

CHINA CLASSIFICATION SOCIETY

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

AMENDMENTS

2014

Beijing

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CHINA CLASSIFICATION SOCIETY

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

AMENDMENTS

(January 2014)

Effective from January 1 2014

Beijing

PART ONE PROVISIONS OF CLASSIFICATION

CHAPTER 5 SURVEYS AFTER CONSTRUCTION

Section 2 TYPES AND PERIODS OF SURVEYS

In paragraph 5.2.3.4, the following sentence is inserted after " afloat as an in-water survey, subject to provisions of Section 11 of this Chapter":

"Ships of less than 15 years of age may be permitted to carry out two consecutive in-water surveys, provided that relevant requirements of Appendix 21 of this Chapter are complied with."

Section 9 SURVEYS OF MACHINERY

New paragraph 5.9.4.9 is added as follows:

"5.9.4.9 As part of the Special Survey of Machinery, a dock trial is to be carried out to attending Surveyors' satisfaction to confirm satisfactory operation of main and auxiliary machinery. If significant repairs are carried out to main or auxiliary machinery or steering gear, consideration should be given to a sea trial to attending Surveyors' satisfaction."

Section 11 SURVEYS OF THE OUTSIDE OF THE SHIP'S BOTTOM AND RELATED ITEMS

The existing paragraph 5.11.2.1(7) is deleted.

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

A new paragraph 5.14.3.1(1)①a(e) is added as follows:

"(e) Damage Stability calculation, where required."

A new paragraph 5.14.3.1(1)①b(g) is added as follows:

"(g) For CSR ships, plans showing, for each structural element, both as-built and renewal thicknesses and any thickness for "voluntary addition"."

The existing paragraph 5.14.3.1(1)④a(b) is replaced by the following:

"(b) For ships between 5 and 10 years of age the survey is to include an Annual Survey and inspection of a representative number of ballast spaces, such as fore peak, aft peak, topside tank, hopper tank, double bottom tank, etc.;".

The existing paragraph 5.14.3.1(1)④a(c) is replaced by the following:

"(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;".

In paragraph 5.14.3.1(1)④a(d), "bulk carriers (including double side skin bulk carriers)" is replaced by "bulk carriers (including double skin bulk carriers)".

The existing paragraph 5.14.3.1(1)④a(h) is replaced by the following:

"(h) In the context of applying (c) to (f) above, as applicable, tank testing for ships over 15 years of age is not required to be carried out as part of the class entry survey unless the class entry survey is being credited as a periodical survey for maintenance of class. If the class entry survey is to be credited as a periodical survey for maintenance of class, consideration may be given by CCS to the acceptance of the tank testing carried out by the losing society provided they were carried out within the applicable survey window of the periodical survey in question."

A new paragraph 5.14.3.1(1)④a(i) is added as follows:

"(i) In the context of applying (a) to (f) above, as applicable, compliance with rules (e.g. 5.3.5 of Section 3 of this Chapter) that require compliance at the forthcoming due periodical surveys are not required to be carried out/completed as part of the class entry survey unless the class entry survey is credited as a periodical survey for maintenance of class."

A new appendix 21 is added as follows:

"Appendix 21 Guidelines for Extended Interval between Surveys in Dry-Dock - Extended Dry-docking (EDD) Scheme

1 General requirements

1.1 Introduction

1.1.1 The intervals between inspections of the outside of the ship's bottom are specified in SOLAS, IACS Regulations and CCS Rules and require a minimum of two inspections to be carried out during the 5 year validity period of the Safety Construction Certificate/Special Survey period. SOLAS Regulation I/10(v) only requires a minimum of two inspections of the outside of the ship's bottom and does not specify a ship must be dry-docked out of the water.

1.1.2 IMO Resolution A.1053(27) as amended, "Survey guidelines for the harmonized system of survey and certification", requires that inspections of the outside of the ship's bottom should normally be carried out with the ship in a dry-dock. However, it also provides that Administrations may give consideration to alternate inspections being carried out with the ship afloat.

1.1.3 This Guidelines recommends the acceptance procedure for pilot schemes which extend the interval between surveys in dry-dock. Ships eligible for the Extended Dry-Docking (EDD) scheme are to meet the provisions and conditions described in this Guidelines.

1.1.4 Qualifying ships may be permitted to carry out two consecutive in-water surveys, subject to the conditions described in this Guidelines. A minimum of two inspections of the outside of the ship's bottom is to be carried out during the statutory renewal period/special survey period of five years and the intervals between any two inspections are not to exceed 36 months.

1.1.5 Pilot schemes which extend the interval between out of water dry-docking surveys are normally tripartite projects between the Owner, Flag Administration and CCS. Acceptance into such a Pilot scheme is subject to the formal written agreement with the ship's Flag Administration including any additional specific Flag Administration requirements.

1.2 Application

1.2.1 Owners/Managers requesting a ship be considered for the EDD scheme, are to apply to CCS in writing confirming and describing compliance with the requirements and conditions specified in this Guidelines.

1.2.2 Upon the Owner's request, the extended interval for each ship will be considered on a case by case basis by CCS. CCS may assist in forwarding the Owner's application to the Flag Administration.

1.2.3 The following ships and ship types are not eligible for the extended dry-docking scheme described in this Guidelines:

- passenger ships;

- ships subject to the Enhanced Survey Program (ESP);

- ships subject to requirements of sections 5 and 16 of Chapter 5 of this PART;

- ships fitted with propulsion thrusters;

- ships where the propeller connection to the shaft is by means of a keyed taper;

- High Speed Craft (HSC).

1.2.4 The dry-docking scheme will operate, based upon the ship's age when entering the scheme. For ships already in service, the extended dry-docking scheme may be implemented at any time until a ship reaches 10 years of age. (Namely that once a ship reaches 10 years of age, inspections of the outside of the ship's bottom must be carried out in dry-dock during the 10 year special survey period.)

1.2.5 No extensions are to be granted for the dry-docking required at the end of each extended dry docking period.

1.3 Information to be submitted by the owner

1.3.1 Prior to acceptance into an EDD scheme, the owner is to submit the following information:

(1) provisions for carrying out maintenance required on electric/electronic sensors e.g. Echo-sounder, Doppler-Log, Speedlog (propeller speedlog or backpressure speedlog), seawater temperature gauges, electronic draught reading, etc.;

(2) provisions for maintaining the draft marks fore, aft and midships as well as loadline marks (painted and welded figures) and all other required hull markings;

(3) maintenance required of thrusters and stabilisers, if fitted, and provision for carrying out surveys or maintenance or as required by the surveyor;

(4) service experience to-date with hull coating system covered by manufacturer's guarantee that the underwater coatings used are designed to last for the extended period since the coating is to remain effective for the extended dry docking period;

(5) impressed cathodic protection system or provisions for renewal of external hull sacrificial anodes in the afloat condition.

1.4 Preparatory reviews by CCS

1.4.1 CCS is to carry out the following reviews prior to accepting a ship into an EDD scheme:

(1) satisfactory review of the items submitted by the owner as required in 1.3 above;

(2) review of ship's history with particular attention to any previous findings affecting the underwater body.

1.5 Arrangements

1.5.1 Prior to acceptance into an EDD scheme, ships enrolled an extended dry-docking interval scheme are to comply with the following provisions:

(1) The ship is to comply with the In-Water Survey provisions in accordance with the corresponding requirements of CCS.

(2) Protective coating in double bottom/double side ballast tanks, void spaces and all other spaces adjacent to the shell is to be maintained in GOOD condition.

(3) The shafting arrangement is to fulfil the applicable CCS's requirements for Tailshaft Condition Monitoring Survey Arrangement. Namely that the ship is to be assigned with SCM class notation.

(4) Hull maintenance scheme to be implemented in accordance with ISM requirements.

2 Survey requirements

2.1 In-Water Survey Requirements

2.1.1 The In-Water Survey is to be carried out in accordance with the requirements of 5.2.3, section 2 and section 11, Chapter 5 of this PART.

2.1.2 An in-water survey plan is to be submitted to CCS for review in advance of the survey and should include the following:

(1) scheduled time and location for survey;

(2) name of approved diving company;

(3) means for cleaning of the hull below waterline;

(4) means of access for examination of sea chests, sea valves and box coolers;

(5) provisions for determining the condition of anchoring equipment, ranging of anchor chain cables and examination of the chain lockers when due for survey and/or as required by the surveyor;

(6) provisions for surveying and maintaining sea connections including thickness measurements of sea chests;

(7) results of inspections by the Owner's personnel of double bottom/double side ballast tanks (during the last 3 years) and other spaces adjacent to the shell with reference to structural deterioration in general, leakages in tank boundaries and piping and condition of the protective coating;

(8) conditions for internal examination of double bottom/double side ballast tanks (e.g., information regarding tank cleaning, gas freeing, ventilation, lighting, etc.).

2.1.3 Prior to commencement of the in-water survey, a survey planning meeting is to be held between the attending surveyor(s), the owner's representative in attendance, the diving company and the master of the ship or an appropriate representative appointed by the owner for the purpose of ascertaining that all the arrangements envisaged in the survey plan are in place, so as to ensure the safe and efficient conduct of the survey work to be carried out.

2.1.4 A comprehensive report of findings, gaugings, clearances and any work undertaken, including recordings of representative CCTV images, must be submitted by the ship owner to all involved parties.

2.2 Special survey/statutory renewal requirements

2.2.1 It should be noted that the periodicity of the ships's Special Survey and Statutory Renewal Surveys will not change, therefore provision must be made for carrying out all such surveys and any repairs afloat, where not dry-docking.

2.3 Survey findings

2.3.1 If the In-Water Survey reveals damage, deterioration or other conditions that requires early attention, the surveyor may require that the ship be dry-docked in order that a detailed survey can be undertaken and necessary repairs carried out.

2.3.2 If temporary repairs carried out to any underwater parts are considered acceptable these must be made permanent within a due date decided by the surveyor.

2.3.3 The owner is to request CCS to perform a survey in dry-dock in any event or circumstance in the operation of the ship which could have led to underwater damages or deterioration in the crew's knowledge or opinion.

2.3.4 If the coating condition in double bottom/double side ballast tanks, void spaces and dry spaces is found in less than GOOD condition, the owner is to restore the coating to GOOD.

3 Termination of scheme

3.1 Termination of EDD scheme

3.1.1 The dry-docking survey required for the special survey at 15 years of age is to be carried out in a dry-dock. All ships in an EDD scheme are to be dis-enrolled once the ship reaches 15 years of age.

3.1.2 The Extended Dry-docking Scheme will be terminated in cases of change of the ship's owner, management or Flag Administration.

3.1.3 CCS may dis-enroll a ship from an EDD scheme at any time should it be found that the conditions for maintaining this extended dry-dock scheme are not fulfilled anymore.

3.1.4 Once the conditions for the scheme are no longer present, the ship will return to the normal docking interval and any due dock survey is to be carried out by the due date."

PART TWO HULL

CHAPTER 1 GENERAL

Section 7 FORE DECK FITTINGS

The existing subparagraph 1.7.2.9(5) is replaced by the following:

"(5) On small hatches located between the main hatches, for example between No.1 and No. 2, the hinges are to be placed on the fore edge or outboard edge, whichever is practicable for protection from green water in beam sea and bow quartering conditions."

CHAPTER 2 HULL STRUCTURES

Section 6 DOUBLE BOTTOMS

In paragraph 2.6.15.3, the words "1.65 times the depth of the web of frames" are replaced by "1.65 times the depth of the web of web frames".

Section 13 DEEP TANKS

In paragraph 2.13.8.5, "2.13.7.5" is replaced by "2.13.7.4".

Section 14 STEMS, STERN FRAMES, BULBOUS BOWS, PROPELLER SHAFT BRACKETS AND RUDDER HORNS

The existing paragraph 2.14.2.5 is replaced by the following:

"2.14.2.5 The section modulus W_z of sole pieces (see Figure 2.14.2.5) about the vertical neutral axis (z-axis) at any considered section, is not to be less than that obtained from the following formula:

$$W_z = \frac{K}{80} Px \qquad \text{cm}^3$$

where: P — supporting force exerted by the sole piece on rudder blade, in N, to be calculated according to the relevant requirements of Section 1, Chapter 3 of this PART;

K — material factor according to 1.5.1.4 of this PART for fabricated sole pieces; material factor according to 3.1.1.5 of this PART for cast sole pieces;

x — distance between the axis of rudder stock and the section under consideration, in m, to be taken not less than $0.5l_s$, l_s being the maximum distance, in m, (see Figure 2.14.2.5)."

In paragraphs 2.14.2.7 and 2.14.2.8, every letter "C" is replaced by "K".

The existing paragraph 2.14.7.3 is replaced by the following:

"2.14.7.3 The section modulus W of rudder horns around the x-axis at any horizontal section is not to be less than that obtained from the following formula:

$$W = \frac{K}{67} M_b \qquad \text{cm}^3$$

where: M_b — bending moment at the section under consideration, in N·m, to be calculated according to 2.14.7.2 of this Section;

K — material factor required in 1.5.1.4 of this PART for fabricated rudder horns; material factor required in 3.1.1.5 of this PART for cast rudder horns."

In paragraphs 2.14.7.4 and 2.14.7.5, every letter "C" is replaced by "K".

Section 23 STRENGTHENING FOR GRABS

In paragraph 2.23.2.1, “GRAB − [X]” is replaced by “Grab(X)”.

Appendix 3 IACS NO.97 RECOMMENDATION FOR UR S11.2.1.3 (Rev. 5, June 2007)

In paragraph 3, the sentence “Table 1 shows the filling level in partially filled BW tanks Nos.1 (P/S) and 5 (P/S) for the operational conditions during ballast voyage.” is moved to be immediately before Table 1.

In Figure 4(d) Case D, the illustration “

” in “Cond. D2-3 (Int.1)*” and the illustration “

” in “Cond. D2-5 (Int.1)*” are replaced by “

”.

CHAPTER 4 STRENGTHENING FOR NAVIGATION IN ICE

Section 2 ICE STRENGTHENING FOR CLASSES B1*, B1, B2 AND B3

The existing Table 4.2.4.2(4) is replaced by the following:

"Selection of l_a Table 4.2.4.2(4)

Structure	Type of framing	l_a (m)
Shell	Transverse	Frame spacing
	Longitudinal	1.7 times frame spacing
Frames	Transverse	Frame spacing
	Longitudinal	Span of longitudinal
Ice stringer	–	Span of side stringer
Web frame	–	2 times web frame spacing

"

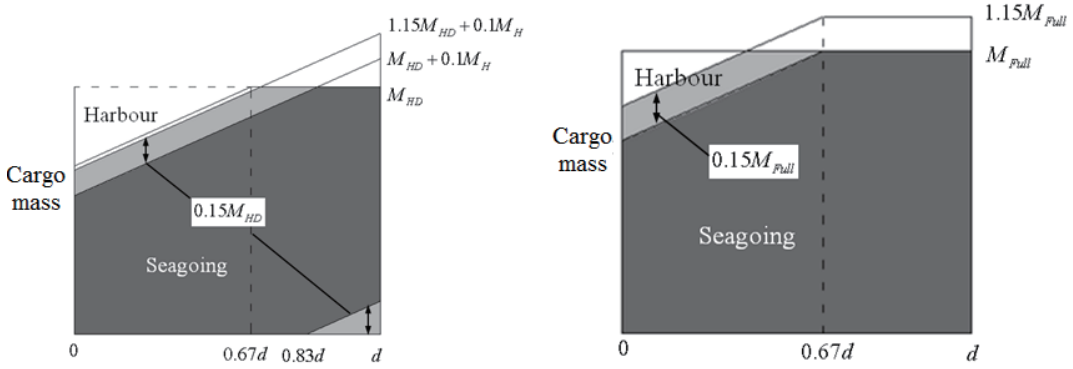
In subparagraph 4.2.4.4(2)(a), the words "*l* — span of the frame, in m; where ice stringers are fitted, it may be taken as the distance between ice stringers or between stringer and deck or between stringers and bottom, whichever is the greatest;" are replaced by "*l* — span of the frame, in m;".

In paragraph 4.2.4.6, the words "Web frames within ice belt" are replaced by "Web frames".

CHAPTER 8 BULK CARRIERS

Appendix 2 HOLD MASS CURVES

The existing Figure 2.1.2 is replaced by the following:



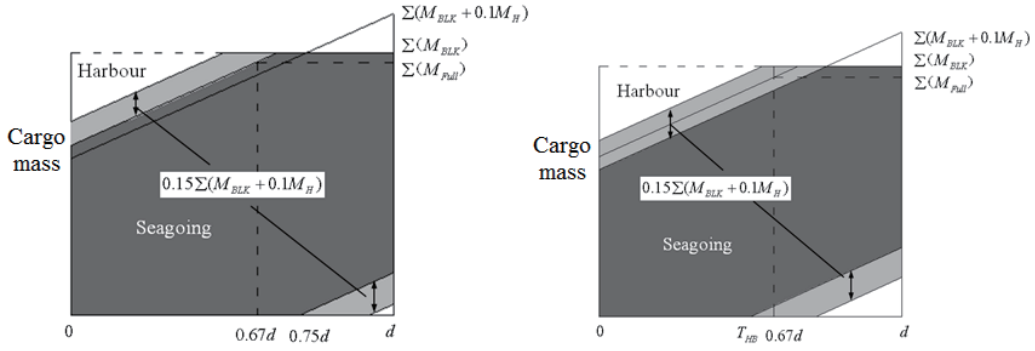
(a) Loaded hold (b) Cargo hold which may be empty at the maximum draught

Figure 2.1.2 Mass Curve for Ships with Alternate Load under Multi-port Condition

In paragraph 2.2.3, the formula " $W_{\max}(T_i) = M_{HD} + 0.1M_H - 1.025V_H \dfrac{(0.67d - T_i)}{h}$ " is replaced by " $W_{\max}(T_i) = M_{HD} - 1.025V_H \dfrac{(0.67d - T_i)}{h}$ ".

In paragraph 3.1.3, the sentence "Mass curves of loaded cargo hold for ships with alternate load of packed cargo under no multi-port condition are shown in Figure 3.1.3." is replaced by "Mass curves of loaded cargo hold for ships with alternate load of packed cargo are shown in Figure 3.1.3."

The existing Figure 3.1.3 is replaced by the following:



(a) Under multi-port condition (b) Under no multi-port condition

Figure 3.1.3 Mass Curves of Loaded Cargo Hold for Ships with Alternate Load of Packed Cargo

In paragraph 3.1.5, the sentence "Mass curves of loaded cargo hold for ships with alternate without packed cargo under no multi-port condition and ships with homogeneous load are shown in Figure 3.1.5." is replaced by "Mass curves of loaded cargo hold for ships with alternate load of packed cargo are shown in Figure 3.1.3."

PART SIX FIRE PROTECTION, DETECTION AND EXTINCTION

CHAPTER 3 FIRE SAFETY MEASURES

Section 4 MISCELLANEOUS

In the existing subparagraph (2) of 3.4.14.1, “4.2.2.7” is replaced by “4.2.2.9”.

PART EIGHT ADDITIONAL REQUIREMENTS

CHAPTER 9 ADDITIONAL REQUIREMENTS FOR SHIPS HAVING INDEPENDENT ICEBREAKING CAPABILITY

The existing Section 3 is replaced by the following:

"Section 3 HULL STRUCTURE

9.3.1 General requirements

9.3.1.1 In respect to the strengthening requirements for ships having an icebreaking capability where the ice load is calculated in accordance with Section 2, Chapter 4 of PART TWO, the actual output power of the main engine at MCR is not to be less than that required for icebreaking in Section 2 of this Chapter.

9.3.2 General requirements for side framing

9.3.2.1 Where a frame or longitudinal frame intersects a boundary between two of the hull regions (see Section 2, Chapter 4 of PART TWO of the Rules), the scantling requirements applicable will be those for the greater region.

9.3.2.2 Extent of tripping brackets: B1* - all regions; B1 – forward and midship regions; B2 and B3 – forward region.

9.3.2.3 The effective weld area attaching ice frames or longitudinal frames to primary members is not to be less than the shear area for the frames or longitudinal frames.

9.3.3 Ice stringers

9.3.3.1 The webs of primary longitudinal members supporting transverse ice frames are to be stiffened and connected to the main or intermediate frames so that the distance s between such stiffeners is not greater than that determined in accordance with the following formula:

$$s = 17.06 \frac{t}{\eta} \sqrt{\frac{t}{F_l}} \quad \text{mm}$$

where: t — thickness, in mm, of the primary longitudinal member adjacent to the shell plating;
F_l — longitudinal distribution coefficient, see Table 9.3.3.1.

Table 9.3.3.1

Ice class	F_1		
	Fore	Midship	Aft
B1*	1.00	0.98	0.89
B1	0.87	0.75	0.64
B2	0.78	0.64	0.51
B3	0.68	0.53	0.37

η — coefficient,

For the forward region, one of the following values is to be taken, whichever is the least:

$$\eta_1 = 0.653 + 3.217\frac{\sqrt{P\Delta}}{10^5}$$

$$\eta_2 = 0.876 + 9.908\frac{\sqrt{P\Delta}}{10^6}$$

$$\eta_3 = 1;$$

For midship and aft regions, one of the following values is to be taken, whichever is less:

$$\eta_1 = 0.653 + 9.908\frac{\sqrt{P\Delta}}{10^6}$$

$$\eta_2 = 1;$$

P — actual output power of the main engine at MCR, not to be less than that required for icebreaking in Section 2 in this Chapter;

Δ — displacement, in t, see 4.2.2.2, Section 2, Chapter 4 of PART TWO of the Rules.

9.3.4 Stem

9.3.4.1 The section moduls W of the stem in the fore and aft direction is not to be less than that determined in accordance with the following formula:

$$W = 1500F_l^{1.5}\eta^3 \quad \text{cm}^3$$

where: F_l, η — see 9.3.3.1.

9.3.4.2 The thickness t of side plates of a welded stem constructed as shown in Figure 9.3.4.2 is to be determined in accordance with the following formula:

$$t = 31\eta\sqrt{F_l} \quad \text{mm}$$

where: F_l, η — see 9.3.3.1.

The dimension of a welded stem is to be determined in accordance with Figure 9.3.4.2.

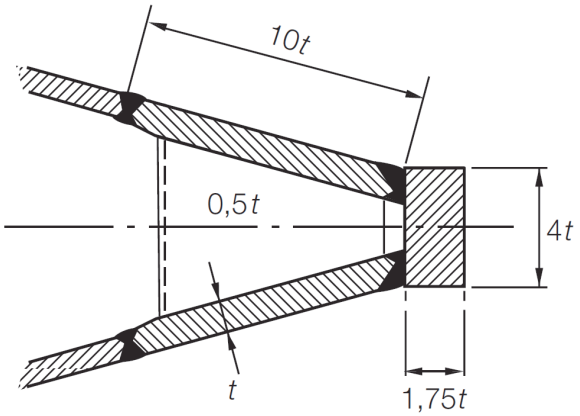


Figure 9.3.4.2 Welded Stem"

Section 4 SIDE FRAMING

The existing Section 4 are deleted.

Section 5 STEM

The existing Section 5 are deleted.

PART NINE DOUBLE-HULL OIL TANKERS STRUCTURE (CSR)

SECTION 8 SCANTLING REQUIREMENTS

The existing Table 8.2.3 is replaced by the following:

Bulkhead	**At lower end of l_{cg}**	**At mid length of l_{cg}**	**At upper end of l_{cg}**
Transverse Bulkhead	C_1	C_{m1}	$0.65C_{m1}$
Longitudinal Bulkhead	C_3	C_{m3}	$0.65C_{m3}$

Where:

C_1 $= a_1 + b_1\sqrt{\frac{A_{dt}}{b_{dk}}}$, but is not to be taken as less than 0.60

$= a_1 - b_1\sqrt{\frac{A_{dt}}{b_{dk}}}$, for transverse bulkhead with no lower stool, but is not to be taken as less than 0.55

a_1 $= 0.95 - \frac{0.41}{R_{bt}}$,

=1.0, for transverse bulkhead with no lower stool

b_1 $= -0.20 + \frac{0.078}{R_{bt}}$,

=0.13, for transverse bulkhead with no lower stool

C_{m1} $= a_{m1} + b_{m1}\sqrt{\frac{A_{dt}}{b_{dk}}}$ but is not to be taken as less than 0.55

$= a_{m1} - b_{m1}\sqrt{\frac{A_{dt}}{b_{dk}}}$ for transverse bulkhead with no lower stool, but is not to be taken as less than 0.60

a_{m1} $= 0.63 + \frac{0.25}{R_{bt}}$

=0.85, for transverse bulkhead with no lower stool

b_{m1} $= -0.25 - \frac{0.11}{R_{bt}}$

=0.34, for transverse bulkhead with no lower stool

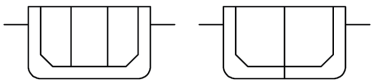
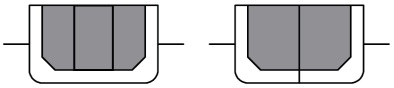
C_3 $= a_3 + b_3\sqrt{\frac{A_{dl}}{l_{dk}}}$ but is not to be taken as less than 0.60

$= a_3 - b_3\sqrt{\frac{A_{dl}}{l_{dk}}}$ for longitudinal bulkhead with no lower stool, but is not to be taken as less than 0.55

a_3 $= 0.86 - \frac{0.35}{R_{bl}}$

=1.0, for longitudinal bulkhead with no lower stool

The existing Table 8.2.9 is replaced by the following:

Structural Member	Design Load Set[1, 5, 6]	Load Component	Draught	Comment	Diagrammatic Representation
Double bottom floors and girders[3]	1	P_{ex}	$0.9T_{SC}$[2]	Sea pressure only	
	2	P_{ex}	T_{SC}		
	12	P_{in}-P_{ex}	0.6 T_{SC}	Net pressure difference between cargo pressure and sea pressure	
	13	P_{in}-P_{ex}	(4)		

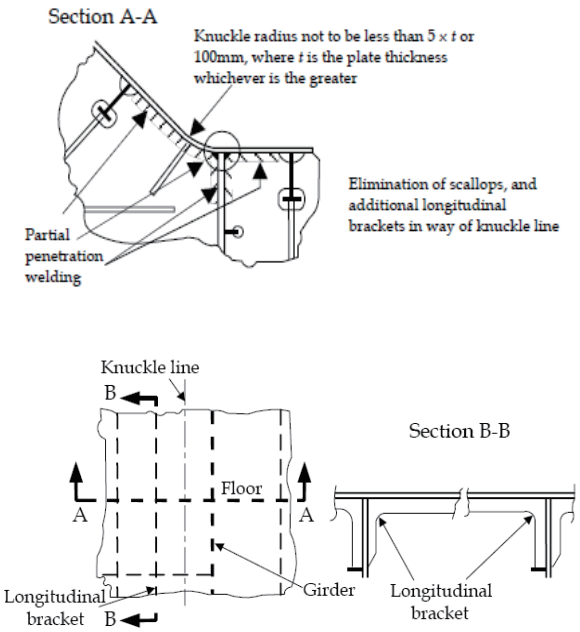
In paragraph 2.6.7.5, the sentence "The required shear area at mid effective bending span is to be taken as 50% of that required in the ends," is replaced by "The required shear area at mid effective shear span is to be taken as 50% of that required in the ends,".

The existing Table 8.4.2 is replaced by the following:

Acceptance Criteria Set	Structural Member		β_a	α_a	$C_{a-\max}$
AC1	Longitudinal Strength Members	Longitudinally stiffened plating	0.9	0.5	0.80
		Transversely or vertically stiffened plating	0.9	1.0	0.80
	Other member		0.8	0	0.80
AC2	Longitudinal Strength Member	Longitudinally stiffened plating	1.05	0.5	0.95
		Transversely or vertically stiffened plating	1.05	1.0	0.95
	Other members, including watertight boundary plating		1.0	0	1.00

APPENDIX C FATIGUE STRENGTH ASSESSMENT

The existing Figure C.2.4 is replaced by the following:



Note: Longitudinal brackets may be omitted if it can be demonstrated that the girder provides sufficient support at the knuckle line.

PART TEN BULK CARRIERS STRUCTURE (CSR)

CHAPTER 2 GENERAL ARRANGEMENT DESIGN

Section 1 SUBDIVISION ARRANGEMENT

A new paragraph 3.1.5 is added as follows:

"3.1.5 Sterntubes

Ref. SOLAS Ch. II-1, Part B-2, Reg.12

Sterntubes are to be enclosed in a watertight space (or spaces) of moderate volume. Other measures to minimise the danger of water penetrating into the ship in case of damage to sterntube arrangements may be taken at the discretion of the Society."

CHAPTER 3 STRUCTURAL DESIGN PRINCIPLES

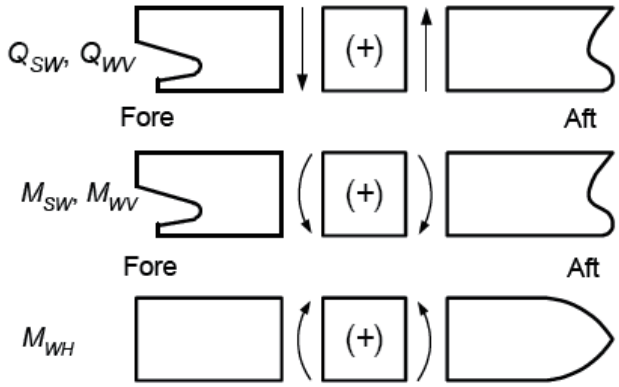
Section 6 STRUCTURAL ARRANGEMENT PRINCIPLES

In paragraph 9.6.3, the formula "$t_{INS} = (0.8+0.4\ell/b)\cdot t$ " is replaced by the formula "$t_{INS} = (0.8+0.4b/\ell)\cdot t$".

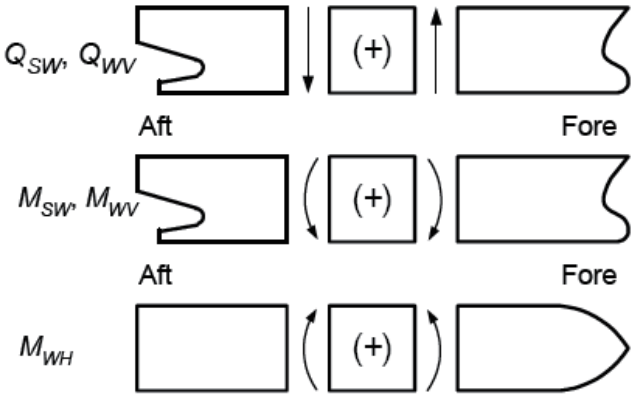
CHAPTER 4 DESIGN LOADS

Section 3 HULL GIRDER LOADS

The existing Figure 1:

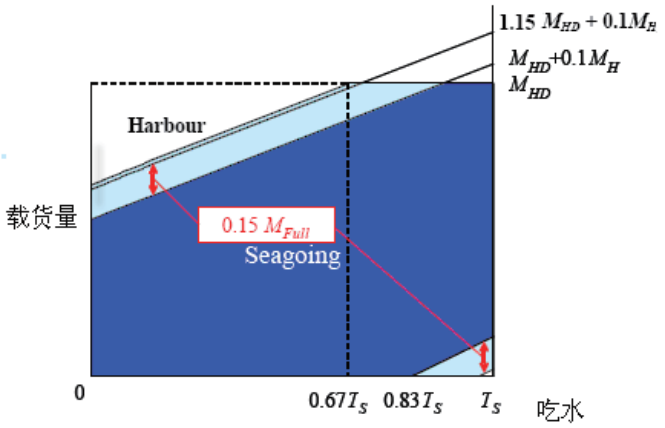


is replaced by:

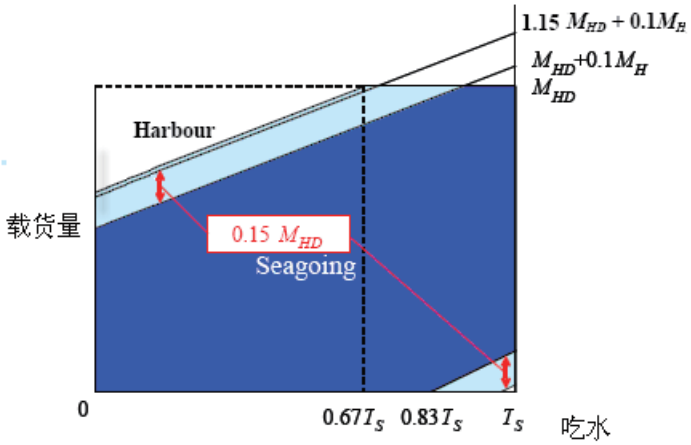


Appendix 1 HOLD MASS CURVES

The existing Figure 1(a):



is replaced by:



”.

In paragraph 2.2.3, the existing formula “ $W_{\max}(T_i) = M_{HD} + 0.1M_H - 1.025V_H \frac{(0.67d - T_i)}{h}$ ” is replaced by “ $W_{\max}(T_i) = M_{HD} - 1.025V_H \frac{(0.67d - T_i)}{h}$ ”.

CHAPTER 6 HULL SCANTLINGS

Section 3 BUCKLING AND ULTIMATE STRENGTH OF ORDINARY STIFFENERS AND STIFFENED PANELS

In Symbols, Table 1 is replaced by the following:

	F_1 [2]	Edge stiffener
Stiffeners sniped at both ends	1.00	
Guidance values where both ends are effectively connected to adjacent structures [1]	1.05	Flat bar
	1.10	Bulb section
	1.21	Angle and tee-sections
	1.30	Girders of high rigidity (e.g. bottom transverses)
[1] Exact values may be determined by direct calculations. [2] An average value of F_1 is to be used for plate panels having different edge stiffeners.		

”

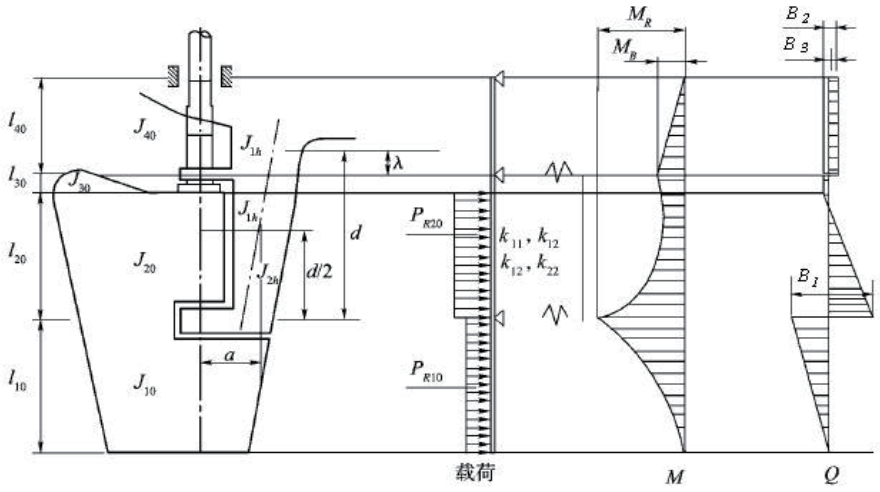
CHAPTER 10 HULL OUTFITTING

Section 1 RUDDER AND MANOEUVRING ARRANGEMENT

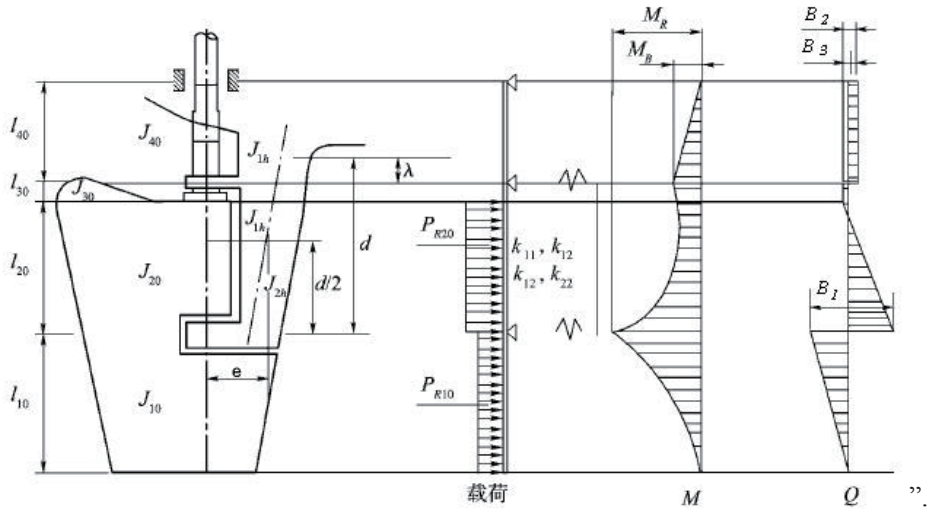
In paragraph 2.1.1, the sentences "κ_1: Coefficient, depending on the aspect ratio λ, taken equal to: $\kappa_1 = (\lambda + 2)/3$, where λ need not be taken greater than 2" are replaced by "κ_1: Coefficient, depending on the aspect ratio Λ, taken equal to: $\kappa_1 = (\Lambda + 2)/3$, where Λ need not be taken greater than 2".

In paragraph 3.2.1, the sentences "M_b: Bending stress at the neck bearing, in N.m" are replaced by "M_b: Bending moment at the neck bearing, in N.m"

The existing Figure 5:



is replaced by:



".

In paragraph 4.5.4, the existing formula $p_{req1} = \dfrac{2Q_F \times 10}{d_m^2 \ell \pi \mu_0}$ is replaced by $p_{req1} = \dfrac{2Q_F}{d_m^2 \ell \pi \mu_0} 10^3$.

CHAPTER 11 CONSTRUCTION AND TESTING

Section 3 TESTING OF COMPARTMENTS

In paragraph 2.3.1, the sentence “When hose testing is required to verify the tightness of the structures, as defined in Tab 1, the minimum pressure in the hose, at least equal to $0.20 \cdot 10^5$ Pa, is to be applied at a maximum distance of 1.5 m. The nozzle diameter is not to be less than 12 mm.” are replaced by the sentences “When hose testing is required to verify the tightness of the structures, as defined in Tab 1, the minimum pressure in the hose, at least equal to $2 \cdot 10^5$ Pa, is to be applied at a maximum distance of 1.5 m. The nozzle diameter is not to be less than 12 mm.”

CHAPTER 13 SHIPS IN OPERATION, RENEWAL CRITERIA

Section 1 MAINTENACE OF CLASS

The paragraph 1.1.2 is deleted and replaced by term “Void”.

The paragraph 1.1.3 is deleted and replaced by term “Void”.

The following requirements are added:

“1.2.3 Deck zone

The deck zone includes all the following items contributing to the hull girder strength above the horizontal strake of the topside tank or above the level corresponding to 0.9D above the base line if there is no topside tank:

- strength deck plating
- deck stringer
- sheer strake
- side shell plating
- top side tank sloped plating, including horizontal and vertical strakes
- longitudinal stiffeners connected to the above mentioned platings.

1.2.4 Bottom zone

The bottom zone includes the following items contributing to the hull girder strength up to the upper level of the hopper sloping plating or up to the inner bottom plating if there is no hopper tank:

- keel plate
- bottom plating
- bilge plate
- bottom girders
- inner bottom plating
- hopper tank sloping plating
- side shell plating
- longitudinal stiffeners connected to the above mentioned platings.

1.2.5 Neutral axis zone

The neutral axis zone includes the plating only of the items between the deck zone and the bottom zone, as for example:

- side shell plating
- inner hull plating, if any.”

Section 2 THICKNESS MEASUREMENT AND ACCEPTANCE CRITERIA

The Section 2 is replaced by the following:

“Section 2 Acceptance criteria

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 4.

$t_{renewal}$: Renewal thickness; Minimum allowable thickness, in mm, below which renewal of structural members is to be carried out

$t_{renewal} = t_{as\text{-}built} - t_C - t_{voluntary\text{-}addition}$

$t_{reserve}$: Reserve thickness; Thickness, in mm, to account for anticipated thickness diminution that may occur during a survey interval of 2.5 year. ($t_{reserve}$ = 0.5 mm)

t_C : Corrosion addition, in mm, defined in Ch 3, Sec3

t_{as_built} : As built thickness, in mm, including $t_{voluntary\text{-}addition}$, if any

$t_{voluntary_addition}$: Voluntary thickness addition; Thickness, in mm, voluntarily added as the Owner's extra margin for corrosion wastage in addition to t_C

t_{gauged} : Gauged thickness, in mm, on one item, i.e average thickness on one item using the various measurements taken on this same item during periodical ship's in service surveys.

1. Local strength criteria

1.1 Application

1.1.1

The items to be considered for the local strength criteria are those defined in UR Z10.2 for single side skin bulk carriers and UR Z10.5 for double side skin bulk carriers.

1.2 Renewal thickness for corrosion other than local corrosion

1.2.1

For each item, steel renewal is required when the gauged thickness t_{gauged} is less than the renewal thickness, as specified in the following formula:

$$t_{gauged} < t_{renewal,}$$

Where the gauged thickness t_{gauged} is such as:

$$t_{renewal} < t_{gauged} < (t_{renewal} + t_{reserve})$$

coating applied in accordance with the coating manufacturer's requirements or annual gauging may be adopted as an alternative to the steel renewal. The coating is to be maintained in good condition.

1.3 Renewal thickness for local corrosion

1.3.1

If pitting intensity in an area where coating is required, according to Ch 3, Sec 5, is higher than 15% (see Fig 1), thickness measurements are to be performed to check the extent of pitting corrosion. The 15% is based on pitting or grooving on only one side of a plate.

In cases where pitting is exceeding 15%, as defined above, an area of 300 mm or more, at the most pitted part of the plate, is to be cleaned to bare metal and the thickness is to be measured in way of the five deepest pits within the cleaned area. The least thickness measured in way of any of these pits is to be taken as the thickness to be recorded.

The minimum remaining thickness in pits, grooves or other local areas as defined in Ch 13, Sec 1, [1.2.1] is to be greater than:

- 75% of the as-built thickness, in the frame and end brackets webs and flanges
- 70% of the as-built thickness, in the side shell, hopper tank and topside tank plating attached to the each side frame, over a width up to 30 mm from each side of it,

without being greater than $t_{renewal}$.

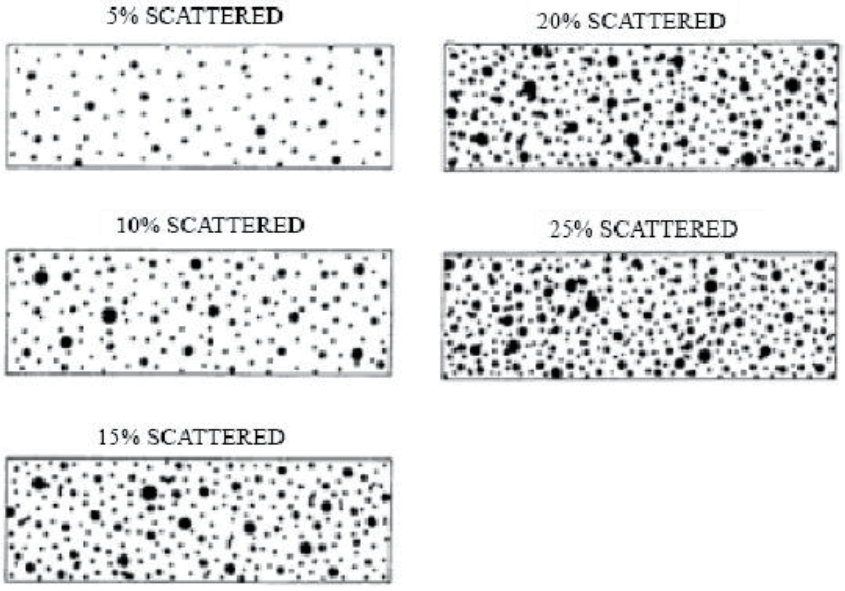


Figure 1: Pitting intensity diagrams (from 5% to 25% intensity)

1.4 Global strength criteria

1.4.1 Items for the global strength criteria

The items to be considered for the global strength criteria are those of the deck zone, the bottom zone and the neutral axis zone, as defined in Ch 13, Sec 1, [1.2].

1.4.2 Renewal thickness

The global strength criteria is defined by the assessment of the bottom zone, deck zone and neutral axis zone, as detailed below.

a) bottom zone and deck zone:

The current hull girder section modulus determined with the thickness measurements is not to be less than 90% of the section modulus calculated according to Ch 5, Sec 1 with the gross offered thicknesses.

Alternatively, the current sectional areas of the bottom zone and of the deck zone which are the sum of the gauged items area of the considered zones, are not to be less than 90% of the sectional area of the corresponding zones determined with the gross offered thicknesses.

b) neutral axis zone:

The current sectional area of the neutral axis zone, which is the sum of the gauged platings area of this zone, is not to be less than 85% of the gross offered sectional area of the neutral axis zone.

If the actual wastage of all items, of a given transverse section, which contribute to the hull girder strength is less than 10% for the deck and bottom zones and 15% for the neutral axis zone, the global strength criteria of this transverse section is automatically satisfied and its checking is no more required."

CHINA CLASSIFICATION SOCIETY

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

AMENDMENTS

(July 2014)

Effective from July 1 2014

Beijing

PART ONE PROVISIONS OF CLASSIFICATION

CHAPTER 1 GENERAL

Section 2 COUNCIL AND COMMITTEES

The existing subparagraph 1.2.3.2(3) is replaced by the following:

"(3) accept and confirm the reports submitted by CCS on assignment, suspension, cancel or reinstatement of class of ships and offshore installations;".

CHAPTER 2 SCOPE AND CONDITIONS OF CLASSIFICATION

Section 1 GENERAL PROVISIONS

A new paragraph 2.1.3.1(34) is added as follows:

"(34) Critical Structural Areas are locations which have been identified from calculations to require monitoring or from the service history of the subject ship or from similar or sister ships (if available) to be sensitive to cracking, buckling or corrosion which would impair the structural integrity of the ship."

Section 2 RULES FOR CLASSIFICATION

The existing paragraph 2.2.1.5 is replaced by the following:

"2.2.1.5 For those not covered in CCS present rules, or the principled requirements therein which need to be further defined in details, or where specific applicability of the rules is needed, or for novel ships or equipment or systems, CCS will develop appropriate guidelines or use IACS Recommendations① to facilitate classification. Where any "guidelines" or IACS Recommendations are referred to in the rules, the paragraphs related to classification in such "guidelines" or IACS Recommendations constitute requirements of the rules."

The existing paragraph 2.2.4.3 is replaced by the following:

"2.2.4.3 The requirements of relevant chapters in PART ONE of the Rules also apply to existing ships, including chemical tankers and liquefied gas carriers."

Section 5 SUBMISSION AND EXAMINATION OF PLANS

The following sentence is added at the end of the existing paragraph 2.5.2.2:

"CCS Plan Approval Center is responsible for examination of the welding specifications for CSR ships."

Section 9 ASSIGNMENT, MAINTENANCE, SUSPENSION, CANCELLATION AND REINSTATEMENT OF CLASS

The following sentences are inserted at the end of the existing subparagraph 2.9.2.1(5)③:

"The above-mentioned overdue surveys to be carried out are to be based upon the survey requirements at the original date due and not on the age of the vessel when the survey is carried out. Such surveys are to be credited from the date originally due."

In the existing subparagraph 2.9.3.1(1), the sentence "The overdue surveys to be carried out are to be based upon the survey requirements at the original date due and not on the age of the vessel when the survey is carried out." is inserted after the sentence "class will be reinstated upon satisfactory completion of the overdue surveys."

---

① IACS Recommendations may be downloaded at IACS website, i.e. http://www.iacs.org.uk/.

Appendix 1 LIST OF CLASS NOTATIONS FOR SEA-GOING SHIPS

In the existing Table A, the descriptions for class notations "Hopper Barge" and "Pile Driving Barge" are replaced by the following:

"

Class notation	Description		Technical requirements to be complied with
Hopper Barge	Hopper barges	Barges dedicated to carrying mud. If self-propelled, the word "ship" is to be used in place of the word "barge"	Ch. 14, Pt. 2 of the Rules
Pile Driving Barge	Pile-driving barges	Barges fitted with pile driving equipment at end or centre of deck, dedicated to pile driving in water	Ch. 13, Pt. 2 of the Rules and relevant requirements

"

In the existing Table B, the class notation "PC N" is replaced by class notations "PC1 ~ 7" which are placed before the notation "Ice Class B1*" in the existing Table E, while the descriptions for "Ice Class B1*, Ice Class B1, Ice Class B2, Ice Class B3, Ice Class B and Icebreaking" are replaced by the following:

"

Class notation	Description		Technical requirements to be complied with
PC 1	Operation in polar waters covered by multi-year ice	Year-round operation in all polar waters	Ch. 13, Pt. 8 of the Rules
PC 2		Year-round operation in moderate multi-year ice conditions	
PC 3		Year-round operation in second-year ice which may include multi-year ice inclusions	
PC 4		Year-round operation in thick first-year ice which may include old ice inclusions	
PC 5		Year-round operation in medium first-year ice which may include old ice inclusions	
PC 6		Summer/autumn operation in medium first-year ice which may include old ice inclusions	
PC 7		Summer/autumn operation in thin first-year ice which may include old ice inclusions	
Ice Class B1*	Operation in waters covered by first-year ice①	Operation in severe ice conditions, not requiring ice breaker assistance. Maximum and minimum ice class draughts fore, amidships and aft, and minimum required main engine output to be stated in classification certificate	Ch. 4, Pt. 2/Ch. 14, Pt. 3 of the Rules②
Ice Class B1		Operation in severe ice conditions and if necessary, with ice breaker assistance. Maximum and minimum ice class draughts fore, amidships and aft, and minimum required main engine output to be stated in classification certificate	
Ice Class B2		Operation in moderate ice conditions and if needed, with ice breaker assistance. Maximum and minimum ice class draughts fore, amidships and aft, and minimum required main engine output to be stated in classification certificate	
Ice Class B3		Operation in light ice conditions and if needed, with ice breaker assistance. Maximum and minimum ice class draughts fore, amidships and aft, and minimum required main engine output to be stated in classification certificate	
Ice Class B		Operation in very light ice conditions and if needed, with ice breaker assistance	
Icebreaking	Capable of breaking ice	Operation in first-year ice conditions and having independent icebreaking capability. This notation is to be used in conjunction with ice notations and added before the type notation, e.g. Icebreaking Tug, Ice Class B1	Ch. 9, Pt. 8 of the Rules

Notes: ① Such as Northern Baltic Sea in winter, Bohai Sea in winter and Northern Huanghai Sea in winter.

② Attention is to be paid to relevant special requirements of international industrial organizations and oil companies.

In the existing Table C, a new class notation "Well Stimulation" is added as follows:

"

Class notation	Description		Technical requirements to be complied with
Well Stimulation	Well stimulation	Offshore engineering support ships used for or designed to be used for the operation of offshore well stimulation	Guidelines for well stimulation

"

In the existing Table E, new class notations "LSFO" and "Anchor Handling" are added and the class notations "CM" and "COMPASS" are amended as follows:

"

Class notation	Description		Technical requirements to be complied with
LSFO	Low sulphur fuel oil	Ships intended to use low sulphur fuel oil with sulphur content not exceeding 0.10% (m/m) may be assigned this notation if the requirements of Guidelines for Use of Low Sulphur Fuel Oils in Ships are complied with	Guidelines for Use of Low Sulphur Fuel Oils in Ships
Anchor Handling	Handling of anchors	Ships capable of handling anchors	Ch. 20, Pt. 8 of the Rules
CM	Monitoring of construction of hull structure	Ships for which the control of structural precision at critical locations of hull (including alignment, fitting-up, edge treatment and technological standards) is in accordance with an approved plan. For tankers and bulk carriers subject to SOLAS Chapter II-1 Part A-1 Regulation 3-10 (Goal-based ship construction standards for bulk carriers and oil tankers) this class notation is necessary	Guidelines for Construction Monitoring of Hull Structures
COMPASS	COMPASS	For ships the design of which has been checked using CCS COMPASS-Structure software, one or more of the following suffixes are to be added. Meanings of the suffixes are as follows: R: For ships the check of which against rules has been performed using COMPASS–Structure; D: For ships of which hull structure direct calculations have been performed using COMPASS–Structure; F: For ships of which hull structure fatigue strength assessment has been performed using COMPASS–Structure. Such notation is necessary for CSR ships	COMPASS-Structure software

"

In the existing Table G, new class notations "LNG Fuel", "CNG Fuel", "Dual Fuel", "HMS", "HMS(×)" and "HMS-HSC" are added as follows:

"

Class notation	Description		Technical requirements to be complied with
LNG Fuel	Liquefied natural gas used as fuel	This notation may be added for ships using liquefied natural gas as fuel	Rules for Ships Powered by Natural Gas Fuel
CNG Fuel	Compressed natural gas used as fuel	This notation may be added for ships using compressed natural gas as fuel	
Dual Fuel	Dual fuel	This notation may be added for ships which not only use natural gas as fuel but also burn fuel oil, or burn fuel oil and natural gas fuel at the same time	

Class notation	Description		Technical requirements to be complied with
HMS	Hull monitoring system	This notation may be assigned when only sensors monitoring the global longitudinal stress amidships are installed in the hull monitoring system	Ch. 21, Pt. 8 of the Rules
HMS(×)		This notation may be assigned when not only sensors monitoring the global longitudinal stress amidships 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 comma ",". The following sensors/components may be selected for the hull monitoring system: G: Sensor monitoring the global hull strain D: Sensor monitoring the local hull strain O: Sensor monitoring the propulsion shaft(s) output A: Sensor monitoring the axial acceleration M: Device for monitoring of hull rigid body motions (six degrees of freedom) P: Sensor monitoring the transient sea pressure acting on the hull (slamming) S: Sensor monitoring the liquid motion pressures in tanks (sloshing) T: Sensor monitoring the temperature B: Device for monitoring the wave W: Wind sensor N: Navigation sensors C: Online link to loading computer that is continuously up-dating the loading condition	
HMS-HSC		This notation may be assigned to the hull monitoring system installed on high speed crafts	

"

In the existing Table I, the descriptions for class notations "SEC" and "GPR" are replaced by the following:

"

Class notation	Description		Technical requirements to be complied with
SEC(I)	SO_x emission control	Sulphur content of all fuel oils used on board is not to exceed 1.0% (m/m) or equivalent means are used	Sec. 3, Ch. 8, Pt. 8 of the Rules
SEC(II)		Sulphur content of all fuel oils used on board is not to exceed 0.5% (m/m) or equivalent means are used	
SEC(III)		Sulphur content of all fuel oils used on board is not to exceed 0.1% (m/m) or equivalent means are used	
GPR	Green passport for recycling	The ship is to carry the Inventory of Hazardous Materials verified by CCS and complying with the requirements of Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships, 2009	
GPR(EU)		The ship is to carry the Inventory of Hazardous Materials verified by CCS and complying with the requirements of EU Regulation No.1257/2013	

"

CHAPTER 3 INSPECTIONS OF PRODUCTS

Section 6 ASBESTOS-FREE CERTIFICATION

In the existing paragraph 3.6.1.2, the words "(in the Form shown in Attachment 1 to this Section)" are deleted.

In the existing paragraph 3.6.2.1, the words "Attachment 2" are replaced by "Attachment".

The existing Attachment 1 is deleted and the existing "Attachment 2" is replaced by "Attachment".

Appendix 1 LIST OF CERTIFICATION REQUIREMENTS FOR CLASSED MARINE PRODUCTS

In the existing Appendix 1, the certification requirements for products are amended and added as follows:

"

No.	Product name	Document		Approval mode				Remarks
		C/E	W	DA	TA-B	TA-A	WA	
8.9	Battery	O	X	—	X	O	—	Type Approval Certificate to be provided for W
8.19	Level measuring system (including sensors)	X	—	—	X	O	—	Approval Certificate to be provided for W
8.20	Temperature monitoring system (including sensors)	X	—	—	X	O	—	Approval Certificate to be provided for W
8.29	Alarm for water ingress into cargo hold (including sensors)	X	—	—	X	O	—	
9.11	Adjustable pitch propeller	X	—	O	O	O	—	
9.11.1	Blade connecting bolt	X	—	—	—	—	X	
9.11.2	Control system (including monitoring and alarm)	X	—	O	O	O	—	
9.11.3	Hydraulic unit	X	—	O	O	O	—	
12.6	Insulation material	O	X	—	—	—	X	Works Approval Certificate to be provided for W
13.6	Hydraulic unit	X	—	O	O	O	—	
13.7	Muffler	X	—	O	X	O	—	

"

Appendix 2 LIST OF CERTIFICATION REQUIREMENTS FOR STATUTORY MARINE PRODUCTS

In the existing Appendix 2, the certification requirements for "Deep-fat cooking equipment" etc., are amended and added as follows:

“

No.	Product name	Document		Approval mode				Remarks
		C/E	W	DA	TA-B	TA-A	WA	
2.16	Deep-fat cooking equipment	O	X	—	X	O	—	Type Approval Certificate to be provided for W
6.36	MF radio installation	X	—	—	X	—	—	
6.37	AIS-SART search and rescue and locating equipment	X	—	—	X	—	—	
6.38	Ship electronic clinometer (navigation bridge)	X	—	—	X	—	—	
6.39	Beidou Satellite positioning and navigation equipment	X	—	—	X	—	—	
6.40	Marine transmitting heading device (THD)	X	—	—	X	—	—	

”

CHAPTER 4 SURVEYS DURING CONSTRUCTION

The following amendments to this Chapter will be implemented from 1 July 2016:

Section 2 SURVEYS AND TESTS

A new sentence is added at the end of 4.2.2.1(5) as follows:

"Construction monitoring is to be conducted for critical structural areas."

The existing paragraph 4.2.2.4 is deleted.

Appendix 1 HULL SURVEY FOR NEW CONSTRUCTION

A new paragraph 1.5 is added as follows:

"1.5 In addition to the above, for Tankers and Bulk Carriers subject to SOLAS Reg. II-1/3-10 (Goal-based ship construction standards for bulk carriers and oil tankers) (hereinafter referred to as "GBS ships"), see also Annex 2 to this Appendix."

In 7.4, "IACS REC47, Shipbuilding and Repair Quality Standard" is amended as "Appendix 2 to this Chapter, Shipbuilding and Repair Quality Standard".

A new paragraph 8.3 is added as follows:

"8.3 In addition to the above, for GBS ships, see also Annex 2 to this Appendix."

The following words are inserted before the existing paragraph 10.1:

"The purposes of this paragraph are applicable to all ships except GBS ships for which the paragraph 3 of Annex 2 to this Appendix is to be applied."

The title of Table 1 is amended as "Items for Hull Survey" and the contents of the table are amended as follows:

1. In the first line of column "Statutory requirements and relevant reference" of No.5 and No.6, the words "Reg. II-1/14 of SOLAS as amended" are replaced by "Reg. II-1/11 of SOLAS as amended".

2. In the first line of column "Statutory requirements and relevant reference" of No.8.5, the words "Reg. II-1/19 of SOLAS as amended" are replaced by "Reg. II-1/16&16-1 of SOLAS as amended".

3. In the last line of column "Statutory requirements and relevant reference" of No.8.5, the words "Reg.I/10 of SOLAS as amended" are replaced by "Reg.I/7 or Reg. I/10 of SOLAS as amended (as appropriate)."

A new Annex 2 is added as follows:

"Annex 2 Requirements for Tankers and Bulk Carriers subject to SOLAS Reg. II-1/3-10 (Goal-based ship construction standards for bulk carriers and oil tankers)

1. Examination and test plan for newbuilding activities

1.1 The shipbuilder is to provide plans of the items which are intended to be examined and tested in accordance with CCS Rules in a document known as the Survey Plan, taking into account the ship type and design. This Survey Plan shall be reviewed at the time of the kick off meeting, and must include:

1.1.1 a set of requirements, including specifying the extent and scope of the construction survey(s) and identifying areas that need special attention during the survey(s), to ensure compliance of construction with mandatory ship construction standards including:

(1) types of surveys (visual, non-destructive examination, etc.) depending on location, materials, welding, casting, coatings, etc.;

(2) establishment of a construction survey schedule for all assembly stages from the kick-off meeting, through all major construction phases, up to delivery;

(3) inspection/survey plan, including provisions for critical areas identified during design approval;

(4) inspection criteria for acceptance;

(5) Interaction with shipyard, including notification and documentation of survey results;

(6) correction procedures to remedy construction defects;

(7) list of items that would require scheduling or formal surveys;

(8) determination and documentation of areas that need special attention throughout ship's life, including criteria used in making the determination;

1.1.2 a description of the requirements for all types of testing during survey, including test criteria.

2. Design Transparency

2.1 For ships subject to compliance with IMO Res. MSC.287(87), IMO Res. MSC.290(87), IMO Res. MSC.296(87) and IMO MSC.1/Circ.1343, readily available documentation is to include the main goal-based parameters and all relevant design parameters that may limit the operation of the ship.

3. Ship Construction File (SCF)

3.1 A Ship Construction File (SCF) with specific information on how the functional requirements of the Goal-based Ship Construction Standards for Bulk Carriers and Oil Tankers have been applied in the ship design and construction is to be provided upon delivery of a new ship, and kept on board the ship and/or ashore and updated as appropriate throughout the ship's service. The contents of the Ship Construction File are to conform to the requirements below.

3.1.1 The following design specific information is to be included in the Ship Construction File (SCF):

(1) areas requiring special attention throughout the ship's life, including critical structural areas;

(2) all design parameters limiting the operation of a ship;

(3) any alternatives to the rules, including structural details and equivalency calculations;

(4) "As built" drawings and information which are verified to incorporate all alterations approved by CCS or flag State during the construction process including scantling details, material details, location of butts and seams, cross section details and locations of all partial and full penetration welds;

(5) net (renewal) scantlings for all the structural constituent parts, as built scantlings and voluntary addition thicknesses;

(6) minimum hull girder section modulus along the length of the ship which has to be maintained throughout the ship's life, including cross section details such as the value of the area of the deck zone and bottom zone, the renewal value for the neutral axis zone;

(7) a listing of materials used for the construction of the hull structure, and provisions for documenting changes to any of the above during the ship's service life;

(8) copies of certificates of forgings and castings welded into the hull (UR W7 and UR W8);

(9) details of equipment forming part of the watertight and weather tight integrity of the ship;

(10) tank testing plan including details of the test requirements (UR S14);

(11) details for the in-water survey, when applicable, information for divers, clearances measurements instructions etc., tank and compartment boundaries;

(12) docking plan and details of all penetrations normally examined at drydocking;

(13) Coating Technical File, for ships subject to compliance with the IMO Performance Standard for Protective Coatings (PSPC②).

3.1.2 Refer to Table A of this Annex for details of information to be further included. This information has to be kept on board the ship and/or ashore and updated as appropriate throughout the ship's life in order to facilitate safe operation, maintenance, survey, repair and emergency measures.

3.1.3 It is to be noted that parts of the content of the SCF may be subject to various degrees of restricted access and that such documentation may be appropriately kept ashore.

3.1.4 The SCF has to include the list of documents constituting the SCF and all information listed in Table A of this Annex, which is required for a ship's safe operation, maintenance, survey, repair and in emergency situations. Details of specific information that is not considered to be critical to safety might be included directly or by reference to other documents.

3.1.5 When developing an SCF, all of the columns in Table A of this Annex have to be reviewed to ensure that all necessary information has been provided.

3.1.6 It may be possible to provide information listed in the annex under more than one Tier II① functional requirement as a single item within the SCF, for example, the Coating Technical File required by the PSPC② is relevant for both "Coating life" and "Survey during construction".

3.1.7 The SCF has to remain with the ship and, in addition, be available to CCS and flag State throughout the ship's life.. Where information not considered necessary to be on board is stored ashore, procedures to access this information should be specified in the onboard SCF. The intellectual property provisions within the SCF should be duly complied with.

3.1.8 The SCF should be updated throughout the ship's life at any major event, including, but not limited to, substantial repair and conversion, or any modification to the ship structure.

---

① Tier II items means the functional requirements included in the International Goal-based Ship Construction Standards for Bulk Carriers and Oil Tankers (GBS), adopted by IMO Res. MSC 287(87).

② Performance standard for protective coatings for dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers, adopted by IMO Res. MSC 215(82), as amended and Performance standard for protective coatings for cargo oil tanks of crude oil tankers, adopted by IMO Res. MSC 288(87), as amended.

4. Determination of number of Surveyor(s)

CCS will assign adequate number of suitable qualified surveyor(s) for new building projects according to the construction progress of each ship to meet appropriate coverage of the examination and testing activities as agreed in the Survey Plan.

Table A – List of Information to be Included in the Ship Construction File (SCF)

Tier II items		Information to be included	Further explanation of the content	Example documents	Normal storage location
DESIGN					
1	Design life	• assumed design life in years	• statement or note on midship section	• SCF-specific	on board ship
				• midship section plan	on board ship
2	Environmental conditions	• assumed environmental conditions	• statement referencing data source or Rule (specific rule and data) or; • in accordance with Rule (date and revision)	• SCF-specific	on board ship
3	Structural strength				
3.1	General design	• applied Rule (date and revision)	• applied design method alternative to Rule and subject structure(s)	• SCF-specific	on board ship
		• applied alternative to Rule		• capacity plan	on board ship
3.2	Deformation and failure modes	• calculating conditions and results;	• allowable loading pattern	• loading manual	on board ship
		• assumed loading conditions	• maximum allowable hull girder bending moment and shear force	• trim and stability booklet	on board ship
3.3	Ultimate strength	• operational restrictions due to structural strength	• maximum allowable cargo density or storage factor	• loading instrument instruction manual	on board ship
				• operation and maintenance manuals	on board ship
				• strength calculation	on shore archive
3.4	Safety margins	• strength calculation results	• bulky output of strength calculation		
			• plan showing highly stressed areas (e.g. critical structural areas) prone to yielding and/or buckling	• areas prone to yielding and/or buckling	on board ship
		• gross hull girder section modulus			
		• minimum hull girder section modulus along the length of the ship to be maintained throughout the ship's life, including cross section details such as the value of the area of the deck zone and bottom zone, the renewal value for the neutral axis zone		• general arrangement plan	on board ship
		• gross scantlings of structural constituent parts	• structural drawing	• key construction plans	on board ship
		• net scantlings of structural constituent parts, as built scantlings and voluntary addition thicknesses	• rudder and stern frame		

Tier II items		Information to be included	Further explanation of the content	Example documents	Normal storage location
			• structural details of typical members	• rudder and rudder stock plans	on board ship
				• structural details	on board ship
				• yard plans	on shore archive
				• dangerous area plan	on board ship
		• hull form			
			• hull form information indicated in key construction plans	• lines plan	on shore archive
			• hull form data stored within an onboard computer necessary for trim and stability and longitudinal strength calculations	or	
				Equivalent	on board ship
4	Fatigue life	• applied Rule (date and revision)	• applied design method alternative to Rule and subject structures	• SCF-specific	on board ship
		• applied alternative to Rule			
		• calculating conditions and results;	• assumed loading conditions and rates	• structural details	on board ship
		• assumed loading conditions			
		• fatigue life calculation results	• bulky output of fatigue life calculation	• fatigue life calculation	on shore archive
			• plan showing areas (e.g. critical structural areas) prone to fatigue	• areas prone to fatigue	on board ship
5	Residual strength	• applied Rule (date and revision)		• SCF-specific	on board ship
6	Protection against corrosion				
6.1	Coating life	• coated areas and target coating life and other measures for corrosion protection in holds, cargo and ballast tanks, other structure-integrated deep tanks and void spaces	• plans showing areas (e.g. critical structural areas) prone to excessive corrosion	• SCF-specific	on board ship
6.2	Corrosion addition			• Coating Technical File required by PSPC (Performance standard for protective coatings for dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers, adopted by IMO Resolution MSC.215(82), as amended and Performance standard for protective coatings for cargo oil tanks of crude oil tankers, adopted by IMO Resolution MSC.288(87), as amended)	on board ship

Tier II items		Information to be included	Further explanation of the content	Example documents	Normal storage location
		• specification for coating and other measures for corrosion protection in holds, cargo and ballast tanks, other structure-integrated deep tanks and void spaces		• areas prone to excessive corrosion	on board ship
		• gross scantlings of structural constituent parts		• key construction plans	on board ship
		• net scantlings of structural constituent parts, as built scantlings and voluntary addition thicknesses			
7	Structural redundancy	• applied Rule (date and revision)		• SCF-specific	on board ship
8	Watertight and weathertight integrity	• applied Rule (date and revision)		• SCF-specific	on board ship
		• key factors for watertight and weathertight integrity	• details of equipment forming part of the watertight and weathertight integrity	• structural details of hatch covers, doors and other closings integral with the shell and bulkheads	on board ship
9	Human element considerations	• list of ergonomic design principles applied to ship structure design to enhance safety during operations, inspections and maintenance of ship		• SCF-specific	on board ship
10	Design transparency	• applied Rule (date and revision) • applicable industry standards for design transparency and IP protection		• intellectual property provisions	on board ship
		• reference to part of SCF information kept ashore		• summary, location and access procedure for part of SCF information on shore	on board ship
CONSTRUCTION					
11	Construction quality procedures	• applied construction quality standard	• recognized national or international construction quality standard	• SCF-specific	on board ship
12	Survey during construction	• survey regime applied during construction (to include all owner and class scheduled inspections during construction)	• applied Rules (date and revision) • copies of certificates of forgings and castings welded into the hull	• SCF-specific • tank testing plan	on board ship on board ship
		• information on non-destructive examination		• non-destructive testing plan	on board ship
				• Coating Technical File required by PSPC	on board ship
IN-SERVICE CONSIDERATIONS					
13	Survey and maintenance	• maintenance plans specific to the structure of the ship where higher attention is called for	• plan showing highly stressed areas (e.g. critical structural areas) prone to yielding, buckling, fatigue and/or excessive corrosion	• SCF-specific • operation and maintenance manuals (e.g. hatch covers and doors)	on board ship on board ship
		• preparations for survey	• arrangement and details of all penetrations normally examined at dry-docking	• docking plan	on board ship

Tier II items		Information to be included	Further explanation of the content	Example documents	Normal storage location
		• gross hull girder section modulus	• detailed information for dry-docking	• dangerous area plan	on board ship
		• minimum hull girder section modulus along the length of the ship to be maintained throughout the ship's life, including cross section details such as the value of the area of the deck zone and bottom zone, the renewal value for the neutral axis zone	• details for in-water survey	• Ship Structure Access Manual	on board ship
				• Means of access to other structure-integrated deep tanks	on board ship
				• Coating Technical File required by PSPC	on board ship
		• gross scantlings of structural constituent parts		• key construction plans	on board ship
		• net scantlings of structural constituent parts, as built scantlings and voluntary addition thicknesses		• rudder and rudder stock	on board ship
				• structural details	on board ship
				• yard plans	on shore archive
			• hull form information indicated in key construction plans	• lines plan	on shore archive
		• hull form		or	
				equivalent	on board ship
14	Structural accessibility	• means of access to holds, cargo and ballast tanks and other structure-integrated deep tanks	• plans showing arrangement and details of means of access	• Ship Structure Access Manual	on board ship
				• means of access to other structure-integrated deep tanks	on board ship
RECYCLING CONSIDERATIONS					
15	Recycling	• identification of all materials that were used in construction and may need special handling due to environmental and safety concerns	• list of materials used for the construction of the hull structure	• SCF-specific	on board ship

Notes:

1. "SCF-specific" means documents to be developed especially to meet the requirements of these GBS guidelines (MSC.1/Circ.1343).
2. "Key construction plans" means plans such as midship section, main O.T. and W.T. transverse bulkheads, construction profiles/plans, shell expansions, forward and aft sections in cargo tank (or hold) region, engine-room construction, forward construction and stern construction drawings.
3. "Yard plans" means a full set of structural drawings, which include scantling information of all structural members.
4. "Hull form" means a graphical or numerical representation of the geometry of the hull. Examples would include the graphical description provided by a lines plan and the numerical description provided by the hull form data stored within an onboard computer.
5. "Lines plan" means a special drawing which is dedicated to show the entire hull form of a ship.
6. "Equivalent (to Lines plan)" means a set of information of hull form to be indicated in key construction plans for SCF purposes. Sufficient information should be included in the drawings to provide the geometric definition to facilitate the repair of any part of the hull structure.
7. "Normal storage location" means a standard location where each SCF information item should be stored. However, those items listed as being on board in the table above should be on board as a minimum to ensure that they are transferred with the ship on a change of owner.
8. "Shore archive" is to be operated in accordance with applicable international standards."

A new Appendix 2 is added as follows:

"Appendix 2 SHIPBUILDING AND REPAIR QUALITY STANDARD

1 Shipbuilding and Remedial Quality Standards for New Construction

1.1 Scope

It is intended that these standards provide guidance where established and recognized shipbuilding or national standards accepted by CCS do not exist.

1.1.1 This standard provides guidance on shipbuilding quality standards for the hull structure during new construction and the remedial standard where the quality standard is not met. The applicability of the standard is in each case to be agreed upon by CCS.

1.1.1.1 Whereas the standard generally applies to:

(1) conventional merchant ship types;

(2) parts of hull covered by CCS rules;

(3) hull structures constructed from normal and higher strength hull structural steel.

1.1.1.2 The standard does generally not apply to the new construction of:

(1) special types of ships as e.g. gas tankers;

(2) structures fabricated from stainless steel or other, special types or grades of steel.

1.1.2 In this standard, both a "Standard" range and a "Limit" range are listed. The "Standard" range represents the target range expected to be met in regular work under normal circumstances. The "Limit" range represents the maximum allowable deviation from the "Standard" range. Work beyond the "Standard" range but within the "Limit" range is acceptable. In cases where no 'limit' value is specified, the value beyond the 'standard' range may be accepted subject to the consideration of CCS.

1.1.3 The standard covers typical construction methods and gives guidance on quality standards for the most important aspects of such construction. Unless explicitly stated elsewhere in the standard, the level of workmanship reflected herein will in principle be acceptable for primary and secondary structure of conventional designs. A more stringent standard may however be required for critical and highly stressed areas of the hull, and this is to be agreed with CCS in each case. In assessing the criticality of hull structure and structural components, reference is made to References 1, 2 and 3 to this Section.

1.1.4 Details relevant to structures or fabrication procedures not covered by this standard are to be approved by CCS on the basis of procedure qualifications and/or recognized national standards.

1.1.5 For use of this standard, fabrication fit-ups, deflections and similar quality attributes are intended to be uniformly distributed about the nominal values. The shipyard is to take corrective action to improve work processes that produce measurements where a skew distribution is evident. Relying upon remedial steps that truncate a skewed distribution of the quality attribute is unacceptable.

1.2 General requirements for new construction

1.2.1 In general, the work is to be carried out in accordance with CCS rules and under the supervision of the CCS Surveyor.

1.2.2 Welding operations are to be carried out in accordance with work instructions accepted by CCS.

1.2.3 Welding of hull structures is to be carried out by qualified welders, according to approved and qualified welding procedures and with welding consumables approved by CCS, see Section 1.3. Welding operations are to be carried out under proper supervision by the shipbuilder. The working conditions for welding are to be monitored by CCS in accordance with Appendix 1 of this Chapter.

1.3 Qualification of personnel and procedures

1.3.1 Qualification of welders

1.3.1.1 Welders are to be qualified in accordance with the procedures of CCS or to a recognized national or international standard. Recognition of other standards is subject to submission to CCS for evaluation. Subcontractors are to keep records of welders qualification and, when required, furnish valid approval test certificates.

1.3.1.2 Welding operators using fully mechanized or fully automatic processes need generally not pass approval testing provided that the production welds made by the operators are of the required quality. However, operators are to receive adequate training in setting or programming and operating the equipment. Records of training and operation experience shall be maintained on individual operator's files and records, and be made available to CCS for inspection when requested.

1.3.2 Qualification of welding procedures

1.3.2.1 Welding procedures are to be qualified in accordance with URW28 or other recognized standard accepted by CCS.

1.3.3 Qualification of NDE operators

1.3.3.1 Personnel performing non-destructive examination for the purpose of assessing quality of welds in connection with new construction covered by this standard, are to be qualified in accordance with CCS rules or to a recognized international or national qualification scheme. Records of operators and their current certificates are to be kept and made available to the Surveyor for inspection.

1.4 Materials

1.4.1 Materials for Structural Members

All materials, including weld consumables, to be used for the structural members are to be approved by CCS as per the approved construction drawings and meet the respective IACS Unified Requirements. Additional recommendations are contained in the following paragraphs.

1.4.1.2 All materials used should be manufactured at a works approved by CCS for the type and grade supplied.

1.4.2 Surface Conditions

1.4.2.1 Definitions

(1) Minor Imperfections: Pitting, rolled-in scale, indentations, roll marks, scratches and grooves.

(2) Defects: Cracks, shells, sand patches, sharp edged seams and minor imperfections exceeding the limits of Table 1.

(3) Depth of Imperfections or defects: The depth is to be measured from the surface of the product.

1.4.2.2 Acceptance without remedies

(1) Minor imperfections, in accordance with the nominal thickness (t) of the product and the limits described in Table 1, are permissible and may be left as they are.

Limits for depth of minor imperfection, for acceptance without remedies **Table 1**

Imperfection surface area Ratio (%)	15 ~ 20%	5 ~ 15%	0 ~ 5%
$t < 20$ mm	0.2 mm	0.4 mm	0.5 mm
20 mm $\leq t < 50$ mm	0.2 mm	0.6 mm	0.7 mm
50 mm $\leq t$	0.2 mm	0.7 mm	0.9 mm

(2) Imperfection surface area Ratio (%) is obtained as influenced area / area under consideration (i.e. plate surface area) × 100%.

(3) For isolated surface discontinuities, influenced area is obtained by drawing a continuous line which follows the circumference of the discontinuity at a distance of 20 mm (Figure 1).

(4) For surface discontinuities appearing in a cluster, influenced area is obtained by drawing a continuous line which follows the circumference of the cluster at a distance of 20 mm (Figure 2).

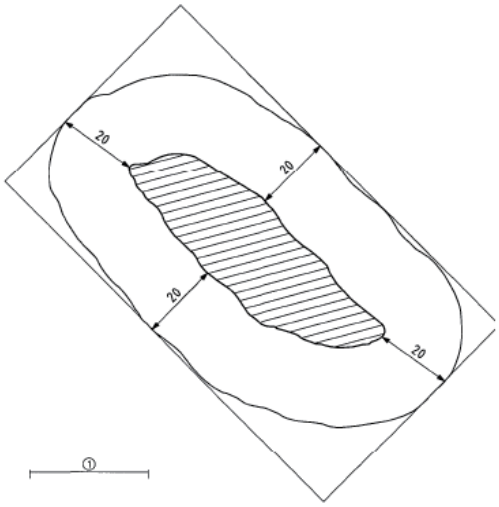


Figure 1 - Determination of the area influenced by an isolated discontinuity (Ref. Nr. EN 10163-1:2004+AC:2007 E)

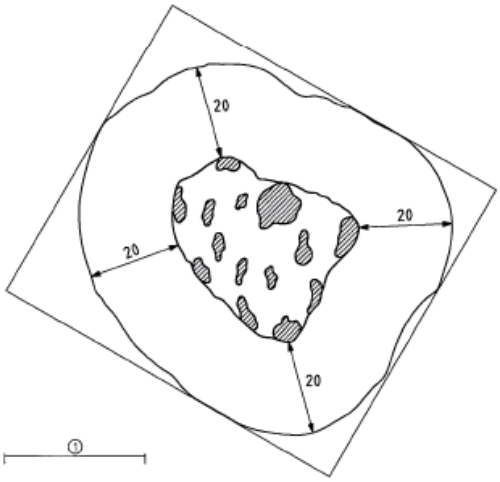


Figure 2 - Determination of the area influenced by clustered discontinuities (Ref. Nr. EN 10163-1:2004+AC:2007 E)

1.4.2.3 Remedial of Defects

(1) Defects are to be remedied by grinding and/or welding in accordance with IACS Rec.12.

1.4.2.4 Further Defects

(1) Lamination

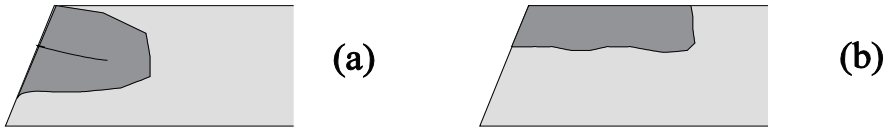
① Investigation to be carried out at the steelmill into the cause and extent of the detected laminations. Severe lamination is to be remedied by local insert plates. The minimum breadth or length of the plate to be replaced is to be:

(a) 1600 mm for shell and strength deck plating in way of cruciform or T-joints;

(b) 800 mm for shell, strength deck plating and other primary members;

(c) 300 mm for other structural members.

② Local limited lamination may be remedied by chipping and/or grinding followed by welding in accordance with sketch (a). In case where the local limited lamination is near the plate surface, the remedial may be carried out as shown in sketch (b). For limitations see paragraph 1.4.2.2.



(2) Weld Spatters

Loose weld spatters are to be removed by grinding or other measures to clean metal surface (see Table 1.9.13), as required by the paint system, on:

① shell plating;

② deck plating on exposed decks;

③ in tanks for chemical cargoes;

④ in tanks for fresh water and for drinking water;

⑤ in tanks for lubricating oil, hydraulic oil, including service tanks.

1.5 Gas Cutting

The roughness of the cut edges is to meet the following requirements:

1.5.1 Free Edges:

	Standard	**Limit**
Strength Members	150 μm	300 μm
Others	500 μm	1000 μm

1.5.2 Welding Edges:

	Standard	Limit
Strength Members	400 μm	800 μm
Others	800 μm	1500 μm

1.6 Fabrication and fairness

1.6.1 Flanged longitudinals and flanged brackets (see Table 1.6.1);

1.6.2 Built-up sections (see Table 1.6.2);

1.6.3 Corrugated bulkheads (see Table 1.6.3);

1.6.4 Pillars, brackets and stiffeners (see Table 1.6.4);

1.6.5 Maximum heating temperature on surface for line heating (see Table 1.6.5);

1.6.6 Block assembly (see Table 1.6.6);

1.6.7 Special sub-assembly (see Table 1.6.7);

1.6.8 Shape (see Table 1.6.8 and 1.6.9);

1.6.9 Fairness of plating between frames (see Table 1.6.10);

1.6.10 Fairness of plating with frames (see Table 1.6.11);

1.6.11 Preheating for welding hull steels at low temperature (see Table 1.6.12).

1.7 Alignment

1.7.1 The quality standards for alignment of hull structural components during new construction are shown in Tables 1.7.1, 1.7.2 and 1.7.3. CCS may require a closer construction tolerance in areas requiring special attention, as follows:

(1) Regions exposed to high stress concentrations;

(2) Fatigue prone areas;

(3) Detail design block erection joints;

(4) High tensile steel regions.

1.8 Welding Joint Details

Edge preparation is to be qualified in accordance with URW28 or other recognized standard accepted by CCS.

Some typical edge preparations are shown in Table 1.8.1, 1.8.2, 1.8.3, 1.8.4 and 1.8.6 for reference.

1.8.1 Typical butt weld plate edge preparation (manual and semi-automatic welding) for reference - see Table 1.8.1 and 1.8.2.

1.8.2 Typical fillet weld plate edge preparation (manual and semi-automatic welding) for reference - see Table 1.8.3 and 1.8.4.

1.8.3 Butt and fillet weld profile (manual and semi-automatic welding) - see Table 1.8.5.

1.8.4 Typical butt weld plate edge preparation (Automatic welding) for reference - see Table 1.8.6.

1.8.5 Distance between welds - see Table 1.8.7.

1.9 Remedial

All the major remedial work is subject to reporting by shipbuilder to CCS for approval in accordance with their work instruction for new building.

Some typical remedial works are shown in Tables 1.9.1 to 1.9.13.

1.9.1 Typical misalignment remedial - see Tables 1.9.1 to 1.9.3.

1.9.2 Typical butt weld plate edge preparation remedial (manual and semi-automatic welding) - see Table 1.9.4 and 1.9.5.

1.9.3 Typical fillet weld plate edge preparation remedial (manual and semi-automatic welding) - see Tables 1.9.6 to 1.9.8.

1.9.4 Typical fillet and butt weld profile remedial (manual and semi-automatic welding) - see Table 1.9.9.

1.9.5 Distance between welds remedial - see Table 1.9.10.

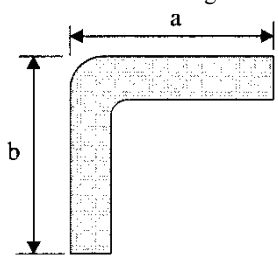
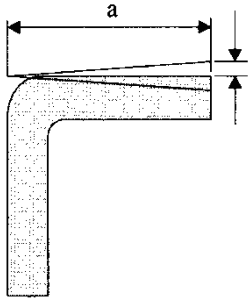
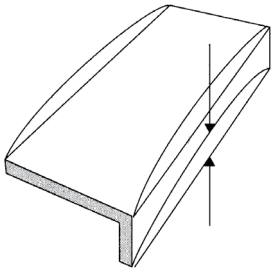
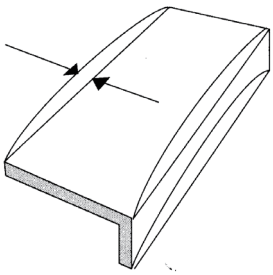
1.9.6 Erroneous hole remedial - see Table 1.9.11.

1.9.7 Remedial by insert plate - see Table 1.9.12.

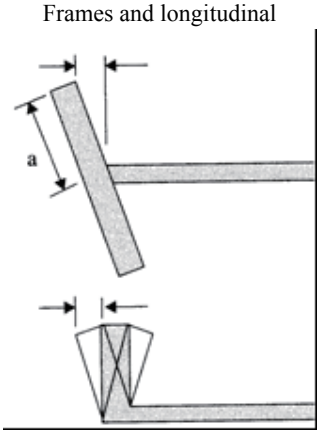
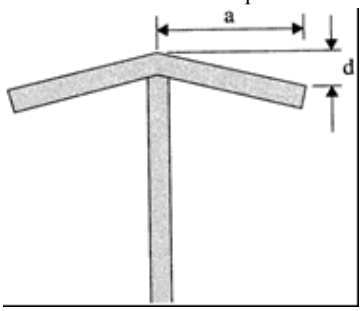
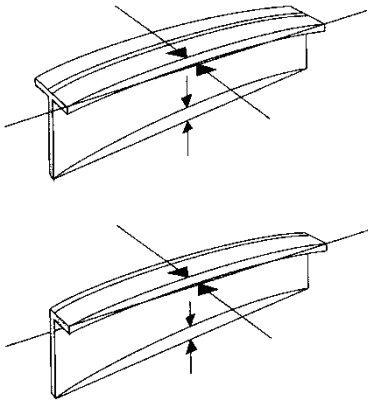
1.9.8 Weld surface remedial - see Table 1.9.13.

1.9.9 Weld remedial (short bead) - see Table 1.9.14.

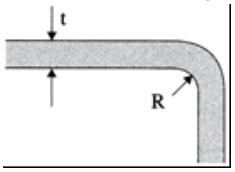
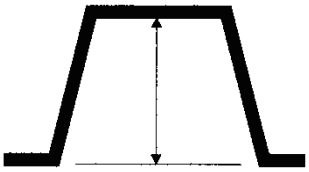
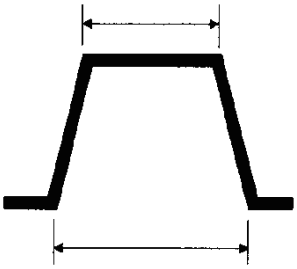
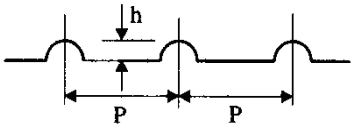
Flanged Longitudinals and Flanged Brackets **TABLE 1.6.1**

Detail	Standard	Limit	Remarks
Breadth of flange  compared to correct size	± 3 mm	± 5 mm	
Angle between flange and web  compared to template	± 3 mm	± 5 mm	per 100 mm of *a*
Straightness in plane of flange and web  	± 10 mm	± 25 mm	per 10 m

Built Up Sections **TABLE 1.6.2**

Detail	Standard	Limit	Remarks
Frames and longitudinal 	± 1.5 mm	± 3 mm	per 100 mm of *a*
Distortion of face plate 	$d \leq 3 + a/100$ mm	$d \leq 5 + a/100$ mm	
Distortion in plane of web and flange of built up longitudinal frame, transverse frame, girder and transverse web 	± 10 mm	± 25 mm	per 10 m in length

Corrugated Bulkheads **TABLE 1.6.3**

Detail	Standard	Limit	Remarks
Mechanical bending 	$R \geq 3t$ mm $R \geq 4.5t$ mm for CSR ships [Note 1]	2t mm [Note 2]	Material to be suitable for cold flanging (forming) and welding in way of radius
Depth of corrugation 	± 3 mm	± 6 mm	
Breadth of corrugation 	± 3 mm	± 6 mm	
Pitch and depth of swedged corrugated bulkhead compared with correct value 	h : ± 2.5 mm Where it is not aligned with other bulkheads P : ± 6 mm Where it is aligned with other bulkheads P : ± 2 mm	h : ± 5 mm Where it is not aligned with other bulkheads P : ± 9 mm Where it is aligned with other bulkheads P : ± 3 mm	

Notes:

1. For CSR Bulk Carriers built under the "Common Structural Rules for Bulk Carriers" with the effective dates of 1 July 2010 and 1 July 2012, the standard is $R \geq 2t$ mm.
2. For CSR ships, the allowable inside bending radius of cold formed plating may be reduced provided the following requirements are complied with.

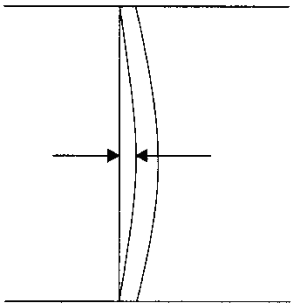
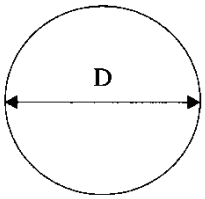
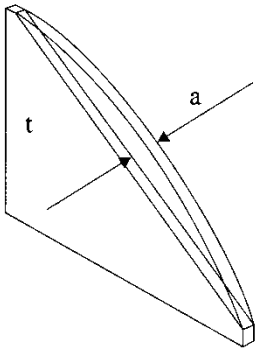
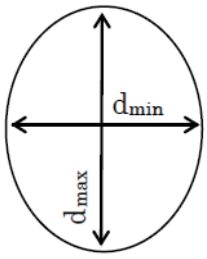
   When the inside bending radius is reduced below 4.5 times the as-built plate thickness, supporting data is to be provided. The bending radius is in no case to be less than 2 times the as-built plate thickness. As a minimum, the following additional requirements are to be complied with:

   a) For all bent plates:
      - 100% visual inspection of the bent area is to be carried out.
      - Random checks by magnetic particle testing are to be carried out.

   b) In addition to a), for corrugated bulkheads subject to lateral liquid pressure:
      - The steel is to be of Grade D/DH or higher.

   The material is impact tested in the strain-aged condition and satisfies the requirements stated herein. The deformation is to be equal to the maximum deformation to be applied during production, calculated by the formula $t_{as\text{-}built}/(2r_{bdg} + t_{as\text{-}built})$, where $t_{as\text{-}built}$ is the as-built thickness of the plate material and r_{bdg} is the bending radius. One sample is to be plastically strained at the calculated deformation or 5%, whichever is greater and then artificially aged at 250℃ for one hour then subject to Charpy V-notch testing. The average impact energy after strain ageing is to meet the impact requirements specified for the grade of steel used.

Pillars, Brackets and Stiffeners **TABLE 1.6.4**

Detail	Standard	Limit	Remarks
Pillar (between decks) 	4 mm	6 mm	
Cylindrical structure diameter (pillars, masts, posts, etc.) 	± *D*/200 mm max. + 5 mm	± *D*/150 mm max. 7.5 mm	
Tripping bracket and small stiffener, distortion at the part of free edge 	$a \leq t/2$ mm	t	
Ovality of cylindrical structure 		$d_{max} - d_{min} \leq 0.02 \times d_{max}$	

Maximum Heating Temperature on Surface for Line Heating TABLE 1.6.5

Item		Standard	Limit	Remarks
Conventional Process AH32-EH32 & AH36-EH36 TMCP type AH36-EH36 ($C_{eq.}$ > 0.38%)	Water cooling just after heating	Under 650℃		
	Air cooling after heating	Under 900℃		
	Air cooling and subsequent water cooling after heating	Under 900℃ (starting temperature of water cooling to be under 500℃)		
TMCP type AH32-DH32 & AH36-DH36 ($C_{eq.}$ ≤ 0.38%) TMCP type EH32 & EH36 ($C_{eq.}$ ≤ 0.38%)	Water cooling just after heating or air cooling Water cooling just after heating or air cooling	Under 1000℃ Under 900℃		

Note:

$$C_{eq} = \mathrm{C} + \frac{\mathrm{Mn}}{6} + \frac{\mathrm{Cr} + \mathrm{Mo} + \mathrm{V}}{5} + \frac{\mathrm{Ni} + \mathrm{Cu}}{15}(\%)$$

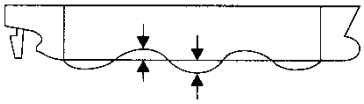
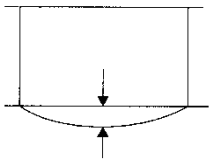
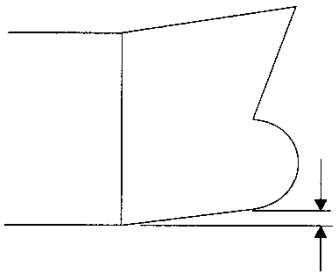
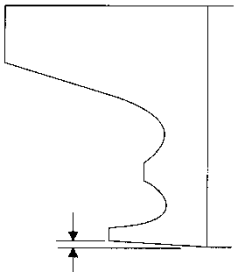
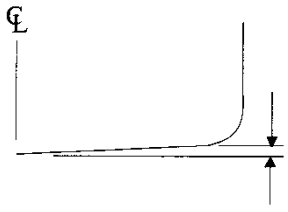
Block Assembly **TABLE 1.6.6**

Item	Standard	Limit	Remarks
Flat Plate Assembly			
Length and Breadth	± 4 mm	± 6 mm	
Distortion	± 10 mm	±20mm	
Squareness	± 5 mm	±10mm	
Deviation of interior members from plate	5 mm	10mm	
Curved plate assembly			
Length and Breadth	± 4 mm	± 8 mm	
Distortion	± 10 mm	± 20 mm	measured along the girth
Squareness	± 10 mm	± 15 mm	
Deviation of interior members from plate	5 mm	10 mm	
Flat cubic assembly			
Length and Breadth	± 4 mm	± 6 mm	
Distortion	± 10 mm	± 20 mm	
Squareness	± 5 mm	± 10 mm	
Deviation of interior members from plate	5 mm	10 mm	
Twist	± 10 mm	± 20 mm	
Deviation between upper and lower plate	± 5 mm	± 10 mm	
Curved cubic assembly			
Length and Breadth	± 4 mm	± 8 mm	
Distortion	± 10 mm	± 20 mm	
Squareness	± 10 mm	± 15 mm	measured along with girth
Deviation of interior members from plate	± 5 mm	± 10 mm	
Twist	± 15 mm	± 25 mm	
Deviation between upper and lower plate	± 7 mm	± 15 mm	

Special Sub-Assembly **TABLE 1.6.7**

Item	Standard	Limit	Remarks
Distance between upper/lower gudgeon	± 5 mm	± 10 mm	
Distance between aft edge of boss and aft peak bulkhead	± 5 mm	± 10 mm	
Twist of sub-assembly of stern frame	5 mm	10 mm	
Deviation of rudder from shaft center line	4 mm	8 mm	
Twist of rudder plate	6 mm	10 mm	
Flatness of top plate of main engine bed	5 mm	10 mm	
Breadth and length of top plate of main engine bed	± 4 mm	± 6 mm	
Note: Dimensions and tolerances have to fulfill engine and equipment manufacturers' requirements, if any.			

Shape **TABLE 1.6.8**

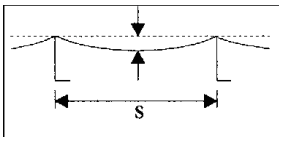
Detail	Standard	Limit	Remarks
Deformation for the whole length 	± 50 mm		per 100 m against the line of keel sighting
Deformation for the distance between two adjacent bulkheads 	± 15 mm		
Cocking-up of fore body 	± 30 mm		The deviation is to be measured from the design line
Cocking-up of aft-body 	± 20 mm		
Rise of floor amidships 	± 15 mm		The deviation is to be measured from the design line

Shape **TABLE 1.6.9**

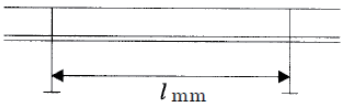
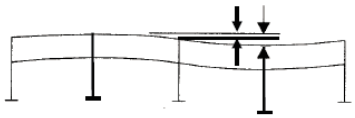
Item	Standard	Limit	Remarks
Length between perpendiculars	±*L*/1000 mm where *L* is in mm		Applied to ships of 100 m length and above. For the convenience of the measurement the point where the keel is connected to the curve of the stem may be substituted for the fore perpendicular in the measurement of the length
Moulded breadth at midship	±*B*/1000 mm where *B* is in mm		Applied to ships of 15 m breadth and above, measured on the upper deck
Moulded depth at midship	±*D*/1000 mm where *D* is in mm		Applied to ships of 10 m depth and above, measured up to the upper deck

Fairness of Plating Between Frames **TABLE 1.6.10**

Item		Standard	Limit	Remarks
Shell plate	Parallel part (side & bottom shell)	4 mm	8 mm	
	Fore and aft part	5 mm		
Tank top plate		4 mm		
Bulkhead	Longl. Bulkhead Trans. Bulkhead Swash Bulkhead	6 mm		
Strength deck	Parallel part	4 mm	8 mm	
	Fore and aft part Covered part	6 mm 7 mm	9 mm 9 mm	
Second deck	Bare part	6 mm	8 mm	
	Covered part	7 mm	9 mm	
Forecastle deck poop deck	Bare part	4 mm	8 mm	
	Covered part	6 mm	9 mm	
Super structure deck	Bare part	4 mm	6 mm	
	Covered part	7 mm	9 mm	
House wall	Outside wall	4 mm	6 mm	
	Inside wall	6 mm	8 mm	
	Covered part	7 mm	9 mm	
Interior member (web of girder, etc.)		5 mm	7 mm	
Floor and girder in double bottom		5 mm	8 mm	



Fairness of Plating with Frames **TABLE 1.6.11**

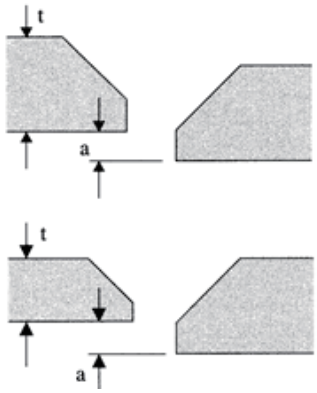
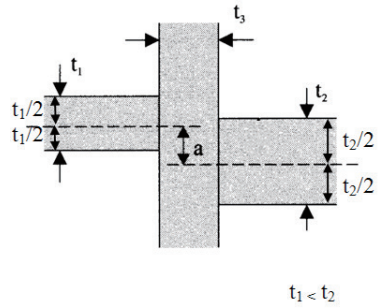
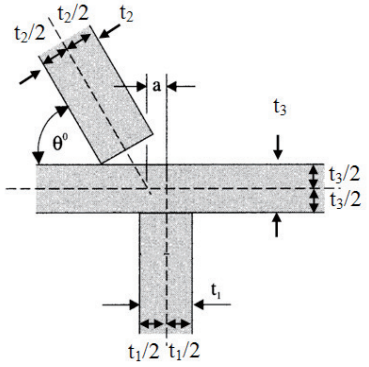
Item		Standard	Limit	Remarks
Shell plate	Parallel part	±2 *l* /1000 mm	±3 *l* /1000 mm	*l* = span of frame (mm) To be measured between on trans. space (min. *l* = 3000 mm)
	Fore and aft part	±3 *l* /1000 mm	±4 *l* /1000 mm	
Strength deck (excluding cross deck) and top plate of double bottom	-	±3 *l* /1000 mm	±4 *l* /1000 mm	
Bulkhead	-		±5 *l* /1000 mm	
Accommodation above the strength deck and others	-	±5 *l* /1000 mm	±6 *l* /1000 mm	
 *l* = span of frame (minimum *l* = 3000 mm)  To be measured between one trans. space				

Preheating for welding hull steels at low temperature **TABLE 1.6.12**

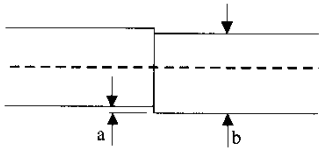
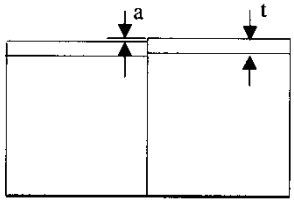
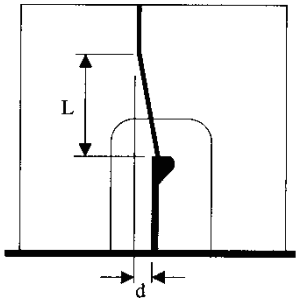
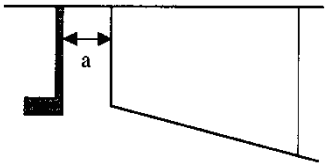
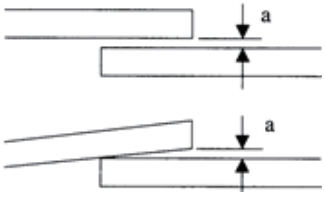
Item		Standard		Limit	Remarks
		Base metal temperature needed preheating	Minimum preheating temperature		
Normal strength steels	A, B, D, E	Below -5℃	20℃ [1)]		
Higher strength steels (TMCP type)	AH32 – EH32 AH36 – EH36	Below 0℃			
Higher strength steels (Conventional type)		Below 0℃			

Note:
1) This level of preheat is to be applied unless the approved welding procedure specifies a higher level.

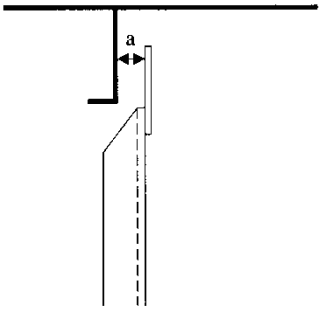
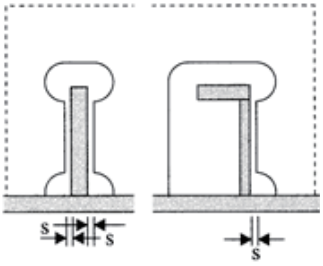
Alignment **TABLE 1.7.1**

Detail	Standard	Limit	Remarks
Alignment of butt welds 		$a \le 0.15t$ strength member $a \le 0.2t$ other but maximum 4.0 mm	t is the lesser plate thickness
Alignment of fillet welds 		Strength member and higher stress member: $a \le t_1/3$ Other: $a \le t_1/2$	Alternatively, heel line can be used to check the alignment. Where t_3 is less than t_1, then t_3 should be substituted for t_1 in the standard
Alignment of fillet welds 		Strength member and higher stress member: $a \le t_1/3$ Other: $a \le t_1/2$	Alternatively, heel line can be used to check the alignment. Where t_3 is less than t_1, then t_3 should be substitute for t_1 in the standard

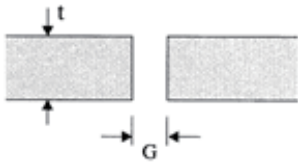
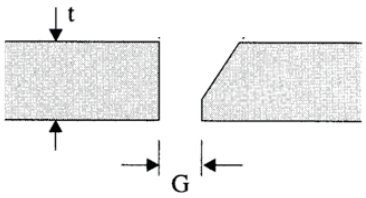
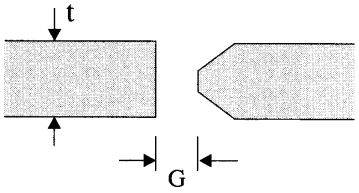
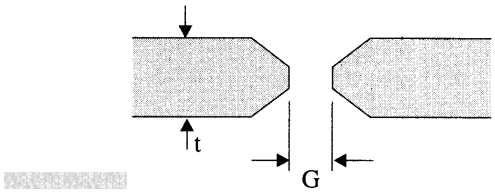
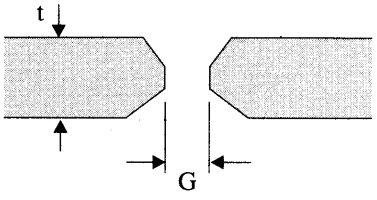
Alignment **TABLE 1.7.2**

Detail	Standard	Limit	Remarks
Alignment of flange of T-longitudinal  *b* (mm)	Strength member $a \leq 0.04b$ (mm)	a = 8.0 mm	
Alignment of height of T-bar, L-angle bar or bulb  	Strength member $a \leq 0.15t$ Other $a \leq 0.20t$	a = 3.0 mm	
Alignment of panel stiffener  	$d \leq L/50$		
Gap between bracket/intercostal and stiffener  	$a \leq 2.0$ mm	a = 3.0 mm	
Alignment of lap welds  	$a \leq 2.0$ mm	a = 3.0 mm	

Alignment **TABLE 1.7.3**

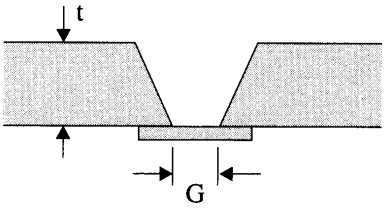
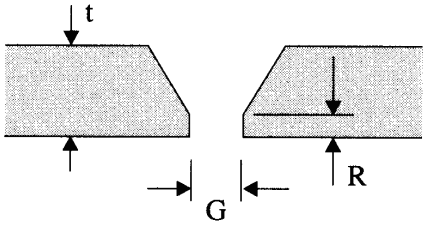
Detail	Standard	Limit	Remarks
Gap between beam and frame 	$a \leq 2.0$ mm	$a = 5.0$ mm	
Gap around stiffener cut-out 	$s \leq 2.0$ mm	$s = 3.0$ mm	

Typical Butt Weld Plate Edge Preparation
(Manual Welding and Semi-Automatic Welding) for Reference TABLE 1.8.1

Detail	Standard	Limit	Remarks
Square butt $t \le 5$ mm 	$G \le 3$ mm	$G = 5$ mm	see Note 1
Single bevel butt $t > 5$ mm 	$G \le 3$ mm	$G = 5$ mm	see Note 1
Double bevel butt $t > 19$ mm 	$G \le 3$ mm	$G = 5$ mm	see Note 1
Double Vee butt, uniform bevels 	$G \le 3$ mm	$G = 5$ mm	see Note 1
Double Vee butt, non-uniform bevel 	$G \le 3$ mm	$G = 5$ mm	see Note 1

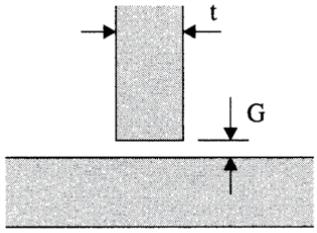
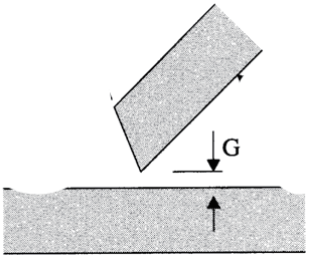
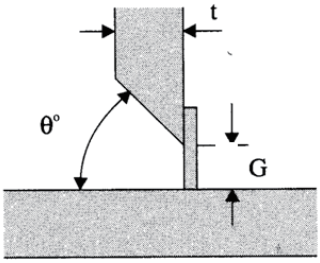
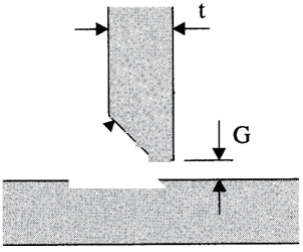
Note 1:
Different plate edge preparation may be accepted or approved by CCS in accordance with UR W28 or other recognized standard accepted by CCS.
For welding procedures other than manual welding, see paragraph 1.3.2 Qualification of weld procedures.

Typical Butt Weld Plate Edge Preparation
(Manual Welding and Semi-Automatic Welding) for Reference TABLE 1.8.2

Detail	Standard	Limit	Remarks
Single Vee butt, one side welding with backing strip (temporary or permanent) 	G = 3 to 9 mm	G = 16 mm	see Note 1
Single Vee butt 	$G \leq 3$ mm	G = 5 mm	see Note 1

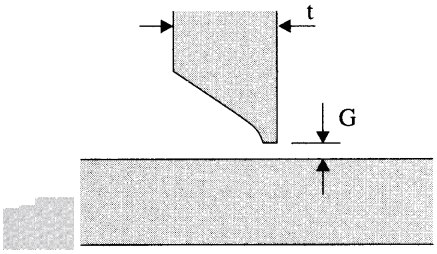
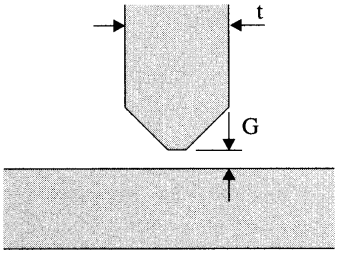
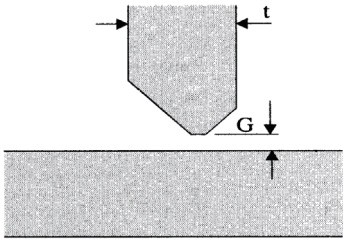
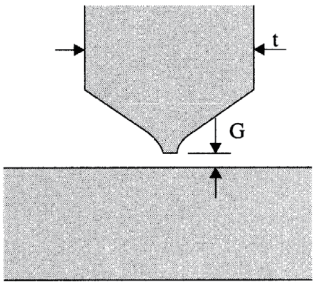
Note 1:
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For welding procedures other than manual welding, see paragraph 1.3.2 Qualification of welding procedures.

Table 1.8.3—Typical Fillet Weld Plate Edge Preparation (Manual Welding and Semi-Automatic Welding) for Reference

Detail	Standard	Limit	Remarks
Tee Fillet 	$G \leq 2$ mm	$G = 3$ mm	see Note 1
Inclined fillet 	$G \leq 2$ mm	$G = 3$ mm	see Note 1
Single bevel tee with permanent backing 	$G \leq 4$ to 6 mm θ° = 30° to 45°	$G = 16$ mm	Not normally for strength member also see Note 1
Single bevel tee 	$G \leq 3$ mm		see Note 1

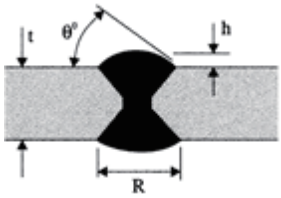
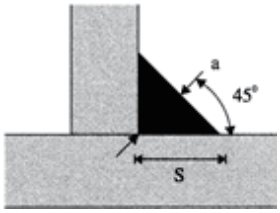
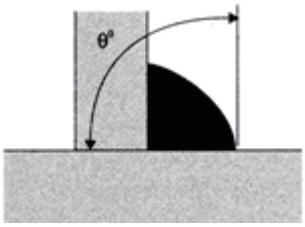
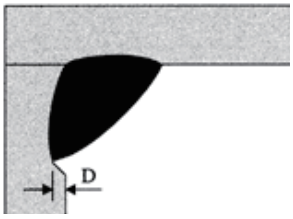
Note 1:
Different plate edge preparation may be accepted or approved by CCS in accordance with UR W28 or other recognized standard accepted by CCS.
For welding procedures other than manual welding, see paragraph 1.3.2 Qualification of welding procedures.

Typical Fillet Weld Plate Edge Preparation
(Manual Welding and Semi-Automatic Welding) for Reference **Table 1.8.4**

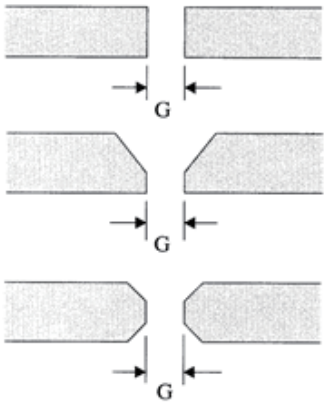
Detail	Standard	Limit	Remarks
Single 'J' bevel tee 	G = 2.5 to 4 mm		see Note 1
Double bevel tee symmetrical t > 19 mm 	$G \leq 3$ mm		see Note 1
Double bevel tee asymmetrical t > 19 mm 	$G \leq 3$ mm		see Note 1
Double 'J' bevel tee symmetrical 	G = 2.5 to 4 mm		see Note 1

Note 1:
Different plate edge preparation may be accepted or approved by CCS in accordance with URW28 or other recognized standard accepted by CCS.
For welding procedures other than manual welding, see paragraph 1.3.2 Qualification of welding procedures.

Butt And Fillet Weld Profile (Manual Welding and Semi-Automatic Welding) Table 1.8.5

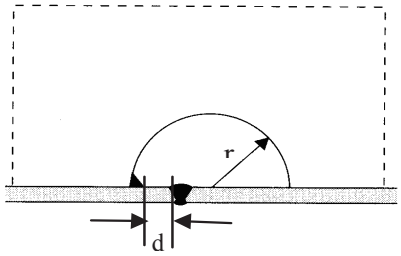
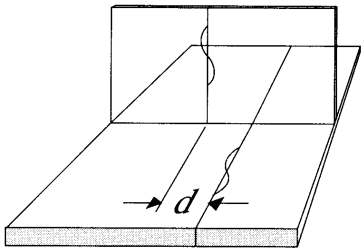
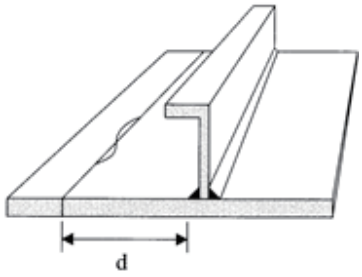
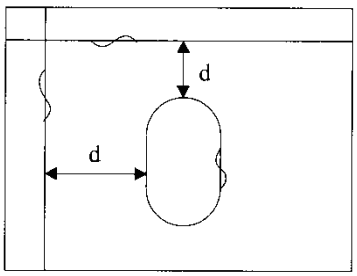
Detail	Standard	Limit	Remarks
Butt weld toe angle 	$\theta \leq 60°$ $h \leq 6$ mm	$\theta \leq 90°$	
Butt weld undercut 		$D \leq 0.5$ mm for strength member $D \leq 0.8$ mm for other	
Fillet weld leg length  s = leg length; a = throat thickness		$s \geq 0.9s_d$ $a \geq 0.9a_d$ over short weld lengths	s_d = design s a_d = *design* a
Fillet weld toe angle 		$\theta \leq 90°$	In areas of stress concentration and fatigue, CCS may require a lesser angle
Fillet weld undercut 		$D \leq 0.8$ mm	

Typical Butt Weld Plate Edge Preparation (Automatic welding) for Reference Table 1.8.6

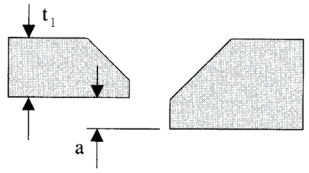
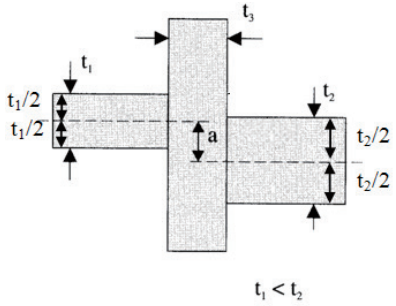
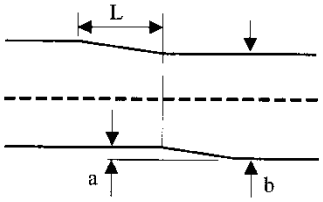
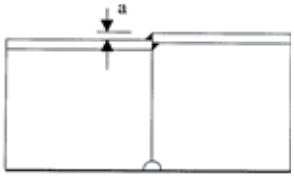
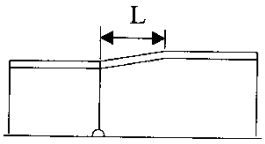
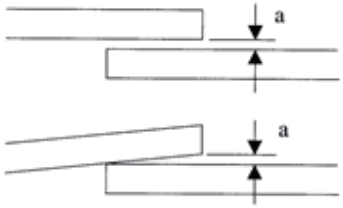
Detail	Standard	Limit	Remarks
Submerged Arc Welding (SAW)  	$0 \leq G \leq 0.8$ mm	$G = 2$ mm	See Note 1

Note 1:
Different plate edge preparation may be accepted or approved by CCS in accordance with UR W28 or other recognized standard accepted by CCS.
For welding procedures other than manual welding, see paragraph 1.3.2 Qualification of welding procedures.

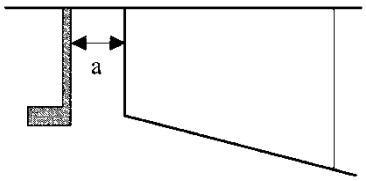
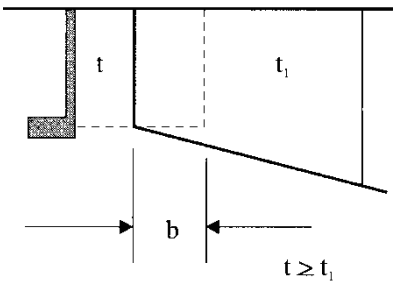
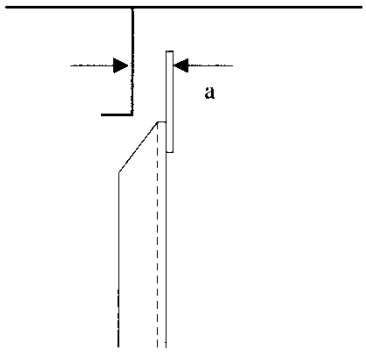
Distance Between Welds **Table 1.8.7**

Detail	Standard	Limit	Remarks
Scallops over weld seams 		for strength member $d \geq 5$ mm for other $d \geq 0$ mm	The "*d*" is to be measured from the toe of the fillet weld to the toe of the butt weld
Distance between two butt welds 		$d \geq 0$ mm	
Distance between butt weld and fillet weld 		for strength member $d \geq 10$ mm for other $d \geq 0$ mm	The "*d*" is to be measured from the toe of the fillet weld to the toe of the butt weld
Distance between butt welds 	for cut-outs $d \geq 30$ mm		
	for margin plates $d \geq 300$ mm	150 mm	

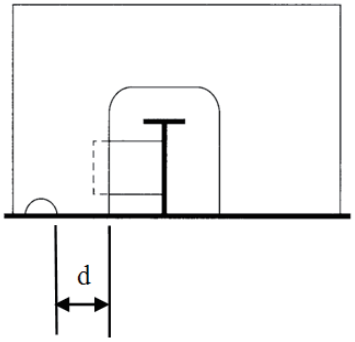
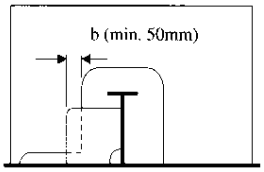
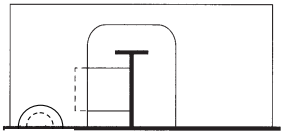
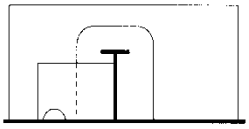
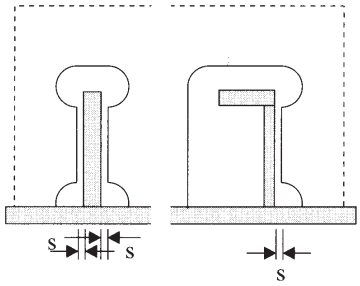
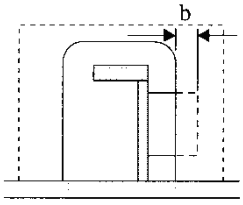
Typical Misalignment Remedial **Table 1.9.1**

Detail	Remedial Standard	Remarks
Alignment of butt joints 	Strength member $a > 0.15t_1$ or $a > 4$ mm release and adjust Other $a > 0.2t_1$ or $a > 4$ mm release and adjust	t_1 is lesser plate thickness
Alignment of fillet welds 	Strength member and higher stress member $t_1/3 < a \leq t_1/2$ - generally increase weld throat by 10% $a > t_1/2$ - release and adjust over a minimum of $50a$ Other $a > t_1/2$ - release and adjust over a minimum of $30a$	Alternatively, heel line can be used to check the alignment Where t_3 is less than t_1 then t_3 should be substituted for t_1 in standard
Alignment of flange of T-longitudinal 	When $0.04b < a \leq 0.08b$, max 8 mm: grind corners to smooth taper over a minimum distance $L = 3a$ When $a > 0.08b$ or 8 mm: release and adjust over a minimum distance $L = 50a$	
Alignment of height of T-bar, L-angle bar or bulb 	When 3 mm $< a \leq 6$ mm: build up by welding When $a > 6$ mm: release and adjust over minimum $L = 50a$ for strength member and $L = 30a$ for other 	
Alignment of lap welds 	3 mm $< a \leq 5$ mm: weld leg length to be increased by the same amount as increase in gap in excess of 3 mm $a > 5$ mm: members to be re-aligned	

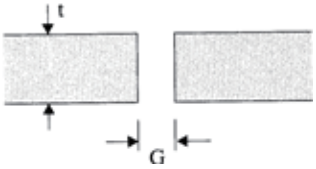
Typical Misalignment Remedial **Table 1.9.2**

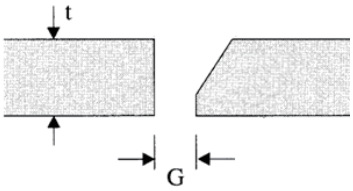
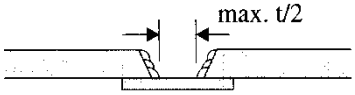
Detail	Remedial Standard	Remarks
Gap between bracket/intercostal and stiffener 	When 3 mm < $a \leq 5$ mm: weld leg length to be increased by increase in gap in excess of 3 mm	
	When 5mm < $a \leq 10$ mm: chamfer 30° to 40° and build up by welding with backing	
	When $a > 10$ mm: increase gap to about 50 mm and fit collar plate  $b = (2t + 25)$ mm, min. 50 mm	
Gap between beam and frame 	3 mm < $a \leq 5$ mm: weld leg length to be increased by the same amount as increase in gap in excess of 3 mm $a > 5$ mm release and adjust	

Misalignment Remedial **TABLE 1.9.3**

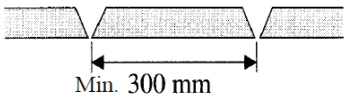
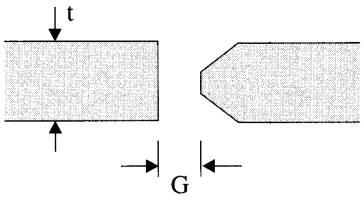
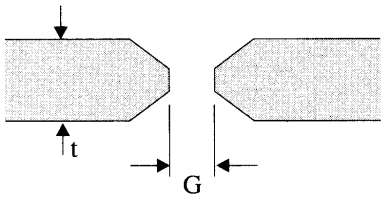
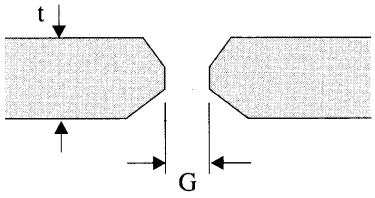
Detail	Remedial standard	Remarks
Position of scallop  	When $d < 75$ mm web plate to be cut between scallop and slot, and collar plate to be fitted  Or fit small collar over scallop  Or fit collar plate over scallop 	
Gap around stiffener cut-out  	When $3 \text{ mm} < s \leq 5$ mm weld leg length to be increased by the same amount as increase in gap in excess of 2 mm	
	When $5 \text{ mm} < s \leq 10$ mm nib to be chamfered and built up by welding	
	When $s > 10$ mm cut off nib and fit collar plate of same height as nib  $20 \text{ mm} \leq b \leq 50$ mm	

Typical Butt Weld Plate Edge Preparation Remedial
(Manual Welding and Semi-Automatic Welding) **TABLE 1.9.4**

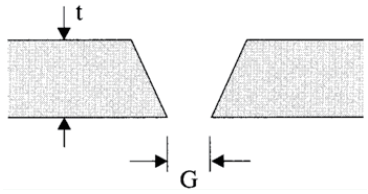
<table>
<tr><th>Detail</th><th>Remedial standard</th><th>Remarks</th></tr>
<tr><td>Square butt (no beveling)

</td><td>When $G \leq 10$ mm
chamfer to 45° and build up by welding

When $G > 10$mm, build up with backing strip; remove, back gouge and seal weld;
or, insert plate, min. width 300 mm</td><td></td></tr>
<tr><td>Single bevel butt

</td><td rowspan="4">When 5 mm $< G \leq 1.5t$ (maximum 25 mm), build up gap with welding on one or both edges to maximum of $0.5t$, using backing strip, if necessary
Where a backing strip is used, the backing strip is to be removed, the weld back gouged, and a sealing weld made


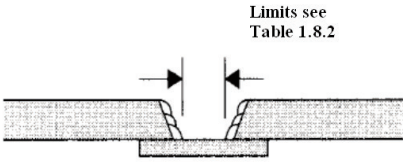
Different welding arrangement by using backing material approved by CCS may be accepted on the basis of an appropriate welding procedure specification

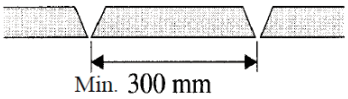
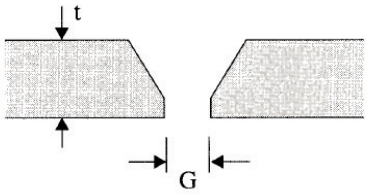
When $G > 25$ mm or $1.5t$, whichever is smaller, use insert plate, of minimum width 300 mm

</td><td rowspan="4"></td></tr>
<tr><td>Double bevel butt

</td></tr>
<tr><td>Double Vee butt, uniform bevels

</td></tr>
<tr><td>Double Vee butt, non-uniform bevel

</td></tr>
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Typical Butt Weld Plate Edge Preparation Remedial
(Manual Welding and Semi-Automatic Welding) **TABLE 1.9.5**

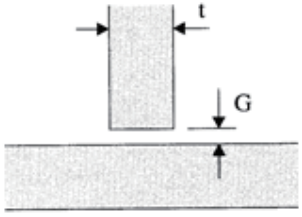
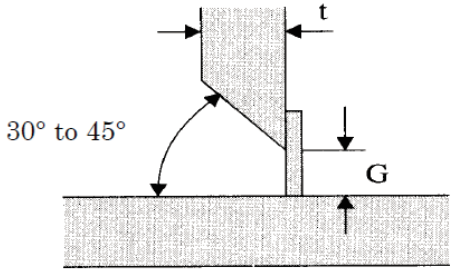
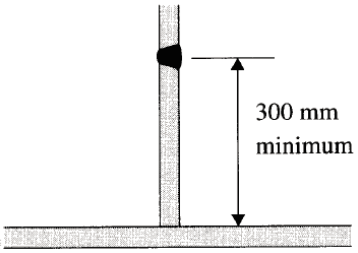
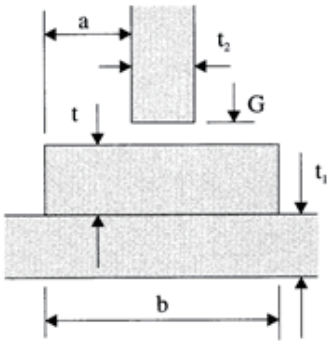
<table>
<tr><th>Detail</th><th>Remedial Standard</th><th>Remarks</th></tr>
<tr><td>Single Vee butt, one side welding

</td><td rowspan="2">When 5 mm < G ≤ 1.5t mm (maximum 25 mm), build up gap with welding on one or both edges, to “Limit” gap size preferably to “Standard” gap size as described in Table 1.8.2

Where a backing strip is used, the backing strip is to be removed, the weld back gouged, and a sealing weld made

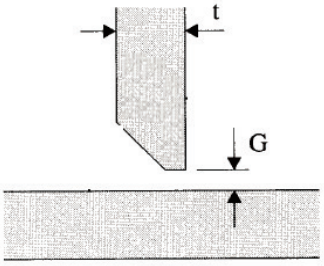
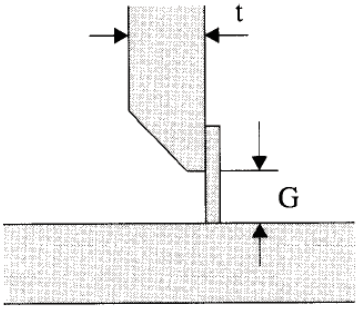
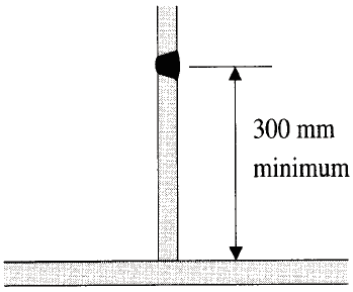
Different welding arrangement by using backing material approved by CCS may be accepted on the basis of an appropriate welding procedure specification


When G > 25 mm or 1.5t, whichever is smaller, use insert plate of minimum width 300 mm

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<tr><td>Single Vee butt

</td></tr>
<tr><td></td><td></td><td></td></tr>
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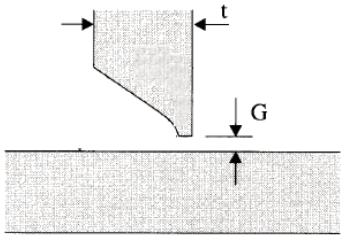
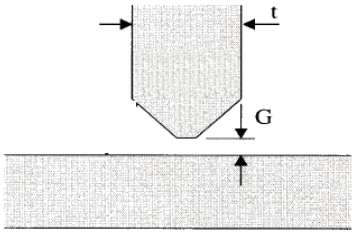
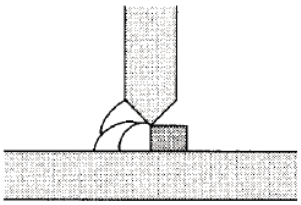
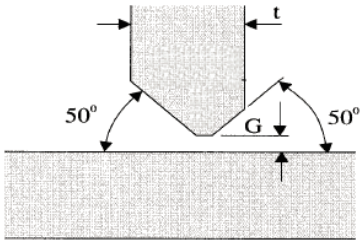
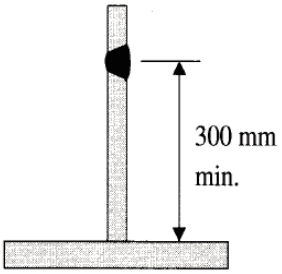
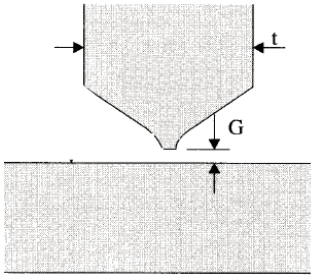
Typical Fillet Weld Plate Edge Preparation Remedial
(Manual Welding and Semi-Automatic Welding) **TABLE 1.9.6**

Detail	Remedial standard	Remarks
Tee Fillet 	3 mm < $G \leq 5$ mm – leg length increased to Rule leg + (G-2)	
	5 mm < $G \leq 16$ mm or $G \leq 1.5t$ - chamfer by 30° to 45°, build up with welding, on one side, with backing strip if necessary, grind and weld. 	
	G > 16 mm or $G > 1.5t$ use insert plate of minimum width 300 mm 	
Liner treatment 	$t_2 \leq t \leq t_1$ $G \leq 2$ mm a = 5 mm + fillet leg length	Not to be used in cargo area or areas of tensile stress through the thickness of the liner

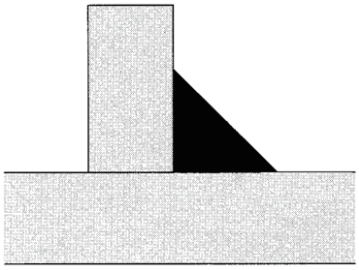
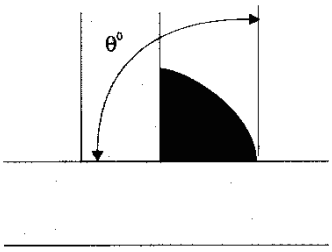
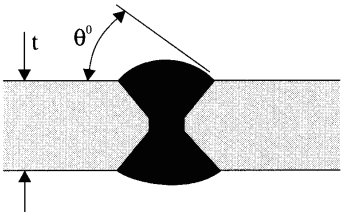
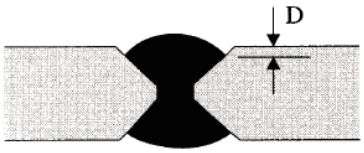
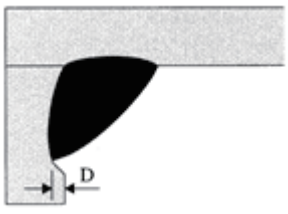
Typical Fillet Weld Plate Edge Preparation Remedial
(Manual Welding and Semi-Automatic Welding) **TABLE 1.9.7**

Detail	Remedial standard	Remarks
Single bevel tee  	3 mm < $G \leq$ 5 mm build up weld	
	5 mm < $G \leq$ 16 mm - build up with welding, with backing strip if necessary, remove backing strip if used, back gouge and back weld  	
	G > 16 mm new plate to be inserted of minimum width 300 mm  	

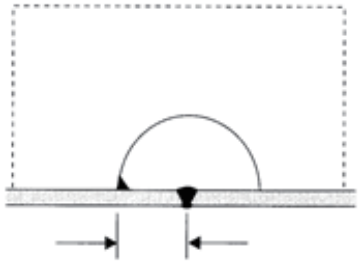
Typical Fillet Weld Plate Edge Preparation Remedial
(Manual Welding and Semi-Automatic Welding) **TABLE 1.9.8**

Detail	Remedial standard	Remarks
Single 'J' bevel tee 	as single bevel tee	
Double bevel tee symmetrical 	When 5 mm < $G \leq$ 16 mm build up with welding using ceramic or other approved backing bar, remove, back gouge and back weld. 	
Double bevel tee asymmetrical 	When G > 16 mm-insert plate of minimum height 300 mm to be fitted. 	
Double 'J' bevel symmetrical 		

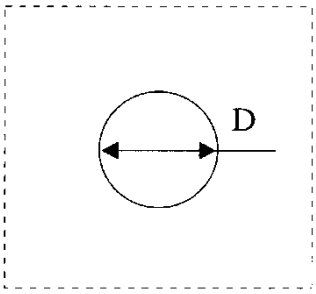
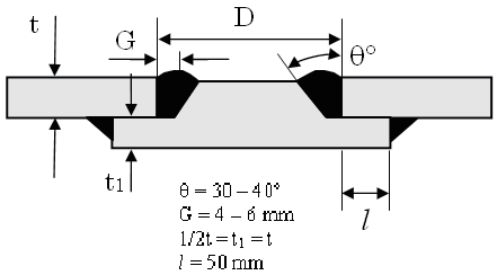
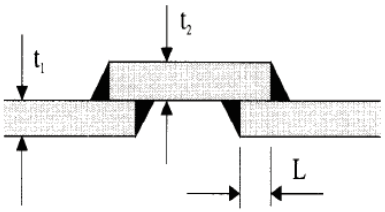
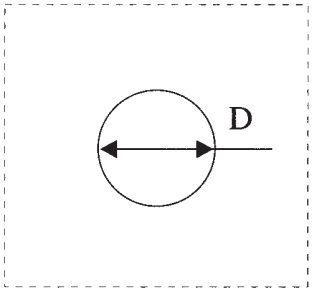
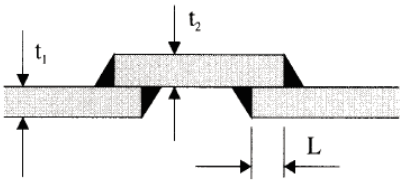
Typical Fillet and Butt Weld Profile Remedial
(Manual Welding and Semi-Automatic Welding) **TABLE 1.9.9**

Detail	Remedial standard	Remarks
Fillet weld leg length 	Increase leg or throat by welding over	Minimum short bead to be referred Table 1.9.14
Fillet weld toe angle 	$\theta > 90°$ grinding, and welding, where necessary, to make $\theta \leq 90°$	
Butt weld toe angle 	$\theta > 90°$ grinding, and welding, where necessary, to make $\theta \leq 90°$	
Butt weld undercut 	For strength member, where $0.5 < D \leq 1$ mm, and for other, where $0.8 < D \leq 1$ mm, undercut to be ground smooth (localized only) or to be filled by welding Where $D > 1$ mm undercut to be filled by welding	
Fillet weld undercut 	Where $0.8 < D \leq 1$ mm undercut to be ground smooth (localized only) or to be filled by welding Where $D > 1$ mm undercut to be filled by welding	

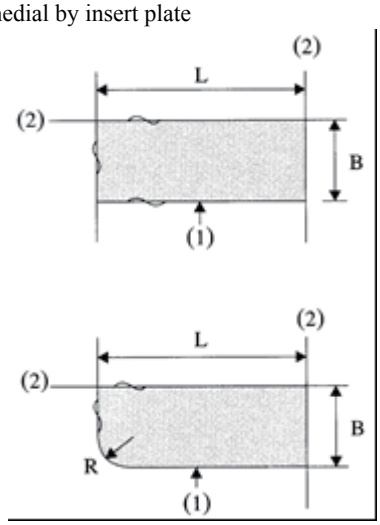
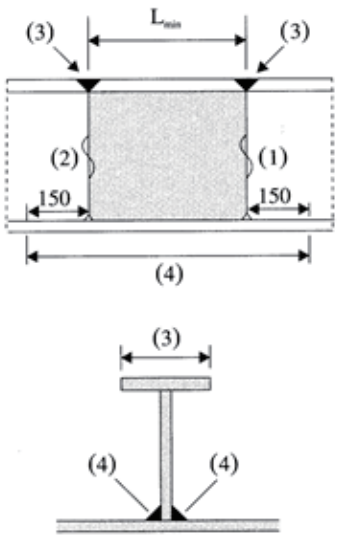
Distance Between Welds Remedial **TABLE 1.9.10**

Detail	Remedial standard	Remarks
Scallops over weld seams 	Hole to be cut and ground smooth to obtain distance	

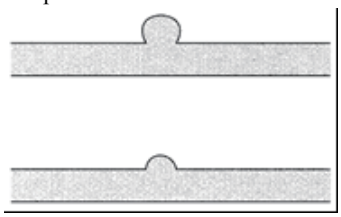
Erroneous Hole Remedial **TABLE 1.9.11**

Detail	Remedial standard	Remarks
Holes made erroneously $D < 200$ mm 	Strength member open hole to minimum 75 mm dia., fit and weld spigot piece  Or open hole to over 300 mm and fit insert plate	Fillet weld to be made after butt weld The fitting of spigot pieces in areas of high stress concentration or fatigue is to be approved by CCS.
	Other open hole to over 300 mm and fit insert plate or fit lap plate  $t_1 = t_2$ $L = 50$ mm, min	
Holes made erroneously $D \geq 200$ mm 	Strength member open hole and fit insert plate	
	Other open hole to over 300 mm and fit insert plate or fit lap plate  $t_1 = t_2$ $L = 50$ mm, min	

Remedial by Insert Plate **TABLE 1.9.12**

Detail	Remedial standard	Remarks
Remedial by insert plate 	L = 300 mm minimum B = 300 mm minimum R = 5t mm 100 mm minimum (1) seam with insert piece is to be welded first (2) original seam is to be released and welded over for a minimum of 100 mm.	
Remedial of built section by insert plate 	$L_{min} \geq$ 300 mm Welding sequence (1)→(2) →(3) →(4) Web butt weld scallop to be filled during final pass (4)	

Weld Surface Remedial **TABLE 1.9.13**

Detail	Remedial standard	Remarks
Weld spatter 	1. Remove spatter observed before blasting with scraper or chipping hammer, etc. 2. For spatter observed after blasting: a) Remove with a chipping hammer, scraper, etc. b) For spatter not easily removed with a chipping hammer, scraper, etc., grind the sharp angle of spatter to make it obtuse	In principle, no grinding is applied to weld surface
Arc strike (HT steel, Cast steel, Grade E of mild steel, TMCP type HT steel, Low temp steel)	Remove the hardened zone by grinding or other measures such as overlapped weld bead etc.	Minimum short bead to be referred Table 1.9.14

Welding Remedial by Short Bead **TABLE 1.9.14**

Detail	Remedial standard	Remarks
Short bead for remedying scar (scratch)	a) HT steel, Cast steel, TMCP type HT steel (C_{eq} > 0.36%) and Low temp steel (C_{eq} > 0.36%) Length of short bead ≥ 50 mm b) Grade E of mild steel Length of short bead ≥ 30 mm c) TMCP type HT steel (C_{eq} ≤ 0.36%) and Low temp steel (C_{eq} ≤ 0.36%) Length of short bead ≥ 10 mm	Preheating is necessary at 100 ± 25°C
Remedying weld bead	a) HT steel, Cast steel, TMCP type HT steel (C_{eq} > 0.36%) and Low temp steel (C_{eq} > 0.36%) Length of short bead ≥ 50 mm b) Grade E of mild steel Length of short bead ≥ 30 mm c) TMCP type HT steel (C_{eq} ≤ 0.36%) and Low temp steel (C_{eq} ≤ 0.36%) Length of short bead ≥ 30 mm	

Notes:
1. When short bead is made erroneously, remove the bead by grinding.
2. $C_{eq} = \mathrm{C} + \frac{\mathrm{Mn}}{6} + \frac{\mathrm{Cr+Mo+V}}{5} + \frac{\mathrm{Ni+Cu}}{15} (\%)$

References:

1. IACS “Bulk Carriers - Guidelines for Surveys, Assessment and Repair of Hull Structure”
2. TSCF “Guidelines for the inspection and maintenance of double hull tanker structures”
3. TSCF “Guidance manual for the inspection and condition assessment of tanker structures”
4. IACS UR W7 “Hull and machinery steel forgings”
5. IACS UR W8 “Hull and machinery steel castings”
6. IACS UR W11 “Normal and higher strength hull structural steel”
7. IACS UR W13 “Thickness tolerances of steel plates and wide flats”
8. IACS UR W14 “Steel plates and wide flats with specified minimum through thickness properties (“Z” quality)”
9. IACS UR W17 “Approval of consumables for welding normal and higher strength hull structural steels”
10. IACS UR W28 “Welding procedure qualification tests of steels for hull construction and marine structures”
11. IACS UR Z10.1 “Hull surveys of oil tankers” and Z10.2 “Hull surveys of bulk carriers” Annex I
12. IACS UR Z23 “Hull survey for new construction”
13. IACS Recommendation No.12 “Guidelines for surface finish of hot rolled plates and wide flats”
14. IACS Recommendation No.20 “Non-destructive testing of ship hull steel welds”

2 Repair Quality Standard for Existing Ships

2.1 Scope

2.1.1 This standard provides guidance on quality of repair of hull structures. The standard covers permanent repairs of existing ships.

2.1.1.1 Whereas the standard generally applies to:

(1) conventional ship types;

(2) parts of hull covered by the rules of CCS;

(3) hull structures constructed from normal and higher strength hull structural steel, the applicability of the standard is in each case to be agreed upon by CCS.

2.1.1.2 The standard does generally not apply to repair of

(1) special types of ships as e.g. gas tankers;

(2) structures fabricated from stainless steel or other, special types or grades of steel.

2.1.2 The standard covers typical repair methods and gives guidance on quality standard on the most important aspects of such repairs. Unless explicitly stated elsewhere in the standard, the level of workmanship reflected herein will in principle be acceptable for primary and secondary structure of conventional design. A more stringent standard may however be required for critical and highly stressed areas of the hull, and is to be agreed with CCS in each case. In assessing the criticality of hull structure and structural components, reference is made to References 1, 2 and 3 to this Section.

2.1.3 Restoration of structure to the original standard may not constitute durable repairs of damages originating from insufficient strength or inadequate detail design. In such cases strengthening or improvements beyond the original design may be required. Such improvements are not covered by this standard, however it is referred to References 1, 2 and 3 to this Section.

2.2 General requirements for repairs and repairers

2.2.1 In general, when hull structure covered by classification is to be subjected to repairs, the work is to be carried out under the supervision of the Surveyor to CCS. Such repairs are to be agreed prior to commencement of the work.

2.2.2 Repairs are to be carried out by workshops, repair yards or personnel who have demonstrated their capability to carry out hull repairs of adequate quality in accordance with CCS requirements and this standard.

2.2.3 Repairs are to be carried out under working conditions that facilitate sound repairs. Provisions are to be made for proper accessibility, staging, lighting and ventilation. Welding operations are to be carried out under shelter from rain, snow and wind.

2.2.4 Welding of hull structures is to be carried out by qualified welders, according to approved and qualified welding procedures and with welding consumables approved by CCS, see Section 2.3. Welding operations are to be carried out under proper supervision of the repair yard.

2.2.5 Where repairs to hull which affect or may affect classification are intended to be carried out during a voyage, complete repair procedure including the extent and sequence of repair is to be submitted to and agreed upon by the Surveyor to CCS reasonably in advance of the repairs. See Reference 8 to this Section.

2.3 Qualification of personnel

2.3.1 Qualification of welders

2.3.1.1 Welders are to be qualified in accordance with the procedures of CCS or to a recognised national or international standard, e.g. EN 287, ISO 9606, ASME Section IX, ANSI/AWS D1.1. Recognition of other standards is subject to submission to CCS for evaluation. Repair yards and workshops are to keep records of welders qualification and, when required, furnish valid approval test certificates.

2.3.1.2 Welding operators using fully mechanised of fully automatic processes need generally not pass approval testing, provided that production welds made by the operators are of the required quality. However, operators are to receive adequate training in setting or programming and operating the equipment. Records of training and production test results shall be maintained on individual operator's files and records, and be made available to CCS for inspection when requested.

2.3.2 Qualification of welding procedures

2.3.2.1 Welding procedures are to be qualified in accordance with the procedures of CCS or a recognised national or international standard, e.g. EN288, ISO 9956, ASME Section IX, ANSI/AWS D1.1. Recognition of other standards is subject to submission to CCS for evaluation. The welding procedure should be supported by a welding procedure qualification record. The specification is to include the welding process, types of electrodes, weld shape, edge preparation, welding techniques and positions.

2.3.3 Qualification of NDE operators

2.3.3.1 Personnel performing non-destructive examination for the purpose of assessing quality of welds in connection with repairs covered by this standard, are to be qualified in accordance with CCS rules or to a recognised international or national qualification scheme. Records of operators and their current certificates are to be kept and made available to the Surveyor for inspection.

2.4 Materials

2.4.1 General requirements for materials

2.4.1.1 The requirements for materials used in repairs are in general the same as the requirements for materials specified in CCS rules for new constructions, (see Reference 5 to this Section).

2.4.1.2 Replacement material is in general to be of the same grade as the original approved material. Alternatively, material grades complying with recognised national or international standards may be accepted by CCS provided such standards give equivalence to the requirements of the original grade or are agreed by CCS. For assessment of equivalency between steel grades, the general requirements and guidelines in Section 2.4.2 apply.

2.4.1.3 Higher tensile steel is not to be replaced by steel of a lesser strength unless specially approved by CCS.

2.4.1.4 Normal and higher strength hull structural steels are to be manufactured at works approved by CCS for the type and grade being supplied.

2.4.1.5 Materials used in repairs are to be certified by CCS applying the procedures and requirements in the rules for new constructions. In special cases, and normally limited to small quantities, materials may be accepted on the basis of alternative procedures for verification of the material's properties. Such procedures are subject to agreement by CCS in each separate case.

2.4.2 Equivalency of material grades

2.4.2.1 Assessment of equivalency between material grades should at least include the following aspects:

(1) heat treatment/delivery condition;

(2) chemical composition;

(3) mechanical properties;

(4) tolerances.

2.4.2.2 When assessing the equivalence between grades of normal or higher strength hull structural steels up to and including grade E40 in thickness limited to 50 mm, the general requirements in Table 2.4.1 apply.

2.4.2.3 Guidance on selection of steel grades to certain recognised standards equivalent to hull structural steel grades specified in CCS rules is given in Table 2.4.2.

Minimum extent and requirements to assessment of equivalency between normal or higher strength hull structural steel grades Table 2.4.1

Items to be considered	Requirements	Comments
Chemical composition	- C; equal or lower - P and S; equal or lower - Mn; approximately the same but not exceeding 1.6% - Fine grain elements; in same amount Detoxidation practice	The sum of the elements, e.g. Cu, Ni, Cr and Mo should not exceed 0.8%
Mechanical properties	- Tensile strength; equal or higher Yield strength; equal or higher - Elongation; equal or higher - Impact energy; equal or higher at same or lower temperature, where applicable	Actual yield strength should not exceed CCS Rule minimum requirements by more than 80 N/mm^2
Condition of supply	- Same or better	Heat treatment in increasing order: - as rolled (AR) - controlled rolled (CR) - normalised (N) - thermo-mechanically rolled (TM)[1)] - quenched and tempered (QT)[1)] [1)] TM- and QT-steels are not suitable for hot forming
Tolerances	- Same or stricter	Permissible under thickness tolerances: - plates: 0.3 mm - sections: according to recognised standards

Guidance on steel grades comparable to the normal and high strength hull structural steel grades given in CCS rules **Table 2.4.2**

Steel grades according to CCS rules (Reference 5 to this Section)							Comparable steel grades			
Grade	Yield stress R_{eH} min. N/mm^2	Tensile strength R_m N/mm^2	elongation A_5 min. %	Average impact energy			ISO 630-80 4950/2/3/ 1981	EN EN 10025-93 EN 10113-93	ASTM A 131	JIS G 3106
				Temp. ℃	J, min.					
					L	T				
A B D E	235	400-502	22	+20 0 -20 -40	- 27 27 27	- 20 20 20	Fe 360B Fe 360C Fe 360D -	S235JRG2 S235J0 S235J2G3 S275NL/ML	A B D E	SM41B SM41B (SM41C) -
A 27 D 27 E 27	265	400-530	22	0 -20 -40	27	20	Fe 430C Fe 430D -	S275J0G3 S275N/M S275NL/ML	- - -	- - -
A 32 D 32 E 32	315	440-590	22	0 -20 -40	31	22	- - -	- - -	AH32 DH32 EH32	SM50B (SM50C) -
A 36 D 36 E 36	355	490-620	21	0 -20 -40	34	24	Fe 510C Fe 510D E355E	S355N/M S355N/M S355NL/ML	AH36 DH36 EH36	SM53B (SM53C) -
A 40 D 40 E 40	390	510-650	20	0 -20 -40	41	27	E390CC E390DD E390E	S420N/M S420N/M S420NL/ML	AH40 DH40 EH40	(SM58) - -

Note: In selecting comparable steels from this table, attention should be given to the requirements of Table 2.4.1 and the dimension requirements of the product with respect to CCS rules.

2.5 General requirements to welding

2.5.1 Correlation of welding consumables with hull structural steels

2.5.1.1 For the different hull structural steel grades welding consumables are to be selected in accordance with IACS UR W17 (see Reference 6 to this Section).

2.5.2 General requirements to preheating and drying out

2.5.2.1 The need for preheating is to be determined based on the chemical composition of the materials, welding process and procedure and degree of joint restraint.

2.5.2.2 A minimum preheat of 50℃ is to be applied when ambient temperature is below 0℃. Dryness of the welding zone is in all cases to be ensured.

2.5.2.3 Guidance on recommended minimum preheating temperature for higher strength steel is given in Table 2.5.1. For automatic welding processes utilising higher heat input e.g. submerged arc welding, the temperatures may be reduced by 50℃. For re-welding or repair of welds, the stipulated values are to be increased by 25℃.

Preheating temperature **Table 2.5.1**

Carbon equivalent [1]	**Recommended minimum preheat temperature (℃)**		
	$t_{comb} \leq 50$ mm [2]	50 mm < $t_{comb} \leq 70$ mm [2]	$t_{comb} > 70$ mm [2]
$C_{eq} \leq 0.39$	- -	50	
$C_{eq} \leq 0.41$	- -	75	
$C_{eq} \leq 0.43$	-	50	100
$C_{eq} \leq 0.45$	50	100	125
$C_{eq} \leq 0.47$	100	125	150
$C_{eq} \leq 0.50$	125	150	175

2.5.3 Dry welding on hull plating below the waterline of vessels afloat

2.5.3.1 Welding on hull plating below the waterline of vessels afloat is acceptable only on normal and higher strength steels with specified yield strength not exceeding 355 MPa and only for local repairs. Welding involving other high strength steels or more extensive repairs against water backing is subject to special consideration and approval by CCS of the welding procedure.

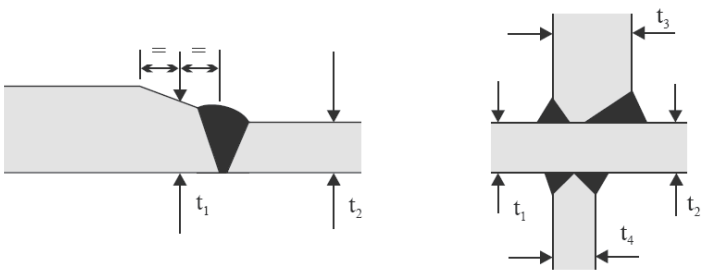
2.5.3.2 Low-hydrogen electrodes or welding processes are to be used when welding on hull plating against water backing. Coated low-hydrogen electrodes used for manual metal arc welding should be properly conditioned to ensure a minimum of moisture content.

2.5.3.3 In order to ensure dryness and to reduce the cooling rate, the structure is to be preheated by a torch or similar prior to welding, to a temperature of minimum 5℃ or as specified in the welding procedure.

Notes:

1) $C_{eq} = \mathrm{C} + \frac{\mathrm{Mn}}{6} + \frac{\mathrm{Cr+Mo+V}}{5} + \frac{\mathrm{Ni+Cu}}{15} (\%)$

2) Combined thickness $t_{comb} = t_1 + t_2 + t_3 + t_4$, see figure



2.6 Repair quality standard

2.6.1 Welding, general

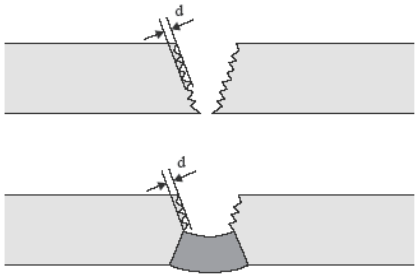


Figure 2.6.1 Groove roughness

Item	Standard	Limit	Remarks
Material Grade	Same as original or higher		See Section 2.4
Welding Consumables	IACS UR W17 (Reference 6 to this Section)	Approval according to equivalent international standard	
Groove / Roughness	See note and Figure 2.6.1	$d < 1.5$ mm	Grind smooth
Pre-Heating	See Table 2.5.1	Steel temperature not lower than 5℃	
Welding with water on the outside	See Section 2.5.3	Acceptable for normal and high strength steels	- Moisture to be removed by a heating torch
Alignment	As for new construction		
Weld Finish	IACS Recommendation 20 (Reference 10 to this Section)		
NDE	IACS Recommendation 20 Reference 10 to this Section)	At random with extent to be agreed with attending surveyors	

Note: Slag, grease, loose mill scale, rust and paint, other than primer, to be removed.

2.6.2 Renewal of plates

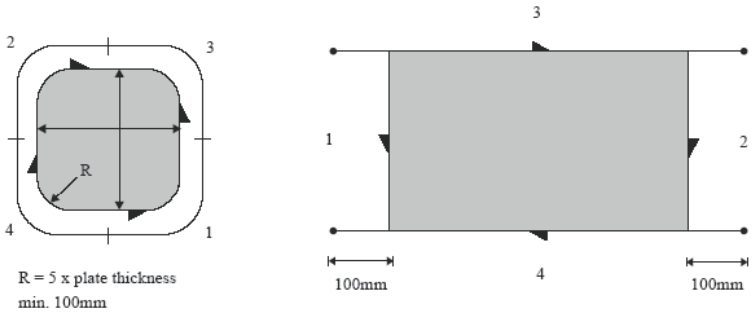


Figure 2.6.2 Welding sequence for inserts

Item	Standard	Limit	Remarks
Size Insert	Min. 300 × 300 mm R = 5 × thickness Circular inserts: D_{min} = 200 mm	Min. 200 × 200 mm Min. R = 100 mm	
Marterial Grade	Same as original or higher		See Section 2.4
Edge Preparation	As for new construction		In case of non-compliance increase the amount of NDE
Welding Sequence	See Figure 2.6.2 Weld sequence is 1 → 2 → 3 → 4		For primary members sequence 1 and 2 transverse to the main stress direction
Alignment	As for new construction		
Weld Finish	IACS Recommendation 20 (Reference 10 to this Section)		
NDE	IACS Recommendation 20 (Reference 10 to this Section)		

2.6.3 Doublers on plating

Local doublers are normally only allowed as temporary repairs, except as original compensation for openings, within the main hull structure.

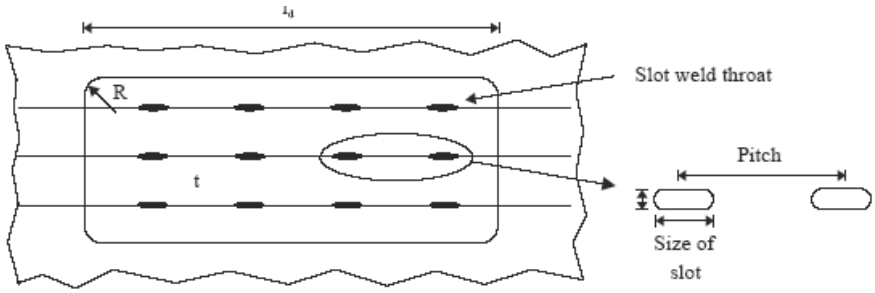


Figure 2.6.3 Doublers on plates

Item	Standard	Limit	Remarks
Existing Plating		General: $t \geq 5$ mm	For areas where existing plating is less than 5 mm plating a permanent repair by insert is to be carried out
Extent / Size	Rounded off corners.	min 300 × 300 mm $R \geq 50$ mm	
Thickness of Doubler (t_d)	$t_d \leq t_p$(t_p = original thickness of existing plating)	$t_d > t_p/3$	
Material Grade	Same as original plate		See Section 2.4
Edge Preparation	As for [newbuilding] new construction		Doublers welded on primary strength members: (L_e: leg length) when $t > L_e + 5$ mm, the edge to be tapered (1:4)
Welding	As for [newbuilding] new construction		Welding sequence similar to insert plates
Weld Size (throat thicknesss))	Circumferential and in slots: 0.6 × t_d		
Slot Welding	Normal size of slot: (80-100) × 2 t_d Distance from doubler edge and between slots:$d \leq 15\ t_d$	Max pitch between slots 200 mm d_{max} = 500 mm	For doubler extended over several supporting elements, see Figure 2.6.3
NDE	IACS Recommendation 20 (Reference 10 to this Section)		

2.6.4 Renewal of internals/stiffeners

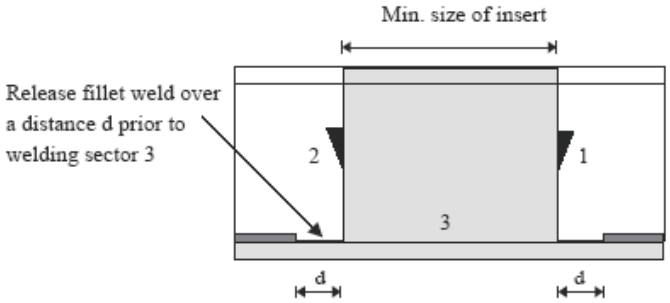


Figure 2.6.4 Welding sequence for inserts of stiffeners

Item	Standard	Limit	Remarks
Size Insert	Min. 300 mm	Min. 200 mm	
Marterial Grade	Same as original or higher		See Section 2.4
Edge Preparation	As for new construction. Fillet weld stiffener web / plate to be released over min. d = 150 mm		
Welding Sequence	See Figure 2.6.4 Welding sequence is 1→2→3		
Alignment	As for new construction		
Weld Finish	IACS Recommendation 20 (Reference 10 to this Section)		
NDE	IACS Recommendation 20 (Reference 10 to this Section)		

2.6.5 Renewal of internals/stiffeners – transitions inverted angle/bulb profile

The application of the transition is allowed for secondary structural elements.

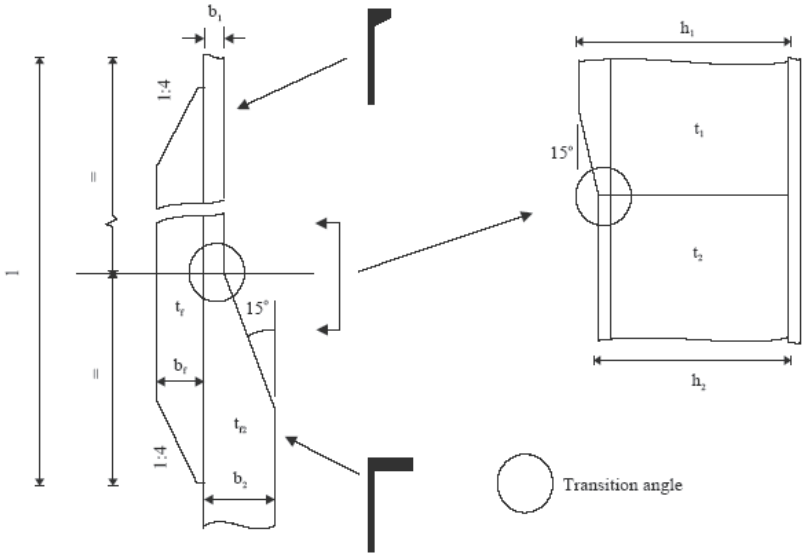


Figure 2.6.5 Transition between inverted angle and bulb profile

Item	Standard	Limit	Remarks
$(h_1 - h_2)$	$\leq 0.25 \times b_1$		
$\lvert t_1 - t_2 \rvert$	2 mm		Without tapering transition
Transition Angle	15 degrees		At any arbitrary section
Flanges	$t_f = t_{f2}$ $b_f = b_{f2}$		
Length of Flatbar	$4 \times h_1$		
Material			See Section 2.4

2.6.6 Application of Doubling Straps

2.6.6.1 In certain instances, doubling straps are used as a means to strengthen and reinforce primary structure. Where this has been agreed and approved, particular attention should be paid to:

(1) the end termination points of the straps, so that toe support is such that no isolated hard point occurs;

(2) in the case of application of symmetrical or asymmetrical-ended straps, the corners at the end of the tapering should be properly rounded;

(3) any butts between lengths of doubling straps, so that there is adequate separation of the butt weld from the primary structure below during welding, and so that a high quality root run under controlled circumstances is completed prior to completing the remainder of the weld. Ultrasonic testing should be carried out on completion to verify full penetration.

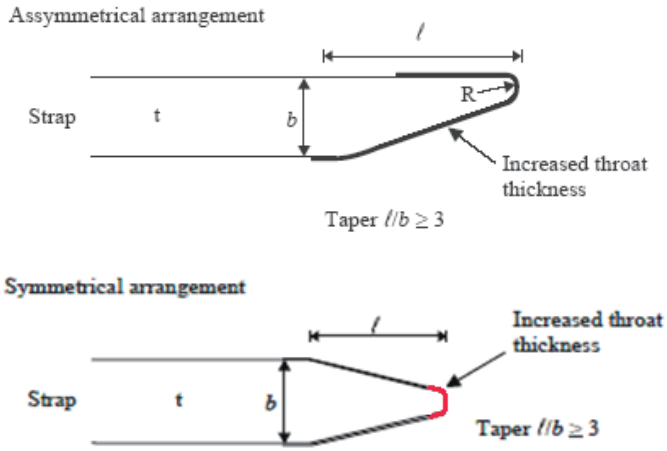


Figure 2.6.6 Application of Doubling Straps

Item	Standard	Limit	Remarks
Tapering	$l/b > 3$		Special consideration to be drawn to design of strap terminations in fatigue sensitive areas
Radius	$0.1 \times b$	min 30 mm	
Material			See paragraph 2.4 General requirement to materials
Weld Size			Depending on number and function of straps. Throat thickness to be increased 15 % toward ends
Welding	Welding sequence from middle towards the free ends		See sketch. For welding of lengths > 1000 mm step welding to be applied

2.6.7 Welding of pitting corrosion

Note:
Shallow pits may be filled by applying coating or pit filler. Pits can be defined as shallow when their depth is less that 1/3 of the original plate thickness.

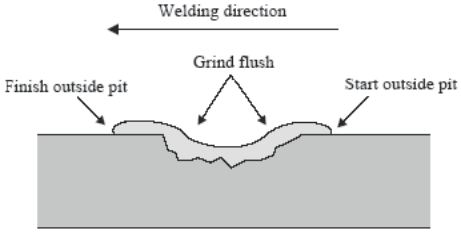


Figure 2.6.7 Welding of pits

Item	Standard	Limit	Remarks
Extent / Depth	Pits / grooves are to be welded flush with the original surface	If deep pits or grooves are clustered together or remaining thickness is less than 6 mm, the plates should be renewed.	See also IACS Recommendation 12 (Reference 9 to this Section)
Cleaning	Heavy rust to be removed		
Pre-Heating	See Table 2.5.1	Required when ambient temperature < 5℃	Always use propane torch or similar to remove any moisture
Welding Sequence	Reverse direction for each layer		See also IACS Recommendation 12 (Reference 9 to this Section)
Weld Finish	IACS Recommendation 20 (Reference 10 to this Section)		
NDE	IACS Recommendation 20 (Reference 10 to this Section)	Min. 10% extent	Preferably MPI

Reference is made to TSCF Guidelines, Ref. 2 & 3.

2.6.8 Welding repairs for cracks

In the event that a crack is considered weldable, either as a temporary or permanent repair, the following techniques should be adopted as far as practicable. Run-on and run-off plates should be adopted at all free edges.

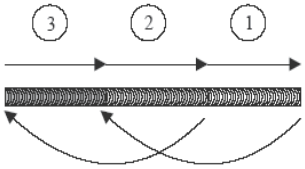


Figure 2.6.8.a Step back technique

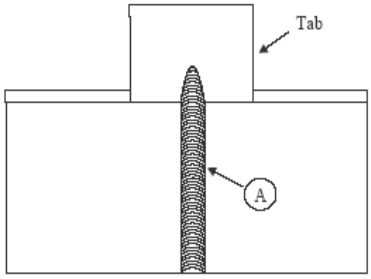


Figure 2.6.8.b End crack termination

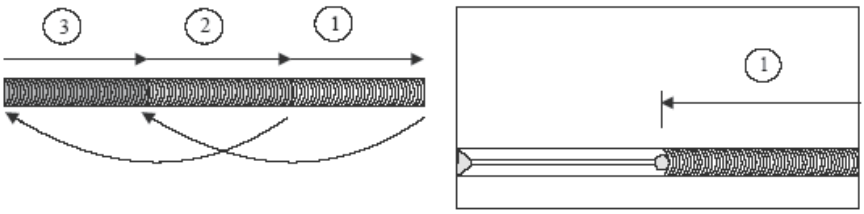


Figure 2.6.8.c Welding sequence for cracks with length less than 300 mm

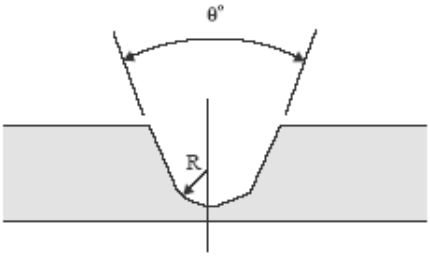


Figure 2.6.8.d Groove preparation (U-groove left and V-groove right)

Item	Standard	Limit	Remarks
Groove Preparation	θ = 45-60º r = 5 mm		For through plate cracks as for newbuilding. Also see Figure 2.6.8.d
Termination	Termination to have slope 1:3		For cracks ending on edges weld to be terminated on a tab see Figure 2.6.8.b
Extent	On plate max. 400 mm length. Vee out 50 mm past end of crack	On plate max 500 mm. Linear crack, not branched	
Welding Sequence	See Figure 2.6.8.c for sequence and direction	For cracks longer than 300 mm step-back technique should be used Figure 2.6.8.a	Always use low hydrogen welding consumables
Weld Finish	IACS Recommendation 20 (Reference 10 to this Section)		
NDE	IACS Recommendation 20 Reference 10 to this Section)	100 % MP or PE of groove	100% surface crack detection + UE or RE for butt joints

References:

1. IACS “Bulk Carriers - Guidelines for Surveys, Assessment and Repair of Hull Structure”
2. TSCF “Guidelines for the inspection and maintenance of double hull tanker structures”
3. TSCF “Guidance manual for the inspection and condition assessment of tanker structures”
4. IACS UR W 11 “Normal and higher strength hull structural steels”
5. IACS UR W 13 “Thickness tolerances of steel plates and wide flats”
6. IACS UR W 17 “Approval of consumables for welding normal and higher strength hull structural steels”
7. IACS Z 10.1 “Hull surveys of oil tankers” and Z 10.2 “Hull surveys of bulk carriers” Table IV
8. IACS UR Z 13 “Voyage repairs and maintenance”
9. IACS Recommendation 12 “Guidelines for surface finish of hot rolled steel plates and wide flats”
10. IACS Recommendation 20 “Non-destructive testing of ship hull steel welds””

CHAPTER 5 SURVEYS AFTER CONSTRUCTION

Section 1 GENERAL PROVISIONS

The existing paragraph 5.1.5.1(5) is deleted, and the existing paragraphs 5.1.5.1(6) to 5.1.5.1(22) are renumbered as 5.1.5.1(5) to 5.1.5.1(21) accordingly.

Item ① of the existing subparagraph 5.1.6.1(1) is replaced by the following:

"① in order to enable the attending Surveyors to carry out the survey, provisions for proper and safe access are to be agreed between the owner and CCS in accordance with the relevant requirements of IACS PR37;".

In the existing subparagraph 5.1.6.1(1), items ③ to ⑤ are replaced by the following:

"③ in cases where the provisions of safety and required access are judged by the attending Surveyors not to be adequate, the survey of the spaces involved is not to proceed."

Item ③ of the existing subparagraph 5.1.6.2(2) is replaced by the following:

"③ hydraulic arm vehicles such as conventional cherry pickers, lifts and movable platforms;"

A new paragraph 5.1.6.7 is added as follows:

"5.1.6.7 Rescue and emergency response equipment

(1) If breathing apparatus and/or other equipment is used as 'rescue and emergency response equipment', then it is recommended that the equipment should be suitable for the configuration of the space being surveyed."

The following amendments to this Section will be implemented from 1 July 2016:

A new paragraph 5.1.7.1(3) is added as follows:

"(3) For tankers and bulk carriers subject to SOLAS Reg. II-1/3-10, the Owner is to arrange the updating of the Ship Construction File (SCF) throughout the ship's life whenever a modification of the documentation included in the SCF has taken place. Documented procedures for updating the SCF are to be included within the Safety Management System."

A new paragraph 5.1.7.3(2) is added as follows:

"(2) For tankers and bulk carriers subject to SOLAS Reg. II-1/3-10, the Ship Construction File (SCF), limited to the items to be retained onboard, is to be available on board."

New paragraphs 5.1.7.4(2), (3) are added as follows:

"(2) For tankers and bulk carriers subject to SOLAS Reg. II-1/3-10, on completion of the survey, the surveyor is to verify that the update of the Ship Construction File (SCF) has been done whenever a modification of the documentation included in the SCF has taken place.

(3) For tankers and bulk carriers subject to SOLAS Reg. II-1/ 3-10, on completion of the survey, the surveyor is to verify any addition and/or renewal of materials used for the construction of the hull structure are documented within the Ship Construction File list of materials."

In 5.1.10.4, "IACS REC47, Shipbuilding and Repair Quality Standard" is amended as "Appendix 2 to Chapter 4 of this PART, Shipbuilding and Repair Quality Standard".

Section 2 TYPES AND PERIODS OF SURVEYS

The following sentence is added at the end of the existing paragraph 5.2.4.4:

"In cases where the vessel has been laid up or has been out of service for a considerable period because of a major repair or modification and the owner elects to only carry out the overdue surveys, the next period of class will start from the expiry date of the special survey. If the owner elects to carry out the next due special survey, the period of class will start from the survey completion date."

In the existing subparagraph 5.2.7.2(4), the word "delegated" is replaced by "authorized".

Section 3 RETROSPECTIVE REQUIREMENTS FOR EXISTING SHIPS

The existing paragraph 5.3.2.3 is replaced by the following:

"5.3.2.3 Stability of ro-ro passenger ships in damaged condition

(1) Application:

① ro-ro passenger ships constructed on or after 1 January 2009 are to comply with Section 10, Chapter 1 of PART TWO of the Rules;

② ro-ro passenger ships constructed on or after 1 July 1997 and before 1 January 2009 are to comply with the November 1995 amendments, which were adopted by resolution 1 of the Conference of Contracting Governments to SOLAS, 1974 and amendments adopted by resolution MSC.47(66);

③ ro-ro passenger ships constructed before 1 July 1997 are to comply with the Rules not later than the date of the first periodical survey after the date of compliance prescribed in Table 5.3.2.3(1), according to the value of A/A_{max}.

Table 5.3.2.3(1)

Value of A/A_{max}	Compliance not later than
Less than 85%	1 October 1998
85% or more but less than 90%	1 October 2000
90% or more but less than 95%	1 October 2002
95% or more but less than 97.5%	1 October 2004
97.5% or more	1 October 2005

"

The existing paragraph 5.3.2.4 is replaced by the following:

"5.3.2.4 Special requirements for ro-ro passenger ships certified to carry 400 persons or more

(1) Application: Notwithstanding the requirements of 5.3.2.3:

① ro-ro passenger ships constructed on or after 1 January 2009 are to comply with Section 10, Chapter 1 of PART TWO of the Rules;

② ro-ro passenger ships certified to carry 400 persons or more constructed on or after 1 July 1997 and before 1 January 2009 are to comply with the November 1995 amendments, which were adopted by resolution 1 of the Conference of Contracting Governments to SOLAS, 1974 and amendments adopted by resolution MSC.47(66);

③ ro-ro passenger ships certified to carry 400 persons or more constructed before 1 July 1997 are to comply with the requirements of ② of this paragraph not later than the date of the first periodical survey after the date of compliance prescribed in Tables 5.3.2.4(1)① and 5.3.2.4(1)② or age of the ship[①] equal to or greater than 20 years, whichever is the latest.

Table 5.3.2.4(1)①

Value of A/A_{max}	Compliance not later than
Less than 85%	1 October 1998
85% or more but less than 90%	1 October 2000
90% or more but less than 95%	1 October 2002
95% or more but less than 97.5%	1 October 2004
97.5% or more	1 October 2010

Table 5.3.2.4(1)②

Number of persons permitted to be carried	Compliance not later than
1,500 or more	1 October 2002
1,000 or more but less than 1,500	1 October 2006
600 or more but less than 1,000	1 October 2008
400 or more but less than 600	1 October 2010

”

The existing paragraph 5.3.2.8 is replaced by the following:

“5.3.2.8 Integrity of the hull and superstructure, damage prevention and control

(1) Application: All ro-ro passenger ships constructed before 1 January 2009 are to comply with regulation 23-2 of the November 1995 amendments, which were adopted by resolution 1 of the Conference of Contracting Governments to SOLAS, 1974, but ro-ro passenger ships constructed before 1 July 1997 are to comply with paragraph 2 of regulation 23-2 of the above-mentioned amendments not later than the date of the first periodical survey after 1 July 1997.”

Section 4 HULL AND EQUIPMENT SURVEYS

In the existing Table 5.4.4.2(2), the words “Fore and aft peaks” are replaced by “Fore and aft peaks (all uses)”.

Section 5 ADDITIONAL REQUIREMENTS FOR HULL AND EQUIPMENT SURVEYS OF GENERAL DRY CARGO SHIPS

① The age of the ship means the time counted from the date on which the keel was laid or the date on which it was at a similar stage of construction or from the date on which the ship was converted to a ro-ro passenger ship.

The existing subparagraph 5.5.1.1(1)③ is deleted, and the existing subparagraphs 5.5.1.1(1)④ to ⑩ are renumbered as 5.5.1.1(1)③ to ⑨ accordingly.

In the existing Table 5.5.4.5(1), the words "Table 5.5.4.4(1)" are replaced by "Table 5.5.4.4(2)".

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

In the 3rd line of the 1st column of the existing Table 5.6.4.3(2)②, the words "One deck transverse, in a cargo oil tank (2)" are replaced by "One deck transverse (2), in a cargo oil tank".

In the 3rd line of the 2nd column of the existing Table 5.6.4.3(2)②, the words "One deck transverse, in two cargo oil tanks (2)" are replaced by "One deck transverse (2), in two cargo oil tanks".

Note (2) of the existing Table 5.6.4.4(1) is replaced by "(2) At least one section is to include a ballast tank within 0.5L amidships."

The existing subparagraph 5.6.4.5(1) is replaced by the following:

"(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 has been submitted by the Owner and reviewed by CCS prior to the testing being carried out;

② 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;

④ the satisfactory results of the testing is recorded in the ship's logbook;

⑤ 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."

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

In the existing subparagraph 5.7.1.1(6), the words "cargo holds of double side skin" are replaced by "cargo holds of double side skin and associated wing spaces".

In the existing subparagraph 5.7.1.1(7), "1.6.1.3" is replaced by "1.6.1.4".

In the existing paragraph 5.7.2.7, the words "1.78 t/m^3 and above" are replaced by "1780 kg/m^3 and above".

In the 2nd column of the existing Table 5.7.4.4(1)②, the words "(B) Forward and aft transverse bulkhead in one side ballast tank, including stiffening system" are replaced by "(B) Forward and aft transverse bulkhead in one ballast tank, including stiffening system".

The existing Table 5.7.4.5(1)② is replaced by the following:

"Minimum Requirements for Thickness Measurements at Special Hull Survey of Double Skin Bulk Carriers Table 5.7.4.5(1)②

Special Survey No.1 Age ≤ 5	Special Survey No.2 5 < Age ≤ 10	Special Survey No.3 10 < Age ≤ 15	Special Survey No.4 and Subsequent Age > 15
Suspect areas	Suspect areas	Suspect areas	Suspect areas
	Within the cargo length: ▪Two transverse sections of deck plating outside line of cargo hatch openings	Within the cargo length: ▪Each deck plate outside line of cargo hatch openings. ▪Two transverse sections, one in the amidship area, outside line of cargo hatch openings. ▪All wind and water strakes	Within the cargo length: ▪Each deck plate outside line of cargo hatch openings. ▪Three transverse sections, one in the amidship area, outside line of cargo hatch openings. ▪Each bottom plate
	Wind and water strakes in way of the two transverse sections considered above. Selected wind and water strakes outside the cargo length area	Selected wind and water strakes outside the cargo length area	All wind and water strakes, full length
	Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Table 5.7.4.4(2)②	Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Table 5.7.4.4(2)②	Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey according to Table 5.7.4.4(2)②

"

Section 8 ADDITIONAL REQUIREMENTS FOR HULL AND EQUIPMENT SURVEYS OF CHEMICAL TANKERS

In the existing subparagraph 5.8.2.1(2), "5.8.2.6" is replaced by "5.8.2.5".

The existing subparagraph 5.8.4.5(1) is replaced by the following:

"(1) The minimum requirements for ballast tank testing are given in (3) of this paragraph and Table 5.8.4.5(1); the minimum requirements for cargo tank testing are given in (4) of this paragraph and Table 5.8.4.5(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 has been submitted by the Owner and reviewed by CCS prior to the testing being carried out;

② 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;

④ the satisfactory results of the testing is recorded in the ship's logbook;

⑤ 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."

Section 11 SURVEYS OF THE OUTSIDE OF THE SHIP'S BOTTOM AND RELATED ITEMS

The following sentences are added at the end of the existing subparagraph 5.11.2.1(6):

"Other propulsion systems which also have manoeuvring characteristics (such as directional propellers, vertical axis propellers, water jet units) are to be examined externally with focus on the condition of gear housing, propeller blades, bolt locking and other fastening arrangements. Sealing arrangement of propeller blades, propeller shaft and steering column is to be verified."

Section 13 BOILER SURVEYS

In the existing paragraph 5.13.4.1, the footnote is replaced by the following:

"① As defined in ②, ③ and ④ in 2.1.3.1(28) of Chapter 2 of this PART."

Appendix 1 CRITERIA FOR RENEWAL OF HULL STRUCTURAL MEMBERS

In the existing paragraph 2.5, the words "Section 12, Chapter 8" are replaced by "Section 11, Chapter 8".

A new paragraph 2.6 is added as follows:

"2.6 For ships other than bulk carriers, ore carriers and combination carriers, contracted for construction on or after 1 July 2012 and complying with Section 20, Chapter 2, PART TWO of the Rules①, and for all weathertight steel cargo hatch covers on exposed decks, steel renewal is required where the gauged thickness of the plating of double skin hatch covers, single skin hatch covers, hatch coamings, coaming stays and stiffeners is less than t_{net} + 0.5 mm. Where the gauged thickness is within the range t_{net} + 0.5 mm and t_{net} + 1.0 mm, coating② or annual gauging may be adopted as an alternative to steel renewal. For the 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 deemed necessary, at the discretion of CCS Surveyor, on the basis of the plating corrosion or deformation condition. In these cases, steel renewal for the internal structures is 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 when gauged thickness is between t_{net} and t_{net} + 0.5 mm, coating or annual gauging may be adopted as an alternative to steel renewal, where t_{net} being the net thickness, to be calculated in accordance with 2.20.2, Section 20, Chapter 2, PART TWO of the Rules."

The existing paragraphs 2.6 and 2.7 are renumbered as 2.7 and 2.8 accordingly.

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

In the existing subparagraph 3.6.1(2), the words "The continuous survey card is to be prepared by the attending Surveyor" are replaced by "The CMS plan is to be approved by the attending Surveyor".

---

① For the definitions of bulk carriers, ore carriers and combination carriers, refer to Appendix 2, Chapter 2 of this PART.
② Coating is to be maintained in GOOD condition, as defined in 5.1.5.1(16) of this Chapter.

CHAPTER 6 SURVEYS RELATED TO CLASS NOTATIONS

Section 3 SURVEYS RELATED TO CLASS NOTATIONS FOR SPECIAL EQUIPMENT

A new paragraph 6.3.5 is added as follows:

"6.3.5 HMS&HMS (×) notations

6.3.5.1 General requirement

(1) This paragraph applies to ships which have been assigned one of the following class notations for hull monitoring systems:

HMS and HMS (×).

6.3.5.2 Initial classification

(1) For a ship intended for the notation HMS or HMS (×), the plans and documents required by 21.1.3 of Chapter 21, PART EIGHT of the Rules are to be submitted for approval.

(2) Initial classification surveys are to include the survey and testing of following items:

① examination of the Type Approval Certificate of the hull monitoring system;

② confirmation that the arrangement of each sensor is in conformity with the approved plans;

③ confirmation that the instruction manual and the log for maintenance and calibration have been kept on board;

④ in the sea trials:

a. confirmation that the initial readings of the sensors comply with the still water loading condition specified in 21.2.2.14, Chapter 21, PART EIGHT of the Rules;

b. carrying out performance tests of system functions;

⑤ confirmation that the software version of the hull monitoring system is the same as that on the approval certificate.

6.3.5.3 Annual surveys

(1) Examination of the log for maintenance and calibration of the hull monitoring system.

(2) Verification of the proper operation of the hull monitoring system.

(3) External examination of each sensor and its protective measures so far as practicable.

6.3.5.4 Intermediate surveys

(1) The scope of the intermediate survey is the same as that of the annual survey.

6.3.5.5 Special surveys

(1) In addition to the requirements of annual surveys mentioned above, the watertightness of sensors installed externally is also to be inspected."

Section 5 SURVEYS RELATED TO CLASS NOTATIONS FOR ENVIRONMENTAL PROTECTION

The existing subparagraph 6.5.1.1(1)① is replaced by the following:

"① CLEAN — with the following special notations:

a. FTP (Fuel Tank Protection);

b. GWC (Grey Water Control);

c. NEC(II) (NOx Emission Control);
NEC(III) (NOx Emission Control);

d. SEC(I) (SOx Emission Control);
SEC(II) (SOx Emission Control);
SEC(III) (SOx Emission Control);

e. RSC (Refrigeration System Control);

f. AFS (Anti-Fouling System);

g. GPR (Green Passport for Recycling);
GPR (EU);

h. BWMS (Ballast Water Management System)."

Section 6 SURVEYS RELATED TO CLASS NOTATIONS FOR REFRIGERATED CARGO INSTALLATIONS

A new paragraph 6.6.4.4 is added as follows:

"6.6.4.4 At the request of the owner and upon approval by CCS Headquarters, a system of continuous surveys may be undertaken whereby the special survey requirements are carried out in regular rotation."

PART TWO HULL

CHAPTER 1 GENERAL

Section 1 GENERAL PROVISIONS

In the existing paragraph 1.1.2.1, a new sentence is added after the first sentence as follows:

"In ships with unusual stern and bow arrangement, the length L is to be specially considered."

New paragraphs 1.1.2.23, 1.1.2.24, 1.1.2.25 and 1.1.2.26 are added as follows:

"1.1.2.23 Main frames are side frames between the collision bulkhead and the aft peak bulkhead, and below the lowest deck.

1.1.2.24 Frames in a 'tween deck space are frames between two decks.

1.1.2.25 Fore peak is a compartment situated before the collision bulkhead and below the bulkhead deck.

1.1.2.26 Aft peak is a compartment situated after the last watertight bulkhead at the aft end of the ship and below the bulkhead deck or the watertight platform deck."

Section 2 HULL STRUCTURAL MEMBERS

The existing paragraph 1.2.3.4 is replaced by the following:

"1.2.3.4 Unless otherwise specified in this PART, the span of curved members is defined as the chord length between span points."

In the existing paragraph 1.2.5.4, the sentence "The thickness t_b (in mm) of tripping brackets is not to be less than 5 + 0.025 L, but need not be greater than that of web of primary members, where L being length of ship." is replaced by "The thickness t_b (in mm) of tripping brackets is not to be less than 5 + 0.025 L, but need not be greater than that of web of primary members, where L being length of ship (which need not be greater than 300 m in calculation)."

The existing paragraph 1.2.6.5 is replaced by the following:

"1.2.6.5 The thickness t of brackets is to be not less than that obtained from the following formulas:

$$t = (0.25\sqrt{W} + 2)\sqrt{\frac{R_{eH_s}}{R_{eH_b}}} + C \text{ mm, for brackets with face plate or flanged brackets}$$

$$t = (0.25\sqrt{W} + 3.5)\sqrt{\frac{R_{eH_s}}{R_{eH_b}}} + C \text{ mm, for brackets without face plate or unflanged brackets}$$

where: W — Rule section modulus of frames, in cm^3;
R_{eH_s} — yield stress of material of frames, in N/mm^2;
R_{eH_b} — yield stress of material of brackets, in N/mm^2;
C — coefficient, taken as 2.5 for brackets in tanks or 1.5 for other brackets.
The minimum thickness of brackets is generally to be 6.5 mm and need not be greater than 15 mm."

The existing paragraph 1.2.6.6 is replaced by the following:

"1.2.6.6 Where the Rule section modulus W of frames is not less than 500 cm^3 or the free edge is more than 50 times the thickness of brackets in length, the brackets are to be flanged or fitted with face plates. The breadth b of the flanges or face plates is not to be less than that obtained from the following formula:

$$b = 0.04\ W + 40 \text{ mm, and not less than 50 mm}$$

where: W — Rule section modulus of frames, in cm^3."

The existing paragraph 1.2.6.7 is replaced by the following:

"1.2.6.7 The arm length h of brackets is not to be less than 2.2 times the web depth of frames (where the ends of frames are welded, it may be reduced to not less than twice the web depth, see Figure 1.2.6.2 (1)), and is not to be less than that obtained from the following formula:

$$h = 75\sqrt{\frac{W}{t - C}} \text{ mm}$$

where: W — Rule section modulus of frames, in cm^3;
t — thickness of brackets, in mm;
C — coefficient, see paragraph 1.2.6.5 of this Section."

In the existing paragraph 1.2.7.3, the sentence "Where the unsupported arm length of brackets is greater than 100 t (t being the web thickness of brackets), stiffeners parallel to the face plates of brackets are to be fitted." is replaced by "Where the side length of the non-stiffened triangle of the bracket is greater than 100 t (t being the web thickness of the bracket), stiffeners parallel to the face plate of the bracket are to be fitted in accordance with paragraph 5.12.2.6 of Chapter 5 of this PART."

Section 3 HULL STRUCTURAL STEEL

The existing paragraph 1.3.2.1 is replaced by the following:

"1.3.2.1 In ships of 90 m or over in length, the hull structural steel is to comply with the requirements of 1.3.2.2. For strength members not covered by Tables 1.3.2.2(1) to 1.3.2.2(6) or in ships of less than 90 m in length, grade A/AH steel can generally be used for hull structure. The steel grade is to correspond to the as-built plate thickness and material class."

The existing paragraph 1.3.2.2 is replaced by the following:

"1.3.2.2 Materials in the various strength members are not to be of lower grade than those corresponding to the material classes and grades specified in Table 1.3.2.2(1) to Table 1.3.2.2(7). General requirements are given in Table 1.3.2.2(1), while additional minimum requirements are given in the following Tables:

Table 1.3.2.2(2): for ships, excluding liquefied gas carriers covered in Table 1.3.2.2(3), with length exceeding 150 m and single strength deck;

Table 1.3.2.2(3): for membrane type liquefied gas carriers with length exceeding 150 m;

Table 1.3.2.2(4): for ships with length exceeding 250 m;

Table 1.3.2.2(5): for single side bulk carriers subjected to SOLAS regulation XII/6.5.3;

Table 1.3.2.2(6): for ships with ice strengthening."

In the existing paragraph 1.3.2.3, "Table 1.3.2.2(6)" is replaced by "Table 1.3.2.2(7)".

In the existing paragraph 1.3.2.4, "Table 1.3.2.2(6)" is replaced by "Table 1.3.2.2(7)".

The existing Table 1.3.2.2(1) is replaced by the following:

"Material Classes and Grades for Ships in General Table 1.3.2.2(1)

Category	Structural member	Material class/grade
Secondary	(1) Longitudinal bulkhead plating, other than that belonging to the Primary category (2) Deck plating exposed to weather, other than that belonging to the Primary or Special category (3) Side plating	Class I within 0.4*L* amidships Grade A/AH outside 0.4*L* amidships
Primary	(1) Bottom plating, including keel plate (2) Strength deck plating, excluding that belonging to the Special category (3) Continuous longitudinal plating of strength members above strength deck, excluding hatch coamings (4) Uppermost strake in longitudinal bulkhead (5) Vertical strake (hatch side girder) and uppermost sloped strake in top wing tank	Class II within 0.4*L* amidships Grade A/AH outside 0.4*L* amidships
Special	(1) Sheer strake at strength deck① (2) Stringer plate in strength deck① (3) Deck strake at longitudinal bulkhead, excluding deck plating in way of inner-skin bulkhead of double-hull ships①	Class III within 0.4*L* amidships Class II outside 0.4*L* amidships Class I outside 0.6*L* amidships
	(4) Strength deck plating at outboard corners of cargo hatch openings in container carriers and other ships with similar hatch opening configurations	Class III within 0.4*L* amidships Class II outside 0.4*L* amidships Class I outside 0.6*L* amidships Min. Class III within cargo region
	(5) Strength deck plating at corners of cargo hatch openings in bulk carriers, ore carriers, combination carriers and other ships with similar hatch opening configurations (5.1) Trunk deck and inner deck plating at corners of openings for liquid and gas domes in membrane type liquefied gas carriers	Class III within 0.6*L* amidships Class II within rest of cargo region
	(6) Bilge strake in ships with double bottom over the full breadth and length less than 150 m	Class II within 0.6*L* amidships Class I outside 0.6*L* amidships
	(7) Bilge strake in other ships①	Class III within 0.4*L* amidships Class II outside 0.4*L* amidships Class I outside 0.6*L* amidships
	(8) Longitudinal hatch coamings of length greater than 0.15*L* including coaming top plate and flange (9) End brackets and deck house transition of longitudinal cargo hatch coamings	Class III within 0.4*L* amidships Class II outside 0.4*L* amidships Class I outside 0.6*L* amidships Not to be less than Grade D/DH

Note: ① Single strakes required to be of Class III within 0.4*L* amidships are to have breadths not less than 800 + 5*L* mm (L being the ship's length), need not be greater than 1,800 mm, unless limited by the geometry of the ship's design."

The existing Table 1.3.2.2(2) is replaced by the following:

"Minimum Material Grades for Ships with Length Exceeding 150 m and Single Strength Deck Table 1.3.2.2(2)

Structural member category	Material grade
Longitudinal plating of strength deck where contributing to the longitudinal strength Continuous longitudinal plating of strength members above strength deck	Grade B/AH within 0.4*L* amidships
Single side strakes for ships without inner continuous longitudinal bulkhead(s) between bottom and the strength deck	Grade B/AH within cargo region

Note: This Table is applicable to ships other than the liquefied gas carriers covered in Table 1.3.2.2(3)."

A new Table 1.3.2.2(3) is added as follows:

"Minimum Material Grades for Membrane Type Liquefied Gas Carriers with Length Exceeding 150 m① **Table 1.3.2.2(3)**

Structural member category		Material grade
Longitudinal plating of strength deck where contributing to the longitudinal strength		Grade B/AH within 0.4*L* amidships
Continuous longitudinal plating of strength members above the strength deck	• Trunk deck plating	Class II within 0.4*L* amidships
	• Inner deck plating • Longitudinal strength member plating between the trunk deck and inner deck	Grade B/AH within 0.4*L* amidships

Note: ① Table 1.3.2.2(3) is applicable to membrane type liquefied gas carriers with deck arrangements as shown in Figure 1. Table 1.3.2.2(3) may apply to similar ship types with a 'double deck' arrangement above the strength deck.

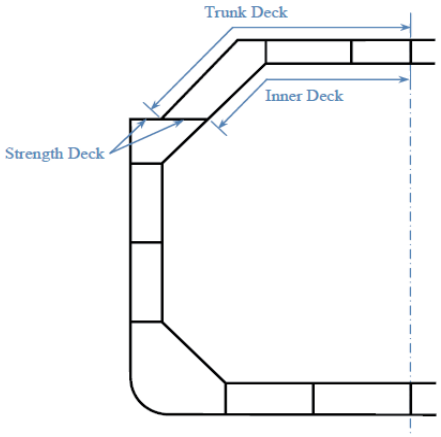


Figure 1.3.2.2 Typical Deck Arrangement for Membrane Type Liquefied Natural Gas Carriers"

The existing Tables 1.3.2.2(3), 1.3.2.2(4), 1.3.2.2(5) and 1.3.2.2(6) are renumbered as 1.3.2.2(4), 1.3.2.2(5), 1.3.2.2(6) and 1.3.2.2(7) respectively.

In the existing paragraph 1.3.2.5, the words "Plating materials for stern frames, rudders, rudder horns and shaft brackets are, in general, …" are replaced by "Plating materials for stern frames supporting the rudder and propeller boss, rudders, rudder horns and shaft brackets are, in general, …".

Section 4 WELD DESIGN FOR HULL STRUCTURES

Item "1 General application (except as required below)" in the existing Table 1.4.4.2 is replaced by the following:

"Weld Factors **Table 1.4.4.2**

Item	Weld factor	Remarks
1. General application (except as required below):		
Watertight or oiltight plate boundaries	0.34	
Non-tight plate boundaries	0.13	
Longitudinals, frames, beams, and other secondary members to shell, deck or bulkhead plating	0.10	
	0.13	In tanks
	0.21	In way of end connections
Panel stiffeners (i.e. small stiffeners)	0.10	
Overlap welds	0.27	
Longitudinals of the flat-bar type to plating	0.21	Double continuous

"

Section 5 APPLICATION OF HIGHER TENSILE STEEL

In the existing paragraph 1.5.3.2, the words "With the exception of 1.5.3.1, Sections 10 and 11, Chapter 2 and Section 9, Chapter 7 of this PART,…" are replaced by "With the exception of 1.5.3.1, Sections 10, 11 and 20, Chapter 2 and Section 9, Chapter 7 of this PART…".

Section 6 CORROSION CONTROL FOR HULL STRUCTURES

The existing paragraph 1.6.1.2 is replaced by the following:

"1.6.1.2 All seawater ballast spaces having boundaries formed by the hull plating are to be applied with an epoxy-based or equivalent coating system according to the coating manufacturer's recommendation. Dedicated seawater ballast tanks of all types of ships of not less than 500 gross tonnage and double-side skin spaces arranged in bulk carriers of 150 m in length and upwards, as specified in SOLAS regulation II-1/3-2, are to be coated in accordance with the Performance Standard for Protective Coatings for Dedicated Seawater Ballast Tanks in All Types of Ships and Double-Side Skin Spaces of Bulk Carriers (PSPC)."

A new paragraph 1.6.1.7 is added as follows:

"1.6.1.7 Impressed current systems are not permitted in oil cargo tanks."

The existing subparagraph 1.6.3.6(4) is replaced by the following:

"(4) For oil tankers, magnesium or magnesium alloy anodes are not permitted in oil cargo tanks and tanks adjacent to cargo tanks."

Section 7 FORE DECK FITTINGS

The existing paragraph 1.7.1.3 is replaced by the following:

"1.7.1.3 The pressures p, acting on air pipes, ventilator pipes and their closing devices may be calculated from:

$$p = 0.5\rho V^2 C_d C_s C_p \quad \text{kN/m}^2$$

where: ρ — density of seawater, taken as 1.025 t/m^3;

V — velocity of water over the fore deck, in m/s;

= 13.5 m/s, for $h \leq 0.5\ h_1$,

$$= 13.5\sqrt{2(1 - \frac{h}{h_1})} \text{ m/s, for } 0.5\ h_1 < h < h_1,$$

where: h — distance from summer load waterline to exposed deck, in m;

h_1 — $0.1L$ or 22 m, whichever is the lesser;

C_d — shape coefficient, taken as 0.5 for pipes, 1.3 for air pipe or ventilator heads in general, 0.8 for an air pipe or ventilator head of cylindrical form with its axis in the vertical direction;

C_s — slamming coefficient, taken as 3.2;

C_p — protection coefficient, taken as 0.7 for pipes and ventilator heads located immediately behind a breakwater or forecastle, 1.0 elsewhere and immediately behind a bulwark."

A new note ④ for Table 1.7.1.7 is added as follows:

"④ For air pipes of other heights, requirements specified in 1.7.1.5 to 1.7.1.12 of this Section are to be met."

The following sentence is added at the end of the existing paragraph 1.7.1.8:

"Pipe thickness is not to be taken less than as indicated in IACS UI LL36."

A new note for Table 1.7.1.9 is added as follows:

"Note: For ventilators of other heights, requirements specified in 1.7.1.5 to 1.7.1.12 of this Section are to be met."

The following sentence is added at the end of the existing paragraph 1.7.1.10:

"Pipe thickness is not to be taken less than as indicated in IACS UI LL36."

In the existing subparagraph 1.7.2.9(1), a new sentence is added after the first sentence as follows:

"This is to be designed to allow a metal to metal contact at a designed compression and to prevent over compression of the gasket by green sea forces that may cause the securing devices to be loosened or dislodged."

The existing subparagraph 1.7.2.9(4) is replaced by the following:

"(4) For small hatch covers located on the exposed deck forward of the fore-most cargo hatch, the hinges are to be fitted such that the predominant direction of green sea will cause the cover to close, which means that the hinges are normally to be located on the fore edge."

The existing paragraph 1.7.2.10 is replaced by the following:

"1.7.2.10 Small hatches on the fore deck are to be fitted with an independent secondary securing device e.g. by means of a sliding bolt, a hasp or a backing bar of slack fit, which is capable of keeping the hatch cover in place, even in the event that the primary securing device became loosened or dislodged. It is to be fitted on the side opposite to the hatch cover hinges."

Section 9 INTACT STABILITY

The existing paragraph 1.9.4.3 is replaced by the following:

"1.9.4.3 The intact stability of towing vessels is also to comply with the relevant requirements of IACS REC 24:

(1) the intact stability requirements of IMO resolution MSC.267(85), Part A Chapter 2.2;

(2) or alternatively, if applicable, the intact stability requirement of IMO resolution MSC.267(85), Part B Chapter 2.4;

(3) additionally:

① The residual area between a righting lever curve and a heeling lever curve developed from 70% of the maximum bollard pull force acting in 90° to the ship-length direction is not to be less than 0.09 m·rad. The area has to be determined between the first interception of the two curves and the second interception or the angle of down flooding, whichever is less.

② Alternatively, the area under a righting lever curve is not to be less than 1.4 times the area under a heeling lever curve developed from 70% of the maximum bollard pull force acting in 90° to ship-length direction. The areas are to be determined between 0° and the 2nd interception or the angle of down flooding, whichever is less.

The heeling lever curve is to be derived by using the following formula:

$$b_h = \frac{0.7TH\cos\theta}{9.81\Delta}$$

where: b_h — heeling arm, in m;
T — maximum bollard pull, in kN;
H — vertical distance, in m, between the towing hook and the centre of the propeller;
θ — heeling angle, in °;
Δ — loading condition displacement, in t.

(4) Openings required to be fitted with weathertight closing devices under the ICLL but, for operational reasons, are required to be kept open are to be considered as downflooding points in stability calculation.

Section 12 STRUCTURAL ARRANGEMENT

The existing paragraph 1.12.4.2 is replaced by the following:

"1.12.4.2 In all cases, stern tubes are to be enclosed in watertight spaces of moderate volume. In passenger ships the stern gland is to be situated in a watertight shaft tunnel or other watertight space separate from the stern tube compartment and of such volume that, if flooded by leakage through the stern gland, the bulkhead deck will not be immersed. In cargo ships, other measures to minimize the danger of water penetrating into the ship in case of damage to stern tube arrangements may be taken upon approval."

A new paragraph 1.12.6.3 is added as follows:

"1.12.6.3 Moving parts penetrating the shell plating below the deepest subdivision draught are to be fitted with an acceptable watertight sealing arrangement. The inboard gland is to be located within a watertight space of such volume that, if flooded, the bulkhead deck will not be submerged."

Section 14 DIRECT STRENGTH CALCULATIONS

The existing paragraph 1.14.6.6 is replaced by the following:

"1.14.6.6 When the stress distribution or stiffness of members is affected by the openings on primary members, the following methods may be adopted:

(1) For openings, e.g. lightening holes, manholes, of web plates of primary structural members, simulation is to be carried out according to Table 1.14.6.6 of this Section.

Simulation of Openings of Web Plates of Primary Structural Members Table 1.14.6.6

$h_0/h < 0.35$ and $g_0 < 1.2$	Modeling not needed for openings
$0.35 \le h_0/h < 0.5$ and $g_0 < 1.2$	Equivalent plate thickness being $t_1 = \dfrac{h-h_0}{h} t_w$
$h_0/h < 0.5$ and $1.2 \le g_0 < 2$	Equivalent plate thickness being $t_2 = \dfrac{h-h_0}{hg_0} t_w$
$h_0/h \ge 0.5$ or $g_0 \ge 2$	Modeling based on geometry of openings or by means of removing the appropriate elements in way of openings

where: t_w — thickness of web plates;
l_0 — opening length perpendicular to height of web plates, see Figure 1.14.6.6(1); where the space d_0 of continuous openings is less than 0.25 h, l_0 is to be taken as the length across the openings, see Figure 1.14.6.6(2);
h_0 — opening height parallel to height of web plates, see Figure 1.14.6.6(1);
h — height of web plates in way of openings, see Figure 1.14.6.6(1);

$$g_0 = 1 + \frac{l_0^2}{2.6(h-h_0)^2}$$

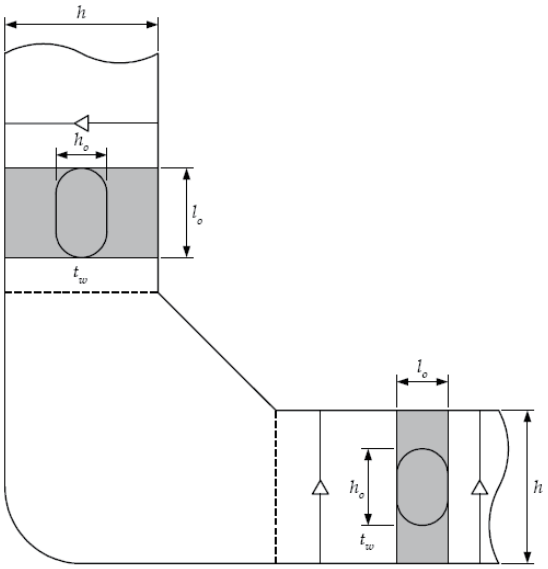


Figure 1.14.6.6(1) Openings of Web Plates

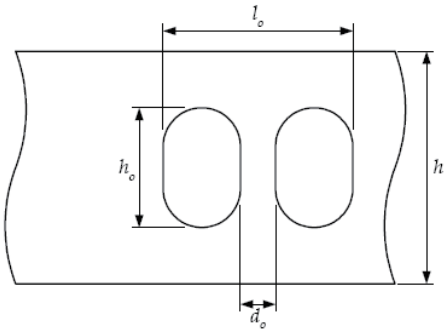


Figure 1.14.6.6(2) Length l_0 for Space of Continuous Openings $d_0 < 0.25\ h$

(2) For detailed stress analysis, the mesh size of the innermost two cycles of elements around the opening is not to be greater than 50 mm × 50 mm. The meshing is to be such that the transition from refined to coarse meshes is smooth. Stiffeners welded directly to the edges of the opening are to be simulated by plate elements; web stiffeners located more than 50 mm away from the edges of the opening can be simulated by rod or beam elements, as indicated in Figure 1.14.6.6(3). The allowable stress is to be as follows:

$$[\sigma_e] = 1.6 \times 235/K \quad \text{N/mm}^2$$

where: K — material factor.

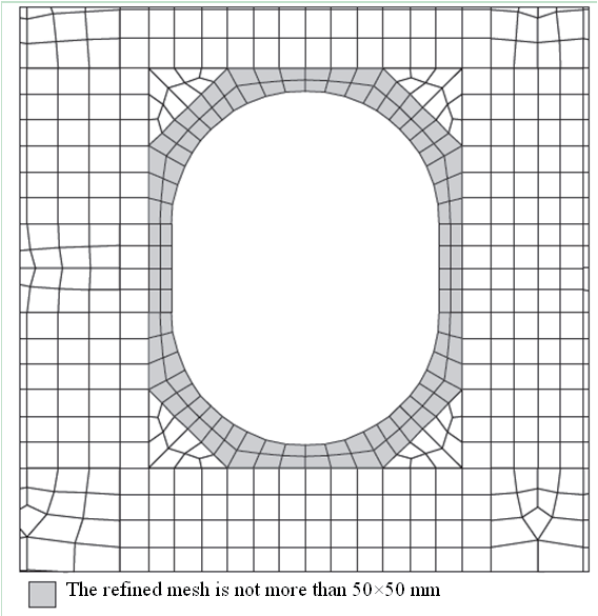


Figure 1.14.6.6(3) Refined Opening of Web Plate"

CHAPTER 2 HULL STRUCTURES

Section 2 LONGITUDINAL STRENGTH

The existing paragraph 2.2.1.2 is replaced by the following:

"2.2.1.2 For ships complying with the following conditions, special considerations are required and documents for such ships are to be submitted to CCS for approval:

(1) For ships having one or more of the following characteristics, direct calculations are to be carried out; see paragraph 2.2.9 of this Section for direct calculation of wave loads:

$$L/B \leq 5$$
$$B/D \geq 2.5$$
$$L \geq 500 \text{ m}$$
$$C_b < 0.6$$

(2) For ships having large deck openings, the longitudinal strength at combined bending and torque is to be checked according to the requirements in Section 2, Chapter 7 of this PART.

(3) For ships having large flare, additional bending moment caused by slamming may be considered.

(4) For ships intended for the carriage of special cargoes (e.g. heated cargoes) or ships of unusual type, direct calculations are to be carried out in accordance with properties of cargoes or ship's type; where direct calculations are impracticable, design loads are to be determined by means of model test."

The existing paragraph 2.2.1.3 is deleted.

In the existing paragraph 2.2.4.7, the words "Deck openings (including manholes) which are smaller than those stated in 2.2.4.6 of this Section need not be deducted from the sectional areas used in the calculation of the hull girder section modulus, provided that the sum b_c of their breadths or shadow area breadths (as shown in Figure 2.2.4.7) in one transverse section complies with the following:" are replaced by "Smaller openings (including manholes, lightening holes, single scallops in way of seams, etc.) smaller than those stated in 2.2.4.6 of this Section need not be deducted from the sectional areas used in the calculation of the hull girder section modulus, provided that the sum b_c of their breadths or shadow area breadths (as shown in Figure 2.2.4.7) in one transverse section complies with the following or that the section modulus at deck or bottom is not reduced by more than 3%:".

A new text is added at the end of the existing paragraph 2.2.5.1:

In ships where part of the longitudinal strength material in the deck or bottom area are forming boundaries of tanks for oil cargoes or ballast water and such tanks are provided with an effective corrosion protection system, certain reductions in the scantlings of these boundaries are allowed. These reductions, however, are in no case to reduce the minimum hull girder section modulus for a new ship by more than 5%."

The existing paragraph 2.2.5.6 is deleted.

The existing paragraph 2.2.5.7 is renumbered as 2.2.5.6.

A new paragraph 2.2.9 is added as follows:

"2.2.9 Direct calculation of wave loads

2.2.9.1 The direct calculation of wave loads is to be based on the following assumptions:

(1) The calculation software is to be based on the three-dimensional linear or non-linear wave theory and approved by the classification society.

(2) Wave statistics based on the marine environment of the North Atlantic, as given in IACS REC 34, are used in the prediction of wave loads for ships in unrestricted service; the prediction of wave loads for ships in restricted service is required to be based on wave statistics of the sea areas in which such ships operate and where there are more than one set of wave statistics, the most severe one is to be used.

(3) The requirements for wave frequencies, wave heading angles and the considered ship speed are given in paragraph 1.14.7.2, Chapter 1 of this PART.

(4) The wave spectrum and energy spread function under consideration are given in paragraph 1.14.7.3, Chapter 1 of this PART.

(5) The long-term prediction results at the probability level of 10^{-8} are taken as calculation results.

2.2.9.2 The hydrodynamic models used in calculation are to comply with the following requirements:

(1) The mass model is to correctly reflect the mass and its distribution of the real ship, ensuring that the error between mass of the model and that of the real ship is not greater than 0.1% and that the error between position of center of gravity of the model and that of the real ship is not greater than 0.1%L.

(2) The model of wetted surface is to be sufficiently refined for an accurate simulation of the shape of the real ship from the hydrodynamic perspective. The error between displacement of the model and that of the real ship is not to be greater than 0.1%, the error between position of center of buoyancy of the model and that of the real ship is not to be greater than 0.1% L, and the number of elements is generally not to be less than 2,000.

2.2.9.3 The wave bending moments and shear forces obtained by the linear wave theory are to be subject to non-linear correction as follows:

(1) The hogging wave bending moment M_W (+) and the sagging wave bending moment M_W (–) are to be calculated by the following formulas:

$$M_W(+) = Mf_{nl-h}M_{W,cal} \qquad \text{kN•m}$$

$$M_W(-) = Mf_{nl-s}M_{W,cal} \qquad \text{kN•m}$$

where: $M_{W,cal}$ — maximum vertical wave bending moment between 0.4L and 0.6L, obtained by direct calculation based on linear wave theory;
M — distribution factor of bending moment along ship length, see Figure 2.2.3.1, Chapter 2 of this PART;
f_{nl-h}, f_{nl-s} — non-linear correction factor, determined by the following formulas:

$$f_{nl-h} = \frac{190C_b}{95C_b + 55(C_b + 0.7)}$$

$$f_{nl-s} = \frac{110(C_b + 0.7)}{95C_b + 55(C_b + 0.7)};$$

where: C_b — block coefficient, taken not less than 0.6.

(2) The hogging wave shear force F_W (+) and the sagging wave shear force F_W (–) are to be calculated by the following formulas:

$$F_W(+) = F_{nl,1}F_{WV,\max} \qquad \text{kN}$$

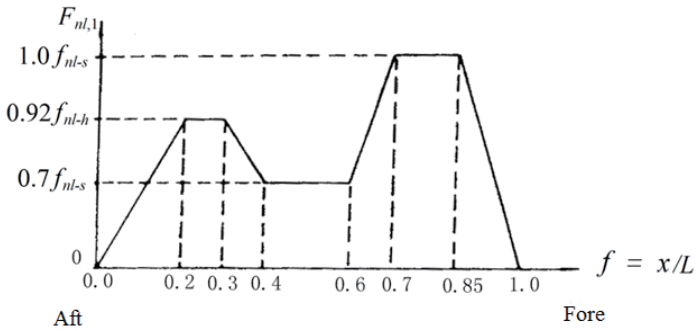
$$F_W(-) = F_{nl,2}F_{WV,\max} \qquad \text{kN}$$

where: $F_{nl,1}$, $F_{nl,2}$ — distribution factors taking non-linear correction into account, see Figures 2.2.9.3(1) and 2.2.9.3(2) respectively. For f_{nl-h}, f_{nl-s} in the Figures, see (1) of this paragraph.

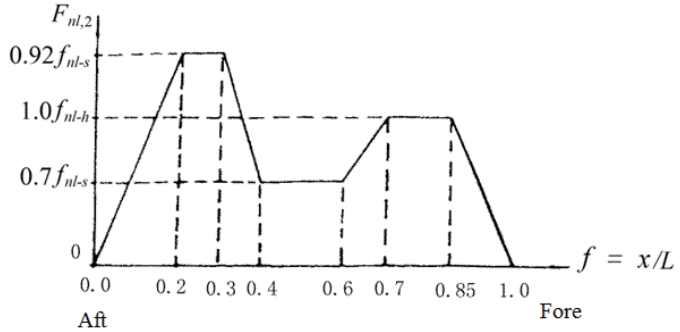
$F_{WV,\max}$ is to be calculated by the following formula:

$$F_{WV,\max} = \max\left(\frac{\max|F_{WV,CAL,A}|}{0.92}, \frac{\max|F_{WV,CAL,F}|}{1.0}\right) \qquad \text{kN}$$

where: $F_{WV,CAL,A}$ — wave shear force, in kN, directly calculated for sections with $x/L < 0.5$;
$F_{WV,CAL,F}$ — wave shear force, in kN, directly calculated for sections with $x/L \geq 0.5$.



Figures 2.2.9.3(1) Distribution of Factor $F_{nl,1}$ along Ship Length



Figures 2.2.9.3(2) Distribution of Factor $F_{nl,2}$ along Ship Length"

Section 3 SHELL PLATING

The existing paragraph 2.3.1.5 is replaced by the following:

"2.3.1.5 The thickness of bottom shell plating is not to be less than that obtained by the following formula:

$$t = 0.035L + 6 \quad \text{mm}$$

where: L — ship length, in m.

The thickness of bottom shell plating beyond $0.4L$ amidships is to be tapered gradually to the end thickness of bottom shell plating."

The existing paragraph 2.3.4.5 is replaced by the following:

"2.3.4.5 The thickness of side shell plating is not to be less than that obtained by the following formula:

$$t = 0.035L + 6 \quad \text{mm}$$

where: L — ship length, in m.

The thickness of side shell plating beyond $0.4L$ amidships is to be tapered gradually to the end thickness of side shell plating."

The existing paragraph 2.3.7.5 is deleted.

Section 7 SIDE FRAMING

The existing paragraph 2.7.2.8 is replaced by the following:

"2.7.2.8 The frames in fore and after peaks are to comply with the following requirements:

(1) The section modulus W and the moment of inertia I of frames below the lowest deck in fore and after peaks are to be respectively not less than the values obtained from the following formulae:

$$W = 4.6sdD \quad \text{cm}^3$$

$$I = 3.5Wl \quad \text{cm}^4$$

where: s — spacing of frames, in m;
d — draught, in m;
D — moulded depth, in m;
L — span of frames, in m, being the vertical distance measured from the upper edge of floor to the side stringer (perforated flat), or distance between side stringers (perforated flats) or from the side stringer (perforated flat) to the lowest deck.

(2) Where the lowest deck in the fore peak is below 1.0 m above the full-load waterline, the 'tween deck frames fitted from the lowest deck up to 1.0 m above the full-load waterline are also to comply with the requirements of (1) above.

(3) Other 'tween deck frames in the fore peak are also to comply with the requirements of paragraph 2.7.2.9 of this Section."

Section 8 DECK FRAMING

The existing paragraph 2.8.1.1 is replaced by the following:

"2.8.1.1 The design head h of decks is to be determined according to Table 2.8.1.1, and the corresponding design load p is to be calculated by the following formula:

$$p = \frac{9.81h}{\gamma} \quad \text{kPa}$$

where: h — design head, in m, see Table 2.8.1.1 of this Section;
γ — stowage rate, in m^3/t, taken as the standard rate of 1.39 m^3/t;

For decks in deep tanks, the relevant requirements in Section 13 of this Chapter are also to be complied with, and the corresponding design load P is to be calculated by the following formula:

$$p = 9.81\rho h \quad \text{kPa}$$

where: h — design head, in m, see Section 13 of this Chapter;
ρ — density of liquid, in t/m^3, to be taken not less than 1.025 t/m^3."

In the existing Table 2.8.1.1, the words "Design cargo load" are replaced by "Permissible cargo load".

In the existing paragraph 2.8.3.7, the following sentence is added after the sentence "Holes cut for the passage of pipes or cables in the web of deck girders are to have a depth not greater than 25% of that of the web and a width not exceeding 60% of the spacing of beams or the web depth, whichever is the greater, otherwise compensation is required.":

"Normally the compensation is achieved by fitting doublers, spigots or insert plates for strengthening, and the cross-sectional area of such strengthening pieces is to be not less than that lost from the web due to openings. The strength level of the material of strengthening pieces is not to be lower than that of the web material."

In the existing paragraph 2.8.7.8, the following sentence is added after the sentence "Holes cut for the passage of pipes or cables in the web of deck transverses are to have a depth not greater than 25% of that of the web and a width not exceeding 60% of the spacing of deck longitudinals or the web depth, whichever is the greater, otherwise compensation is required.":

"Normally the compensation is achieved by fitting doublers, spigots or insert plates for strengthening, and the cross-sectional area of such strengthening pieces is to be not less than that lost from the web due to openings. The strength level of the material of strengthening pieces is not to be lower than that of the web material."

In the existing paragraph 2.8.7.9, the last sentence "Large brackets are to be fitted with stiffeners." is deleted.

Section 12 WATERTIGHT BULKHEADS

The existing paragraph 2.12.4.5 is replaced by the following:

"2.12.4.5 The minimum web depth of stiffeners is to meet the requirements of 2.11.1.4 of this Chapter, and the thickness t of the web is to meet the following requirements:

For rolled or combined stiffeners with flange or face plate: $t \geq \frac{d_w}{60\sqrt{K}}$ mm

For flat bar stiffeners: $t \geq \frac{d_w}{18\sqrt{K}}$ mm

where: d_w — depth of stiffener webs, in mm;
K — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also paragraph 1.14.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower strength level may be taken."

The existing paragraph 2.12.5.3 is replaced by the following:

"2.12.5.3 The plating thickness t of bulkheads with symmetrical corrugations is to comply with the requirements of 2.12.3.1 of this Section, and the following formula is to be complied with:

$t \geq \frac{a}{85\sqrt{K}}$ mm at top

$t \geq \frac{a}{70\sqrt{K}}$ mm at bottom

where: a — width of corrugation flange, in mm;
K — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also paragraph 1.14.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower strength level may be taken."

The existing paragraph 2.12.6.2 is replaced by the following:

"2.12.6.2 The scantlings of double plate bulkheads are to comply with the requirements of 2.12.3.1 and 2.12.6.1 of this Section and in addition, the following requirements:

(1) The plating thickness t_p of double plate bulkheads is to comply with the following requirements:

$t_p \geq \frac{s}{75\sqrt{K}}$ mm at top

$t_p \geq \frac{s}{65\sqrt{K}}$ mm at bottom

where: s — spacing of webs, in mm;
K — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also paragraph 1.14.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower strength level may be taken.

(2) The plating thickness t_w and shear area A_w of the web of double plate bulkheads are to comply with the following requirements:

$t_w \geq \frac{b}{85\sqrt{K}}$ mm at top

$A_w \geq 0.12\frac{W}{l}$ cm²

$t_w \geq \frac{b}{75\sqrt{K}}$ mm at bottom

$A_w \geq 0.18\frac{W}{l}$ cm²

where: b — spacing of plates of double plate bulkheads, in mm;

W — section modulus required in 2.12.6.1 of this Section, in cm³;
l — span of webs, in m;
K — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also paragraph 1.14.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower strength level may be taken."

Section 13 DEEP TANKS

The existing paragraph 2.13.1.2 is deleted.

The existing paragraph 2.13.3.2 is replaced by the following:

"2.13.3.2 The plating thickness t of corrugated bulkheads is to comply with the requirements of 2.13.2.1 of this Section, and the following formula is to be complied with:

$$t \geq \frac{a}{70\sqrt{K}} \quad \text{mm}$$

where: a — width of corrugation flange, in mm;
K — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also paragraph 1.14.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower strength level may be taken."

The existing paragraph 2.13.4.2 is replaced by the following:

"2.13.4.2 The plating thickness t_p of double plate bulkheads is to comply with the requirements of 2.13.2.1 of this Section and in addition, the following requirements are to be complied with:

$$t_p \geq \frac{s}{75\sqrt{K}} \quad \text{mm} \quad \text{at top}$$

$$t_p \geq \frac{s}{65\sqrt{K}} \quad \text{mm} \quad \text{at bottom}$$

where: s — spacing of webs, in mm;
K — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also paragraph 1.14.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower strength level may be taken."

The existing paragraph 2.13.4.3 is replaced by the following:

"2.13.4.3 The plating thickness t_w and shear area A_w of the web of double plate bulkheads are to comply with the following requirements:

$$t_w \geq \frac{b}{85\sqrt{K}} \quad \text{mm} \quad \text{at top}$$

$$A_w \geq 0.07\frac{W}{l} \quad \text{cm}^2$$

$$t_w \geq \frac{b}{75\sqrt{K}} \quad \text{mm} \quad \text{at bottom}$$

$$A_w \geq 0.10\frac{W}{l} \quad \text{cm}^2$$

where: b — spacing of plates of double plate bulkheads, in mm;

W — section modulus required in 2.13.4.1 of this Section, in cm^3;
l — span of webs, in m;
K — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also paragraph 1.14.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower strength level may be taken."

Section 14 STEMS, STERN FRAMES, BULBOUS BOWS, PROPELLER SHAFT BRACKETS AND RUDDER HORNS

In the existing paragraph 2.14.2.11, the words "the thickness of the floor or of the lower strake of the bulkhead is to be increased by 3 mm" are replaced by "the thickness of the floor is to be increased by 3 mm".

Section 15 STRENGTHENING AT ENDS OF SHIP

In the existing paragraph 2.15.3.1, the sentence "For oil tankers of 20,000 tons deadweight and over, the minimum forward draught is to be determined according to the conditions in which only segregated ballast tanks are used." is replaced by "For every oil tanker subject to Regulation 18 of MARPOL 73/78 Annex I, the minimum forward draught is to be determined according to the conditions in which only segregated ballast tanks are used."

Section 17 SUPERSTRUCTURES AND DECKHOUSES

The "V" in the existing paragraph 2.17.2.2 is deleted.

The following sentence is added at the end of the existing paragraph 2.17.3.2:

"The section modulus of house side stiffeners need not be greater than that of side frames on the deck situated directly below, taking account of spacing and span."

Section 20 HATCHWAYS AND HATCH COVERS

In the existing paragraph 2.20.1.2, subparagraphs 2.20.3.1(2) and 2.20.4.1(2), item ② of subparagraph 2.20.3.2, item ① of subparagraph 2.20.4.2(3) and item ③ of subparagraph 2.20.4.2(3), the words "design cargo load" are replaced by "permissible cargo load".

The existing subparagraph 2.20.2.1(1) is replaced by the following:

"(1) These requirements apply to all ships other than bulk carriers, ore carriers and combination carriers, as defined in Appendix 2, Chapter 2 of PART ONE, and are for all cargo hatch covers and coamings on exposed decks."

In item ① of the existing subparagraph 2.20.2.8(3), the sentence "The effective breadth of the coaming plate is not to be larger than the effective plate breadth stipulated in 2.20.2.4(2) of this Section." is replaced by "The effective breadth of the coaming plate is not to be larger than the effective plate breadth stipulated in 2.20.2.4(1) of this Section."

In the existing subparagraph 2.20.2.10(2), the words "For single skin hatch covers and for the plating of double skin hatch covers" are replaced by "For plating of double skin hatch covers, single skin hatch covers, hatch coamings, coaming stays and stiffeners".

In the existing subparagraph 2.20.2.10(2), the sentence "Coating is to be maintained in good condition according to the requirements of Section 6, Chapter 1 of this PART." is replaced by "Coating is to be maintained in GOOD condition, as defined in 5.1.5.1(16), Chapter 5 of PART ONE."

In item ① of the existing subparagraph 2.20.3.2(2), the formula "$W = 0.782\ spl^2$ cm^3" is replaced by "$W = 0.782\ Kspl^2$ cm^3", and a new description "K — material factor" is added for the formula.

In item ② of the existing subparagraph 2.20.3.2(2), the formula "$W = 1.064\ spl^2$ cm^3" is replaced by "$W = 1.064\ Kspl^2$ cm^3", and a new description "K — material factor" is added for the formula.

In item ① of the existing subparagraph 2.20.4.2(2), the formula "$W = 0.782\ spl^2$ cm^3" is replaced by "$W = 0.782\ Kspl^2$ cm^3", and a new description "K — material factor" is added for the formula.

In item ⑤ of the existing subparagraph 2.20.4.2(2), the formula "$W = 0.664\ spl^2$ cm^3" is replaced by "$W = 0.664\ Kspl^2$ cm^3", and a new description "K — material factor" is added for the formula.

In item ① of the existing subparagraph 2.20.4.2(3), the formula "$W = 1.064\ spl^2$ cm^3" is replaced by "$W = 1.064\ Kspl^2$ cm^3", and a new description "K — material factor" is added for the formula.

In item ③ of the existing subparagraph 2.20.4.2(3), the formula "$W = 1.064\ spl^2$ cm^3" is replaced by "$W = 1.064\ Kspl^2$ cm^3", and a new description "K — material factor" is added for the formula.

The existing paragraph 2.20.5 is replaced by the following:

"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."

The existing Section 23 is replaced by the following:

"Section 23 STRENGTHENING FOR GRABS

2.23.1 General requirements

2.23.1.1 This Section applies to bulk carriers. The bulk carriers covered by this Section are intended primarily to carry dry cargo in bulk, and include such types as ore carriers and combination carriers.

2.23.2 Class notation

2.23.2.1 The class notation Grab (X) is assigned to ships with holds designed for loading/unloading by grabs having a maximum specific weight up to (X) tons, in compliance with the requirements of this Section.

2.23.3 Structural strengthening

2.23.3.1 The net thickness t_{GR}, in mm, of the inner bottom plating is not to be less than that obtained from the following formula:

$$t_{GR} = 0.28(M_{GR} + 50)\sqrt{sK} + t_c \quad \text{mm}$$

where: M_{GR}— mass of unladen grab, in tons;
s — spacing, in m, of ordinary stiffeners, measured at mid-span;
K — material factor;
t_c — corrosion addition, in mm, see relevant requirements of Section 3, Chapter 3, PART TEN of the Rules.

2.23.3.2 The thickness t_{GR}, in mm, of hopper tank sloping plate, transverse lower stool, transverse bulkhead plating and inner hull up to a height of 3.0 m above the lowest point of the inner bottom, excluding bilge wells, is to be not less than the value obtained from the following formula:

$$t_{GR} = 0.28(M_{GR} + 42)\sqrt{sK} + t_c \quad \text{mm}$$

where: M_{GR}— mass of unladen grab, in tons;
s — spacing, in m, of ordinary stiffeners, measured at mid-span;
K — material factor;
t_c — corrosion addition, in mm, see relevant requirements of Section 3, Chapter 3, PART TEN of the Rules."

CHAPTER 3 EQUIPMENT AND OUTFITS

Section 1 RUDDERS

The existing paragraph 3.1.8.7 is deleted, and the existing paragraph 3.1.17 is renumbered as 3.1.18.

The existing paragraph 3.1.15 is replaced by the following:

"3.1.15 Quadrants and tillers

3.1.15.1 The section modulus W of the tiller at any section from the centre of the rudder stock about the vertical axis is not to be less than that obtained from the following formula:

$$W = 0.14(1 - \frac{D_s}{R})D_t^3 \quad \text{mm}^3$$

where: D_s — distance from the section under consideration to the centerline of the stock on the tiller, not greater than the bore diameter of the pin, in mm, see Figure 3.1.15.2;
D_t — stock diameter, in mm, at the tiller, calculated according to 3.1.5.1 of this Section;
R — radius of quadrant or length of tiller, in mm.

For quadrants having more than one arm, the combined section modulus of the arms is not to be less than that required in the above formula.

For tillers of rectangular section, the breadth to depth ratio is not to be more than 2.

3.1.15.2 Depth of boss of the quadrant or tiller $h \geq 1.0D_t$, and its outside diameter $D_0 \geq 1.8D_t$, see Figure 3.1.15.2. Where the depth of boss of the tiller h is greater than D_t, the required outer diameter D_0 can be reduced accordingly. It is to be ensured that $h \times D_0^2 \geq 1.8D_t^3$, and D_0 cannot be less than $1.6D_t$ in any case. The definition of D_t is the same as in 3.1.15.1 of this Section.

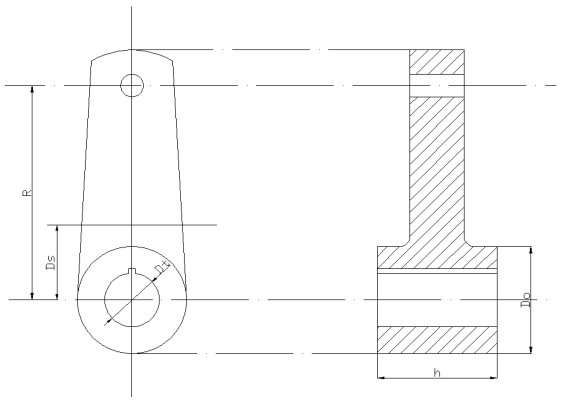


Figure 3.1.15.2

3.1.15.3 Where the boss of a tiller (quadrant) is composed of two half pieces, at least one key is to be fitted and each end of the key is to be secured by at least 2 bolts. The bolts are to be pretightened and the prestressing force on each bolt is to correspond to 70% of the permissible stress of bolt material. Where double keys are used, the prestressing force can be reduced appropriately. The total cross-sectional area A_b of all bolts is not to be less that obtained by the following formula:

$$A_b = 0.2 \times \frac{D_t^3}{b} \quad \text{mm}^2$$

where: D_t — diameter of the rudder stock, in mm, at the tiller, calculated according to 3.1.5.1 of this Section;
b — distance from the centerline of the bolt to that of the stock, in mm.

3.1.15.4 The cross-sectional area A_r and moment of inertia I_r of the rod connecting the tiller (quadrant) to the tiller are not to be less than those obtained from the following formulas:

$$A_r = 0.12 \times \frac{D_t^3}{R} \quad \text{mm}^2$$

$$I_r = 6.6 \times \frac{D_t^3 l^2}{R} \quad \text{mm}^4$$

where: D_t — diameter of the rudder stock, in mm, at the tiller of a passive rudder, calculated according to 3.1.5.1 of this Section;
l — length of the connecting rod, in mm;
R — length of the tiller of the passive rudder, in mm.

3.1.15.5 For a rotary vane type steering gear, the rotor and blades of the gear are to comply with the requirements of 3.1.15.1 and 3.1.15.2 for boss of the tiller and the tiller. ”

A new paragraph 3.1.17 is added as follows:

“3.1.17 Connection of rudder tiller to stock

3.1.17.1 The connection of the rudder tiller to stock is to be such that mechanical forces are transmitted from the steering gear to the rudder stock in any operational condition. The torque T_d transmitted by such connection is not to be less than twice the design torque of the steering gear, but need not be greater than the design yield torque T_f of the stock calculated according to 3.1.8.4 of this Section. The design torque of the steering gear is corresponding to the design pressure in 13.1.6.5 of Chapter 13, PART THREE of the Rules.

3.1.17.2 For torque transmission by friction, the average surface pressure p_r for the connection of tiller to stock is not to be less than that obtained from the following formula:

$$p_r \geq \frac{2T_{fr}}{\pi D_m^2 l f} \times 10^3 \quad \text{N/mm}^2$$

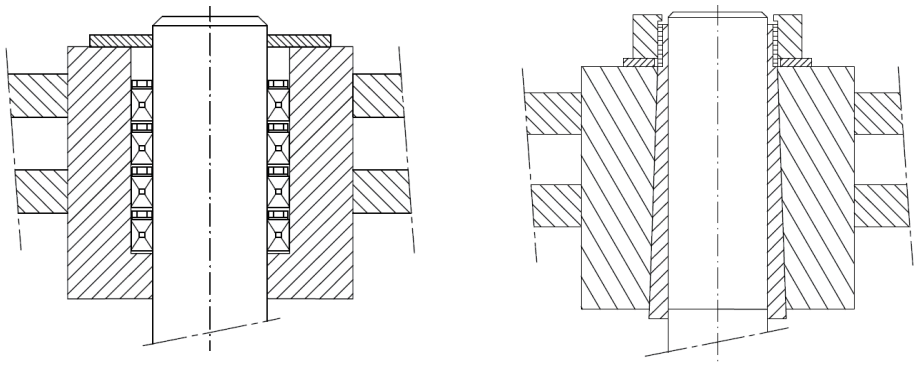
where: T_{fr} — torque transmitted by friction, in N·m;
= T_d, for keyless connection;
= $0.5T_d$, for keyed connection;
T_d — torque transmitted through connection of tiller to stock, in N·m, determined according to 3.1.17.1 of this Section;
D_m — diameter of the tiller or mean diameter of the taper, in mm;
l — length of the effectively connected portion of the tiller, in mm;
f — coefficient of friction, taken as 0.15 for hydraulic fit or 0.18 for dry fit.

3.1.17.3 For conical connection, nuts are to be used for securing against axial displacement. The size of nuts is to comply with the requirements of 3.1.8.5 of this Section.

3.1.17.4 Where the tiller is connected to the stock by means of several expansion sleeves or conical sleeves, as indicated in Figure 3.1.17.4, the influence of axial forces is also to be taken into account. In this case, the torque T_{d1} transmitted by the connection of tiller to stock is not to be less than that obtained from the following formula:

$$T_{d1} = \sqrt{T_d^2 + (2 \times W \times D_m)^2 \times 10^{-4}} \qquad \text{N·m}$$

where: T_d — torque, in N·m, determined according to 3.1.17.1 of this Section;
W — weight of rudder and rudder stock, in kg;
D_m — diameter of rudder stock, in mm.



(a) Expansion sleeve (b) Conical sleeve

Figure 3.1.17.4

3.1.17.5 The taper of cone on diameter is to be not greater than 1:15 for keyless conical connection and not greater than 1:10 for keyed conical connection.

3.1.17.6 For keyed connection, the shear area A_s of the key is not to be less than that obtained from the following formula:

$$A_s = \frac{70\left(T_d - k_{key} T_{fr}\right)}{D_k R_{eH}} \qquad \text{cm}^2$$

where: T_d — torque transmitted through connection of tiller to stock, in N·m, calculated according to 3.1.17.1 of this Section;
k_{key} — coefficient, determined as follows:
= 0.7 where boss of tiller is composed of two half pieces and secured by bolts;
= 0.9 for hydraulic fitting of tiller to stock;
= 1.0 in other cases.
T_{fr} — torque transmitted by friction, in N·m, calculated according to the following formula:

$$T_{fr} = \frac{\pi p_r D_m^2 l f}{2} \times 10^{-3}$$

where: p_r — average surface pressure for the connection of tiller to stock, in N/mm², determined according to 3.1.17.2 of this Section. Where hydraulic fitting or shrinkage fit is adopted for the conical connection, the average push-up surface pressure is to be taken;
D_m, l, f — same as in 3.1.17.2 of this Section;
D_k — mean diameter, in mm, of rudder stock cone in way of the position where the key is fitted;
R_{eH} — yield stress, in N/mm², of key material.

3.1.17.7 For keyed connections, the compressed area A_k of keys (round edge portion not included) is not to be less than that obtained from the following formula:

$$A_k = \frac{22\left(T_d - k_{key} T_{fr}\right)}{D_k R_{eH}} \qquad \text{cm}^2$$

where: T_d, k_{key}, T_{fr}, D_k — same as in 3.1.17.6 of this Section;
R_{eH} — yield stress, in N/mm², of key material.

3.1.17.8 Where two keys are fitted, the shear area A_s and compressed area A_k of each key can be taken as 2/3 of the value obtained for one key.

3.1.17.9 The keyway is to have an adequately rounded end. The radius of curvature is usually not to be less than 5% of the thickness of the key. The compressive stress on the stock/tiller keyway is not to exceed 90% of the yield stress of the material used.

3.1.17.10 Where the hydraulic fitting or shrinkage fit is adopted for the conical connection, the push-up length and the average push-up surface pressure are to be determined in accordance with the following requirements:

(1) The push-up length S is to meet the following:

$$S_1 \le S \le S_2$$

The minimum push-up length S_1 $\quad S_1 = \frac{1}{k_1}[\frac{2p_r D_m k_2^2}{E(k_2^2-1)} + 0.02]$ mm

The maximum push-up length S_2 $\quad S_2 = \frac{1}{k_1}[1.4R_{eH}D_m \frac{k_2^2}{E\sqrt{3k_2^4+1}} + 0.02]$ mm

where: p_r — average surface pressure for the connection of tiller to stock, in N/mm^2, determined according to 3.1.17.2 of this Section;
k_1 — taper of cone on diameter;
$k_2 = (D_m + 2t_a)/D_m$;
D_m — mean diameter of cone, in mm;
t_a — mean thickness of boss of tiller, in mm;
R_{eH} — yield stress of material of boss of tiller or rudder stock, whichever is less, in N/ mm^2;
E — elastic modulus, to be taken as 2.06×10^5, in N/mm².

(2) The average push-up surface pressure P is to be calculated by the following formula:

$$P = \frac{SE(k_2^2-1)k_1}{2D_m k_2^2} \quad \text{N/mm}^2$$

where: k_1, k_2, D_m and E — same as in (1) above;
S — the push-up length determined in accordance with (1) above, in mm."

Section 2 ANCHORING AND MOORING EQUIPMENT

The following sentences are added at the end of the existing paragraph 3.2.1.1:

"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 current speed of 2.5 m/sec, wind speed of 25 m/sec and a scope of chain cable between 6 and 10, the scope being the ratio between length of chain paid out and water depth.

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 following sentences are added at the end of the existing paragraph 3.2.1.2:

"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 below as A_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."

A new Figure 3.2.1.2 is added as follows:
"

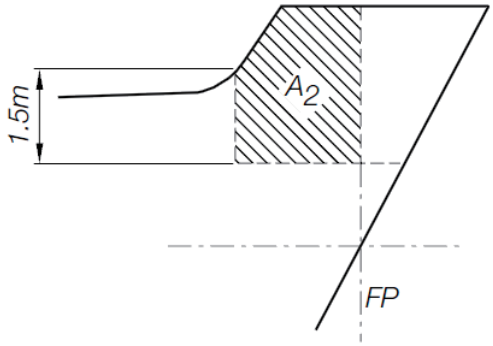


Figure 3.2.1.2"

Section 7 SUPPORT STRUCTURE FOR DECK EQUIPMENT

In the existing Table 3.7.2.7, the words "Type of structural member" are replaced by "Type of element", the words "Beam/Cross beams" are replaced by "Beam element".

In the existing Table 3.7.4.12, the words "Type of structural member" are replaced by "Type of element", the words "Beam/Cross beams" are replaced by "Beam element".

CHAPTER 4 STRENGTHENING FOR NAVIGATION IN ICE

Section 1 GENERAL PROVISIONS

The existing paragraph 4.1.1.2 is replaced by the following:

"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."

Section 2 ICE STRENGTHENING FOR CLASSES B1*, B1, B2 AND B3

In the existing subparagraph 4.2.4.6(2), the words "taken as $M = 0.193Fl$, where F is given in 4.2.4.6(1);" are replaced by "taken as $M = 0.193Fl$, where F is given in 4.2.4.6(1) and l is span of web frames;".

Section 3 ICE STRENGTHENING FOR CLASS B

In the existing paragraph 4.3.2.3, the following text is added at the end:

"Where it is difficult to fit intermediate longitudinals and such longitudinals will be spaced not more than 700 mm apart, they may be dispensed with, provided that the plate thickness t within the region complies with the following formula:

$$t = 1.58t_0, \text{ but need not be greater than 25 mm}$$

where: t_0 — the Rule thickness of amidships shell plating according to Section 3, Chapter 2 of this PART, in mm."

The existing paragraph 4.3.2.4 is replaced by the following:

"4.3.2.4 Tripping brackets or similar supports against tripping are to be fitted in way of an inclined frame fitted to the ice shell plating in the fore peak or within the region from the stem to $0.075L$ (where the latter has a larger scope than the former) in accordance with 4.2.4.4(4)(b)."

CHAPTER 5 DOUBLE HULL OIL TANKERS

Section 1 GENERAL PROVISIONS

A new paragraph 5.1.9 is added as follows:

"5.1.9 Material factor

5.1.9.1 Unless otherwise stated, the value of the material factor K is to comply with the requirements of Section 5, Chapter 1 of this PART.

5.1.9.2 For calculation of the longitudinal strength, K is to be taken as $235/R_{eH}$ for stainless steel ($235/R_{eH}$ being the yield stress of stainless steel, in N/mm^2) and not less than 0.72.

5.1.9.3 For calculation of the local strength where the boundaries of liquid cargos are of stainless steel, K is to be not less than 0.72 and comply with the following requirements:

(1) For duplex stainless steel, K is to be not less than the value obtained by the following formula:

$$K = \frac{235}{-65\ln(T) + 200 + R_{eH}}$$

(2) For austenitic stainless steel containing no nitrogen, K is to be not less than the value obtained by the following formula:

$$K = \frac{235}{-40\ln(T) + 127 + R_{eH}}$$

(3) For austenitic stainless steel containing nitrogen, K is to be not less than the value obtained by the following formula:

$$K = \frac{235}{-48\ln(T) + 142 + R_{eH}}$$

where: T— maximum design temperature for carriage of liquid cargo, in℃, to be taken not less than 35℃."

Section 7 PLANE TRANSVERSE OILTIGHT BULKHEADS

The existing paragraph 5.7.2.2 is replaced by the following:

"5.7.2.2 The thickness t of the bulkhead plating is to comply with the following requirements:

(1) Where horizontal girders and vertical stiffeners are fitted on the bulkhead:

$t \geq \frac{s}{70\sqrt{K}}$ mm, for the upper 3/4 of the bulkhead

$t \geq \frac{s}{60\sqrt{K}}$ mm, for the lower 1/4 of the bulkhead

(2) Where vertical webs and horizontal stiffeners are fitted on the bulkhead:

$$t \geq \frac{s}{85\sqrt{K}} \quad \text{mm, for the upper 3/4 of the bulkhead}$$

$$t \geq \frac{s}{70\sqrt{K}} \quad \text{mm, for the lower 1/4 of the bulkhead}$$

where: s — spacing of stiffeners, in m;

K — material factor. In the case of higher tensile steel where the material factor for a lower strength level can still satisfy the requirements for plate buckling check (see also paragraph 1.14.9, Chapter 1 of this PART) in direct calculation, the value of K for a lower strength level may be taken."

CHAPTER 6 SINGLE HULL OIL TANKERS

Section 1 GENERAL PROVISIONS

A new paragraph 6.1.4 is added as follows:

"6.1.4 Minimum thickness

6.1.4.1 The minimum thicknesses of structural members in cargo tank regions, pump rooms, cofferdams and other void spaces are to comply with the requirements of 5.1.6 of Section 1, Chapter 5 of this PART."

Section 8 TRUNK STRUCTURE

The existing paragraph 6.8.1.3 is replaced by the following:

"6.8.1.3 For the calculation of side, deck, bottom and bulkhead scantlings where the moulded depth D is involved, it is to be replaced by the design moulded depth D_1; where the design pressure head is measured to deck at side, it is to be increased by $(D_1\text{-}D)$."

CHAPTER 7 CONTAINER SHIPS

Appendix 2 DIRECT STRENGTH CALCULATION OF CONTAINER SHIPS

The existing paragraph 2.5.4.5 is deleted.

CHAPTER 8 BULK CARRIERS

Section 3 SIDE FRAMING

In the existing paragraph 8.3.3.4, the words “the vertical distance measured between the intersections of sloping plating with the side shell” are replaced by “the distance measured between the intersection of sloping plating with the side shell”.

Section 6 TOPSIDE TANKS

In the existing paragraph 8.6.2.1, the formulas “$t = 4s\sqrt{h} + 2.5$ mm” and “$t = 12s$ mm” are replaced by “$t_1 = 4s\sqrt{h} + 2.5$ mm” and “$t_2 = 12s$ mm” respectively.

Section 11 EVALUATION OF SCANTLINGS OF HATCH COVERS OF CARGO HOLDS

In the existing paragraph 8.11.3.6(1), the sentence “The biaxial compressive stress in the hatch cover panels, when calculated by means of FEM shell element model, is to be in accordance with the requirements of 1.14.9, Chapter 1 of this PART.” is replaced by “The biaxial compressive stress in the hatch cover panels, when calculated by means of FEM shell element model, is to be in accordance with the requirements of 2.20.2.6, Chapter 2 of this PART.”

Section 14 DOUBLE SIDE STRUCTURE

In the existing paragraph 8.14.6.1, the formulas “$t = 4s\sqrt{h} + 3.5$ mm” and “$t = 12s$ mm” are replaced by “$t_1 = 4s\sqrt{h} + 3.5$ mm” and “$t_2 = 12s$ mm” respectively.

CHAPTER 9 ROLL ON-ROLL OFF SHIPS, PASSENGER SHIPS, RO-RO PASSENGER SHIPS AND FERRIES

Section 4 BOW DOORS AND INNER DOORS

In the existing subparagraph 9.4.3.1(1), a new paragraph is added after the words "…with the considered point being the same as that of angle, see Figure 9.4.3.1(1);":

"*h* — height, in m, of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser."

The following sentence is added at the end of the existing subparagraph 9.4.3.1(2):

"For bow doors, including bulwark, of unusual form or proportions, e.g. ships with a rounded nose and large stem angles, the areas and angles used for determination of the design values of external forces are to be specially considered."

The existing subparagraph 9.4.5.1(1) is replaced by the following:

"(1) Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure given in 9.4.3.2(1) and permissible stresses given in 9.4.2.1 of this Section. Normally, formulae for simple beam theory may be applied."

PART THREE MACHINERY INSTALLATIONS

CHAPTER 1 GENERAL

Section 2 GENERAL PROVISIONS

A new paragraph 1.2.9.5 is added as follows:

"1.2.9.5 Ships using distillates with a sulphur content not more than 0.10% m/m are to comply with the relevant requirements of this PART and in addition, the requirements of CCS Guidelines for Use of Low Sulphur Fuel Oils in Ships."

CHAPTER 2 PUMPING AND PIPING SYSTEMS

Section 6 PUMPS, VALVES AND FITTINGS

In the existing paragraph 2.6.2.8, the words “, but need not exceed the design pressure plus 7 MPa” are deleted.

CHAPTER 3 SHIP'S PIPING AND VENTILATING SYSTEMS

Section 10 AIR, OVERFLOW AND SOUNDING PIPES

The following sentence is added at the end of the existing paragraph 3.10.4.1:

"When an air pipe serves several tanks, the sectional area of the air pipe is to be at least the combined area of the largest air pipes for two tanks."

The following sentence is added at the end of the existing paragraph 3.10.5.1:

"When an air pipe serves several tanks, the air pipe of one tank is not to be considered as the overflow pipe of another tank, except the shared overflow pipe connected to the overflow tank."

The following sentence is added at the end of the existing paragraph 3.10.6.1:

"When an overflow pipe serves several tanks, the sectional area of the overflow pipe is to be at least the combined area of the largest overflow pipes for two tanks."

CHAPTER 6 BOILERS AND PRESSURE VESSELS

Section 2 DESIGN AND MANUFACTURE

In the existing paragraph 6.2.5.1, the following sentence is added at the end of the description for R^{T}_{m10000}:

"In general, it is to be selected according to the relevant requirements of CCS Rules for Materials and Welding when the metal temperature is more than 350℃."

Below the existing paragraph 6.2.6.1, the paragraph number "6.2.6.2" is added before the sentence "For boilers of Class II and pressure vessels of Classes II and III…".

CHAPTER 7 STEAM TURBINES

Section 4 FITTINGS

The existing paragraph 7.4.2.1 is replaced by the following:

"7.4.2.1 Main ahead turbines are to be provided with a quick acting device which will automatically shut off the steam supply in the case of dangerous lowering of oil pressure in the bearing lubricating system. This device is to be so arranged as not to prevent the admission of steam to the astern turbine for braking purposes.
Where deemed necessary, appropriate means are to be provided to protect the turbines in case of:

(1) abnormal axial rotor displacement (see 7.4.4 Protective devices for axial displacement);

(2) excessive condenser pressure;

(3) high condensate level."

A new paragraph 7.4.2.2 is added as follows:

"7.4.2.2 Auxiliary turbines having governors operated other than hydraulically in which the lubricating oil is inherent in the system, are to be provided with an alarm device and a means of shutting off the steam supply in the case of lowering of oil pressure in the bearing lubricating oil system."

The existing paragraph 7.4.2.2 is renumbered as 7.4.2.3.

CHAPTER 8 GAS TURBINES

Section 4 FITTINGS

A new paragraph 8.4.9 is added as follows:

"8.4.9 Safety protection

8.4.9.1 Main gas turbines are to be equipped with a quick closing device (shut-down device) which automatically shuts off the fuel supply to the turbines at least in case of:

(1) overspeed;

(2) unacceptable lubricating oil pressure drop;

(3) loss of flame during operation;

(4) excessive vibration;

(5) excessive axial displacement of each rotor (except for gas turbines with rolling bearings);

(6) excessive high temperature of exhaust gas;

(7) unacceptable lubricating oil pressure drop of reduction gear;

(8) excessive high vacuum pressure at the compressor inlet."

A new paragraph 8.4.10 is added as follows:

"8.4.10 Alarming devices

8.4.10.1 Main gas turbines are to be provided with alarming devices in accordance with the requirements of Table 8.4.10.1.

8.4.10.2 Suitable alarms are to be operated by the activation of shutdown devices.

Alarms and Safeguards for Main Gas Turbines Table 8.4.10.1

Monitoring parameter	Alarm	Shutdown
Turbine speed	Overspeed	Overspeed
Lubricating oil pressure	Low*	Too low
Lubricating oil pressure of reduction gear	Low*	Too low
Differential pressure across lubricating oil filter	Large	
Lubricating oil temperature	High	
Oil fuel supply pressure	Low	
Oil fuel temperature	High	
Cooling medium temperature	High	
Bearing temperature	High	
Flame and ignition	Failure	Failure
Automatic starting	Failure	
Vibration	Large*	Too large
Axial displacement of rotor	Large	Large
Exhaust gas temperature	High*	Too high
Vacuum pressure at the compressor inlet	High*	Too high
Control system	Loss	

Note: Alarms marked with "*" are to be activated at the suitable setting points prior to arriving the critical condition for the activation of shutdown devices."

CHAPTER 9 DIESEL ENGINES

Section 1 GENERAL PROVISIONS

In the existing paragraph 9.1.10.1, the existing item (4) is deleted and the existing items (5) to (18) are renumbered as (4) to (17) accordingly.

The existing item (11) in paragraph 9.1.10.2 is replaced by the following:

"(11) Arrangement of foundation (for main engines only, including foundation bolts, chocks and stoppers);".

Section 2 MATERIALS

In the third line of the existing Table 9.2.2.3, "UT" is replaced by "UT③".

A new note ③ is added for the existing Table 9.2.2.3 as follows:

"③ Ultrasonic tests may be omitted for connecting rods of the diesel engine having a cylinder bore of less than 200 mm."

Section 7 FITTINGS

A new paragraph 9.7.6.4 is added as follows:

"9.7.6.4 Definitions for low-speed, medium-speed and high-speed engines are as follows:

Low-Speed Engines means diesel engines having a rated speed of less than 300 r/min;

(2) Medium-Speed Engines means diesel engines having a rated speed of 300 r/min and above, but less than 1,400 r/min;

(3) High-Speed Engines means diesel engines having a rated speed of 1,400 r/min and above."

Footnote ① of the existing paragraph 9.7.6 is replaced by the following:

"① Paragraph 9.7.6.4 applies to engines when an application for certification of an engine is dated on or after 1 January 2015 or which are installed in new ships for which the date of contract for construction is on or after 1 January 2015."

Appendix 4 PROGRAM FOR TYPE TESTING OF NON-MASS PRODUCED I.C. ENGINES

In "General Requirements", the sentence ", and the load points for the test may be selected according to the range of application." is added after the sentence "Engines which are subject to type testing are to be tested in accordance to the scope as specified below".

In the existing paragraph 2.1, the sentence "The load points may be selected according to the range of application." is deleted.

CHAPTER 10 TRANSMISSON GEARING

Sections 1, 2 and 3 of Appendix 1 are replaced by the following:

"Appendix 1 APPRAISAL OF GEAR STRENGTH①

1 General

1.1 Application

1.1.1 This Appendix is applicable to the enclosed speed reduction gearing used by main propulsion machinery and driving auxiliary machinery of a ship and a mobile drilling unit, where the transmitted power is equal to or more than 100 kW.

1.1.2 This Appendix is applicable to strength appraisal of involute spur and helical gears having parallel axis, and of bevel gears having transverse contact ratio ε_{va} for equivalent cylindrical gear.

1.1.3 This Appendix includes tooth surface contact stress, tooth root bending stress and alignment of gearbox shafting.

1.1.4 The strength appraisal method of this Appendix is only to consider steel gears with infinite life.

1.2 Symbol, name and unit

1.2.1 The main symbols used in this Appendix are listed below. Other symbols introduced in connection with the definition of influence factors are described in the appropriate sections.

a — centre distance, in mm;
b — common face width, in mm;
$b_{1,2}$ — face width of pinion, wheel, in mm;
b_e — effective face width, in mm;
$d_{1,2}$ — reference diameter of pinion, wheel, in mm;
$d_{a1,2}$ — tip diameter of pinion, wheel, in mm;
$d_{b1,2}$ — base diameter of pinion, wheel, in mm;
$d_{f1,2}$ — root diameter of pinion, wheel, in mm;
$d_{w1,2}$ — working pitch diameter of pinion, wheel, in mm;
$d_{e1,2}$ — out pitch diameter of pinion, wheel, in mm;
F_t — nominal tangential load, in N;
$h_{1,2}$ — tooth depth, in mm;
$h_{a1,2}$ — addendum, in mm;
$h_{f1,2}$ — dedendum, in mm;
h_{ao} — addendum of cutter, in mm;
$h_{F1,2}$ — bending moment arm for load acting at the outer point of single tooth pair contact for pinion, wheel, in mm;

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① The requirements of this Appendix are to be uniformly implemented from 1 January 2015 to any marine gear subject to approval and to any type approved marine gear from the date of the first renewal after 1 January 2015. For a marine gear approved prior to 1 January 2015 where no failure has occurred, and no changes in design/scantlings of the gear meshes or materials or declared load capacity data have taken place, the requirements of this Appendix may be waived.

HV — Vickers hardness;

HRC — Rockwell hardness;

HB — Brinell hardness;

m_n — normal module, in mm;

$n_{1,2}$ — rotational speed of pinion, wheel, in r/min;

N_L — number of load cycles;

P — maximum continuous power or nominal power transmitted by the gear set (determined according to purpose), in kW;

P_{ro} — protuberance of tool, in mm;

P_{bt} — plane base terminal, in mm;

q_s — base circle parameter;

R_a — arithmetic mean of roughness, in μm;

R_z — mean peak-to-valley roughness, in μm;

S_{Fn} — tooth root chord in the critical section, in mm;

$T_{1,2}$ — torque in way of pinion, wheel, in N·m;

u — gear ratio;

V — linear velocity at pitch diameter, in m/s;

x — addendum modification coefficient of pinion, wheel;

$x_{hm1,2}$ — profile shift coefficient (midface);

$x_{sm1,2}$ — tooth thickness modification coefficient (midface);

$z_{1,2}$ — number of teeth;

$z_{n1,2}$ — virtual number of teeth;

$\alpha_{Fen1,2}$ — normal pressure angle relevant to direction of application of load at the outer point of single pair tooth contact of pinion, wheel, in º;

α_{pro} — cutter boss angle, in º;

α_n — normal pressure angle at reference cylinder, in º;

α_t — transverse pressure angle at reference cylinder, in º;

β — helix angle at reference cylinder, in º;

β_b — helix angle at base cylinder, in º;

ε_α — transverse contact ratio;

ε_β — overlap ratio;

ε_γ — total contact ratio;

$\rho_{ao1,2}$ — tip radius of tool of pinion, wheel, in mm;

$\rho_{F1,2}$ — root fillet radius at the 30º tangent point, in mm;

R_m — tensile strength, in N/mm²;

R_{eH} — yield point, in N/mm²;

$\delta_{1,2}$ — reference cone angle of pinion, wheel, in º;

$\delta_{a1,2}$ — tip angle of pinion, wheel, in º;

Σ — shaft angle, in º;

β_m — mean spiral angle, in º;

S — cone distance, in mm;

S_m — middle cone distance, in mm;

S_e — outer cone distance, in mm.

In calculation, pinion and wheel are indicated respectively by subscript 1 and subscript 2.

1.3 Definitions①

1.3.1 For the purpose of this Appendix:

(1) For internal gears, z_2, a, d_{a2}, d_2, d_{b2}, d_{w2} are negative.

(2) The pinion is defined as the gear with the less teeth, therefore:

$$|u| = \frac{|z_2|}{z_1} \geq 1$$

where: for external gears, u is positive; for internal gears, u is negative.

(3) In the equation of surface durability, b is the common face width on the pitch diameter.

(4) In the equation of tooth root bending stress, b_1 and b_2 are the face widths at the respective tooth roots. In any case, b_1 and b_2 are not to be taken as greater than b by more than one module m_n on either side.

(5) The common face width b may be used also in the equation of teeth root bending stress if significant crowning or end relief has been adopted.

(6) Geometry equations concerned are as follows:

$$\tan\alpha_t = \tan\alpha_n / \cos\beta$$

$$\tan\beta_b = \tan\beta\cos\alpha_t$$

$$d_{1,2} = z_{1,2}m_n / \cos\beta$$

$$d_{b1,2} = d_{1,2}\cos\alpha_t$$

$$d_{W1} = \frac{2a}{u+1}$$

$$d_{W2} = \frac{2au}{u+1}$$

$$a = 0.5(d_{w1} + d_{w2})$$

$$z_{n1,2} = z_{1,2} / (\cos^2\beta_b \cdot \cos\beta)$$

$$m_t = m_n / \cos\beta$$

$$inv\alpha = \tan\alpha - \pi\alpha / 180\,, \quad \alpha(°)$$

$$inv\alpha_{tw} = inv\alpha_t + 2\tan\alpha_n(x_1+x_2)/(z_1+z_2) \quad \text{or} \quad \cos\alpha_{tw} = \frac{m_t(z_1+z_2)}{2a}\cos\alpha_t$$

$$\alpha_{tw} = \arccos\left(\frac{d_{b1}+d_{b2}}{2a}\right), \quad \alpha_{tw}(°)$$

$$x_{hm1} + x_{hm2} = \frac{\left(z_1+z_2\right)\cdot\left(inv\alpha_{tw} - inv\alpha_t\right)}{2\tan\alpha_n}$$

$$x_{hm1,2} = \frac{h_{ao}}{m_n} - \frac{d_{1,2} - d_{f1,2}}{2m_n}$$

$$\varepsilon_\alpha = \frac{0.5\sqrt{d_{a1}^2 - d_{b1}^2} \pm 0.5\sqrt{d_{a2}^2 - d_{b2}^2} - a\sin\alpha_{tw}}{\pi \cdot m_t \cdot \cos\alpha_t}$$

where the positive sign is used for external gears, the negative sign for internal gears.

① The following definitions are mainly based on the ISO 6336 standard for the calculation of load capacity of spur and helical gears.

$$\varepsilon_\beta = \frac{b \cdot \sin\beta}{\pi m_n}$$

where for double helix, b is to be taken as the width of one helix.

$$\varepsilon_r = \varepsilon_\alpha + \varepsilon_\beta$$

$$v = \frac{\pi \cdot d_{1,2} n_{1,2}}{60 \cdot 10^3}$$

$$P_{bt} = \pi m_n \cos\alpha_t / \cos\beta$$

1.3.2 Equations for bevel gears

1.3.2.1 The calculation of bevel gear strength is technically based on the equivalent cylindrical gear at the bevel gear midsection. The calculation of geometric parameters of the equivalent cylindrical gear is shown in 1.3.2.3 of this Appendix.

1.3.2.2 Index m refers to the midsection of bevel gear; index v refers to the virtual (equivalent) cylindrical gear.

1.3.2.3 The geometric parameters of the equivalent cylindrical gear are to be calculated as follows:

(1) Number of teeth z_v:

$$z_{v1,2} = \frac{z_{1,2}}{\cos\delta_{1,2}}$$

For Σ = 90º:

$$z_{v1} = z_1 \frac{\sqrt{u^2+1}}{u}$$

$$z_{v2} = z_2 \sqrt{u^2+1}$$

(2) Gear ratio u_v:

$$u_v = u \frac{\cos\delta_1}{\cos\delta_2} = \frac{z_{v2}}{z_{v1}}$$

For Σ = 90º:

$$u_v = (\frac{z_2}{z_1})^2 = u^2$$

(3) Reference diameter d_v:

$$d_{v1,2} = \frac{d_{m1,2}}{\cos\delta_{1,2}} = \frac{d_{e1,2}}{\cos\delta_{1,2}} \frac{S_m}{S_e}$$

For Σ = 90º:

$$d_{v1} = d_{m1} \frac{\sqrt{u^2+1}}{u}$$

$$d_{v2} = u^2 d_{v1}$$

(4) Centre distance a_v:

$$a_v = \frac{d_{v1} + d_{v2}}{2}$$

(5) Tip diameter d_{va}:

$$d_{va1,2} = d_{v1,2} + 2h_{am1,2}$$

(6) Base diameter d_{vb}:

$$d_{vb1,2} = d_{v1,2} \times \cos\alpha_{vt}$$

$$\alpha_{vt} = \arctan(\frac{\tan\alpha_n}{\cos\beta_m})$$

(7) Helix angle at base cylinder β_{vb}:

$$\beta_{vb} = \arcsin(\sin\beta_m \cos\alpha_n)$$

(8) Transverse contact ratio $\varepsilon_{v\alpha}$:

$$\varepsilon_{v\alpha} = \frac{g_{va}\cos\beta_m}{m_{mn}\pi\cos\alpha_{vt}}$$

$$g_{va} = \frac{1}{2}\left[\sqrt{d_{va1}^2 - d_{vb1}^2} + \sqrt{d_{va2}^2 - d_{vb2}^2}\right] - a_v \sin\alpha_{vt}$$

(9) Overlap ratio $\varepsilon_{v\beta}$:

$$\varepsilon_{v\beta} = \frac{b\sin\beta_m}{m_{mn}\pi}$$

(10) Modified contact ratio $\varepsilon_{v\gamma}$:

$$\varepsilon_{v\gamma} = \sqrt{\varepsilon_{v\alpha}^2 + \varepsilon_{v\beta}^2}$$

(11) Mean addendum h_{am}:

$$h_{am1,2} = m_{mn} \times (1 + x_{hm1,2})$$

1.3.2.4 The geometric parameters of the normal section of the equivalent cylindrical gear are to be calculated as follows:

(1) Number of teeth z_{vn}:

$$z_{vn1} = \frac{z_{v1}}{\cos^2\beta_{vb}\cos\beta_m}$$

$$z_{vn2} = u_v z_{vn1}$$

(2) Reference diameter d_{vn}:

$$d_{vn1} = \frac{d_{v1}}{\cos^2\beta_{vb}} = z_{vn1} m_{mn}$$

$$d_{vn2} = u_v d_{vn1} = z_{vn2} m_{mn}$$

(3) Centre distance a_{vn}:

$$a_{vn} = \frac{d_{vn1} + d_{vn2}}{2}$$

(4) Tip diameter d_{van}:

$$d_{van1,2} = d_{vn1,2} + d_{va1,2} - d_{v1,2} = d_{vn1,2} + 2h_{am1,2}$$

(5) Base diameter d_{vbn}:

$$d_{vbn1,2} = d_{vn1,2}\cos\alpha_n = z_{vn1,2}m_{mn}\cos\alpha_n$$

(6) Contact ratio $\varepsilon_{v\alpha n}$:

$$\varepsilon_{v\alpha n} = \frac{\varepsilon_{v\alpha}}{\cos^2\beta_{vb}}$$

1.4 Nominal tangential loads F_t, F_{mt}

1.4.1 The nominal tangential loads, F_t, F_{mt}, tangential to the reference cylinder and perpendicular to the relevant axial plane, are calculated directly from the maximum continuous power or nominal power transmitted by the gear set by means of the following equations:

$$T_{1,2} = \frac{30\cdot 10^3 P}{\pi\cdot n_{1,2}}$$

Cylindrical gears:

$$F_t = \frac{2000T_{1,2}}{d_{1,2}} = \frac{19.1P\times 10^6}{n_{1,2}d_{1,2}}$$

Bevel gears:

$$F_{mt} = \frac{2000T_{1,2}}{d_{m1,2}} = \frac{19.1P\times 10^6}{n_{1,2}d_{m1,2}}$$

$$V_{mt} = \frac{d_{m1,2}n_{1,2}}{19098}$$

1.5 Relevant factors

1.5.1 Application factor K_A

1.5.1.1 The application factor K_A accounts for dynamic overloads from sources external to gearing. K_A, for gears designed for infinite life, is defined as the ratio between the maximum repetitive cyclic torque applied to the gear and the nominal rated torque.

1.5.1.2 Factor K_A mainly depends on:

(1) characteristics of driving and driven machines;

(2) ratio of masses;

(3) type of couplings;

(4) operating conditions.

1.5.1.3 The application factor K_A should be determined by measurements or by system analysis. Where a value determined in such a way cannot be supplied, the following values in Table 1.5.1.3 may be considered.

Application factor K_A **Table 1.5.1.3**

Equipment type		K_A
Main propulsion diesel engines	With hydraulic coupling or equivalent parts	1.00
	With high elasticity coupling (general angle of torsion more than 6°)	1.30
	With elasticity coupling (general angle of torsion 2° to 6°)	1.40
	With other couplings	1.50
Auxiliary gears	Electric motor and diesel engine, with hydraulic coupling or equivalent parts	1.00
	Diesel engine with high elasticity coupling (general angle of torsion more than 6°)	1.20
	Diesel engine with elasticity coupling (general angle of torsion 2° to 6°)	1.30
	Diesel engine, with other couplings	1.40

1.5.1.4 Where the ship using reduction gearing for main propulsion has an ice or PC N class notation, the nominal tangential force or the application factor is to be calculated according to the torque transmitted by reduction gearing in association with the ice or PC N class notation. See the relevant requirements in Chapter 14 of this PART or Chapter 13 of PART EIGHT.

1.5.2 Load sharing factor K_γ

1.5.2.1 The load sharing factor K_γ accounts for the maldistribution of load in multiple path transmissions (dual tandem, epicyclic, double helix, etc.).

1.5.2.2 K_γ is defined as the ratio between the maximum load through an actual path and the evenly shared load. The factor mainly depends on accuracy and flexibility of the branches.

1.5.2.3 The load sharing factor K_γ is to be determined by measurements or by system analysis. Where a value determined in such a way cannot be supplied, the following values may be considered for epicyclic gears:

up to 3 planetary gears: K_γ =1.00;

4 planetary gears: K_γ =1.20;

5 planetary gears: K_γ =1.30;

6 planetary gears and over: K_γ =1.40;

other gear arrangements: K_γ = 1.00.

Bevels:

for $\varepsilon_\gamma \leq 2$: K_γ = 1.00;

for $2 < \varepsilon_\gamma < 3.5$: $K_\gamma = 1 + 0.2\sqrt{(\varepsilon_\gamma - 2)\times(5 - \varepsilon_\gamma)}$;

for $\varepsilon_\gamma \geq 3.5$: K_γ = 1.30.

1.5.3 Internal dynamic factor K_V

1.5.3.1 The internal dynamic factor K_V accounts for internally generated dynamic loads due to vibrations of pinion and wheel against each other. K_V is defined as the ratio between the maximum load which dynamically acts on the tooth flanks and the maximum externally applied load ($F_t \bullet K_A \bullet K_y$).

1.5.3.2 The factor K_V mainly depends on:

(1) transmission errors (depending on pitch and profile errors);

(2) masses of pinion and wheel;

(3) gear mesh stiffness variation as the gear teeth pass through the meshing cycle;

(4) transmitted load including application factor;

(5) pitch line velocity;

(6) dynamic unbalance of gears and shaft;

(7) shaft and bearing stiffnesses;

(8) damping characteristics of the gear system.

1.5.3.3 Where all the following conditions are satisfied, the internal dynamic factor K_V is to be calculated as follows:

(1) running velocity in the subcritical range, i.e.:

$$\frac{v \cdot z_1}{100}\sqrt{\frac{u^2}{1+u^2}} < 10 \quad \text{m/s}$$

(2) spur gears ($\beta = 0°$) and helical gears with $\beta \leq 30°$;

(3) pinion with relatively low number of teeth, $z_1 < 50$;

(4) solid disc wheels or heavy steel gear rim.

This method may be applied to all types of gears if $\frac{v \cdot z_1}{100}\sqrt{\frac{u^2}{1+u^2}} < 3$ m/s, as well as to helical gears where $\beta > 30°$.

For gears other than the above, reference is to be made to Method B outlined in the reference standard ISO 6336-1.

(1) For spur gears and for helical gears with overlap ratio $\varepsilon_\beta \geq 1$:

$$K_V = 1 + \left(\frac{K_1}{K_A \frac{F_t}{b}} + K_2\right) \cdot \frac{v \cdot z_1}{100} K_3 \sqrt{\frac{u^2}{1+u^2}}$$

If $K_A F_t / b$ is less than 100 N/mm, this value is assumed to be equal to 100 N/mm.

Numerical values for the factor K_1 are to be as specified in Table 1.5.3.3.

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. In case of mating gears with different accuracy grades, the grade corresponding to the lower accuracy is to be used.

For all accuracy grades, the factor K_2 is to be in accordance with the following:

for spur gears, K_2=0.0193;

for helical gears, K_2=0.0087.

Factor K_3 is to be in accordance with the following:

If $\frac{v \cdot z_1}{100}\sqrt{\frac{u^2}{1+u^2}} \le 0.2$, then $K_3 = 2.0$;

If $\frac{v \cdot z_1}{100}\sqrt{\frac{u^2}{1+u^2}} > 0.2$, then $K_3 = 2.071 - 0.357\frac{v \cdot z_1}{100}\sqrt{\frac{u^2}{1+u^2}}$

(2) For helical gears with overlap ratio $\varepsilon_\beta < 1$, the value K_V is determined by linear interpolation between values determined for spur gears ($K_{v\alpha}$) and helical gears ($K_{v\beta}$) in accordance with:

$$K_V = K_{v\alpha} - \varepsilon_\beta(K_{v\alpha} - K_{v\beta})$$

where: $K_{v\alpha}$ is the K_V value for spur gears, in accordance with 1.5.3.3(1);
$K_{v\beta}$ is the K_V value for helical gears, in accordance with 1.5.3.3(1).

1.5.3.4 K_V of bevel gears is to be calculated according to 1.5.3.3, with z_1, V, F_t therein being substituted by Z_{v1}, V_{mt}, F_{mt} respectively.

1.5.4 Face load distribution factors $K_{H\beta}$ and $K_{F\beta}$

1.5.4.1 The face load distribution factors, $K_{H\beta}$ for contact stress and $K_{F\beta}$ for tooth root bending stress, account for the effects of non-uniform distribution of load across the face width.

$K_{H\beta}$ is defined as follows:

$$K_{H\beta} = \frac{\text{maximum load per unit facewidth}}{\text{mean load per unit facewidth}}$$

$K_{F\beta}$ is defined as follows:

$$K_{F\beta} = \frac{\text{maximum bending stress at tooth root per unit facewidth}}{\text{mean bending stress at tooth root per unit facewidth}}$$

1.5.4.2 The factors $K_{H\beta}$ and $K_{F\beta}$ mainly depend on:

(1) gear tooth manufacturing accuracy;

(2) errors in mounting due to bore errors;

(3) bearing clearances;

(4) wheel and pinion shaft alignment errors;

(5) elastic deflection of gear elements, shafts, bearings, housing and foundations which support the gear elements;

(6) thermal expansion and distortion due to operating temperature;

(7) compensating design elements.

1.5.4.3 The face load distribution factors $K_{H\beta}$ and $K_{F\beta}$ are to be determined according to the Method C outlined in the reference standard ISO 6336-1.

$K_{F\beta}$ is defined as follows:

$$K_{F\beta} = (K_{H\beta})^N$$

where: $N = \dfrac{(b/h)^2}{1+(b/h)+(b/h)^2}$, where (b/h) is the ratio of tooth width and tooth depth, to be taken as the minimum value of b_1/h_1 and b_2/h_2. Only one helical face width is to be taken for herringbone gear b. When $b/h <$ 3 the value $b/h = 3$ is to be used.

In case of gears where the ends of the face width are lightly loaded or unloaded (end relief or crowning): $K_{F\beta} = K_{H\beta}$,

1.5.4.4 Calculation of $K_{H\beta}$, $K_{F\beta}$ for bevel gears

(1) $K_{H\beta}$ is to be calculated as follows:

For $b_e \geq 0.85b$:

$$K_{H\beta} = 1.5K_{H\beta-b}$$

For $b_e < 0.85b$:

$$K_{H\beta} = 1.5K_{H\beta\text{-}be}\frac{0.85b}{b_e}$$

where: $K_{H\beta-b}$ — assembling factor, see Table 1.5.4.4.

Assembling Factor $K_{H\beta\text{-}be}$ **Table 1.5.4.4**

Mounting conditions of pinion and wheel		
Both members straddle mounted	One member straddle mounted	Neither member straddle mounted
1.10	1.25	1.50

(2) $K_{F\beta}$ is to be calculated as follows:

$$K_{F\beta} = \frac{K_{H\beta}}{K_{F0}}$$

where: K_{F0} — curvature factor of tine length for bending strength, depending on helix angle and curvature in the direction of tine length, to be calculated as follows:

$$K_{F0} = 0.211(\frac{r_{c0}}{S_m})^q + 0.789$$

$$q = \frac{0.279}{\lg(\sin\beta_m)}$$

where: r_{c0} — radius of tool, in mm;
S_m — middle cone distance, in mm;
β_m — helical angle at midpoint;
$K_{F0} = 1.15$, for $K_{F0} > 1.15$;
$K_{F0} = 1$, for $K_{F0} < 1$;
$K_{F0} = 1$, for straight or zero bevel gears.

1.5.5 Transverse load distribution factors $K_{H\alpha}$ and $K_{F\alpha}$

1.5.5.1 The transverse load distribution factors, $K_{H\alpha}$ for contact stress and $K_{F\alpha}$ for tooth root bending stress, account for the effects of pitch and profile errors on the transversal load distribution between two or more pairs of teeth in mesh.

1.5.5.2 The factors $K_{H\alpha}$ and $K_{F\alpha}$ mainly depend on:

(1) total mesh stiffness;

(2) total tangential load, i.e. equivalent tangential load, including load produced by K_A, K_V, $K_{H\beta}$;

(3) base pitch error;

(4) tip relief;

(5) running-in allowance.

1.5.5.3 The transverse load distribution factors $K_{H\alpha}$ and $K_{F\alpha}$ of cylindrical gears are to be determined according to Method B outlined in the reference standard ISO 6336-1.

1.5.5.4 K_{Ha} of bevel gears is to be determined as follows:

(1) Contact ratio $\varepsilon_{vr} \leq 2$ for equivalent cylindrical gear

$$= \frac{}{vr}\left[0.9 + \frac{0.4c_r(f_{pt} - y\ )}{F_{mtH}/b}\right]$$

$$F_{mtH} = F_{mt}K_AK_\gamma K_V K_{H\beta}$$

where: c_r — mesh stiffness, see 1.5.7 of this Appendix;
f_{pt} — pitch deviation of pinion or wheel, whichever is the greater;
y_α — running-in allowance, see 1.5.6 of this Appendix;
F_{mt} — nominal tangential load, see 1.4 of this Appendix;
For K_A, K_γ, K_V and $K_{H\beta}$, see 1.5 of this Appendix.

(2) Contact ratio $\varepsilon_{vr} > 2$ for equivalent cylindrical gear

$$K_{H\alpha} = 0.9 + \frac{0.4c_r(f_{pt} - y_\alpha)}{F_{mtH}/b}\sqrt{\frac{2(\varepsilon_{vr} - 1)}{\varepsilon_{vr}}}$$

(3) $K_{Ha} = 1$, for $K_{Ha} < 1$;

$K_{H\alpha} = \dfrac{\varepsilon_{vr}}{\varepsilon_{va} Z_{LS}^2}$, for $K_{H\alpha} > \dfrac{\varepsilon_{vr}}{\varepsilon_{va} Z_{LS}^2}$, where Z_{LS} is as given in 2.7 of this Appendix.

1.5.5.5 $K_{F\alpha}$ of bevel gears is to be determined as follows:

$$K_{F\alpha} = K_{H\alpha}$$

$K_{F\alpha} = 1$, for $K_{F\alpha} < 1$;

$K_{F\alpha} = \dfrac{\varepsilon_{vr}}{\varepsilon_{va} Y_\varepsilon}$, for $K_{F\alpha} > \dfrac{\varepsilon_{vr}}{\varepsilon_{va} Y_\varepsilon}$ where Y_ε is as given in 3.6 of this Appendix.

1.5.6 Running-in allowance y_a

1.5.6.1 The running-in allowance y_a is the amount due to running-in by which the mesh alignment error is reduced from the start of the operation. In lack of direct experience, the value may be calculated according to Table 1.5.6.1.

Running-in Allowance **Table 1.5.6.1**

Gear material	Running-in allowance y_a	Limitation	
		Tangential speed at reference diameter/(m/s)	Maximum running-in allowance/μm
Quenched and tempered steels	$y_\alpha = \dfrac{160 f_{pt}}{\sigma_{H\lim}}$	$v_{mt} \leq 5$	not limited
		$5 < v_{mt} \leq 10$	$y_\alpha \leq 12800/\sigma_{H\lim}$
		$v_{mt} > 10$	$y_\alpha \leq 6400/\sigma_{H\lim}$
Hardened steel and nitrided steels	$y_\alpha = 0.075 f_{pt}$	Unlimited	$y_\alpha \leq 3$
Two gears of different materials	$y_\alpha = \dfrac{y_{\alpha 1} + y_{\alpha 2}}{2}$	$y_{\alpha 1}$ to be taken for pinion material; $y_{\alpha 2}$ to be taken for wheel material	

1.5.7 Mesh stiffness c_γ

1.5.7.1 The mesh stiffness is the load to be applied on the line of contact to induce a deflection of 1 μm at 1 mm face width for one or more pairs of simultaneously meshed precision gears.

1.5.7.2 The mesh stiffness of bevel gears may be determined as follows:

$$c_\gamma = c_{\gamma 0} c_F c_b$$

where: $c_{\gamma 0}$ — mesh stiffness in the mean condition, taken as 20 N/mm·μm if no direct experience being available;
c_F and c_b — modification coefficients:

$c_F = 1$, for $F_{mt}K_A / b_e \geq 100$ N/mm;
$c_F = F_{mt}K_A/100b_e$, for $F_{mt}K_A/b_e < 100$ N/mm;
$c_b = 1$, for $b_e/b \geq 0.85$;
$c_b = b_e/0.85b$, for $b_e/b < 0.85$.

2 Surface Durability

2.1 Calculation requirements

2.1.1 The criterion for surface durability is based on the Hertz pressure on the operating pitch point or at the inner point of single pair contact. The surface contact stress σ_H must be equal to or less than the permissible contact stress σ_{HP}.

2.1.2 Surface contact stress and permissible contact stress of pinion and wheel are to be calculated respectively.

2.2 Surface contact stress σ_H

2.2.1 Surface contact stress σ_H is to be determined as follows:

$$\sigma_H = \sigma_{HO}\sqrt{K_A K_\gamma K_V K_{H\alpha} K_{H\beta}} \le \sigma_{HP}$$

where: σ_{HO} = basic value of contact stress for pinion and wheel:

(1) Cylindrical gears:

for pinion:

$$\sigma_{HO} = Z_B Z_H Z_E Z_\varepsilon Z_\beta \sqrt{\frac{F_t}{d_1 b} \times \frac{u+1}{u}} \quad \text{N/mm}^2$$

for wheel:

$$\sigma_{HO} = Z_D Z_H Z_E Z_\varepsilon Z_\beta \sqrt{\frac{F_t}{d_1 b} \times \frac{u+1}{u}} \quad \text{N/mm}^2$$

(2) Bevel gears:

$$\sigma_{HO} = Z_{M\text{-}B} Z_H Z_E Z_{LS} Z_\beta Z_K \sqrt{\frac{F_{mt}}{d_{v1} l_{bm}} \times \frac{u_v+1}{u_v}} \quad \text{N/mm}^2$$

For the shaft angle $\Sigma = \delta_1 + \delta_2 = 90°$, the following applies:

$$\sigma_{HO} = Z_{M\text{-}B} Z_H Z_E Z_{LS} Z_\beta Z_K \sqrt{\frac{F_{mt}}{d_{m1} l_{bm}} \times \frac{\sqrt{u_v+1}}{u_v}} \quad \text{N/mm}^2$$

where: Z_B — single pair tooth contact factor for pinion , see 2.3 of this Appendix;
Z_D — single pair tooth contact factor for wheel, see 2.3 of this Appendix;
$Z_{M\text{-}B}$ — mid-zone factor, see 2.3 of this Appendix;
Z_H — zone factor, see 2.4 of this Appendix;
Z_E — elasticity factor, see 2.5 of this Appendix;
Z_ε — contact ratio factor, see 2.6 of this Appendix;
Z_{LS} — load sharing factor, see 2.7 of this Appendix;
Z_K — bevel gear factor (flank), see 2.8 of this Appendix;
Z_β — helix angle factor, see 2.9 of this Appendix;
l_{bm} — length of middle line of contact, see 3.7 of this Appendix;
for K_A, K_V, $K_{H\alpha}$ and $K_{H\beta}$, see 1.5 of this Appendix.

2.2.2 Permissible contact stress σ_{HP} is to be determined as follows:

$$\sigma_{HP} = (\sigma_{H\lim} / S_H) Z_N Z_L Z_V Z_R Z_W Z_X \quad \text{N/mm}^2$$

where: $\sigma_{H\lim}$ — endurance limit for contact stress, see 2.10 of this Appendix;
Z_N — life factor for contact stress, see 2.11 of this Appendix;
Z_L, Z_V, Z_R — lubrication factor, velocity factor and roughness factor respectively, see 2.12 of this Appendix;
Z_W — hardness ratio factor, see 2.13 of this Appendix;
Z_X — size factor for contact stress, see 2.14 of this Appendix;
S_H — safety factor for contact stress, see 2.15 of this Appendix.

2.3 Single pair tooth contact factors Z_B, Z_D and mid-zone factor $Z_{M\text{-}B}$

2.3.1 The single pair tooth contact factors, Z_B for pinion and Z_D for wheel, account for the influence of the tooth flank curvature on contact stresses at the inner point of single pair contact in relation to Z_H.

The mid-zone factor $Z_{M\text{-}B}$ is used to convert the contact stress at the pitch point to the contact stress at the midpoint M of loading, see Figure 2.3.1.

2.3.2 The single pair tooth contact factors, Z_B for pinion and Z_D for wheel, are to be determined as follows:

2.3.2.1 For spur gears, $\varepsilon_\beta = 0$

(1) $Z_B = M_1$ or 1, whichever is greater:

$$M_1 = \frac{\tan \alpha_{tw}}{\sqrt{\left[\sqrt{(\frac{d_{a1}}{d_{b1}})^2 - 1} - (\frac{2\pi}{z_1})\right]\left[\sqrt{(\frac{d_{a2}}{d_{b2}})^2 - 1} - (\varepsilon_\alpha - 1)(\frac{2\pi}{z_2})\right]}}$$

(2) $Z_D = M_2$ or 1, whichever is greater:

$$M_2 = \frac{\tan \alpha_{tw}}{\sqrt{\left[\sqrt{(\frac{d_{a2}}{d_{b2}})^2 - 1} - (\frac{2\pi}{z_2})\right]\left[\sqrt{(\frac{d_{a1}}{d_{b1}})^2 - 1} - (\varepsilon_\alpha - 1)(\frac{2\pi}{z_1})\right]}}$$

2.3.2.2 For helical gears,

(1) if $\varepsilon_\beta \geq 1$, $Z_B = Z_D = 1$;

(2) if $\varepsilon_\beta < 1$, to be calculated by interpolation:

$$Z_B = M_1 - \varepsilon_\beta (M_1 - 1), \text{ and } Z_B \geq 1;$$

$$Z_D = M_2 - \varepsilon_\beta (M_2 - 1), \text{ and } Z_D \geq 1.$$

2.3.2.3 For internal gears, $Z_D = 1$.

2.3.3 Mid-zone factor $Z_{M\text{-}B}$

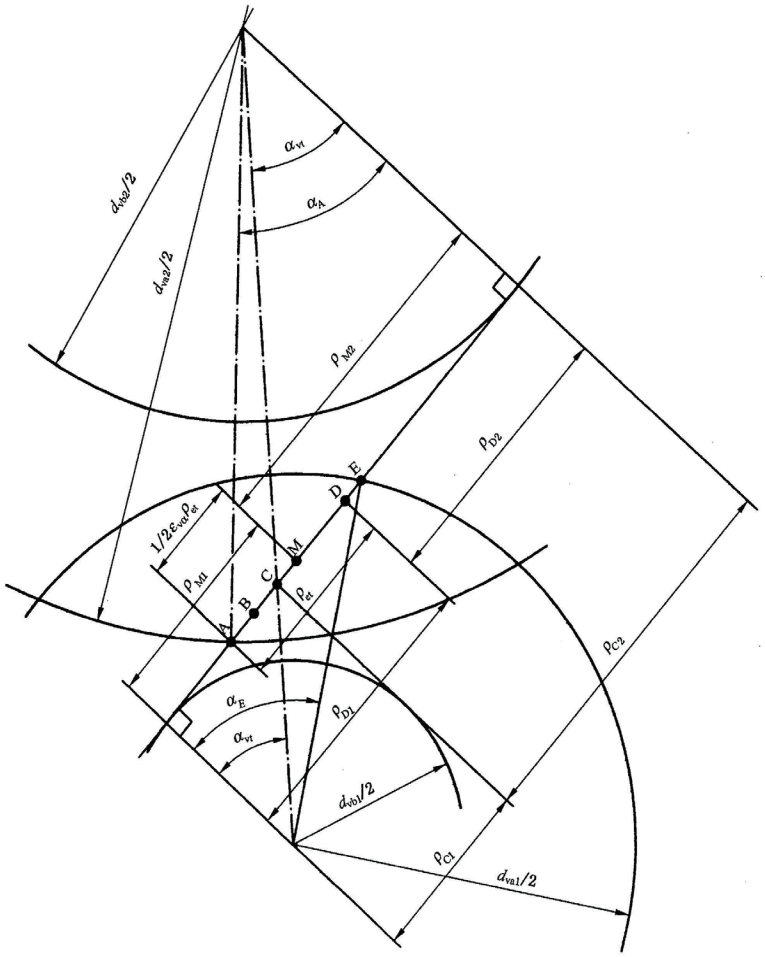


Figure 2.3.1 Radius of Curvature at Midpoint M and Single-Pair Mesh Point B of the Pinion, for Determination of Mid-Zone Factor

The factor $Z_{M\text{-}B}$ may be calculated as follows:

$$Z_{M\text{-}B} = \frac{\tan \alpha_{vt}}{\sqrt{\left[\sqrt{(\frac{d_{va1}}{d_{vb1}})^2 - 1} - F_1 \frac{\pi}{z_{v1}}\right]\left[\sqrt{(\frac{d_{va2}}{d_{vb2}})^2 - 1} - F_2 \frac{\pi}{z_{v2}}\right]}}$$

where: F_1, F_2 — auxiliary factors, see Table 2.3.3.

Auxiliary Factors for Determination of Mid-Zone Factor Table 2.3.3

Overlap ratio of equivalent cylindrical gear	F_1	F_2
$\varepsilon_{v\beta} = 0$	2	$2(\varepsilon_{v\alpha} - 1)$
$0 < \varepsilon_{v\beta} \leq 1$	$2 + (\varepsilon_{v\alpha} - 2)\varepsilon_{v\beta}$	$2\varepsilon_{v\alpha} - 2 + (2 - \varepsilon_{v\alpha})\varepsilon_{v\beta}$
$\varepsilon_{v\beta} > 1$	$\varepsilon_{v\alpha}$	$\varepsilon_{v\alpha}$

2.4 Zone factor Z_H

2.4.1 The zone factor, Z_H, accounts for the influence on the Hertzian pressure of tooth flank curvature at pitch point and transforms the tangential load at the reference cylinder to the normal load at the pitch cylinder.

2.4.2 The zone factor Z_H is to be calculated as follows:

(1) For cylindrical gears:

$$Z_H = \sqrt{\frac{2\cos\beta_b}{\cos^2\alpha_t \tan\alpha_{tw}}}$$

(2) For bevel gears:

$$Z_H = 2\sqrt{\frac{\cos\beta_{vb}}{\sin(2\alpha_{vt})}}$$

Some normal common pressure angles of bevel gears may be obtained from Figure 2.4.2.

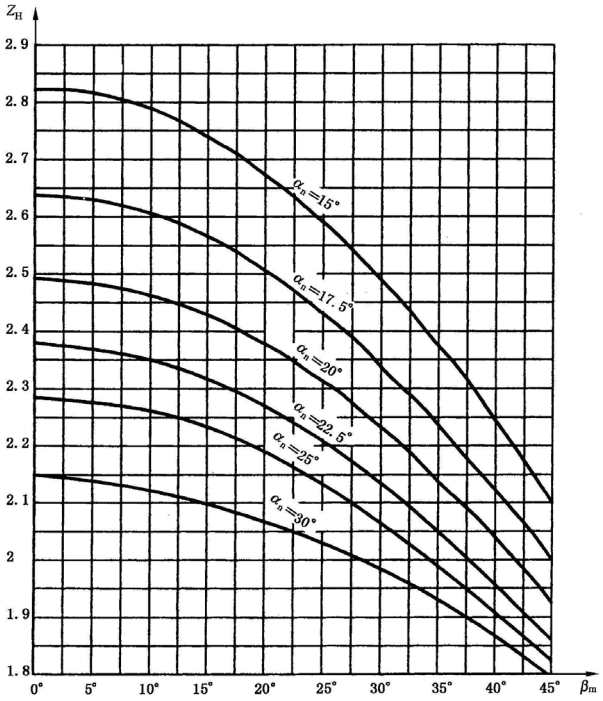


Figure 2.4.2 Zone Factor Z_H for X-Zero Bevel Gears

2.5 Elasticity factor Z_E

2.5.1 The elasticity factor, Z_E, accounts for the influence of the material properties E (modulus of elasticity) and v (Poisson's ratio) on the contact stress.

2.5.2 The factor Z_E is to be calculated as follows:

$$Z_E = \sqrt{\frac{1}{\pi\left(\frac{1-v_1^2}{E_1} + \frac{1-v_2^2}{E_2}\right)}}$$

For $E_1 = E_2 = E$ and $v_1 = v_2 = v$:

$$Z_E = \sqrt{\frac{E}{2\pi(1-v^2)}}$$

For $v = 0.3$ in respect to steel and hard aluminum alloys:

$$Z_E = \sqrt{0.175E}$$

Where the modulus of elasticity of the material of a pair is E_1 or E_2, the following applies:

$$E = \frac{2E_1E_2}{E_1 + E_2}$$

For steel gears (E = 206000 N/mm^2, v = 0.3):

$$Z_E = 189.8 \quad \sqrt{\text{N/mm}^2}$$

2.5.3 In other cases, reference is to be made to ISO 6336-2 standard.

2.6 Contact ratio factor Z_ε

2.6.1 The contact ratio factor, Z_ε, accounts for the influence of the transverse contact ratio and the overlap ratio on the specific surface load of gears.

2.6.2 The contact ratio factor Z_ε is to be calculated as follows:

Spur gears: $Z_\varepsilon = \sqrt{\frac{4 - \varepsilon_\alpha}{3}}$

Helical gears: $Z_\varepsilon = \sqrt{\frac{4 - \varepsilon_\alpha}{3}(1 - \varepsilon_\beta) + \frac{\varepsilon_\beta}{\varepsilon_\alpha}}$ for $\varepsilon_\beta < 1$

$Z_\varepsilon = \sqrt{\frac{1}{\varepsilon_\alpha}}$ for $\varepsilon_\beta \geq 1$

2.7 Bevel gear load sharing factor Z_{LS}

2.7.1 The load sharing factor, Z_{LS}, accounts for the load sharing between two or more pairs of teeth in contact.

2.7.2 The load sharing factor, Z_{LS}, may be calculated as follows:

(1) Z_{LS} = 1 for $\varepsilon_{vr} \leq 2$ or $\varepsilon_{v\beta} < 1$.

(2) For $\varepsilon_{vr} > 2$ and $\varepsilon_{v\beta} > 1$, Z_{LS} is to be calculated as follows:

$$Z_{LS} = \left\{1 + 2\left[1 - \left(\frac{2}{\varepsilon_{vr}}\right)^{1.5}\right]\sqrt{1 - \frac{4}{\varepsilon^2_{vr}}}\right\}^{-0.5}$$

2.7.3 Where Z_{LS} obtained according to 2.7.2(2) is less than 0.837, Z_{LS} is to be taken as 0.837.

2.8 Bevel gear factor Z_K

2.8.1 The bevel gear factor Z_K is an empirical factor and accounts for the difference between bevel and cylindrical loading and adjusts the contact stresses so that the same permissible stresses may apply.

2.8.2 Z_K = 0.8 may be taken in lack of detailed data.

2.9 Helix angle factor Z_β

2.9.1 The helix angle factor, Z_β, accounts for the influence of helix angle on surface durability, allowing for such variables as the distribution of load along the lines of contact.

2.9.2 Z_β is to be calculated as follows:

(1) Cylindrical gears:

$$Z_\beta = \sqrt{\frac{1}{\cos\beta}}$$

(2) Bevel gears:

$$Z_\beta = \sqrt{\frac{1}{\cos\beta_m}}$$

2.10 Endurance limit for contact stress $\sigma_{H\lim}$

2.10.1 For a given material, $\sigma_{H\lim}$ is the limit of repeated contact stress which can be permanently endured.

2.10.2 The value of $\sigma_{H\lim}$ may be regarded as the level of contact stress which the material will endure without pitting for at least 5×10^7 (2×10^5 for nitrided steels) load cycles. For this purpose, pitting is defined by:

(1) for not surface hardened gears: pitted area > 2% of total active flank area;

(2) for surface hardened gears: pitted area > 0.5% of total active flank area, or > 4% of one particular tooth flank area.

2.10.3 The $\sigma_{H\lim}$ values are to correspond to a failure probability of 1% or less.

2.10.4 The endurance limit mainly depends on:

(1) material composition, cleanliness and defects;

(2) mechanical properties;

(3) residual stresses;

(4) heat treatment, depth of hardened zone, hardness gradient;

(5) material structure (forged, rolled bar, cast).

2.10.5 The $\sigma_{H\lim}$ values are to be taken from Table 2.10.5.

Endurance Limit for Contact Stress $\sigma_{H\lim}$ **Table 2.10.5**

Material and heat treatment	$\sigma_{H\lim}$ (N/mm²)
Alloy steel quench-hardening (surface hardness 58 ~ 63 HRC)	1550
Nitrated steel gas nitrating (surface hardness 700 ~ 850HV)	1280
Quenched and tempered steel liquid or gas nitrating (surface hardness 450 ~ 650HV)	1000
Quenched and tempered steel flame or induction quenching (surface hardness 500 ~ 650HV)	0.75 HV+750
Alloy quenching and tempering	1.4 HV+350
Carbon steel quenching and tempering or normalizing	1.5 HV+250

Note: For cast steel, the value of $\sigma_{H\lim}$ is to be reduced by 15%.

2.10.6 The endurance limit for contact stress $\sigma_{H\lim}$ is to be determined, in general, making reference to values indicated in ISO 6336-5 standard, for material quality MQ.

2.11 Life factor Z_N

2.11.1 The life factor Z_N is the ratio of the higher permissible contact fatigue strength for a limited life (limited number of stress cycles) and a static strength to the contact fatigue strength at 5×10^7 cycles.

2.11.2 The factor Z_N mainly depends on:

(1) material and heat treatment;

(2) number N_L of load cycles (service life);

(3) lubrication;

(4) failure criterion;

(5) required operational smoothness;

(6) pitch line velocity;

(7) cleanliness of material;

(8) plasticity and fracture toughness of material;

(9) residual stresses;

(10) influence factors (Z_R, Z_V, Z_L, Z_W, Z_X).

2.11.3 Unlimited life is generally required for the gear of marine gearbox, in this case $Z_N = 1$.

2.11.4 For ships in restricted service, Z_N can be raised as appropriate, generally to be taken from Figure 2.11.4.

2.11.5 The life factor Z_N is to be determined according to Method B outlined in the reference standard ISO 6336-2.

2.12 Influence factors of lubrication film on contact stress, Z_L, Z_V and Z_R

2.12.1 The lubricant factor, Z_L, accounts for the influence of the type of lubricant and its viscosity. The velocity factor, Z_V, accounts for the influence of the pitch line velocity. The roughness factor, Z_R, accounts for the influence of the surface roughness on the surface endurance capacity. The factors may be determined for the softer material where gear pairs are of different hardness.

2.12.2 The factors mainly depend on:

(1) viscosity of lubricant in the contact zone;

(2) the sum of the instantaneous velocities of the tooth surfaces;

(3) load;

(4) relative radius of curvature at the pitch point;

(5) surface roughness of teeth flanks;

(6) hardness of pinion and gear.

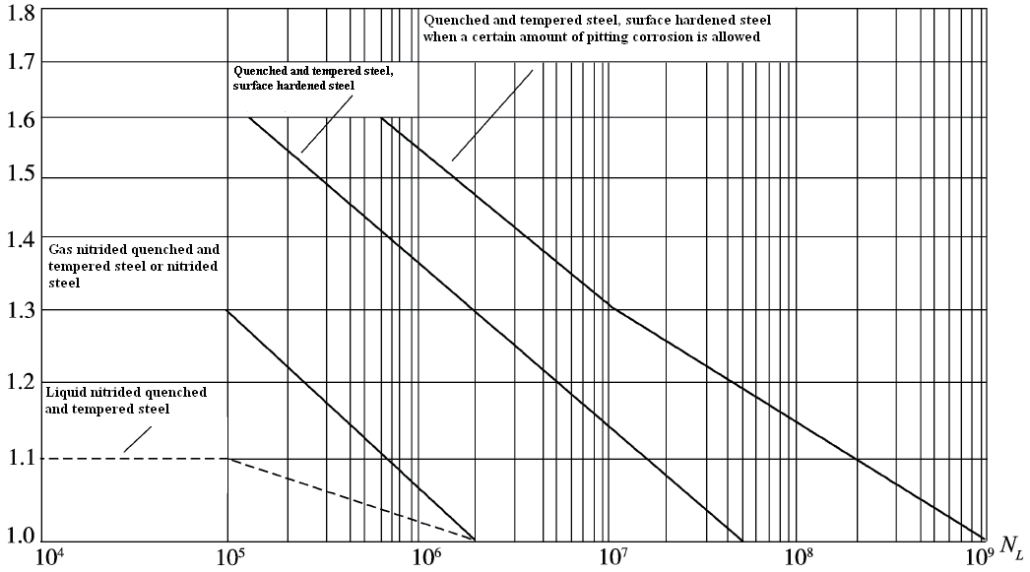


Figure 2.11.4 Life Factor Z_N

2.12.3 The lubricant factor Z_L is to be calculated as follows:

$$Z_L = C_{ZL} + \frac{4(1.0 - C_{ZL})}{(1.2 + 134/\nu_{40})^2}$$

where: C_{ZL} — factor:

for 850 N/mm² ≤ $\sigma_{H\lim}$ ≤ 1,200 N/mm²,

$$C_{ZL} = 0.83 + 0.08\frac{\sigma_{H_{\lim}} - 850}{350}$$

if $\sigma_{H\lim}$ < 850 N/mm², take C_{ZL} =0.83;

if $\sigma_{H\lim}$ >1,200 N/mm², take C_{ZL} =0.91;

ν_{40} — nominal kinematic viscosity of the oil at 40℃.

2.12.4 The velocity factor Z_V is to be calculated as follows:

$$Z_V = C_{ZV} + \frac{2(1.0 - C_{ZV})}{\sqrt{0.8 + 32/V}}$$

where: C_{ZV} — factor:

for 850 N/mm² ≤ $\sigma_{H\lim}$ ≤ 1200 N/mm²,

$$C_{ZV} = C_{ZL} + 0.02$$

if $\sigma_{H\lim}$ <850 N/mm², take C_{ZV} =0.85;

if $\sigma_{H\lim}$ >1,200 N/mm², take C_{ZV} =0.93.

2.12.5 The roughness factor Z_R is to be calculated as follows:

$$Z_R = (\frac{3}{R_{Z10}})^{C_{ZR}}$$

where: R_{Z10} — relative mean roughness (curvature radius relative to pitch point ρ_{red} = 10 mm):

$$R_{Z10} = \frac{R_{Z1} + R_{Z2}}{2} \sqrt[3]{\frac{10}{\rho_{red}}}$$

R_{Z1} and R_{Z2} — mean peak-to-valley roughness determined respectively for the pinion and the wheel (refer to ISO 6336-2 standard);

ρ_{red} — relative radius of curvature, to be determined from the following equation:

(1) for cylindrical gears:

$$\rho_{red} = \frac{\rho_1 \rho_2}{\rho_1 + \rho_2}$$

(2) for bevel gears:

$$\rho_{\text{red}} = \frac{\rho_{v1} \rho_{v2}}{\rho_{v1} + \rho_{v2}}$$

where: $\rho_{1,2} = 0.5 \times d_{b1,2} \times \tan \alpha_{tw}$;

$\rho_{v1,2} = 0.5 \times d_{vb1,2} \times \tan \alpha_{tw}$.

If the roughness stated is an arithmetic mean roughness, i.e. R_a value (= *CLA* value) (= *AA* value) the following approximate relationship can be applied:

$$R_a = CLA = AA = R_Z/6$$

where: C_{ZR} — factor:

for 850 N/mm² ≤ $\sigma_{H\,\text{lim}}$ ≤ 1,200 N/mm², $C_{ZR} = 0.32 - 0.0002\sigma_{H\,\text{lim}}$;

if $\sigma_{H\,\text{lim}}$ < 850 N/mm², take C_{ZR} =0.15;

if $\sigma_{H\,\text{lim}}$ > 1,200 N/mm², take C_{ZR} =0.08.

2.13 Hardness ratio factor Z_W

2.13.1 The hardness ratio factor, Z_W, accounts for the increase of surface durability of a soft steel gear meshing with a significantly harder gear (mean peak-to-valley roughness $R_Z \leq 6$ μm or rough arithmetic mean value $R_a \leq 1$ μm) with a smooth surface in the following cases.

(1) Surface-hardened pinion with through-hardened wheel

If *HB* < 130, $Z_W = 1.2 \cdot (\frac{3}{R_{zH}})^{0.15}$;

If 130 ≤ *HB* ≤ 470, $Z_W = (1.2 - \frac{HB-130}{1700}) \cdot (\frac{3}{R_{zH}})^{0.15}$;

If *HB* > 470, $Z_W = (\frac{3}{R_{zH}})^{0.15}$.

where: *HB* = Brinell hardness of the tooth flanks of the softer gear of the pair;

R_{ZH} — equivalent roughness, μm.

$$R_{zH} = \frac{R_{z1} \cdot (\frac{10}{\rho_{red}})^{0.33} \cdot (\frac{R_{z1}}{R_{z2}})^{0.66}}{(v \cdot v_{40}/1500)^{0.33}}$$

ρ_{red} — relative radius of curvature.

(2) Through-hardened pinion and wheel

When the pinion is substantially harder than the wheel, the work hardening effect increases the load capacity of the wheel flanks. Z_W applies to the wheel only, not to the pinion.

If $HB_1/HB_2 < 1.2$, $Z_W = 1$

If $1.2 \le HB_1/HB_2 \le 1.7$, $Z_W = 1 + \left(0.00898\frac{HB_1}{HB_2} - 0.00829\right) \times (u - 1)$

If $HB_1/HB_2 > 1.7$, $Z_w = 1 + 0.00698 \cdot (u - 1)$

If gear ratio $u > 20$ then the value $u = 20$ is to be used.

In any case, if calculated $Z_W < 1$ then the value $Z_W = 1.0$ is to be used.

2.14 Size factor of contact stress, Z_X

2.14.1 The size factor, Z_X, accounts for the influence of tooth dimensions on permissible contact stress and reflects the non-uniformity of material properties.

2.14.2 The factor mainly depends on:

(1) material and heat treatment;

(2) tooth and gear dimensions;

(3) ratio of case depth to tooth size;

(4) ratio of case depth to equivalent radius of curvature.

2.14.3 For through-hardened gears and for surface-hardened gears with adequate case depth relative to tooth size and radius of relative curvature, $Z_X = 1$. When the case depth is relatively shallow, then a smaller value of Z_X is to be chosen.

2.15 Safety factor for contact stress, S_H

2.15.1 The safety factor for contact stress S_H is to satisfy the following guidance values:

Main propulsion gears: $S_H \ge 1.20$;

Auxiliary gears: $S_H \ge 1.15$.

3 Tooth Root Bending Strength

3.1 Calculation requirements

3.1.1 The criterion for tooth root bending strength is the permissible limit of local tensile strength in the root fillet. The root stress σ_F is to be equal to or less than the permissible root stress σ_{FP}.

3.1.2 The root stress σ_F and the permissible root stress σ_{FP} are to be calculated separately for the pinion and the wheel.

3.1.3 The following formulae and definitions apply to gears having rim thickness greater than 3.5 m_n.

3.1.4 The result of rating calculations made by following this method are acceptable for normal pressure angles up to 25° and reference helix angles up to 30°. For larger pressure angles and large helix angles, the calculated results are to be confirmed by experience as by ISO 6336-3 Method A and the relevant standard.

3.2 Tooth root bending stress for pinion and wheel s_F

3.2.1 Tooth root bending stress for pinion and wheel s_F is to be calculated as follows:

(1) For cylindrical gears:

$$\sigma_F = \frac{F_t}{bm_n} Y_F Y_S Y_\beta Y_B Y_{DT} K_A K_\gamma K_v K_{F\alpha} K_{F\beta} \le \sigma_{FP}$$

(2) For bevel gears:

$$\sigma_F = \frac{F_{mt}}{bm_{mn}} Y_{Fa} Y_{Sa} Y_\varepsilon Y_K Y_{LS} K_A K_\gamma K_v K_{F\beta} K_{F\alpha} \le \sigma_{FP}$$

where: Y_F, Y_{Fa} — tooth form factor, see 3.3 of this Appendix;
Y_S, Y_{Sa} — stress correction factor, see 3.4 of this Appendix;
Y_b — helix angle factor, see 3.5 of this Appendix;
Y_ε — contact ratio factor, see 3.6 of this Appendix;
Y_K — bevel gear factor, see 3.7 of this Appendix;
Y_{LS} — load sharing factor, see 3.8 of this Appendix;
Y_B — rim thickness factor, see 3.15 of this Appendix;
Y_{DT} — deep tooth factor, see 3.16 of this Appendix;
for F_t, K_A, K_γ, K_V, K_{Fa} and $K_{F\beta}$, see 1.4 and 1.5 of this Appendix;
for b and m_n, see 1.2 of this Appendix.

3.2.2 Permissible tooth root bending stress for pinion and wheel, σ_{FP}, is to be calculated as follows:

$$\sigma_{FP} = \frac{\sigma_{FE} \times Y_N \times Y_d}{S_F} Y_{\delta relT} \times Y_{RrelT} \times Y_X \quad \text{N/mm}^2$$

where: σ_{FE} — bending endurance limit, see 3.9 of this Appendix;
Y_d — design factor, see 3.10 of this Appendix;
Y_N — life factor, see 3.11 of this Appendix;
$Y_{\delta relT}$ — relative notch sensitivity factor, see 3.12 of this Appendix;
Y_{RrelT} — relative surface factor, see 3.13 of this Appendix;
Y_X — size factor of bending stress, see 3.14 of this Appendix;
S_F — safety factor for tooth root bending stress, see 3.17 of this Appendix.

3.3 Tooth form factors Y_F, Y_{Fa}

3.3.1 The tooth form factors, Y_F and Y_{Fa}, represent the influence on nominal bending stress of the tooth form with load applied at the outer point of single pair tooth contact.

3.3.2 Y_F and Y_{Fa} are to be determined separately for the pinion and the wheel. In the case of helical gears, the form factors for gearing are to be determined in the normal section, i.e. for the virtual spur gear with virtual number of teeth z_n.

3.3.3 Tooth form factor of cylindrical gears, Y_F

For the pinion and the wheel, the tooth form factor is to be calculated as follows:

$$Y_F = \frac{6\frac{h_F}{m_n}\cos\alpha_{Fen}}{(\frac{S_{Fn}}{m_n})^2\cos\alpha_n}$$

where: h_F — bending moment arm for tooth root bending stress for application of load at the outer point of single tooth pair contact;

S_{Fn} — tooth root normal chord in the critical section;

α_{Fen} — pressure angle at the outer point of single tooth pair contact in the normal section.

h_F, α_{Fen} and S_{Fn} are shown in Figures 3.3.3(1) and 3.3.3(2).

For the calculation of h_F, α_{Fen} and S_{Fn}, the procedure outlined in the reference standard ISO 6336-3 (Method B) is to be used.

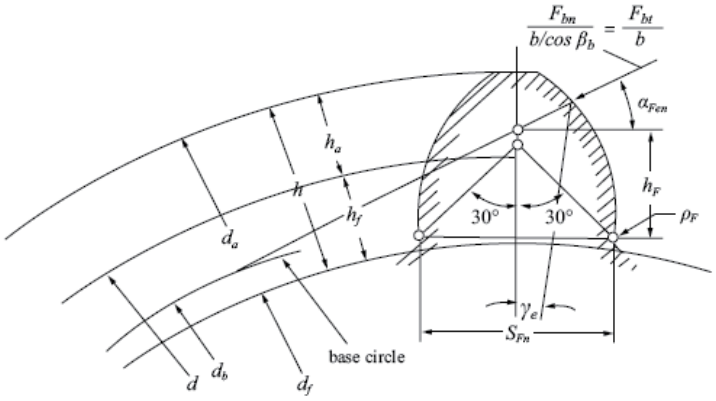


Figure 3.3.3(1) Dimensions of h_F, S_{Fn} and α_{Fen} for External Gear

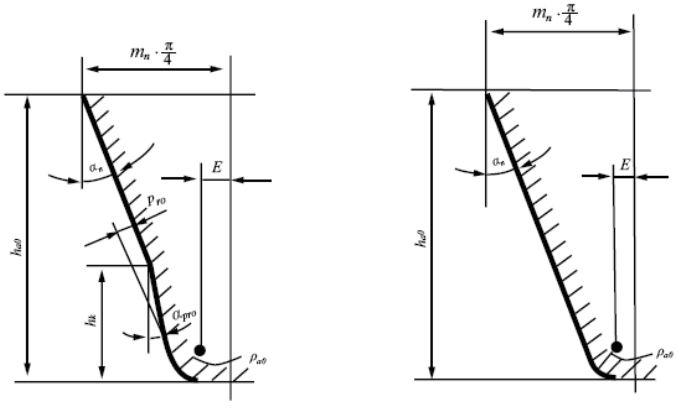


Figure 3.3.3(2) Cutter Reference Standard Rack

3.3.4 Tooth form factor for bevel gears, Y_{Fa}

3.3.4.1 The tooth form factor Y_{Fa} represents the influence on nominal bending stress of the tooth form with load applied at the tooth tip. In calculation by this method, the section at 30° tangent point of the tooth root transition curve beyond the normal tooth profile of the equivalent cylindrical gear is the critical section.

3.3.4.2 The tooth form factor is to be determined separately for the pinion and the wheel. Depending on different manufacturing methods, specific equations are respectively given in 3.3.4.4 and 3.3.4.5, with relevant parameters being defined in Figure 3.3.4.

3.3.4.3 The tooth form factor of generated gears is also to comply with the following:

(1) the contact point of the 30° tangent lies on the fillet curve generated by cutter tip radius;

(2) the cutter must have a tip fillet radius ($\rho_{a0} \neq 0$).

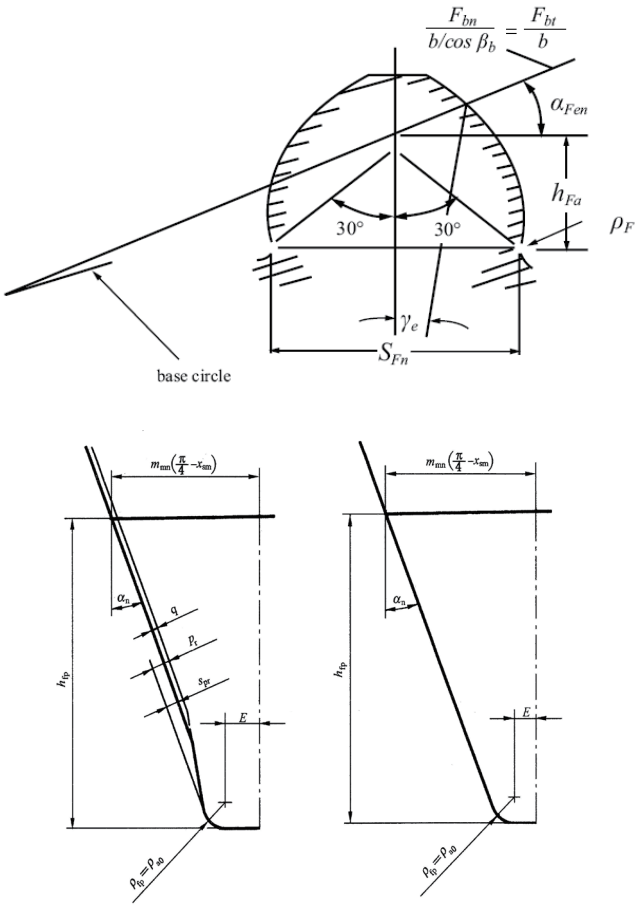


Figure 3.3.4 Factors Influencing Tooth Form of Bevel Gears

3.3.4.4 The tooth form factor of generated gears may be calculated as follows:

(1) Tooth form factor Y_{Fa}:

$$Y_{Fa} = \frac{6(\frac{h_{Fa}}{m_{mn}})\cos\alpha_{Fan}}{(\frac{S_{Fn}}{m_{mn}})^2\cos\alpha_n}$$

(2) For calculation of tooth root chord S_{Fn} in the critical section and bending moment arm h_{Fa}, the auxiliary values *E, G, H* and θ are first to be determined:

$$E = (\frac{\pi}{4} - x_{sm})m_{mn} - h_{ao}\tan\alpha_n - \frac{\rho_{ao}(1-\sin\alpha_n) - s_{pr}}{\cos\alpha_n}$$

$$G = \frac{\rho_{ao}}{m_{mn}} - \frac{h_{ao}}{m_{mn}} + x_{hm}$$

$$H = \frac{2}{z_{vn}}(\frac{\pi}{2} - \frac{E}{m_{mn}}) - \frac{\pi}{3}$$

$$\theta = \frac{2G}{z_{vn}}\tan\theta - H$$

It is recommended to take the initial value $\theta = \pi/6$ to obtain θ by iterative method.

(3) Tooth root chord S_{Fn} in the critical section:

$$\frac{s_{Fn}}{m_{mn}} = Z_{vn}\sin(\frac{\pi}{3} - \theta) + \sqrt{3}(\frac{G}{\cos\theta} - \frac{\rho_{ao}}{m_{mn}})$$

(4) Tooth root fillet radius ρ_F in the critical section:

$$\frac{\rho_F}{m_{mn}} = \frac{\rho_{ao}}{m_{mn}} + \frac{2G^2}{\cos\theta(z_{vn}\cos^2\theta - 2G)}$$

(5) Bending moment arm h_{Fa}:

$$\alpha_{an} = \arccos(d_{vbn}/d_{van})$$

$$\gamma_a = \frac{1}{z_{vn}}[\frac{\pi}{2} + 2(x_{hm}\tan\alpha_n + x_{sm})] + inv\alpha_n - inv\alpha_{an}$$

$$\alpha_{Fan} = \alpha_{an} - \gamma_a$$

$$\frac{h_{Fa}}{m_{mn}} = \frac{1}{2}\left[(\cos\gamma_a - \sin\gamma_a\tan\alpha_{Fan})\frac{d_{van}}{m_{mn}} - z_{vn}\cos(\frac{\pi}{3} - \theta) - \frac{G}{\cos\theta} + \frac{\rho_{ao}}{m_{mn}}\right]$$

For gears having a basic rack profile of $\alpha_n = 20^o$、$h_{a0}/m_{mn} = 1.25$、$\rho_{a0}/m_{mn} = 0$ and $x_{sm} = 0$, the tooth form factor may be obtained from Figure 3.3.4.4.

3.3.4.5 Tooth form factor Y_{Fa} of form cutting

The tooth form factor of form cutting may be calculated as follows:

(1) Tooth root chord in the critical section

$$s_{Fn2} = \pi m_{mn} - 2E - 2\rho_{a02}\cos 30^o$$

where: E is to be calculated according to 3.3.4.4(2).

(2) Fillet radius at contact point of 30° tangent

$$\rho_{F2} = \rho_{a02}$$

(3) Bending moment arm

$$h_{Fa2} = h_{a02} - \frac{\rho_{a02}}{2} + m_{mn} - (\frac{\pi}{4} + x_{sx2} - \tan a_n)m_{mn}\tan a_n$$

(4) The tooth form factor is to be calculated as follows:

$$Y_{Fa} = \frac{6\frac{h_{Fa2}}{m_{mn}}}{(\frac{S_{Fn2}}{m_{mn}})^2}$$

3.4 Stress correction factors Y_S, Y_{Sa}

3.4.1 The stress correction factors are used to convert the nominal bending stress to the local tooth root stress, taking into account the effects of stress concentration at the tooth root transition curve and stresses other than bending stresses on the root stress.

3.4.2 The factors apply to the load application at the outer point of single tooth pair contact and are to be determined separately for the pinion and for the wheel.

3.4.3 Y_S value is to be determined with the following equation (having range of validity: $1 \le q_s < 8$):

(1) Stress correction factor Y_S of cylindrical gears:

$$Y_S = (1.2 + 0.13L)\, q_s^{(\frac{1}{1.21+2.3/L})}$$

(2) Stress correction factor Y_{Sa} of bevel gears:

$$Y_{Sa} = (1.2 + 0.13L_a) q_s^{(\frac{1}{1.21+2.3/L_a})}$$

where : q_s — notch parameter, $q_s = \frac{S_{Fn}}{2\rho_F}$

$L = \frac{S_{Fn}}{h_F}$

$L_a = \frac{S_{Fn}}{h_{Fa}}$

ρ_F = root fillet radius in the critical section, mm. For the calculation of ρ_F the procedure outlined in the reference standard ISO 6336-3 is to be used.

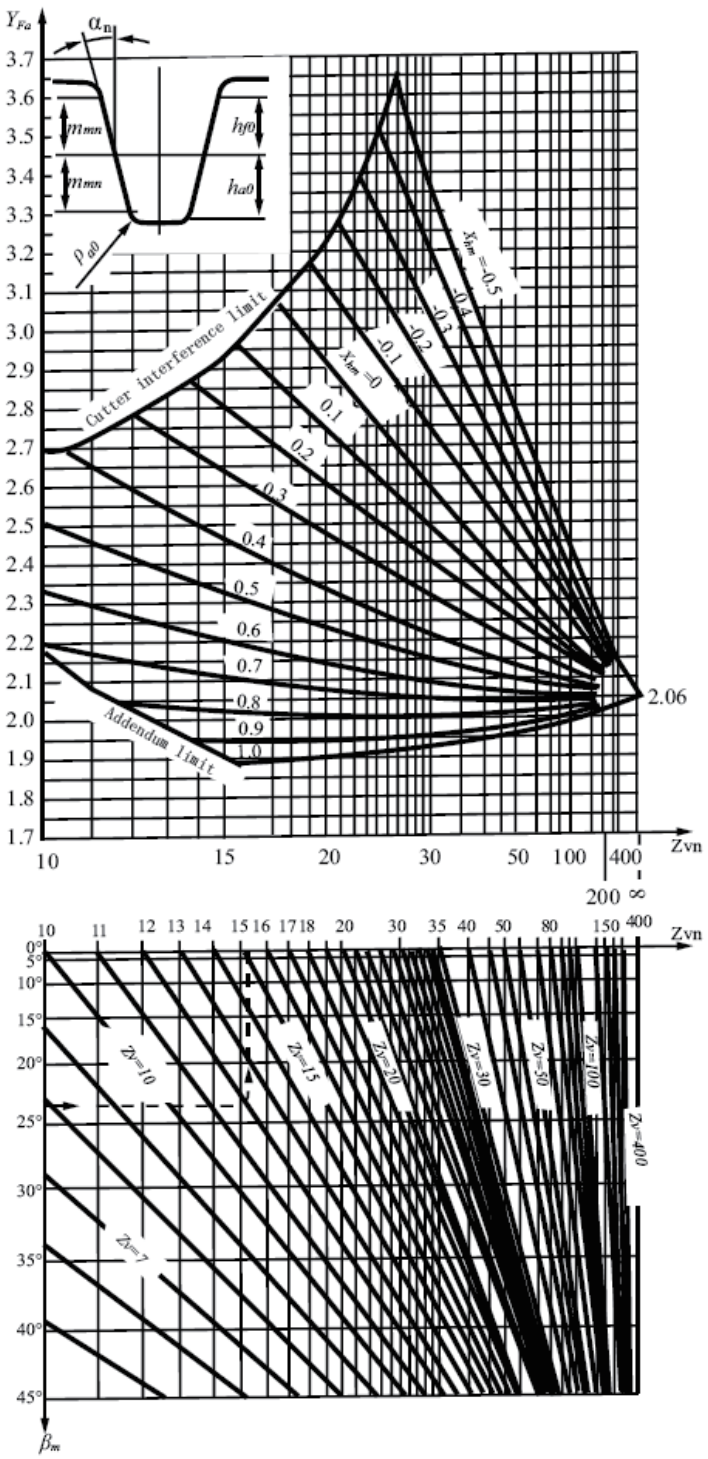


Figure 3.3.4.4 Tooth Form Factor of Generated Gears

For bevel gears having the basic rack profile of the tooth with $\alpha_n = 20^o$、$h_{a0}/m_{mn} = 1.25$、 $\rho_{a0}/m_{mn} = 0$ and $x_{sm} = 0$, the stress correction factors may be obtained from Figure 3.4.3.

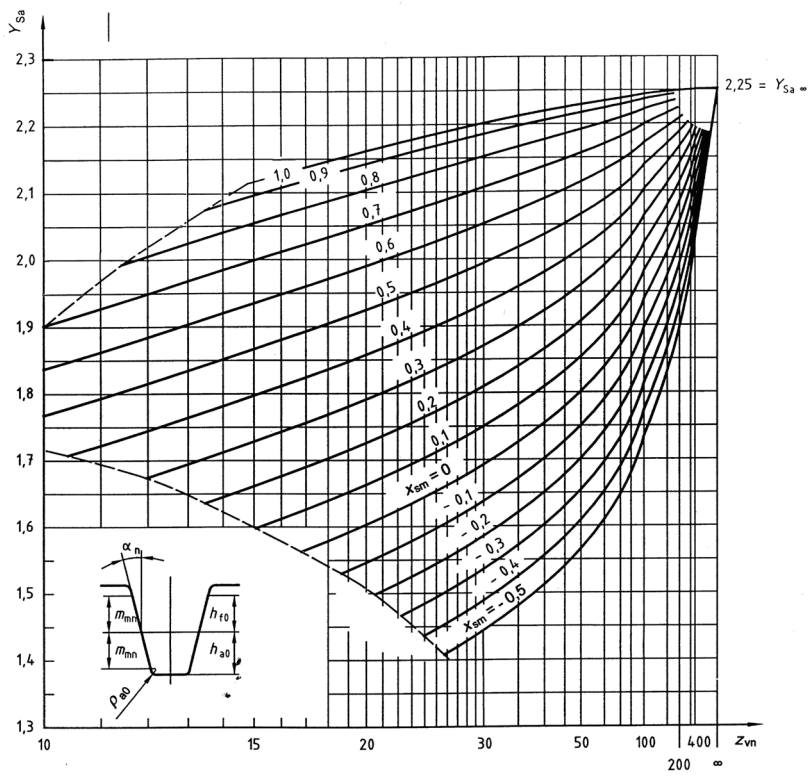


Figure 3.4.3 Stress Correction Factors for Tooth Form Factor of Generated Gear with Load Applied at Tooth Tip

3.5 Helix angle factor Y_β

3.5.1 The helix angle factor, Y_β, covers the effects of an oblique line of contact caused by the helix angle of cylindrical gears on the root stress.

3.5.2 The helix angle factor, Y_β, is to be calculated as follows:

$$Y_\beta = 1 - \varepsilon_\beta \frac{\beta}{120}$$

where : β — reference helix angle in degrees, 30° is substituted for $\beta > 30°$;
ε_β — overlap ratio, the value 1.0 is substituted for ε_β when $\varepsilon_\beta > 1.0$.

3.6 Contact ratio factor Y_ε

3.6.1 The contact ratio factor Y_ε covers the effects of an oblique line of contact caused by the helix angle of bevel gears on the root stress.

3.6.2 The contact ratio factor Y_ε may be calculated as follows:

(1) For $\varepsilon_{v\beta} = 0$:

$$Y_\varepsilon = 0.25 + \frac{0.75}{\varepsilon_{va}}$$

(2) For $0 < \varepsilon_{v\beta} \leq 1$:

$$Y_\varepsilon = 0.25 + \frac{0.75}{\varepsilon_{va}} - \varepsilon_{v\beta}\left(\frac{0.75}{\varepsilon_{va}} - 0.375\right)$$

For $\varepsilon_{v\beta} > 1$:

$$Y_\varepsilon = 0.625$$

3.6.3 Where Y_ε calculated according to 3.6.2 is less than 0.625, Y_ε is to be taken as 0.625.

3.7 Bevel gear factor Y_K

3.7.1 The bevel gear factor Y_K accounts for the differences between bevel and cylindrical gears in respect to root stress.

3.7.2 The bevel gear factor Y_K may be calculated as follows:

$$Y_K = (\frac{1}{2} + \frac{l'_{bm}}{2b})^2 \frac{b}{l'_{bm}}$$

$$l'_{bm} = l_{bm} \cos \beta_{vb}$$

where: l'_{bm} — projected length of the middle line of contact;

l_{bm} — length of the middle line of contact:

For $\varepsilon_{v\beta} < 1$: $l_{bm} = \dfrac{b\varepsilon_{va}}{\cos \beta_{vb}} \dfrac{\sqrt{\varepsilon_{vr}^2 - [(2 - \varepsilon_{va})(1 - \varepsilon_{v\beta})]^2}}{\varepsilon_{vr}^2}$;

For $\varepsilon_{v\beta} \geq 1$: $l_{bm} = \dfrac{b\varepsilon_{va}}{\cos \beta_{vb} \varepsilon_{vr}}$.

3.8 Load sharing factor Y_{LS}

3.8.1 The load sharing factor, Y_{LS}, accounts for the distribution of load between two or more pairs of teeth.

3.8.2 The factor Y_{LS} may be calculated as follows:

$$Y_{LS} = Z_{LS}^2$$

where: Z_{LS} — load sharing factor, see 2.7 of this Appendix.

3.8.3 Where Z_{LS} calculated according to 3.8.2 is less than 0.7, Z_{LS} is to be taken as 0.7.

3.9 Bending endurance limit σ_{FE}

3.9.1 For a given material, bending endurance limit σ_{FE} is the local tooth root stress which can be permanently endured. According to the reference standard the number of 3×10^6 cycles is regarded as the beginning of the endurance limit. The σ_{FE} values are to correspond to a failure probability 1% or less.

σ_{FE} is defined as the unidirectional pulsating stress with a minimum stress of zero (disregarding residual stresses due to heat treatment). Other conditions such as alternating stress or prestressing etc., are covered by the design factor Y_d.

3.9.2 The endurance limit σ_{FE} mainly depends on:

(1) material composition, cleanliness and defects;

(2) mechanical properties;

(3) residual stresses;

(4) heat treatment, depth of hardened zone, hardness gradient;

(5) material structure (forged, rolled bar, cast).

3.9.3 The bending endurance limit σ_{FE} may be obtained from pulsation test or gear loading operation test. Where fatigue test is not available, σ_{FE} value of forged steel may be taken from Table 3.9.3.

Bending endurance limit σ_{FE} **Table 3.9.3**

Gear material and heat treatment	σ_{FE} (N/mm²)
Alloy steel quench-hardening (surface hardness 58 ~ 63 HRC) General alloy steels MnCr steels CrNi	 830 850 920
Nitrated steel gas nitrating (surface hardness 700 ~ 800 HV)	750
Quenched and tempered alloy steel liquid or gas nitriding (surface hardness 500 ~ 700 HV)	650
Quenched and tempered alloy steel flame or induction quenching (surface hardness 500 ~ 650 HV)	0.7 HV + 250
Alloy quenching and tempering	0.4 R_m + 200
Carbon steel quenching and tempering or normalizing	0.25 R_m + 250

3.9.4 Where it is hot rolled steel, σ_{FE} value in Table 3.9.3 is to be reduced by 15%; while cast steel, by 30%.

3.9.5 Where root surface hardness of quench-hardening is less than 58 HRC, σ_{FE} value in Table 3.9.3 is to be reduced by 20% (58 – HRC), HRC is the measuring hardness of the tooth surface.

3.9.6 Where tooth root fillet cloudburst treatment is taken for enhancing the tooth bending fatigue strength, σ_{FE} value may be raised as appropriate. Generally, when $m_n \leq 6$, σ_{FE} value may be as 200 more than that mentioned in Table 3.9.3; when $m_n > 6$, σ_{FE} value may be increased by 200 – 10 (m_n –6).

3.9.7 The bending endurance limit σ_{FE} is to be determined, in general, making reference to values indicated in ISO 6336-5 standard, for material quality MQ.

3.10 Design factor Y_d

3.10.1 The design factor, Y_d, takes into account the influence of load reversing and shrink fit prestressing on the tooth root strength, relative to the tooth root strength with unidirectional load as defined for σ_{FE}.

3.10.2 The design factor, Y_d, is to be determined as follows:

(1) for gears with unidirectional load: $Y_d = 1.0$;

(2) for gears with occasional part load in reversed direction, such as idler gear and planet wheel: $Y_d = 0.7$;

(3) for gears with performance in reversing: $Y_d = 0.9$;

(4) for gears shrinking on assembled gear rings: $Y_d = 0.8$.

3.11 Life factor Y_N

3.11.1 The life factor Y_N accounts for the higher tooth root bending stress permissible when a limited life (number of cycles) is required.

3.11.2 The factor Y_N mainly depends on:

(1) material and heat treatment;

(2) number of load cycles (service life);

(3) influence factors (Y_{drelT}, Y_{RrelT}, Y_X).

3.11.3 Unlimited life is generally considered for marine gearing, so $Y_N = 1$ is to be taken.

3.11.4 For the marine gearboxes of ships in restricted service, Y_N may be raised as appropriate, and may generally be selected from Figure 3.11.4.

3.11.5 The life factor Y_N may also be determined according to Method B outlined in the reference standard ISO 6336-3.

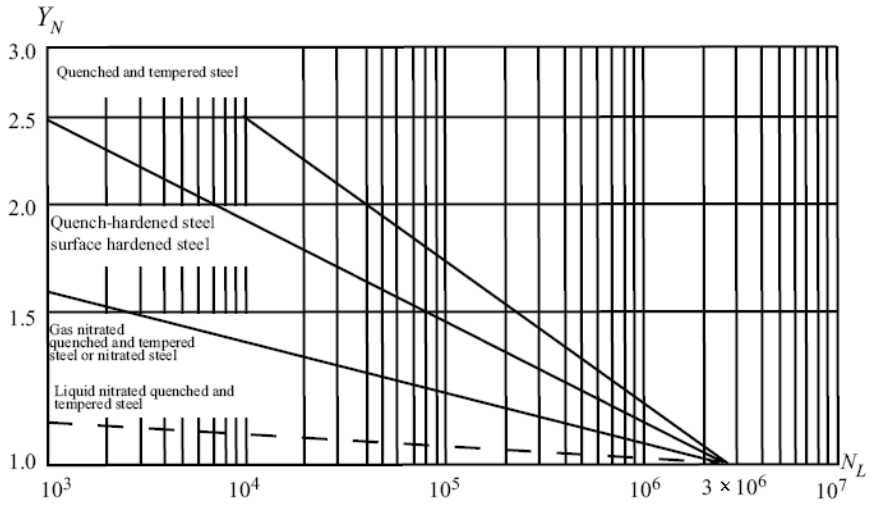


Figure 3.11.4 Life factor Y_N

3.12 Relative notch sensitivity factor Y_{drelT}

3.12.1 The relative notch sensitivity factor, Y_{drelT}, indicates the extent to which the theoretically concentrated stress lies above the fatigue endurance limit.

3.12.2 The factor Y_{drelT} mainly depends on:

(1) material;

(2) relative stress gradient.

3.12.3 $Y_{\delta relT}$ is to be determined as follows:

$$Y_{\delta relT} = \frac{1 + \sqrt{0.2\rho' \ (1 + 2q_s)}}{1 + \sqrt{1.2\rho'}}$$

where: q_s — notch parameter, see 3.4 of this Appendix;
ρ' — slip-layer thickness, mm, from Table 3.12.3.

Value of Slip-layer Thickness ρ' **Table 3.12.3**

Material		ρ', in mm
case hardened steels, flame or induction hardened steels		0.0030
through-hardened steels①, yield point R_e	500N/mm^2	0.0281
	600N/mm^2	0.0194
	800N/mm^2	0.0064
	1000N/mm^2	0.0014
nitrided steels		0.1005
① The given values of ρ' can be interpolated for values of R_e not stated above		

3.13 Relative surface factor Y_{RrelT}

3.13.1 The relative surface factor, Y_{RrelT}, takes into account the dependence of the root strength on the surface condition in the tooth root fillet, mainly the dependence on the peak-to-valley surface roughness.

3.13.2 The relative surface factor, Y_{RrelT} is to be determined from Table 3.13.2. The method applied here is only valid when scratches or similar defects deeper than $2R_z$ are not present.

Relative surface factor Y_{RrelT} **Table 3.13.2**

Material and heat treatment	$R_Z < 1$	$1 \le R_Z \le 40$
case hardened steels, through - hardened steels ($R_m \ge 800$ N/mm^2)	1.120	$1.674 - 0.529\ (R_Z + 1)^{0.1}$
normalised steels ($R_m < 800$ N/mm^2)	1.070	$5.306 - 4.203\ (R_Z + 1)^{0.01}$
nitrided steels	1.025	$4.299 - 3.259\ (R_Z + 1)^{0.0058}$

Notes: ① R_z — mean peak-to-valley roughness of tooth root fillets, in mm.
② If the roughness stated is an arithmetic mean roughness, i.e. R_a value (= *CLA* value) (= *AA* value) the following approximate relationship can be applied: $R_a = CLA = AA = R_Z/6$.

3.14 Size factor of bending stress Y_X

3.14.1 The size factor of bending stress, Y_X, takes into account the decrease of the strength with increasing size.

3.14.2 The factor Y_X mainly depends on:

(1) material and heat treatment;

(2) tooth and gear dimensions;

(3) ratio of case depth to tooth size.

3.14.3 The size factor Y_X is to be determined according to Table 3.14.3.

Size Factor of Bending Stress Y_X **Table 3.14.3**

Y_X	m_n	Status
1.00	$m_n \le 5$	Generally
$1.03 - 0.06\ m_n$	$5 < m_n < 30$	Normalized and through-hardened steels
0.85	$m_n \ge 30$	
$1.05 - 0.01\ m_n$	$5 < m_n < 25$	Surface hardened steels
0.80	$m_n \ge 25$	

3.15 Rim thickness factor, Y_B

The rim thickness factor, Y_B, is a simplified factor used to de-rate thin rimmed gears. For critically loaded applications, this method should be replaced by a more comprehensive analysis. Factor Y_B is to be determined as follows:

(1) for external gears:

If $S_R/h \geq 1.2$, $Y_B = 1$,

If $0.5 < \frac{S_R}{h} < 1.2$, $Y_B = 1.6 \cdot \ln(2.242 \frac{h}{S_R})$

where: S_R — rim thickness of external gears, mm;
h — tooth height, mm.

The case $S_R/h \leq 0.5$ is to be avoided.

(2) for internal gears:

If $S_R/m_n \geq 3.5$, $Y_B = 1$;

If $1.75 < S_R/m_n < 3.5$, $Y_B = 1.15 \cdot \ln(8.324 \frac{m_n}{S_R})$

where: S_R — rim thickness of internal gears, mm.
The case $S_R/h \leq 1.75$ is to be avoided.

3.16 Deep tooth factor, Y_{DT}

The deep tooth factor, Y_{DT}, adjusts the tooth root stress to take into account high precision gears and contact ratios within the range of virtual contact ratio $2.05 \leq \varepsilon_{\alpha n} \leq 2.5$, where:

$$\varepsilon_{\alpha n} = \frac{\varepsilon_\alpha}{\cos^2 \beta_b}$$

Factor Y_{DT} is to be determined as follows:

If ISO accuracy grade ≤ 4 and $\varepsilon_{\alpha n} > 2.5$, $Y_{DT} = 0.7$;
If ISO accuracy grade ≤ 4 and $2.05 < \varepsilon_{\alpha n} \leq 2.5$, $Y_{DT} = 2.366 - 0.666 \cdot \varepsilon_{\alpha n}$;
in all other cases, $Y_{DT} = 1.0$.

3.17 Safety factor for tooth root bending stress S_F

3.17.1 The safety factor for tooth root bending stress S_F is to comply with the following requirements:

main propulsion gears: $S_F \geq 1.55$;
auxiliary gears: $S_F \geq 1.40$."

CHAPTER 11 SHAFTING AND PROPELLERS

Section 4 PROPELLERS

In the existing paragraph 11.4.3.2, the following sentence and Figure 11.4.3.2 are added after the sentence "For aerofoil sections with trailing edge washback, the value of A_1 obtained from above formula is to be increased by 30%.":

"The trailing edge washback is the offset of the trailing edge of the tangent plane of the propeller blade in respect to the pitch baseline (external chord) of the blade face, as shown in Figure 11.4.3.2, e.g. 0.6*R* without washback and 0.25R with washback.

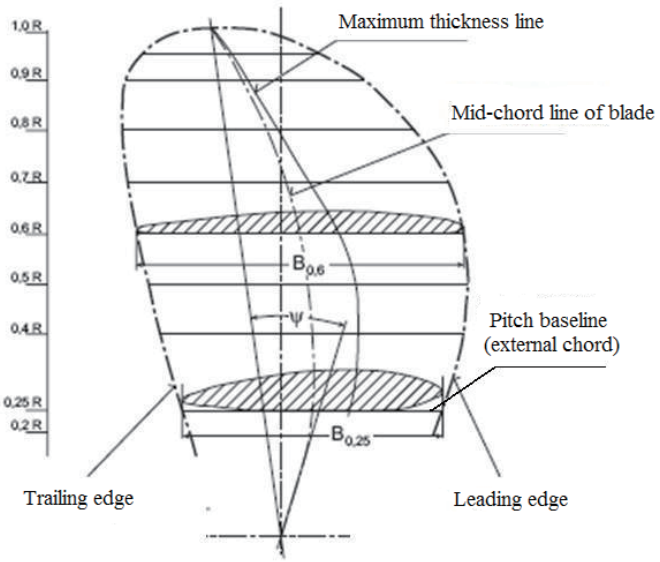


Figure 11.4.3.2"

In the existing paragraph 11.4.3.3, the description "ε — backward rake angle, in °;" is replaced by the following:

"ε — rake angle of propeller blade, in degrees. The value of the rake angle is positive for backward rake and negative for forward rake. The rake angle is, as shown in the side view of propeller, is an angle taken in one of the following three conditions:

— ε_1 and ε_2 are backward rake angles: the more backward one is to be taken ($\varepsilon = \varepsilon_1$, as shown in Figure 11.4.3.3.3(1));

— ε_1 and ε_2 are forward rake angles: the less forward one is to be taken ($\varepsilon = \varepsilon_2$, as shown in Figure 11.4.3.3.3(2));

— ε_1 and ε_2 are rake angles on both sides of the centreline: the backward one is to be taken ($\varepsilon = \varepsilon_1$, as shown in Figure 11.4.3.3.3(3)).

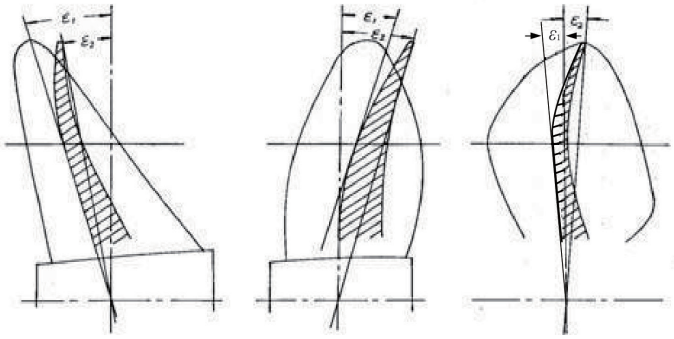
ε_1 is the angle measured from the line perpendicular to shaft centerline to the tangent to the backward thickness line at the radius 0.6*R* of the side projection of propeller blade;

ε_2 is the angle obtained by the following formula:

$$\varepsilon_2 = \tan^{-1}\frac{e}{R}$$

where: e — rake (radial inclination of blade section forward or backward from the reference line, taken as the distance between the blade tip projected on the propeller shaft and the intersection of the reference line and the propeller axis), in m;

R — the same as in 11.4.3.2.



(1) (2) (3)

Figure 11.4.3.3 Rake Angle of Propeller Blade”

CHAPTER 12 SHAFT VIBRATION AND ALIGNMENT

Section 1 GENERAL PROVISIONS

In the existing paragraph 12.1.2.2, “ $\frac{16n_c}{18-r} \sim \frac{(18-r)n_e}{16}$ ” is replaced by “ $\frac{16n_c}{18-r} \sim \frac{(18-r)n_c}{16}$ ”.

CHAPTER 13 STEERING GEAR AND WINDLASSES

Section 1 STEERING GEAR

In the existing paragraph 13.1.6.3, the words “are to be full penetration type” are replaced by “are to be full penetration type or of equivalent strength”.

The existing paragraph 13.1.12.3 is replaced by the following:

“13.1.12.3 Testing on board

After installation on board the vessel, the steering gear is to be subject to a hydraulic tightness test under 1.25 times the design pressure and a running test in mooring condition.”

CHAPTER 14 STRENGTHENING FOR NAVIGATION IN ICE

Section 1 GENERAL PROVISIONS

In the existing paragraph 14.1.1.2, the words "…notations B1*, B1, B2 and B3…" are replaced by "…notations B1*, B1, B2, B3 and B…"

A new paragraph 14.1.1.4 is added as follows:

"14.1.1.4 In addition to complying with the requirements of 14.1.1.2, ships with ice notation B are to be designed to ensure supply of cooling water when navigating in ice. For this purpose, at least one cooling water inlet chest is to be so arranged as to prevent its grating and sea suction from being blocked by brash ice."

PART FOUR ELECTRICAL INSTALLATIONS

CHAPTER 1 GENERAL

Section 1 GENERAL PROVISIONS

New subparagraphs (31) to (33) are added in the existing paragraph 1.1.2.1 as follows:

"(31) Zone 0 is an area in which an explosive gas atmosphere is present continuously or for long periods.

(32) Zone 1 is an area in which an explosive gas atmosphere is likely to occur in normal operation.

(33) Zone 2 is an area in which an explosive gas atmosphere is not likely to occur in normal operation and, if it does occur, is likely to do so only infrequently and will exist for a short period only."

CHAPTER 2 ELECTRICAL INSTALLATIONS IN SHIPS

Section 1 MAIN SOURCE OF ELECTRICAL POWER

A new paragraph 2.1.1.5 is added as follows:

"2.1.1.5 A main source of electrical power may be provided as necessary for non-self-propelled ships. Where the main source of electrical power is the generator, the provisions of 2.1.1.1 to 2.1.1.3 of this Chapter need not be complied with."

Section 4 POWER SUPPLY AND DISTRIBUTION

A new sentence is added at the end of the existing paragraph 2.4.8.3 as follows:

"In the event of any failure of the power supply of the radio distribution board, an audible and visual alarm is to be given in the navigation bridge."

Section 7 LIGHTING AND NAVIGATION LIGHTS

In the existing paragraph 2.7.1.2, the words "fire-fighting equipment control stations," are deleted.

Section 9 SAFETY SYSTEMS FOR SHIPS AND PERSONS ONBOARD

The existing sentence in subparagraph 2.9.2.1(8) is replaced by "if the public address system is used to give the general alarm, the general emergency alarms as required by 2.9.1 of this Section may not be fitted, provided that the following requirements are fulfilled:".

The existing sentence in item ① of subparagraph 2.9.2.1(8) is replaced by "the performance requirements of 2.9.1 of this Section are to be complied with;".

The existing paragraph 2.9.3 is replaced by the following:

"2.9.3 Pre-discharge alarms of fire extinguishing medium

2.9.3.1 In any ro-ro spaces and other spaces in which personnel normally work or to which they have access, which are protected by fixed gas fire-extinguishing systems, means are to be provided for automatically activating audible and visual alarms for the release of fire-extinguishing medium. The alarms are to operate for the time required to evacuate the space, but in no case less than 20 s before the medium is released.

2.9.3.2 Machinery spaces, cargo pump-rooms, vehicle spaces, ro-ro spaces and special category spaces which are protected by fixed high-expansion foam fire-extinguishing systems are to be provided with audible and visual alarms for the release of fire-extinguishing medium in order to give warning of the release of the system. The alarms are to operate for the time required to evacuate the space, but in no case less than 20 s before the medium is released.

2.9.3.3 The above-mentioned alarm system is to be supplied by the emergency source of electrical power."

The words "For passenger ships," are added at the beginning of the existing paragraph 2.9.7.2.

Section 14 SPECIAL REQUIREMENTS FOR HIGH VOLTAGE ELECTRICAL INSTALLATIONS

In the existing paragraph 2.14.5.1, the footnote is replaced by "Refer to IEC Publication 60092-353 Electrical installations in ships – Part 353: Power cables for rated voltages 1 kV and 3 kV and IEC Publication 60092-354 Electrical installations in ships – Part 354: Single- and three-core power cables with extruded solid insulation for rated voltages 6 kV (U_m = 7.2 kV) up to 30 kV (U_m = 36 kV)."

Section 16 ADDITIONAL REQUIREMENTS FOR OIL TANKERS

This Section is replaced by the following:

"2.16.1 General requirements

2.16.1.1 Electrical installations on tankers carrying crude oil and oil products are to comply with the provisions of this Section and other provisions of this PART as appropriate.

2.16.1.2 The classification of typical hazardous areas of oil tankers is carried out in accordance with zone 0, zone 1 and zone 2 based on the provisions of IEC60092-502 in this Section. For areas or spaces not mentioned in this Section, the classification of hazardous areas may be carried out in accordance with the principles given in IEC60079-10-1.

2.16.1.3 Electrical equipment and cables are, in principle, not to be installed in any hazardous areas. If it is impracticable to avoid doing so, the relevant provisions of this Section are to be complied with.

2.16.2 Distribution systems

2.16.2.1 The following distribution systems may be used:

(1) DC, two-wire, insulated;

(2) AC, single-phase, two-wire, insulated;

(3) AC, three-phase, three-wire, insulated.

2.16.2.2 No direct electrical connection is allowed between power networks operating at different voltages.

2.16.2.3 All circuits of generation, supply and distribution systems are not to be earthed, and hull return system is not permitted with the following exceptions:

(1) intrinsically safe circuits;

(2) power supplied control circuits and instrumentation circuits where technical or safety reasons preclude the use of a system with no connection to earth, provided the current in the hull is limited to not more than 5 A in both normal and fault conditions;

(3) limited and locally earthed systems, provided that any possible resulting current does not flow directly through any of the hazardous spaces;

(4) AC distribution systems with 1,000 V (root mean square) and over between phases, provided that any possible resulting current does not flow directly through any of the hazardous spaces.

2.16.3 Cables and their installation

2.16.3.1 All cables, other than those of intrinsically safe circuits, installed in zone 0 and zone 1, are to be provided with at least one of the following:

(1) a non-metallic impervious sheath in combination with braiding or other metallic covering;

(2) copper or stainless steel sheath (for mineral insulated cables only). Aluminium sheathed cables may be considered for special applications.

2.16.3.2 Cables of intrinsically safe circuits are to have a metallic shielding with at least a non-metallic external impervious sheath.

2.16.3.3 Where cables are subject to lengthy immersion in the cargo, the construction of the cables is to be such as to withstand the substances to which they can be exposed, or the cables are to be enclosed in casings (such as metallic pipes) capable of withstanding such substances.

2.16.3.4 Where corrosion may be expected, a non-metallic impervious sheath is to be applied over the metal meshwork, metallic sheath or steel armour of the cable.

2.16.3.5 Where cables pass through gastight bulkheads or decks separating hazardous areas from non-hazardous areas, arrangements are to be such that the gastight integrity of the bulkhead or deck is not impaired.

2.16.3.6 Cables installed on deck or on fore and aft gangways are to be protected against mechanical damage. Cables are to be so installed as to avoid strain or chafing and due allowance is to be made for expansion or working of the structure. Where ring-type expansion bends are fitted, they are to be accessible for maintenance.

2.16.3.7 Cables installed in pump rooms are to be suitably protected against mechanical damage.

2.16.3.8 Flexible cables or wires for portable electrical appliances are not to pass through hazardous areas or spaces, with the exception of flexible cables or wires of intrinsically safe type.

2.16.4 Electrical equipment in hazardous areas

2.16.4.1 For electrical equipment installed in hazardous areas, the appropriate certified explosion-proof equipment is to be selected in accordance with the category of hazardous areas, and the explosion group and temperature class are not to be lower than II A T3.

2.16.4.2 The following equipment is allowed to be installed in zone 0:

(1) certified intrinsically-safe apparatus of category “ia”;

(2) simple electrical apparatus and components (for example thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically safe circuits of category “ia”, not capable of storing or generating electrical power or energy in excess of the limits given in IEC 60079-14;

(3) submersible pumps, having at least two independent methods of shutting down automatically in the event of low liquid level.

2.16.4.3 The following equipment is allowed to be installed in zone 1:

(1) electrical equipment specified in 2.16.4.2 of this Section;

(2) certified intrinsically-safe apparatus of category “ib”;

(3) simple electrical apparatus and components (for example thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically safe circuits of category “ib”, not capable of storing or generating electrical power or energy in excess of the limits given in IEC 60079-14;

(4) certified flameproof (type “d”);

(5) certified pressurized (type “p”);

(6) certified increased safety (type “e”);

(7) certified encapsulated (type “m”);

(8) certified sand filled (type “q”);

(9) certified specially (type “s”)①;

(10) anodes or electrodes of an impressed current cathodic protection system, or transducers such as those for depth-sounding or log systems, provided that such fittings are housed within a gastight enclosure, and are not located adjacent to a cargo tank bulkhead;

(11) through runs of cable.

2.16.4.4 The following equipment is allowed to be installed in zone 2:

(1) electrical equipment specified in 2.16.4.3 of this Section;

(2) non-sparking electrical equipment “n”;

(3) the type which ensures the absence of sparks and arcs and of “hot spots” during its normal operation.

2.16.4.5 Transmitting aerials and any associated riggings are to be sited well clear of gas and vapour outlets.

2.16.4.6 For the electrical equipment permitted in hazardous areas or spaces, all switches and protective devices are to be capable of interrupting all poles or phases and are to be located in a non- hazardous area or space. Such equipment, switches and protective devices are to be clearly and durably labelled for identification purposes.

2.16.5 Earth connection and static electricity protection

2.16.5.1 The metal casings of all electrical equipment in any hazardous areas or spaces, regardless of the working voltage, are to be reliably earthed.

2.16.5.2 Cargo tanks, process plants and piping systems are to be earthed in accordance with 1.3.4.12 of this PART for the control of static electricity.

2.16.5.3 All rigging is to be effectively bonded to ship’s hull.

2.16.6 Classification of hazardous areas of oil tankers carrying cargo oils having a flash point (closed cup) not exceeding 60℃

2.16.6.1 Zone 0 is to include the following areas or spaces:

(1) cargo tanks, slop tanks, any pipework of pressure-relief or other venting systems for cargo and slop tanks;

(2) interior spaces containing the pipes and equipment containing cargo oil.

2.16.6.2 Zone 1 is to include the following areas or spaces:

(1) cofferdams and ballast tanks adjoining cargo tanks;

(2) cargo pump rooms and the mechanical ventilation is to comply with the following requirements:

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① Where explosion-proof types (flameproof, increased safety, intrinsically-safe, pressurized, oil filled, sand filled, encapsulated and non-sparking) not included in the special standards are used for electrical equipment, they may be treated as electrical equipment certified specially (type “s”).

① audible and visual alarms are to be given at a manned location in case of failure of the mechanical ventilation in the cargo pump room;

② actions are to be taken to restore ventilation immediately after failure of the mechanical ventilation;

③ where the mechanical ventilation can not be restored for an extended period, the remaining electrical equipment other than those mentioned below is to be capable of being disconnected outside of hazardous areas and provided with means against unauthorized re-connections:

(a) intrinsically safe equipment;

(b) flameproof lighting;

(c) general emergency alarm sounder of flameproof type, without internal sparking contacts;

④ where the mechanical ventilation has been stopped for an extended period or it is initially used, the cargo pump room is to be purged for at least five air changes before connecting the electrical equipment (except the intrinsically safe equipment, flameproof lighting and general emergency alarm sounder of flameproof type);

(3) enclosed or semi-enclosed spaces immediately above cargo tanks (e.g. 'tween-deck spaces) or having bulkheads above and in line with cargo tank bulkheads;

(4) spaces other than cofferdams adjoining to and below the top of a cargo oil tank (e.g. trunks, passageways and general cargo holds), and double bottom and pipe tunnels below cargo tanks;

(5) areas on open deck, or semi-enclosed spaces on open deck, within 3 m of any cargo tank outlet, gas or vapour outlet①, cargo manifold valve, cargo valve, cargo pipe flange, cargo pump-room ventilation outlets and cargo tank pressure/vacuum relief valve provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation;

(6) areas on open deck, or semi-enclosed spaces on open deck above and in the vicinity of any cargo gas outlet intended for the passage of large volumes of gas or vapour mixture during cargo loading and ballasting or during discharging, within a vertical cylinder of unlimited height and 6 m radius centred upon the centre of the outlet, and within a hemisphere of 6 m radius below the outlet;

(7) areas on open deck, or semi-enclosed spaces on open deck, within 1.5 m of cargo pump room entrances, cargo pump room ventilation inlet, openings into cofferdams or other zone 1 spaces;

(8) areas on open deck over all cargo tanks (including all ballast tanks within the cargo tank area) where structures are restricting the natural ventilation and to the full breadth of the ship plus 3 m fore and aft of the forward-most and aft-most cargo tank bulkhead, up to a height of 2.4 m above the deck;

(9) areas on open deck within spillage coamings surrounding cargo manifold valves and 3 m beyond these, up to a height of 2.4 m above the deck;

(10) compartments for cargo hoses;

(11) enclosed or semi-enclosed spaces in which pipes containing cargoes are located.

2.16.6.3 Zone 2 is to include the following areas or spaces:

(1) areas of 1.5 m surrounding the open spaces or semi-enclosed spaces in zone 1 as specified in 2.16.6.2, if not otherwise specified in this standard;

① Such areas are sight ports, tank cleaning openings, ullage openings, sounding pipes, cargo vapour outlets.

(2) spaces 4 m beyond the area defined in 2.16.6.2(6);

(3) areas within 2 m beyond areas on open deck, or semi-enclosed spaces on open deck, within 3 m of any cargo tank outlet, cargo tank pressure/vacuum relief valve provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation;

(4) the spaces forming an air-lock leading to zone 1;

(5) areas on open deck extending to the coamings fitted to keep any spills on deck and away from the accommodation and service areas and 3 m beyond these up to a height of 2.4 m above the deck;

(6) areas on open deck over all cargo tanks (including all ballast tanks within the cargo tank area) where unrestricted natural ventilation is guaranteed and to the full breadth of the ship plus 3 m fore and aft of the forward-most and aft-most cargo tank bulkhead, up to a height of 2.4 m above the deck surrounding open or semi-enclosed spaces of zone 1;

(7) spaces forward of the open deck areas to which reference is made in 2.16.6.2(8) and 2.16.6.3(6) of this Section, below the level of the main deck, and having an opening on to the main deck or at a level less than 0.5 m above the main deck, unless:

① the entrances to such spaces do not face the cargo tank area and, together with all other openings to the spaces, including ventilating system inlets and exhausts, are situated at least 5 m from the foremost cargo tank and at least 10 m measured horizontally from any cargo tank outlet or gas or vapour outlet; and

② the spaces are mechanically ventilated.

(8) fore peak tank and vent pipe openings as defined in 3.4.14.1, Chapter 3, PART SIX of the Rules.

2.16.6.4 The hazards in some hazardous areas or spaces, e.g. those having direct openings into hazardous areas or spaces, may be reduced or these zones or spaces may be regarded as non-hazardous areas or spaces, provided that the arrangements of ventilation, pressurization, doors at openings, and other safety precautions are in compliance with relevant acceptable standards①.

2.16.7 Classification of hazardous areas of oil tankers carrying cargo oils having a flash point (closed cup) exceeding 60℃ and not heated or heated to a temperature more than 15℃ below their flash point

2.16.7.1 The interiors of cargo tanks, slop tanks, any pipework of pressure/vacuum relief valve or other venting systems for cargo and slop tanks, pipes and equipment containing the cargo or handling flammable gas or vapour belong to zone 2.

2.16.8 Classification of hazardous areas of oil tankers carrying cargo oils having a flash point (closed cup) exceeding 60℃ and heated to a temperature above their flash point or heated to a temperature within 15℃ of their flash point

2.16.8.1 Such tankers are to comply with the requirements for oil tankers carrying cargo oils having a flash point (closed cup) not exceeding 60℃, as specified in 2.16.6 of this Section."

Section 17 ADDITIONAL REQUIREMENTS FOR SHIPS CARRYING VEHICLES WITH FUEL IN THEIR TANKS FOR THEIR OWN PROPULSION

The existing paragraph 2.17.1.2 is replaced by the following:

① See IEC publication 60092-502: Electrical installations in ships –Part 502: Tankers – Special Features.

"2.17.1.2 The certified explosion-proof equipment required by this Section is to comply with the provisions of 1.3.3 of this PART, and the explosion group and temperature class are not to be lower than II A, T3."

The existing paragraph 2.17.2 is replaced by the following:

"**2.17.2 Carriage of vehicles in special category spaces, closed ro-ro spaces① above the bulkhead deck of passenger ships and in closed ro-ro cargo spaces (with not less than 10 air changes per hour) of cargo ships".**

The existing paragraph 2.17.3 is replaced by the following:

"**2.17.3 Carriage of vehicles in special category spaces, closed ro-ro spaces below the bulkhead deck of passenger ships and in closed ro-ro cargo spaces (with less than 10 air changes per hour) of cargo ships".**

The existing paragraph 2.17.4 is replaced by the following:

"**2.17.4 Carriage of vehicles in cargo spaces of passenger ships and cargo ships"**.

A new paragraph 2.17.4.3 is added as follows:

"2.17.4.3 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 and the temperature rise on the surface is not to exceed 200℃."

The existing paragraph 2.17.5 is deleted and the existing paragraphs 2.17.6 and 2.17.6.1 are renumbered as 2.17.5 and 2.17.5.1 accordingly.

Section 19 ADDITIONAL REQUIREMENTS FOR BULK CARRIERS

In the existing paragraph 2.19.2.1, the footnote is replaced by "See resolution MSC.188(79) adopted by IMO - Performance Standards for Water Level Detectors on Bulk Carriers and Single Hold Cargo Ships Other than Bulk Carriers."

① With not less than 10 air changes per hour.

CHAPTER 3 CONSTRUCTION AND TESTING OF ELECTRICAL EQUIPMENT

Section 5 CABLES

In the existing paragraph 3.5.1.1, the footnote to "Fire-resisting cables are to additionally comply with the relevant requirements for fire-resisting cables of acceptable standards." is replaced by:

"Refer to IEC publication 60331-21; or

IEC publication 60331-1 for testing electric cables of greater than 20 mm overall diameter;

IEC publication 60331-2 for testing electric cable of up to 20 mm overall diameter;

IEC publication 60331-23 for testing electric data cables;

IEC publication 60331-25 for testing optical fibre cables."

PART SIX FIRE PROTECTION, DETECTION AND EXTINCTION

CHAPTER 2 FIRE EXTINCTION SYSTEMS

Section 2 FIXED GAS FIRE-EXTINGUISHING SYSTEMS

2.2.1 General requirements

2.2.1.1 Means are to be provided for automatically giving audible warning of the release of fire-extinguishing medium into any space in which personnel normally work or to which they have access. The alarm is to operate for not less than 20 s before the medium is released.

Where automatic audible alarms are fitted to warn of the release of fire-extinguishing medium into cargo pump rooms onboard tankers carrying crude oil or petroleum products having a flash point not exceeding 60℃ (closed-cup test), they may be of the pneumatic type or electric type:

(1) if pneumatically operated, air-operated alarms may be used provided the air supply is clean and dry; in cases where the periodic testing of such alarms is required, CO_2-operated alarms should not be used owing to the possibility of the generation of static electricity in the CO_2 cloud;

(2) ~~if electrically operated, the alarms are to be certified intrinsically safe and the arrangements are to be such that the electrical actuating mechanism is located outside the cargo pump room, in accordance with the requirements of Section 16, Chapter 2 of PART FOUR.~~ if electrically operated, the alarms are to satisfy the requirements of Section 16, Chapter 2 of PART FOUR and the arrangements are to be such that the electrical actuating mechanism is located outside the cargo pump room, except where the alarms are certified intrinsically safe.

CHAPTER 3 FIRE SAFETY MEASURES

Section 3 PROTECTION OF CARGO PUMP ROOMS

~~3.3.2 Lighting and sighting ports in cargo pump room/engine room bulkheads~~

~~3.3.2.1 Where the cargo pump room is illuminated through glazed ports, these are to be effectively protected from mechanical damage and are to have strong covers secured from the side of the safe space.~~

~~3.3.2.2 Glazed ports are to be so constructed that glass and sealing will not be impaired by the working of the ship.~~

~~3.3.2.3 The glass and the protection of the light fitting are not to impair the integrity of the bulkhead and are to be of equivalent strength.~~

~~3.3.2.4 The fitting is to have the same resistance to fire and smoke as the unpierced bulkhead.~~

The subsequent paragraphs are renumbered accordingly.

Section 4 MISCELLANEOUS

3.4.14 Fore peak ballast system on oil tankers

3.4.14.1 The fore peak tank can be ballasted with the system serving other ballast tanks within the cargo area, provided:

(1) the fore peak tank is considered as hazardous;

(2) the vent pipe openings are located on open deck at an appropriate distance from sources of ignition. In this respect, the hazardous zones distances are to be determined according to the hazardous zones defined in paragraphs ~~4.2.2.7~~4.2.2.9 and 4.2.3.1 of IEC 60092-502: Electrical installations in ships - Tankers – Special features;

(3) means are provided, on the open deck, to allow measurement of flammable gas concentrations within the fore peak tank by a suitable portable instrument;

(4) the sounding arrangement to the fore peak tank is direct from open deck;

(5) the access to the fore peak tank is direct from open deck. Alternatively, indirect access from the open deck to the fore peak tank through an enclosed space may be accepted provided that:

① in case the enclosed space is separated from the cargo tanks by cofferdams, the access is through a gas tight bolted manhole located in the enclosed space and a warning sign is to be provided at the manhole stating that the fore peak tank may only be opened after it has been proven to be gas free; or any electrical equipment which is not certified safe in the enclosed space is isolated;

② in case the enclosed space has a common boundary with the cargo tanks and is therefore hazardous, the enclosed space can be well ventilated.

3.4.15 Arrangement of oxygen, acetylene cylinders

3.4.15.1 Storage of oxygen, acetylene cylinders is to meet the following requirements:

(1) The design, construction and approval of gas cylinders are to comply with the applicable requirements of PART THREE of the Rules or requirements of the recognized standards. Each gas cylinder is to be provided with proper pressure relief device such as a fusible plug or a rupture disc.

(2) Pipes, pipe fittings, pipe joints and valves are to comply with the requirements of Class I piping systems. Materials for acetylene on the high-pressure side between the cylinders and the regulator are to be steel. Copper or copper alloys containing more than 65% copper are not to be used in the whole fixed acetylene piping. Materials for oxygen piping are to be of steel or copper. Materials for both oxygen and acetylene systems are to be corrosion resistant, all the pipes of the fixed piping are to be seamless drawn.

(3) The connections between fixed pipe sections are to be carried out by means of butt welding. Other types of connections including threaded connections and flange connections are not permitted.

(4) Where there are two or more cylinders of each gas, separate dedicated storage rooms are to be provided for each gas.

(5) Storage rooms are to be constructed of steel, not located below the open deck, and be well ventilated and accessible from the open deck. The ventilation arrangement is to be separate from the ship's ventilation systems.

(6) Electrical installation or other possible sources of ignition are not to be fitted in acetylene storage room.

(7) Securing arrangements of gas cylinders are to be released easily and quickly for the expeditious removal of cylinders in the event of fire.

(8) Prominent and permanent "NO SMOKING" signs are to be displayed at the gas cylinder storage room.

(9) Where cylinders are stowed in open locations means are to be provided to:

① protect cylinders and associated piping from physical damage;

② minimize exposure to hydrocarbons;

③ ensure suitable drainage.

(10) ~~If the work area for oxyacetylene welding is more than one layer deck or over away from gas storage room or passes through bulkhead, fixed pipes are to be provided between gas cylinder and work area for welding. Suitable protection is to be provided at the position passing through deck or bulkhead. Outlet stations are to be fitted with shut-off valves.~~ If the pipes connecting the work station for oxyacetylene welding and gas storage room need to pass through deck or bulkhead, fixed pipes are to be provided between gas cylinder and work station for welding and they are not to pass through accommodation spaces, service spaces and control stations. Suitable protection is to be provided at the position passing through deck or bulkhead. Outlet stations of fixed pipes are to be fitted with shut-off valves.

PART SEVEN AUTOMATION SYSTEMS

CHAPTER 2 BASIC REQUIREMENTS

Section 6 COMPUTER SYSTEMS

2.6.6.4 Where a display unit is used for alarm in place of a general indicating lamp in computer systems of categories II and III, the following requirements are to be satisfied:

(1) The indication of the display unit is to be clear under the bright environmental condition. Data and information shown on the display unit are to be capable of being easily read by an operator in a normal working position.

(2) The display unit is to be capable of clearly indicating all the alarm signals.

(3) The display unit is to be capable of distinguishing the status of fault alarms, i.e., the status before and after acknowledgment; but this distinction is not to be shown by means of different colors only.

(4) ~~A printer is to be provided for recording the faults and their time.~~ A storage device and an output interface are to be provided in order to record and output the faults and their time.

(5) ~~At least a standby display unit or lamp panel is to be provided.~~ For the centralized monitoring and alarm system in the engine room, at least a standby display unit or lamp panel is to be provided, or a printer is to be provided in order to record the faults and their time.

(6) The display unit is to be capable of normal operation in the event of a failure of the normal power supply.

(7) Where a display unit is common to parameter and alarm displays, the parameter display is not to interfere with the initiation of alarm signals.

The existing paragraph 2.6.8 is replaced by the following:

"2.6.8 Tests and evidence

2.6.8.1 Tests and evidence are to be in accordance with Table 2.6.8.1. Definitions and notes relating to Table 2.6.8.1 are given in Appendix 1 of this Chapter.

Tests and Evidence of Computer Systems **Table 2.6.8.1**

No.	Tests and evidence	System category		
		I	II	III
1.	**Evidence of quality system**			
	Quality plan for software		**M**	**M**
	Inspection of components (only Hardware) from sub-suppliers		**M**	**M**
	Quality control in production		**M**	**M**
	Final test reports	**M**	**M**	**S**
	Traceability of software	**M**	**M**	**S**
2.	**Hardware and software description**			
	Software description		**M**	**S**

No.	Tests and evidence	System category		
		I	II	III
	Hardware description		**M**	**S**
	Failure analysis for safety related functions only			**S**
3.	**Evidence of software testing**			
	Evidence of software testing according to quality plan		**M**	**S**
	Analysis regarding existence and fulfilment of programming procedures for safety related functions			**S**
4.	**Hardware tests**			
	Tests according to CCS Guidelines for Type Approval Test of Electric and Electronic Products, 2006		**W**	**W**
5.	**Software tests**			
	Module tests		**M**	**S**
	Subsystem tests		**M**	**S**
	System test		**M**	**S**
6.	**Performance tests**			
	Integration test		**M**	**W**
	Fault simulation		**W**	**W**
	Factory Acceptance Test (FAT)	**M**	**W**	**W**
7.	**On-board test**			
	Complete system test	**M**	**W**	**W**
	Integration test		**W**	**W**
	Operation of wireless equipment to demonstrate electromagnetic compatibility		**W**	**W**
8.	**Modifications**			
	Tests after modifications	**M**	**S/W**	**S/W**

Notes: *M* = Evidence kept by manufacturer and submitted on request.
S = Evidence checked by CCS.
W = To be witnessed by CCS."

A new Appendix 1 is added as follows:

"Appendix 1 DEFINITIONS AND NOTES RELATING TO TESTS AND EVIDENCE OF COMPUTER SYSTEMS

1.1 Evidence of quality system

1.1.1 Quality plan for software: a plan for software lifecycle activities is to be produced which defines relevant procedures, responsibilities and system documentation, including configuration management.

1.1.2 Inspection of components (only Hardware) from sub-suppliers: proof that components and/or sub-assemblies conform to specification.

1.1.3 Quality control in production: evidence of quality assurance measures on production.

1.1.4 Final test reports: reports from testing of the finished product and documentation of the test results.

1.1.5 Traceability of software: modification of program contents and data, as well as change of version has to be carried out in accordance with a procedure and is to be documented.

2.1 Hardware and software description

2.1.1 Software description: software is to be described, e.g.:

- Description of the basic and communication software installed in each hardware unit;

- Description of application software (not program listings);

- Description of functions, performance, constraints and dependencies between modules or other components.

2.1.2 Hardware description: hardware is to be described, e.g.:

- System block diagram, showing the arrangement, input and output devices and interconnections;

- Connection diagrams;

- Details of input and output devices;

- Details of power supplies.

2.1.3 Failure analysis for safety related functions only (e.g. FMEA): the analysis is to be carried out using appropriate means, e.g.:

- Fault tree analysis;

- Risk analysis;

- FMEA or FMECA.

The purpose is to demonstrate that for single failures, systems will fail to safety and that systems in operation will not be lost or degraded beyond acceptable performance criteria when specified by CCS.

3.1 Evidence of software testing

3.1.1 Evidence of software testing according to quality plan: procedures for verification and validation activities are to be established, e.g.:

- Methods of testing;

- Test programs producing;

- Simulation.

3.1.2 Analysis regarding existence and fulfilment of programming procedures for safety related functions: specific assurance methods are to be planned for verification and validation of satisfaction of requirements, e.g.:

- Diverse programs;

- Program analysis and testing to detect formal errors and discrepancies to the description;

- Simple structure.

4.1 Hardware tests

4.1.1 Tests according to CCS Guidelines for Type Approval Test of Electric and Electronic Products, 2006 will normally be a type approval test. Special consideration may be given by CCS to tests witnessed and approved by another IACS member society.

5.1 Software tests

5.1.1 Module tests: software module tests are to provide evidence that each module performs its intended function and does not perform unintended functions.

5.1.2 Subsystem tests: subsystem testing is to verify that modules interact correctly to perform the intended functions and do not perform unintended functions.

5.1.3 System test: system testing is to verify that subsystems interact correctly to perform the functions in accordance with specified requirements and do not perform unintended functions.

6.1 Performance tests

6.1.1 Integration tests: programmable electronic system integration testing is to be carried out using satisfactorily tested system software, and as far as practicable intended system components.

6.1.2 Fault simulation: faults are to be simulated as realistically as possible to demonstrate appropriate system fault detection and system response. The results of any required failure analysis are to be observed.

6.1.3 Factory Acceptance Test (FAT): factory acceptance testing is to be carried out in accordance with a test program accepted by CCS. Testing is to be based on demonstrating that the system fulfils the requirements specified by CCS.

7.1 On-board tests

7.1.1 Complete system test: testing is to be performed on the completed system comprising actual hardware components with the final application software, in accordance with an approved test program.

7.1.2 Integration tests: on board testing is to verify that correct functionality has been achieved with all systems integrated.

7.1.3 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 its self fail as a result of electromagnetic interference during expected operating conditions. Where electromagnetic interference caused by wireless data communication equipment is found to be causing failure of equipment required for Category II or III systems, the layout and/or equipment is to be changed to prevent further failures occurring.

8.1 Modifications

8.1.1 Tests after modifications: modifications to approved systems are to be notified in advance and carried out to the satisfaction of CCS, see 2.6.1.4 of this Chapter."

CHAPTER 3 REQUIREMENTS FOR CLASS NOTATIONS AUT-0 OF PERIODICALLY UNATTENDED MACHINERY SPACES

Section 10 AUTOMATIC CONTROL AND MONITORING ITEMS

Except for items 8 and 9 of "1.2 Lubricating oil system" in the existing Table 3.10.1.1, all "low speed engines" and "low speed diesel engines" in this Section are replaced by "crosshead diesel engines" while all "medium/high speed engines" and "medium/high speed diesel engines" are replaced by "trunk piston diesel engines".

The contents of 1.10 in the existing Table 3.10.1.1 are replaced by the following:

"

Item	CCS		Mode of protective control action	Mode of alarm at BCS	Remarks
	Display	Limit alarm			
1	2	3	4	5	6
1.10 Fuel valve coolant ~~(Necessary for low speed engines)~~					
Pressure of fuel valve coolant	Pressure	Low	c	R	The requirement is to be complied with if the crosshead diesel engine is fitted with a separate fuel valve cooling system
Temperature of fuel valve coolant	Temperature	High	_	Y	
Level of fuel valve coolant in expansion tank	–	Low	_	Y	

"

CHAPTER 4 REQUIREMENTS FOR MACHINERY NOTATIONS OF CONSTANTLY ATTENDED MACHINERY SPACES

Section 2 REQUIREMENTS FOR AUTOMATION OF SHIPS WITH CLASS NOTATION MCC

Except for items 8 and 9 of "1.2 Lubricating oil system" in the existing Table 4.2.6.1, all "low speed engines" and "low speed diesel engines" in paragraph 4.2.6 are replaced by "crosshead diesel engines" while all "medium/high speed engines" and "medium/high speed diesel engines" are replaced by "trunk piston diesel engines".

The contents of 1.10 in the existing Table 4.2.6.1 are replaced by the following:

"

Item	CCS		Mode of protective control action	Remarks
	Display	Limit alarm		
1	2	3	4	5
1.10 Fuel valve coolant ~~(Necessary for low speed engines)~~				
Pressure of fuel valve coolant	Pressure	Low	c	The requirement is to be complied with if the crosshead diesel engine is fitted with a separate fuel valve cooling system

"

Section 3 REQUIREMENTS FOR AUTOMATION OF SHIPS WITH CLASS NOTATION BRC

Except for items 8 and 9 of "1.2 Lubricating oil system" in the existing Table 4.3.4.1, all "low speed engines" and "low speed diesel engines" in paragraph 4.3.4 are replaced by "crosshead diesel engines" while all "medium/high speed engines" and "medium/high speed diesel engines" are replaced by "trunk piston diesel engines".

The contents of 1.10 in the existing Table 4.3.4.1 are replaced by the following:

"

Item	CCS		Mode of protective control action	Mode of alarm at BCS	Remarks
	Display	Limit alarm			
1	2	3	4	5	6
1.10 Fuel valve coolant ~~(Necessary for low speed engines)~~					
Pressure of fuel valve coolant	Pressure	Low	c	Y	The requirement is to be complied with if the crosshead diesel engine is fitted with a separate fuel valve cooling system
Temperature of fuel valve coolant	Temperature	High	–	Y	
Level of fuel valve coolant in expansion tank	–	Low	–	Y	

"

PART EIGHT ADDITIONAL REQUIREMENTS

CHAPTER 1 ADDITIONAL REQUIREMENTS FOR FIRE-FIGHTING SHIPS

Section 3 PROTECTION AND FIRE-FIGHTING EQUIPMENT

1.3.4.3 Seawater suctions

(1) Seawater suctions for the fire-fighting pumps are not to be arranged for other purposes.

(2) The seawater suction valve, pressure valve and the pump motor are to be operable from the same position. Valves with nominal diameter exceeding 450 mm are to be power actuated as well as manually operable.

(3) Starting of fire-fighting pumps when water inlet valves are closed is to be prevented either by an interlock system or by an audible and visual alarm.

(4) Seawater inlets and sea chests are to be of a design ensuring an even and sufficient supply of water to the pumps. The location of the seawater inlets and sea chests is to be such that the water supply is not impeded by the ship's motions or by the water flow to and from bow thrusters, side thrusters, azimuth thrusters or main propellers.

(5) Seawater suctions of the fire-fighting pumps are to be arranged as low as practicable to avoid icing.

(6) ~~Seawater suctions are to be provided with strainers to ensure the efficient operation of pumps and efficient means are to be provided for cleaning the strainers of seawater suctions.~~ Seawater suctions are to be fitted with gratings having a free passage area not less than twice that of the sea suction valve, and efficient means are to be provided for cleaning the gratings in order to ensure the efficient operation of pumps.

CHAPTER 3 ADDITIONAL REQUIREMENTS FOR OIL RECOVERY SHIPS

Section 2 CONSTRUCTION AND FIRE SAFETY

3.2.2 Arrangement of recovered oil tanks

3.2.2.6 Where cofferdams are impractical to arrange, any tank adjacent to the machinery spaces or pipe tunnel may be accepted for storage of recovered oil, provided that bulkheads of the tank are:

(1) accessible for inspection;

(2) carried continuously through abutting plate panels, except that full penetration welding is to be used for the fillet welds of bulkheads and decks. Welds on tank boundaries are to be reduced to a minimum insofar as practicable.

3.2.3 Access and other openings

3.2.3.1 In general, no access door or any other opening is to be permitted between safe spaces (such as accommodation, service and machinery spaces, control stations and navigation bridge) and gas-hazardous zones. Access doors may be accepted between such spaces and gas-hazardous zones of Category 1, provided that the following conditions are met:

(1) an air lock is to consist of two steel doors substantially gastight which should be spaced not less than 1.5 m apart (watertight doors may be considered as gastight doors);

(2) safe spaces are under positive pressure mechanical ventilation in relation to the gas-hazardous zones;

(3) the doors are to be self-closing and without any holding back arrangements;

~~(4) signs are provided to warn that the doors are to be kept closed during oil recovery operations.~~

~~3.2.3.2 Access, ventilation openings (inlets and outlets) and other openings to safe spaces such as accommodation, service and machinery spaces, control stations and navigation bridge, which are in frequent use during oil recovery operations and not fitted with weathertight closing appliances, are to be located outside gas-dangerous zones. Where these openings are located inside gas-hazardous zones, they are to be fitted with air locks, and the height of their doorsills is to comply with the relevant provisions for load lines.~~

3.2.3.1 Ventilation openings to safe spaces such as accommodation, service and machinery spaces, control stations and navigation bridge are not to be located inside gas-hazardous zones.

3.2.3.2 In general, no access door or any opening other than access openings and ventilation openings is to be permitted between safe spaces (such as accommodation, service and machinery spaces, control stations and navigation bridge) and gas-hazardous zones.

(1) Access doors may be accepted between such safe spaces and gas-hazardous zones of Category 1, provided that the following conditions are met:

① an air lock is to consist of two steel doors substantially gastight which should be spaced not less than 1.5 m apart (watertight doors may be considered as gastight doors);

② safe spaces are under positive pressure mechanical ventilation in relation to the gas-hazardous zones;

③ the doors are to be self-closing and without any holding back arrangements;

④ signs are provided to warn that the doors are to be kept closed during oil recovery operations or cleaning and gas-freeing operations of recovered oil tanks.

(2) Any opening other than access openings and ventilation openings may be accepted between such safe spaces and gas-hazardous zones of Category 1, provided that the following conditions are met:

① the closing appliance is to be confirmed as gastight;

② signs are provided to warn that they are to be kept closed during oil recovery operations or cleaning and gas-freeing operations of recovered oil tanks, and means are provided to prevent unauthorized opening.

3.2.3.3 Where the access doors mentioned in 3.2.3.2 above are not used as the means of escape specified in statutory requirements and they will not be used (opened) during oil recovery operations or cleaning and gas-freeing operations of recovered oil tanks (including accidental and emergency conditions the ship might encounter during the operations), air locks may not be fitted. In addition to complying with the requirement that the doors are to be self-closing and without any holding back arrangements, the following requirements are at least to be met:

(1) gastight closing can be achieved, which has been confirmed;

(2) signs are provided to warn that the doors are to be kept closed during oil recovery operations or cleaning and gas-freeing operations of recovered oil tanks, and means are provided to prevent unauthorized opening.

3.2.3.~~3~~4 Oil handling spaces on deck are to be provided with a coaming around all pumps, transfer flanges and other connections. Each coaming is to have a height sufficient to prevent recovered oil from entering accommodation, machinery, control and service spaces or passing overboard. The coaming is to have a height of at least 150 mm. Where drains are provided for the coaming, closing devices for these drains are to be permanently attached.

CHAPTER 8 ADDITIONAL REQUIREMENTS FOR SHIPS WITH REGARD TO ENVIRONMENTAL PROTECTION

Section 1 GENERAL PROVISIONS

8.1.3.1(4) ~~SEC (SO_x Emission Control);~~

SEC(I) (SO_x Emission Control);
SEC(II) (SO_x Emission Control);
SEC(III) (SO_x Emission Control);

8.1.3.1(7) GPR (Green Passport for Recycling);

GPR (EU);

8.1.4.2 (14) Inventory of Hazardous Materials on board (for GPR or GPR (EU) notation only);

Section 3 OTHER CLASS NOTATIONS

8.3.5 SO_x emission control — ~~SEC~~ SEC(I)/(II)/(III) notations

8.3.5.1 For assignment of the SEC(I) notation, ~~all fuel oil used on board is to have a sulphur content of less than 1.0 percent m/m~~the sulphur content of all fuel oils used on board is not to exceed 1.0% m/m.

8.3.5.2 For assignment of the SEC(II) notation, the sulphur content of all fuel oils used on board is not to exceed 0.5% m/m.

8.3.5.3 For assignment of the SEC(III) notation, the sulphur content of all fuel oils used on board is not to exceed 0.1% m/m.

8.3.5.4 As an alternative to the requirements in 8.3.5.1 to 8.3.5.3 above, an approved exhaust gas cleaning system or other approved means may be used to control SO_x emission below the corresponding standards. The SO_x emission standard corresponding to the above fuel oil sulphur limits is to be in compliance with the provisions of resolution MEPC.184(59).

8.3.7 Green passport for recycling – GPR and GPR (EU) notation

8.3.7.1 For assignment of the GPR notation, the ship is to carry the Inventory of Hazardous Materials in compliance with Regulation 5 of the Annex to Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships, 2009 of IMO and provide related ship particulars. For assignment of the GPR (EU) notation, the ship is to carry the Inventory of Hazardous Materials in compliance with Article 5 of Regulation (EU) No. 1257/2013.

(1) Ship particulars are to include:

① distinctive number or letters;

② type of the ship;

③ gross tonnage;

④ IMO Number;

⑤ name of the shipyard;

⑥ name of the shipowner;

⑦ date of delivery.

(2) The Inventory of Hazardous Materials consists of three parts:

① part 1 – hazardous materials in the ship's structure and equipment;

② part 2 – operationally generated wastes;

③ part 3 – stores.

Part 1 is to be completed for the application of the GPR or GPR (EU) notation. Parts 2 and 3 are to be completed by the shipowner prior to the ship's planned recycling and the application of the final survey.

8.3.7.2 The Inventory of Hazardous Materials is to be developed in accordance with 2011 Guidelines for the development of the Inventory of Hazardous Materials adopted by IMO Marine Environment Protection Committee by resolution MEPC.197(62) and to be verified by CCS①. ~~In addition, sampling and testing are to be carried out in accordance with the Guidelines for the Development of the Inventory of Hazardous Materials, Survey and Certification of Ships which is released by the Society, and the test reports are to be submitted accordingly.~~

8.3.7.3 The ship is to establish maintenance procedure for the Inventory of Hazardous Materials covering the life of the ship and designated personnel are to be responsible for updating and maintaining the Inventory of Hazardous Materials.

① Refer to CCS Guidelines for Development and Survey of the Inventory of Hazardous Materials of Ships.

CHAPTER 9 ADDITIONAL REQUIREMENTS FOR SHIPS HAVING INDEPENDENT ICEBREAKING CAPABILITY

Section 1 GENERAL PROVISIONS

~~9.1.1.1 This Chapter applies to ships not specially designed for icebreaking duties and navigating in first-year ice conditions, complying with the requirements of PART TWO and PART THREE of the Rules for ice strengthening and having an independent icebreaking capability. According to the provisions of 4.2.1.2 of Section 2, Chapter 4 of PART TWO of the Rules, ships of ice class notation B1* already have the capability of independent navigation in ice corresponding to ice class notation without the assistance of icebreaker. But according to the requirements of this Chapter, the independent icebreaking capability is to be higher than that of the ship with B1* notation according to the provisions of Chapter 4 of PART TWO, i.e. the icebreaking capacity of removing obstacles for other ships navigating in ice.~~

9.1.1.1 This Chapter applies to ships not specially designed for icebreaking duties and navigating in first-year ice conditions, complying with the ice strengthening requirements of PART TWO and PART THREE of the Rules for B1*, B1, B2 and B3 notations and having an independent icebreaking capability. Ships assigned ice class notation B1* in accordance with the provisions of Section 2, Chapter 4, PART TWO of the Rules, already have the capability of independent navigation in ice corresponding to the ice class notation without the assistance of an icebreaker. For ships complying with the requirements of this Chapter, their independent icebreaking capability is to be better than that of the ships assigned B1* notation in accordance with the provisions of PART TWO and PART THREE of the Rules, i.e. having the icebreaking capacity of removing obstacles for other ships navigating in ice.

~~9.1.2.1 For a ship complying with the requirements for ice strengthening and the requirements of this Chapter, the special features notation "Icebreaking" is to be added after its type notation, together with a corresponding ice class notation, e.g. Icebreaking Tug, Ice Class B1.~~

9.1.2.1 For a ship complying with the requirements for ice strengthening and the requirements of this Chapter, the special features notation "Icebreaking" is to be added before its type notation, together with a corresponding ice class notation, e.g. Icebreaking Tug, Ice Class B1.

Section 2 ENGINE OUTPUT

9.2.1.2 The output N_1 required for icebreaking is not to be less than that determined in accordance with the following formula:

$$N_1 = 0.736 f_1 f_2 f_3 f_4 \left[240 B h_0 (1 + h_0 + 0.035 v^2) + 70 S_c \sqrt{L} \right] \quad \text{kW}$$

where: B — breadth of the ship, in m;

L — length of the ship, in m;

f_1 — coefficient, to be calculated as below and taken not less than 1.0:

$$f_1 = \frac{1.2B}{\sqrt[3]{\Delta}}$$

where: Δ means displacement, in t, see 4.2.2.2 of Section 2, Chapter 4, PART TWO of the Rules;

f_2 — coefficient, to be taken as 0.9 for controllable pitch propeller and 1.0 for fixed pitch propeller;

f_3 — coefficient, to be taken as 0.9 when entry angle of the portion of the fore-body below the waterline is 45º or less, and 1.0 when the angle is greater than 45º, and the product $f_2 f_3$ is not to be taken less than 0.85;

f_4 — coefficient, to be taken as 1.1 with bulbous bow and 1.0 without bulbous bow;

h_0 — ice thickness, in m, see Table 4.2.4.2(1) of Section 2, Chapter 4, PART TWO of the Rules;

v — ship speed, in kn, when breaking ice of thickness h_0, not to be taken less than 5 kn;

S_c — depth of snow cover, in m, not to be taken less than 0.3 m.

CHAPTER 13 ADDITIONAL REQUIREMENTS FOR POLAR CLASS SHIPS

Section 1 DESCRIPTION AND APPLICATION OF POLAR CLASS NOTATIONS

CHAPTER 16 COMFORT ON BOARD

Section 1 GENERAL PROVISIONS

16.1.1.4 In the design and construction of ships, the vibration and noise on board ships are to be controlled in accordance with CCS Guidelines for Shipboard Vibration Control and Guidelines for Control and Measurement of Noises for Ships and Marine Products.

Section 2 NOISE

16.2.1.3 Measured noise levels slightly greater than those specified in the comfort criteria may be accepted. Not more than 20 percent of the passenger cabins, 30 percent of the public spaces and 20 percent of the crew cabins are to exceed the relevant noise criteria by more than ~~3~~1.5 dB(A).

Passenger Ships – Maximum Allowable Noise Levels in dB(A) of Passenger Spaces

Table 16.2.2.1

Location	Comfort grade (noise)		
	1	2	3
Passenger cabins, superior	45	47	50
Passenger cabins, standard	49	52	55
Passenger public spaces	55	58	62
Hospital	49~~55~~	52~~57~~	55~~60~~
Theatre	53	55	60
Open deck recreation areas①②③	65	69	73

Crew Cabins and Public Spaces – Maximum Allowable Noise Levels in dB(A)

Table 16.2.3.1

Location	Comfort grade (noise)		
	1	2	3
Sleeping cabins	49~~52~~	52~~55~~	55~~60~~
Hospital	49~~55~~	52~~57~~	55~~60~~
Conference rooms, offices, mess rooms	55~~57~~	57~~60~~	60~~65~~
Crew public spaces~~, mess rooms, lounges~~	57	60	65
Galleys, changing rooms, laundries, bathrooms	70	73	75
Open deck recreation areas①	70	73	75

Crew Work Areas – Maximum Allowable Noise Levels in dB(A) **Table 16.2.3.2**

Location	Comfort grade (noise)		
	1	2	3
Engine control room	70	73	75
Wheelhouse	60	63	65
Radio room	55	57	60
Workshops	85	85	85
~~Continuously attended machinery spaces~~	~~90~~	~~90~~	~~90~~
~~Not continuously attended~~ machinery spaces	110	110	110

Crew Spaces – Minimum Airborne Sound Insulation Indices, R_w **Table 16.2.3.3**

Location	Comfort grade (noise)		
	1	2	3
Crew cabins	40~~37~~	38~~33~~	35~~30~~
Crew cabin to corridor	35	32	30
Crew cabin to stairwell	35	32	30
Crew cabin to passenger/crew public space	45	45	45

16.4.1.2 The measurement of noise on board ships is to be undertaken in accordance with CCS Guidelines for Control and Measurement of Noises for Ships and Marine Products. The measurement of vibration on board ships is to be undertaken in accordance with 16.4.2 to 16.4.4.

16.4.2 Instrumentation

~~16.4.2.1 The noise measurement and calibration equipment is to comply with ISO 2923, IEC 61672, IEC 61260 and IEC 60942.~~

16.4.2.1~~2~~ The vibration measurement and calibration equipment is to comply with ~~ISO 6954(2000)~~ISO 6954:2000 and ISO 8041, and the instrumentation is to include at least a transducer with an appropriate amplifier, and an FFT analyser.

16.4.2.2~~3~~ The instrumentation used is to be within a calibration validity period specified by the calibration authority, and copies of relevant documents are to be provided prior to measurements and together with the measurement report.

16.4.3.4 Generally the main engine is to operate with the power output corresponding to the designed normal seagoing condition, or at least ~~85%~~80% of the maximum continuous power available. All machineries and equipment that may operate simultaneously under normal operation conditions are to be run simultaneously.

16.4.3.6 The tests are to be conducted in sea conditions not greater than sea state 3 on the WMO sea state code, with the wind force being not greater than ~~3~~4 on the Beaufort scale.

16.4.3.8 Ship course is to be kept constant as far as possible, with rudder angle variations being ~~limited to less than~~ within the range of ±2 degrees portside or starboard, for the duration of the measurement.

16.4.4 Noise measurements

16.4.4.1 Noise measurements are to be conducted in accordance with ISO 2923, IMO Resolution A.468(XII) and GB/T 4595. Sound insulation measurements are to be conducted in accordance with ISO 140.

16.4.4.2 Air conditioning and mechanical ventilation are to be in normal operation, with their power complying with the design requirements.

16.4.4.3 Doors and windows are to be shut, unless they have to be kept open in normal use.

16.4.4.4 Measurement locations are to be chosen so that the assessment represents the overall noise environment on board the ship. In large spaces, such as restaurants and open deck recreation areas, sufficient measurements are to be taken at locations not greater than 7 m apart.

16.4.4.5 Where the measured noise level exceeds the relevant criterion by 3 dB(A), octave band readings are to be taken, with centre frequencies from 31.5 Hz to 8000 Hz.

~~16.4.4.6 The noise measurement report is to comply with ISO 2923, and is to include measurement locations indicated on a general arrangement plan, tabulated dB(A) noise levels (together with octave band analysis for positions where the level exceeds the specified criterion by 3 dB(A), with centre frequencies from 31.5 Hz to 8000 Hz), ship and machinery details, test conditions, details of measuring and analysis equipment, and copies of the relevant instrument calibration certificates.~~

16.4.4~~5~~ Vibration measurements

16.4.45.1 Vibration measurements are to be conducted in accordance with ~~ISO 6954(2000)~~ISO 6954:2000 and ~~ISO 4868~~ ISO 20283-2.

16.4.45.2 Measurement locations are to be chosen so that the assessment represents the overall vibration environment on board the ship. In cabins, vibration readings are to be taken in the centre of the floor area. In large spaces, such as restaurants, sufficient measurements are required to define the vibration profile.

16.4.45.3 The vibration measurement report is to comply with ~~ISO 6954(2000)~~ISO 6954:2000 and ~~GB/T 7453~~ISO 20283-2, containing measurement positions and directions indicated on a general arrangement plan, tabulated vibration levels, ship and machinery details, test conditions, and copies of the relevant instrument calibration certificates.

A new Chapter 20 is added as follows:

"CHAPTER 20 ADDITIONAL REQUIREMENTS FOR ANCHOR HANDLING

Section 1 GENERAL PROVISIONS

20.1.1 Application

20.1.1.1 The requirements of this Chapter apply to anchor-handling ships.

20.1.2 Class notation

20.1.2.1 Ships complying with the requirements of this Chapter will be assigned the following class notation:

(1) Anchor Handling.

20.1.3 Plans and documents

20.1.3.1 The following plans are to be submitted for approval:

(1) Foundation and supporting structure of anchor handling winch;

(2) Stern rollers, towing pins, shark jaws and their supporting structures;

(3) Stability booklet (additional requirements for anchor handling);

(4) Construction profile and shell expansion.

20.1.3.2 The following plans or documents are also to be submitted for information:

(1) Arrangement of anchor handling equipment;

(2) Type and rated parameters of the anchor handling winch.

Section 2 HULL STRUCTURE

20.2.1 General requirements

20.2.1.1 Where not provided in this Chapter, the hull structure of anchor-handling ships is to comply with the relevant requirements of Chapter 2, PART TWO of the Rules.

20.2.2 Shell plating

20.2.2.1 The side shell in way of the stern rollers immediately adjacent to high duty mooring bollards and in other high load areas is to be suitably reinforced. Where an anchor-handling ship is not provided with any fender, the thickness of shell plating is not to be less than that required in Section 3, Chapter 2, PART TWO of the Rules and not to be less than 11 mm.

20.2.3 Deck plating

20.2.3.1 The deck plating near the stern and that subject to concentrated loads are to be suitably increased in thickness. Where an anchor handling ship is an offshore supply ship, the increased thickness of deck plating is not to be less than 2 times that required by 11.3.2.1, Section 3, Chapter 11, PART TWO of the Rules.

20.2.3.2 Where the anchor and chain are kept on the deck, effective means (e.g. wooden sheathing) are to be provided to uniformly distribute their weight on the deck.

Section 3 ANCHOR HANDLING EQUIPMENT AND SUPPORTING STRUCTURES

20.3.1 Anchor handling arrangement

20.3.1.1 The following equipment is to be provided on anchor-handling ships:

(1) anchor handling winches;

(2) stern rollers;

(3) shark jaws;

(4) towing pins.

20.3.1.2 Anchor handling winches are to be designed in such a way as to allow an emergency release in all operating conditions, and this should be operable from the navigation bridge. After an emergency release, the braking of winches is to be capable of being restored to normal function immediately.

20.3.2 Equipment and supporting structures

20.3.2.1 The anchor handling winch and associated accessories are to be capable of sustaining the maximum load from the hoisting, rendering and braking including any dynamic loads as applicable without permanent deformation.

20.3.2.2 The foundation and supporting structures of anchor handling winches are to be capable of sustaining the maximum braking load or 1.5 times the maximum hoisting load, whichever is greater. The considered stress is not to be greater than the following permissible values:

Normal stress $[\sigma] = 0.9R_{eH}$

Shear stress $[\tau] = 0.5R_{eH}$

Equivalent stress $[\sigma_e] = 1.0R_{eH}$

where: R_{eH} is yield stress of material, in N/ mm^2.

20.3.2.3 Stern rollers, shark jaws and towing pins are to be sized such that they, together with their supporting structures, are capable of sustaining 2 times the maximum static working load in all conditions of their arrangement, and the permissible stress under consideration is to be in accordance with 20.3.2.2 of this Section.

Section 4 STABILITY

20.4.1 General

20.4.1.1 The stability during anchor handling operations is to comply with the requirements of 20.4.2 of this Section in addition to the relevant requirements of the Administration.

20.4.2 Additional requirements for intact stability

20.4.2.1 The vertical and transverse tensions in the most unfavorable condition are at least to comply with the following requirements:

(1) The maximum acceptable tension in wire/line/chain, including the maximum acceptable transverse tension that can be accepted in order for the ship's maximum heeling to be limited to one of the following angles, whichever occurs first:

① heeling angle equivalent to a GZ value equal to 50% of GZ max;

② the angle which results in water on working deck;

③ 15º.

(2) The heeling moment is to be calculated as the total effect of the horizontal and vertical transverse components of tension in the wire/line/chain. The torque arm of the horizontal components is to be calculated as the distance from the height of the work deck at the guide pins to the center of main propulsion propeller or to center of stern side propeller if this projects deeper. The torque arm of the vertical components is to be calculated from the centre of the outer edge of the stern roller and with a vertical straining point on the upper edge of the stern roller.

20.4.2.2 The following loading conditions intended for anchor handling are to be included in the Stability Booklet:

(1) ship at the maximum load line draft, with full stores and fuel and fully loaded with all liquid and dry cargo distributed below deck and with remaining deadweight distributed as above-deck weight (anchors, chain, etc.) corresponding to the worst service departure condition in which all the relevant stability criteria are met;

(2) ship with 10% stores and fuel and fully loaded cargoes of (1) above, arrival condition;

(3) ship at the maximum load line draft, with full stores, a full set of rig anchors on deck to be deployed during single trip (and rig chains, if appropriate) and fuel loaded to the maximum deadweight, corresponding to the worst service departure condition in which all the relevant stability criteria are met;

(4) ship with 10% stores and fuel and fully loaded cargoes of (3) above, arrival condition;

(5) ship in the worst anticipated operating condition.

20.4.2.3 The conditions given in 20.4.2.2 of this Section are to include the following items:

(1) the loads on the deck (including the weight of anchors, chains and wires/lines) and winch reels (loaded with heaviest possible wire/line types);

(2) the vertical force from the tension, upon which calculations of trim and curve for righting arm are based;

(3) the weight of the anchors and wires/lines/chains;

(4) the righting arm curve corrected for the free surface (using the vertical centre of gravity), including any roll reduction tanks in use. Consideration is to be given to fuel oil and fresh water used as well as any ballast water necessary during the operations;

(5) if a ship is fitted with rig chain locker(s) below the main deck, the opening(s) is to be considered as a downflooding point for the stability calculations. As an alternative, where the ship's stability is in compliance with the requirements of this Section in the condition of the single chain locker being flooded (and taking the effects of the maximum free surface into account) during the stability calculation, the opening(s) may not be regarded as the downflooding point(s);

(6) if a ship is fitted with open rig chain lockers on the main deck, effective means to drain these lockers are to be provided. If not, the lockers are to be considered flooded and the appropriate free surface effects included in all stability calculations.

20.4.3 Stability information to be supplied to the Master

20.4.3.1 The stability booklet is to include the following items:

(1) Information stating the maximum tension in wire/line/chain, as well as corresponding lateral point of direction according to the calculations, is to be provided and be displayed next to the control desk or at another location where the navigator on duty can easily see the information from his command post.

(2) The displayed information is to be in the form of simple sketches showing the ship's righting moment/arm curves in addition to a table stating the relevant combinations of tension and point of direction which gives the maximum acceptable heeling moment.

(3) Any tank restrictions (i.e. ballast tank and roll reduction tank usage, fuel oil burn off sequences, etc.) determined by the stability calculations.

20.4.3.2 During anchor handling operations, all weathertight access and emergency hatches, and doors on the work deck, are to be kept closed, except when actually being used for transit under safe conditions."

A new Chapter 21 is added as follows:

"CHAPTER 21 HULL MONITORING SYSTEMS

Section 1 GENERAL PROVISIONS

21.1.1 General requirements

21.1.1.1 This Chapter applies to hull monitoring systems installed voluntarily on board ships.

21.1.1.2 The ships provided with hull monitoring systems in accordance with this Chapter may apply for a corresponding class notation.

21.1.1.3 The hull monitoring system may be used to collect and monitor hull stress, wave and operational parameters. The system is to give warning when changes of these data approach levels that require action.

21.1.1.4 For ships not complying with the requirements of this Chapter, other arrangements achieving safety level to the same extent as that specified by this Chapter may be used, subject to agreement of CCS.

21.1.1.5 In no case is the hull monitoring system (including sensors) to be installed to damage the hull structure and impair the performance of ship, or give rise to any potential safety hazard. The system is not intended as a substitute for correct judgment and responsibility of crew members.

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: Only sensors monitoring the global longitudinal stress amidships are installed in the hull monitoring system.

(2) HMS(×): Not only sensors monitoring the global longitudinal stress amidships 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 comma ","①.

The following sensors/components may be selected for the hull monitoring system:

Letters Specifying Selected Sensors/Components Table 21.1.2.1

Letter	Explanation
G	Sensor monitoring the global hull strain
D	Sensor monitoring the local hull strain
O	Sensor monitoring the propulsion shaft(s) output
A	Sensor monitoring the axial acceleration
M	Device for monitoring of hull rigid body motions (six degrees of freedom)
P	Sensor monitoring the transient sea pressure acting on the hull (slamming)
S	Sensor monitoring the liquid motion pressures in tanks (sloshing)
T	Sensor monitoring the temperature
B	Device for monitoring the wave
W	Wind sensor
N	Navigation sensors
C	Online link to loading instrument that is continuously up-dating the loading condition

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 (D,A) upon request of the owner.

(3) HMS-HSC: applicable to high speed craft and the sensors/components installed in the hull monitoring system are to comply with Table 21.4.3.3.

21.1.2.2 The class notations specified in 21.1.2.1 are to be assigned on the basis of approved drawings, certification of equipment and onboard survey.

21.1.2.3 The hull monitoring system (including sensors) is to be furnished with a type approval certificate of CCS.

21.1.3 Plans and documents

21.1.3.1 Documents containing the following information are to be submitted for approval:

(1) arrangement of sensors (including the information on each sensor);

(2) diagrams of power systems of the hull monitoring system.

21.1.3.2 The following documents are to be submitted for information:

(1) explanation on relevant software (including data processing unit);

(2) instruction manuals of the hull monitoring system.

21.1.4 Documents to be kept on board

21.1.4.1 Instruction manuals are to be kept on board. The manuals are at least to contain the following instructions on:

(1) operation;

(2) setting and calibration of sensors and system;

(3) identification of faults;

(4) repairs;

(5) systematic maintenance and function testing (showing how components and systems are to be tested and what is to be observed during the tests);

(6) interpretation of measuring results.

21.1.4.2 A log for maintenance and calibration of the hull monitoring system is to be kept onboard.

Section 2 SYSTEM DESIGN

21.2.1 System composition and components

21.2.1.1 The hull monitoring system generally consists of a computer system (upper layer) and sensors installed in appropriate spaces (lower layer). Relevant information monitored by each sensor is transferred to the computer system. Upon receipt of such information, processing, display, alarm and storage are carried out by the computer system.

21.2.1.2 Sensors are to be so selected as to ensure that they are suitable for use in the marine environment and their type and accuracy are also suitable for use of the signal.

21.2.1.3 In the case that the ship already has installed a sensor for monitoring of a certain parameter, installation of a separate sensor for the hull monitoring system is not required.

21.2.1.4 Wave sensors may be used to monitor the wave condition, which produces a two dimensional spectrum (wave frequency and relative direction between wave and ship heading). Based on the spectrum, significant wave height, main wave direction and main wave period may be derived.

21.2.1.5 An anemometer giving speed and dominant direction of the wind may be used.

21.2.1.6 The speed of the ship may be taken from the GPS system or the speed log.

21.2.1.7 The course of the ship may be taken from the GPS system or the gyro compass.

21.2.2 System requirements

21.2.2.1 The hull monitoring system is to have functions of processing and display, and provide relevant information to ship's operators.

21.2.2.2 The system is to include a computer with sufficient capacity to perform the tasks required, e.g. process the sensor signals, display the information required on a screen, give alarms and store the data.

21.2.2.3 All electrical components that are exclusively used in the hull monitoring system, i.e. not sensors included in the navigation system, are to be powered through an UPS (un-interruptible power supply). In case of main power failure, the UPS is to have sufficient capacity to maintain normal operation of the hull monitoring system for at least 10 minutes.

21.2.2.4 The hull monitoring system is to automatically re-start for normal operation at return of main power.

21.2.2.5 In the case that the ship is equipped with a loading instrument, the still water shear forces and bending moments are to be transferred to the hull monitoring system. These data can be entered manually, read from a disk or transferred through an electronic link. The system may use this information to calculate the bending stress at the global strain positions.

21.2.2.6 The system is to be designed to give visual and audible alarm for at least the following incidents:

(1) power failure;

(2) sensor failure;

(3) signal from a sensor exceeding the alarm threshold value.

21.2.2.7 The programs and data held in the data recording system are to be protected from corruption by loss of power.

21.2.2.8 The user interface (display, keyboard and alarms) is at least to be installed on the bridge.

21.2.2.9 A data storage device suitable for saving time series and statistical information is to be used.

21.2.2.10 The system is to have minimum data storage capacity and functionality as specified in 21.3.9.

21.2.2.11 The hull monitoring system is to be configurable. The configuration is to include all settings that are relevant for a specific installation. Such settings will typically be calibration factors, sensors threshold values, filter cut-off frequencies, statistical calculations that are selected for the different sensors etc.

21.2.2.12 The system is to have output port for providing Voyage Data Recorder with all IMO mandatory information (IMO resolution MSC.333(90)) from the system. The port is to be compliant with IEC 61162.

21.2.2.13 Information on how to interpolate the vertical hull girder bending moment values from the loading instrument to the strain gauge positions is to be included in the computer programme of the system so that the loading instrument readings can be used for setting and checking the system.

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 minimised 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.

21.2.3 System installation

21.2.3.1 The position of the strain gauges is to take account of the structural configuration of the ship and its mode of operation.

21.2.3.2 Deck-mounted strain gauges are to be protected from green seas on deck by appropriate siting or by using breakwaters or similar means. Strain gauges installed in other positions are to be suitably protected against external damages.

21.2.3.3 Motion sensors to measure motions are to be placed in positions where their functioning will not be affected by vibrations. Accelerometers and motion monitoring devices are to be mounted on a structural point where local structural vibration will be minimal. If resilient mounts are used, it is to be demonstrated that they have frequency characteristics that do not affect the signal in the frequency range of interest.

21.2.3.4 The rigid body motions are to be referred to the center of gravity in loaded condition.

21.2.4 Loads due to transient sea pressure (slamming)

21.2.4.1 Loads due to transient sea pressure (slamming) are preferably to be measured in terms of normal stress (strain) at the structure on which the pressure is acting, e.g. the pressure loads are to be measured as normal stress on longitudinal(s) or plating.

21.2.4.2 The loads may alternatively be measured using pressure transducer(s) mounted through the hull.

21.2.4.3 An accelerometer in the bow area may be used as an indicator of slamming incidents.

21.2.5 Loads due to liquid motions in tanks (sloshing)

21.2.5.1 Loads due to liquid motions in tanks (sloshing) are preferably to be measured in terms of stress (strain) in the structure on which the loads are acting.

21.2.5.2 The loads may alternatively be measured in terms of pressure using a pressure transducers mounted through the tank wall.

21.2.6 Structural temperature

21.2.6.1 Temperature sensors installed on the supporting structure① of cargo tanks containing cooled or heated cargo, are at least to have an operational range that covers the temperature of the cargo and the temperature in the structure when the cargo hold is empty.

① For liquid tanks provided with the independent tank, the supporting structure means the saddle supporting the liquid tank; For the integral tank, the supporting structure mainly means the inner side of bulkhead.

Section 3 DATA PROCESSING AND STORAGE

21.3.1 General requirements

21.3.1.1 The parameters given in 21.4.3 are to be processed and made available for the hull monitoring display.

21.3.1.2 The measured signals are to be split into given time intervals for data processing. The results from the data processing for each time interval are to be stored. The time interval selected is to be set during the initial configuration of the software.

21.3.1.3 The type of processing each individual sensor signal is subjected to is to be defined during the initial configuration of the system. The configuration is to be included in the documentation.

21.3.2 Data filtering

21.3.2.1 The software is to include high-pass and low-pass time domain digital filters. The cut-off frequency of the filters is to be configurable through the software.

21.3.2.2 The filters are to be designed to have a stop-band attenuation of at least 40 dB.

21.3.2.3 The filters are to be initiated at the start-up of the hull monitoring software, and be continuously active as long as the software is running during normal operation. The part of the filtered signal that is corrupted by the settling of the filter during start-up is not to be used in the subsequent data analyses.

21.3.2.4 The system is to have the capability to simultaneously perform filtering on all the measured time series of hull responses. The time series subjected to filtering are to be configurable through the software.

21.3.2.5 The system is to be able to put the time signal from all sensors measuring the ship responses through the following filtering processes, giving four different time series:

(1) no filtering (static value and both wave and vibrations responses are maintained);

(2) high-pass filtering (static value and low cycle temperature fluctuation are removed, the wave response and vibration responses of the signal are maintained);

(3) low-pass filtering (static value and the wave response is maintained);

(4) high-pass filtering (only the vibration response is maintained).

21.3.2.6 The software is to be able to display each of the four different time series described in 21.3.2.5.

21.3.2.7 The software is to be able to perform the data analyses described in 21.3.3 through 21.3.6 on each of the four different time series described in 21.3.2.5.

21.3.3 Statistical calculations

21.3.3.1 The software is to be able to perform the statistical calculations on the time series described in 21.3.1.2 and 21.3.2.5. The sensors selected for statistical calculations and statistical operation to be performed are to be configurable in the initial set-up of the software.

21.3.3.2 The following statistical parameters are to be calculated for each of the selected ship response parameters:

(1) maximum value;

(2) minimum value;

(3) mean value;

(4) standard deviation;

(5) skewness;

(6) kurtosis;

(7) mean zero crossing period.

21.3.3.3 For each of the ship responses, a histogram of all the peaks in the time history is to be established. The amplitude for each response is to be divided into pre-set intervals, and the number of peaks within each interval is to be counted. Hence, the histogram will contain the number of peak occurrences within each interval. The intervals are to be set during configuration of the software.

21.3.3.4 Similar histograms of the ship responses as described for the peaks in 21.3.3.3 are also to be established for the troughs.

21.3.3.5 For transient phenomena, such as liquid impacts (slamming and sloshing), the integrated energy of each impact is to be calculated.

21.3.3.6 For transient phenomena, such as liquid impacts (slamming and sloshing), the rise time of each impact is to be calculated. The limits for the calculation are to be configurable.

21.3.3.7 Based on assumptions of statistical distribution of the parameters derived in 21.3.3.2 to 21.3.3.5, a curve for the probability of exceeding a certain value within a given time period is to be estimated. The time period is to be configurable through the software.

21.3.3.8 Based on the probability curve, the probability of exceeding a predefined threshold value is to be found. The threshold value is to be configurable through the software.

21.3.4 Fatigue life estimation

21.3.4.1 The fatigue life of the structural elements equipped with strain sensors is to be estimated based on the measured time history.

21.3.4.2 The stress response histograms are to be established for each strain sensor using a type of cycle count method.

21.3.5 Loads due to transient sea pressure (slamming)

21.3.5.1 The number of transient peaks recorded by the sensor installed for the recording of slamming incidents exceeding the threshold level, is to be counted. The number count for a pre-defined time period is to be made available for the display. The threshold value and the time period are to be configurable through the software.

21.3.6 Hull stress

21.3.6.1 The hull girder strain (stress) may often be influenced by strain induced by temperature differences in the hull structure. This strain may be caused by temperature differences between the cargo and the environments or by partial heating of the hull structure due to sunshine. These effects may be reflected as low cycle variations of the measured strain. The strain due to these temperature differences is normally not to be included in the analyses performed by the hull monitoring system. The hull monitoring system is to have the capability to optionally remove the strain due to temperature differences in the hull girder.

21.3.6.2 The hull monitoring system is to have the capability to read the still water bending/torsion moments calculated by the loading instrument (if applicable). This information could either be typed manually into the hull monitoring system or be transferred electronically by disk or data link. Based on this information, the hull monitoring system is to be capable of computing the strain (stress) due to the still water bending moments at each position where a sensor measuring global hull strain (stress) is positioned. In the case when the sensor position does not correspond to a section for where the still water bending moments are computed, a linear interpolation between the moments on each side of the sensor position may be applied.

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.

(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 at each sensor position.

21.3.7 Threshold values and alarms

21.3.7.1 The hull monitoring software is to be designed to allow input of a minimum and a maximum threshold value for each sensor.

21.3.7.2 The measured values are to be compared to the given threshold values for each sensor. In the case that the computed value exceeds 80% of a threshold value, an alarm is to be given.

21.3.7.3 The cause of the alarm is to be automatically written to an alarm log that is to be stored on an electronic device.

21.3.8 Trend predictions

21.3.8.1 The results from the calculations for each time interval are to be arranged in such way that a sequence of the latest data from each individual sensor can be displayed as a trend.

21.3.8.2 A 4 hour data sequence from each individual sensors is to form the basis for a forecast trend prediction of the expected response from each individual sensor for at least the next hour. The measured and the predicted data is to be made available for the display.

21.3.8.3 When the signal from an individual sensor exceeds 80% of the specified threshold value for that sensor, the expected time to reach the threshold value is to be predicted based on trend analyses. The measured and the predicted data is to be made available for the display.

21.3.9 Data storage

21.3.9.1 The system is to have capacity to store at least one year of statistical data and 24 hours of time series from all sensors. For sensors dedicated to slamming and sloshing measurements, it is sufficient to store the time sequences where the transients are exceeding a given threshold value.

21.3.9.2 The system is to have the capability to back-up the recorded data on a medium suitable to be read on a personal computer (PC).

21.3.9.3 The data back-up files are to include all the recorded data presented on a suitable text format. The files are to include sufficient information to clearly describe the content of the files.

21.3.9.4 For each time interval, the system is to store the results from all the calculations for all the individual parameters recorded. The data is to be labelled with a time stamp (date and time) corresponding to the beginning of the time interval.

21.3.9.5 The system is to automatically store time series for all the measured parameters for a number of time intervals corresponding to at least a period of the last 4 hours of recording. Time series older than this period is to automatically be deleted from the storage device.

21.3.9.6 The system is to have the functionality to permanently store the data specified in 21.3.9.5. The system is to have the storage capacity to permanently store at least 12 such periods.

Section 4 DISPLAY AND MONITORING

21.4.1 Display

21.4.1.1 The hull monitoring system is to have a display suitable for presentation of screen images.

21.4.1.2 The system is to have at least screens that display the following information:

(1) clearly visualise the position of each individual sensor;

(2) the status of each individual sensor, i.e. whether the sensor is operational or faulty;

(3) real time information of the measured time series of each individual sensor;

(4) signal level from each individual sensor compared to the threshold values;

(5) trends of the statistical parameters for each individual sensor, including forecast predictions;

(6) alarm status.

21.4.2 Manual input

21.4.2.1 The system is to be provided with means for manual input.

21.4.3 Extent of monitoring

21.4.3.1 For the class notation HMS, sensors monitoring the global longitudinal stress amidships are to be installed port and starboard.

21.4.3.2 For the class notation HMS(×), in addition to sensors monitoring the global longitudinal stress amidships which are installed port and starboard, other parameters may also be monitored. Recommended parameters to be monitored for the various types of ships and available sensors/components are given in Table 21.4.3.2.

Recommended Parameters to be Monitored for the Various Types of Ships and Available Sensors/Components Table 21.4.3.2

No.	Parameter	Applicable ship type	Available sensors/ components	Remarks
	Vertical accelerations at forward perpendicular ($0.01L$①) at centerline	a, b, c, d	A	① L is length of ship as defined in 1.1.2.1, Chapter 1, PART TWO of the Rules
	Transverse acceleration in the $0.4L$ mid ship area	b, c, d	A	To monitor inertia loading on sensitive cargo. Sudden change in response may indicate irregular situations such as ingress of water in holds or at vehicle decks
	Global longitudinal stress at the quarter length $L/4$ from mid ship (port and starboard)	a②, b②, c②, d③	G	② For ships with length L>180 m ③ For ships with hull girder sectional modulus < $1.5W_{rule}$ and with length L>180 m
4	Longitudinal stress close to bottom ($L/2$) amidships (port and starboard)	b④, c⑤	G	④ Longitudinal stresses ($L/2$) amidships below the neutral axis, e.g. at bilge area. Only for ships with large openings in deck ⑤ Longitudinal stresses ($L/2$) amidships below the neutral axis, e.g. at bilge area
5	Double bottom bending	b⑥	D	⑥ For Bulk Carriers with class notation BC-B and BC-A, one strain sensor in inner bottom of each hold
6	Bending/shear stress in pillar bulkheads	c⑦	D	⑦ For ships with operational limits with respect to draught with empty holds
7	Lateral loads at bottom near forward perpendicular	a, b, c, d	P	
8	Lateral loads at side	a, b, c, d	P	
9	Lateral loads at the bow door	d⑧	P	⑧ For Ro-Ro Ships only
10	Loading instrument	a, b, c, d	C	Ship provided with a loading instrument may choose whether to establish an online link to the hull monitoring system
11	Position, speed/course	a, b, c, d	N	
12	Power output and revolutions of propulsor (s)	a, b, c, d	O	
13	Wave condition	a, b, c, d	B	
14	Wind condition	a, b, c, d	W	
15	Structural temperature	a	T	
16	Sloshing response of liquid in tanks	a	S	
17	Ship's attitude	a, b, c, d	M	
In the Table, a: Oil tankers, petroleum asphalt tankers, chemical tanker, liquefied gas carriers; b: Bulk carriers and ore carriers; c: Container ships; d: General cargo ships, ro-ro ships, passenger ships and other ships.				

21.4.3.3 For the class notation HMS-HSC, the parameters to be monitored and corresponding types of sensors are given in Table 21.4.3.3.

Parameters to be Monitored for High Speed Craft and Corresponding Types of Sensors

Table 21.4.3.3

No.	Parameter	Available types of sensors	Remarks
1	Vertical, transverse and longitudinal acceleration at the centerline of each hull in the fore body (fore of forward perpendicular)	A	Must be installed
2	Vertical, transverse and longitudinal acceleration at the longitudinal center of gravity (LCG)	A	Must be installed
3	Vertical, transverse and longitudinal acceleration at the centerline of each hull aft body (aft of aft perpendicular)	A	Must be installed
4	Global longitudinal stress amidships	G	Recommended to be installed
5	Global transverse stress in wet deck in center between each hull	D	Recommended to be installed (for multi-hull ships with length L>50 m)
6	Lateral loads at bottom near forward perpendicular	P	Recommended to be installed

Section 5 COMPONENT REQUIREMENTS

21.5.1 General requirements

21.5.1.1 All components are to be replaceable and designed for easy maintenance.

21.5.1.2 Electrical equipment and installation in hazardous areas are to be in accordance with PART FOUR of the Rules.

21.5.1.3 All equipment located at the navigation bridge is to be fitted with dimmers and has displays which do not interfere undue with the night vision of the officer of the watch.

21.5.2 Sensors

21.5.2.1 Strain sensors are to be designed in such way that the measured value is not influenced by changes in temperature.

21.5.2.2 Sensors for measuring global hull strain are to be mounted in such way that influence of local strain is minimised.

21.5.2.3 Sensors that are part of other systems, can be utilised in the hull monitoring system. Connections to such sensors are to be made in such way that they do not influence performance of the other systems. Failure of the hull monitoring system is not to influence the performance of other systems.

21.5.2.4 Accelerations are to be measured over a range of -20 m/s^2 to +20 m/s^2. The measurement uncertainty of the acceleration is to be less than 2% of the measured value, or 0.10 m/s^2, whichever is the greater.

21.5.2.5 The rigid body ship motions is to be measured by a device with integrated sensors, giving the 6º of freedom (3 translations and 3 rotations). The translations (accelerations) are to be measured over a range of -20 m/s^2 to +20 m/s^2. The angles are to be measured over a range of -90º to +90º, -45º to +45º and -180º to +180º, for the roll, pitch and yaw motions respectively. The measurement uncertainty is to be less than 2% of the measured value, or 0.10 m/s^2 for translations and 0.5º for angles, whichever is the greater.

21.5.2.6 The sea pressure acting on the hull is to be measured over a range of 0 MPa (atmospheric pressure) – 2 MPa. The measurement uncertainty of the pressure is to be less than 2% of the measured value, or 0.01 MPa, whichever is the greater.

21.5.2.7 The liquid motion pressures in tanks (sloshing) is to be measured over a range of 0 MPa (atmospheric pressure) – 4 MPa. The measurement uncertainty of the pressure is to be less than 4% of the measured value, or 0.02 MPa, whichever is the greater.

21.5.2.8 The structural strain is to be measured in a range related to the yielding strain of the material. The measurement uncertainty is to be less than 3% of the measured value or 20 micro strain, whichever is the greater. For ships made of steel or aluminium, a range from -2 000 micro strain to +2 000 micro strain can be assumed. For ships constructed using special material qualities or different types of materials, i.e. composite materials, the strain range is to be specially considered by CCS.

21.5.2.9 The sensors installations designed for low frequency responses, i. e. motions and wave loading are to record the physical quantities within the specified uncertainties within the frequency range 0.01 – 3 Hz. Installations designed to measure slamming responses are to record the physical quantity within the specified uncertainties in the frequency range 5 – 100 Hz. Installations designed to measure sloshing responses are to record the physical quantity within the specified uncertainties in the frequency range 30 – 1200 Hz. For the physical quantity recorded above, the uncertainty is to be within the specified range.

21.5.2.10 The data processing unit is to be capable of handling information supplied by all sensors including navigational instruments at the actual transfer rate.

21.5.2.11 The information from the sea-state parameters is at least to be updated and submitted every 10 minutes.

21.5.3 Signal conditioning units

21.5.3.1 The signal conditioning units are to be matched to the connected sensor.

21.5.3.2 The signals from analogue sensors are to be low-pass filtered prior to digitising to avoid signal noise. The filters are to be matched to the frequency range for the different sensors.

21.5.3.3 The sensors installations designed for low frequency responses, i.e. motions and wave loading are to be digitised with at least 20 Hz. Installations designed to measure slamming responses are to be digitised with at least 500 Hz. Installations designed to measure sloshing responses in tanks are to be digitised with at least 3 kHz.”

Section 11 General Requirements

Table 11.4.1 is replaced by the following：

“

Equipment Number		Stockless bower anchors		Chain cable stud link bower chain diameter			
		Number of Anchors	Mass per anchor	Length	Normal strength steel (Grade 1)	Higher strength steel (Grade 2)	Extra higher strength steel (Grade 3)
Greater than or equal to	less than		(kg)	(m)	(mm)	(mm)	(mm)
5000	5200	2	15400	742.5	124	111	97

”

PART TEN BULK CARRIERS STRUCTURE(CSR)

Chapter 10 Hull Outfitting

Section 3 Equipment

Table 1 is replaced by the following:

Equipment number EN A < EN ≤ B		Stockless anchors		Stud link chain cables for anchors			
		N (1)	Mass per anchor kg	Total length m	Diameter，mm		
A	B				Grade 1	Grade 2	Grade 3
110	130	2	360	247.5	19.0	17.5	
130	150	2	420	275.0	20.5	17.5	
1060	1140	3	3300	495.0	58.0	50.0	46.0
4200	4400	3	12900	715.0	114.0	100.0	87.0



CHINA CLASSIFICATION SOCIETY

RULES FOR CLASSIFICATION OF SEA-GOING STEEL SHIPS

PART ELEVEN
BULK CARRIERS AND OIL TANKERS STRUCTURES (CSR)

2014

In line with the effective date of IACS CSR

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IACS Common Structural Rules for Bulk Carriers and Oil Tankers

PART 11-1 GENERAL HULL REQUIREMENTS

[PART 1, GENERAL HULL REQUIREMENTS, IACS Common Structural Rules for Bulk Carriers and Oil Tankers]

CHAPTER 1 RULE GENERAL PRINCIPLES

Section 1 APPLICATION

CCS 1.1.1a Oil tankers and bulk carriers having a length of 150 m and above and contracted for construction on and after 1 July 2016 are to comply with CCS Guidelines for Construction Monitoring of Hull Structures(2014) and to be assigned the class notation CM.
CCS 1.1.3a Unless provided otherwise, “the Society” in this PART means “CCS”.

CCS 2.5.2a The supporting structures of lifting appliances are to comply with the requirements of 4, Section 4, Chapter 11 of this PART.

Section 2 RULE PRINCIPLES

CCS 3.1.6a This PART applies to ships complying with the design basis specified in this Section. For ships which are not designed on this basis, equivalence or substitution is to be granted in accordance with paragraph 2.2.5, Section 2, Chapter 2,PART ONE of the Rules.
CCS 3.2.1a For ships not complying with the conditions of 3.2.1, the dynamic hull girder loads, ship motions, ship accelerations and sea water dynamic pressures are also to be calculated in accordance with CCS 3.2.1b to CCS 3.2.1e in addition to being calculated in accordance with the requirements of Chapter 4 of this PART.
CCS 3.2.1b Where the ship length L is greater than 350 m, vertical wave bending moments, vertical wave shear forces, horizontal wave bending moments and torsional moments of hull girder are to be calculated in accordance with CCS Appendix A of this PART. Where the maximum value of envelope is greater than the calculation value of Section 4, Chapter 4 of this PART (C_b is to be taken not less than 0.6 during calculation), the structural strength check is to be carried out by using the direct calculation results of CCS Appendix A of this PART.
CCS 3.2.1c Where the ship length L is not greater than 350 m, horizontal wave bending moments and torsional moments of hull girder are to be calculated in accordance with CCS Appendix A of this PART. Where the maximum value of envelope is greater than the calculation value of Section 4, Chapter 4 of this PART (C_b is to be taken not less than 0.6 during calculation), the structural strength check is to be carried out by using the direct calculation results of CCS Appendix A of this PART.
Where the ship length L is not greater than 350 m, the vertical wave bending moment and vertical wave shear force of hull girders are to be calculated according to Section 4, Chapter 4 of this PART (with C_b being taken not less than 0.6).
CCS 3.2.1d Direct calculation of ship motions and accelerations in each dynamic load case is to be carried out in accordance with CCS Appendix A of this PART. Direct calculation of sea water dynamic pressures is to be carried out in accordance with CCS Appendix A of this PART.
CCS 3.2.1e For ships not complying with the conditions of 3.2.1 of this Section, relevant structural strength assessment is also to be carried out in accordance with the calculation results of CCS 3.2.1d in addition to the structural strength assessment using hull motions, accelerations and sea water dynamic pressures specified in Chapter 4 of this PART.
CCS 3.4.4a For ships operating for long periods in areas with lower mean daily average temperature, the steels used for hull structures exposed to low temperature are to comply with the requirements of CCS 2.4.1a to CCS 2.4.1e, Section 1, Chapter 3 of this PART.

Section 3 VERIFICATION OF COMPLIANCE

CCS 1.1.3a The appraisal of the design of materials and equipment used in the construction of the ship and their inspection at works are to comply with the relevant requirements of Chapter 3, PART ONE of the Rules.

CCS 2.2.3a For other plans and documents available on board which are to be submitted, see Appendix 1, Chapter 4, PART ONE of the Rules.

CCS 3.1.3a Relevant procedures are to comply with the requirements of Section 5 Submission and

Examination of Plans, Chapter 2, PART ONE of the Rules.

CCS 6.1.2a Where design parameters other than those in 3 DESIGN BASIS, Section 2, Chapter 1 are used (e.g. increased fatigue life),equivalence or substitution is to be granted in accordance with paragraph 2.2.5, Section 2, Chapter 2, PART ONE of the Rules.

Section 4 SYMBOLS AND DEFINITIONS

CCS 3.1.1a For ships with unusual stem or stern arrangements, the Rule length L is 97% of the distance, in m, measured on the waterline at the scantling draught T_{SC} from the forward side of the stem to the after side of the stern frame.

Section 5 LOADING MANUAL AND LOADING INSTRUMENTS

CCS 3.1.2a The loading instruments are to comply with the requirements of Appendix 1, Chapter 2, PART TWO of CCS Rules for Classification of Sea-going Steel Ships.

CHAPTER 2 GENERAL ARRANGEMENT DESIGN

Section 1 GENERAL

Section 2 SUBDIVISION ARRANGEMENT

CCS 3.1.1a Where the shafting arrangements make enclosure of the stern tube in a watertight compartment impractical, equivalence or substitution is to be granted in accordance with paragraph 2.2.5, Section 2, Chapter 2, PART ONE of the Rules and effective means are to be provided to ensure the watertightness of the stern tube.

CCS 3.1.3a The location of the aft peak bulkhead on ships powered and/or controlled by equipment that does not require the fitting of a stern tube and/or rudder trunk is to be in accordance with paragraph 2.2.5, Section 2, Chapter 2, PART ONE of the Rules and if the relevant requirements of paragraph 1.1 of this Section are complied with, may be specially considered.

Section 3 COMPARTMENT ARRANGEMENT

CCS 2.1.1a For bulk carriers, a double bottom may not be fitted in way of watertight tanks (including dry tanks) of moderate size, provided the safety of the ship is not impaired in the event of bottom or side damage.

CCS 2.4.1a Small wells constructed in the double bottom in connection with drainage arrangements of holds, etc., are not to extend downward more than necessary. A well extending to the outer bottom is, however, permitted at the after end of the shaft tunnel. Other wells (e.g., for lubricating oil under main engines) may be permitted if satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with requirements. In no case is the vertical distance from the bottom of such a well to a plane coinciding with the keel line to be less than 500 mm.

CCS 6.1.1a Stern tubes are to be enclosed in watertight spaces of moderate volume. Other measures to minimize the danger of water penetrating into the ship in case of damage to the stern tube arrangement may be taken subject to approval.

Section 4 ACCESS ARRANGEMENT

CHAPTER 3 STRUCTURAL DESIGN PRINCIPLES

Section 1 MATERIALS

CCS 1.1.1a Materials used for hull structures are to comply with the relevant provisions of PART ONE of CCS Rules for Materials and Welding.
CCS 1.2.1a Materials are to be tested in compliance with the applicable requirements of Chapter 1, PART ONE of CCS Rules for Materials and Welding.
CCS 1.3.1a Welding and other cold or hot manufacturing processes of this Section are to comply with the applicable requirements of Section 1, Chapter 5, PART THREE of CCS Rules for Materials and Welding.

CCS 2.1.3a For higher tensile steels other than those indicated in Table 1, the chemical composition, deoxidation method, condition of supply and mechanical properties of the steels are to be submitted to CCS for approval.
CCS 2.3.2a For strength members not mentioned in Table 3 to Table 7, Grade A/AH is generally to be used.
CCS 2.4.1a For ships intended to operate in areas with low air temperatures (with design temperature below and including -20ºC),e.g. regular service during winter seasons to Arctic or Antarctic waters, the materials in exposed structures are to be selected based on the design temperature t_D of CCS 2.4.1e and in accordance with the provisions of CCS 2.4.1b to CCS 2.4.1e.
CCS 2.4.1b Grades of hull structural steel above the lowest ballast waterline (BWL) exposed to low air temperatures are not to be lower than those as given in Table CCS 2.4.1b.
CCS 2.4.1c Grades of steel for hull structural members of different material classes are to be selected according to Table CCS 2.4.1cdepending on plate thickness and design temperature. Where the design temperature t_D is below -55ºC, the grades of steel are to be subject to special consideration by CCS.
CCS 2.4.1d Single strakes required to be of class III or of grade E/EH or FH are to have breadths not less than800 + 5L mm (L being length of the ship), but need not be greater than 1,800 mm.

Material Classes at Low Air Temperatures **Table CCS 2.4.1b**

Structural member category	Structural member	Material class	
		Within 0.4Lamidships	Outside 0.4Lamidships
Secondary	Deck plating exposed to weather in general, side plating above BWL, transverse bulkheads above BWL	I	I
Primary	Strength deck plating① Continuous longitudinal members above strength deck, excluding longitudinal hatch coamings Longitudinal bulkhead above BWL Top wing tank bulkhead above BWL	II	I
Special	Sheer strake at strength deck, including rounded gunwale② Stringer plate in strength deck② Deck strake at longitudinal bulkhead③ Continuous longitudinal hatch coamings④	III	II

Notes: ① Plating at corners of large hatch openings to be specially considered. Class III or grade E/EH to be applied in positions where high local stresses may occur.
② Not to be less than grade E/EH within 0.4 L amidships in ships with length exceeding 250 m.
③ In ships with breadth exceeding 70 m at least three deck strakes to be class III.
④ Not to be less than grade D/DH.

Material Grade Requirements for Classes I, II and III at Low Temperatures

Table CCS 2.4.1c

Class I								
Plate thickness (mm)	–20 ~ –25℃		–26 ~ –35℃		–36 ~ –45℃		–46 ~ –55℃	
	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel
$t \leq 10$	A	AH	B	AH	D	DH	D	DH
$10 < t \leq 15$	B	AH	D	DH	D	DH	D	DH
$15 < t \leq 20$	B	AH	D	DH	D	DH	E	EH
$20 < t \leq 25$	D	DH	D	DH	D	DH	E	EH
$25 < t \leq 30$	D	DH	D	DH	E	EH	E	EH
$30 < t \leq 35$	D	DH	D	DH	E	EH	E	EH
$35 < t \leq 45$	D	DH	E	EH	E	EH	–	FH
$45 < t \leq 50$	E	EH	E	EH	–	FH	–	FH
Class II								
Plate thickness (mm)	–20 ~ –25℃		–26 ~ –35℃		–36 ~ –45℃		–46 ~ –55℃	
	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel
$t \leq 10$	B	AH	D	DH	D	DH	E	EH
$10 < t \leq 20$	D	DH	D	DH	E	EH	E	EH
$20 < t \leq 30$	D	DH	E	EH	E	EH	–	FH
$30 < t \leq 40$	E	EH	E	EH	–	FH	–	FH
$40 < t \leq 45$	E	EH	–	FH	–	FH	–	–
$45 < t \leq 50$	E	EH	–	FH	–	FH	–	–
Class III								
Plate thickness (mm)	–20 ~ –25℃		–26 ~ –35℃		–36 ~ –45℃		–46 ~ –55℃	
	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel	Mild steel	Higher tensile steel
$t \leq 10$	D	DH	D	DH	E	EH	E	EH
$10 < t \leq 20$	D	DH	E	EH	E	EH	–	FH
$20 < t \leq 25$	E	EH	E	EH	E	FH	–	FH
$25 < t \leq 30$	E	EH	E	EH	–	FH	–	FH
$30 < t \leq 35$	E	EH	–	FH	–	FH	–	–
$35 < t \leq 40$	E	EH	–	FH	–	FH	–	–
$40 < t \leq 50$	–	FH	–	FH	–	–	–	–

Note: "–" in the Table = Not applicable.

CCS 2.4.1e The design temperature t_D is to be taken as the lowest mean daily average air temperature in the area of operation, where:

mean: statistical mean over observation period (at least 20 years)
average: average during one day and night
lowest: lowest during year

For seasonally restricted service the lowest value within the period of operation applies.
Figure CCS 2.4.1e illustrates the temperature definition.

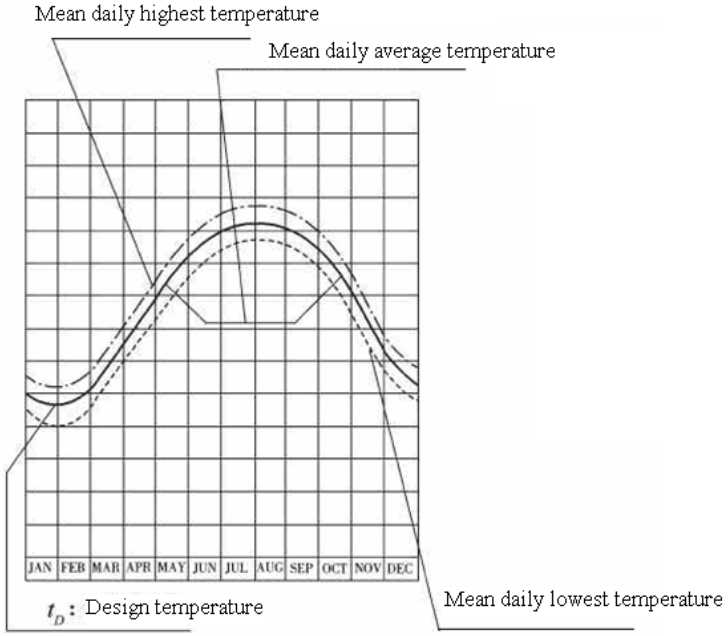


Figure CCS 2.4.1e Commonly Used Definitions of Temperatures

CCS 2.5.1a Where tee or cruciform connections employ full penetration welds, and the plate material is subject to significant stress in through-thickness direction, Z-direction steels with full thickness properties are to be used, which are to comply with the requirements of Section 10, Chapter 3, PART ONE of CCS Rules for Materials and Welding.

CCS 2.6.1a For the calculation of longitudinal strength, k is to be taken not less than 0.72 for duplex stainless steels; for austenitic stainless steels, k is to be taken as:

$$k=\frac{235}{R_{eH}}$$

where: R_{eH}— specified minimum yield stress of stainless steels, in N/mm^2.

CCS 2.6.1b For the calculation of local strength, k is to be taken not less than $235/R_{eH}$ for stainless steels in addition to complying with the following provisions:

(1) for duplex stainless steels, k is to be taken not less than the value obtained from the following formula:

$$k=\frac{235}{-65\ln(\mathrm{T})+200+R_{eH}}$$

(2) for austenitic stainless steels not containing nitrogen, k is to be taken not less than the value obtained from the following formula:

$$k=\frac{235}{-40\ln(\mathrm{T})+127+R_{eH}}$$

(3) for austenitic stainless steels containing nitrogen, k is to be taken not less than the value obtained from the following formula:

$$k=\frac{235}{-48\ln(\mathrm{T})+142+R_{eH}}$$

where: T– temperature of liquid cargo, in ºC.

CCS 3.1.1a Mechanical properties and chemical composition of steel forgings and castings to be used for structural members are to comply with the requirements of Section 2, Chapter 5 and Section 2, Chapter 6 of PART ONE of CCS Rules for Materials and Welding.

CCS 3.1.2a Steels of structural members intended to be welded are to comply with the applicable requirements of Section 2, Chapter 5 and Section 2, Chapter 6 of PART ONE of CCS Rules for Materials and Welding.

CCS 3.1.3a The steel forgings and castings used are to be tested in accordance with the applicable requirements of 5.1.5, Section 1, Chapter 5 and 6.1.6, Section 1, Chapter 6 of PART ONE of CCS Rules for Materials and Welding.
CCS 3.2.1a Rolled bars in general may not be accepted in lieu of steel forgings for primary hull structures (e.g. rudder stock). Where they are used for those other than primary structural members, they are to be subject to the agreement of CCS. In this case, the quality and testing are to comply with relevant requirements for forgings in Chapter 5, PART ONE of CCS Rules for Materials and Welding.
CCS 3.3.1a Steel castings intended for stems, stern frames, rudders, parts of steering gear and deck machinery are to comply with the requirements for carbon and carbon-manganese weldable steels having minimum tensile strength, Rm = 400 N/mm^2, specified in Section 2, Chapter 6, PART ONE of CCS Rules for Materials and Welding.
CCS 3.3.2a For the welding of steel castings to main plating contributing to hull strength members, the technological measures such as preheating temperature and post-weld heat treatment are to be determined in accordance with the carbon equivalent and structural rigidness, subject to the agreement of CCS.
The impact properties and non-destructive examinations of steel castings for primary hull structures are to comply with the respective requirements of 6.2.4.3, Section 2 and 6.1.8, Section 1, Chapter 6, PART ONE of CCS Rules for Materials and Welding.

CCS 4.1.1a Aluminium alloys are to comply with the requirements of Chapter 8, PART ONE of CCS Rules for Materials and Welding.
CCS 4.1.2a When the design temperature of aluminium alloy structures for low temperature service is lower than -55ºC, 5083 aluminium alloys in annealed condition are to be used.
CCS 4.2.2a In general, the application of extruded plating is limited to decks, bulkheads, superstructures and deckhouses. For other uses, equivalence or substitution is to be granted in accordance with paragraph 2.2.5, Section 2, Chapter 2 of the Rules.
CCS 4.3.3a The as-welded properties of aluminium alloys of series 6000 are to comply with the requirements of 3.2.6.1, Section 2, Chapter 3, PART THREE of CCS Rules for Materials and Welding.

CCS 5.1.1a Other materials and products such as parts made of iron castings, products made of copper alloys, rivets, anchors, chain cables and wire ropes are in general to comply with the applicable requirements of Chapters 7 to 10 of PART ONE of CCS Rules for Materials and Welding.
CCS 5.1.1b The materials of cranes, masts, derrick posts, derricks and accessories are to be selected based on factors such as design temperatures, plate thickness and type of cranes in accordance with the requirements of Chapter 6 of CCS Rules for Lifting Appliances of Ships and Offshore Installations.
CCS 5.1.2a Plastics and other non-metallic materials are to comply with the requirements of PART TWO of CCS Rules for Materials and Welding.
CCS 5.2.2a Iron castings are in general not be used for windows or sidescuttles. Iron castings not less than 300 N/mm^2 in specified minimum tensile strength and not less than 15% in specified minimum elongation may be used subject to the agreement of CCS.

Section 2 NET SCANTLING APPROACH

Section 3 CORROSION ADDITIONS

CCS 1.1.1a Where other materials are used, the corrosion additions of materials are to be determined in accordance with the submitted corrosion resistance information of materials. Such information is to include testing and/or historic data demonstrating that corrosion additions meet the design life of 25 years and is subject to the agreement of CCS.

Section 4 CORROSION PROTECTION

CCS 1.1.1a Dedicated seawater ballast tanks of all types of ships of not less than 500 gross tonnage and double-side skin spaces arranged in bulk carriers of 150 m in length and upwards are to comply with the requirements of IMO SOLAS Regulation II-1/3-2 and to be coated during construction in accordance with the

Performance standard for protective coatings for dedicated seawater ballast tanks in all types of ships and double-side skin spaces of bulk carriers (PSPC-WBT).
CCS 1.1.2a Cargo oil tanks of crude oil tankers of 5,000 tons deadweight and above are to comply with the requirements of IMO SOLAS Regulation II-1/3-11 and to be coated during construction in accordance with the Performance standard for protective coatings for cargo oil tanks of crude oil tankers (PSPC-COT) or protected by alternative means of corrosion protection or utilization of corrosion resistance material to maintain required structural integrity for 25 years in accordance with the Performance standard for alternative means of corrosion protection for cargo oil tanks of crude oil tankers.

Section 5 LIMIT STATES

Section 6 STRUCTURAL DETAIL PRINCIPLES

CCS 5.2.8a Alternative arrangements are to be based on their ability to transmit load with equivalent effectiveness, and equivalence or substitution is to be granted in accordance with paragraph 2.2.5, Section 2, Chapter 2, PART ONE of the Rules.

CCS 7.5.2a Where bilge keels are fitted, they are not to be welded directly to the shell plating. A ground bar, or doubler, is to be fitted on the shell plating and the ground bar or doubler may be welded directly to the shell and kept continuous. Bull welds in the bilge keels and those in the ground bar or doubler are to be staggered, and bull welds in the ground bar or doubler and those in the shell plating are to be staggered.
CCS 7.5.4a Other types of end detail design may be accepted provided that bilge keels and flat bars are gradually tapered at their ends and equivalent to 7.5.4.

CCS 8.1.1a Alternative types of framing are to be based on compliance with the requirements for strength and structural arrangements in this PART, and equivalence or substitution is to be granted in accordance with paragraph 2.2.5, Section 2, Chapter 2, PART ONE of the Rules.

CCS 10.6.1a Watertight trunks, tunnels, duct keels and ventilators are to be of the same strength as watertight bulkheads at corresponding levels. The means used for making them watertight, and the arrangements adopted for closing openings in them, are to be in compliance with the requirements of Section 3, Chapter 4, PART ONE of the Rules.

Section 7 STRUCTURAL IDEALISATION

CCS 1.1.1a For the definition of a span where the structural arrangement is different from that defined in this Section, equivalence or substitution is to be, based on the geometrical characteristics of end brackets of stiffeners and primary supporting members, their end constraints and actual load-carrying capacity, granted in accordance with paragraph 2.2.5, Section 2, Chapter 2, PART ONE of the Rules.

CHAPTER 4 LOADS

Section 1 INTRODUCTION

Section 2 DYNAMIC LOAD CASES

Section 3 SHIP MOTIONS ANDACCELERATIONS

Section 4 HULL GIRDER LOADS

Section 5 EXTERNAL LOADS

Section 6 INTERNAL LOADS

CCS 6.1.2a Where l_s>0.13Lor b_s>0.56$B$for the tank, level 3 sloshing impact loads are to be calculated in accordance with relevant requirements of Section 2 of CCS Guidelines for Assessment of Sloshing Loads and Structural Scantlings of Tanks.

Section 7 DESIGN LOAD SCENARIOS

Section 8 LOADING CONDITIONS

CCS 2.5.1a Where the hull structural arrangement is different from that covered by the Rules, for load conditions used for FE analysis, they are to be determined according to CCS Appendix B of this PART.

CCS 3.2.2a For tankers with two oil-tight longitudinal bulkheads, where the cargo tank length is less than 0.15L, the draughts corresponding to the load conditions are determined according to CCS Appendix B of this PART.

CCS 3.2.3a For tankers with one oil-tight longitudinal bulkheads, where the cargo tank length is less than 0.15L, the draughts corresponding to the load conditions are determined according to CCS Appendix B of this PART.

Appendix1 HOLD MASS CURVES

CHAPTER 5 HULL GIRDER STRENGTH

Section 1 HULL GIRDER YIELDING STRENGTH

Section 2 HULL GIRDER ULTIMATE STRENGTH

Section 3 HULL GIRDER RESIDUAL STRENGTH

Appendix1 DIRECT CALCULATION OF SHEAR FLOW

Appendix2 HULL GIRDER ULTIMATE CAPACITY

CCS 3.2.1a The non-linear finite element analysis method used for the assessment of the ultimate strength of hull girders are given in CCS Appendix C of this PART.

CHAPTER 6 HULL LOCAL SCANTLING

Section 1 GENERAL

Section 2 LOAD APPLICATION

Section 3 MINIMUM THICKNESSES

Section 4 PLATING

Section 5 STIFFENERS

Section 6 PRIMARY SUPPORTING MEMBERSAND PILLARS

CCS 2.2.2a Alternatively, the scantlings of primary supporting members within the cargo area may be verified by direct strength assessment in accordance with the requirements of CCS 4.1.2a, Section 4, Chapter 1 of PART 11-2.

CHAPTER 7 DIRECT STRENGTH ANALYSIS

Section 1 STRENGTH ASSESSMENT

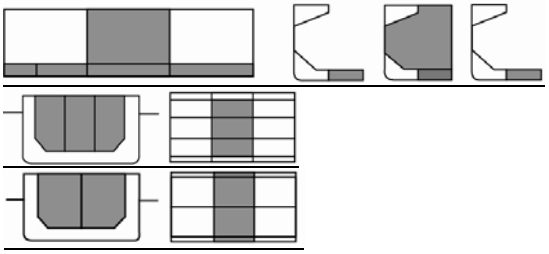
Section 2 CARGO HOLD STRUCTURAL STRENGTH ANALYSIS

CCS 4.4.5a For the considered conditions not included in the tables of loading conditions in Section 8, Chapter 4, the hull girder shear force is to be adjusted as follows:

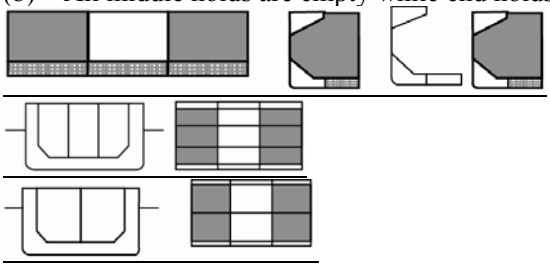
(1) The shear force of hull girders is to be adjusted for the following load combinations:

① Loading pattern: alternate loading of holds in longitudinal direction.

(a) All middle holds are loaded while end holds are empty, as shown in the figure below.



(b) All middle holds are empty while end holds are loaded, as shown in the figure below.

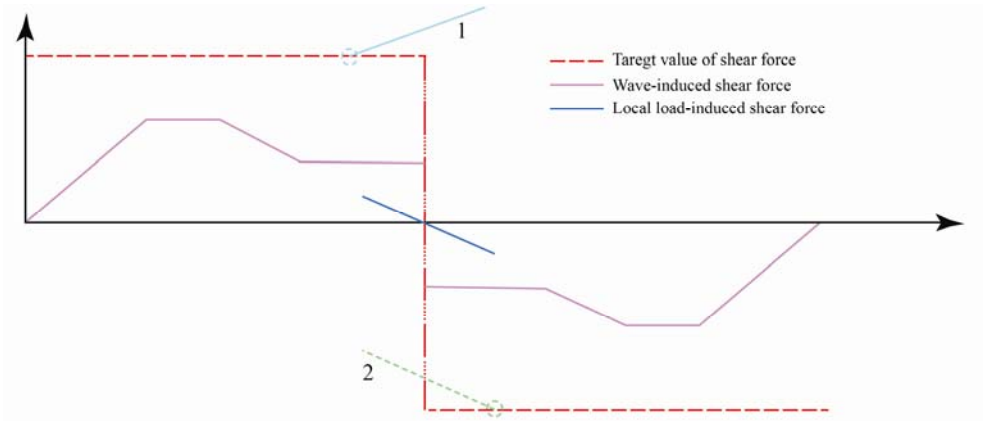


② Dynamic load cases: head sea model (HSM) or following sea model (FSM) or harbor condition.

③ Target bulkheads:

(a) For the model of a mid-hold of which both fore and aft bulkheads are located fore or aft of 0.5*L* amidships, the shear force adjustment is to be made at the bulkhead location defined in Table 4, Section 2, Chapter 7.

(b) For the model of a mid-hold situated amidships, of which the fore bulkhead is located fore of 0.5*L* amidships and the aft bulkhead aft of 0.5*L* amidships, the shear force adjustment is to be made at the bulkhead location where the absolute target value is greater. E.g.: where the absolute target value at the aft bulkhead is greater than that at the fore bulkhead, the shear force adjustment is to be made at the aft bulkhead location according to 1 as shown in the figure below, otherwise according to 2.



④ Method of hull girder shear force adjustment:

The method of hull girder shear force adjustment is to be in accordance with 4.4.5, Section 2, Chapter 7.

(2) For other load combinations:

The hull girder shear force adjustment is to be in accordance with 4.4.5, Section 2, Chapter 7.

(3) The target hull girder shear forces are to be taken in accordance with 4.3, Section 2, Chapter 7 and the shear force adjustment procedure is to be in accordance with the relevant requirements of 4.4, Section 2, Chapter 7.

Section 3 LOCAL STRUCTURAL STRENGTH ANALYSIS

CCS 2.1.5a Additional fine mesh analysis is to be carried out in the following cases:

Where there is a significant variation in the end connection arrangement between stiffeners or scantlings, e.g. a variation of the shape or arm length of the stiffener end connection bracket, the connecting structure with the maximum relative deflection between supports is to be selected from attached end connections for analysis.

CCS 2.1.6a Additional fine mesh analysis is to be carried out in the following cases:

(1) For corrugation structure fitted with lower stool, where the corrugation unit which has been selected for fine mesh analysis is not intersected by the diaphragm of lower stool, the fine mesh analysis is to be carried out to the corrugation unit with the maximum yield utilisation factor that is intersected by the diaphragm of lower stool.

(2) For longitudinal corrugated bulkheads not fitted with lower stool, where the corrugation unit which has been selected for fine mesh analysis is not intersected by the double bottom floor, the fine mesh analysis is to be carried out to the corrugation unit with the maximum yield utilisation factor that is intersected by the double bottom floor.

(3) For transverse corrugated bulkheads not fitted with lower stool, where the corrugation unit which has been selected for fine mesh analysis is not intersected by the double bottom girder, the fine mesh analysis is to be carried out to the corrugation unit with the maximum yield utilisation factor that is intersected by the double bottom girder.

(4) When the shape of the corrugation unit as defined in 3.3.2, Section 4, Chapter 8 of this PART is different from the one which has been selected for fine mesh analysis, the fine mesh analysis is to be carried out to the location with the maximum yield utilisation factor for areas of the corrugation units having a different shape respectively.

CHAPTER 8 BUCKLING

Section 1 GENERAL

Section 2 SLENDERNESS REQUIREMENTS

Section 3 PRESCRIPTIVE BUCKLING REQUIREMENTS

Section 4 BUCKLING REQUIREMENTS FOR DIRECT STRENGTH ANALYSIS

Section 5 BUCKLING CAPACITY

CCS 2.2.4a The correction factor, F_{long}, of U type stiffened panel in hatch cover is calculated in accordance with the following formula:

$$F_{long} = \left(1.55 - 0.55\frac{b_1}{b_2}\right) \cdot \left[1 + c\left(\frac{t_w}{t_p}\right)^3\right]$$

where: b_1 — width of opening of U type, in mm, see Figure CCS 2.2.4a;
b_2 — web spacing of two adjacent U type, in mm, see Figure CCS 2.2.4a;
c =0.2, when $b_2 \geq b_1$.

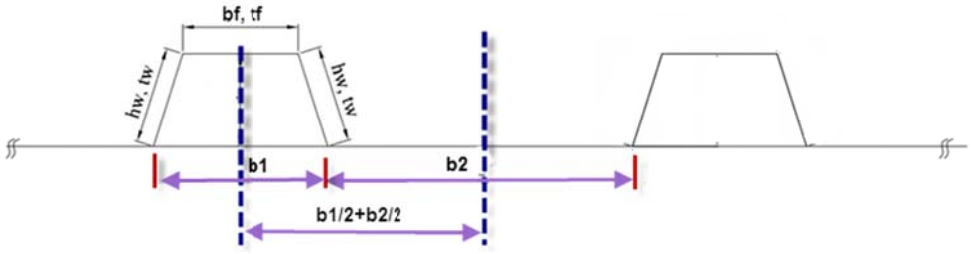


Figure CCS 2.2.4a U Type of Hatch Cover

Appendix 1 STRESS BASED REFERENCE STRESSES

CHAPTER 9 FATIGUE

Section 1 GENERAL CONSIDERATIONS

CCS 1.1.3a Where the fatigue strength of details other than those specified in Section 2 of this Chapter needs to be verified, fatigue assessment may be carried out in accordance with the requirements of this Chapter.

CCS 1.1.5a S-N curves in Chapter 9 of this PART or those in air and/or corrosive environment in IIW, HSE or ISO standards may be used, taking into account the applicability of the minimum yield stress. S-N curves obtained from testing may also be used and the probability of survival is not to be less than 97.7%.

CCS 1.1.5b Where S-N curves of other standards are used, relevant technical documents are to be submitted as audit basis.

CCS 1.1.5c Where S-N curves obtained from testing are used, relevant testing reports are to be submitted as audit basis and the qualification proof of testing organization is also to be submitted.

CCS 1.1.5d Where S-N curves in corrosive environment are obtained from testing, the evidence demonstrating that the corrosive environment used in testing is equivalent to that of sea water is also to be submitted.

Section 2 STRUCTURAL DETAILS TO BE ASSESSED

CCS 2.1.1a The requirements in Table 16 apply to the hot spots corresponding to the 6th item in Table 3 of Section 2, Chapter 9. Fatigue assessment of the following hot spots is to be carried out, see Figure CCS 2.1.1a.

(1) in way of corner of curvature of free edge of the cut-out, see hot spots 1, 2 and 3 in Figure CCS 2.1.1a;

(2) intersection of web of transverse frame to longitudinal web, see hot spots 4 and 5 in Figure CCS 2.1.1a;

(3) intersection of lug plate to longitudinal web, see hot spots 6 and 7 in Figure CCS 2.1.1a;

(4) intersection of web of transverse frame to lug plate, see hot spots 8, 9, 10 and 11 in Figure CCS 2.1.1a (where hot spots 10 and 11 are located near the middle point of side length);

(5) intersection of web of transverse frame to attached plating of longitudinal, see hot spots 12 and 13 in Figure CCS 2.1.1a.

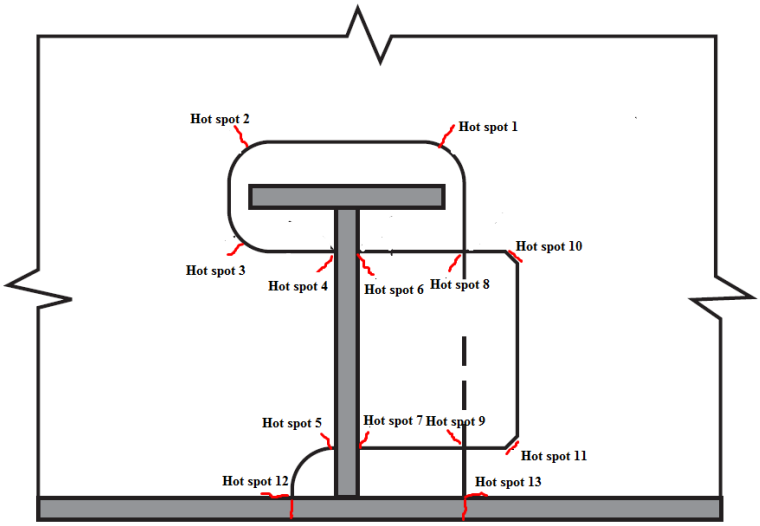


Figure CCS 2.1.1a Critical Hot Spot

CCS 2.1.1b The general requirements for FE modeling of Table 16 are given in 2.1.1 to 2.1.7 of Section 5.

CCS 2.1.1c The FE modeling requirements in way of the cut-out in Table 16 are given in CCS 2.2.1a of Section 6. In way of hot spots 10 and 11, the number of mesh along the side length is not to be less than 4.

CCS 2.1.1d The fatigue assessment method in Table 16 is given in Sections 1 and 3.

Section 3 FATIGUE EVALUATION

CCS 4.2.3a Surface finishing factors are to be selected according to the joint configurations in Table 4, Section 3, Chapter 9 of this PART and submitted to CCS as the basis for selection of such factors corresponding to joint configurations. For the surface finishing factor corresponding to joint configuration 2, edge cutting process, edge treatment and surface finishing are to be taken into account.

CCS 7.2.2a For weld toe in critical locations, reference may be made to the requirements of 3.3.1 of CCS Guidelines for Construction Monitoring of Hull Structures.
CCS 7.2.3a Where the benefit derived from the post-weld treatment is taken into account, the relevant workmanship requirements of post-weld treatment need to be approved by CCS.
CCS 7.2.3b Where grinding is applied, the following requirements are to be complied with:
The grinding standard of structural details including the extent, smoothness particulars, final weld profile, grinding workmanship and quality acceptance criteria are to be clearly shown on the applicable drawings and submitted for review together with supporting calculations. The applicable conditions, methods and workmanship requirements for grinding are to be in accordance with paragraph 6, Section 3, Chapter 9 of this PART. Grinding has to extend to areas well outside the high stress region.

Section 4 SIMPLIFIED STRESS ANALYSIS

CCS 5.3.1a FE model extent
(1) FE model extent
The FE model, as shown in Figure CCS 5.3.1a(1), is to cover at least four web frame spacings in the longitudinal stiffener direction with the detail to be considered located at the middle web frame. The same type of end connection is to be modeled at all the web frames. In the transverse direction, the model is to cover at least half the stiffener spacing on both sides; in the vertical direction, it is to maintain at least half the web height.

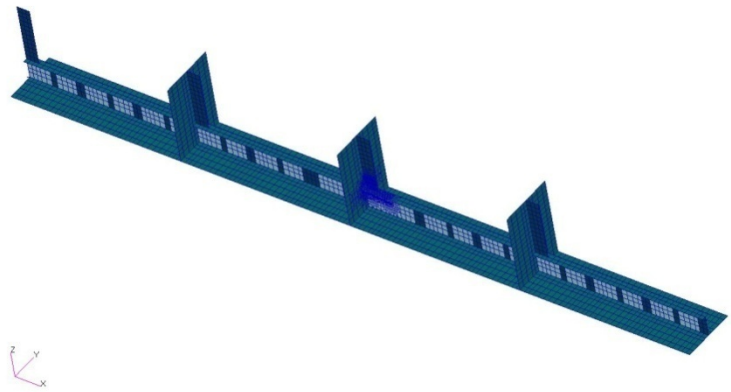


Figure CCS 5.3.1a(1) Longitudinal Extent of Fine Mesh Finite Element Model

(2) FE mesh size
At the location of the hot spots under consideration, the mesh size of at least 10 elements is to be the same as the thickness of the flange of longitudinals. In the remaining part of the model, the mesh size is to be taken as1/10 of the spacing of longitudinals. Attention is to be given to the smooth transition of mesh size. It is recommended to use mm as the length unit during modeling.
(3) Load case
Axial load case: enforced displacement of 1 mm applied to the model ends.
Lateral load case: uniformly distributed unit load applied to the attached plating of longitudinal, in 1 kN/m^2, i.e. 0.001 Mpa.
(4) Boundary conditions
Symmetry conditions:

a) angular displacement $\theta_x = 0$, displacement $\delta_y = 0$ along the longitudinal edge of the attached plate, see Figure CCS 5.3.1a(2);

b) angular displacement $\theta_z = 0$, displacement $\delta_y = 0$ along vertical edge on web frames, see Figure CCS 5.3.1a(3);
c) angular displacement $\theta_y = 0$, displacement $\delta_z = 0$ along transverse edge on top of web frames, see Figure CCS 5.3.1a(4);
d) angular displacement $\theta_x = 0$, displacement $\delta_z = 0$ on top of the web stiffener, see Figure CCS 5.3.1a(5).

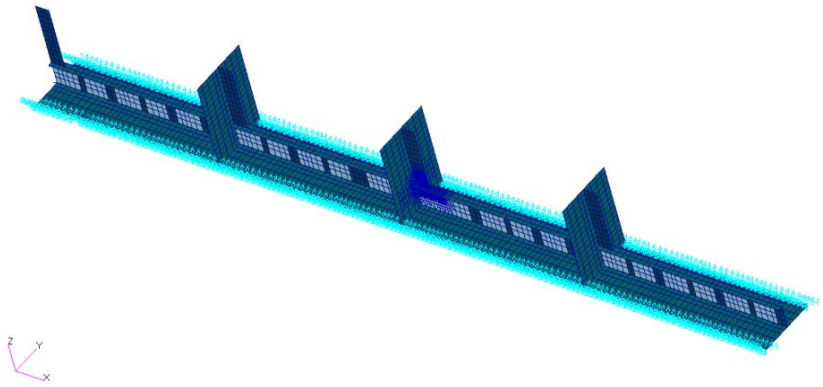


Figure CCS 5.3.1a(2) Boundary Condition of Fine Mesh Finite Element Model (a)

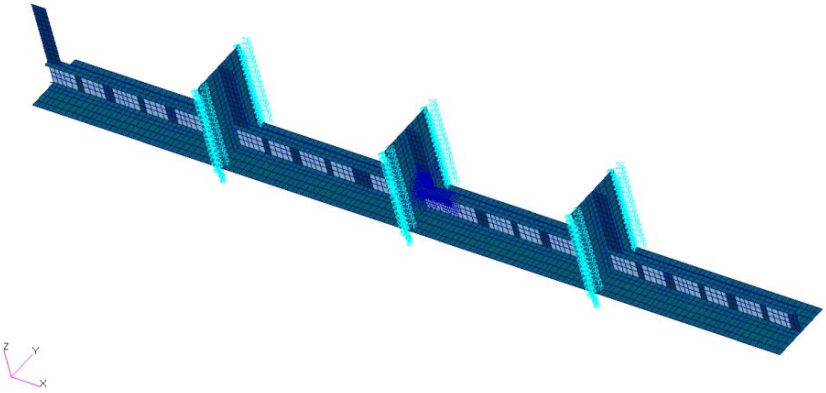


Figure CCS 5.3.1a(3) Boundary Conditions of Fine Mesh Finite Element Model (b)

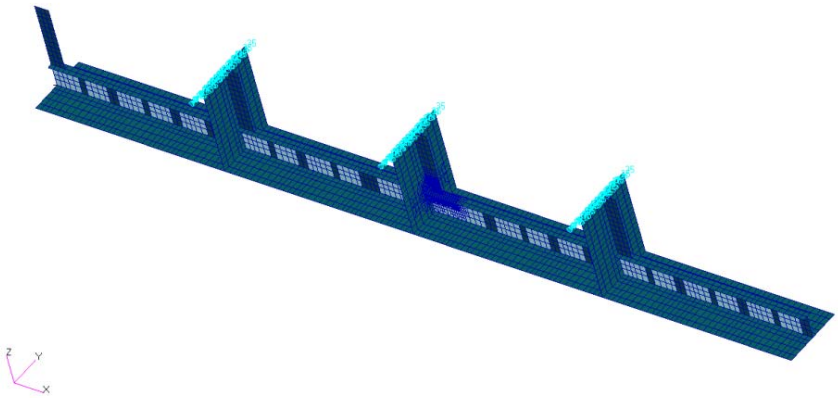


Figure CCS 5.3.1a(4) Boundary Conditions of Fine Mesh Finite Element Model (c)

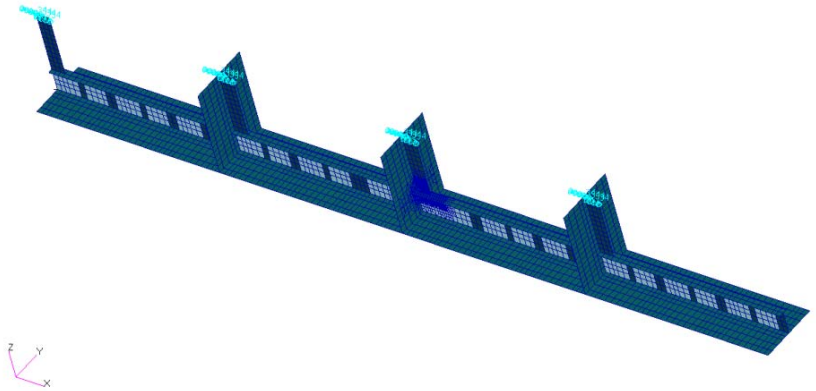


Figure CCS 5.3.1a(5) Boundary Conditions of Fine Mesh Finite Element Model (d)

For axial load case: the model is to be fixed for displacement in the longitudinal direction at the aft end of the model while enforced axial displacement is applied at the forward end, or vice versa.
For lateral load case: the model is to be fixed in all degrees of freedom at both forward and aft ends.

CCS 5.3.1b Calculation of stress concentration factors

(1) The geometrical stress concentration factor, K_g, is calculated in accordance with the following formula:

$$K_g = \frac{\sigma_{HS}}{\sigma_{nom}}$$

where: σ_{HS} — hot spot stress, in N/mm^2, to be calculated in accordance with (2) of this paragraph;

σ_{nom} — nominal stress, in N/mm^2, to be calculated in accordance with (3) of this paragraph and taken as σ_{axial} or $\sigma_{lateral}$.

(2) Hot spot stress σ_{HS}, in N/mm^2, is calculated in accordance with the following formula according to the process as specified in 3.1, Section 5 of Chapter 9:

$$\sigma_{HS} = 1.12\sigma$$

where: σ —longitudinal stress obtained from interpolation of FE calculation, in N/mm^2.

(3) Calculation of nominal stress

a) The nominal stress σ_{axial}, in N/mm^2, of axial load case is calculated in accordance with the following formula:

$$\sigma_{axial} = \frac{\Delta l}{l} E$$

where: Δl — axial enforced displacement, in mm;

l — length of FE model, in mm;

E — Young's modulus of elasticity, 2.06×10^5 N/mm^2.

b) The nominal stress $\sigma_{lateral}$, in N/mm^2, of bending load case under lateral load is calculated in accordance with the following formula:

$$\sigma_{lateral} = \frac{sl^2(1-\frac{6x_e}{l}+\frac{6x_e^{\ 2}}{l^2})}{12Z_{eff-n50}}10^3$$

where: s — spacing of longitudinals, in m;

l — full length, in m, see definition of l in Symbols of Section 7, Chapter 3;

$Z_{eff-n50}$ — section modulus, in cm^3,deducting corrosion addition of$0.5t_c$ and considering attached plating;

x_e — distance, in m, from the hot spot to the closest end of full length l.

Section 5 FINITE ELEMENT STRESS ANALYSIS

Section 6 DETAIL DESIGN STANDARD

CCS 2.2.1a FE modeling

(1) FE model of standard design is to be established according to Table 1 of [2.1], and FE model of alternative design is also to be established according to the modeling method in [2.2.3].

(2) The mesh size in way of hot spot is in general to be t×t. When the hot spots are classified as hot spot type "b" as specified in 1.1.3 of Section 5 and Table 16 of Section 2, the mesh size is to be 10×10 mm. The mesh size is to extend at least five elements in all directions. Outside this area, the mesh size may gradually be increased in accordance with the requirements in 2 of Section 5.

(3) Simulated beam elements are to be fitted in way of the edge of cut-out and hot spot type "b". The height of the simulated beam elements is to be consistent with plate thickness of web, the width may be neglected and the area is taken as 1 mm^2.

(4) Shell elements are to be used in the overlap scope of web of transverse frame and lug plates. In order to simulate fillet welds, web of transverse frame and lug plates are to be connected by shell elements in way of the boundary of overlap scope. The height of shell element is to be the distance between mid-layers of web of transverse frame and lug plates having a thickness equal to 2 times the net thickness of web plate, see Figure 2.2.1a(4).

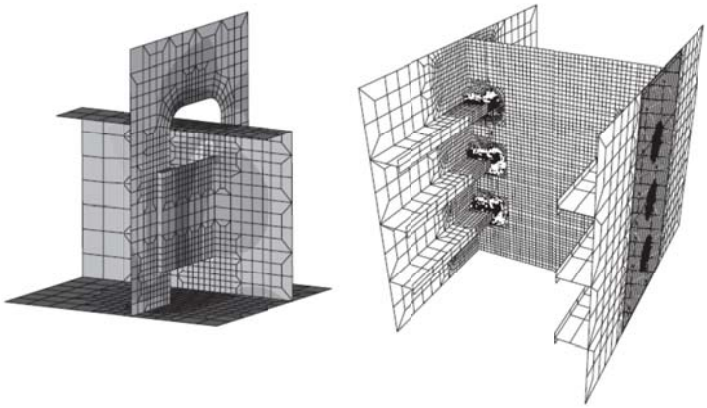


Figure 2.2.1a(1) FE Model of Equivalent Alternative Design

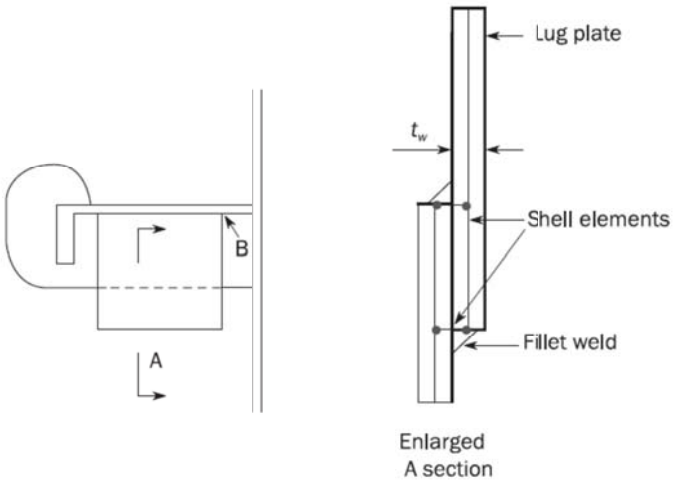


Figure 2.2.1a(4) Element Modeling of Overlap of Lug Plate and Web of Transverse Frame

CCS 2.2.1b Load case

(1) Three load cases are to be applied to the models of the standard design and alternative designs:

LC1: External pressure of unit value, fixed boundary conditions at top and bottom of model.
LC2: Shear stress by prescribed unit displacement at the model top and fixed boundary conditions at the model bottom.
LC3: Axial load by prescribed unit displacement at the model top and fixed boundary conditions at the model bottom.
(2) The forward and aft part of the model are to have symmetry condition in a double hull structure. Load application and boundary conditions are shown in Figure CCS 2.2.1b(2).

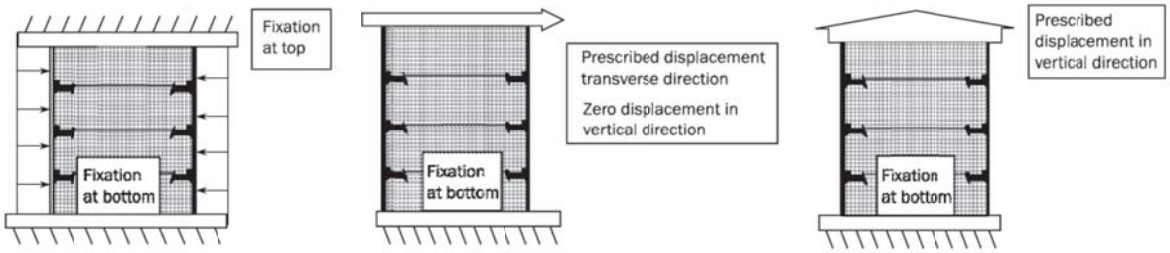


Figure CCS 2.2.1b(2) Load Application and Boundary Conditions

CCS 2.2.1c Reference stress
The stress for assessment is the maximum of the combination of axial and bending stress of simulated beam.
CCS 2.2.1d Assessment criteria of equivalent design
The reference stress (see CCS 2.2.1c) in way of critical hot spots around the cut-out of equivalent design is not greater than the corresponding value of standard design.
CCS 2.2.2a The critical hot spots in way of the cut-out of alternative design for connection of stiffeners to transverse frames are selected as follows, see Figure CCS 2.2.2a:
(1) in way of corner of curvature of free edge of the cut-out, see hot spots 1, 2 and 3 in Figure CCS 2.2.2a;
(2) intersection of web of transverse frame to longitudinal web, see hot spots 4 and 5 in Figure CCS2.2.2a;
(3) intersection of lug plate to longitudinal web, see hot spots 6 and 7 in Figure CCS 2.2.2a;
(4) intersection of web of transverse frame to lug plate, see hot spots 8, 9, 10 and 11 in Figure CCS 2.2.2a (where hot spots 10 and 11 are located near the middle point of side length);
(5) intersection of web of transverse frame to attached plating of longitudinal, see hot spots 12 and 13 in Figure CCS 2.2.2a.
CCS 2.2.2b In way of hot spots 10 and 11, the number of mesh along the side length is not to be less than 4.

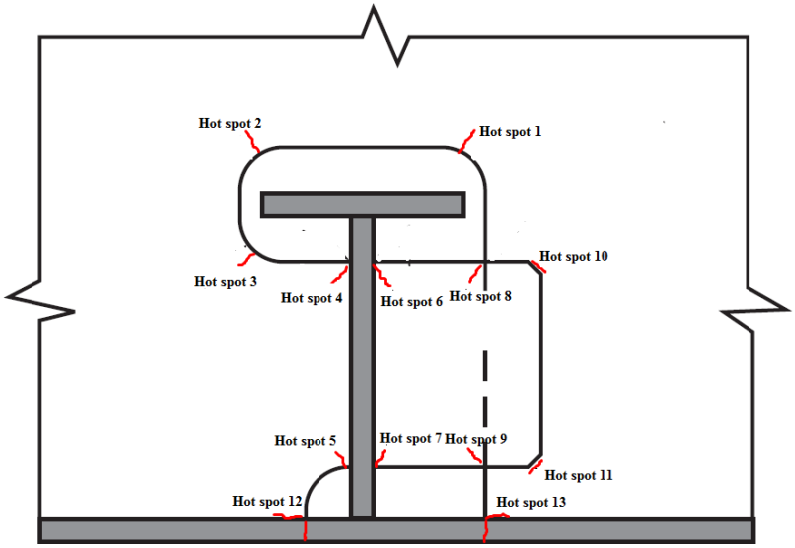


Figure CCS 2.2.2a Selection of Critical Hot Spot in way of Cut-out

CHAPTER 10 OTHER STRUCTURES

Section 1 FORE PART

Section 2 MACHINERY SPACE

Section 3 AFT PART

Section 4 TANKS SUBJECT TO SLOSHING

CCS 1.3.7a Where l_s>0.13Lor b_s>0.56$B$for the tank, the structural strength assessment under level 3 sloshing loads is to be carried out in accordance with relevant requirements of Section 3 of CCS Guidelines for Assessment of Sloshing Loads and Structural Scantling of Tanks.

CHAPTER 11 SUPERSTRUCTURE, DECKHOUSES AND HULL OUTFITTING

Section 1 SUPERSTRUCTURES, DECKHOUSES AND COMPANIONWAYS

CCS 3.3.1a The scantlings of end bulkheads of deckhouses which do not protect openings in the freeboard deck, superstructure deck or in the top of a lowest tier deckhouse are to comply with the requirements of paragraphs 3.3.2 and 3.3.3. The scantlings of end bulkheads of deckhouses which do not protect machinery casings are also to comply with the requirements of paragraphs 3.3.2 and 3.3.3, provided they do not contain accommodation or do not protect equipment essential to the operation of the ship.

Section 2 BULWARK AND GUARD RAILS

Section 3 EQUIPMENT

CCS 2.1.2a For ships with EN greater than 16000, the determination of the equipment may be according to the direct calculation method of OCIMF.

CCS 3.1.3a All anchors and chain cables are to be tested at establishments and on machines recognized by CCS, under the supervision of CCS surveyors and in accordance with the relevant requirements of 10.1.2, Section 1 and 10.2.2, Section 2, Chapter 10 of CCS Rules for Materials and Welding.
CCS 3.3.1a Where agreed by the applicant, consideration will be given to the use of special types of anchors. High Holding Power (HHP) and Super High Holding Power (SHHP) anchors complying with the requirements of Section 1, Chapter 10 of CCS Rules for Materials and Welding do not require prior adjustment or special placement on the sea bottom.
CCS 3.4.1a The characteristics of the steel used and the method of manufacture of chain cables are to be approved by CCS for each manufacturer. The material from which chain cables are manufactured and the completed chain cables themselves are to be tested respectively in accordance with the applicable requirements of Section 12, Chapter 3 and Section 2, Chapter 10, PART ONE of CCS Rules for Materials and Welding.
CCS 3.7.1a The power of windlass is to comply with the requirements of Section 2, Chapter 13, PART THREE of CCS Rules for Classification of Sea-going Steel Ships.

Section 4 SUPPORTING STRUCTURE FOR DECK EQUIPMENT AND FITTINGS

CCS 2.1.3a For the strength check of supporting structure and foundation, a three-dimensional FE model may be applied in the analysis. The principles for extent, element types and boundary conditions of a three-dimensional model are as follows:
(1) Extent and boundary conditions: The structural model is a local three-dimensional one (hereinafter referred to as local model), centred on the centroid of a plane rectangle ($a \times b$) for effects of the foundation and extending outwards for a distance respectively at least one time the length and width corresponding to the rectangle ($3a \times 3b$). This extension reaches vertically from the foundation plane to the first platform (deck) under main deck or at least $D/4$ (D being moulded depth). Where there is no primary support member of the structure at the boundary taken in the above way, the model is to further extend until the boundary is at such support member. Free or fixed support may be taken into account for boundary conditions. Where the boundary conditions or the extent of the model is sensitive to calculation results of the centre area, the extent taken for the local model is to be suitably extended again, provided that calculation results of the centre area will not be affected.
(2) Idealization of local model: The principles for element selection, properties and model meshing etc. are as given in Section 1 of Chapter 7.
CCS 2.1.3b In accordance with the design load of 2.1.3, the allowable equivalent stress of plate element $[\sigma_e] = 1.00R_{eH}$, where: R_{eH} – yield stress of material, in N/mm^2.

CCS 3.1.5a In accordance with the design load of 3.1.5, strength assessment may also be carried out to the

supporting structure in accordance with 2.1.3a and 2.1.3b.

CCS 4.1.2a In addition to the requirements of 4.1.2, the applicable requirements of Section 10, Chapter 3 of CCS Rules for Lifting Appliances of Ships and Offshore Installations are also to be complied with.
CCS 4.1.11a In accordance with the design load of 4.1.11, a three-dimensional FE model may be applied in the analysis for the supporting structure in accordance with 2.1.3a. The allowable equivalent stress $[\sigma_e] = 0.67R_{eH}$, where: R_{eH} – yield stress of material, in N/mm^2.

CCS 5.1.4a In accordance with the design load of 5.1.4, strength assessment may also be carried out to the supporting structure in accordance with 2.1.3a and 2.1.3b.

CCS 6.1.1a The strength assessment is carried out to the supporting structure of other deck equipment in accordance with the strength analysis method and criteria of this Section based on the design load submitted by the manufacturer.
CCS 6.1.1b For the connection structures of hull outfitting equipment to the deck, it is to be noted that:
(1) For the supporting structures of pipelines, open type sections (e.g. T, L, I, X etc.) are used and the corresponding supporting structures are strengthened by using web plates, collar plates and backing brackets. Ring support is used for large pipelines.
(2) Where pipelines pass through the deck, seamless casing pipes or those with welds ground are used to assist pipelines passing through the deck.
(3) Local transition is to be avoided in way of the backing strengthening under the deck. Transition is to made from the structure to the stiffener or frame.
(4) Stress concentration or high stress areas are to be avoided for cut-outs such as manholes/hatches. The watertight manhole covers are to be such that their strength is equivalent to the local strength of the associated deck. The edge of cut-outs is to be ground smooth.

Section 5 SMALL HATCHWAYS

CCS 1.2.1a Materials used for the construction of small steel hatch covers are to comply with the applicable requirements of Chapter 3, PART ONE of CCS Rules for Materials and Welding.
CCS 1.2.2a Small hatch covers constructed of materials other than steel are to provide a strength equivalent to that of small steel hatch covers.
CCS 1.3.2a Subject to the agreement of the flag Administration, the height of hatch coamings may be appropriately reduced provided that the safety of the ship is not thereby impaired and that effective measures are taken. In this case, the scantlings of the hatch covers are to comply with the requirements of 2.2. The arrangement of sealing gasket and securing devices is to comply with the relevant requirements of this Section, taking into account the strength and arrangement of pressure head, stoppers and securing devices as well as factors such as the effectiveness of drainage and sealing materials.
CCS 1.4.3a The design of special securing arrangement and the rigidity of edge of hatch covers is to take into account the strength and arrangement of pressure head, stoppers and securing arrangement as well as factors such as the effectiveness of drainage measures and sealing materials.
CCS 1.5.3a For the coaming plates of tank access small hatchways that enclose an area of 1.2 m^2 or more, and/or those that are not configured with a well rounded shape, stiffeners are to be fitted on the hatch coaming. The thickness of hatch coaming and the stiffeners on the coaming plate are to comply with the requirements of 6.3.1 and 6.3.2, Section 5, Chapter 1 of PART 11-2.

CHAPTER 12 CONSTRUCTION

Section 1 CONSTRUCTION AND FABRICATION

CCS 1.2.1a Where other standards are used by the shipyard, documents are to be provided by the shipyard to demonstrate that such standards are equivalent to IACS Recommendation No. 47.
CCS 1.2.3a Where block boring is used, the shaft alignment is to comply with the relevant requirements of Section 5, Chapter 12, PART THREE MACHINERY of CCS Rules for Classification of Sea-going Steel Ships.

Section 2 FABRICATION BY WELDING

CCS 1.2.2a Welding procedures are also to comply with the applicable requirements of Section 1, Chapter 5, PART THREE of CCS Rules for Materials and Welding.

CCS 2.1.1a The approval of welding consumables, welding procedures and qualification tests of welders are to comply with the requirements of Chapters 2,3 and 4 of PART THREE of CCS Rules for Materials and Welding.
CCS 2.1.1b The qualification tests of automatic submerged arc welding operators are to comply with the requirements of Section 3, Chapter 3 of CCS Guidelines for Inspection of Hull Welds.

CCS 3.1.2a The quality standard adopted by the shipyard is to be in accordance with paragraph 1.2.1, Section 1 of this Chapter. In special cases, equivalence or substitution is to be granted in accordance with paragraph 2.2.5, Section 2, Chapter 2, PART ONE of the Rules.

CCS 4.1.1a NDE is to be carried out in accordance with the applicable requirements of Section 3, Chapter 5, PART THREE of CCS Rules for Materials and Welding.
CCS 4.1.2a The acceptance standards of NDE of welds are to comply with the applicable requirements of Chapter 7 of CCS Guidelines for Inspection of Hull Welds.

Section 3 DESIGN OF WELD JOINTS

CCS 1.2.1a The requirements given in this Section are considered minimum for electric-arc welding in hull construction, but alternative methods, arrangements and details are to be approved in accordance with paragraph 2.2.5, Section 2, Chapter 2, PART ONE of the Rules.

CCS 4.2.1a Slot welds are not adopted in general. Where internal access for welding from the back side is not practicable, e.g. where direct application of fillet welding is not practicable for the connection of plating to internal webs, slot welds may be adopted. However, slot welds of doublers on the outer shell and strength deck are not permitted within 0.6 L amidships.

CHAPTER 13 SHIP IN OPERATION - RENEWAL CRITERIA

Section 1 PRINCIPLES AND SURVEYREQUIREMENTS

Section 2 ACCEPTANCE CRITERIA

CCS Appendix A WAVE LOAD DIRECT CALCULATION METHOD BASED ON EQUIVALENT DESIGN WAVE METHOD

Symbols:

V : Speed vector of three directions x, y and z of any point in the flow field, in m/s.

Φ : Velocity potential of any point in the flow field.

p : Pressure of any point in the flow field, in N/m^2.

t : Time, in s.

U : Ship speed under consideration, in m/s.

X, Y, Z : Coordinate x, y and z of any point, in m.

L : Rule length, in m.

ω_e : Encounter frequency.

$\eta_i(i=1,6)$: Ship motions in six degrees of freedom.

θ : Roll amplitude, in rad.

φ : Pitch amplitude, in rad.

a_X , a_Y , a_Z : Acceleration of any point.

f_S : Coefficient for symbol. For vertical bending moment, hogging is positive and sagging is negative. For horizontal bending moment, tension on the starboard side is positive and compression on the starboard side is negative.

f_{ps} : Coefficient for strength assessments which is dependent on the applicable design load scenario specified in Section 7, Chapter 4 of PART 11-1 and to be taken as:

f_{ps}= 1.0 for extreme design load scenario and fatigue assessment.

f_{ps}= 0.8 for the ballast water exchange design load scenario.

f_{ps}= 0.8 for the accidental flooded design load scenario at sea.

f_{ps}= 0.4 for the harbour/sheltered water design load scenario.

f_β : Heading correction factor, to be taken as:

- For strength assessment

  f_β= 0.8 for BSR and BSP load cases for the extreme sea loads design load scenario.

  f_β=1.0 for HSM, HSA, FSM, OST and OSA load cases for the extreme sea loads design load scenario.

  f_β=1.0 for ballast water exchange at sea, harbour/sheltered water and accidental flooded design load scenarios.

- For fatigue assessment

  f_β=1.0.

f_m : Distribution factor for vertical wave bending moment along the ship's length, see Figure 3-1.

f_{nl} : Coefficient considering nonlinear effects applied to vertical wave bending moment. For hogging, it is taken as $f_{nl\text{-}vh}$; for sagging, it is taken as $f_{nl\text{-}vs}$.

$f_{nl\text{-}vh}$: Taken as $\dfrac{0.19C_B}{0.15C_B+0.0385}$.

$f_{nl\text{-}vs}$: Taken as $\dfrac{0.11C_B+0.077}{0.15C_B+0.0385}$.

M_{WV} : Vertical wave bending moment in given loading and given equivalent design wave, in kNm.

Q_{WV} : Vertical wave shear force in given loading and given equivalent design wave, in kN.

M_{WH} : Horizontal wave bending moment in given loading and given equivalent design wave, in kNm.

M_{WT} : Wave torsional moment in given loading and given equivalent design wave, in kNm.

P_{ex} : Total sea pressure in given loading and given equivalent design wave, in kN/m^2.

P_{es} : Hydrostatic pressure in given loading and given equivalent design wave, in kN/m^2.

P_{ed} : Hydrodynamic pressure in given loading and given equivalent design wave, in kN/m^2.

P_{in} : Total internal pressure in given loading and given equivalent design wave, in kN/m^2.

1 GENERAL PROVISIONS

1.1 Application

This Appendix is applicable to the wave load direct calculation of oil tankers and bulk carriers with unrestricted worldwide navigation and may also be used as a reference for the wave load direct calculation of oil tankers and bulk carriers of other service areas.

1.2 Reference coordinate system

The ship's geometry, motions, accelerations and loads are defined with respect to the following right-hand coordinate system (see Figure 1-1):

Origin: at the intersection among the longitudinal plane of symmetry of ship, the aft end of *L* and the baseline;

X axis: longitudinal axis, positive forwards;

Y axis: transverse axis, positive towards portside;

Z axis: vertical axis, positive upwards.

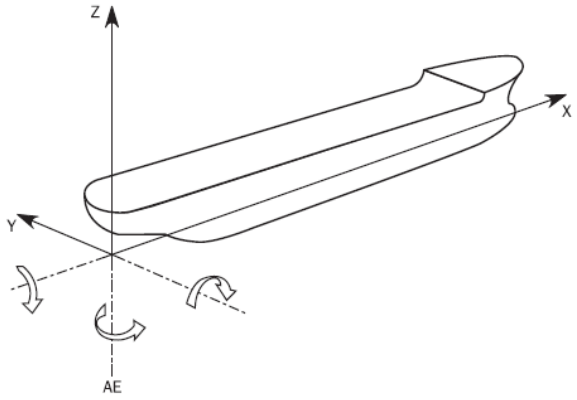


Figure 1-1 Reference Coordinate System

2 PRINCIPLE OF EQUIVALENT DESIGN WAVE METHOD

2.1 Wave load direct calculation method

Wave load direct calculation method is based on the three-dimensional linear potential flow theory.

Once the fluid velocity potential at the junction of fluid and hull together with its partial derivative in relation to the space coordinate are obtained, the interacting forces between fluid and hull can be obtained, then hull motion responses and section loads will be obtained, based on the Bernoulli's equation.

The solution for velocity potential is mainly to solve a boundary integral equation for meeting definite conditions, i.e. the fluid domain condition, the free surface condition, the body surface condition, the bottom condition and the remote radiation condition. Current solving methods mainly include free surface Green function method in frequency domain or time domain and the simple Green function method.

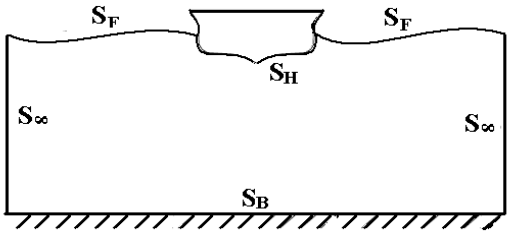


Figure 2-1 Boundary Condition for the Solution of Velocity Potential

Based on the Bernoulli's equation, the diffraction pressure response function and hydrodynamic coefficient will be obtained and then the ship's motions, accelerations and radiation pressure response function together with the response function of section loads will be obtained when the velocity potential is obtained.

2.2 Long term and short term prediction of linear wave loads

2.2.1 Short term prediction of linear wave loads

The short-term wave may be regarded as stationary random Gaussian process with average value of zero. Based on the random process theory, the response wave loads (output)subject to the wave (input) will also be stationary random Gaussian process with average value of zero. The relationship between input wave spectrum S_ζ and output response spectrum S_w is expressed by the following formula:

$$S_W\left(\omega, H_{1/3}, T_Z, V, \beta+\theta\right) = H^2\left(\omega, V, \beta+\theta\right) S_\zeta\left(\omega, H_{1/3}, T_Z, \theta\right)$$

where: ω is wave frequency, $H_{1/3}$ is significant wave height, T_Z is average zero-crossing period, V is ship speed, β is course and θ is heading angle.

For a stationary random Gaussian process with average value of zero, under the narrow spectrum assumption, the amplitude complies with Rayleigh distribution and the corresponding probability density is:

$$f_0(x) = \frac{2x}{E\left[\left(H_{1/3}, T_Z\right), V, \beta\right]} \exp\left[-\frac{x^2}{E\left[\left(H_{1/3}, T_Z\right), V, \beta\right]}\right]$$

where: E is two times wave load variance, expressed as follows:

$$E\left[\left(H_{1/3}, T_Z\right), V, \beta\right] = 2\int_{-\pi/2}^{+\pi/2}\int_0^\infty S_W\left(\omega, H_{1/3}, T_Z, V, \beta+\theta\right) d\omega d\theta$$

The distribution function, 1/3 significant value and 1/10 significant value of loads are obtained in accordance with load response function and wave parameters.

2.2.2 Long term prediction of linear wave loads

Where it is assumed that short term conditions consisting of various different sea states and navigation conditions are independent from each other, the long term probability distribution will be the weighted combination of short term probability distribution, i.e. the exceedance probability of the wave load amplitude X greater than certain fixed value x is:

$$Q(x) = P\{X \geq x\} = \sum_i \sum_j \sum_k p_i\left(H_{1/3}, T_Z\right) p_j(\beta)\, p_k(V) \exp\left\{\frac{-x^2}{E\left[\left(H_{1/3}, T_Z\right)_i, \beta_j, V_k\right]}\right\}$$

The probability of occurrence of heading angle is assumed to be uniformly distributed between 0 and 2π. The probability of occurrence of sea state depends on the wave statistics of the navigation area of ship and at present the unrestricted service area is taken as the sea state of North Atlantic. After the navigation area of ship and probability level are determined, the maximum value of corresponding wave load characteristic may be obtained according to the above formula. Such value means the maximum wave load likely to occur once on average during the service period with number of cycles *n*.

2.3 Equivalent design wave method

2.3.1 General principle

For the structural strength assessment of ships and offshore engineering, the combination of load components is a complicated issue. The actual irregular wave is transformed to an equivalent regular wave by the equivalent design wave method, assuming that the maximum value of combined loads occurs when one of the variable loads reaches the maximum value during the service period and corresponding transient values are used for other variable loads. The method is also referred to as dynamic load method. The selected wave load components which have a deciding effect on structural strength generally include ship motion and acceleration, wave bending moment, torsional moment and shear force, sea pressure etc.

2.3.2 Determination of relevant parameters

The main steps of determination of parameters of equivalent design wave are as follows, see Figure 2-2:

a. selection of target loads to carry out hydrodynamic analysis and calculate the response function of target loads under different headings and frequencies;
b. determination of predominant load and its probability level, carrying out spectrum analysis to solve the long-term distribution value of predominant load under the probability level;
c. determination of heading, frequency and phase of equivalent design wave in accordance with long-term statistics and response function, calculation of design wave height;
d. calculation of relevant load components of equivalent design wave in accordance with its heading, frequency, phase and wave height;
e. application of relevant loads of the equivalent design wave for structural analysis.

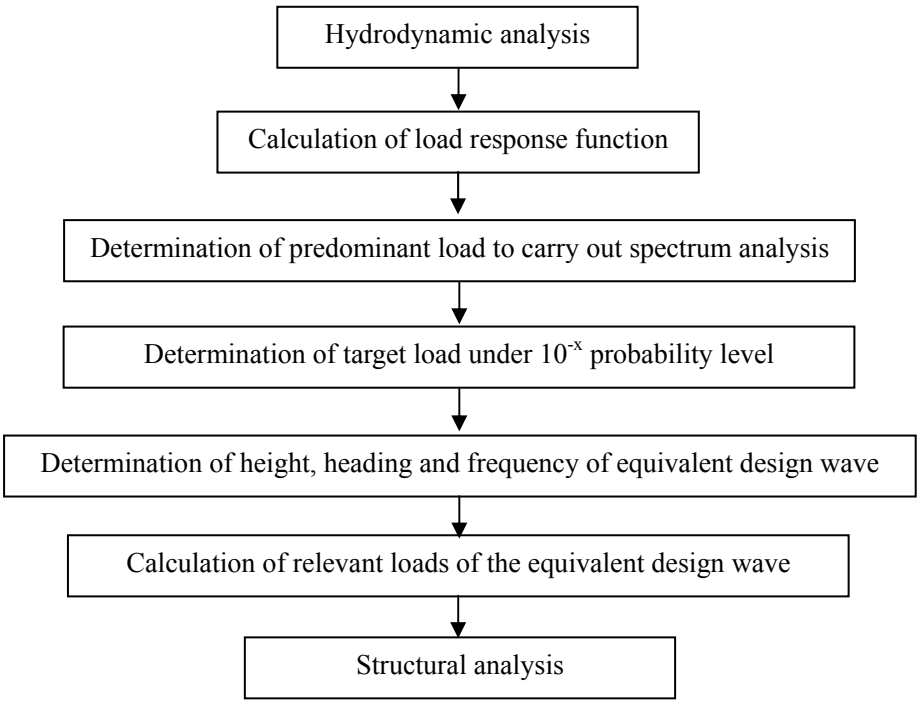


Figure 2-2 Flow Chart of Wave Load Calculation by Equivalent Design Wave Method

3 WAVE LOAD CALCULATION AND APPLICATION BASED ON EQUIVALENT DESIGN WAVE METHOD

3.1 Basic assumption and provision

3.1.1 General

This part specifies the basic assumption, basic calculation steps, calculation model requirements and calculation software requirements. Relevant calculation is to comply with the provisions of sub-sections.

3.1.2 Relevant assumption

The wave load calculation based on equivalent design wave method is based on the following assumptions:

a. based on the three-dimensional linear potential flow theory;
b. based on the wave environment of North Atlantic, and the wave scatter diagram and short-term and long-term prediction of wave loads are based on IACS Rec.34;
c. the two parameter P-M spectrum recommended by IACS Rec.34 is used as the wave spectrum;
d. the heading step is 30 deg. and the probability of occurrence of all headings are equal;
e. the calculation frequency is 0.2 rad/s to 1.2 rad/s and the frequency interval is 0.05 rad/s;
f. $\cos^2$is used as the energy transfer function of wave;
g. the strength assessment is based on 10^{-8}probability level and the speed is taken as 5 knots;
h. the fatigue assessment is based on 10-2 probability level and the speed is taken as 75% of the service speed.

3.1.3 Calculation steps

The main steps of calculation of wave loads based on equivalent design wave method are as follows:

a. selection of loading pattern, establishment of hydrodynamic model and mass distribution model;
b. calculation of wave load response function of each heading;
c. selection of wave environment for long-term prediction of target wave load, in order to obtain the limit value and phase of relevant target load;
d. determination of parameters such as wave height, heading, frequency and phase of equivalent design wave;
e. calculation of hull girder loads, acceleration in way of ship's center of gravity and distribution of sea pressure of relevant equivalent design wave, calculation of internal pressure in accordance with position of compartment and loaded cargo.

3.1.4 Requirements for calculation model

The calculation model of wave loads based on equivalent design wave method is to comply with the following requirements:

a. the mass model is to be fine enough in order to ensure that the error between mass of model and that of real ship is not greater than 0.1% and the error between position of center of gravity of model and that of real ship is not greater than 0.1%L;
b. the model of wetted surface is to simulate the shape of real ship in so far as practicable, the error between displacement of model and that of real ship is not greater than 0.1% and the error between position of center of buoyancy of model and that of real ship is not greater than 0.1%L;
c. the number of meshes of the wetted surface model is to be sufficient and the mesh length is generally not to be greater than one percent of the ship's length.

3.1.5 Requirements for calculation software

The calculation software of wave loads based on equivalent design wave method is to be based on the three-dimensional linear potential flow theory and approved by CCS.

3.2 Loading conditions

3.2.1 General requirements

For the loading conditions for structural strength assessment, see relevant provisions of Section 8, Chapter 4 of PART 11-1.

For the loading conditions for fatigue strength assessment, see relevant provisions of Section 8, Chapter 4 of PART 11-1. Unless there is more accurate data, the time scale factor of corresponding loading condition is given in Section 1, Chapter 9 of PART 11-1.

3.2.2 Loading conditions to be considered in the strength assessment

Prescriptive method

(1) The following loading conditions are to be considered for oil tankers:
   a. homogeneous full load (departure);
   b. normal ballast condition (arrival);
   c. emergency ballast condition (arrival);
   d. other potential critical loading conditions in the loading manual.

(2) The following loading conditions are to be considered for bulk carriers:
   a. homogeneous heavy cargo full load (departure);
   b. homogeneous light cargo full load (departure);
   c. alternate heavy cargo full load (departure);
   d. alternate light cargo full load (departure);
   e. heavy ballast condition (arrival);
   f. normal ballast condition (arrival);
   g. other potential critical full load in the loading manual.

Loading conditions to be considered in FE method

(1) The following loading conditions are to be considered for oil tankers fitted with one longitudinal bulkhead:
   a. optional loading condition of 0.9 T_{SC};
   b. partial loading condition of 0.60 T_{SC};
   c. emergency ballast condition of $T_{BAL\text{-}EM}$.

(2) The following loading conditions are to be considered for oil tankers fitted with two longitudinal bulkheads:
   a. optional loading condition of 0.9 T_{SC};
   b. partial loading condition of 0.65 T_{SC};
   c. partial loading condition of 0.60 T_{SC};
   d. emergency ballast condition of $T_{BAL\text{-}EM}$.

(3) The following loading conditions are to be considered for bulk carriers:
   a. homogeneous light cargo, homogeneous heavy cargo, alternate heavy cargo, alternate light cargo of T_{SC};
   b. partial loading condition of 0.67 T_{SC};
   c. partial loading condition of 0.75 T_{SC};
   d. partial loading condition of 0.83 T_{SC};
   e. heavy ballast condition of $T_{BAL\text{-}H}$.

3.2.3 Loading conditions to be considered in the fatigue assessment

Loading conditions to be considered for bulk carriers include:

a. homogeneous light cargo full load (departure);
b. homogeneous heavy cargo full load (departure);
c. heavy ballast condition (arrival);
d. normal ballast condition (arrival).

The following loading conditions are to be considered for oil tankers:

a. homogeneous full load (departure);
b. normal ballast condition (arrival).

3.3 Equivalent design wave

3.3.1 Introduction

The equivalent design wave to be calculated is to represent the dynamic load cases corresponding to the most critical condition of relevant structures, mainly including the minimum and maximum of vertical bending moment of head sea and following sea amidships, the minimum and maximum of $L/4$ torsional moment, the minimum and maximum of pressure at waterline, the minimum and maximum of roll, the minimum and maximum of vertical acceleration of head sea and oblique sea, etc.

- HSM load cases:
  HSM-1 and HSM-2: Head sea EDWs that minimise and maximise the vertical wave bending moment amidships respectively.
- HSA load cases:
  HSA-1 and HSA-2: Head sea EDWs that maximise and minimise the head sea vertical acceleration at FP respectively.
- FSM load cases:
  FSM-1 and FSM-2: Following sea EDWs that minimise and maximise the vertical wave bending moment amidships respectively.
- BSR load cases:
  BSR-1P and BSR-2P: Beam sea EDWs that minimise and maximise the roll motion downward and upward on the port side respectively with waves from the port side.
  BSR-1S and BSR-2S: Beam sea EDWs that maximise and minimise the roll motion downward and upward on the starboard side respectively with waves from the starboard side.
- BSP load cases:
  BSP-1P and BSP-2P: Beam sea EDWs that maximise and minimise the hydrodynamic pressure at the waterline amidships on the port side respectively.
  BSP-1S and BSP-2S: Beam sea EDWs that maximise and minimise the hydrodynamic pressure at the waterline amidships on the starboard side respectively.
- OST load cases:
  OST-1P and OST-2P: Oblique sea EDWs that minimise and maximise the torsional moment at 0.25$L$from the AE with waves from the port side respectively.
  OST-1S and OST-2S: Oblique sea EDWs that maximise and minimise the torsional moment at 0.25$L$from the AE with waves from the starboard side respectively.
- OSA load cases:
  OSA-1P and OSA-2P: Oblique sea EDWs that maximise and minimise the pitch acceleration with waves from the port side respectively.
  OSA-1S and OSA-2S: Oblique sea EDWs that maximise and minimise the pitch acceleration with waves from the starboard side respectively.

3.3.2 Application of equivalent design wave

The equivalent design waves to be considered for strength assessment include 7 categories, i.e. HSM, HAS, FSM, BSR, BSP, OST and OSA.

The equivalent design waves to be considered for fatigue assessment include 5 categories, i.e. HSM, FSM, BSR, BSP and OST.

3.4 Load calculation

3.4.1 Motion and acceleration

The roll angle θ and pitch angle φ of hull are calculated in accordance with the following formulae:

$$\theta = f_{ps}\,\mathrm{Re}(\eta_4),\quad \varphi = f_{ps}\,\mathrm{Re}(\eta_5)$$

The acceleration response function of any point of hull is determined from the following formulae:

$$a_X = f_{ps}\left\{-g\sin\left[\mathrm{Re}(\eta_4)\right]+a_{surge}+z\cdot a_{pitch}-y\cdot a_{yaw}\right\}$$
$$a_Y = f_{ps}\left\{g\sin\left[\mathrm{Re}(\eta_5)\right]+a_{sway}+x\cdot a_{yaw}-z\cdot a_{roll}\right\}$$
$$a_Z = f_{ps}\left(a_{heave}+y\cdot a_{roll}-x\cdot a_{pitch}\right)$$

$\eta_i\,(i=1,6)$ denotes ship motions in six degrees of freedom, where η_{Re} is real part, η_{Im} is imaginary part, $a_{surge}=\mathrm{Re}(\ddot{\eta}_1)$, $a_{sway}=\mathrm{Re}(\ddot{\eta}_2)$, $a_{heave}=\mathrm{Re}(\ddot{\eta}_3)$, $a_{roll}=\mathrm{Re}(\ddot{\eta}_4)$, $a_{pitch}=\mathrm{Re}(\ddot{\eta}_5)$ and $a_{yaw}=\mathrm{Re}(\ddot{\eta}_6)$.

The relationship between speed $\dot{\eta}_i$ of six degrees of freedom and motion is as follows:

$$\dot{\eta}_i = i\omega_e\cdot\left(\eta_{i,\mathrm{Re}}+i\eta_{i,\mathrm{Im}}\right)=-\omega_e\eta_{i,\mathrm{Im}}+i\omega_e\eta_{i,\mathrm{Re}},\ \ \mathrm{Re}(\dot{\eta}_i)=-\omega_e\eta_{i,\mathrm{Im}}$$

The relationship between acceleration $\ddot{\eta}_i$ of six degrees of freedom and motion is as follows:

$$\ddot{\eta}_i = -\omega_e^2\cdot\left(\eta_{i,\mathrm{Re}}+i\eta_{i,\mathrm{Im}}\right)=-\omega_e^2\eta_{i,\mathrm{Re}}-i\omega_e^2\eta_{i,\mathrm{Im}},\ \mathrm{Re}(\ddot{\eta}_i)=-\omega_e^2\eta_{i,\mathrm{Re}}$$

where: ω_e is encounter frequency.

3.4.2 Hull girder loads

3.4.2.1 Hull girder still water loads

The hull girder vertical still water bending moment and vertical shear force are to taken as the permissible still water bending moment and permissible still water shear force.

3.4.2.2 Hull girder vertical wave bending moment

The hull girder vertical wave bending moment under equivalent design wave specified by each loading condition is calculated in accordance with the following formula:

$$M_{WV} = f_S f_{ps} f_\beta f_m f_{nl} M_{WV,MID,MAX}$$

where: $M_{WV,MID,MAX}$ is taken as the maximum of vertical wave bending moment between 0.4*L* and 0.6*L* in corresponding condition.

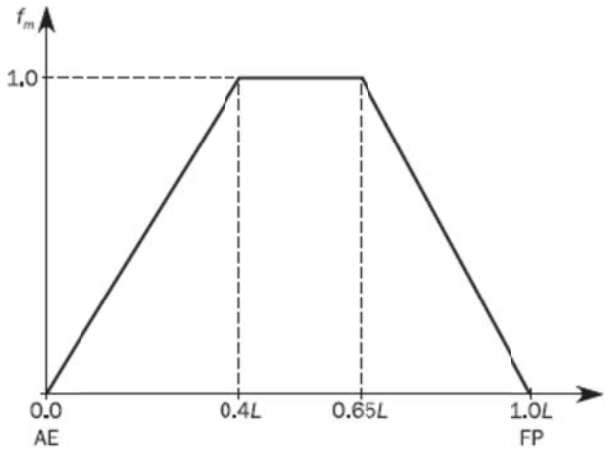


Figure 3-1 Distribution Factor f_m along the Ship's Length

The envelope of hull girder vertical wave bending moment is to be taken as the envelope of wave bending moment of all conditions.

3.4.2.3 Calculation of hull girder vertical wave shear force

For a given loading condition, the wave shear force at any section under any equivalent design wave is to be taken as:

$$Q_{WV} = f_{ps} f_\beta f_q f_{lp} Q_{WV,MAX}$$

where: f_q — distribution factor of vertical wave shear force, to be taken as f_{q-pos} if it is greater than or equal to zero, see Figure 3-2 and f_{q-neg} if it is less than zero, see Figure 3-3;

f_{lp} — coefficient for symbol of vertical wave shear force, f_{lp}=1.0 for hogging and $x/L<0.5$, or sagging

and $x/L \geq 0.5$, otherwise f_{lp}=-1.0;

$Q_{WV,MAX}$ — to be taken as $MAX\left(\frac{MAX|Q_{WV,CAL,A,i}|}{0.92}, \frac{MAX|Q_{WV,CAL,F,i}|}{1.0}\right)$, where $Q_{WV,CAL,A,i}$ is calculation value of wave shear force of each section when $x/L < 0.5$ and $Q_{WV,CAL,F,i}$ is calculation value of wave shear force of each section when $x/L \geq 0.5$.

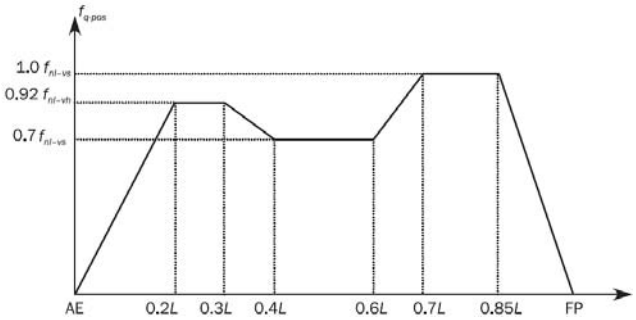


Figure 3-2 Distribution Factor f_{q-pos} along the Ship's Length

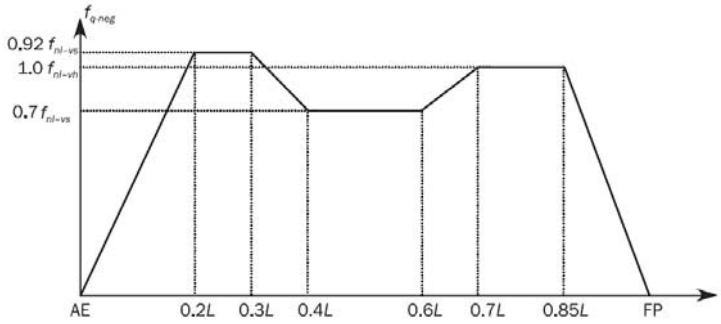


Figure 3-3 Distribution Factor f_{q-neg} along the Ship's Length

3.4.2.4 Hull girder horizontal wave bending moment

The hull girder horizontal wave bending moment under equivalent design wave specified by each loading condition is calculated in accordance with the following formula:

$$M_{WH} = f_S f_{ps} f_\beta f_m M_{WH,MID,MAX}$$

where: $M_{WH,MID,MAX}$ is the maximum of horizontal wave bending moment between 0.4L and 0.6Lunder the equivalent design wave.

3.4.2.5 Hull girder wave torsional moment

The hull girder torsional moment is considered for only OST and OSA cases for each loading condition and is to be taken as the fitted value of 20 calculation points uniformly distributed along the ship's length. The value between any two calculation points is obtained by linear interpolation, taking into account the correction of f_β.

$$M_{WT} = f_{ps} M_{WT,CAL}$$

3.4.3 Sea pressure

3.4.3.1 Hydrostatic pressure

The hydrostatic pressure is calculated in accordance with the following formula, but not to be less than zero:

$$P_{es} = \rho g(T_{LC} - z)$$

3.4.3.2 Hydrodynamic pressure

The wave dynamic pressure of any point of section under equivalent design wave specified by each loading condition is to be taken as the linear fitted value of pressure of three points of bottom centre line point, bilge calculation point and water line point, but is not to be less than $-\rho g(T_{LC} - z)$ below the water line and not less than zero above the water line, i.e.:

$P_{ed} = f_{ps} f_{nl} \left[P_{ctr} + \frac{|y|}{0.5B_{local}} \left(P_{bilge} - P_{ctr} \right) \right]$, between bottom centre line point and bilge calculation point;

$P_{ed} = f_{ps} f_{nl} \left[P_{bilge} + \frac{z}{T_{LC}} \left(P_{WL} - P_{bilge} \right) \right]$, between bilge calculation point and static equilibrium water line point;

$P_{ed} = f_{ps} f_{nl} \left[P_{WL} - 10 \left(z - T_{LC} \right) \right]$, above the water line.

The bilge reference point is taken by referring to the figure 3-4.

The pressure of three points of bottom centerline point, bilge calculation point and water line point is to be taken as the fitted value of 20 calculation points uniformly distributed along the ship's length. The interpolation function between any two section is to be taken as the cubic function determined by four calculation points nearby.

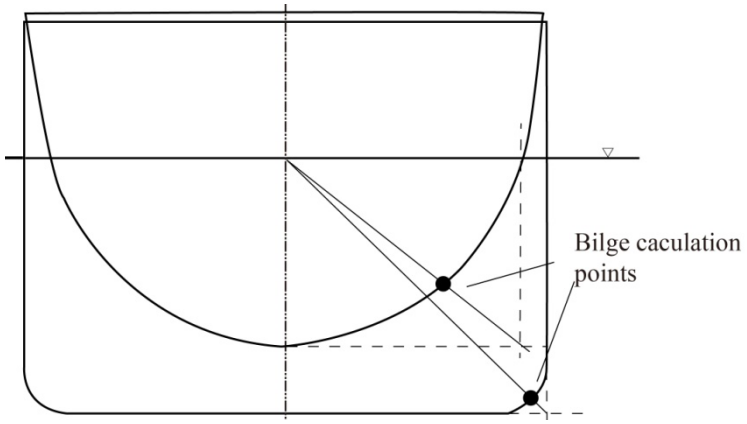


Figure 3-4 Bilge Calculation Points

3.4.3.3 Total sea pressure

The total sea pressure is calculated in accordance with the following formula, but not to be less than zero:

$$P_{ex} = P_{es} + P_{ed}$$

3.4.4 Pressure in tanks

3.4.4.1 Liquid pressure in tanks

The static liquid pressure in tanks P_{ls} is calculated in accordance with 1.2, Section 6, Chapter 4 of PART 11-1.

The dynamic liquid pressure in tanks P_{ld} is calculated in accordance with 1.3, Section 6, Chapter 4 of PART 11-1, where the acceleration of center of gravity of compartment a_X, a_Y and a_Z are taken as the results calculated in accordance with 3.4.1 of this Appendix.

3.4.4.2 Dry bulk cargo pressure in tanks

The calculation formulae of dry bulk cargo static pressure P_{bs}, dynamic pressure P_{bd}, static shear load $P_{bs\text{-}s}$ and dynamic shear loads $P_{bs\text{-}d}$, $P_{bs\text{-}dx}$, $P_{bs\text{-}dy}$ are given in 2, Section 6, Chapter 4 of PART 11-1, where the acceleration of center of gravity of compartment a_X, a_Y and a_Z are taken as the results calculated in accordance with 3.4.1 of this Appendix.

3.4.4.3 Total internal pressure

The total internal pressure P_{in} is to be taken as the sum of static and dynamic pressure of liquids or dry bulk cargoes in tanks, but not to be less than zero.

3.5 Application of relevant loads

3.5.1 Correspondence between relevant loads and PART 11-1

Name of load	Symbol of the Rules	Paragraph of definition in PART 11-1	Symbol of this Appendix	Paragraph of this Appendix
Roll angle	θ	Symbols, Section 3, Chapter 4	θ	3.4.1
Pitch angle	φ	Symbols, Section 3, Chapter 4	φ	3.4.1
Acceleration at any point	a_X, a_Y, a_Z	Table 4, Section 4, Chapter 1	a_X, a_Y, a_Z	3.4.1
Vertical wave bending moment	$M_{wv\text{-}LC}$	3.5.2, Section 4, Chapter 4	M_{WV}	3.4.2.2
Vertical wave shear force	$Q_{wv\text{-}LC}$	3.5.3, Section 4, Chapter 4	Q_{WV}	3.4.2.3

Name of load	Symbol of the Rules	Paragraph of definition in PART 11-1	Symbol of this Appendix	Paragraph of this Appendix
Horizontal wave bending moment	$M_{wh\text{-}LC}$	3.5.4, Section 4, Chapter 4	M_{WH}	3.4.2.4
Wave torsional moment	$M_{wt\text{-}LC}$	3.5.5, Section 4, Chapter 4	M_{WT}	3.4.2.5
Total sea pressure	P_{ex}	Table 4, Section 4, Chapter 1	P_{ex}	3.4.3.3
Hydrostatic pressure	P_S	1.2.1, Section 5, Chapter 4	P_{es}	3.4.3.1
Hydrodynamic pressure	P_W	1.3 and 1.4, Section 5, Chapter 4	P_{ed}	3.4.3.2
Total internal pressure	P_{in}	Table 4, Section 4, Chapter 1	P_{in}	3.4.4.3
Static liquid pressure	P_{ls}	1.2, Section 6, Chapter 4	P_{ls}	3.4.4.1
Dynamic liquid pressure	P_{ld}	1.3, Section 6, Chapter 4	P_{ld}	3.4.4.1
Dry bulk cargo static pressure	P_{bs}	2.4.2, Section 6, Chapter 4	P_{bs}	3.4.4.2
Dry bulk cargo dynamic pressure	P_{bd}	2.4.3, Section 6, Chapter 4	P_{bd}	3.4.4.2

3.5.2 Application of relevant loads in prescriptive methods

3.5.2.1 Hull girder strength

The still water bending moment and shear force for hull girder strength assessment are to use relevant permissible values.

The envelope of vertical wave bending moment and shear force for hull girder strength assessment is taken as the value calculated in accordance with 3.4.2.2 and 3.4.2.3 of this Appendix.

3.5.2.2 Yielding and buckling strength of plating and stiffeners

The design load sets for assessment of yielding and buckling strength of plating and stiffeners are given in Table 1, Section 2, Chapter 6 of PART 11-1, and relevant loads are given in this Appendix.

3.5.2.3 Fatigue strength of longitudinals

The assessment of fatigue strength of longitudinals is given in Tables 1 to 3, Section 2, Chapter 9 of PART 11-1, and relevant loads are given in this Appendix.

3.5.3 Application of relevant loads in FE methods

3.5.3.1 Strength assessment

Loading conditions and dynamic load cases for FE strength assessment are given in 1 to 4, Section 8, Chapter 4 of PART 11-1, and relevant loads are given in this Appendix.

3.5.3.2 Fatigue assessment

Loading conditions and dynamic load cases for FE fatigue assessment are given in 5, Section 8, Chapter 4 of PART 11-1, and relevant loads are given in this Appendix.

CCS Appendix B SUPPLEMENTARY REQUIREMENTS FOR DIRECT CALCULATION LOAD CONDITIONS

1 GENERAL

1.1 General requirements

1.1.1 Direct calculation of load conditions for special structural arrangement in compliance with the requirements of 2.5.1 of Section 8, Chapter 4 of PART 11-1 is to be carried out according to the requirements of this Appendix.

1.1.2 This Appendix specifies the general principles for determining the direct calculation load conditions for the above mentioned special structural arrangement and direct calculation conditions for specific structural arrangement.

1.1.3 The structural FE model and boundary conditions, calculation and applying of loads, loads adjustment, calculation criteria included in this Appendix are to comply with the requirements for direct calculation in Chapter 7 of PART 11-1.

1.2 Application

1.2.1 This Appendix is applicable to double or single hull bulk carriers and oil tankers with one or two longitudinal bulkhead in compliance with the requirements of PART 11-1.

1.2.2 The direct calculation load conditions as specified in this Appendix are only applicable to structural strength assessment.

1.3 Symbols and definitions

1.3.1 The parameters and symbols used in this Appendix are those defined in Chapter 4 of PART 11-1.

2 GENERAL PRINCIPLES

2.1 General requirements

2.1.1 The types and density of dry bulk cargo, density of cargo oil, density of ballast water and fuel oil are to comply with the requirements of Chapter 4 of PART 11-1.

2.1.2 Typical loading patterns (departure, arrival, harbour, partially filled ballast tanks) are to comply with the requirements of Section 8, Chapter 4 of PART 11-1.

2.1.3 The loading condition and draught are to comply with the requirements of Section 8, Chapter 4 of PART 11-1 and the worst loading pattern is to be selected as the case to be checked according to the actual situation specified in the loading manual.

2.2 Principles for selection of loading condition

2.2.1 Oil tankers are to comply with the requirements for design loading condition as specified in Section 8, Chapter 4 of PART 11-1, including:

(1) heavy ballast condition where all ballast tanks may be full, partially full or empty, 100% filling of fore peak water ballast tanks;

(2) other seagoing conditions in loading manual where these differ significantly from the ballast conditions;

(3) any specified non-uniform distribution of loading.

2.2.2 Bulk carriers are to comply with the requirements for design loading condition as specified in Section 8, Chapter 4 of PART 11-1, including:

(1) homogeneous light and heavy cargo loading conditions;

(2) alternate loading conditions;

(3) multiport loading conditions, where applicable;

(4) alt-block loading conditions, where applicable;

(5) load case where heavy ballast conditions of designated heavy ballast hold or normal ballast condition in case of no heavy ballast hold, including ballasting of fore peak tank.

2.2.3 Special structural arrangement loading conditions

(1) Loading pattern

In general, cargo tanks and dry bulk cargo holds in cargo tank/hold region are to comply with the requirements for typical structural arrangement as specified in PART 11-1. Where the arrangement of cargo hold or double hull mid hold (ballast tank or fuel oil tank) is inconsistent with the typical structure as specified in PART 11-1, the loading pattern is to be defined according to the requirements of Chapter 8 of PART 11-1 and the actual location of cargo hold or double hull mid hold.

(2) Draught

Draught of oil tanker in loading conditions is to comply with the requirements of Section 8, Chapter 4 of PART 11-1. For tankers with two oil-tight longitudinal bulkheads, where the cargo tank length is less than 0.15 L or tankers with one centreline oil-tight longitudinal bulkhead, where the cargo tank length is less than 0.11L. The load case draught is to be taken the draught as required by the Rules or the actual draught in loading manual. Generally, the draught which imposes more severe effect to the structural strength is to be selected.

Draught of bulk carriers in loading conditions is to comply with the requirements of Section 8, Chapter 4 of PART 11-1.

(3) Target location for hull girder shear force adjustment

The cargo hold region selected for direct calculation model is to be arranged with 3 cargo holds and 4 transverse bulkheads. The shear force is to be adjusted at target bulkhead in alternate loading conditions included in load cases in case of special structural arrangement.

3 TYPICAL ADDITIONAL LOADING CONDITIONS

3.1 Oil tankers

3.1.1 There are in general various forms of arrangement for the slop tank in the aftmost region of cargo tank in oil tankers. In addition to the general arrangement as given in Section 8, Chapter 4 of PART 11-1, typical arrangements for slop tank of oil tankers are shown in Figure 3.1.1(1) and Figure 3.1.1(2).

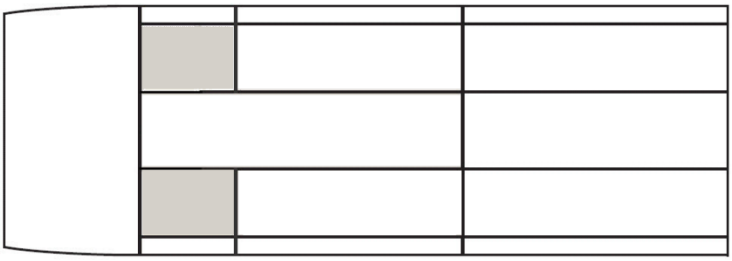


Figure 3.1.1(1) Typical arrangement for slop tank-1

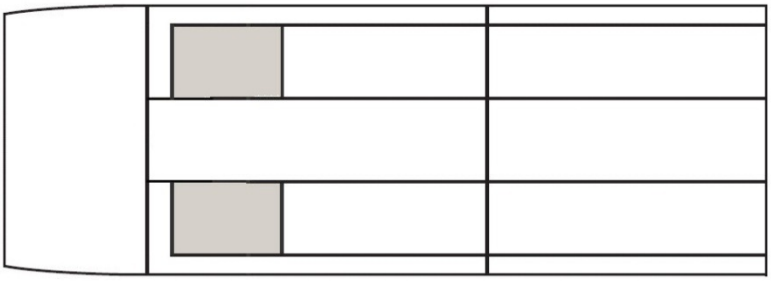
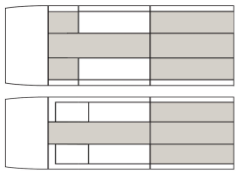
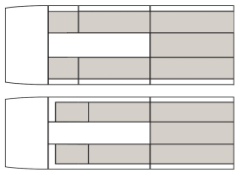
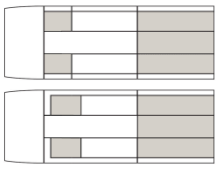
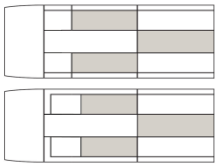
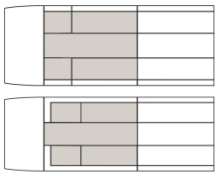
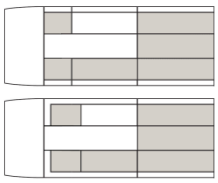
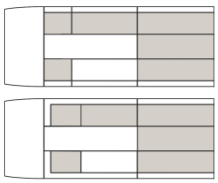
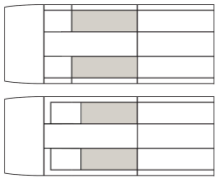
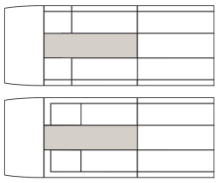
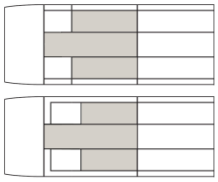
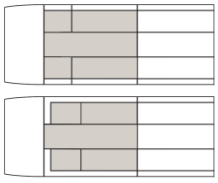
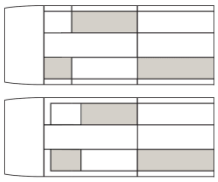


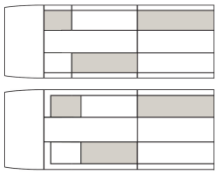
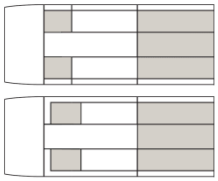
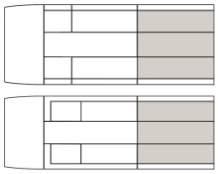
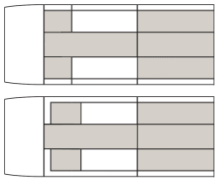
Figure 3.1.1(2) Typical arrangement for slop tank-2

3.1.2 The load cases for the above mentioned arrangement for slop tank are shown in Table 3.1.2.

Load Cases **Table 3.1.2**

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	% of perm. SWBM	% of perm. SWSF	Aftmost cargo hold
Seagoing conditions					
A1[4]		$0.9T_{SC}$	100% (sagging)	100%	all LC[2]
			100% (hogging)	100%	all LC [2]
A2[4]		$0.9T_{SC}$	100% (sagging)	100%	all LC [2]
			100% (hogging)	100%	all LC [2]
A3-1[1][3]		$0.65T_{SC}$	100% (hogging)	100% Max SFLC	HSM-2 FSM-2
				100%	Group 2LC[9]except HSM-2, FSM-2
			100% (sagging)	100% Max SFLC	HSM-1 FSM-1
				100%	Group 1 LC[8] except HSM-1, FSM-1
A3-2[1][4]		$0.65T_{SC}$	100% (hogging)	100% Max SFLC	HSM-2 FSM-2
				100%	Group 2LC[9] except HSM-2, FSM-2
			100% (sagging)	100% Max SFLC	HSM-1 FSM-1
				100%	Group 1 LC[8] except HSM-1, FSM-1
A4[3]		$0.6T_{SC}$	100% (sagging)	100%	all LC[1]
A5-1[3]		$0.65T_{SC}$	100% (sagging)	100% Max SFLC	HSM-1 FSM-1
				100%	Group 1 LC[8] except HSM-1, FSM-1
			100% (hogging)	100% Max SFLC	HSM-2 FSM-2
				100%	Group 2LC[9] except HSM-2, FSM-2
A5-2[4]		$0.65T_{SC}$	100% (sagging)	100% Max SFLC	HSM-1 FSM-1
				100%	Group 1 LC[8]except HSM-1, FSM-1
			100% (hogging)	100% Max SFLC	HSM-2 FSM-2
				100%	Group 2LC[9] except HSM-2, FSM-2

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	% of perm. SWBM	% of perm. SWSF	Aftmost cargo hold
A6[4]		$0.6T_{SC}$	100% (hogging)	100%	all LC [1]
A7a[4]		T_{LC}	100% (hogging)	100%	all LC [1]
A7b[4]		T_{LC}	100% (hogging)	100%	all LC [1]
Harbour and testing conditions					
A9[3]		$0.25T_{SC}$	100% (sagging)	100%	N/A
A10[4]		$0.25T_{SC}$	100% (sagging)	100%	N/A
A11-1[3]		$0.6T_{SC}$	100% (sagging)	100%[5] Max SFLC	N/A
				100%[6] Max SFLC	N/A
A11-2[4]		$0.6T_{SC}$	100% (sagging)	100%[5] Max SFLC	N/A
				100%[6] Max SFLC	N/A
A12a[5]		$0.33T_{SC}$	N/A	N/A	N/A

No.	Loading pattern	Still water loads			Dynamic load cases
		Draught	% of perm. SWBM	% of perm. SWSF	Aftmost cargo hold
A12b[5]		$0.33T_{SC}$	N/A	N/A	N/A
A13-1[3]		$0.65T_{SC}$	100% (hogging)	100%[5] Max SFLC	N/A
				100%[6] Max SFLC	N/A
A13-2[4]		$0.33T_{SC}$	100% (hogging)	100%[5] Max SFLC	N/A
				100%[6] Max SFLC	N/A
14[4]		T_{SC}	100% (hogging)	100%	N/A

Notes:

(1) 100% filling of fuel and water ballast tanks in engine room, with tank boundaries at the forward engine room bulkhead.
(2) "All LC" means: all the dynamic load cases as defined in Ch 4, Sec 2 for both sagging and hogging and both P and S.
(3) The required adjustment in shear force at aft bulkhead of the considered hold is to be done at forward slop tank bulkhead.
(4) The required adjustment in shear force at aft bulkhead of the considered hold is to be done at forward machinery space bulkhead.
(5) The shear force and bending moment that results from the application of local loads are to be used for non-hull girder adjustment conditions.
(6) The shear force is to be adjusted to target value at forward machinery bulkhead.
(7) The shear force is to be adjusted to target value at forward bulkhead of the mid-hold.
(8) Group1 LC means: all Head sea LC in sagging, all Following sea LC in sagging, all Beam Sea LC and all Oblique Sea load cases.
(9) Group2 LC means: all Head sea LC in hogging, all Following sea LC in hogging, all Beam Sea LC and all Oblique Sea load cases.

3.1.3 In addition to the above mentioned typical tank arrangement, the general principles for determining the target location of shear force adjustment are as follows in cases there are other special arrangement for cargo tank, slop tank and ballast tank in the aftmost region of oil tanker.

(1) in general, the forward machinery bulkhead is to be taken as the reference location;
(2) where alternate loading condition is taken for slop tank and adjacent cargo tank, forward bulkhead of slop tank is to be taken as the reference location.

3.2 Bulk carriers

3.2.1 Special arrangement for the double hull tanks (fuel oil tank, ballast tank, empty tank) of bulk carriers are shown in Figure 3.2.1.

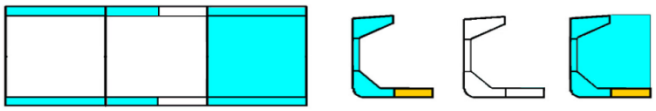
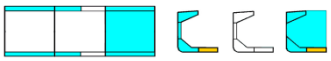


Figure 3.2.1 Special arrangement for bulk carriers

3.2.2 For special arrangement as shown in Figure 3.2.1, load cases are to be supplemented according to Table 3.2.2 for heavy ballast condition in addition to the load cases as required in Section 8 of Chapter 4.

Additional load cases in heavy ballast conditions **Table 3.2.2**

No.	Description	Loading pattern Aft Mid Fore	Draught	% of perm. SWBM	% of perm. SWSF	Dynamic load case
Seagoing conditions						
1	Deepest Ballast (4.2.1 of Section 8, Chapter 4 of PART 11-1)		T_{HB}	100% (hogging)	100%(1)	FSM-2 BSR-1P,BSR-1S OST-2P,OST-2S
				100% (sagging)	100%(1)	BSP-1P,BSP-1S BSR-1P,BSR-1S OST-1P,OST-1S

Note:
(1) The shear force is to be adjusted to target value at watertight transverse bulkhead of double hull ballast tank of the mid-hold.

CCS Appendix C ASSESSMENT OF ULTIMATE STRENGTH OF HULL GIRDERS USING NON-LINEAR FEM

1 GENERAL

1.1 Application

1.1.1 The non-linear finite element method for assessment of the ultimate strength of hull girders, as provided in this Appendix, is applicable to the assessment of the ultimate strength of intact hull girders and damaged hull girders after collision/grounding.

1.1.2 For the hull girder FE models in this Appendix, the relevant non-linear effects given in paragraph 3.1.1, Appendix 2, Chapter 5, PART 11-1 of the Rules are to be taken into account.

2 SINGLE SPAN FE MODEL

2.1 Application

2.1.1 The longitudinal extent of the single span FE model is one span of transverse web frames, its transverse extent is the entire breadth of the ship and its vertical extent is the entire moulded depth.

2.1.2 The FE model is to cover all longitudinal continuous members and the stiffeners having an influence on local buckling.

2.1.3 The FE model is to take into account manholes and lightening holes in hull structures.

2.1.4 The FE model is to use net scantlings, i.e. the as-built scantlings deducted by half the corrosion addition. For corrosion addition, see Section 3, Chapter 3, PART 11-1 of the Rules.

2.1.5 For the stress-strain curve of hull structural materials, a bilinear model is to be used taking into account the strain-hardening effects.

2.2 Finite element types and meshing

2.2.1 4-nodes shell elements are to be used for plates, stiffeners and primary supporting members, and beam elements may also be used for stiffener flanges and for web stiffeners of primary supporting members.

2.2.2 The mesh size of the FE model is to be such that local buckling deformations and stress redistribution after localized plastic collapse of structural members (including plating, stiffeners, primary supporting members, etc.) is sufficiently presented. Meshes are to be square as far as possible.

2.3 Initial geometric imperfections

2.3.1 For all longitudinal members of the FE model, the initial geometric imperfections, which may lead to the most critical failure of hull girders, are to be considered.

2.3.2 For the mode of initial geometric imperfections, the overall deformations of stiffened plates between web frames, local deformation of plating and sideways initial deformations of stiffeners are to be considered.

2.3.3 For the amplitude of initial geometric imperfections, deformations from welding or assembly are to be taken into account.

2.4 Boundary conditions and loading

2.4.1 An independent point is to be established at the intersection of neutral axis of cross sections of fore and aft ends of the model respectively.

2.4.2 The two independent points are to be related to the nodes on fore end and aft end of the model respectively, and simply supported restraints are to be applied to the independent points.

2.4.3 An equal hogging/sagging bending moment (or rotation angle)is to be applied to the two independent points and the bending moment (or rotation angle) is to be increased gradually.

2.4.4 When the bending moment-curvature curve reaches its extreme value point and the hogging or sagging failure of the model is evident, the bending moment at this point is the ultimate load-carrying capacity of hull girders.

2.5 Damages due to collision and grounding

2.5.1 For assumptions regarding damage extents, see paragraph 2.2, Section 3, Chapter 5, PART 11-1 of

the Rules.

2.6 Checking criteria

2.6.1 When single span FE model is used to check the ultimate strength and residual strength of hull girders, the partial safety factors of the checking criteria need to be specially considered.

3 CARGO HOLD FE MODEL

3.1 General

3.1.1 The longitudinal extent of a cargo hold FE model is the length of one cargo compartment, its transverse extent is the entire breadth of the ship and its vertical extent is the entire moulded depth, taking into account the effects of lateral loads (including both internal and external loads).

3.1.2 The cargo hold FE model is to cover all transverse members other than transverse bulkheads, upper and lower stools.

3.1.3 Other requirements for the cargo hold FE model are given in paragraphs 2.1.3 to 2.1.6.

3.2 Finite element types and meshing

3.2.1 The requirements for meshing of the cargo hold FE model are given in paragraph 2.2.

3.3 Initial geometric imperfections

3.3.1 The requirements for initial geometric imperfections of the cargo hold FE model are given in paragraph 2.3.

3.4 Lateral loads

3.4.1 The lateral loads in both full load and ballast conditions are to be considered. For bulk carriers, the lateral loads in alternate loading conditions are also to be considered, if applicable.

3.5 Boundary conditions and loading

3.5.1 The boundary conditions for the cargo hold FE model are given in paragraphs 2.4.1and 2.4.2.

3.5.2 The lateral loads specified in paragraph 3.4.1 are to be applied to the FE model.

3.5.3 An equal hogging/sagging bending moment (or rotation angle)is to be applied to the two independent points and the bending moment (or rotation angle) is to be increased gradually.

3.5.4 When the bending moment-curvature curve reaches its extreme value point and the hogging or sagging failure of the model is evident, the bending moment at this point is the ultimate load-carrying capacity of hull girders.

3.6 Damages due to collision and grounding

3.6.1 For assumptions regarding vertical and transverse damage extents, see paragraph 2.2, Section 3, Chapter 5, PART 11-1 of the Rules, and special consideration is to be given to the longitudinal damage extent.

3.7 Checking criteria

3.7.1 When the cargo hold FE model is used to check the ultimate strength and residual strength of hull girders, the partial safety factors of the checking criteria need to be specially considered.

PART 11-2 SHIP TYPES

[PART 2, SHIP TYPES, IACS COMMON STRUCTURAL RULES FOR BULK CARRIERS AND OIL TANKERS]

CHAPTER 1 BULK CARRIERS

Section 1 GENERAL ARRANGEMENT DESIGN

Section 2 STRUCTURAL DESIGN PRINCIPLES

CCS 3.3.2a CCS is to check the structural strength in compliance with the requirements in Chapter 7 of PART 11-1.
CCS 3.3.4a Where two or more hatchways are arranged athwartships, the corner radius is not to be less than 5% of the total width of these hatchways.

Section 3 HULL LOCAL SCANTLINGS

CCS 4.1.2a Where appropriate reinforcements are fitted in way of the openings in the outermost bay, e.g. circular flat bars attached to the inner edge of an opening or stiffeners fitted around an opening, η_2 may be taken as 1.1.
CCS 4.1.3a Where appropriate reinforcements are fitted in way of the openings in the outermost bay, e.g. circular flat bars attached to the inner edge of an opening or stiffeners fitted around an opening, η_2 may be taken as 1.1.

Section 4 HULL LOCAL SCANTLINGS FOR BULK CARRIERS *L*<150 m

CCS 4.1.2a As an alternative to 4.1.1, the scantlings of primary supporting members within the midship cargo hold region may be verified by direct strength assessment according to the requirements in Chapter 7 of PART 11-1 and the load combinations as given in Table CCS 4.1.2a.

Table CCS 4.1.2a FE Load combinations

No.	Description	Loading pattern	Draught	Permissible still water bending moment (%)	Permissible still water shear force (%)	Dynamic load case
Seagoing conditions						
1	Full load		T_{SC}	50% sag.	100%	BSP-1P，BSP-1S，OST-1P，OST-1S
2	Slack load		T_{SC}	0%	100%	BSP-1P，BSP-1S
3	Normal ballast		T_{BAL-N} changed to T_{BAL-N}	100% hog.	100%	FSM-2BSR-1P,BSR-1SOST-2P,OST-2S
4	Heavy ballast (if any)		T_{BAL-H}	0%	100% Max SFLC	FSM-2HSM-2
					100%	BSR-1P,BSR-1S
				100% sag.	100% Max SFLC	HSM-1
					100% Max SFLC	HSM-1
					100%	BSR-1P,BSR-1S

No.	Description	Loading pattern	Draught	Permissible still water bending moment (%)	Permissible still water shear force (%)	Dynamic load case
5	Alternate Load loaded hold (if any)		T_{SC}	100% hog.	100% Max SFLC	FSM-2HSM-2
					100%	OST-2P, OST-2S
				0%	100% Max SFLC	FSM-1 HSM-1
					100% Max SFLC	FSM-1 HSM-1
					100%	BSP-1P, BSP-1S OST-1P, OST-1S
6	Alternate Load empty hold (if any)		T_{SC}	100% hog.	100% Max SFLC	FSM-2 HSM-2
					100%	OST-2P, OST-2S
				0%	100% Max SFLC	FSM-1 HSM-1
					100% Max SFLC	FSM-1 HSM-1
					100%	BSP-1P, BSP-1S OST-1P, OST-1S
7	Multiport (if any)		$0.83T_{SC}$	100% hog.	100% Max SFLC	FSM-2 HSM-2,
					100% Max SFLC	FSM-2 HSM-2,
					100%	OST-2P, OST-2S
				100% sag.	100% Max SFLC	HSM-1
					100%	BSP-1P, BSP-1S OST-1P, OST-1S
8	Multiport (if any)		$0.67T_{SC}$	100% sag.	100%	BSP-1P, BSP-1S OST-1P, OST-1S
9	Multiport (if any)		$0.67T_{SC}$	100% sag.	100%	BSP-1P, BSP-1S OST-1P, OST-1S
10	Multiport (if any)		$0.75T_{SC}$	100% hog.	100%	FSM-2 HSM-2 BSR-1P, BSR-1S OST-2P, OST-2S
				100% sag.	100%	BSP-1P, BSP-1S BSR-1P, BSR-1S OST-1P, OST-1S
11	Multiport (if any)		$0.75T_{SC}$	100% hog.	100%	FSM-2 HSM-2 BSR-1P, BSR-1S OST-2P, OST-2S
				100% sag.	100%	BSP-1P, BSP-1S BSR-1P, BSR-1S OST-1P, OST-1S
Harbour conditions						
12	Harbour condition		$0.67T_{SC}$	100% hog.	100%	N/A
				100% sag.	100%	N/A

No.	Description	Loading pattern	Draught	Permissible still water bending moment (%)	Permissible still water shear force (%)	Dynamic load case
13	Harbour condition		$0.67T_{SC}$	100% hog.	100%	N/A
				100% sag.	100%	N/A
14	Harbour condition		T_{H1}	100% hog.	100%	N/A
				100% sag.	100%	N/A
15	Harbour condition		T_{H1}	100% hog.	100%	N/A
				100% sag.	100%	N/A
16	Harbour condition		T_{H2}	100% hog.	100% Max SFLC	N/A
					100% Max SFLC	N/A
				100% sag	100% Max SFLC	N/A
					100% Max SFLC	N/A

Other loading conditions from the Loading Manual, which are not covered in the above Table are also to be considered. In these cases, actual values of draught and hull girder static loads are to be used, and dynamic load cases corresponding to the loading patterns are to be applied. For example, while the still water bending moment corresponding to the loading pattern is positive, dynamic load cases with hogging wave bending moment are to be applied.

CCS 4.1.2b The scantlings of the primary supporting members in the midship cargo region are also to comply with the minimum thickness requirements in Section 3, Chapter 6 and the aspect ratio requirements in Section 2, Chapter 8 of PART 11-1.

CCS 4.7.1a The requirements of this paragraph apply to the primary supporting members considered as clamped at both ends. For boundary conditions deviated significantly from the above, strength check is to be performed in accordance with CCS 4.1.2a.

CCS 4.7.2a For the primary supporting members with reduced end fixity, strength check is to be performed in accordance with CCS 4.1.2a.

Section 5 CARGO HATCH COVERS

CCS 1.2.1a Materials used for the construction of steel hatch covers are to comply with the material grade requirements for class I as specified in Table 8 of 2.3 in Section 1, Chapter 3 of PART 11-1.

CCS 1.2.2a Where other materials are used, the corrosion additions of materials are to be determined in accordance with the submitted corrosion resistance information of materials. Such information is to include testing and/or historic data demonstrating that corrosion additions meet the design life of 25 years and is subject to the agreement of CCS.

CCS 2.1.2a The height of hatch coamings may be reduced, on condition that the Administration is satisfied that the safety of the ship is not thereby impaired and that effective measures are taken. In such cases, the scantlings of hatch covers, the arrangement of gaskets and securing devices are to comply with the relevant requirements of this Section, taking into account the strength and arrangement of pressure heads, stoppers and securing devices as well as the effectiveness of drainage and sealing materials.

CCS 4.1.5a In the case of carriage of special cargoes on the hatch covers which may temporarily retain water during navigation, lateral loads on the hatch covers shall be determined with the method specified in 4.1.4

taking into account the quality of the retained water.

CCS 4.1.6a In the case of carriage of containers on the hatch covers, the concentrated force P is to be determined by the following formula:

$$P = P_S\left(1 + a_Z\right) \quad \text{kN}$$

where: P_S —container stack weight, in kN;

a_Z — vertical acceleration, in m/s^2, see 3.2.4, Section 3, Chapter 4 of PART 11-1.

CCS 5.1.1a When the hatch cover is arranged as a grillage of longitudinal and transverse primary supporting members, it is to be modeled as follows:

(1) The cover geometry is to be idealized as realistically as possible. Element size is to be appropriate to account for effective breadth. In way of force transfer points and cut-outs 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. Buckling stiffeners may be disregarded for the stress calculation.

(2) A right-hand 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, positive upwards.

(3) Scantlings are to be based on net thicknesses for FE analysis.

(4) The extent of the FE model is to be determined as follows:

① For symmetry of the hatch cover girders or loads about only the *x*-axis or *y*-axis, it may be limited to a half of the hatch cover for check.

② For non-symmetry of hatch cover girders or loads about any of the axes, the whole hatch cover is to be taken for strength evaluation, see Figure CCS 5.1.1a(1).

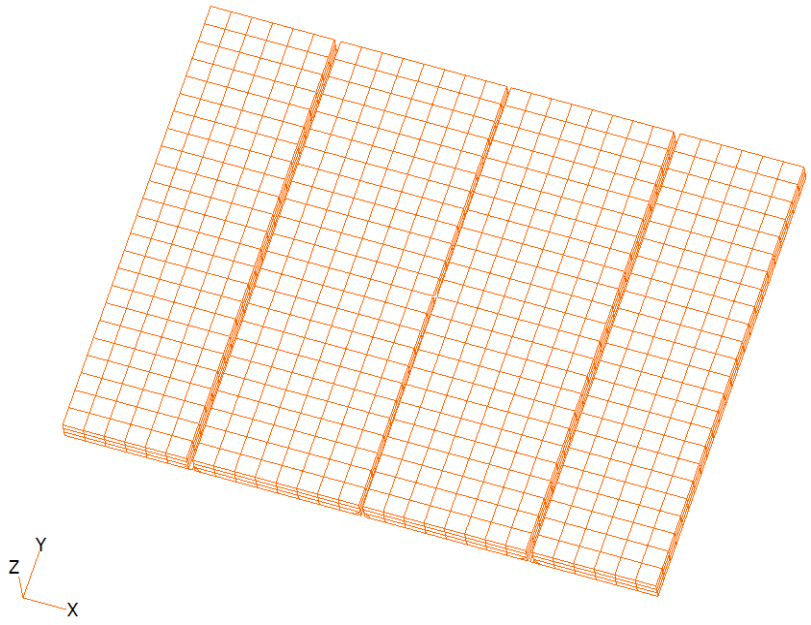


Figure CCS 5.1.1a(1) Finite Element Hatch Cover Model

(5) The model element is to comply with the following requirements:

① All plating, including girders and stiffeners, is to be represented by the finite element model.

② 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.

③ All stiffeners are to be modeled using beam, rod or plate elements.

(6) The element mesh size is to be controlled as follows:

① The mesh size is not to be greater than the spacing of stiffeners.

② The girders are to be represented by at least 3 elements in the depth.

③ Triangular and distorted quadrilateral elements with corner angles less than 60 degrees and greater than 120 degrees are to be avoided.

(7) Boundary conditions are to be determined as follows:

① For symmetry of the hatch cover girders and loads about the *x*-axis, 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 CCS 5.1.1a(2).

② For symmetry of the hatch cover girders and loads about the *y*-axis, 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 CCS 5.1.1a.

③ Boundary nodes in way of bearing pads on the hatch coamings are to be fixed against displacement in the *z* direction, i.e. $\delta_y = 0$.

④ Lifting stoppers are to be fixed against displacements in the direction determined by the stoppers.

⑤ Hinges in folding type hatch covers are to be represented as rigid links which tie together displacements in the *z* direction.

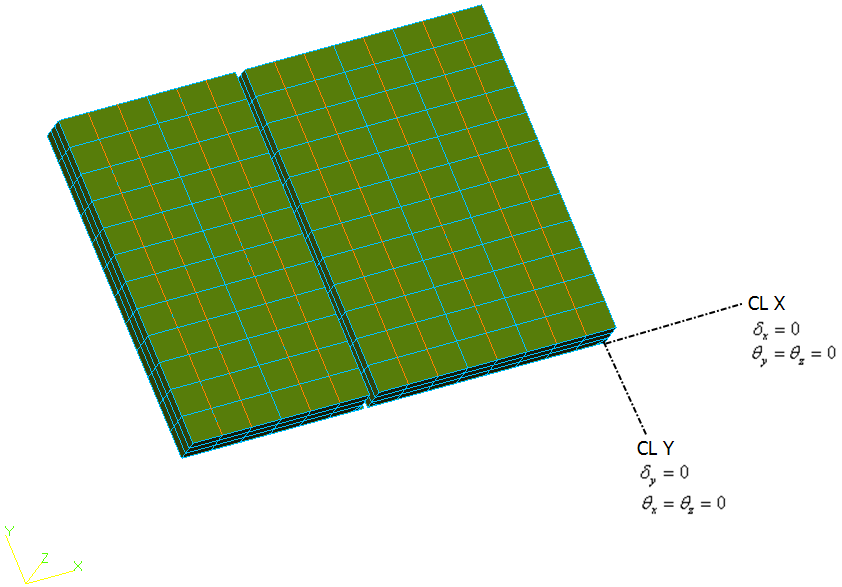


Figure CCS 5.1.1a(2) Boundary Conditions of Hatch Cover Model

CCS 5.1.2a The scantlings of hatch covers supporting containers are to comply with the requirements of 5 of this Section, taking into account the container loads in CCS 4.1.6a.

CCS 6.3.4a Unless otherwise stated in this Section, weld connections and materials are to be dimensioned and selected in accordance with the applicable requirements in Table 2 of Section 3, Chapter 12 and Section 1, Chapter 3 of PART 11-1.

CCS 7.3.1a The closing arrangements, securing devices and stoppers of hatch cover are to comply with the requirements of this Section taking into account the effectiveness of arrangement, spacing, structure, area of securing devices and moment of inertia for edges under situation of special design.

CCS 7.3.5a The permissible stress criteria for securing devices of hatch cover is to be:

(1) For securing devices such as rods or bolts, the tensile stress is not to exceed 120/k, N/mm^2.

(2) For other types of securing devices, the permissible stress is to be as follows:

normal stress: $\sigma = 120/k$ N/mm^2

equivalent stress: $\sigma_e = 150/k$ N/mm^2

shear stress: $\tau = 80/k$ N/mm^2.

Section 6 ADDITIONAL CLASS NOTATION GRAB

CHAPTER 2 OIL TANKERS

Section 1 GENERAL ARRANGEMENT DESIGN

CCS 4.1.2a The strength of watertight doors is to be equivalent to that of the surrounding structure and to comply with the recognized standard.

Section 2 STRUCTURAL DESIGN PRINCIPLES

Section 3 HULL LOCAL SCANTLING

CCS 1.2.1 Table 1(3) Where the optional loading conditions exceed the minimum Rule required loading conditions, the most unfavorable draught between the actual draught and the Rule required draught is to be taken if the minimum Rule required draught is exceeded.

Section 4 HULL OUTFITTING

CCS 2.1.1a The connection structures of hull outfitting equipment to the deck are to comply with the requirements of CCS 6.1.1b in Section 4, Chapter 11 of PART 11-1.

CCS Appendix A IACS REC.14 − HATCH COVER SECURING AND TIGHTNESS (CORR.1 OCT. 2005)

1. Application

1.1 The following recommendations apply to steel hatch covers that are fitted to hatch openings on weather decks.

1.2 The recommendations, when relevant, also apply to the non-weathertight hatch covers which are accepted on container ships in accordance with the UI LL 64.

1.3 Where large relative movements between cover and ship structure or between cover elements are expected for ships having comparatively long/wide hatch ways, the application of these arrangements specified in the Recommendations for the gasket and securing arrangements are to be specially considered.

2. Design and Weathertightness

2.1 General

2.1.1 The weight of covers and any cargo stowed thereon, together with inertial forces generated by ship motions, are to be transmitted to the ship structure through suitable contact, such as continuous steel to steel contact of the cover skirt plate with the ship's structure or by means of defined bearing pads.

2.2 Weathertight Hatch Covers

2.2.1 The arrangement of weathertight hatch covers is to be such that weathertightness can be maintained in all sea conditions.

2.2.2 Weathertight sealings are to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary weathertightness. Similar sealing is to be arranged between cross-joint elements. Where fitted, compression flat bars or angles are to be well rounded where in contact with the gasket and are to be made of a corrosion-resistant material.

2.2.3 The gasket material is to be of a quality suitable for all environmental conditions likely to be experienced by the ship, and is to be compatible with the cargoes carried. The material and form of gasket selected is to be considered in conjunction with the type of cover, the securing arrangement and the expected relative movement between cover and ship structure. The gasket is to be effectively secured to the cover.

3. Drainage Arrangement

3.1 General

3.1.1 Drain openings are to be arranged at the ends of drain channels and are to be provided with effective means for preventing ingress of water from outside, such as non-return valves or equivalent.

3.2 Weather tight Hatch Covers

3.2.1 Drainage is to be arranged inside the line of gasket by means of a gutter bar or vertical extension of the hatch side and end coaming.

3.2.2 Cross-joints of multi-panel covers are to be arranged with drainage of water from the space above the gasket and a drainage channel below the gasket.

3.2.3 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.

4. Securing Devices

4.1 General

4.1.1 Devices used to secure hatch covers, i.e. bolts, wedges or similar, are to be suitably spaced along the coamings and between cover elements.

4.1.2 The minimum gross sectional area of each securing device is not to be less than:

$$A = \frac{1.4\bar{a}}{f} \qquad \text{cm}^2$$

where

$\bar{a}$ = half the distance between the two adjacent securing devices, measured along hatch cover periphery, see Fig. 1, m

$f = (\sigma_F/235)^m$

σ_F = minimum upper yield stress of the material, not to be taken greater than 70% of the ultimate tensile strength, N/mm^2

m = 0,75 for $\sigma_F > 235$ N / mm^2

= 1,00 for $\sigma_F \le 235$ N / mm^2

Where the packing line pressure (see 4.2.2) exceeds 5 N/mm, the cross-sectional area of the securing devices is to be increased in direct proportion.
Rods or bolts are to have a minimum gross diameter not less than 19 mm for hatchways exceeding 5 m^2 in area.
4.1.3 Securing devices are to be of reliable construction and securely attached to the hatchway coamings, decks or covers. Individual securing devices on each cover are to have approximately the same stiffness characteristics.
4.1.4 Where rod cleats are fitted, resilient washers or cushions are to be incorporated.
4.1.5 Where hydraulic cleating is adopted, a positive means is to be provided to ensure that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.
4.2 Weathertight Hatch Covers
4.2.1 Arrangement and spacing of securing devices are to be determined with due attention to the effectiveness for weathertightness, depending upon the type and the size of the hatch cover, as well as on the stiffness of the cover edges between the securing devices.
4.2.2 Between cover and coaming and at cross-joints, a packing line pressure sufficient to obtain weathertightness is to be maintained by the securing devices. The packing line pressure is to be specified.
4.2.3 The cover edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices. The gross moment of inertia of edge elements is not to be less than:

$$I = 6\ pa^4 \quad cm^4$$

where

p = packing line pressure, with $p \geq 5$ N/mm

a = maximum of the distances, a_i, between two consecutive securing devices, measured along the hatch cover periphery (see Fig. 1), not to be taken as less than 2.5 a_c, m

a_c : max ($a_{1.1}$, $a_{1.2}$) , m

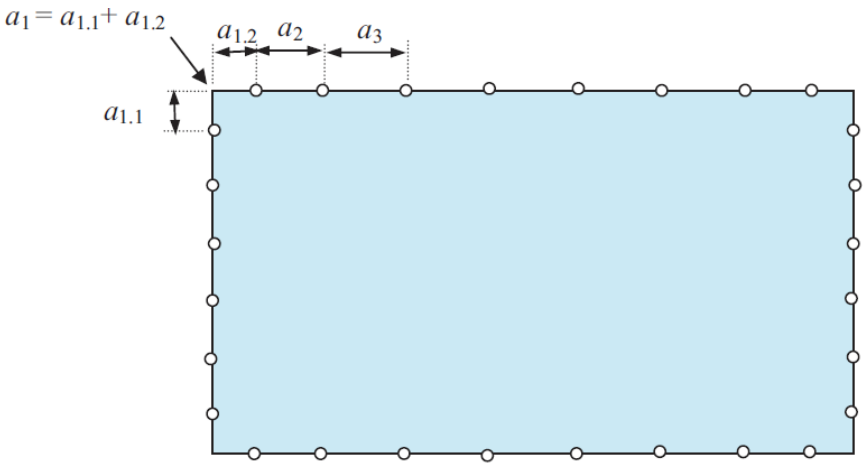


Fig. 1 Distance between securing devices, measured along hatch cover periphery

When calculating the actual gross moment of inertia of the edge element, the effective breadth of the attached plating of the hatch cover, in m, is to be taken equal to the lesser of the following values:
- 0,165 a
- half the distance between the edge element and the adjacent primary member

4.2.4 The angle section or equivalent section bearing the rubber seal is to be of adequate size and well integrated with the cover edge element structure to ensure uniform sealing pressure all along the line of contact

5. Securing Arrangement for Hatch Covers carrying Deck Cargo

5.1 In addition to the recommendations given in 4, all hatch covers, especially those carrying deck cargo are to be effectively secured against horizontal shifting due to the horizontal forces arising from ship motions.
5.2 To prevent damage to hatch covers and ship structure, the location of stoppers is to be compatible with the relative movements between hatch covers and ship structure. The number should be as small as practically possible.

5.3 Considerations are to be given for assessment of cargo loads that towards the end of the ship vertical acceleration forces may exceed the gravity force. The resulting lifting forces must be considered when dimensioning the securing devices according to 4. Also lifting forces from cargo secured on the hatch cover during rolling are to be taken into account.
5.4 Hatch coamings and supporting structure are to be adequately stiffened to accommodate the loading from hatch covers.
5.5 At cross-joints of multi-panel covers vertical guides (male/female) are to be fitted to prevent excessive relative vertical deflections between loaded/unloaded panels.
5.6 In the absence of hatch cover lifting under loads arising from the ship's rolling motion, securing devices for non-weathertight hatch covers may be omitted. In such cases, it is to be proven by means of grillage and/or finite element analyses 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 above the hatch cover supports, where h_E must not be less than:

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

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

where

e = largest distance from the inner edges of the transverse cover guides to the ends of the cover edge plate, mm
s = total clearance within the transverse cover guide, with $10 \leqslant s \leqslant 40$, mm
d = distance between upper edge of transverse stopper and hatch cover supports, mm

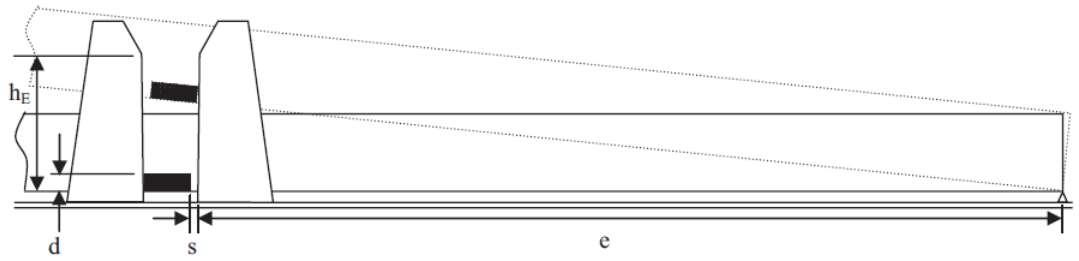


Fig. 2 Height of transverse cover guides

The transverse cover guides and their substructure are to be dimensioned in accordance with the transverse loads acting at a height h_E and an allowable stress defined by each Classification Society.

6. Tightness Testing of Weathertight Hatch Covers

6.1 Upon completion of installation of hatch covers, a chalk test is to be carried out.
6.2 This is to be followed by a hose test with a pressure of water not less than 200 kN/m^2.
The following may be assumed for guidance:
Nozzle diameter: minimum 12 mm
Water pressure: sufficient for a free height of water with the stream directed upwards of 10 meters maximum
Distance to structure: maximum 1,5 meters
6.3 Alternative methods of tightness testing will be considered.

7. Operation Test

7.1 All hatch covers are to be operationally tested.

8. Operation and Maintenance

8.1 It is recommended that ships with steel hatch covers are supplied with an operation and maintenance manual including:
- Operating and closing instructions
- Maintenance requirements for packings, securing devices and operating items
- Cleaning instructions for the drainage system
- Corrosion prevention instructions
- List of spare parts.

CCS Appendix B IACS REC.34 - Standard Wave Data
(CORR. Nov. 2001)

1. This recommendation is valid for ships carrying goods at sea, excluding vessels that operate at a fixed location (for example FPSO s), specifically aiming at ships as covered by UR S11, and focusing on extreme wave loads.

2. Wave data as described by the scatter diagram given in TABLE 1, describe the wave data of the North Atlantic as defined in FIGURE 1, covering areas 8,9,15 and 16, as defined in Global Wave Statistics/1/ with changes according to /2/.

3. When calculating design wave bending moments, it is recommended to use a return period of at least 20 years, corresponding to about 10^{-8} probability of exceedance per cycle.

4. When calculating the pressure head from green seas on horizontal deck plates and hatch covers, the relative motion in the undisturbed wave at the centre line for the considered area, at a return period of 20 years, can be applied as a first approximation.

5. Combination of loads should be performed, preferably using simultaneous values, to ensure application of the design loads at a consistent probability level.

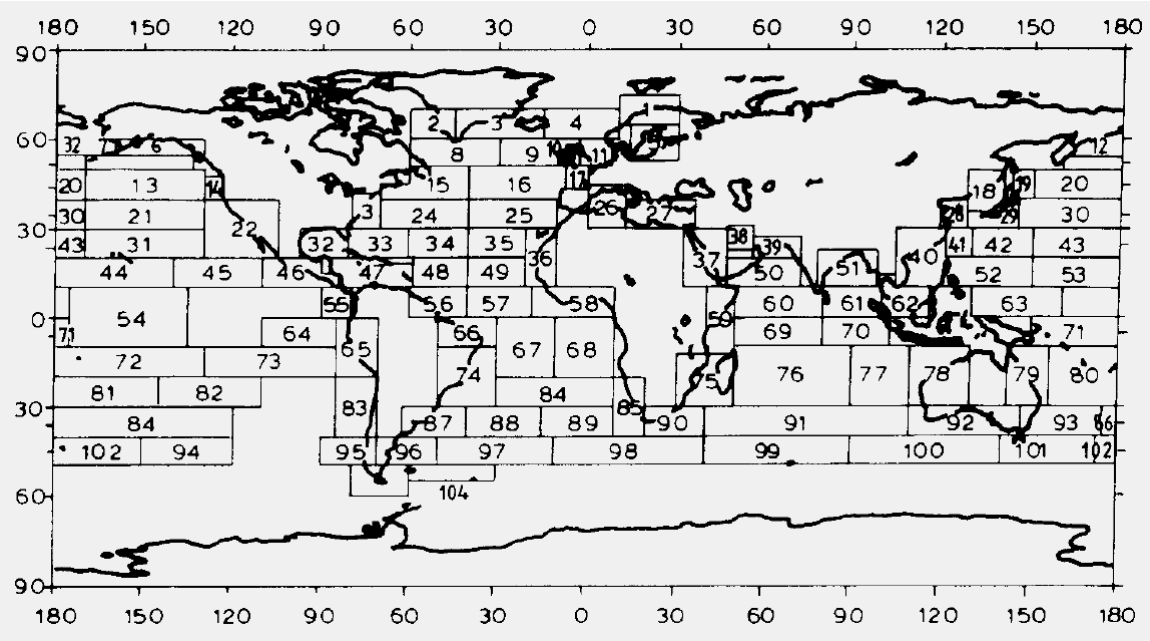


Figure 1 Definition of the extent of the North Atlantic

Table 1, Probability of sea-states in the North Atlantic described as occurrence per 100000 observations.
Derived from BMT's Global Wave Statistics

Hs/Tz	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	SUM
0.5	0.0	0.0	1.3	133.7	865.6	1186.0	634.2	186.3	36.9	5.6	0.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	3050
1.5	0.0	0.0	0.0	29.3	986.0	4976.0	7738.0	5569.7	2375.7	703.5	160.7	30.5	5.1	0.8	0.1	0.0	0.0	0.0	22575
2.5	0.0	0.0	0.0	2.2	197.5	2158.8	6230.0	7449.5	4860.4	2066.0	644.5	160.2	33.7	6.3	1.1	0.2	0.0	0.0	23810
3.5	0.0	0.0	0.0	0.2	34.9	695.5	3226.5	5675.0	5099.1	2838.0	1114.1	337.7	84.3	18.2	3.5	0.6	0.1	0.0	19128
4.5	0.0	0.0	0.0	0.0	6.0	196.1	1354.3	3288.5	3857.5	2685.5	1275.2	455.1	130.9	31.9	6.9	1.3	0.2	0.0	13289
5.5	0.0	0.0	0.0	0.0	1.0	51.0	498.4	1602.9	2372.7	2008.3	1126.0	463.6	150.9	41.0	9.7	2.1	0.4	0.1	8328
6.5	0.0	0.0	0.0	0.0	0.2	12.6	167.0	690.3	1257.9	1268.6	825.9	386.8	140.8	42.2	10.9	2.5	0.5	0.1	4806
7.5	0.0	0.0	0.0	0.0	0.0	3.0	52.1	270.1	594.4	703.2	524.9	276.7	111.7	36.7	10.2	2.5	0.6	0.1	2586
8.5	0.0	0.0	0.0	0.0	0.0	0.7	15.4	97.9	255.9	350.6	296.9	174.6	77.6	27.7	8.4	2.2	0.5	0.1	1309
9.5	0.0	0.0	0.0	0.0	0.0	0.2	4.3	33.2	101.9	159.9	152.2	99.2	48.3	18.7	6.1	1.7	0.4	0.1	626
10.5	0.0	0.0	0.0	0.0	0.0	0.0	1.2	10.7	37.9	67.5	71.7	51.5	27.3	11.4	4.0	1.2	0.3	0.1	285
11.5	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.3	13.3	26.6	31.4	24.7	14.2	6.4	2.4	0.7	0.2	0.1	124
12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.0	4.4	9.9	12.8	11.0	6.8	3.3	1.3	0.4	0.1	0.0	51
13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.4	3.5	5.0	4.6	3.1	1.6	0.7	0.2	0.1	0.0	21
14.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	1.2	1.8	1.8	1.3	0.7	0.3	0.1	0.0	0.0	8
15.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.6	0.7	0.5	0.3	0.1	0.1	0.0	0.0	3
16.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.1	0.1	0.0	0.0	0.0	1
SUM:	0	0	1	165	2091	9280	19922	24879	20870	12898	6245	2479	837	247	66	16	3	1	100000

The Hs and Tz values are class midpoints.

6. For evaluation of extreme global bending moments it is recommended to use zero speed, provided the vessel does not have a service restriction, in which case the limitation should be checked as well. The effect of forward speed (2/3 of design speed) is recommended to be checked, especially for local dynamic pressures.

7. The Bretschneider or two parameter Pierson-Moskowitz spectrum is recommended for the North Atlantic, described by the following expression:

$$S(\omega) = \frac{H_S^2}{4\pi}\left(\frac{2\pi}{T_Z}\right)^4 \omega^{-5} \exp\left(-\frac{1}{\pi}\left(\frac{2\pi}{T_Z}\right)^4 \omega^{-4}\right)$$

where:

H_S = The significant wave height (m)

ω = Angular wave frequency (rad/s)

T_Z = The average zero up - crossing wave period (s)

$$T_Z = 2\pi\left(\frac{m_0}{m_2}\right)^{\frac{1}{2}}$$

The spectral moments of order n of the response process for a given heading may be described as

$$m_n = \int_{\omega} \sum_{\theta_0-90^o}^{\theta_0+90^o} f_s(\theta)\omega^n \cdot S(\omega/H_S, T_Z, \theta) d\omega$$

using a spreading function usually defined as $f_S(\theta) = k\cos^2(\theta)$

where k is selected such that:

$$\sum_{\theta_0-90^\circ}^{\theta_0+90^\circ} f_S(\theta) = 1$$

where

θ_0 =main wave heading

θ =relative spreading around the main wave heading

8. In long term calculations, all wave headings (0-360°) can be assumed to have an equal probability of occurrence and at most 30° spacing between headings should be applied.

9. When calculating vertical bending moments (Sag and Hog) proper corrections for non-linear effects are to be applied.

10. The dynamic sea pressure can be derived above the mean waterline (WL) based on linear calculation methods by a reduction of 1-one meter pressure head per meter distance from the mean WL using a dynamic sea pressure at a return period of 20 years, corresponding to about 10^{-8} probability per cycle. In case dynamic sea pressures at 10^{-4} probability per cycle are applied, a reduction of 1/2-half meter pressure head per meter distance above the mean WL should apply to ensure dynamic sea pressures at sufficient height above the mean WL.

11. When calculating design sea pressures at ship ends, due consideration should be taken to the occurrence of non-linearity s such as slamming on the bottom and non-vertical ship sides.

References

/1/ British Marine Tec hnology (Primary contributors Hogben N., Da Cunha, L.F. and Oliver, H.N.). “Global Wave Statistics”, Unwin Brothers Limited, London 1986.

/2/ Bitner-Gregersen, E.M., Cramer, E.H., Korbijin, F., “Environmental Description for Long-term Load Response of Ship Structures”, ISOPE June 1995, The Hague, The Netherlands.