2.12.4.

13.2.13.2 Design vertical ice force at the bow

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

$$F_{IB} = \min(F_{IB,1}, F_{IB,2}) \quad \text{MN}$$

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

$F_{IB,2} = 1.20 CF_F$ MN;

where: K_I — indentation parameter, $= K_f / K_h$;

γ_{stem} — stem angle, [°], to be measured between the horizontal axis and the stem tangent at the upper ice waterline(UIWL) (buttock angle as per Figure 13.2.3.2 measured on the centerline);

α_{stem} — waterline angle measured in way of the stem at the upper ice waterline (UIWL) (°) (see Figure 13.2.3.2(1));

where: B_{UI} — moulded breadth corresponding to the upper ice waterline (UIWL), in m;

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

13.2.13.5 Longitudinal strength criteria

The strength criteria provided in Table 13.2.13.5 are to be satisfied. The design stress is not to exceed the permissible stress.

Longitudinal Strength Criteria **Table 13.2.13.5**

Failure mode	Applied stress	Permissible stress when $R_{eH}/\sigma_u \leq 0.7$	Permissible stress when $R_{eH}/\sigma_u > 0.7$
Tension	σ_a	ηR_{eH}	$0.41\eta\ (\sigma_u + R_{eH})$
Shear	τ_a	$\eta R_{eH} / (3)^{0.5}$	$0.41\eta\ (\sigma_u + R_{eH}) / (3)^{0.5}$
Buckling	σ_a	σ_c for plating and for web plating of stiffeners	

		σ_c /1.1 for stiffeners
	τ_a	τ_c

Notes: σ_a — applied vertical bending stress, in N/mm^2;

τ_a— applied vertical shear stress, in N/mm^2;

R_{eH} — yield stress of the material, in N/mm^2;

σ_u— ultimate tensile strength of material, in N/mm^2;

σ_c— critical buckling stress in compression, according to 2.2.7 of Section 2, Chapter 2 of PART TWO of the Rules, in N/mm^2;

τ_c— critical buckling stress in compression, according to 2.2.7 of Section 2, Chapter 2 of PART TWO of the Rules, in N/mm^2;

η = 0.8;

η = 0.6 for ships which are assigned the additional notation “Icebreaker”.

13.2.17.3 Where direct calculation is used to check the strength of structural systems, the load patch specified in 13.2.3 is to be applied, without being combined with any other loads. The load patch is to be applied at locations where the capacity of these members under the combined effects of bending and shear is minimized. Special attention is to be paid to the shear capacity in way of lightening holes and cut-outs in way of intersecting members.

Section 3 MACHINERY INSTALLATIONS

13.3.1 General requirements

13.3.1.1 The contents of this Section apply to main propulsion, steering gear, emergency and auxiliary systems essential for the safety of the ship and the crew.

13.3.1.2 Systems subject to damage by freezing, shall be drainable.

13.3.1.3 Vessels classed PC1 to PC5 inclusive shall have means provided to ensure sufficient vessel operation in the case of propeller damage including the Controllable Pitch (CP) mechanism. Sufficient vessel operation means that the vessel should be able to reach safe haven (safe location) where repairs can be undertaken. This may be achieved either by a temporary repair at sea, or by towing, assuming assistance is available.

13.3.1.4 Means shall be provided to free a stuck propeller by turning it in reverse direction. This shall also be possible for a propulsion plant intended for unidirectional rotation.

13.3.1.5 The propeller shall be fully submerged at the ship’s LIWL.

13.3.2 Drawings and particulars to be submitted

13.3.2.1 Details of the intended environmental operational conditions and the required ice strengthening for the machinery, if different from ship’s ice class.

13.3.2.2 Detailed drawings and descriptions of the main propulsion, steering, emergency and auxiliary machinery and information on the essential main propulsion load control functions. The descriptions are to include operational limitations.

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

13.3.2.4 Calculations and documentation indicating compliance with the requirements of this Section.

13.3.3 Materials

13.3.3.1 Materials shall 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.

13.3.3.2 Materials exposed to sea water

Materials exposed to sea water, such as propeller blades, propeller hubs and cast thruster bodies shall have an elongation not less than 15% on a test specimen according to CCS Rules for Materials and Welding.

Charpy V-notch impact testing is to be carried out for materials other than bronze and austenitic steel. The tests shall be carried out on three specimens at minus 10 ºC, and the average energy value is to be not less

than 20 J. However, Charpy V impact test requirements of CCS Rules for Materials and Welding as applicable for ships with ice class notation, shall also be applied.

13.3.3.3 Materials exposed to sea water temperature

Charpy V-notch impact testing is to be carried out for materials other than bronze and austenitic steel. The tests shall be carried out on three specimens at minus 10 ºC, and the average energy value is to be not less than 20 J. However, the Charpy V impact test requirements of CCS Rules for Materials and Welding as applicable for ships with ice class notation, shall also be applied.

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 requirement does not apply to surface hardened components, such as bearings and gear teeth or sea water cooling lines (heat exchangers, pipes, valves, fittings etc.).

For a definition of structural boundaries exposed to sea water temperature see Figure 13.2.12.3, Section 2 of this Chapter.

13.3.3.4 Material exposed to low air temperature

Materials of exposed machinery and foundations shall be manufactured from steel or other approved ductile material. An average impact energy value of 20 J taken from three Charpy V tests is to be obtained at 10 ºC below the lowest design temperature. Charpy V impact tests are not required for bronze and austenitic steel.

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

For a definition of structural boundaries exposed to air temperature see Figure 13.2.12.3, Section 2 of this Chapter.

13.3.4 Definition of main parameters and loads

13.3.4.1 The symbols, names, and units of parameters used in this Section are as follows:

c —— chord length of blade section, m;

$c_{0.7}$ —— chord length of blade section at 0.7R propeller radius, in m;

$c_{LE0.8}$ ——leading edge portion of chord length of blade section at 0.8R propeller radius, in m;

$c_{TE0.8}$ ——trailing edge portion of chord length of blade section at 0.8R propeller radius, in m;

D —— propeller diameter, in m;

d —— external diameter of propeller hub (at propeller plane), in m;

D_{pin} —— diameter of shear pin, in m;

D_{limit} —— limit value for propeller diameter, in m;

EAR —— expanded blade area ratio;

F_b —— maximum backward blade force for the ship's service life (negative sign), in kN;

F_{ex} —— ultimate blade load resulting from blade failure through plastic bending, abbreviated as blade failure load, in kN;

F_f —— maximum forward blade force for the ship's service life (positive sign), in kN;

F_{ice} —— ice load, in kN;

$(F_{ice})_{max}$—— maximum ice load for the ship's service life , in kN;

h_0 —— depth of the propeller centreline from lower ice waterline (LIWL), in m;

H_{ice} —— ice block dimension for propeller load definition, in m;

I —— equivalent mass moment of inertia of all parts on engine side of component under consideration , in kgm^2;

I_t —— equivalent mass moment of inertia of the whole propulsion system, in kgm^2;

$LIWL$ —— lower ice waterline, in m;

m —— slope for S-N curve in log/log scale;

M_{BL} —— blade bending moment, in kNm;

n —— propeller rotational speed, in r/s;

n_n —— nominal propeller rotational speed at MCR in free running condition, in r/s;

N —— number of ice load cycles;

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;

$P_{0.7}$ —— propeller pitch at 0.7R radius, in m;

$P_{0.7n}$ —— propeller pitch at 0.7R radius at MCR in free running condition, in m;

$P_{0.7b}$ —— propeller pitch at 0.7R radius at MCR in bollard condition, in m;

PCD —— pitch circle diameter, in m;

$Q(\varphi)$ —— torque, in kNm;

Q_{Amax} —— maximum response torque amplitude as a simulation result, in kNm;

Q_{emax} —— maximum engine torque, in kNm;

$Q_F(\varphi)$ —— Ice torque excitation for frequency domain calculations, in kNm;

Q_{fr} —— friction torque in pitching mechanism; reduction of spindle torque, in kNm;

Q_{max} —— maximum torque on the propeller resulting from propeller/ice interaction , in kNm;

Q_{motor} —— electric motor peak torque, in kNm;

Q_n —— nominal torque at MCR in free running condition, in kNm;

$Q_r(t)$ —— response torque along the propeller shaft line, in kNm;

Q_{peak} —— maximum of the response torque $Q_r(t)$, in kNm;

Q_{smax} —— maximum spindle torque of the blade for the ship's service life, in kNm;

Q_{sex} —— extreme spindle torque corresponding to the blade failure load F_{ex}, in kNm;

Q_{vib} —— Vibratory torque at considered component, taken from frequency domain open water TVC, in kNm;

r —— blade section radius, in m;

R —— propeller radius, in m;

$R_{p0.2}$ —— yield strength of the selected material (when the plastic strain is 0.2%), in MPa, to be selected according to CCS Rules for Materials and Welding;

R_m —— tensile strength of blade material, in MPa, to be selected according to CCS Rules for Materials and Welding;

S —— safety factor;

S_{fat} —— Safety factor for fatigue;

S_{ice} —— Ice strength index for blade ice force;

T —— Hydrodynamic propeller thrust in bollard condition, in kN;

T_b —— maximum backward propeller ice thrust for the ship's service life, in kN;

T_f —— maximum forward propeller ice thrust for the ship's service life, in kN;

T_n —— propeller thrust at MCR in free running condition, in kN;

T_r —— maximum response thrust along the shaft line, in kN;

T_{kmax} —— maximum torque capacity of flexible coupling, in kNm;

T_{kmax2} —— T_{kmax} at N= 1 load cycle, in kNm;

T_{kmax1} —— T_{kmax} at N= 5×10^4 load cycles, in kNm;

T_{kv} —— vibratory torque amplitude at N= 10^6 load cycles, in kNm;

ΔT_{kmax} —— maximum range of T_{kmax} at N=5×10^4 load cycles, in kNm;

t —— maximum blade section thickness, in m;

Z —— number of propeller blades;

z_{pin} —— number of shear pins;

α_i —— duration of propeller blade/ice interaction expressed in rotation angle, in °;

α_1 —— phase angle of the blade order excitation component for the propeller ice torque, in °;

α_2 —— phase angle of the blade order excitation component for the propeller ice torque, in °;

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;

σ_{exp} —— mean fatigue strength of blade material at 10^8 cycles to failure in sea water, in MPa;

σ_{fat} —— equivalent fatigue ice load stress amplitude for 10^8 stress cycles, in MPa;

σ_{fl} —— characteristic fatigue strength for blade material, in MPa;

σ_{ref1} —— reference stress, $\sigma_{ref1} = 0.6 \cdot R_{p0.2} + 0.4 \cdot R_m$, in MPa;

σ_{ref2} —— reference stress, $\sigma_{ref2} = 0.7 \cdot R_m$ or $\sigma_{ref2} = 0.6 \cdot R_{p0.2} + 0.4 \cdot R_m$, whichever is less, in MPa;

σ_{st} —— maximum stress resulting from F_b or F_f, in MPa;

$(\sigma_{ice})_{bmax}$ —— principal stress caused by the maximum backward propeller ice load, in MPa;

$(\sigma_{ice})_{fmax}$ —— principal stress caused by the maximum forward propeller ice load, in MPa;

$(\sigma_{ice})_{Amax}$ —— maximum ice load stress amplitude at the considered location on the blade, in MPa;

σ_{mean} —— mean stress, in MPa;

$(\sigma_{ice})_A(N)$ —— blade stress amplitude distribution, in MPa.

13.3.4.2 The definition and use of loads used in this Section are given in Table 13.3.4.2:

Definition and use of loads **Table 13.3.4.2**

Load	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. Ice contact pressure at leading edge is shown with small arrows. See Figure 13.3.4.2.	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.
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	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,

Load	Definition	Use of the load in design process
	to the hydrodynamic thrust.	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.

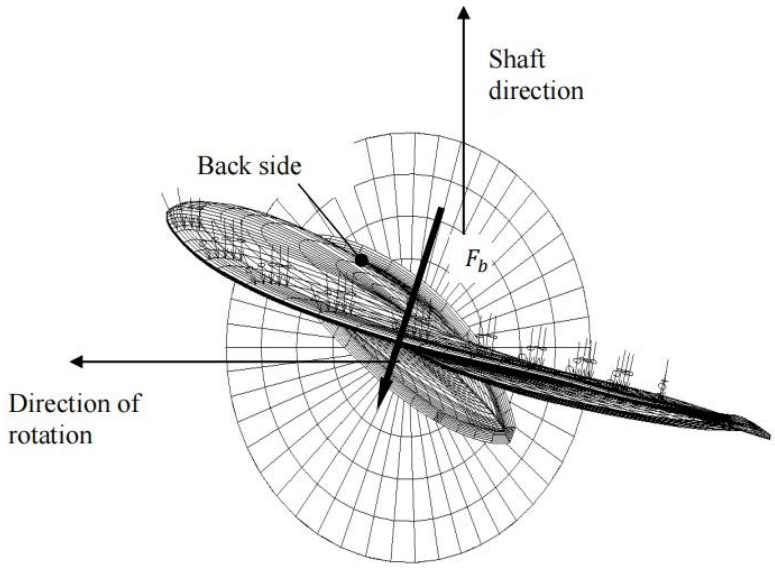


Figure 13.3.4.2 Direction of the backward blade force

13.3.5 Ice interaction loads

13.3.5.1 Propeller/ice interaction

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-mounted propellers shall receive special consideration. The given loads are expected, single occurrence, maximum values for the whole ship's 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 azimuthing and fixed thrusters with geared transmission or an integrated electric motor ("geared and podded propulsors").

However, the load models of the regulations do not include propeller/ice interaction loads when ice enters the propeller of a turned azimuthing thruster from the side (radially) or loads when ice blocks hit on the propeller hub of a pulling propeller. Ice loads resulting from ice impacts on the body of thrusters shall be estimated on a case by case basis, however are not included within the following section.

The loads given in section 13.3.5 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 the propeller mills an ice block while rotating ahead.

13.3.5.2 Ice class factors

The dimensions of the considered design ice block are $H_{ice}\times 2H_{ice}\times 3H_{ice}$. The design ice block H_{ice} and ice strength index S_{ice} used for the estimation of propeller ice loads are defined for each Ice class in Table 13.3.5.2 below.

Design ice block and ice strength index **Table 13.3.5.2**

Ice class	H_{ice}[m]	S_{ice}[−]
PC1	4.0	1.2
PC2	3.5	1.1
PC3	3.0	1.1
PC4	2.5	1.1
PC5	2.0	1.1
PC6	1.75	1
PC7	1.5	1

13.3.5.3 Design ice loads for open propellers

(1) Maximum backward blade force F_b

when $D<D_{limit}$:

$$F_b = -27 S_{ice}\left(\frac{EAR}{Z}\right)^{0.3}(nD)^{0.7}D^2 \quad \text{kN}$$

when $D\geq D_{limit}$:

$$F_b = -23 S_{ice}\left(\frac{EAR}{Z}\right)^{0.3}(nD)^{0.7}H_{ice}^{1.4}D \quad \text{kN}$$

where: $D_{limit} = 0.85H_{ice}^{1.4}$;

S_{ice} and H_{ice} are selected in accordance with Table 13.3.5.2;

n —— the nominal rotational speed at MCR in the free running open water condition for CP-propellers and 85% of the nominal rotational speed (at MCR free running condition) for a FP-propeller (regardless driving engine type), in r/s.

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

(2) Maximum forward blade force F_f

when $D<D_{limit}$:

$$F_f = 250\frac{EAR}{Z}D^2 \quad \text{kN}$$

when $D\geq D_{limit}$:

$$F_f = 500\left(\frac{1}{1-\frac{d}{D}}\right)H_{ice}\frac{EAR}{Z}D \quad \text{kN}$$

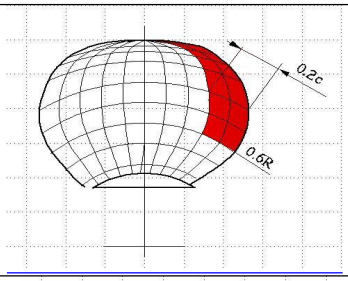
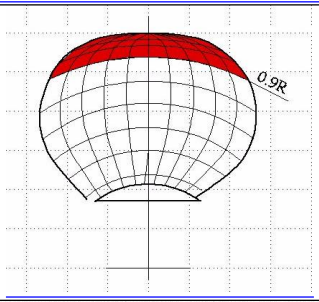
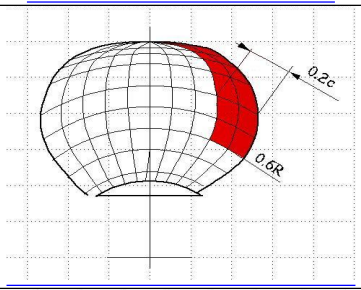
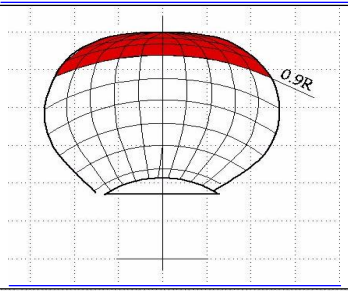
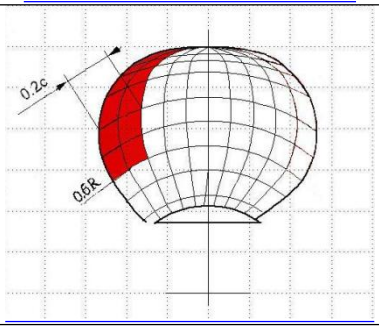
where: $D_{limit} = \left(\frac{2}{1-\frac{d}{D}}\right)H_{ice}$, in m;

H_{ice} is selected in accordance with Table 13.3.5.2;

(3) Load cases

Load cases 1-4 shall be covered, as given in Table 13.3.5.3(3), for CP and FP propellers. In order to obtain blade ice loads for a reversing propeller, load case 5 shall also be covered for propellers where reversing is possible.

Load cases for open propellers **Table 13.3.5.3(3)**

Load case	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 0.6R to the tip and from the leading edge to 0.2 times the chord length.	
Load case 2	50 % F_b	Uniform pressure applied on the back of the blade (suction side) on the propeller tip area outside 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.	
Load case 4	50%F_f	Uniform pressure applied on propeller face (pressure side) on the propeller tip area outside 0.9R radius.	
Load case 5	60%F_f or 60%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	

13.3.5.4 Design ice loads for ducted propellers

(1) Maximum backward blade force F_b

when $D < D_{limit}$:

$$F_b = -9.5 S_{ice} \left(\frac{EAR}{Z} \right)^{0.3} (nD)^{0.7} D^2 \quad \text{kN}$$

when $D \geq D_{limit}$:

$$F_b = -66 S_{ice} \left(\frac{EAR}{Z} \right)^{0.3} (nD)^{0.7} H_{ice}^{1.4} D^{0.6} \quad \text{kN}$$

where: $D_{limit} = 4\, H_{ice}$, in m;

S_{ice} and H_{ice} are selected in accordance with Table 13.3.5.2;

n is the same as 13.3.5.3(1).

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

(2) Maximum forward blade force F_f

when $D < D_{limit}$:

$$F_f = 250 \frac{EAR}{Z} D^2 \quad \text{kN}$$

when $D \geq D_{limit}$:

$$F_f = 500 \left(\frac{1}{1 - \frac{d}{D}} \right) H_{ice} \frac{EAR}{Z} D \quad \text{kN}$$

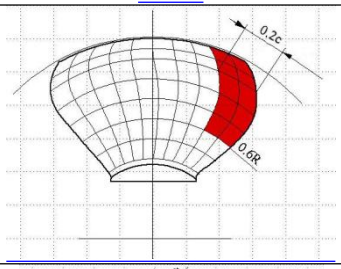
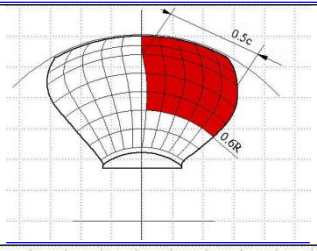
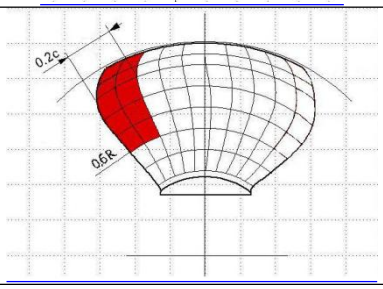
where: $D_{limit} = \left(\frac{2}{1 - \frac{d}{D}} \right) H_{ice}$, in m;

H_{ice} is selected in accordance with Table 13.3.5.2;

(3) Load case

Load cases 1 and 3 shall be covered as given in Table 13.3.5.4(3) for all propellers. In order to obtain blade ice loads for a reversing propeller, load case 5 shall also be covered for propellers, where reversing is possible.

Load cases for ducted propellers **Table 13.3.5.4(3)**

Load case	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 0.6R 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%F_f or 60%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.	

13.3.5.5 Design ice loads for both open and ducted propellers

(1) Maximum blade spindle torque Q_{smax} for CP mechanism designing

The spindle torque Q_{smax} around the axis of the blade fitting shall be determined both for the maximum backward blade force F_b and forward blade force F_f, which are applied as per Table 13.3.5.3(3) and Table 13.3.5.4(3). If the above method gives a value which is less than the default value given by the formula below, the default value shall be used.

$$Q_{smax} = 0.25Fc_{0.7} \quad \text{kNm}$$

where: F is taken as either F_b or F_f, whichever has the greater absolute value.

The blade failure spindle torque Q_{sex} is defined under 13.3.5.6.

(2) Load distributions (spectra) for blade loads

The Weibull-type distribution (probability that F_{ice} exceeds $(F_{ice})_{max}$), as given in Figure 13.3.5.5(2) is used for the fatigue design of the blade.

$$P\left(\frac{F_{ice}}{(F_{ice})_{\max}} \geqslant \frac{F}{(F_{ice})_{\max}}\right) = e^{\left(-\left(\frac{F}{(F_{ice})_{\max}}\right)^k \ln(N_{ice})\right)}$$

where: k —shape parameter of the spectrum, for open propeller, k=0.75; for ducted propeller, k=1.0;

N_{ice} —number of load cycles in the spectrum, see 13.3.5.5(3);

F_{ice} —random variable for ice loads on the blade, $0 \leq F_{ice} \leq (F_{ice})_{max}$.

This results in a blade stress amplitude distribution:

$$(\sigma_{ice})_A(N) = (\sigma_{ice})_{A\max}\left\{1 - \frac{\log(N)}{\log(N_{ice})}\right\}^{\frac{1}{k}}$$

where: $(\sigma_{ice})_{A\max} = \dfrac{(\sigma_{ice})_{f\max} - (\sigma_{ice})_{b\max}}{2}$

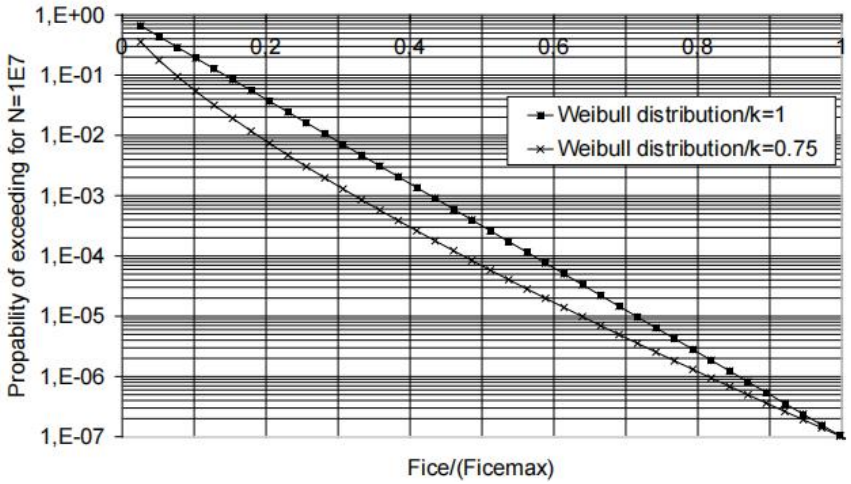


Figure 13.3.5.5(2) The Weibull-type distribution (probability of exceedance) that is used for fatigue design

(3) Number of ice loads

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

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

where: N_{class} — reference number of impacts per propeller revolution for each ice class (Table 13.3.5.5(3));

k_1 — propeller position coefficient, to be taken as 1 for centre propeller; 2 for wing propeller; 3 for pulling propeller (wing and centre);

k_2 — immersion coefficient, to be determined as follows:

when $f < 0$, $k_2 = 0.8 - f$;

when $0 \leqslant f \leqslant 1$, $k_2 = 0.8 - 0.4f$;

when $1 < f \leqslant 2.5$, $k_2 = 0.6 - 0.2f$;

when $f > 2.5$, $k_2 = 0.1$;

where: $f = \dfrac{h_0 - H_{ice}}{D/2} - 1$, if h_0 is not known, h_0 may be taken as $D/2$.

k_3 — thruster type coefficient, to be taken as 1 for fixed thrusters and 1.2 for azimuthing thrusters;

For vessels with the additional notation Icebreaker, the above stated number of load cycles N_{ice} shall 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).

Reference number of impacts **Table 13.3.5.5(3)**

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

13.3.5.6 Blade failure load for both open and ducted Propellers

(1) Bending force F_{ex}

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

$$F_{ex} = \frac{0.3ct^2\sigma_{ref1}}{0.8D - 2r} \times 10^3 \quad \text{kN}$$

where: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 located typically at the termination of the fillet into the blade profile.

The failure load may be calculated alternatively 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.

(2) Spindle torque Q_{sex}

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 equation below.

$$Q_{sex} = \max(c_{LE0.8}, 0.8c_{TE0.8}) C_{spex} F_{ex}$$

where: $C_{spex} = C_{sp} C_{fex} = 0.7\left[1 - \left(4\frac{EAR}{Z}\right)^3\right]$, to be taken not less than 0.3;

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

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

Figure 13.3.5.6(2) illustrates the spindle torque values due to blade failure loads across the whole chord length.

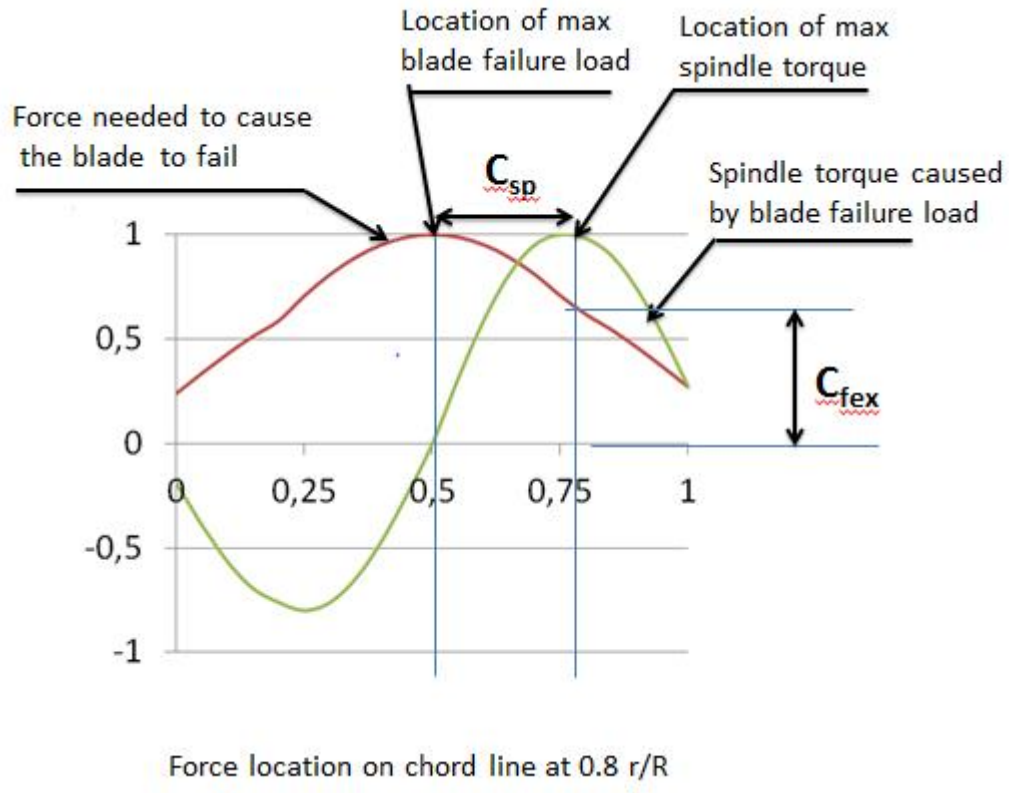


Figure 13.3.5.6(2) Schematic figure showing blade failure load and related spindle torque when the force acts at different location on the chord line at radius 0.8R

13.3.5.7 Axial design loads acting on open and ducted propellers

(1) Maximum ice thrust on propeller

Forward thrust T_f:

$$T_f = 1.1F_f \quad \text{kN}$$

Backward thrust T_b:

$$T_b = 1.1F_b \quad \text{kN}$$

However, the load models within this Section do not include propeller/ice interaction loads where an ice block hits the propeller hub of a pulling propeller.

(2) Design thrust along the propulsion shaft line for 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 directional load shall 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:

$$T_r = T + 2.2T_f \quad \text{kN}$$

In a backward direction:

$$T_r = 1.5T_b \quad \text{kN}$$

If the hydrodynamic bollard thrust, T, is not known, T is to be taken as follows:

Value of T **Table 13.3.5.7(2)**

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

Note: T_n is the nominal propeller thrust at MCR in the free running open water condition, in kN.

For pulling type propellers ice interaction loads on propeller hub must be considered in addition to the above. These will be specially considered by CCS.

13.3.5.8 Torsional design loads acting on open and ducted propellers

(1) Design ice torque on propeller for open propellers

when $D < D_{limit}$:

$$Q_{\max} = k_{open}\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}(nD)^{0.17}D^3 \quad \text{kNm}$$

when $D \geq D_{limit}$:

$$Q_{\max} = 1.9k_{open}H_{ice}^{1.1}\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}(nD)^{0.17}D^{1.9} \quad \text{kNm}$$

where: $D_{limit} = 1.8\ H_{ice}$, in m;

H_{ice} is selected in accordance with Table 13.3.5.2;

k_{open} ——14.7 for PC1~PC5; 10.9 for PC6~PC7;

$P_{0.7}$ ——propeller pitch at 0.7R, in m; (For CP propellers, $P_{0.7}=P_{0.7b}$; if $P_{0.7b}$ is not known, $P_{0.7}=0.7P_{0.7n}$)

n —— the rotational propeller speed in r/s in bollard condition. If not known, n is to be taken as follows:

Value of n **Table 13.3.5.8(1)**

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

Note: n_n is the nominal propeller rotational speed at MCR in the free running open water condition, in r/s.

(2) Design ice torque on propeller for ducted propellers

when $D < D_{limit}$:

$$Q_{max} = k_{ducted}\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}(nD)^{0.17}D^{3} \quad \text{kNm}$$

when $D \geq D_{limit}$:

$$Q_{max} = 1.9k_{ducted}H_{ice}^{1.1}\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}(nD)^{0.17}D^{1.9} \quad \text{kNm}$$

where: $D_{limit} = 1.8\ H_{ice}$, in m;

H_{ice} is selected in accordance with Table 13.3.5.2;

k_{ducted} ——10.4 for PC1~PC5; 7.7 for PC6~PC7;

$P_{0.7}$ and n are selected in accordance with 13.3.5.8(1).

(3) 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 shall be calculated at the least favourable phase angle for ice versus engine excitation, when calculated in time domain. The engine firing pulses shall 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 13.3.5.9

① Excitation for the time domain calculation

The propeller ice torque excitation for shaft line transient dynamic analysis (time domain) is defined as 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 defined as:

when $\varphi = 0 \ldots a_i$,

$$Q(\varphi) = C_q Q_{max} sin[\varphi(180/a_i)] \quad \text{kNm}$$

when $\varphi = a_i \ldots 360$,

$$Q(\varphi) = 0 \quad \text{kNm}$$

where: φ is rotation angle starting when the first impact occurs.

Parameters C_q and α_i for different blade numbers are given in Table 13.3.5.8(3)①.

Ice impact magnification C_q and duration α_i factors for different blade numbers

Table 13.3.5.8(3)①

Torque excitation	Propeller/ ice interaction	C_q	α_i (°)			
			Z=3	Z=4	Z=5	Z=6
Excitation case 1	Single ice block	0.75	90	90	72	60
Excitation case 2	Single ice block	1.0	135	135	135	135
Excitation case 3	Two ice blocks (phase shift=360°/(2Z))	0.5	45	45	36	30
Excitation case 4	Single ice block	0.5	45	45	36	30

The total ice torque is obtained by summing the torque of single blades, taking into account the phase shift 360°/Z.

At the beginning and at the end of the milling sequence (within calculated duration) linear ramp functions shall be used to increase C_q to its maximum within one propeller revolution and vice versa to decrease it to zero (see Figure 13.3.5.8(3)①).

The number of propeller revolutions during a milling sequence shall be obtained from the formula:

$$N_Q = 2H_{ice}$$

The number of impacts for blade order excitation:

$$ZN_Q$$

where: H_{ice} is selected in accordance with Table 13.3.4.2.

An illustration of all excitation cases for different blade numbers is given in Figure 13.3.5.8(3)①.

The dynamic simulation shall be performed for all excitation cases starting at MCR nominal, MCR bollard condition and just above all resonance speeds (1st engine and 1st blade harmonic), so that the resonant vibration responses can be obtained. For a fixed pitch propeller plant the dynamic simulation shall 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 shall be applied. On these cases, the excitation shall follow the shaft speed.

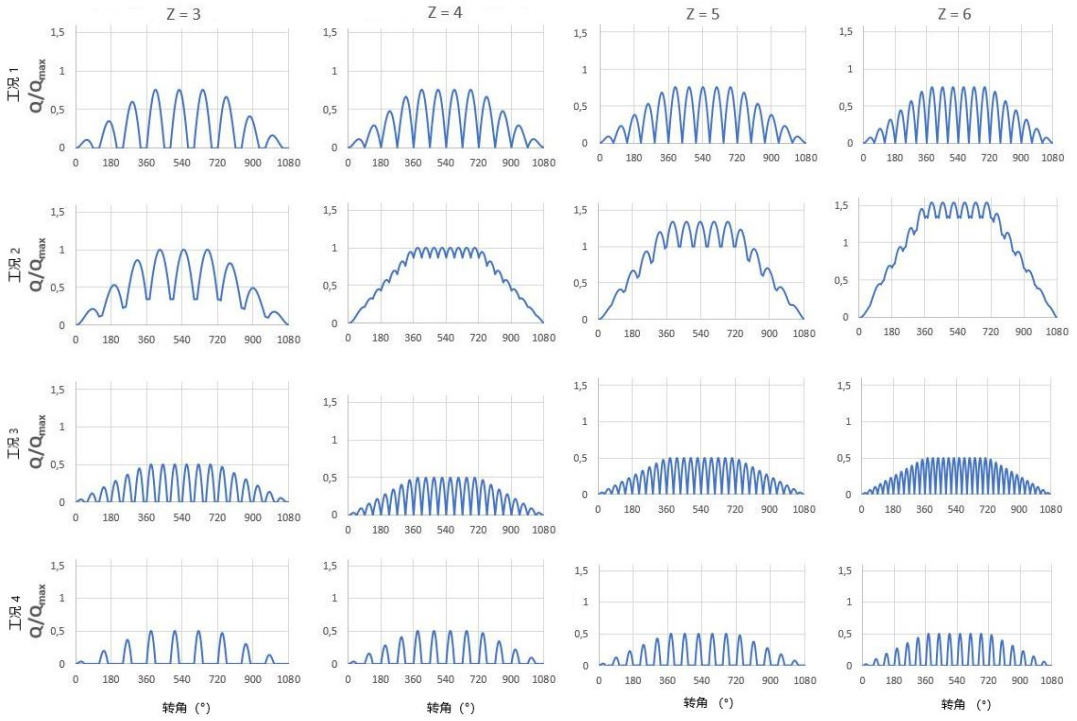


Figure 13.3.5.8(3)①　Ice block torque excitation cases for 3~6 blade propellers

② Frequency domain excitation

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.

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

where: φ ——angle of rotation;

C_{q0} ——mean torque component;

C_{q1} ——first blade order excitation amplitude;

C_{q2} ——second blade order excitation amplitude;

E_0 ——Number of ice blocks simultaneously participating in the impact.

Coefficients for simplified excitation torque estimation are given in Table 13.3.5.8(3)②.

Coefficients for simplified excitation torque estimation Table 13.3.5.8(3)②

Torque excitation	Z=3					
	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Case 1	0.375	0.375	-90	0	0	1
Case 2	0.7	0.33	-90	0.05	-45	1
Case 3	0.25	0.25	-90	0	0	2
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
Case 1	0.45	0.36	-90	0.06	-90	1
Case 2	0.9375	0	-90	0.0625	-90	1
Case 3	0.25	0.251	-90	0	0	2
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
Case 1	0.45	0.36	-90	0.06	-90	1
Case 2	1.19	0.17	-90	0.02	-90	1
Case 3	0.3	0.25	-90	0.048	-90	2
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
Case 1	0.45	0.375	-90	0.05	-90	1
Case 2	1.435	0.1	-90	0	0	1
Case 3	0.3	0.25	-90	0.048	-90	2
Case 4	0.2	0.25	0	0.05	-90	1

Torsional vibration responses shall be calculated for all excitation cases.

The results of the relevant excitation cases at the most critical rotational speeds are to be used in the following way:

The highest response torque (between the various lumped masses in the system) is in the following referred to as peak torque Q_{peak}, see Figure 13.3.5.8(3)②.

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}, see Figure 13.3.5.8(3)②.

Q_{Amax} can by determined by:

$$Q_{Amax} = \left[\max(Q_r(t)) - \min(Q_r(t))\right] / 2 \quad \text{kNm}$$

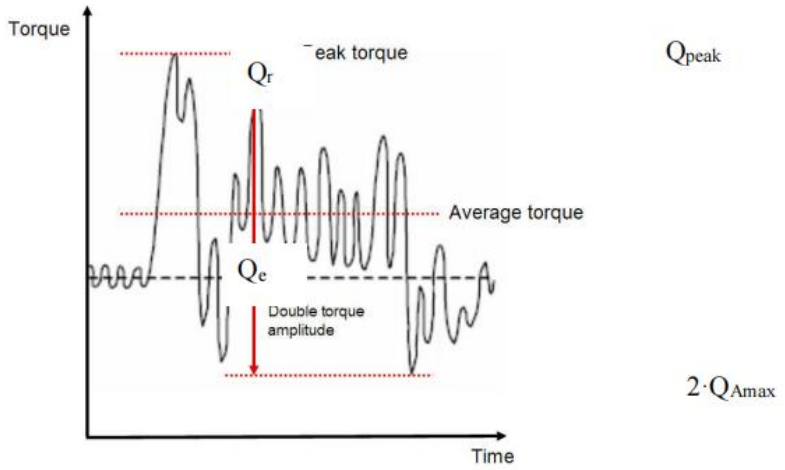


Figure 13.3.5.8(3)② Interpretation of different torques in a measured curve, as example

(4) Design torque along shaft line

① 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, the following estimation of the maximum response torque can be used to calculate the design torque along the propeller shaft line.

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

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

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

where: 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 shall be taken as follows:

Value of Q_{emax} **Table 13.3.5.9(1)**

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.

② 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 shall 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.

13.3.5.9 Torsional vibration calculation

(1) 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 shall be applied.

(2) 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.

(3) 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:

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

where: Q_{emax} ——the maximum engine torque at considered rotational speed;

Q_{opw} ——the maximum open water response of engine excitation at considered shaft speed and determined by frequency domain analysis;

Q_{ice} ——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.

13.3.6 Design

13.3.6.1 Design principle

The propulsion line shall be designed according to the pyramid strength principle in terms of its strength. This means that the loss of the propeller blade shall not cause any significant damage to other propeller shaft line components.

The propulsion line components shall 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.

13.3.6.2 Fatigue design in general

The design loads shall be based on the ice excitation and where necessary (shafting) dynamic analysis, described as a sequence of blade impacts (13.3.5.8(3)①). The shaft response torque shall be determined according 13.3.5.8(4).

The propulsion line components are to be designed so as to prevent accumulated fatigue failure when considering the relevant loads using the linear elastic Miner's rule as defined below.

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

where: k —— the number of stress levels;

$N_{1...k}$——the number of load cycles to failure of the individual stress level class;

$n_{1...k}$——the accumulated number of load cycles of the case under consideration, per class;

D_{mds}——Miners damage sum.

The stress distribution should 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) should be in accordance with the Weibull distribution.

13.3.6.3 Propeller blades

(1) Calculation of blade stresses due to static loads

The blade stresses (equivalent and principal stresses) shall be calculated for the design loads given in 13.3.5.3 and 13.3.5.4. Finite element analysis (FEA) shall be used for stress analysis as part of the final approval for all propeller blades. The von Mises stresses, taken as σ_{st}, shall comply with criteria in (2).

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

$$\sigma_{st} = A_1 \frac{M_{BL}}{100 \times ct^2} \quad \text{MPa}$$

where: constant A_1 is the $\frac{\text{actual stress}}{\text{stress obtained with beam equation}}$. If the actual value is not available, A_1 should be taken as 1.6. $M_{BL}=(0.75-r/R)RF$, for relative radius $r/R<0.5$, where F is the maximum of F_b and F_f, whichever is greater.

(2) Acceptability criterion for static loads

The following criterion for calculated blade stresses shall 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.

(3) Fatigue design of propeller blade

For materials with a two slope S-N curve the fatigue calculations defined in this chapter are not required if the following criterion is fulfilled.

$$\sigma_{exp} \geqslant B_1 \cdot \sigma_{ref2}^{B_2} \cdot \log(N_{ice})^{B_3}$$

where: B_1, B_2 and B_3 are coefficients for propellers given in Table 13.3.6.2(3).

Value of B_1, B_2 and B_3 Table 13.3.6.3(3)

Coefficient	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 shall 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 section 13.3.5.

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

$$\Delta\sigma_{max} = 2 \cdot \sigma_{Amax} = \left|(\sigma_{ice})_{f\max}\right| + \left|(\sigma_{ice})_{b\max}\right| \quad \text{MPa}$$

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), see Figure 13.3.6.3(3)-1. One slope S-N curve (the slope can be chosen), see Figure 13.3.6.3(3)-2.

The type of the S-N-curve shall 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 shall be used.

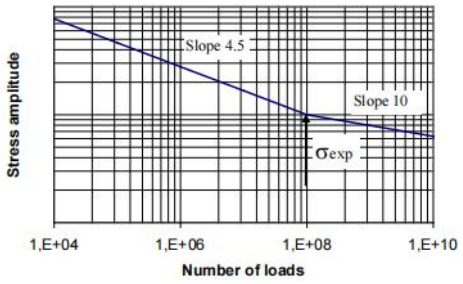


Figure 13.3.6.3(3)-1 Two-slope *S-N* curve

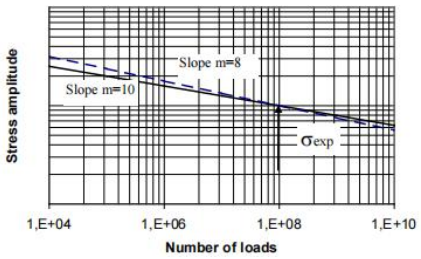


Figure 13.3.6.3(3)-2 Constant-slope *S-N* curve

① Equivalent fatigue stress

A more general method of determining the equivalent fatigue stress of propeller blades is described in 13.3.6.5, where the principal stresses are considered according to 13.3.5.3 and 13.3.5.4 using the Miner's rule. For a total number of load blocks $n_{bl} > 100$, both methods deliver the same result. Therefore, they are regarded as equivalent.

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

$$\sigma_{fat} = \rho \cdot (\sigma_{ice})_{\max} \quad \text{MPa}$$

where:$(\sigma_{ice})_{\max}$ —— mean value of the principal stress amplitudes resulting from design forward and backward blade forces at the location being studied, to be determined as follows:

$$(\sigma_{ice})_{\max} = 0.5 \cdot \left((\sigma_{ice})_{f\max} - (\sigma_{ice})_{b\max} \right) \quad \text{MPa}$$

where: $(\sigma_{ice})_{f\max}$ is principal stress resulting from forward load, $(\sigma_{ice})_{b\max}$ is 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 $(\sigma_{ice})_{f\max}$ and $(\sigma_{ice})_{b\max}$. Case 5 is excluded from the fatigue analysis.

② Calculation of parameter ρ for two-slope S-N curve

When $5 \times 10^6 \le N_{ice} \le 1 \times 10^8$, the error of the following method to determine the parameter ρ is sufficiently small.

The parameter ρ relates the maximum ice load to the distribution of ice loads according to the regression formula.

$$\rho = C_1 \cdot (\sigma_{ice})_{\max}^{C_2} \cdot \sigma_{fl}^{C_3} \cdot \log(N_{ice})^{C_4}$$

where: $\sigma_{fl} = \gamma_{e1} \cdot \gamma_{e2} \cdot \gamma_v \cdot \gamma_m \cdot \sigma_{exp}$, is the blade material fatigue strength at 10^8 load cycles, see 13.3.6.3(3)④.

The coefficients C_1, C_2, C_3 and C_4 are given in Table 13.3.6.3(3)②.

Value of C_1, C_2, C_3 and C_4 Table 13.3.6.3(3)②

Coefficient	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

③ Calculation of parameter ρ for constant-slope S-N curve

For materials with a constant-slope S-N curve, see Figure 13.3.6.3(3)-2, the factor ρ shall be calculated from the following formula:

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

where: k ——shape parameter of the Weibull distribution, k=1.0 for ducted propellers and k=0.75 for open propellers.

N_R ——reference number of load cycles (=10^8);

G ——Values for the parameter G are given in Table 13.3.6.3(3)③ below. Linear interpolation may be used to calculate the value of G for m/k ratios other than those given in the Table 13.3.6.3(3)③.

Value for the parameter *G* for different m/k ratios **Table 13.3.6.3(3)③**

m/k	*G*	*m/k*	*G*	*m/k*	*G*	*m/k*	*G*
3	6	5.5	287.9	8	40320	10.5	11.899E6
3.5	11.6	6	720	8.5	119292	11	39.917E6
4	24	6.5	1871	9	362880	11.5	136.843E6
4.5	52.3	7	5040	9.5	1.133E6	12	479.002E6
5	120	7.5	14034	10	3.623E6		

④ Acceptability criterion for fatigue

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

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

where: $\sigma_{fl} = \gamma_{e1} \cdot \gamma_{e2} \cdot \gamma_v \cdot \gamma_m \cdot \sigma_{exp}$, in MPa;

γ_{e1}—— reduction factor due to scatter (equal to one standard deviation);

γ_{e2}—— reduction factor for test specimen size effect;

σ_{exp} in Table 13.3.6.3(3)④ 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 Table 13.3.6.3(3)④ may be used, provided the values are determined under conditions approved by CCS.

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%

Table 13.3.6.3(3)④

Bronze and brass（a=1.0）		Stainless steel（a=0.05）	
Mn-Bronze, Cu1 (high tensile brass)	84 MPa	Ferritic (12Cr 1Ni)	144 MPa①
Mn-Ni-Bronze, Cu2 (high tensile brass)	84 MPa	Martensitic (13Cr 4Ni/13Cr 6Ni)	156 MPa
Ni-Al-Bronze, Cu3	120 MPa	Martensitic (16Cr 5Ni)	168 MPa
Mn-Al-Bronze, Cu4	113 MPa	Austenitic (19Cr 10Ni)	132 MPa

Note: ① This value may be used, provided a perfect galvanic protection is active. Otherwise a reduction of about 30 MPa shall be applied.

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

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 (γ_{e2}) is:

$$\gamma_{\varepsilon 2} = 1 - a \cdot \ln(\frac{t}{0.025})$$

where: a —— as given in Table 13.3.6.3(3)④;

t —— the maximum blade thickness at the considered point.

The mean stress effect γ_m is:

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

The following values should be used for the reduction factors if actual values are not available:

$\gamma_{\varepsilon 1} = 0.85$, $\gamma_v = 0.75$, $\gamma_m = 0.75$.

13.3.6.4 Blade bolts, propeller hub and CP mechanism

(1) General

The blade bolts, CP mechanism, propeller boss and the fitting of the propeller to the propeller shaft shall be designed to withstand the maximum static and fatigue design loads (as applicable), as defined in 13.3.5.3, 13.3.5.4, 13.3.5.5 and 13.3.6.3. The safety factor against yielding due to static loads and against fatigue shall be greater than 1.5, if not stated otherwise. The safety factor for loads, resulting from propeller blade failure as defined in 13.3.5.6 shall be greater than 1.0 against yielding.

Provided that calculated stresses duly considering local stress concentrations are less than yield strength, or maximum of 70% of tensile strength of respective materials, detailed fatigue analysis is not required. In all other cases components shall be analysed for cumulative fatigue. An approach similar to that used for shafting assessment may be applied (13.3.6.5).

(2)Blade bolts

Blade bolts shall withstand the following bending moment considered around a tangent on bolt pitch circle, or any other relevant axis for non-circular joints, parallel to considered root section:

$$M_{bolt} = S \cdot F_{ex}(0.8\frac{D}{2} - r_{bolt}) \quad \text{kNm}$$

where: r_{bolt}—— radius to the bolt plane;

S —— 1.0 safety factor.

Blade bolt pre-tension shall be sufficient to avoid separation between mating surfaces when the maximum forward and backward ice loads defined in 13.3.5.3 and 13.3.5.4 (open and ducted propellers respectively) are applied. For conventional arrangements, the following formula may be applied:

$$d_{bb} = 41 \cdot \sqrt{\frac{F_{ex}(0.8D - d) \cdot S \cdot \alpha}{R_{p0.2} \cdot z_{bb} \cdot PCD}} \quad \text{mm}$$

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, in mm;

z_{bb}—— number of blade bolts;

S—— 1.0 safety factor.

(3) CP mechanism

Separate means, e.g. dowel pins, shall be provided in order to withstand the spindle torque resulting from blade failure Q_{sex} (see 13.3.5.6(2)) or ice interaction Q_{smax} (see 13.3.5.5(1)) whichever is greater. Other components of the CP mechanism shall not 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 between the blade and blade carrier can be calculated using the formula:

$$d_{fp} = 66 \cdot \sqrt{\frac{Q_s - Q_{fr}}{PCD \cdot z_{pin} \cdot R_{p0.2}}} \quad \text{mm}$$

where: Q_s —— $\max(S \cdot Q_{s\max}; S \cdot Q_{sex})$, in kNm;

S —— 1.3 for $Q_{s\max}$, 1.0 for Q_{sex};

Q_{fr} —— friction between connected surfaces, $= 0.33 \cdot Q_s$, in kNm. CCS may approve alternative Q_{fr}

calculation according to reaction forces due to F_{ex}, or F_f, F_b whichever is relevant, utilising a friction coefficient = 0.15.

The stress in the actuating pin can be estimated by:

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

where: F_m —— $(Q_s - Q_{fr}) / l_m$, in kN;

l_m —— distance pitching centre of blade – axis of pin, in m;

h_{pin} —— height of actuating pin, in mm;

d_{pin} —— diameter of actuating pin, in 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, in kNm.

The blade failure spindle torque Q_{sex} shall not lead to any consequential damage.

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

$$Q_{sa\max} = \frac{Q_{sb} + Q_{sf}}{2} \quad \text{kNm}$$

where: Q_{sb} —— spindle torque due to $|F_b|$, in kNm;

Q_{sf} —— spindle torque due to $|F_f|$, in kNm.

(4) Servo pressure

The design pressure for the servo system shall be taken as the pressure caused by Q_{smax} or, Q_{sex} when not protected by relief valves on the hydraulic actuator side, reduced by relevant friction losses in bearings caused by the respective ice loads. The design pressure shall in any case not be less than relief valve set pressure.

13.3.6.5 Propulsion line components

The ultimate load resulting from total blade failure F_{ex} as defined in 13.3.5.6 shall 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 shall be designed to withstand the operational propeller/ice interaction loads as given in 13.3.5.

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

Cumulative fatigue calculations shall be conducted 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 $k = 1$), with Figure 13.3.6.5-1 as an example:

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

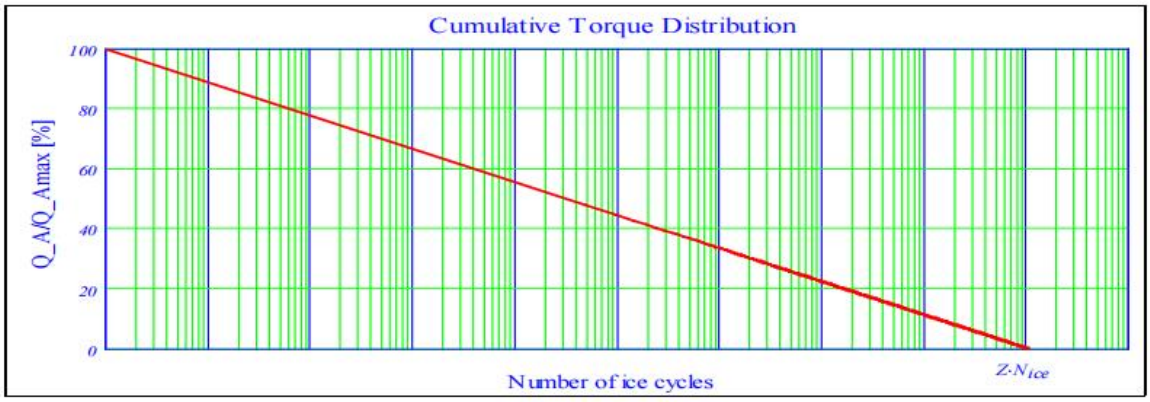


Figure 13.3.6.5-1 Cumulative torque distribution

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

The Weibull exponent should be considered as k = 1.0 for both open and ducted propeller torque and bending forces. The load distribution is an accumulated load spectrum, and the load spectrum should be divided into a minimum of ten load blocks when using the Miner summation method.

The load spectrum used counts the number of cycles for 100% load to be the number of cycles above the next step, e.g. 90 % load. This ensures that the calculation is on the conservative side. Consequently, the fewer stress blocks used the more conservative the calculated safety margin, see Figure 13.3.6.5-2.

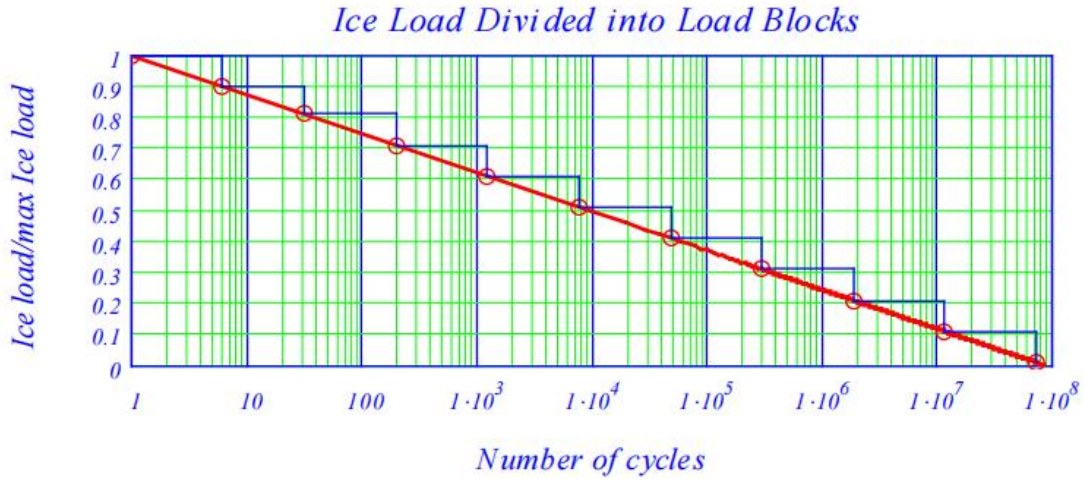


Figure 13.3.6.5-2 Example of ice load distribution (spectrum) for the shafting (k = 1)

The load spectrum is divided into n_{bl}-number of load blocks for the Miner summation 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} is the number of load blocks.

(1) Propeller fitting to the shaft

Keyless cone mounting or flange mounting may be generally used for propeller fitting to the shaft. Key mounting alone is not permitted.

① Keyless cone mounting

The friction capacity (at 0℃) shall be at least S = 2.0 times the highest peak torque Q_{peak} as determined in 13.3.5.9 without exceeding the permissible hub stresses.

The necessary surface pressure can be determined as:

$$p_{0°C} = \frac{2 \cdot S \cdot Q_{peak}}{\pi \cdot \mu \cdot D_S^2 \cdot L \cdot 10^3} \quad \text{MPa}$$

where: μ —— 0.15 for steel-steel; 0.13 for steel-bronze;

D_S —— the shrinkage diameter at the mid-length of the taper, in m;

L —— the effective length of taper, in m.

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

② Flange mounting

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

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

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

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

$$d_{pin} = 66 \cdot \sqrt{\frac{Q_{peak} \cdot S}{PCD \cdot z_{pin} \cdot R_{p0.2}}} \quad \text{mm}$$

where: Z_{pin}—— number of shear pins;

S —— 1.3 safety factor.

The bolts are to be designed so that the blade failure load F_{ex} (13.3.5.6) in backward direction does not cause yielding of the bolts. The following equation should be applied:

$$d_b = 41 \cdot \sqrt{\frac{F_{ex} \cdot (0.8 \cdot D / PCD + 1) \cdot \alpha}{R_{p0.2} \cdot z_b}} \quad \text{mm}$$

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, in mm;

z_b —— number of flange bolts.

(2) Propeller shaft

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

① The blade failure load F_{ex} (13.3.5.6) applied parallel to the shaft (forward or backwards) shall not cause yielding. The bending moment need not to be combined with any other loads. The diameter in way of the aft stern tube bearing shall not be less than:

$$d_p = 160 \cdot \sqrt[3]{\frac{F_{ex} \cdot D}{R_{p0.2} \cdot \left(1 - \frac{d_i^4}{d_p^4}\right)}} \quad \text{mm}$$

where: d_p —— propeller shaft diameter, in mm;

d_i —— propeller shaft inner diameter, in mm, 0 for solid shaft.

Forward from the aft stern tube bearing the shaft diameter may be reduced based on direct calculation of the actual bending moment, 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.

Bending due to maximum blade forces F_b and F_f have been disregarded since the resulting stress levels are much lower than the stresses caused by the blade failure load.

② The stresses due to the peak torque Q_{peak} shall have a minimum safety factor of S =1.5 against yielding in plain sections and S =1.0 in way of stress concentrations in order to avoid bent shafts.

Considering peak torque, the minimum shaft diameter is not to be less than that calculated from the following formulae:

Plain shaft:
$$d_p = 210 \cdot \sqrt[3]{\frac{Q_{peak} \cdot S}{R_{p0.2} \cdot \left(1 - \frac{d_i^4}{d_p^4}\right)}} \quad \text{mm}$$

Notched shaft:
$$d_p = 210 \cdot \sqrt[3]{\frac{Q_{peak} \cdot S \cdot \alpha_t}{R_{p0.2} \cdot \left(1 - \frac{d_i^4}{d_p^4}\right)}} \quad \text{mm}$$

where:α_t —— local stress concentration factor in torsion.

Notched shaft diameter shall in any case not be less than the required plain shaft diameter.

③ The torque amplitudes (13.3.5.8(4)) with the corresponding number of load cycles shall be used in an accumulated fatigue evaluation where the safety factor is S_{fat}=1.5. If the plant has high engine excited torsional vibrations (e.g. direct coupled 2-stroke engines), this shall also be considered.

④ The fatigue strengths σ_F and τ_F (3 million cycles) of shaft materials may be assessed on the basis of the material's yield or 0.2% proof strength as:

$$\sigma_F = 0.436 \cdot R_{p0.2} + 77 = \tau_F \cdot \sqrt{3} \quad \text{MPa}$$

This is valid for small polished specimens (no notch) and reversed stresses, see "VDEH 1983 Bericht Nr. ABF11 Berechnung von Wöhlerlinien für Bauteile aus Stahl".

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 smaller value of yield or 0.7 of tensile strength/√3. The criterion utilises 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.

(3) Intermediate shaft

The intermediate shafts are to be designed to fulfil the requirements of 13.3.6.5(2)②~④.

(4) Shaft connections

Shaft connections are to satisfy the following requirements. Keyed connections (except for splined shaft) are not to be used.

① Shrink fit couplings (keyless)

See 13.3.6.5(1)①. A safety factor of S = 1.8 shall be applied

② Flange mounting

The flange thickness is to be at least 20% of the required shaft diameter.

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

The flange fillet radius is to be at least 8% of the shaft diameter.

The diameter of ream fitted (light press fit) bolts shall be chosen so that the peak torque is transmitted with a safety factor of 1.9. This accounts for a prestress. Pins shall transmit the peak torque with a safety factor of 1.5 against yielding (see the formula in 13.3.6.5(1)②) .

The bolts are to be designed so that the blade failure load F_{ex} (13.3.5.6) in backward direction does not cause yielding.

③ Splined shaft connections

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 peak torque shall be applied.

(5) Gear transmissions

① Shafts

Shafts in gear transmissions shall meet the same safety level as intermediate shafts, but where relevant, bending stresses and torsional stresses shall be combined (e.g. by von Mises for static loads). Maximum permissible deflection in order to maintain sufficient tooth contact pattern shall be considered for the relevant parts of the gear shafts.

② Gearing

The gearing shall fulfil following three acceptance criteria: tooth root stresses, pitting of flanks, and scuffing. In addition to above 3 criteria subsurface fatigue may need 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 multiple input single output gears).

The load spectrum (see 13.3.6.5) may 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 operating at higher speeds 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 can be assessed on the basis of the international standard ISO 6336 Pt. 1-6, provided that "method B" is used. Equivalent requirements in Appendix 1, Chapter 10, PART THREE of the

Rules can also be applied.

For Bevel Gears the methods or standards used or acknowledged by CCS can be applied provided that they are properly calibrated.

Tooth root safety shall be assessed against the peak torque, torque amplitudes (with the pertinent average torque) as well as the ordinary loads (open water free running) by means of accumulated fatigue analyses. The resulting factor of safety is to be at least 1.5. (Ref ISO 6336 Pt 1, 3 and 6 and Appendix 1, Chapter 10, PART THREE of the Rules)

The safety against pitting shall 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 and Appendix 1, Chapter 10, PART THREE of the Rules)

The scuffing safety (flash temperature method – ref. ISO/TR 13989-1 and ISO/TR 13989-2) based on the peak torque shall 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 at the discretion of CCS. (It should be noted that high overloads can initiate subsurface fatigue cracks that may lead to a premature failure. In lieu of analyses UT inspection intervals may be used.)

③ Bearings

See 13.3.6.5(9).

④ Gear wheel shaft connections

The torque capacity shall be at least 1.8 times the highest peak torque Q_{peak} (at considered rotational speed) as determined in 6.5 without exceeding the permissible hub stresses of 80% yield.

(6) Clutches

Clutches shall have a static friction torque of at least 1.3 times the peak torque Q_{peak} and dynamic friction torque 2/3 of the static.

Emergency operation of clutch after failure of e.g. operating pressure shall be made possible within reasonably short time. If this is arranged by bolts, it shall be on the engine side of the clutch in order to ensure access to all bolts by turning the engine.

(7) Elastic couplings

There shall be a separation margin of at least 20% between the maximum response torque 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, is reached, expressed as follows:

$$Q_{peak} < 0.8 \cdot T_{kmax}(N=1) \quad \text{kNm}$$

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 (similar to Figure 13.3.6.5-1):

$$\frac{Q_r(N=x)}{Q_r(N=1)} = 1 - \frac{\log(x)}{\log(Z \cdot N_{ICE})} \quad \text{and}$$

$$\frac{Q_A(N=x)}{Q_A(N=1)} = 1 - \frac{\log(x)}{\log(Z \cdot N_{ICE})}$$

where $Q_r(N=1)$ corresponds to Q_{peak} and $Q_A(N=1)$ to Q_{Amax}.

$$Q_r(\mathrm{N}=5\times10^4) \cdot S < T_{kmax}(\mathrm{N}=5\times10^4) \quad \text{kNm}$$

$$Q_r(\mathrm{N}=1\times10^6) \cdot S < T_{kv} \quad \text{kNm}$$

$$Q_A(\mathrm{N}=5\times10^4) \cdot S < \Delta T_{\mathrm{kmax}}(\mathrm{N}=5\times10^4) \quad \text{kNm}$$

where $Q_r(N=1)$ corresponds to Q_{peak} and $Q_A(N=1)$ to Q_{Amax}.

S is the general safety factor for fatigue, equal to 1.5.

See figures below when using the above formulae:

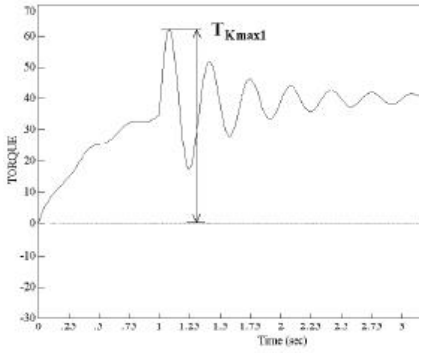


Figure 13.3.6.5(7)-1

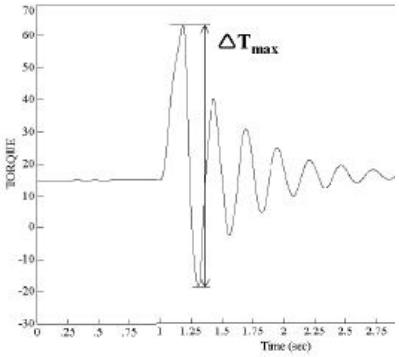


Figure 13.3.6.5(7)-2

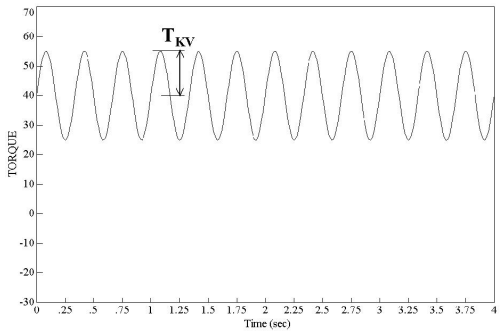


Figure 13.3.6.5(7)-3

The torque amplitude (or range Δ) shall not lead to fatigue cracking, i.e. exceeding the permissible vibratory torque. The permissible torque may be determined by interpolation in a Weibull torque distribution where T_{kmax1} respectively ΔT_{kmax} refer to 50000 cycles and T_{kv} refer to 10^6 cycles. See illustration in below Figures 13.3.6.5(7)-1, 13.3.6.5(7)-2 and 13.3.6.5(7)-3.

$$T_{k\max 1}(\mathrm{N}=5\times10^4)\geq Q_r(\mathrm{N}=5\times10^4) \quad \text{kNm}$$

(8) Crankshafts

Special considerations apply for plants with large inertia (e.g. flywheel, tuning wheel or PTO) in the non-driving end front of the engine (opposite to main power take off).

(9) Bearings

The aft stern tube bearing as well as the next shaft line bearing are to withstand F_{ex} as given in 13.3.5.6, in such a way that the ship can maintain operational capability. Rolling bearings are to have an 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 the maximum response thrust specified in 13.3.5.7 and the axial force resulting from the blade failure load specified in 13.3.5.6. For the purpose of calculation, except for F_{ex}, the shafts are assumed to rotate at rated speed. For pulling propellers special consideration is to be given to loads from ice interaction on the propeller hub.

(10) Seals

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 installed are to be suitable for the intended application. The manufacturer is to provide service experience in similar applications and/or testing results for consideration by CCS.

13.3.6.6 Azimuthing main propulsors

In addition to the above requirements, special consideration shall be given to those loading cases which are extraordinary for propulsion units when compared with conventional propellers. The estimation of load cases shall reflect the way the thrusters are intended to operate on the specific ship. In this respect, for example, the loads caused by the impacts of ice blocks on the propeller hub of a pulling propeller shall be considered. Furthermore, loads resulting from the thrusters operating at an oblique angle to the flow shall be considered. The steering mechanism, the fitting of the unit, and the body of the thruster shall be designed to withstand the loss of a blade without damage. The loss of a blade shall 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 shall also be designed for estimated loads caused by thruster body/ice interaction. The

thruster body shall withstand the loads obtained when the maximum ice blocks, which are given in section 13.3.5.2, 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 should be considered. The thickness of the sheet should be taken as the thickness of the maximum ice block entering the propeller, as defined in section 13.3.5.2.

13.3.7 Prime movers

13.3.7.1 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 operated even when the CP system is at full pitch as limited by mechanical stoppers.

13.3.7.2 The arrangement of compressed air for mechanical starting arrangements (including capacity of air receivers and charging capacity) is to satisfy relevant requirements of 9.5.1, Chapter 9, PART THREE of the Rules. In addition, for a ship with the ice class PC1~PC6, if its propulsion engine has to be reversed for going astern, the charging time required by 9.5.1.2, Chapter 9, PART THREE of the Rules is not to exceed 0.5h.

13.3.7.3 Provisions shall be made for heating arrangements to ensure ready starting from cold of the emergency power units at an ambient temperature applicable to the Polar Class of the ship. Emergency power units shall be equipped with starting devices with a stored energy capability of at least three consecutive starts at the above mentioned temperature. The source of stored energy shall be protected to preclude critical depletion by the automatic starting system, unless a second independent mean of starting is provided. A second source of energy shall be provided for an additional three starts within 30 min., unless manual starting can be demonstrated to be effective.

13.3.8 Equipment fastening loading accelerations

13.3.8.1 Essential equipment and supports shall be suitable for the accelerations as indicated in the following paragraphs. Accelerations are to be considered as acting independently.

13.3.8.2 Longitudinal Impact Accelerations, a_l

Maximum longitudinal impact acceleration at any point along the hull girder is calculated by the following formula:

$$a_l = (F_{IB} / \Delta)\{[1.1\tan(\gamma+\varphi)]+[7\frac{H}{L}]\} \quad \text{m/s}^2$$

where: φ ——maximum friction angle between steel and ice, normally taken as 10 degrees;

γ ——bow stem angle at waterline, in degrees;

Δ ——displacement, in kt;

L ——length between perpendiculars, in m;

H ——distance in meters from the water line to the point being considered, in m;

F_{IB} ——vertical impact force, defined in 13.2.13.2(1).

13.3.8.3 Vertical Accelerations, a_v

Combined vertical impact acceleration at any point along the hull girder is calculated by the following formula:

$$a_v = 2.5\,(F_{IB} / \Delta)F_X \quad \text{m/s}^2$$

where: F_{IB} and Δ are the same as 13.3.8.2;

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.

13.3.8.4 Transverse impact acceleration, a_t

Combined transverse impact acceleration at any point along hull girder is calculated by the following formula:

$$a_t = 3F_i\frac{F_X}{\Delta} \quad \text{m/s}^2$$

where: Δ is the same as 13.3.8.2;

F_i ——total force normal to shell plating in the bow area due to oblique ice impact, defined in 13.2.3.2(2);

F_X—— 1.5 at FP, 0.25 at midships, 0.5 at FP, 1.5 at AP for vessels conducting ice breaking astern. Intermediate values to be interpolated linearly.

13.3.9 Auxiliary systems

13.3.9.1 Machinery shall be protected from the harmful effects of ingestion or accumulation of ice or snow. Where continuous operation is necessary, means should be provided to purge the system of accumulated ice or snow.

13.3.9.2 Means should be provided to prevent damage to tanks containing liquids due to freezing.

13.3.9.3 Vent pipes, intake and discharge pipes and associated systems shall be designed to prevent blockage due to freezing or ice and snow accumulation.

13.3.10 Sea Inlets and Cooling Water Systems

13.3.10.1 Cooling water systems for machinery that is essential for the propulsion and safety of the vessel, including sea chest inlets, shall be designed for the environmental conditions applicable to the ice class.

13.3.10.2 At least two sea chests are to be arranged as ice boxes (sea chests for water intake in severe ice conditions) for ice class PC1 to PC5 inclusive. The calculated volume for each of the ice boxes shall be at least $1m^3$ for every 750 kW of the totally installed power. For PC6 and PC7 there shall be at least one ice box located preferably near centre line.

13.3.10.3 Ice boxes are to be designed for an effective separation of ice and venting of air.

13.3.10.4 Sea inlet valves are to be secured directly to the ice boxes. The valve shall be a full bore type.

13.3.10.5 Ice boxes and sea bays are to have vent pipes and are to have shut off valves connected directly to the shell.

13.3.10.6 Means are to be provided to prevent freezing of sea bays, ice boxes, ship side valves and fittings above the load water line.

13.3.10.7 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.

13.3.10.8 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.

13.3.10.9 Openings in ship 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. 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.

13.3.11 Ballast tanks

13.3.11.1 Efficient means are to be provided to prevent freezing in fore and after peak tanks and wing tanks located above the water line and where otherwise found necessary.

13.3.12 Ventilation systems

13.3.12.1 The air intakes for machinery and accommodation ventilation are to be located on both sides of the ship at locations where manual de-icing is possible. Anti-icing protection of the air inlets may be accepted as an equivalent solution (De-icing and anti-icing are defined in Chapter 23 of this PART) to location on both sides of the ship and manual de-icing. Notwithstanding the above, multiple air intakes are to be provided for the emergency generating set and are to be as far apart as possible.

13.3.12.2 The temperature of the inlet air shall be suitable for the safe operation of the machinery and the thermal comfort in the accommodation. Accommodation and ventilation air intakes shall be provided with means of heating, if needed.

13.3.13 Steering systems

13.3.13.1 The design ice force on rudder shall be transmitted to the rudder stops required by 13.1.5.8, Chapter 13, PART THREE of the Rules without damage to the steering system.

An ice knife shall in general be fitted to protect the rudder in centre position. The ice knife shall extend below BWL. Design forces shall be determined according to the 13.2.15 of this Chapter.

13.3.13.2 The rudder actuator is to be designed for a holding torque obtained by multiplying the open water torque (considering however a maximum speed of 18 knots), by following factors in Table 13.3.13.2:

Ice class factors of steering system **Table 13.3.13.2**

Ice class	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Factor	5	5	3	3	3	1.5	1.5

13.3.13.3 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.

13.3.13.4 The rudder actuator is to be protected by torque relief arrangements, assuming the following turning speeds listed in Table 13.3.13.4 [deg/s] without an undue pressure rise (see 13.1.7.2(2), Chapter 13, PART THREE of the Rules for undue pressure rise). 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 (13.1.7.2, Chapter 13, PART THREE of the Rules).

Steering gear turning speeds **Table 13.3.13.4**

Ice class	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Turning speeds (°/s)	10	10	7.5	7.5	7.5	6	6

13.3.13.5 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 arrangement is to be so designed that the pressure cannot exceed 115% of the set pressure of the safety valves when the rudder is being forced to move at the speed indicated in Table 13.3.13.5, also when taking 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.

Steering gear turning speeds for icebreaker s **Table 13.3.13.5**

Ice class	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Turning speeds (°/s)	40	40	20	20	20	15	15

13.3.14 Alternative design

13.3.14.1 As an alternative to this Section– a comprehensive design study may be submitted and may be requested to be validated by an agreed test programme.

CHAPTER 15 ADDITIONAL REQUIREMENTS FOR ELECTRICALLY PROPELLED SHIPS

Section 2 ADDITIONAL REQUIREMENTS FOR ELECTRICAL PROPULSION INSTALLATIONS

15.2.10 Monitoring instrumentation and alarms

Electric propulsion system monitoring, alarm and safety action item list **Table 15.2.10.1**

System	Monitored parameter	Without class notations			BRC, MCC & AUT-0 notations			Remark
		Alarm	Display	Auto shut-down	Alarm	Display	Auto shut-down	
Propulsion generator (AC & DC)	Bearing lub. oil inlet pressure – low or bearing temperature – high	√	√	√	√	√	√	Prime mover automatic shutdown
	Voltage – off-limits (high/low)		√		√	√		To read all phases
	Frequency – off-limits (high/low)		√		√	√		For AC propulsion generators only
	Current		√			√		To read all phases
	Power		√			√		To indicate power consumed and power available for propulsion in bridge and centralized control station
	Stator windings temperature – high	√	√		√	√		To read all phases; for generators > 500 kW
	Main generator circuit breakers – open/close					√		
	Generator running		√			√		
	Failure of on-line generator				√			
	Transfer of standby generator				√			
	Generator cooling medium temperature – high	√			√	√		If applicable
	Failure of generator cooling pump or fan motor				√			If applicable
	Field voltage and current		√			√		~~Not applicable to asynchronous generator~~ Applicable to electrical excitation system where provided
	Interpole windings temperature – high	√	√		√	√		For DC generators
Propulsion Motor (AC & DC)	Bearing lub. oil inlet pressure – low or bearing temperature – high	√	√	√	√	√	√	
	Voltage – off-limits (high/low)		√		√	√		To read all phases.
	Field voltage					√		

System	Monitored parameter	Without class notations			BRC, MCC & AUT-0 notations			Remark
		Alarm	Display	Auto shut-down	Alarm	Display	Auto shut-down	
	Frequency – off-limits (high/low)				√	√		For AC propulsion motors only. For propulsion motor controlled by frequency converter, the monitoring of the output of frequency converter may be taken as an alternative
	Armature current		√			√		To read all phases
	Field current		√			√		For synchronous motors
	Stator windings temperature – high	√			√	√		To read all phases; for AC motors > 500 kW only
	Motor circuit breakers – open/close					√		
	Motor running		√			√		
	Motor overspeed	√	√	√	√	√	√	For DC propulsion motors
	Failure of on-line motor				√			
	Transfer of standby motor				√			
	Motor cooling medium temperature – high	√			√	√		If applicable
	Failure of cooling pump or fan motor				√			If applicable
	Interpole current		√			√		For DC propulsion motors only
	Differential protection or similar protection	√			√			For motors ≥ 1500 kW
Propulsion Semiconductor converter	Voltage (input)		√			√		
	Current (input)		√			√		
	Overload (high current)	√			√			Alarms before protective device is activated
	Open/close position for assignment switches					√		
	Converter cooling medium temperature – high	√	√		√	√		If applicable
	Failure of converter cooling pump or fan motor	√			√			If applicable
	Inter-phase reactor temperature – high				√	√		
	Tripping of filter circuit fuse	√			√			
Propulsion Transformer	Transformer windings temperature – high	√	√		√	√		
Others	Field circuit earth fault	√			√			May be omitted in circuits of brushless excitation systems and of motors rated up to 500 kW
	Main propulsion circuit earth fault		√			√		

CHAPTER 17 ADDITIONAL REQUIREMENTS FOR GEOTEXTILES LAYERS

Section 1 GENERAL PROVISIONS

17.1.1 Application

17.1.1.1 This Chapter applies to ships provided with special equipment for laying geotextiles.

17.1.1.2 Geotextiles layers are, in addition to the provisions of this Chapter, to comply with the relevant requirements of other PARTs and Chapters of the Rules as well as the relevant provisions of CCS Rules for Materials and Welding and of the flag State Administration, if any.

17.1.2 Notation

17.1.2.1 Ships complying with the provisions of this Chapter may be assigned the notation: Geotextiles Layer.

17.1.3 Definition

17.1.3.1 Geotextiles layers mean ships provided with special equipment for laying geotextiles, which are engaged in operations of laying soft mattress related to construction of cofferdams on land and floating structure projects under different environmental conditions such as coastal shoals and deep-water harbors.

17.1.4 Plans and documents

17.1.4.1 In addition to the plans and documents required in the relevant PARTs and Chapters of the Rules, the following plans and documents are to be submitted to CCS for approval (where applicable):

(1) Plan of reinforcement structure of geotextiles laying turning plate equipment;

(2) Plan of reinforcement structure of geotextiles laying positioning equipment.

17.1.4.2 The following plans and documents are to be submitted to CCS for information (where applicable):

(1) Information related to geotextiles laying equipment (such as turning plate, guide beam, coil drum and crane, etc.);

(2) Strength calculations of reinforcement structure of geotextiles laying equipment;

(3) Arrangement plan of positioning equipment of geotextiles laying operation;

(4) Strength calculations of reinforcement structure of geotextiles laying operation.

For special structures and arrangement, expansion of the submission scope of plans and documents may be required if deemed necessary by CCS.

Section 2 HULL STRUCTURE AND ARRANGEMENT

17.2.1 Hull structure

17.2.1.1 For hull structural strength, consideration is to be given to necessary reinforcement of the support structure of the equipment used in geotextiles laying operation.

17.2.2 Requirements for the support structure of geotextiles laying equipment

17.2.2.1 The strength of support and reinforcement structure of geotextiles laying equipment and geotextiles laying operation positioning equipment is to be checked by referring to the relevant requirements of Section 7, Chapter 3, PART TWO of the Rules.

17.2.3 Bunker

17.2.3.1 The bunker cannot be directly positioned under the working deck, unless a void hold or ballast tank etc. is arranged between the working deck and the bunker.

17.2.4 Hold arrangement

17.2.4.1 The working deck is to be distant from the engine room air inlet and outlet as far as possible.

Section 3 EQUIPMENT

17.3.1 General provisions

17.3.1.1 Geotextiles layers are to be capable of anchor mooring positioning or dynamic positioning.

17.3.2 Wheel house

17.3.2.1 A geotextiles layer is to be provided with a wheel house with good vision or a 360° video system for the whole ship, and communication by means of hardwired connection between the wheel house and the remote control station is to be provided.

CHAPTER 19 AC SHORE CONNECTION SYSTEMS

Section 1 GENERAL PROVISIONS

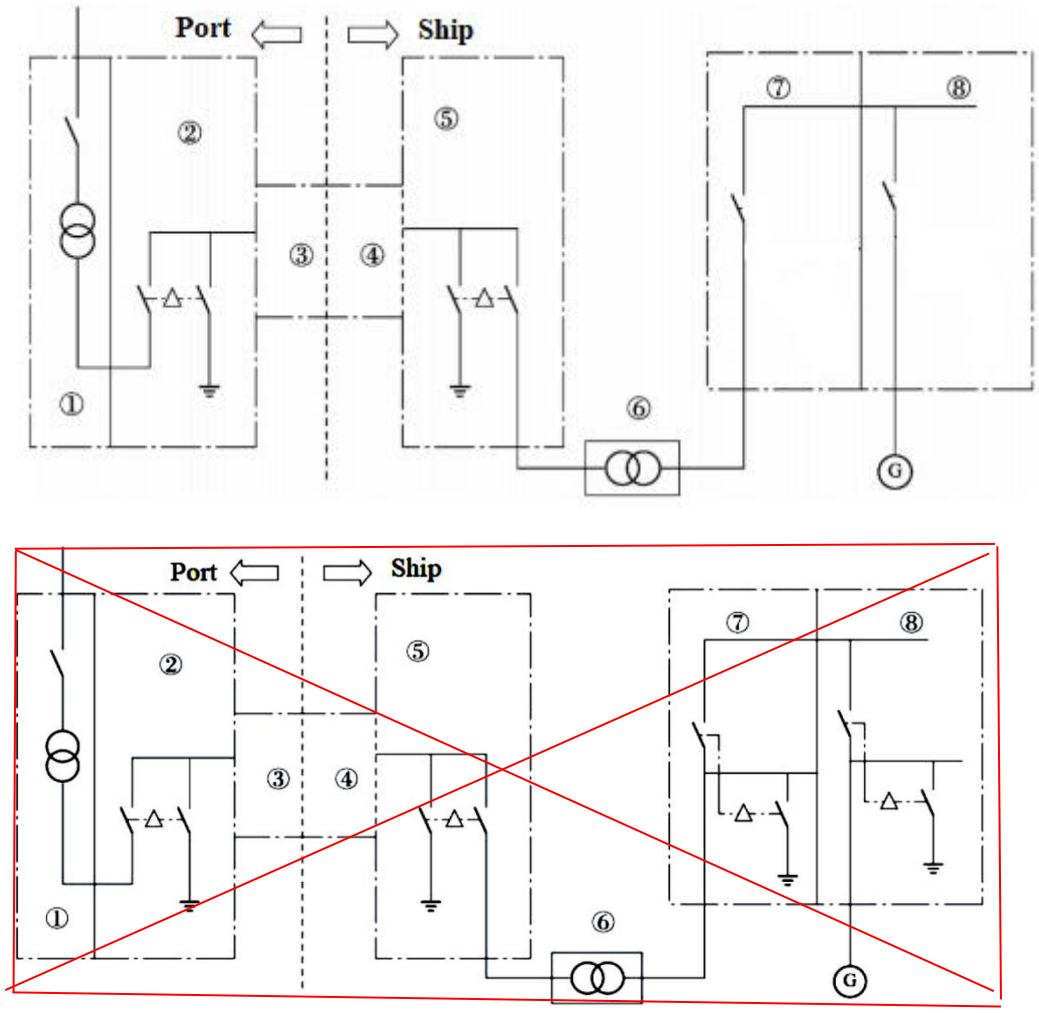
19.1.3 Definitions and terms

19.1.3.1 For the purpose of this Chapter, the following definitions apply:

(1) An **AC shore connection system** is the equipment used for power supply to ships in port, consisting of shipside and shore installations.

(2) An **AC low voltage shore connection system** is an AC shore connection system with rated voltages (voltage between phases) of 1 kV or less for power supply from port (shore supply) to ship's power distribution system.

(3) An **AC high voltage shore connection system** is an AC shore connection system with rated voltages (voltage between phases) of shore supply to ship's distribution system from 1 kV up to and including 15 kV. A typical AC HVSC system is shown in Figure 19.1.3.1(3).



① HV shore supply system (including transformers); ② HV shore distribution box; ③ Shore connection socket box; ④ Cable management system and cables (with plugs); ⑤ Shore connection switchboard; ⑥ Transformer; ⑦ Shore receiving control panel; ⑧ Generator panel of main switchboard

Figure 19.1.3.1(3) Diagram of a Typical AC High Voltage Shore Connection System

19.3.3 Shore receiving control panel

19.3.3.1 The shore receiving control panel is to be in accordance with the applicable requirements in Section 3, Chapter 3, PART FOUR of the Rules.

19.3.3.2 The shore receiving control panel is in general to be a component of the main switchboard, which is to be provided with isolation switches or circuit breakers.

CHAPTER 21 HULL MONITORING SYSTEMS

Section 1 GENERAL PROVISIONS

21.1.2 Class notations

21.1.2.1 Upon request of the owner and in accordance with different sensors/components of the hull monitoring system, the following class notations may be assigned:

(1) HMS(×): Sensors monitoring the global longitudinal stress amidships are installed in the hull monitoring system, and also sensors/components monitoring other parameters may be selected, where within the brackets there will be letters specifying the selected sensors/components and multiple letters are separated by comma ",”[①] and arranged in alphabetical order indicated in the table.

The following sensors/components in Table 21.1.2.1 may be selected for the hull monitoring system:

Letters Specifying Selected Sensors/Components Table 21.1.2.1

Letter	Description
Gn	Sensor monitoring the global hull strain
Dn	Sensor monitoring the local hull strain
On	Sensor monitoring the propulsion shaft(s) output
An	Sensor monitoring the axial acceleration
Mn	Device for monitoring of hull rigid body motions (six degrees of freedom)
Pn	Sensor monitoring the transient sea pressure acting on the hull (slamming)
Sn	Sensor monitoring the liquid motion pressures in tanks (sloshing)
Tn	Sensor monitoring the temperature
Bn	Device for monitoring the wave
Wn	Wind sensor
Nn	Navigation sensors
Ln	Backed up statistics and triggered time series to be sent to CCS periodically
Cn	Online link to loading instrument that is continuously up-dating the loading condition

Note: n denotes the number of sensors or devices.

(2) HMS-HSC (×): applicable to high speed craft and the sensors/components installed in the hull monitoring system are to comply with Table 21.4.3.2.

Section 2 SYSTEM DESIGN

21.2.2 System requirements

21.2.2.14 Each strain gauge is initially to be set to a stress calculated in an agreed ~~still water~~ loading condition. This calculated stress is to be compatible with the output of the loading instrument and calculations made using the loading manual. The set-up is not to be carried out when dynamic stresses are present and is to be made when temperature effects are minimized and in absence of large gradients. ~~In the event that the difference is greater than 5% of the approved value or 10 N/mm^2 occurs, whichever is the greater, the setup of still water loading condition is to be repeated.~~ The initial reading of the global strain gauge is to be checked against an agreed loading condition in calm water. In the event that the difference is greater than 5% of the approved value or 5 N/mm^2 occurs, whichever is the greater, the setup and subsequent checking are to be repeated.

Section 3 DATA PROCESSING AND STORAGE

[①] For example, a bulk carrier equipped with sensors monitoring the global longitudinal stress amidships and also sensors monitoring the axial acceleration and local hull strain may be assigned the class notation HMS (Gn, Dn, An) upon request of the owner.

21.3.6 Hull stress

21.3.6.3 The hull monitoring system is to have the following three options for each individual strain sensor, to be selected independently, for input to the statistical analyses and the alarm handler. The option is to be selected during the initial installation of the hull monitoring system, with explanations given in the configuration file.

(1) measured strain as recorded (including possible effects due to temperature differences in the hull structure);

(2) measured strain high-passed filtered in order to remove low cycle temperature effects;

(3) measured strain high-passed filtered in order to remove low cycle temperature effects, and then have a strain offset added to the filtered strain signal, corresponding to the strain ~~calculated by the loading instrument~~ due to still water loading at each sensor position.

CHAPTER 24 ADDITIONAL REQUIREMENTS FOR STAND-BY SHIPS AND RESCUE SHIPS

Section 1 GENERAL PROVISIONS

24.1.1 Application

24.1.1.1 Unless expressly provided otherwise, this Chapter applies to ~~ships providing safety stand-by and rescue services for offshore installations or ships in operation and engaged in rescue operations at sea for ships and crew in distress~~ stand-by ships and rescue ships.

24.1.1.2 Stand-by ships and rescue ships are, in addition to the provisions of this Chapter, to comply with the relevant requirements of other PARTs and Chapters of the Rules as well as the relevant provisions of CCS Rules for Materials and Welding and of the flag State Administration, if any.

24.1.2 Notation

24.1.2.1 Stand-by ships complying with the provisions of this Chapter may be assigned the notation: Stand-by Ship~~ and Rescue Ship~~.

24.1.2.2 Rescue ships complying with the provisions of this Chapter may be assigned the notation: Rescue Ship.

24.1.3 Definitions

24.1.3.1 Stand-by ship means ships ~~engaged in unrestricted service and~~ providing safety stand-by and conventional rescue for offshore installations or ships in operation, capable of receiving personnel evacuated from offshore engineering installations and offshore structures or from other ships on account of an emergency, or of rescuing personnel from sea. ~~Rescue ship means ships engaged in unrestricted service and providing rescue operations at sea for ships and crew in distress.~~

24.1.3.2 Rescue ship means ships engaged in rescue operations at sea for ships and crew in distress.

24.1.3.~~2~~3 Survivors mean personnel evacuated from offshore engineering installations and offshore structures or from other ships on account of an emergency, or rescued from sea.

24.1.4 Plans and documents

24.1.4.1 In addition to those required in the relevant PARTs and Chapters of the Rules, the following plans and documents are to be submitted to CCS for approval. For special structures and arrangements, the scope of plans and documents to be submitted for approval may be expanded if deemed necessary by CCS:

(1) Arrangement of safety and rescue equipment;

(2) System diagram and arrangement of searchlights;

(3) System diagram of aviation frequency two-way VHF radiotelephone apparatus.

24.1.4.2 The following plans and documents are to be submitted to CCS site surveyors:

(1) Operation manual, in working language, available onboard for the crew. The operation manual is to include:

① safety stand-by and rescue information and training details provided by the ship owner or operator;

② maintenance and operation of safety and rescue equipment, including the arrangement and information on the use of radio apparatus onboard provided as required;

③ safety and rescue procedures, to guide the evacuation of personnel from offshore engineering installations and offshore structures or from other ships, or the rescue of personnel from sea;

④ operation details of safety and rescue;

⑤ dynamic capability analysis (ship's mooring, heading keeping capability, speed, etc., under the specified sea conditions).

Section 2 CONSTRUCTION AND ARRANGEMENT

24.2.1 Superstructures and deckhouses

24.2.1.1 The structure is to comply with the relevant requirements of Chapter 11, PART TWO of the Rules.

24.2.1.2 Windows are to comply with the relevant requirements of Chapter 11, PART TWO of the Rules.

24.2.1.3 Navigation bridge

(1) The navigation bridge is to be so arranged that there is an unobstructed view all around. Clear view at the navigation bridge is to be ensured during safe rescue operations.
(2) Windows are to be installed from the outside except for those on the aft bulkhead.

24.2.2 Rescue zone

24.2.2.1 A rescue zone with a length of not less than 5 m is to be established and extended as far as possible on each side of the ship.

24.2.2.2 The rescue zone is to be located well clear of the propellers and as close to midships as practicable, with a clear deck area portside to starboard to permit the boarding of survivors and to carry on rescue operations.

24.2.2.3 ~~Bulwarks or~~ Handrails in the rescue zone are to be provided with doors or chains which are readily openable ~~or removable~~, or removable stanchions are to be used. Bulwarks in the rescue zone are to be provided with doors, openings or other means of embarkation. Such means of embarkation are to be arranged to facilitate the hanging and use of boarding nets.

24.2.2.4 The rescue zone is to be provided with boarding nets fitted with lifelines.

24.2.2.5 The rescue zone is to be free of hull fittings and projections and overboard discharges which would impede rescue operations.

24.2.2.6 The rescue zone is to be provided with lighting required by 24.4.5.

24.2.2.7 The rescue zone is to be marked so as to be readily identified from seaward.

Section 3 ACCOMMODATION SPACES FOR SURVIVORS

24.3.1 Provision requirements for the spaces

24.3.1.1 General requirements

(1) Spaces provided for shelter of the survivors are to be enclosed from the weather and provided with heating, lighting and ventilation facilities.

(2) In emergency, the survivors may be lodged in the accommodation spaces other than the following spaces: sanitary area, galley, the master's cabin, radio room, navigation bridge and main passages that are to be kept unblocked.

(3) The dimension of the shelter spaces for the survivors is to be indicated on the general arrangement plan.

24.3.1.2 The area of the shelters is to be determined as 0.75 m^2 for every assigned survivors, including free spaces and floors for movable furniture, fixed seating and fixed beds; other fixed furniture, toilets and bathrooms are not to be included.

24.3.1.3 Sanitary facilities

(1) Dedicated sanitary facilities are to be provided for the survivors. One set of fixtures comprising a toilet, a washing basin and shower, is to be provided for every 50 survivors.

(2) Fresh water tanks and potable water tanks of sufficient quantity are to be provided for the survivors onboard.

24.3.1.4 Treatment area

(1) The treatment area is to be readily accessible for the survivors from the rescue zone and is to be effectively isolated from the crew's accommodation area.

(2) Given the situation when the survivors are transferred to the helicopter winching area, the arrangement of the treatment area is to make transfer passage easily accessible and unobstructed.

(3) Corridors and doors leading to the rescue zone are to be sufficient in width to allow the passage of stretchers transferring survivors.

Section 4 RESCUE AND SAFETY EQUIPMENT

24.4.1 ~~Fast~~ Rescue boats

24.4.1.1 A rescue boat is to be provided on a stand-by ship.

24.4.1.~~1~~2 A readily available fast rescue boat is to be provided on a rescue ship.

~~24.4.1.2~~(1) The rescue boat and its launching appliances are to comply with the requirements of Chapters V and VI of the International Life-saving Appliance (LSA) Code.

~~24.4.1.3~~(2) Where davits for rescue boats have to rely on electricity for operation, they are to be power supplied by emergency switchboard.

24.4.2 Rescue nets

24.4.2.1 Rescue nets are not to be less than 5 m in width with the center of gravity at bottom.

24.4.2.2 The length of the rescue nets is to extend at least 1 m below the waterline at lightest draught.

24.4.3 Searchlights

24.4.3.1 Two searchlights capable of rotating 360° horizontally are to be provided. The searchlights are remotely controllable at the navigation bridge.

24.4.3.2 The searchlights are to provide at least 50 lux illumination at a distance of 250 m.

24.4.4 Water spray fire extinguishing systems

24.4.4.1 The water spray fire extinguishing system is to be provided on a rescue ship to protect the rescue operation area on the open deck against the heat and fire in the boundary of the rescue zone.

24.4.4.2 The nozzles of the water spray fire extinguishing system are to be arranged to give an even distribution of waterspray over the whole rescue operation area on the open deck.

24.4.4.3 The water spray fire extinguishing system is to ensure even distribution of water spray in the rescue operation area.

24.4.4.4 The water spray fire extinguishing system is to have a capacity of at least 5 *l*/min per m^2 of the protected area which is internally insulated to A-60 class and at least 10 *l*/min per m^2 of other protected areas.

24.4.4.5 The pumping capacity is to be sufficient to supply simultaneously at the required pressure the sections which serve the maximum area of the rescue zone. Where the main fire pumps are used for this purpose, they are to be capable of operating this system, the water monitors and the hose stations simultaneously at the required pressure. A connection with a shut-off valve is to be fitted between the piping system for the water monitors and the supply line for the water spray fire extinguishing system.

24.4.4.6 Means are to be taken to ensure that necessary visibility from the navigation bridge and the remote-control station can be maintained during the water spray operations.

24.4.5 Deck illumination

24.4.5.1 Main lighting and emergency lighting are to be provided in the following areas:

(1) rescue boat stowage locations, launching appliances, reception and rescue areas;

(2) to provide floodlighting of the sea in way of the rescue zone and rescue boat launch and recovery area;

(3) the helicopter winching deck area and access routes leading to and from the reception area.

24.4.6 Treatment facilities

24.4.6.1 Treatment facilities, including stretchers, blankets or coverings, bandages and dressing, splints, thermal insulation blankets and insulation materials, etc. are to be provided.

24.4.6.2 The treatment facilities are to be readily available.

24.4.6.3 The treatment facilities are to be appropriately wrapped, labeled, stored and marked.

24.4.7 Towing

24.4.7.1 Means to tow rescue boats, lifeboats or liferafts are to be provided.

24.4.8 Other life-saving appliances

24.4.8.1 The relevant life-saving appliances are to be provided according to Table 24.4.8.1.

Other Life-Saving Appliances **Table 24.4.8.1**

Appliance	Quantity
~~Safety ropes with parachute straps and hooks~~ Fall protection equipment (e.g. safety harness and safety line with hook)	3
Throw lines	4
Diver ladders	2
~~Extra-large~~ Lifejackets	~~6~~ Assigned number of survivors
Long handle hooks	2
Lifebuoys with self-igniting lights~~, reflective tapes~~ and ropes (not less than 30 m in length)	4
~~Note: The number of lifejackets is to be determined according to the maximum assigned number of survivors.~~	

24.4.9 Helicopter winching deck area

24.4.9.1 Helicopter winching deck area is to be provided. The area is to be unobstructed and well-illuminated.

Section 5 NAVIGATION AND COMMUNICATION EQUIPMENT

24. 5.1 Navigation equipment

24.5.1.1 Regardless of its dimension, shipborne navigation equipment required to be provided for cargo ships of 500 gross tonnage and above according to ~~SOLAS Reg. V/19~~ the Administration is to be provided.

24.5.2 Radiocommunications

24.5.2.1 One two-way VHF radiotelephone using aviation frequency (121.5 MHz and 123.1 MHz) is to be provided, in addition to the radio equipment required by ~~SOLAS Ch.IV~~ the Administration.

CHAPTER 26 ADDITIONAL REQUIREMENTS FOR INSTALLATION OF BALLAST WATER MANAGEMENT SYSTEMS

Section 1 GENERAL PROVISIONS

26.1.2 Definitions

Applicability of the requirements for each BWMS technology **Table 26.1.2.2**

BWMS's Technology category*→ Requirements of this Chapter ↓	1 In-line UV or UV + Advanced Oxidation Technology (AOT) or UV + TiO or UV + Plasma	2 In-line Flocculation	3a In-line membrane separation and de-oxygenation (injection of N from a N Generator)	3b In-line de-oxygenation (injection of Inert Gas from Inert Gas Generator)	3c In-tank de-oxygenation with Inert Gas Generator	4 In-line full flow electrolysis	5 In-line side stream electrolysis (2)	6 In-line (stored) chemical injection	7a In-line side-stream ozone injection without gas/liquid separation tank and without	7b In-line side-stream ozone injection with gas/liquid separation tank and Discharge water treatment tank	8 In-tank pasteurization and de-oxygenation with N2 generator
26.1.1and 26.1.2	x	x	x	x	x	x	x	x	x	x	x
26.2.1.1 to 26.2.1.4	x	x	x	x	x	x	x	x	x	x	x
26.2.1.5			x	x	x						x
26.2.1.6	x	x	x	x	x	x	x	x	x	x	x
26.2.1.7			x	x	x						x
26.2.1.8				x						x	
26.2.1.9	x	x	x	x	x	x	x	x	x	x	x
26.2.2.1（1）				x	x				x	x	
26.2.2.1（2）						x	x	x			
26.2.2.2	x	x	x	x		x	x	x	x	x	
26.2.2.3	x	x	x	x	x	x	x	x	x	x	x
26.2.2.4	x	x	x	x		x	x	x	x	x	
26.2.3.1（1）		x	x			x	x	x	x	x	x
26.2.3.1（2）			x	x	x				x	x	x
26.2.3.1（3）									x	x	
26.2.3.1（4）						x	x	x	x	x	
26.2.3.1（5）						x	x	x			
26.2.3.1（6）			x	x	x				x	x	x
26.2.3.2（1）to（4）		x	x	x	x	x	x	x	x	x	x
26.2.3.2（5）			x			x	x	x	x	x	x
26.2.3.2（6）			x			x	x	x	x	x	x
26.2.3.2（7）			x			~~x~~	~~x~~	~~x~~	x	x	x
26.2.3.2（8）			x			x	x	x	x	x	x
26.2.3.3		x				x	x	x	x	x	
26.2.3.4						x	x	x	x	x	

CHAPTER 36 ONBOARD CARBON CAPTURE SYSTEM

Section 1 GENERAL PROVISIONS

36.1.1 General requirements

36.1.1.1 This Chapter applies to ships applying for the Onboard Carbon Capture System notation, for the purpose of providing standards for the design, survey and operational safety of ships provided with OCCS so as to minimize the harm to ships, crew members and the environment caused by OCCS.

36.1.1.2 Ships provided with the onboard carbon capture system are, in addition to the provisions of this Chapter, to satisfy applicable requirements of others parts and chapters of the rules and relevant requirements of the Guidelines for Onboard Carbon Capture Systems.

36.1.2 Class notation

36.1.2.1 Ships complying with the provisions of this Chapter ~~may be~~ are assigned the onboard carbon capture system notation upon satisfactory survey:

OCCS (Onboard Carbon Capture System)

36.1.2.2 For OCCS ready ships, the ready notation and requirements are to satisfy relevant requirements of the Guidelines for Onboard Carbon Capture Systems.

36.1.3 Plans and information

36.1.3.1 The following plans and information are to be submitted for approval as a minimum:

~~(1) schematic diagram of onboard carbon capture system;~~

~~(2) energy consumption calculations of onboard carbon capture system.~~

(1) relevant piping system plan of onboard carbon capture system;

(2) power load calculations;

(3) electrical system plan of onboard carbon capture system.

36.1.3.2 The following plans and information are to be submitted for information as a minimum:

(1) technical description and installation plan of onboard carbon capture system, including:

① system design parameters;

② system carbon dioxide capture capacity calculation;

③ list of system equipment;

④ system arrangement plan.

(2) operation and maintenance manual of onboard carbon capture system;

(3) carbon dioxide absorber safety data sheet;

(4) risk assessment report of onboard carbon capture system.

36.1.3.3 The scope of plans and information submitted for approval may be expanded when deemed necessary by CCS.

Section 2 DESIGN AND ARRANGEMENT

36.2.1 System design

36.2.1.1 The onboard carbon capture system is to be able to adapt to the environmental and working conditions of the ship's operation.

36.2.1.2 The carbon dioxide capture capacity of the onboard carbon capture system is to meet the expected design objectives, and the capacity of carbon dioxide storage tank is to meet the expected design volume.

36.2.1.3 The strength and tightness design of the onboard carbon capture system is to meet the set conditions and the possible low temperature condition in case of leakage of carbon dioxide.

36.2.1.4 The onboard carbon capture system is to be provided with necessary redundant safety protection measures and capable of preventing and dealing with accidents.

36.2.1.5 The onboard carbon capture system is to be provided with monitoring, alarm and control systems.

36.2.1.6 The design of onboard carbon capture system is to facilitate shipboard operation and maintenance.

36.2.1.7 The energy supply (e.g. electricity, steam etc.) on board is to satisfy the expected operating requirements of the onboard carbon capture system.
36.2.1.8 The onboard carbon capture system is to minimize the potential risk to ships, essential equipment, personnel and the environment. Chemical substances in storage and use are to ensure that they will not cause harm to personnel and the environment.

36.2.2 Arrangement and safety requirements

36.2.2.1 Shipboard installation, arrangement and operation of onboard carbon capture system are to meet the following requirements:
(1) mechanical and high temperature protection is to be considered;
(2) life-saving appliances, muster station and means of escape are not to be affected;
(3) the impact of the change of ship tonnage on the applicable standards after the addition of the system;
(4) navigation bridge visibility is to comply with SOLAS regulation V/22 and the relevant provisions of the flag State;
(5) the normal operation of the ship's essential equipment (e.g. as main engines, generators and boilers, etc.) is not affected.
36.2.2.2 After the onboard carbon capture system is installed, the ship’s structural strength is to satisfy the requirements for longitudinal and local strength of the rules.
36.2.2.3 The effect of windage area, lightship center of gravity, heel and trim on ship stability is to be considered for ships provided with onboard carbon capture system.
36.2.2.4 The mechanical properties, chemical composition, manufacturing and testing of materials used in the equipment and pipelines of onboard carbon capture system are to comply with the relevant provisions of CCS Rules for Materials and Welding, and corrosion prevention measures are be considered (if necessary). Materials (including coatings) used in equipment, pipelines and components in contact with seawater is not to cause any harm to marine organisms.
36.2.2.5 Detectors are to be fitted where carbon dioxide leakage or accumulation is likely to occur. When the detector operates, audible and visual alarm signals are to be given on the bridge and in the ~~central control station (if any)~~ onboard carbon capture system control station.
36.2.2.6 The installation and operation of the onboard carbon capture system is to minimize the impact on the fuel combustion device.
36.2.2.7 During the operation and maintenance of the onboard carbon capture system, all operations that may pose risks to personnel are to be provided with appropriate protective equipment on board.

Section 3 SURVEYS

36.3.1 General requirements

36.3.1.1 Equipment and components of the onboard carbon capture system are to satisfy ~~be furnished with CCS certificates in accordance with~~ the applicable requirements of Chapter 3, PART ONE of the rules.
36.3.1.2 Equipment constituting the onboard carbon capture system is to be subject to surveys and tests in accordance with approved plans and relevant standards.

36.3.2 ~~Initial s~~Surveys during construction

36.3.2.1 Surveys and functional testing are to be carried out to devices, equipment, systems, components and installation of relevant pipelines of the onboard carbon capture system.
36.3.2.2 Sea trials are to be carried out to the system in accordance with the requirements of the sea trial programme

36.3.3 Surveys after construction

36.3.3.1 Ships provided with the onboard carbon capture system are to be subject to annual surveys, intermediate surveys and special surveys. ~~For ships subject to continuous surveys, all required survey items are generally to be completed every year~~.

CHAPTER 37 ADDITIONAL REQUIREMENTS FOR CARRYING DRY CARGO IN BULK

Section 1 GENERAL PROVISIONS

37.1.1 General requirements

37.1.1.1 Ships which are intended to carry dry cargo in bulk, with a configuration different from that defined in 8.1.1.1, Chapter 8, PART TWO of the rules, are assigned the notation: SOLAS XII where the requirements of this Chapter are satisfied.

37.1.2 Additional requirements for SOLAS XII bulk cargo carriage

37.1.2.1 Ships applying for the SOLAS XII notation are, in addition to satisfying the applicable requirements SOLAS Chapter XII, to satisfy applicable requirements of Chapter 8, PART TWO of the rules based on specific configuration.

CHINA CLASSIFICATION SOCIETY

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

AMENDMENTS

2024

PART NINE COMMON STRUCTURAL RULES FOR BULK CARRIERS AND OIL TANKERS

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PART 9-1 GENERAL HULL REQUIREMENTS

CHAPTER 4 LOADS

SECTION 6 INTERNAL LOADS

4 STEEL COIL LOADS IN CARGO HOLDS OF BULK CARRIERS

4.1 General

4.1.3 Arrangement of steel coils independently of the floor locations

For steel coils loaded without respect to the location of floors in the inner bottom, see Figure 9:
The number n_2 of load point dunnages per elementary plate panels is to be found in comply with Table 9.
The distance l_{lp}, in m, between outermost load point dunnages per elementary plate panel is to be found in comply with Table 10.

Number n_2 of load point dunnages per elementary plate panel **Table 9**

n_2(1) (2)	n_3(3)				
	2	3	4	5	6
1	$0 < \frac{l}{l_{st}} \le 0.5$	$0 < \frac{l}{l_{st}} \le 0.33$	$0 < \frac{l}{l_{st}} \le 0.25$	$0 < \frac{l}{l_{st}} \le 0.2$	~~$0 < \frac{l}{l_{st}} \le 0.17$~~
2	$0.5 < \frac{l}{l_{st}} \le 1.2$	$0.33 < \frac{l}{l_{st}} \le 0.67$	$0.25 < \frac{l}{l_{st}} \le 0.5$	$0.2 < \frac{l}{l_{st}} \le 0.4$	~~$0.17 < \frac{l}{l_{st}} \le 0.33$~~
3	$1.2 < \frac{l}{l_{st}} \le 1.7$	$0.67 < \frac{l}{l_{st}} \le 1.2$	$0.5 < \frac{l}{l_{st}} \le 0.75$	$0.4 < \frac{l}{l_{st}} \le 0.6$	~~$0.33 < \frac{l}{l_{st}} \le 0.5$~~
4	$1.7 < \frac{l}{l_{st}} \le 2.4$	$1.2 < \frac{l}{l_{st}} \le 1.53$	$0.75 < \frac{l}{l_{st}} \le 1.2$	$0.6 < \frac{l}{l_{st}} \le 0.8$	~~$0.5 < \frac{l}{l_{st}} \le 0.67$~~
5	$2.4 < \frac{l}{l_{st}} \le 2.9$	$1.53 < \frac{l}{l_{st}} \le 1.87$	$1.2 < \frac{l}{l_{st}} \le 1.45$	$0.8 < \frac{l}{l_{st}} \le 1.2$	~~$0.67 < \frac{l}{l_{st}} \le 0.83$~~
6	$2.9 < \frac{l}{l_{st}} \le 3.6$	$1.87 < \frac{l}{l_{st}} \le 2.4$	$1.45 < \frac{l}{l_{st}} \le 1.7$	$1.2 < \frac{l}{l_{st}} \le 1.4$	~~$0.83 < \frac{l}{l_{st}} \le 1.2$~~
7	$3.6 < \frac{l}{l_{st}} \le 4.1$	$2.4 < \frac{l}{l_{st}} \le 2.73$	$1.7 < \frac{l}{l_{st}} \le 1.95$	$1.4 < \frac{l}{l_{st}} \le 1.6$	~~$1.2 < \frac{l}{l_{st}} \le 1.37$~~
8	$4.1 < \frac{l}{l_{st}} \le 4.8$	$2.73 < \frac{l}{l_{st}} \le 3.07$	$1.95 < \frac{l}{l_{st}} \le 2.4$	$1.6 < \frac{l}{l_{st}} \le 1.8$	~~$1.37 < \frac{l}{l_{st}} \le 1.53$~~
9	$4.8 < \frac{l}{l_{st}} \le 5.3$	$3.07 < \frac{l}{l_{st}} \le 3.6$	$2.4 < \frac{l}{l_{st}} \le 2.65$	$1.8 < \frac{l}{l_{st}} \le 2.0$	~~$1.53 < \frac{l}{l_{st}} \le 1.7$~~
10	$5.3 < \frac{l}{l_{st}} \le 6.0$	$3.6 < \frac{l}{l_{st}} \le 3.93$	$2.65 < \frac{l}{l_{st}} \le 2.9$	$2.0 < \frac{l}{l_{st}} \le 2.4$	~~$1.7 < \frac{l}{l_{st}} \le 1.87$~~

(1) In case l/l_{st} is greater than the value given in Table 9, n_2 is to be considered as greater than 10.
(2) For plating, n_2 is to be based on l. For stiffener, n_2 is to be derived with l replaced by l_{bdg}.
(3) The number of dunnages, n_3, considered at the design stage is to reflect the intended operation conditions. Unusual arrangements with 5 or more dunnages per row of steel coil need to be carefully considered by the designer and ship owner.

Distance between outermost load point dunnages per elementary plate panel, l_{lp}, in m

Table 10

n_2(1)	n_3				
	2	3	4	5	6
1	Actual breadth of dunnages				
2	0.5 l_{st}	0.33 l_{st}	0.25 l_{st}	0.2 l_{st}	0.17 l_{st}
3	1.2 l_{st}	0.67 l_{st}	0.50 l_{st}	0.4 l_{st}	0.33 l_{st}
4	1.7 l_{st}	1.20 l_{st}	0.75 l_{st}	0.6 l_{st}	0.5 l_{st}
5	2.4 l_{st}	1.53 l_{st}	1.20 l_{st}	0.8 l_{st}	0.67 l_{st}
6	2.9 l_{st}	1.87 l_{st}	1.45 l_{st}	1.2 l_{st}	0.83 l_{st}
7	3.6 l_{st}	2.40 l_{st}	1.70 l_{st}	1.4 l_{st}	1.2 l_{st}
8	4.1 l_{st}	2.73 l_{st}	1.95 l_{st}	1.6 l_{st}	1.37 l_{st}
9	4.8 l_{st}	3.07 l_{st}	2.40 l_{st}	1.8 l_{st}	1.53 l_{st}
10	5.3 l_{st}	3.60 l_{st}	2.65 l_{st}	2.0 l_{st}	1.7 l_{st}
(1) When $n_2 > 10$, l_{lp} is to be taken equal to l.					

4.3 Static loads

4.3.1 Static loads on the inner bottom

The static load $F_{sc\text{-}ib\text{-}s}$, in kN, on the inner bottom due to steel coils is to be taken as:

$F_{sc\text{-}ib\text{-}s} = M_{sc\text{-}ib} \cdot g$

where:

$M_{sc\text{-}ib}$: Equivalent mass of steel coils, in t, to be taken as:

$$M_{sc-ib} = K_S W \frac{n_1 n_2}{n_3} \quad \text{for} \quad n_2 \leq 10 \text{ ~~and } n_3 \leq 5~~$$

$$M_{sc-ib} = K_S W n_1 \frac{l}{l_{st}} \quad \text{for} \quad n_2 > 10 \text{ ~~or } n_3 > 5~~, \text{ for plating}$$

$$M_{sc-ib} = K_S W n_1 \frac{l_{bdg}}{l_{st}} \quad \text{for} \quad n_2 > 10, \text{ for stiffener}$$

K_S : Coefficient to be taken as:

$K_S = 1.4$ when steel coils are lined up in one tier with a key coil.

$K_S = 1.0$ in other cases.

4.3.2 Static load on the hopper side

The static load $F_{sc\text{-}hs\text{-}s}$, in kN, on the hopper side due to steel coils is to be taken as:

$F_{sc\text{-}hs\text{-}s} = \cos\theta_h \, M_{sc\text{-}hs} \cdot g$

where:

$M_{sc\text{-}hs}$: Equivalent mass of steel coils, in t, to be taken as:

$$M_{sc-hs} = C_k W \frac{n_2}{n_3} \quad \text{for} \quad n_2 \leq 10 \text{ ~~and } n_3 \leq 5~~$$

$$M_{sc-hs} = C_K W \frac{l}{l_{st}} \quad \text{for} \quad n_2 > 10 \text{ ~~or } n_3 > 5~~, \text{ for plating}$$

$$M_{sc-hs} = C_K W \frac{l_{bdg}}{l_{st}}$$ for n_2>10, for stiffener

C_k : Coefficient to be taken as:
C_k = 3.2 when steel coils are lined up two or more tiers, or when steel coils are lined up one tier and key coil is located second or 3rd from hopper sloping plate or inner hull plate.
C_k = 2.0 for other cases.

CHAPTER 6 HULL LOCAL SCANTLING

SECTION 4 PLATING

2 SPECIAL REQUIREMENTS

2.2 Bilge Plating

2.2.2 Bilge ~~plate~~ plating thickness

a) The net thickness of transversely stiffened bilge plating is not to be taken less than the ~~offered~~ net required thickness for the adjacent bottom shell plating ~~or~~ and adjacent side shell plating, by Ch 6 and Ch 8, Sec 2 and Sec 3, whichever is greater. When bilge plating is divided into two or more strakes, in accordance with this requirement, the net thicknesses of lower and upper strakes are to be determined in comparison with the net required thicknesses of adjacent bottom shell plating and side shell plating respectively.

CHAPTER 8 BUCKLING

SECTION 1 GENERAL

2 APPLICATION

2.1 Scope

2.1.3 Enlarged stiffener

Enlarged stiffeners~~, with or without web stiffening,~~ used for Permanent Means of Access (PMA), whose net web height are above 700 mm, and net offered section modulus are 3 times greater than the smaller one of adjacent surrounding stiffeners not used for PMA, are to comply with the following requirements:

a) Slenderness requirements for primary supporting members as follows:
- For enlarged stiffener web, see item (a) of Ch 8, Sec 2, [4.1.1].
- For enlarged stiffener flange, see item (b) of Ch 8, Sec 2, [4.1.1] and Ch 8, Sec 2, [5.1].
- For stiffeners fitted on enlarged stiffener web, see Ch 8, Sec 2, [3.1.1] and Ch 8, Sec 2, [3.1.3].

b) Buckling strength of prescriptive requirements as follows:
- For enlarged stiffener web, see Ch 8, Sec 3, [3.2].

- For stiffeners fitted on enlarged stiffener web, see Ch 8, Sec 3, [3.1] and Ch 8, Sec 3, [3.3].

c) All structural elements used for PMA are to be complied with for the buckling requirements of the FE analysis in Ch 8, Sec 4 when applicable.

d) Buckling strength of longitudinal PMA platforms without stiffeners fitted on enlarged stiffener web is to be checked using the criteria for local supporting members in Ch 8, Sec 3, [3.1] and Ch 8, Sec 3, [3.3].

SECTION 2 SLENERNESS REQUIREMENTS

4 PRIMARY SUPPORTING MEMBERS

4.1 Proportions and stiffness

4.1.1 Proportions of web plate and flange

The net thicknesses of the web plates and flanges of primary supporting members are to satisfy the following criteria:

a) Web plate:

$$t_w \geq \frac{s_w}{C_w}\sqrt{\frac{R_{eH}}{235}}$$

b) Flange:

$$t_f \geq \frac{b_{f-out}}{C_f}\sqrt{\frac{R_{eH}}{235}}$$

where:

s_w : Plate breadth, in mm, taken as the spacing of the web stiffeners.

C_w : Slenderness coefficient for the web plate taken as:

$C_w = 100$

C_f : Slenderness coefficient for the flange taken as:

$C_f = 12$

R_{eH} : Specified minimum yield stress of the plate material, in N/mm^2.

For the web plates, a lower R_{eH} may be used in this slenderness criterion provided the requirements specified in Sec 3 and Sec 4, if applicable, are satisfied for the structure assumed in the same lower R_{eH}.

If requirement b) is not fulfilled, the effective free flange outstand, in mm, used in strength assessment including the calculation of actual net section modulus, is to be taken as:

$$b_{f-out-\max} = C_f t_f \sqrt{\frac{235}{R_{eH}}}$$

CHAPTER 9 FATIGUE

SECTION 2 STRUCTURAL DETAILS TO BE ASSESSED

2 FINITE ELEMENT ANALYSIS

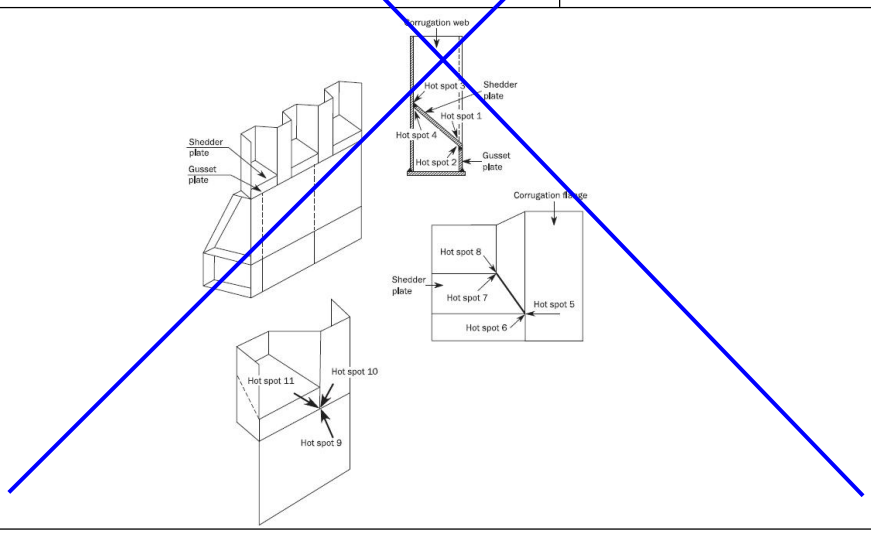
2.1 Structural details to be assessed

2.1.1 General

Critical structural details to be checked for fatigue by finite element analysis according to Ch 9, Sec 5 are given in [2.1.2] to [2.1.4].

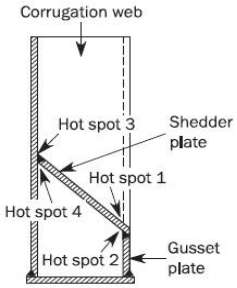
Table 4 to Table ~~18~~19 give the list of hot spots for structural details.

Hot spots for corrugated bulkhead to lower stool connection **Table 8**

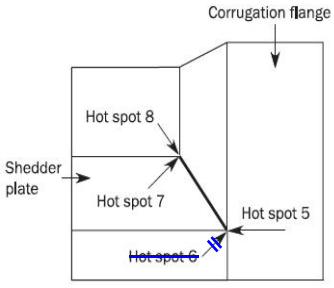
Hot spot location	Procedure for calculation of hot spot stress
Hot spots 1 and 3: Corrugation web above shedder plate Hot spot 4: Corrugation web below shedder plate Hot spot 5, 7 and 8: Corrugation flange Hot spot 5 and 8: Corrugation flange Hot spot 6: Gusset plate Hot spot 10: Corrugation corner to stool top plate Hot spot 11: Gusset plate in way of corrugation corner	Ch 9, Sec 5, [3.1] type 'a'
Hot spot 2: Corrugation web below shedder plate	Ch 9, Sec 5, [4.3]
	

Hot spot location	Procedure for calculation of hot spot stress	
	Cold/hot formed corrugations (Bent type)	Built-up corrugations (welded)
Hot spots 1 and 3: Corrugation web above shedder plate Hot spot 4: Corrugation web below shedder plate	Ch 9, Sec 5, [3.1] type 'a'	Ch 9, Sec 5, [4.3]
Hot spot 2: Corrugation web below shedder plate	Ch 9, Sec 5, [4.3]	
Hot spot 5: Corrugation flange	Ch 9, Sec 5 [3.1] type 'a'	
~~Hot spot 6: Gusset plate~~ Hot spot 8: Corrugation flange	Ch 9, Sec 5, [3.1] type 'a'	Ch 9, Sec 5, [4.3]
Hot spot 6: Gusset plate in case of welded gusset plate/shedder plate	Ch 9, Sec 5, [4.3]	
Hot spot 6: Gusset plate in case of bent type gusset plate/shedder plate	Ch 9, Sec 5, [3.1] type 'a'	
Hot spot 7: Shedder plate	Ch 9, Sec 5, [4.3]	
Hot spot 9: Lower stool plate to stool top plate	Ch 9, Sec 5 [3.1] type 'a'	

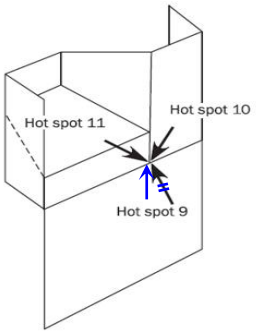
Hot spot 10: Corrugation corner to stool top plate Hot spot 11: Gusset plate in way of corrugation corner	Ch 9, Sec 5, [4.3]



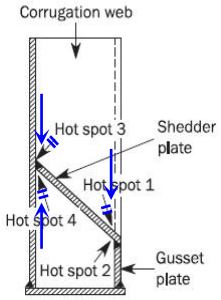
Built-up corrugations



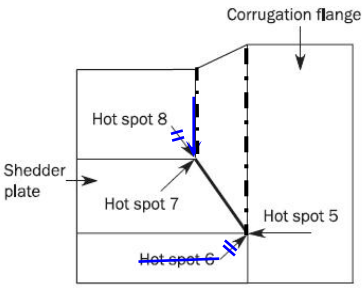
Built-up corrugations



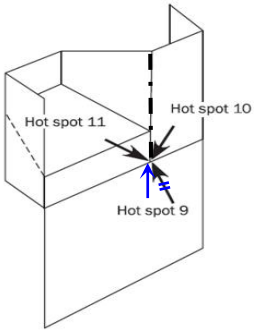
Built-up corrugations



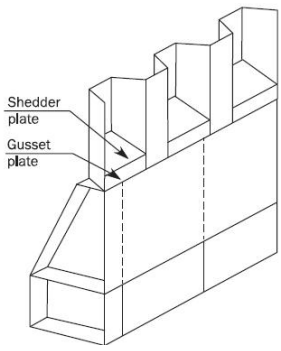
Cold/hot formed corrugations

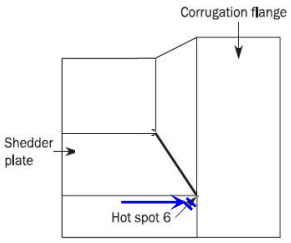


Cold/hot formed corrugations

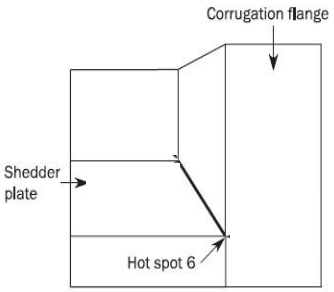


Cold/hot formed corrugations





Bent type Shedder/Gusset plate

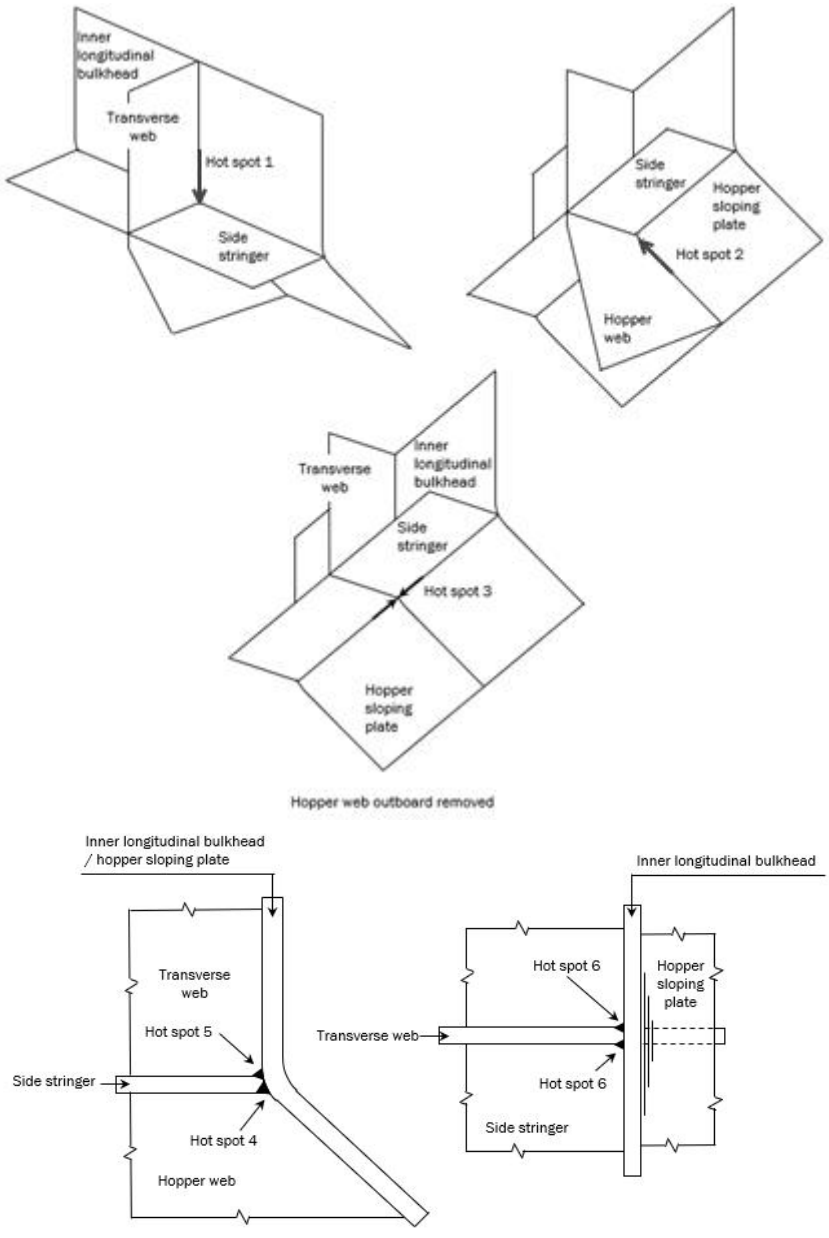


Welded Shedder/Gusset plate

-·—·—·—: the knuckle line of cold/hot formed connections

Hot spots for radiused upper hopper knuckle connection **Table 19**

Hot spot location	Procedure for calculation of hot spot stress
Hot spot 1: Inner longitudinal bulkhead plate on ballast tank side, above side stringer Hot spot 2: Radiused hopper sloping plate on ballast tank side, below side stringer Hot spot 3: Radiused hopper sloping plate on ballast tank side, below side stringer, towards hopper web Hot spot 4: Hopper web, below side stringer Hot spot 5: Transverse web, above side stringer Hot spot 6: Side stringer, to transverse web	Ch 9, Sec 5, [3.3]



SECTION 5 FINITE ELEMENT STRESS ANALYSIS

3 Hot Spot Stress for Details Different From Web-Stiffened Cruciform Joints

3.3 Bent hopper knuckle

3.3.1

The hot spot stress at the inner bottom/hopper sloping plate and inner hull/hopper sloping plate in transverse, vertical and longitudinal directions (i.e. hot spots 1, 2 and 3 defined in Ch 9, Sec 2, Table 5 and Table 19) of a bent hopper knuckle is to be taken as the surface principal stress read out from a point shifted away from the intersection line between the considered member and abutting member by the weld leg length.

3.3.2

The procedure for calculation of hot spot stress at flange such as inner bottom/hopper sloping plate and inner hull/hopper sloping plate is the same that for web-stiffened cruciform joints as described in [4.2.1]. The procedure that applies for hot spots on the ballast tank side of the inner bottom/hopper plate and inner hull/hopper sloping plate in way of a bent hopper knuckle is in principle the same as that applied on the cargo tank side of the inner bottom plate for welded knuckle in Figure 18 and Figure 19. The intersection line is taken at the mid-thickness of the joint assuming median alignment. The plate angle correction factor and the reduction of bending stress as applied for a web-stiffened cruciform joint in [4.2.2] are not to be applied for the bent hopper knuckle type.

3.3.3

The stress at hot spots located in way of the web such as transverse web, side stringer and side girder (i.e. hot spots 4, 5 and 6 defined in Ch 9, Sec 2, Table 5 and Table 19) at a bent hopper knuckle type is to be derived as described for web-stiffened cruciform joints in [4.3.1].

PART 2 SHIP TYPES

CHAPTER 1 BULK CARRIERS

SECTION 3 HULL LOCAL SCANTLINGS

SYMBOLS

For symbols not defined in this section, refer to Pt 1, Ch 1, Sec 4.

C_{XG}, C_{YS}, C_{YR}, C_{YG}, C_{ZP}, C_{ZR} : Load combination factors, as defined in Pt 1, Ch 4, Sec 2.

d_{shr} : Effective shear depth of the stiffener as defined in Pt 1, Ch 3, Sec 7, [1.4.3].

F_R : Resultant force, in kN, as defined in Pt 1, Ch 4, Sec 6, Table 7.

$F_{sc\text{-}ib\text{-}s}$: Static load, in kN, as defined in Pt 1, Ch 4, Sec 6, [4.3.1]. ~~l is to be substituted by l_{bdg} for stiffeners.~~

$F_{sc\text{-}ib}$: Total load, in kN, as defined in Pt 1, Ch 4, Sec 6, [4.2.1]. ~~l is to be substituted by l_{bdg} for stiffeners.~~

$F_{sc\text{-}hs\text{-}s}$: Static load, in kN, as defined in Pt 1, Ch 4, Sec 6, [4.3.2]. ~~l is to be substituted by l_{bdg} for stiffeners.~~

$F_{sc\text{-}hs}$: Total load, in kN, as defined in Pt 1, Ch 4, Sec 6, [4.2.2]. ~~l is to be substituted by l_{bdg} for stiffeners.~~

...

SECTION 4 HULL LOCAL SCANTLINGS FOR BULK CARRIERS L<150M

4 PRIMARY SUPPORTING MEMBERS

4.2 Design load sets

4.2.1 Application

Design load sets as given in Table 3 are to be considered for primary supporting members on cargo hold boundaries of bulk carriers less than 150 m in length.

Design load sets for primary supporting members in cargo hold region Table 3

Item	Design load set	Load component	Draught	Design load	Loading condition
~~Bulk cargo hold assigned as ballast hold~~ ~~Bulk cargo hold~~ • Double bottom floors and girders • Stringers and transverse web frames in double side structures ~~Compartments not carrying liquids~~	WB-4 ~~(1)~~	P_{in}-P_{ex} ~~(1)~~	T_{BAL-H}	S+D	Heavy ballast condition
	WB-6 ~~(1)~~	P_{in}	-	S	Harbour/test condition
	BC-11	P_{in}-P_{ex} ~~(1)~~	T_{SC}	S+D	Full load ~~Cargo loading~~ condition
	BC-12	P_{in}-P_{ex} ~~(1)~~	T_{SC}	S	Harbour condition
	FD-1~~(2)~~	P_{in}	T_{SC}	S+D	Flooded condition
	FD-2~~(2)~~	P_{in}	-	S	Flooded condition

~~(1) Pex is to be considered for external shell only.~~
~~(2) FD-1 and FD-2 are not applicable to external shell.~~
(1) Only applicable to holds assigned as ballast hold.
(2) Not applicable to holds assigned as ballast hold.

4.2.2 Loading conditions

The severest loading conditions from the loading manual or otherwise specified by the designer are to be considered for the calculation of Pin in design load sets BC-11 to BC-12.

~~If primary supporting members support deck structure or tank/watertight boundaries, applicable design load sets in Pt 1, Ch 6, Sec 2, Table 1 are also to be considered~~. For Primary supporting member in bilge hopper tanks and topside tanks, applicable design load sets in Pt 1, Ch 6, Sec 2, Table 1 are to be considered.

SECTION 5 CARGO HATCH COVERS

5 STRENGTH CHECK

5.5 ~~Stiffeners and primary supporting members of variable cross section~~ (VOID)

~~5.5.1~~
~~The net section modulus Z, in cm3, of stiffeners and primary supporting members with a variable cross section is to be taken not less than the greater of the values given by the following formulae:~~

~~$Z = Z_{CS}$~~

~~$Z = \left(1 + \frac{3.2\alpha - \psi - 0.8}{7\psi + 0.4}\right) Z_{CS}$~~

~~where:~~

~~Z_{CS} : Net section modulus, in cm3, for a constant cross section, complying with the checking criteria in [5.4.4].~~

~~a : Coefficient taken equal to:~~

~~$\alpha = \frac{l_1}{l_0}$~~

~~ψ : Coefficient taken equal to:~~

~~$\psi = \frac{Z_1}{Z_0}$~~

~~l_1 : Length of the variable section part, in m, as shown in Figure 3.~~

~~l_0 : Span measured, in m, between end supports, as shown in Figure 3.~~

~~Z_1 : Net section modulus at end, in cm3, as shown in Figure 3.~~

~~Z_0 : Net section modulus at mid-span, in cm3, as shown in Figure 3.~~

~~Moreover, the net moment of inertia, in cm4, of stiffeners and primary supporting members with a variable cross section is to be taken not less than the greater of the values given by the following formulae:~~

~~$I = I_{CS}$~~

~~$I = \left[1 + 8\alpha^3 \left(\frac{1-\varphi}{0.2 + 3\sqrt{\varphi}}\right)\right] I_{CS}$~~

~~where:~~

~~I_{CS} : Net moment of inertia, in cm4, with a constant cross section complying with [5.4.5].~~

~~φ : Coefficient taken equal to:~~

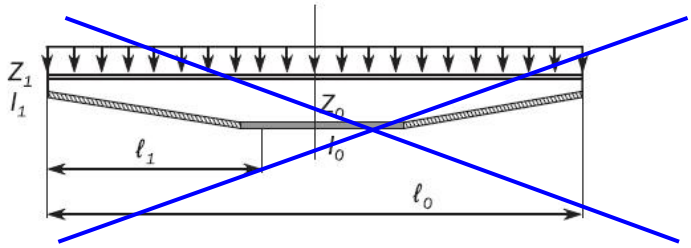
~~$\varphi = \frac{I_1}{I_0}$~~

~~I_1 : Net moment of inertia at end, in cm4, as shown in Figure 3.~~

~~I_0 : Net moment of inertia at mid-span, in cm4, as shown in Figure 3.~~

~~The use of these formulae is limited to the determination of the strength of stiffeners and primary supporting members in which abrupt changes in the cross section do not occur along their length.~~

Figure 3 : ~~Variable cross section stiffener~~ (VOID)



CHINA CLASSIFICATION SOCIETY

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

AMENDMENTS

2024

PART TEN SHIPS IN RESTRICTED SERVICE

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CHAPTER 1 SURVEYS AFTER CONSTRUCTION OF SHIPS ENGAGED ON NON-INTERNATIONAL VOYAGES

Section 3 SURVEYS OF MACHINERY

1.3.5 Surveys of propeller shafts and tube shafts

1.3.5.1 Relevant requirements for surveys of propeller shafts and tube shafts are given in Section 12, Chapter 5, PART ONE of the rules.

~~Interval of surveys~~

~~(1) Water-lubricated bearings:~~

~~① Unless provided otherwise, propeller shafts are to be fitted with a continuous metallic liner, or continuous cladding or fiberglass reinforced plastic coating between liners which effectively prevents seawater from contacting the steel shaft, or made by anti-corrosion material, and the interval of surveys is 5 years.~~

~~② In the case of shafts other than those mentioned in ① above, the interval of surveys is 3 years for single shafting arrangements and 5 years for multi-shafting arrangements.~~

~~③ An extension for 1 year may be granted at the request of the owner.~~

~~(2) Oil-lubricated bearings:~~

~~① Propeller shafts are to be designed in compliance with the rule requirement, and the interval of surveys is 5 years.~~

~~② An extension for 1 year may be granted twice at the request of the owner. For ships other than passenger ships, an extension for a period not exceeding 5 years may be granted.~~

~~1.3.5.2 Survey items~~

~~(1) The propeller is to be removed and the complete shaft is to be sufficiently drawn, the entire surface of one-third length of the taper from the large end at the after part of shaft is to be examined by crack detection, including the keyway. For flange connection propeller shafts, the transition round corner between shaft and flange are to be examined by crack detection.~~

~~(2) The clearance of bearing of the propeller shaft may be obtained by measuring the diameter of bearing guard, the diameter of bearing or the total clearance, or weardown of the shaft.~~

~~(3) Tightness of fore and aft oil sealing glands of the propeller shaft is to be examined.~~

~~(4) The fitting of propeller is to be examined.~~

~~(5) Tightness and performance of blades of controllable pitch propellers is to be examined. If necessary, all working parts are to be dismantled and examined and after re-assembly, subjected to operational test and tightness test together with control gear.~~

~~(6) Azimuth propulsion arrangements are to be examined by a method recommended by the manufacturer.~~

~~(7) Dynamic positioning systems, position-keeping mooring aids, side thrusters are to be generally examined and operationally tested and if any doubt exists, opened up and examined; subjected to operational test and tightness test after re-assembly.~~

~~1.3.5.3 Survey of propeller shafts with water-lubricated bearing related to extension of interval of surveys~~

~~(1) The items for such survey are as follows:~~

~~① check of operating records of the propeller shaft;~~

~~② examination of fitting of the propeller shaft seal at the side of engine room;~~

~~③ check of bearing wear records from previous survey of the propeller shaft.~~

~~(2) Where the above items are found to be in normal condition, an extension may be given for a period not exceeding 1 year.~~

~~1.3.5.4 Survey of propeller shafts with oil-lubricated bearing related to extension for 1 year:~~

~~(1) The items for such survey are as follows:~~

~~① check of operating records of the propeller shaft;~~

~~② check of records of lubricating oil consumption;~~

~~③ examination of fitting of the propeller shaft seal at the side of engine room and internal condition of the sealing arrangement;~~

~~④ check of oil sample analysis results;~~

~~⑤ confirming that bearing clearances will not exceed the specified limits within the 1-year period of extension.~~

~~(2) Where the above items are found to be in normal condition, an extension may be given for a period not~~

exceeding 1 year, but no more than two extensions.

1.3.5.5 Survey of propeller shafts with oil-lubricated bearing related to extension for 5 years[①]:

(1) The items for such survey are as follows:

① check of operating records of the propeller shaft;

② check of records of lubricating oil consumption;

③ examination of external condition of fore and aft shaft seal arrangements;

④ examination of sealing bush, renewal of aft shaft seal arrangement depending on specific structural condition;

⑤ check of oil sample analysis results;

⑥ confirming that there is no damage of propeller resulting in abnormal vibration;

⑦ measuring bearing clearances and confirming that the clearances will not exceed the specified limits within the 5-year period of extension.

(2) Where the above items are found to be in normal condition, an extension may be given for a period not exceeding 5 year.

1.3.5.6 Survey related to notation SCM

(1) For ships which are assigned the notation SCM in accordance with Appendix 14 - "Guidelines for Screwshaft Condition Monitoring System", Chapter 5, PART ONE of the Rules, if they are found satisfactory at a survey of the items specified in (3), (4) and (5) below, the interval of drawing the shaft for examination as specified in 1.3.5.2(1) for the normal survey may be extended to a maximum period not exceeding 15 years.

(2) Notwithstanding the notation SCM, the interval between normal surveys is to comply with 1.3.5.1.

(3) The shaft condition monitoring (SCM) is to be verified during each annual survey of the ship, covering:

① onboard condition monitoring records, including lubricating oil consumption records, lubricating oil operating temperature records, propeller shaft condition monitoring records, etc.;

② confirmation that lubricating oil samples have been submitted to an approved analysis organization at least once every 6 months for analysis and test of water content, chloride content, bearing material, content of bearing metal particles and oil aging (resistance to oxidation);

③ verification that analysis and test records of the analysis organization together with a conclusion on the condition and suitability of the oil are kept on board;

④ verification of an oil analysis report within the last 3 months.

(4) In addition to the items of (3) above, the following are to be confirmed for all shafts during the normal survey specified in 1.3.5.1:

① weardown of shafts;

② effectiveness of shaft seal arrangements.

(5) For shafts with keyed propeller attachment, the propeller is to be removed during the period of the normal survey specified in 1.3.5.1 for non-destructive examination by an approved crack-detection method (e.g. magnetic particle or dye penetrant inspection) of key, keyway and exposed portions of propeller shaft.

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① Surveys related to extension of survey interval are to be carried out in dry dock or on a slipway.

CHAPTER 2 HULL

Section 1 GENERAL PROVISIONS

2.1.3 Reduction of rule scantlings of structural members

2.1.3.6 The thickness of the plate keels is not to be less than ~~that~~ the calculated value of rule required thickness of the bottom plating plus 1.5 mm, and in no case less than that of the adjacent bottom plating.