RULES FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

Part C Hull Construction and Equipment

RULES

2016 AMENDMENT NO.1

Rule No.40 30th June 2016

Resolved by Technical Committee on 5th February 2016

Approved by Board of Directors on 22nd February 2016

Rule No.40 30th June 2016
AMENDMENT TO THE RULES FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

"Rules for the survey and construction of steel ships" has been partly amended as follows:

Part C HULL CONSTRUCTION AND EQUIPMENT

Amendment 1-1

Chapter 23 BULWARKS, GUARDRAILS, FREEING ARRANGEMENTS, CARGO PORTS AND OTHER SIMILAR OPENINGS, SIDE SCUTTLES, RECTANGULAR WINDOWS, VENTILATORS AND GANGWAYS

23.6 Ventilators

23.6.2 Thickness of Ventilator Coamings

Sub-paragraph -1 has been amended as follows.

1 The thickness of ventilator coamings in Positions I and II specified in **20.1.2** leading to spaces below the freeboard deck or within enclosed superstructures is not to be less than that given by Line 1 in **Table C23.7**. Where the height of the coamings is reduced by the provisions in **23.6.1**, the thickness may be suitably reduced.

23.6.5 Closing Appliances

Sub-paragraph -2 has been amended as follows.

2 All ventilator openings in exposed positions on the freeboard and superstructure decks are to be provided with efficient weathertight closing appliances. Where ~~the height of~~ the coaming of any ventilator ~~exceeds~~ extends to more than 4.5 *m* above the surface of the deck ~~for the freeboard deck, raised quarter decks and superstructure decks for 0.25L_f forward~~ in Position I or more than 2.3 *m* ~~for the other superstructure decks~~ above the surface of the deck in Position II specified in **20.1.2**, such closing appliances may be omitted unless required in **-1**.

Paragraph 23.6.7 has been amended as follows.

23.6.7 Ventilators for Emergency Generator Room

The ~~height of~~ coamings of ventilators supplying the emergency generator room is to ~~be at least~~ extend to more than 4.5*m* above the surface of the deck in Position I ~~for the freeboard deck, raised quarter decks and superstructure decks in 0.25L_f forward~~, and more than 2.3*m* ~~for the other superstructure decks~~ above the surface of the deck in Position II specified in **20.1.2**. The ventilator openings are not to be fitted with weathertight closing appliances. However, where due to vessel size and arrangement this requirement is not practicable, the height of ventilator coamings is to be at the discretion of the Society.

EFFECTIVE DATE AND APPLICATION (Amendment 1-1)

1. The effective date of the amendments is 30 June 2016.

Amendment 1-2

Chapter 1 GENERAL

1.1 General

Table C1.1 has been amended as follows.

Table C1.1 Application of Mild Steels for Various Structural Members

<table>
<tr><th rowspan="2">Structural member</th><th rowspan="2" colspan="2">Application</th><th colspan="6">Thickness of plate : t (mm)</th></tr>
<tr><th>$t≤15$</th><th>$15<t≤20$</th><th>$20<t≤25$</th><th>$25<t≤30$</th><th>$30<t≤40$</th><th>$40<t≤50$</th></tr>
<tr><td colspan="9">(Omitted)</td></tr>
<tr><td colspan="9">Cargo Hatch</td></tr>
<tr><td rowspan="3">Cargo hatch coaming longitudinally extended on the strength deck</td><td rowspan="3">longitudinal members over 0.15L (including face plate and its flange, but excluding other stiffeners. See Fig. C1.1) and end brackets and deck house transition</td><td>within 0.4L amidship</td><td colspan="4">D</td><td colspan="2">E</td></tr>
<tr><td>within 0.6L amidship excluding the above</td><td colspan="5">D</td><td>E</td></tr>
<tr><td>other than those mentioned above</td><td colspan="6">D</td></tr>
<tr><td>Hatch cover</td><td colspan="2">—top plates, bottom plates and primary supporting members</td><td colspan="4">A</td><td>B</td><td>D</td></tr>
<tr><td colspan="9">Stern</td></tr>
<tr><td>Stern frame, rudder horn, rudder trunk, shaft bracket</td><td colspan="2">—</td><td colspan="2">A</td><td>B</td><td colspan="2">D</td><td>E</td></tr>
<tr><td colspan="9">Rudder</td></tr>
<tr><td>Rudder plate</td><td colspan="2">—</td><td colspan="2">A</td><td>B</td><td colspan="2">D</td><td>E</td></tr>
<tr><td colspan="9">Other</td></tr>
<tr><td colspan="3">Other members than those mentioned above (including stiffeners)</td><td colspan="6">A*1*4</td></tr>
</table>

(Remarks and Notes are omitted.)

Table C1.2 has been amended as follows.

Table C1.2 Application of High Tensile Steels for Various Structural Members

Structural member	Application		Thickness of plate : t (mm) $t≤15$	$15<t≤20$	$20<t≤25$	$25<t≤30$	$30<t≤40$	$40<t≤50$
(Omitted)								
Cargo Hatch								
Cargo hatch coaming longitudinally extended on the strength deck	longitudinal members over 0.15*L* (including face plate and its flange, but excluding other stiffeners) and end brackets and deck house transition	within 0.4*L* amidship	*DH*				*EH*	
		within 0.6*L* amidship excluding the above	*DH*					*EH*
		other than those mentioned above	*DH*					
Hatch cover	—top plates, bottom plates and primary supporting members		*AH*					*DH*
Stern								
Stern frame, rudderhorn, rudder trunk, shaft bracket	—		*AH*			*DH*		*EH*
Rudder								
Rudder plate	—		*AH*			*DH*		*EH*
Other								
Other members than those mentioned above (including stiffeners)			*AH*					

(Notes are omitted.)

Chapter 2 STEMS AND STERN FRAMES

2.2 Stern Frames

Paragraph 2.2.5 has been amended as follows.

2.2.5 Rudder Horns

1 The scantling of each cross-section of the rudder horn ~~(See **Fig. C2.3**)~~ is to be determined by the following formulae **(1)** to **(3)**, considering the bending moment, shear force, and torque acting on the rudder horn when the rudder force specified in **3.2** is applied to the rudder.

(1) The section modulus Z_x with respect to the horizontal X-axis is not to be less than:

$$~~Z_x =~~ \frac{MK_{rh}}{67} \quad (cm^3)$$

Where:

M: Bending moment at the section considered, as deemed <u>appropriate by the Society</u> ~~obtained from the following formula (See **Fig. C2.3**)~~.

~~$M = Bz \quad (M_{max} = Bd) \quad (N\text{-}m)$~~

~~B: Supporting force in the pintle bearing (N) as given in **3.4.1**~~

~~z: Distance (m) from the mid-point of the length of the pintle bearing to the section under consideration, as specified in **Fig. C2.3**~~

K_{rh}: Material factor of the rudder horn obtained from the requirements in **3.1.2**

(2) The total sectional area A_h of the members in the Y-direction is not to be less than:

$$~~A_h =~~ \frac{BK_{rh}}{48} \quad (mm^2)$$

Where:

<u>B: Supporting force in the pintle bearing (N) as given in **3.4.1**</u>

K_{rh}: As specified in **(1)**

(3) At no section within the height <u>of the rudder horn</u>~~d~~, the equivalent stress is to exceed $120/K_{rh}$ (N/mm^2).

The equivalent stress σ_e is to be obtained from the following formula:

$$\sigma_e = \sqrt{\sigma_b^2 + 3(\tau^2 + \tau_t^2)} \quad (N/mm^2)$$

The bending stress, shear stress and torsional stress acting on the rudder horn are to be ~~obtained from the following formulae respectively:~~ <u>at the discretion of the Society.</u>

~~Bending stress: $\sigma_b = \frac{M}{Z_x} \quad (N/mm^2)$~~

~~Shear stress: $\tau = \frac{B}{A_h} \quad (N/mm^2)$~~

~~Torsional stress: $\tau_t = \frac{1000T_h}{2A_t t_h} \quad (N/mm^2)$~~

~~Where:~~

~~T_h: The torsional moment at the section considered which is obtained from the following formula (See **Fig. C2.3**).~~

~~$T_h = Bc(z) \quad (N/mm^2)$~~

~~A_t: Area in the horizontal section enclosed by the rudder horn (mm^2)~~

~~t_h: Plate thickness of the rudder horn (mm)~~

~~M, Z_x, B and K_{rh}: As specified in **(1)**~~
~~B, A_h: As specified in **(2)**~~

2 At the connection between the rudder horn and the hull structure, particular attention is to be paid to structural continuity.

3 When the connection between the rudder horn and the hull structure is designed as a curved transition into the hull plating, particular attention is to be paid to the effectiveness of the rudder horn plate in bending and to the stresses in the transverse web plates.

4 The thickness of the rudder horn side plating is not to be less than:

$$2.4\sqrt{LK} \quad (mm)$$

K_{rh}: As specified in **-1(1)**

5 Connection to hull structure

The rudder horn plating is to be effectively connected to the aft ship structure, e.g. by connecting the plating to side shell and transverse/longitudinal girders, in order to achieve a proper transmission of forces (*See* **Fig.C2.3**).

Brackets or stringer are to be fitted internally in horn, in line with outside shell plate (*See* **Fig.C2.3**) except in cases where not practicable.

Transverse webs of the rudder horn are to be led into the hull up to the next deck in a sufficient number.

Strengthened plate floors are to be fitted in line with the transverse webs in order to achieve a sufficient connection with the hull.

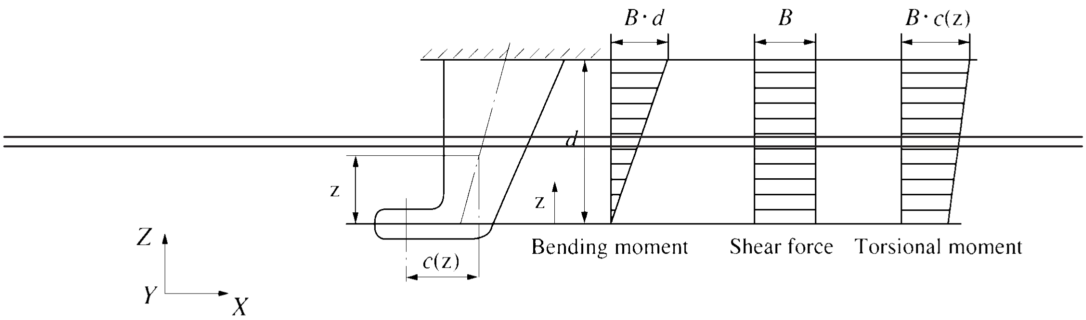
The centre line bulkhead (wash-bulkhead) in the after peak is to be connected to the rudder horn.

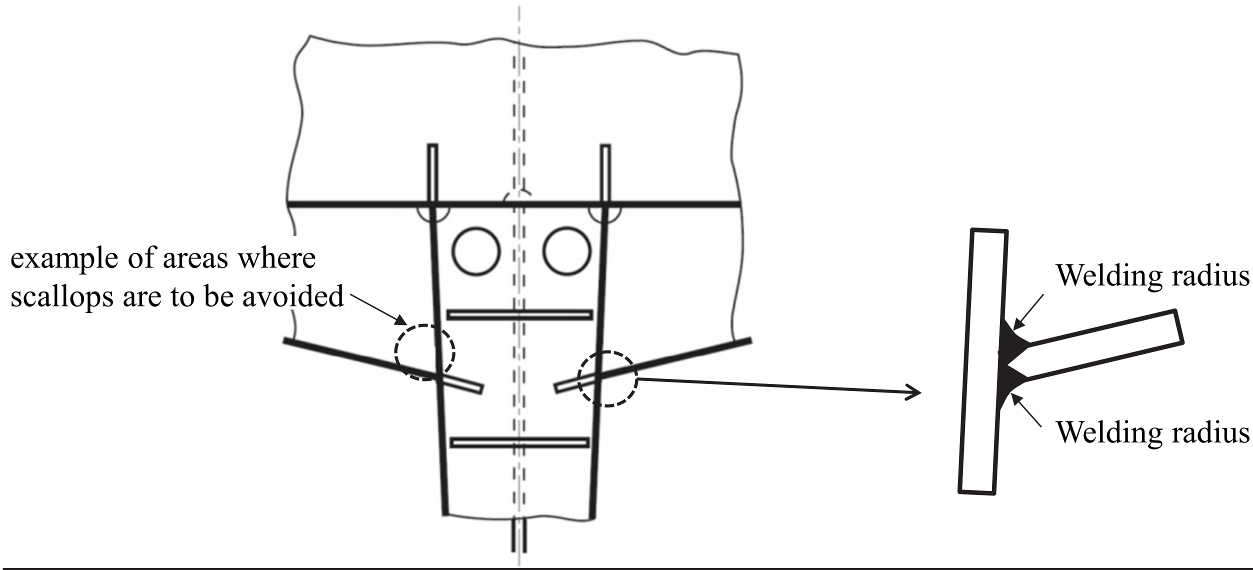
Scallops are to be avoided in way of the connection between transverse webs and shell plating (*See* **Fig.C2.3**).

The weld at the connection between the rudder horn plating and the side shell is to be full penetration. The welding radius is to be as large as practicable and may be obtained by grinding (*See* **Fig.C2.3**).

Fig. C2.3 has been amended as follows.

Fig. C2.3 ~~Rudder Horn~~ Connection of rudder horn to aft ship structure





2.2.6 Attachment of Stern Frame to Floor Plates

The stern frame is to be extended upward at the part of the propeller post and connected securely to the transom floor of thickness not less than the value obtained from the following formula.

$0.035L+8.5$ (mm)

2.2.7 Gudgeons

1 The depth of gudgeons is not to be less than the length of pintle bearing.

2 The thickness of the gudgeon is not to be less than $0.25d_{p0}$. For ships specified in ~~**3.1.3**~~**3.1.5**, the thickness of the gudgeon is to be appropriately increased.

Where:

d_{p0}: Actual diameter of the pintle measured at the outer surface of the sleeve (mm)

Paragraph 2.2.8 has been added as follows.

2.2.8 Rudder trunk

1 Materials, welding and connection to hull

This requirement applies to both trunk configurations (extending or not below stern frame).

The steel used for the rudder trunk is to be of weldable quality, with a carbon content not exceeding 0.23% on ladle analysis and a carbon equivalent C_{EQ} not exceeding 0.41%.

The weld at the connection between the rudder trunk and the shell or the bottom of the skeg is to be full penetration.

The fillet shoulder radius r (mm) (*See* **Fig.C2.4**) is to be as large as practicable and to comply with the following formulae:

$r = 60$ when $\sigma \geq 40 / K_s$ (N/mm^2)

$r = 0.1d_l$, without being less than 30, when $\sigma < 40 / K_s$ (N/mm^2)

Where

d_l: rudder stock diameter axis defined in **3.5.2**.

σ : bending stress in the rudder trunk (N/mm^2).

K_s: material factor as given in **3.1.2**.

The radius may be obtained by grinding. If disk grinding is carried out, score marks are to be avoided in the direction of the weld. The radius is to be checked with a template for accuracy. Four profiles at least are to be checked. A report is to be submitted to the Surveyor.

Rudder trunks comprising of materials other than steel are to be specially considered by the Society.

2 Scantlings

Where the rudder stock is arranged in a trunk in such a way that the trunk is stressed by forces due to rudder action, the scantlings of the trunk are to be such that:

- the equivalent stress due to bending and shear does not exceed $0.35\sigma_Y$,
- the bending stress on welded rudder trunk is to be in compliance with the following formula:

  $\sigma \leq 80 / K_s$ (N/mm^2)

  with:

  σ : As defined in **-1**.

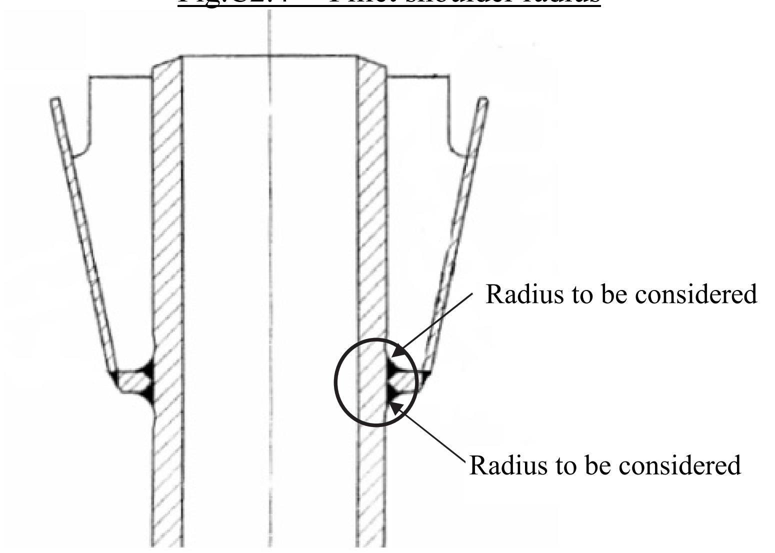
  K_s: Material factor for the rudder trunk as given in **3.1.2**, not to be taken less than 0.7

  σ_Y : Yield stress (N/mm^2) of the material used

For calculation of bending stress, the span to be considered is the distance between the mid-height of the lower rudder stock bearing and the point where the trunk is clamped into the shell or the bottom of the skeg.

Fig. C2.4 has been added as follows.

Fig.C2.4 Fillet shoulder radius



Chapter 3 has been amended as follows.

Chapter 3 RUDDERS

3.1 General

3.1.1 Application

1 The requirements in this Chapter apply to double plate rudders of stream line section and ordinary shape, being divided into the following types.

(1) Type *A*: Rudders with upper and bottom pintles (*See* **Fig. C3.1** (*A*))

(2) Type *B*: Rudders with neck bearing and bottom pintle (*See* **Fig. C3.1** (*B*))

(3) Type *C*: Rudders having no bearing below the neck bearing (*See* **Fig. C3.1** (*C*))

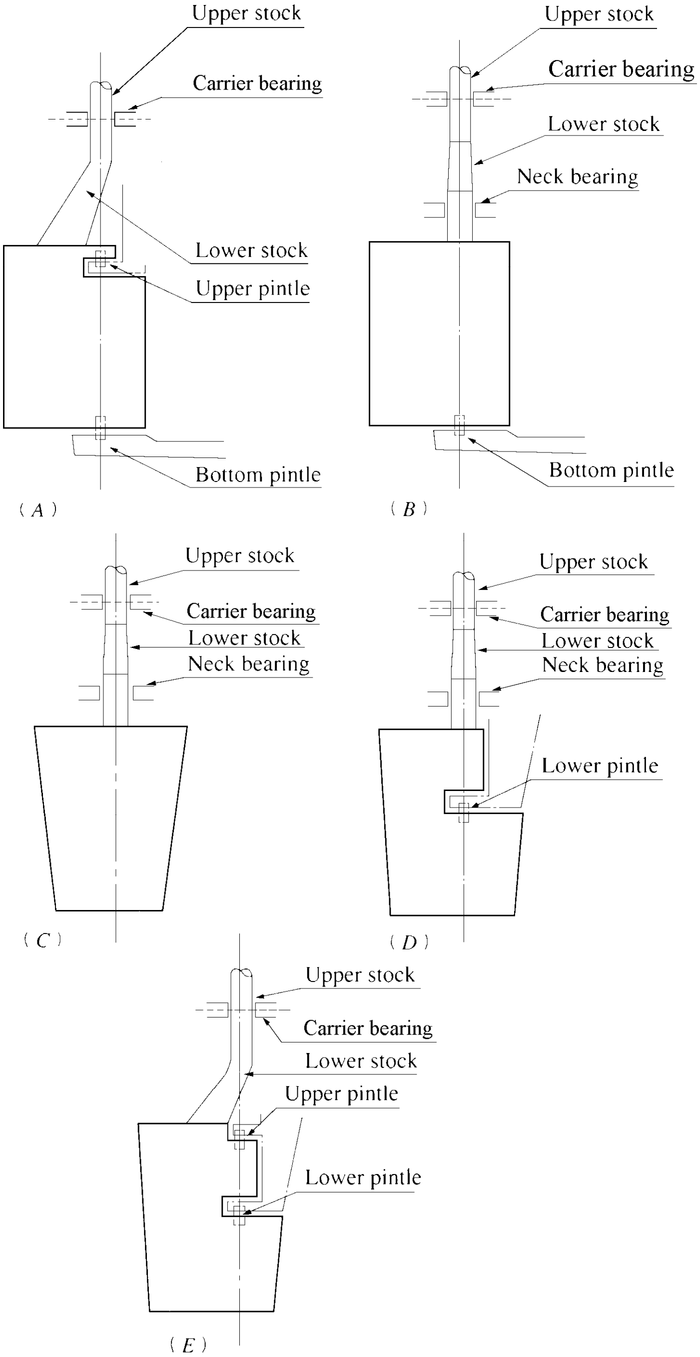
(4) Type *D*: Mariner type rudders with neck bearing and pintle, of which lower end is fixed (*See* **Fig. C3.1** (*D*))

(5) Type *E*: Mariner type rudders with two pintles, of which lower ends are fixed (*See* **Fig. C3.1** (*E*))

2 The construction of rudders having three or more pintles and of those having special shape or sectional form will be specially considered by the Society.

3 The construction of rudders designed to move more than 35 *degrees* on each side will be specially considered by the Society.

Fig C3.1


Upper stock
Carrier bearing
Lower stock
Upper pintle
Bottom pintle
(A)
Upper stock
Carrier bearing
Lower stock
Neck bearing
Bottom pintle
(B)
Upper stock
Carrier bearing
Lower stock
Neck bearing
(C)
Upper stock
Carrier bearing
Lower stock
Neck bearing
Lower pintle
(D)
Upper stock
Carrier bearing
Lower stock
Upper pintle
Lower pintle
(E)

3.1.2 Materials

1 Welded members of rudders such as rudder plates, rudder frames and rudder main pieces are to be made of rolled steel conforming to the requirements in **Part K**.

2 The required scantlings may be reduced when high tensile steels are used. When reducing the scantling, the material factor K is to be the values specified in **1.1.7-2(1)**.

~~1~~3 Rudder stocks, pintles, coupling bolts, keys, edge bars and cast parts of rudders are to be made of rolled steel, steel forging or carbon steel casting conforming to the requirements in **Part K** ~~**of the Rules**~~.

4 For rudder stocks, pintles, coupling bolts, keys, and edge bars, the minimum yield stress is not to be less than 200N/mm^2. The requirements in this Chapter are for materials with a yield stress of 235N/mm^2. If materials having a yield stress differing from 235N/mm^2 are used, the material factor K is to be determined by the following formula.

$$K = \left(\frac{235}{\sigma_Y} \right)^e$$

Where:

$e = 0.75$ for $\sigma_Y > 235$ N/mm^2

$e = 1.00$ for $\sigma_Y \leq 235$ N/mm^2

Where:

σ_Y : Yield stress (N/mm^2) of material used, and is not to be taken as greater than $0.7\sigma_B$ or 450N/mm^2, whichever is smaller.

σ_B : Tensile strength (N/mm^2) of material used

~~2~~5 When the rudder stock diameter is reduced because of using steels with a yield stress exceeding 235N/mm, special consideration is to be given to deformation of the rudder stock to avoid excessive edge pressures at the edge of bearings.

~~3 Welded members of rudders such as rudder plates, rudder frames and rudder main pieces are to be made of rolled steel conforming to the requirements in **Part K of the Rules**. The required scantlings may be reduced when high tensile steels are used. When reducing the scantling, the material factor K is to be the values specified in **1.1.7-2(1)**.~~

3.1.3 Welding and design details

1 Slot welding is to be limited as far as possible. Slot welding is not to be used in areas with large in-plane stresses transversely to the slots or in way of cut-out areas of Type *A*, *D* and *E* rudders.

When slot welding is applied, the length of slots is to be minimum 75 *mm* with breadth of 2t, where t is the rudder plate thickness (*mm*). The distance between ends of slots is not to be more than 125 *mm* (*See* **Fig. C3.2**). The slots are to be fillet welded around the edges and filled with a suitable compound, e.g. epoxy putty. Slots are not to be filled with weld.

Continuous slot welds may be used in lieu of slot welds. When continuous slot welding is applied, the root gap is to be between 6-10 *mm*. The bevel angle is to be at least 15° (*See* **Fig. C3.2**).

2 In way of the rudder horn recess of Type *A*, *D* and *E* rudders the radii in the rudder plating are not to be less than 5 *times* the plate thickness, but in no case less than 100 *mm*. Welding in side plate are to be avoided in or at the end of the radii. Edges of side plate and weld adjacent to radii are to be ground smooth.

3 Welds between plates and heavy pieces (solid parts in forged or cast steel or very thick plating) are to be made as full penetration welds. In way of highly stressed areas e.g. cut-out of Type *A*, *D*

and *E* rudders and upper part of Type *C* rudders, cast or welding on ribs is to be arranged. Two sided full penetration welding is normally to be arranged. Where back welding is impossible, one side welding using steel backing bars is, in principle, to be performed. In such cases, one-sided continuous welding is to be used to weld the steel backing bars to heavy pieces. Other welding procedures, however, may be approved when deemed appropriate by the Society.

4 Requirements for welding and design details of rudder trunks are described in **2.2.8**.

5 Requirements for welding and design details when the rudder stock is connected to the rudder by horizontal flange coupling are described in **3.8.1-5**.

6 Requirements for welding and design details of rudder horns are described in **2.2.5-5**.

3.1.4 Equivalence

1 The Society may accept alternatives to requirements given in this Chapter, provided they are deemed to be equivalent.

2 Direct analyses adopted to justify an alternative design are to take into consideration all relevant modes of failure, on a case by case basis. These failure modes may include, amongst others: yielding, fatigue, buckling and fracture. Possible damages caused by cavitation are also to be considered.

3 If deemed necessary by the Society, lab tests, or full scale tests may be requested to validate the alternative design approach.

3.1.~~3~~5 Increase in Diameter of Rudder Stocks for Special Cases

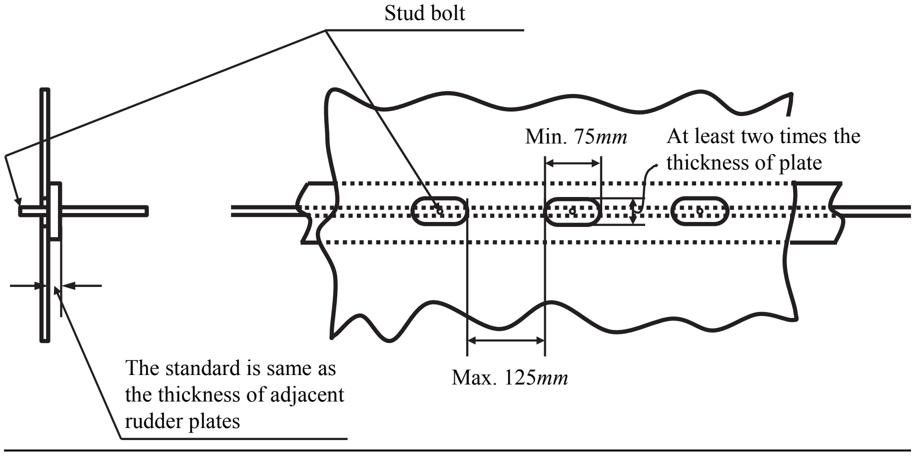
1 In ships which may be frequently steered at a large helm angle when sailing at their maximum speed, such as fishing vessels, the diameters of rudder stocks and pintles, as well as the section modulus of main pieces, are not to be less than 1.1 times those required in this Chapter.

2 In ships which might require quick steering, the diameter of rudder stocks is to be properly increased beyond the requirements in this Chapter.

3.1.~~4~~6 Sleeves and Bushes

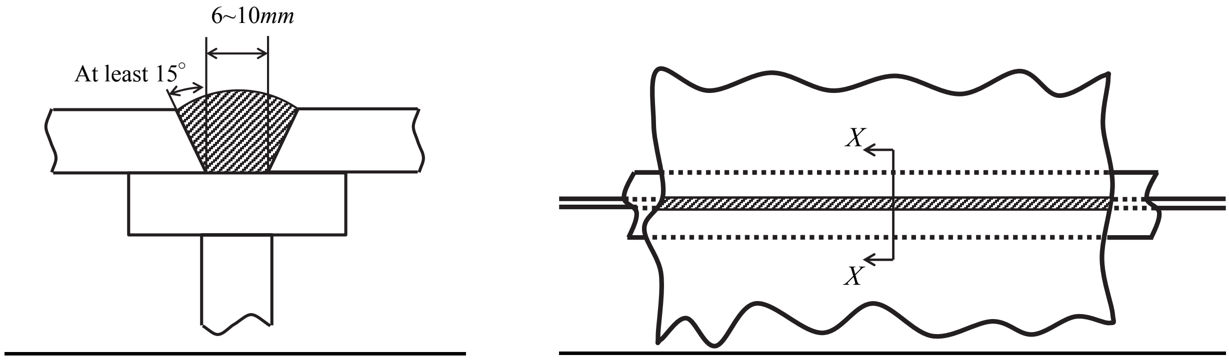
Bearings located up to well above the designed maximum load line are to be provided with sleeves and bushes.

Fig. C3.2 Slot welding and Continuous slot welding



Note: The standard leg length of slot welding is F_1.

(a) Slot welding



[Section *X-X*]

(b) Continuous slot welding

3.2 Rudder Force

The rudder force F_R is used to determine the rudder scantlings and is obtained from the following formula, for ahead and astern conditions. However, when the rudder is arranged behind the propeller that produces an especially great thrust, the rudder force is to be appropriately increased.

$$F_R = 132 K_1 K_2 K_3 A V^2 \quad (N)$$

Where:

A: Area of rudder plate (m^2)

V: Speed of ship (Kt)

When the speed is less than 10 *knots*, V is to be replaced by V_{min} obtained from the following formula:

$$V_{\min} = \frac{V+20}{3} \quad (kt)$$

For the astern condition, the astern speed V_a is to be obtained from the following formula. However, when the maximum astern speed is designed to exceed V_a, the design maximum astern speed is to be used.

$$V_a = 0.5V \quad (kt)$$

Where:

K_1: Factor depending on the aspect ratio Λ of the rudder area obtained by the following formula.

$$K_1 = \frac{\Lambda + 2}{3}$$

~~Where:~~

Λ : As obtained from the following formula, however, Λ is not required to be greater than 2

$$\Lambda = \frac{h^2}{A_t}$$

~~Where:~~

h: Mean height of rudder (m), which is determined according to the coordinate system in **Fig. C3.~~2~~3**

A_t: Sum of rudder plate area A (m^2) and area of rudder post or rudder horn, if any, within the mean height of rudder h

K_2: Factor depending on the rudder profile (*See* **Table C3.1**)

K_3: Factor depending on the location of rudder, as specified below:
For rudders outside the propeller jet: 0.8
For rudders behind a fixed propeller nozzle: 1.15
Otherwise: 1.0

Fig. C3.~~2~~3 Coordinate System of Rudders

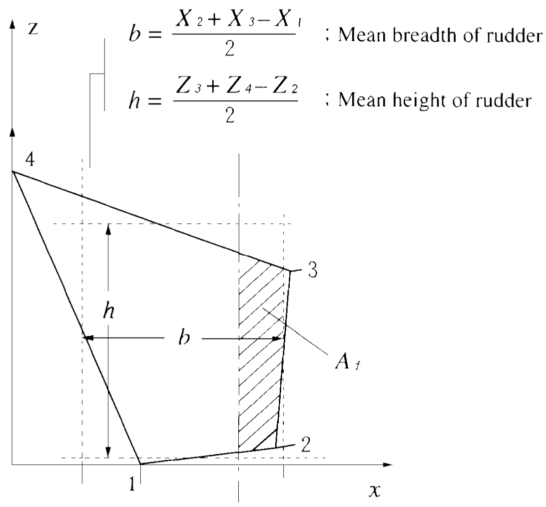
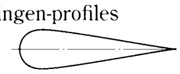
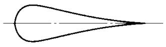
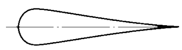
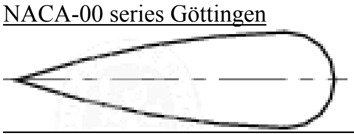
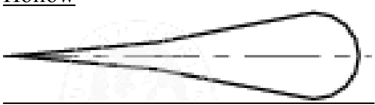
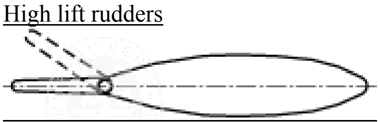
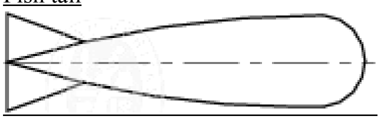


Table C3.1 Factor K_2

Profile type	K_2	
	Ahead condition	Astern condition
$NACA$-00 Göttingen-profiles 	1.1	0.80
Hollow Profiles 	1.35	0.90
Flat side profiles 	1.1	0.90

Profile Type	K_2	
	Ahead condition	Astern condition
NACA-00 series Göttingen 	1.10	0.80
Flat side 	1.10	0.90
Hollow 	1.35	0.90
High lift rudders 	1.70	to be specially considered; if not known: 1.30
Fish tail 	1.40	0.80
Mixed profiles (e.g. HSVA)	1.21	0.90

3.3 Rudder Torque

3.3.1 Rudder Torque of Type B and C Rudders

The rudder torque T_R of Type B and C rudders is to be obtained for ahead and astern conditions, respectively, according to the following formula.

$$T_R = F_R r \quad (N\text{-}m)$$

Where:

F_R: As specified in **3.2**

r: Distance from the centre of the rudder force on the rudder to the centreline of the rudder stock, determined by the following formula

$$r = b(\alpha - e) \quad (m)$$

For the ahead condition, r is not to be less than r_{min} obtained from the following formula.

$$r_{min} = 0.1b \quad (m)$$

Where:

b: Mean breadth (m) of rudder determined by the coordinate system in **Fig. C3.~~2~~3**

α: To be as follows:
For ahead condition: 0.33
For astern condition: 0.66

e: Balance factor of the rudder obtained from the following formula.

$$e : \frac{A_f}{A}$$

Where:

A_f: Portion (m^2) of the rudder plate area situated ahead of the centreline of the rudder stock

A: As specified in **3.2**

3.3.2 Rudder Torque of Type A, D and E Rudders

The rudder torque T_R of Type A, D and E rudders is to be obtained for the ahead and astern conditions, respectively, according to the following formula:

$$T_R = T_{R1} + T_{R2} \quad (N\text{-}m)$$

For the ahead condition, T_R is not to be less than T_{Rmin} obtained from the following formula:

$$T_{R\min} = 0.1 F_R \frac{A_1 b_1 + A_2 b_2}{A} \quad (N\text{-}m)$$

Where:

T_{R1} and T_{R2}: Rudder torque (N-m) of portion of A_1 and A_2, respectively

A_1 and A_2: Areas of respective rectangles (m^2) determined by dividing the rudder area into two parts so that $A = A_1 + A_2$ (A_1 and A_2 include A_{1f} and A_{2f} respectively), as specified in **Fig. C3.~~3~~4**. A_{1f} and A_{2f} are areas situated ahead of the centreline of the rudder stock.

b_1 and b_2: Mean breadth (m) of portions A_1 and A_2 determined by applying **Fig. C3.~~2~~3**.

F_R and A: As specified in **3.2**.

T_{R1} and T_{R2}, the rudder torque of portions A_1 and A_2, are to be obtained from the following formulae.

$$T_{R1} = F_{R1} r_1 \quad (N\text{-}m)$$

$$T_{R2} = F_{R2} r_2 \quad (N\text{-}m)$$

F_{R1} and F_{R2}, the rudder force of portions A_1 and A_2, are to be obtained from the following formulae.

$$F_{R1} = F_R \frac{A_1}{A} \quad (N)$$

$$F_{R2} = F_R \frac{A_2}{A} \quad (N)$$

r_1 and r_2, the distances from each centre of rudder force of portions A_1 and A_2 to the centreline of the rudder stock, are to be determined from the following formulae.

$$r_1 = b_1(\alpha - e_1) \quad (m)$$

$$r_2 = b_2(\alpha - e_2) \quad (m)$$

e_1 and e_2, the balance factors of portions A_1 and A_2 respectively are to be obtained from the following formulae.

$$e_1 = \frac{A_{1f}}{A_1}, e_2 = \frac{A_{2f}}{A_2}$$

α is to be as follows:

For parts of a rudder not behind a fixed structure such as rudder horn:

For ahead condition: 0.33

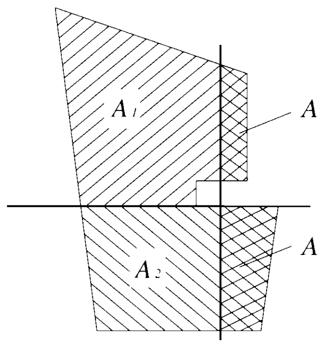
For astern condition: 0.66

For parts of a rudder behind a fixed structure such as the rudder horn:

For ahead condition: 0.25

For astern condition: 0.55

Fig. C3.~~3~~4 Division of Rudder



3.4 Rudder Strength Calculation

3.4.1 Rudder Strength Calculation

1 The rudder strength is to be sufficient to withstand the rudder force and rudder torque as given in **3.2** and **3.3**. When the scantling of each part of a rudder is determined, the following moments and forces are to be considered.

For rudder body: bending moment and shear force

For rudder stock: bending moment and torque

For pintle bearing and rudder stock bearing: supporting force

2 The bending moments, shear forces, and supporting forces to be considered are to be determined by direct calculation or by a simplified approximation method as deemed appropriate by the Society.

3.5 Rudder Stocks

3.5.1 Upper Stocks

The diameter d_u of the upper stock, which is the stock above the bearing centre of the rudder carrier required for the transmission of the rudder torque, is to be determined such that torsional stress does not exceed $68/K_S$ (N/mm^2).

Considering this, the diameter of the upper stock may be determined by the following formula:

$$d_u = 4.2\sqrt[3]{T_R K_S} \quad (mm)$$

Where:

T_R: As specified in **3.3**

K_S: Material factor for rudder stock, as given in **3.1.2**

3.5.2 Lower Stocks

The diameter d_l of the lower stock, which is the stock below the bearing centre of the rudder carrier subject to the combined forces of torque and bending moment, is to be determined such that the equivalent stress in the rudder stock does not exceed $118/K_S$ (N/mm^2).

The equivalent stress σ_e is to be obtained from the following formula.

$$\sigma_e = \sqrt{\sigma_b^2 + 3\tau_t^2} \quad (N/mm^2)$$

The bending stress and torsional stress acting on the lower stock are to be determined as follows:

Bending stress: $\sigma_b = \dfrac{10.2M}{d_l^3} \times 10^3 \quad (N/mm^2)$

Torsional stress: $\tau_t = \dfrac{5.1T_R}{d_l^3} \times 10^3 \quad (N/mm^2)$

Where:

M: Bending moment (N-m) at the section of rudder stock considered

T_R: As specified in **3.3**

When the horizontal section of the lower stock forms a circle, the lower stock diameter d_l may be determined by the following formula:

$$d_l = d_u \sqrt[6]{1 + \frac{4}{3}\left[\frac{M}{T_R}\right]^2} \quad (mm)$$

Where:

d_u: Diameter of upper stock (mm) as given in **3.5.1**

3.6 Rudder Plates, Rudder Frames and Rudder Main Pieces

3.6.1 Rudder Plate

The rudder plate thickness t is not to be less than that obtained from the following formula:

$$t = 5.5S\beta\sqrt{\left(d + \frac{F_R \times 10^{-4}}{A}\right)K_{p1}} + 2.5 \quad (mm)$$

Where:

A and F_R: As specified in **3.2**

K_{pl}: Material factor for the rudder plate as given in **3.1.2**

β : To be obtained from the following formula:

$$\beta = \sqrt{1.1 - 0.5\left(\frac{S}{a}\right)^2},$$

but need not exceed 1.0 ($\dfrac{a}{S} \geq 2.5$)

Where:

S: Spacing (m) of horizontal or vertical rudder frames, whichever is smaller

a: Spacing (m) of horizontal or vertical rudder frames, whichever is greater

<u>The rudder plating in way of the solid part is to be of increased thickness per **3.7.4**.</u>

3.6.2 Rudder Frames

1 The rudder body is to be stiffened by horizontal and vertical rudder frames enabling it to withstand bending like a girder.

2 The standard spacing of horizontal rudder frames is to be obtained from the following formula:

$$0.2\left(\frac{L}{100}\right)+0.4 \quad (m)$$

3 The standard distance from the vertical rudder frame forming the rudder main piece to the adjacent vertical frame is to be 1.5 *times* the spacing of horizontal rudder frames.

4 The thickness of rudder frames is not to be less than 8 *mm* or 70% of the thickness of the rudder plates as given in **3.6.1**, whichever is greater.

3.6.3 Rudder Main Pieces

1 Vertical rudder frames forming the rudder main piece are to be arranged forward and afterward of the centre line of the rudder stock at a distance approximately equal to the thickness of the rudder if the main piece consists of two rudder frames, or at the centreline of the rudder stock if the main piece consists of one rudder frame.

2 The section modulus of the main piece is to be calculated in conjunction with the vertical rudder frames specified in **-1** above and the rudder plates attached thereto. The breadth of the rudder plates normally taken into calculation are to be as follows:

(1) Where the main piece consists of two rudder frames, the breadth is 0.2 *times* the length of the main piece.

(2) Where the main piece consists of one rudder frame, the breadth is 0.16 *times* the length of the main piece.

3 The section modulus and the web area of horizontal sections of the main piece are to be such that bending stress, shear stress, and equivalent stress should not exceed the following values.

Bending stress: $\sigma_b = \frac{110}{K_m}$ (N/mm^2)

Shear stress: $\tau = \frac{50}{K_m}$ (N/mm^2)

Equivalent stress: $\sigma_e = \sqrt{\sigma_b{}^2 + 3\tau^2} = \frac{120}{K_m}$ (N/mm^2)

Where:

K_m: Material factor for the rudder main piece as given in **3.1.2**

In the cases of Type *A*, *D* and *E* rudders, however, the section modulus and the web area of a horizontal section of the main piece in way of cutouts are to be such that bending stress, shear stress, and equivalent stress should not exceed the following values regardless of high tensile or ordinary steels.

Bending stress: ~~$\sigma_b = \frac{75}{K_m}$~~ $\sigma_b = 75$ (N/mm^2)

Shear stress: ~~$\tau = \frac{50}{K_m}$~~ $\tau = 50$ (N/mm^2)

Equivalent stress: ~~$\sigma_e = \sqrt{\sigma_b{}^2 + 3\tau^2} = \frac{100}{K_m}$~~ $\sigma_e = \sqrt{\sigma_b{}^2 + 3\tau^2} = 100$ (N/mm^2)

~~Where:~~

~~K_m: Material factor for the rudder main piece as given in **3.1.2**~~

4 The upper part of the main piece is to be so constructed as to avoid structural discontinuity.
5 Maintenance openings ~~and cutouts of rudder plates in Type *A*, *D* and *E* rudders~~ are to be rounded off properly.

3.6.4 Connections

Rudder plates are to be effectively connected to rudder frames, free from defects, with due attention paid to the workmanship.

3.6.5 Painting and Draining

The internal surfaces of rudders are to be coated with effective paint, and a means for draining is to be provided at the bottoms of the rudders.

3.7 Connections of rudder blade structure with solid parts

3.7.1 Solid part protrusions

Solid parts in forged or cast steel, which house the rudder stock or the pintle, are normally to be provided with protrusions.
These protrusions are not required when the web plate thickness is less than:

- 10 *mm* for web plates welded to the solid part on which the lower pintle of Type *A*, *D* and *E* rudders is housed and for vertical web plates welded to the solid part of the rudder stock coupling of Type *C* rudders.
- 20 *mm* for other web plates.

3.7.2 General

The solid parts are in general to be connected to the rudder structure by means of two horizontal web plates and two vertical web plates.

3.7.3 Minimum section modulus of the connection with the rudder stock housing

The section modulus of the cross-section of the structure of the rudder blade (cm^3) formed by vertical web plates and rudder plating, which is connected with the solid part where the rudder stock is housed is to be not less than:

$$c_S\, d_l^3 \left(\frac{H_E - H_X}{H_E}\right)^2 \frac{K_{pl}}{K_s} 10^{-4} \ (cm^3)$$

Where:

c_S: Coefficient, to be taken equal to:

$c_S = 1.0$ if there is no opening in the rudder plating or if such openings are closed by a full penetration welded plate

$c_S = 1.5$ if there is an opening in the considered cross-section of the rudder

d_l: Rudder stock diameter (*mm*)

H_E : Vertical distance between the lower edge of the rudder blade and the upper edge of the solid part (*mm*)

H_X : Vertical distance between the considered cross-section and the upper edge of the solid part (*mm*)

K_{pl} : Material factor for the rudder blade plating as given in **3.1.2**.

K_s: Material factor for the rudder stock as given in **3.1.2**.

The actual section modulus of the cross-section of the structure of the rudder blade is to be calculated with respect to the symmetrical axis of the rudder. The breadth of the rudder plating (*m*) to be considered for the calculation of section modulus is to be not greater than:

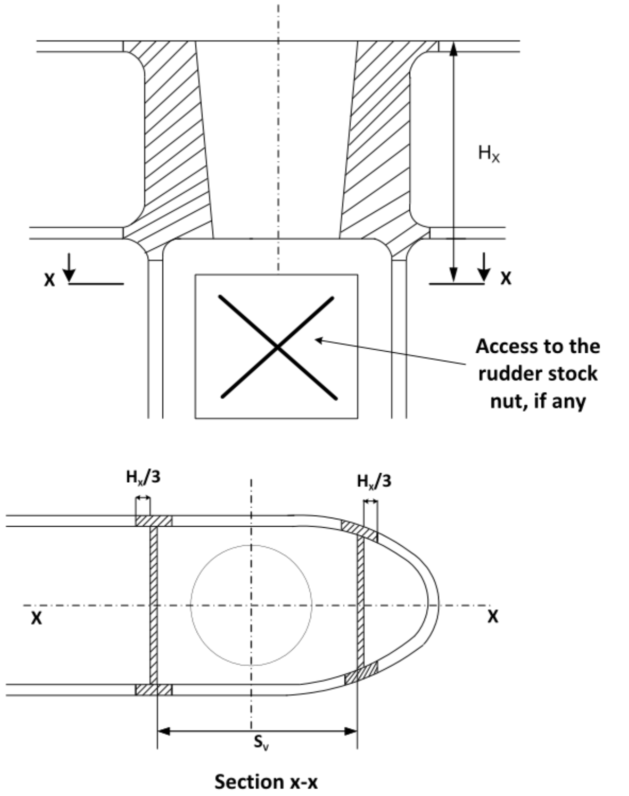
$$b = s_V + 2\frac{H_X}{3}$$

Where:

s_V = spacing between the two vertical webs (m) (*See* **Fig. C3.5**)

Where openings for access to the rudder stock nut are not closed by a full penetration welded plate, they are to be deducted (*See* **Fig. C3.5**).

Fig. C3.5 Cross-section of the connection between rudder blade structure and rudder stock housing



3.7.4 Thickness of the Horizontal Web Plates

The thickness of the horizontal web plates connected to the solid parts (mm), as well as that of the rudder blade plating between these webs, is to be not less than the greater of the following values:

$t_H = 1.2t$

$$t_H = 0.045\frac{d_S^2}{s_H}$$

Where:

t: As defined in **3.6.1**

d_S: Diameter (mm) to be taken equal to:

- d_l for the solid part housing the rudder stock
- d_p for the solid part housing the pintle

d_l: Rudder stock diameter (mm) defined in **3.5.2**

d_p: Pintle diameter (mm) defined in **3.9.1**

s_H: Spacing between the two horizontal web plates (mm).

The increased thickness of the horizontal webs is to extend fore and aft of the solid part at least to the next vertical web.

3.7.5 Thickness of the Vertical Web Plates

The thickness of the vertical web plates welded to the solid part where the rudder stock is housed as well as the thickness of the rudder side plating under this solid part is to be not less than the values obtained (*mm*) from **Table C3.2**.

The increased thickness is to extend below the solid piece at least to the next horizontal web.

Table C3.2 Thickness of side plating and vertical web plates

Type of rudder	Thickness of vertical web plates (*mm*)		Thickness of rudder plating (*mm*)	
	Rudder blade without opening	Rudder blade with opening	Rudder blade without opening	Area with opening
Type *A* and *B* rudders	1.2*t*	1.6*t*	1.2*t*	1.4*t*
Type *C*, *D* and *E* rudders	1.4*t*	2.0*t*	1.3*t*	1.6*t*
t = thickness of the rudder plating, in mm, as defined in **3.6.1**				

3.~~7~~8 Couplings between Rudder Stocks and Main Pieces

3.~~7~~8.1 Horizontal Flange Couplings

1 Coupling bolts are to be reamer bolts, and at least 6 reamer bolts are to be used in each coupling.

2 The diameter of coupling bolts d_b is not to be less than the dimension obtained from the following formula:

$$d_b = 0.62\sqrt{\frac{d^3 K_b}{n e_m K_s}} \quad (mm)$$

Where:

d: Stock diameter (*mm*), the greater of the diameters d_u or d_l according to **3.5.1** and **3.5.2**

n: Total number of bolts

e_m: Mean distance (*mm*) of the bolt axes from the centre of the bolt system

K_s: Material factor for the rudder stock as given in **3.1.2**

K_b: Material factor for the bolts as given in **3.1.2**

3 The thickness of the coupling flanges t_f is not to be less than that determined by the following formula, provided that the thickness is not less than $0.9d_b$ (*mm*).

$$t_f = d_b\sqrt{\frac{K_f}{K_b}} \quad (mm)$$

Where:

K_f: Material factor for flange as given in **3.1.2**

K_b: As specified in **-2**

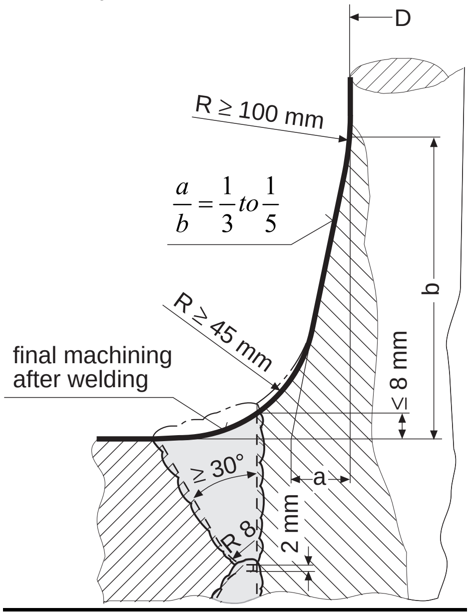
d_b: Bolt diameter (*mm*), determined by a number of bolts not exceeding 8

4 The width of the material ~~outside~~ between the perimeter of the bolt holes of the coupling flanges and the perimeter of the flange is not to be less than $0.67d_b$ (*mm*).

5 The welded joint between the rudder stock and the flange is to be made in accordance with **Fig.C3.6** or equivalent.

6 Coupling bolts are to be fitted bolts and their nuts are to be locked effectively.

Fig. C3.6 Welded joint between rudder stock and coupling flange



3.~~7.3~~8.2 Vertical Flange Couplings

1 Coupling bolts are to be reamer bolts, and at least 8 reamer bolts are to be used in each coupling.

2 The diameter of the coupling bolts d_b is not to be less than the dimension obtained from the following formula.

$$d_b = \frac{0.81d}{\sqrt{n}}\sqrt{\frac{K_b}{K_s}} \quad (mm)$$

Where:

d: Stock diameter (*mm*), the greater of the diameters d_u or d_l according to **3.5.1** and **3.5.2**

n: Number of bolts

K_b: Material factor for bolts as given in **3.1.2**

K_s: Material factor for the rudder stock as given in **3.1.2**

3 The first moment of area M of the bolts about the centreline of the coupling flange is not to be less than the value obtained from the following formula:

$M = 0.00043d^3$ (cm^3)

4 The thickness of the coupling flanges is to be at least equal to the bolt diameter.

5 The width of the flange material ~~outside~~ between the perimeter of the bolt holes and the perimeter of the flange is not to be less than $0.67d_b$ (*mm*).

6 Coupling bolts are to be fitted bolts and their nuts are to be locked effectively.

3.~~7.2~~8.3 Cone Couplings with Key

1 Tapering and coupling length

Cone couplings that are mounted or dismounted without hydraulic arrangements (e.g. oil injection and hydraulic nut) are to ~~be tapered~~ have a taper c on diameter of 1:8～1:12 ~~of the diameter~~. (*See* **Fig. C3.4~~~~7**)

Where:

$c = (d_0 - d_u)/\ell$

~~The taper length l of rudder stocks fitted into the rudder plate and secured by the slugging nut is generally not to be less than 1.5 *times* the rudder stock diameter d_0 at the top of the rudder. In this~~

case, for couplings between stock and rudder, a key is to be provided. The scantling of the key is to be to the discretion of the Society.

The cone coupling is to be secured by a slugging nut. The nut is to be secured, e.g. by a securing plate.

The cone shapes are to fit exactly. The coupling length ℓ is to be, in general, not less than $1.5d_0$.

2 For couplings between stock and rudder a key is to be provided, the shear area of which is not to be less than:

$$a_s = \frac{17.55 M_Y}{d_k \sigma_{Y1}} \quad (cm^2)$$

where:

M_Y : Design yield moment of rudder stock (N-m)

$$M_Y = 0.02664 \frac{d_u^3}{K_S}$$

Where the actual diameter d_{ua} is greater than the calculated diameter d_u, the diameter d_{ua} is to be used. However, d_{ua} applied to the above formula need not be taken greater than 1.145 d_u.

d_u: Stock diameter (mm) according to **3.5.1**

K_S : Material factor for stock as given in **3.1.2**

d_k: Mean diameter of the conical part of the rudder stock (mm) at the key

σ_{Y1} : Minimum yield stress of the key material (N/mm^2)

The effective surface area (cm^2) of the key (without rounded edges) between key and rudder stock or cone coupling is not to be less than:

$$a_k = \frac{5 M_Y}{d_k \sigma_{Y2}} \quad (cm^2)$$

Where:

σ_{Y2} : Minimum yield stress of the key, stock or coupling material (N/mm^2) whichever is less.

23 The dimensions of the slugging nut as specified in **-1** are to be as follows (*See* **Fig. C3.47**):

External thread diameter: $d_g \geq 0.65 d_0$ (mm)

Length of nut height: $h_n \geq 0.6 d_g$ (mm)

Outer diameter of nut: $d_n \geq 1.2 d_e$ or $1.5 d_g$ (mm), whichever is greater

4 It is to be proved that 50% of the design yield moment is solely transmitted by friction in the cone couplings. This can be done by calculating the required push-up pressure and push-up length according to **3.8.4-2** and **-3** for a torsional moment $M_Y' = 0.5 M_Y$.

35 Notwithstanding the provisions in **-1 -2 and -3** above, where a key is fitted to the couplings between stocks and rudders, and it is considered that the entire rudder torque is transmitted by friction the key at the couplings, the scantlings of the key as well as the push-up force and push-up length are to be at the discretion of the Society.

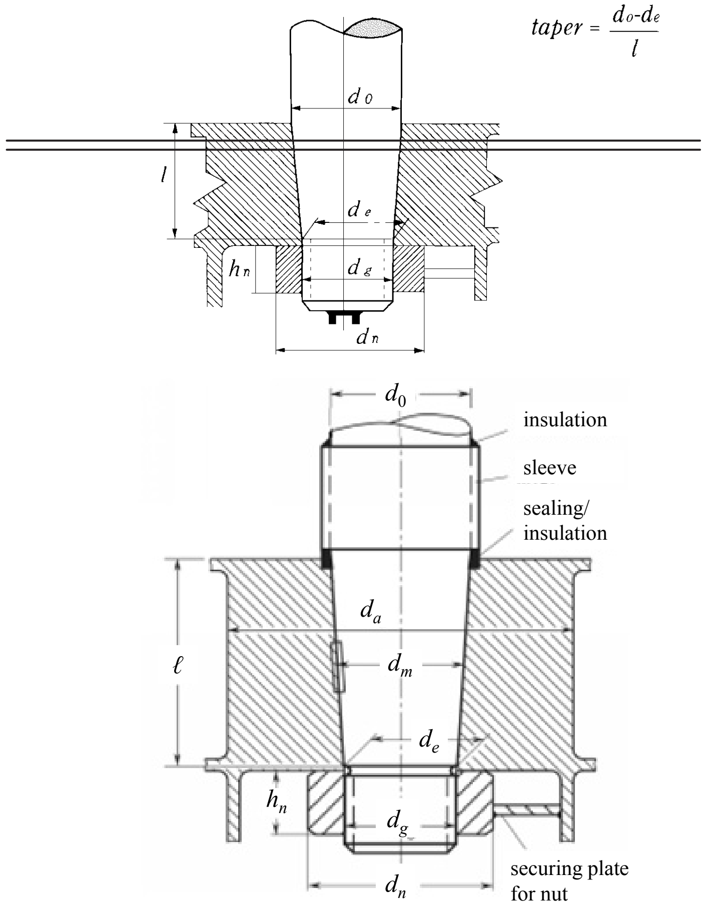
4 Cone couplings that are mounted or dismounted with hydraulic arrangements (e.g. oil injection and hydraulic nut) are to be tapered 1:12～1:20 of the diameter. (*See* **Fig. C3.4**)

The push-up force and the push-up length are to be to the discretion of the Society.

56 The nuts fixing the rudder stocks are to be provided with efficient locking devices.

67 Couplings of rudder stocks are to be properly protected from corrosion.

Fig. C3.47 Cone coupling with key



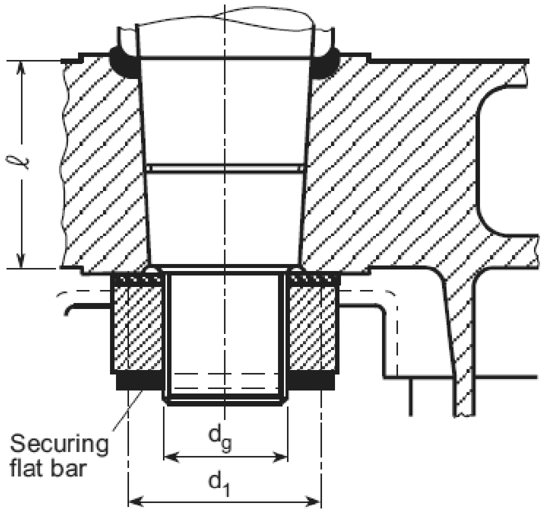
3.8.4 Cone couplings with special arrangements for mounting and dismounting the couplings

1 Where the stock diameter exceeds 200 *mm*, the press fit is recommended to be effected by a hydraulic pressure connection. In such cases the cone is to be more slender, c ≈1:12 to ≈1:20.

In case of hydraulic pressure connections the nut is to be effectively secured against the rudder stock or the pintle.

For the safe transmission of the torsional moment by the coupling between rudder stock and rudder body the push-up pressure and the push-up length are to be determined according to **-2** and **-3** respectively.

Fig. C3.8 Cone coupling without key



2 Push-up pressure

The push-up pressure is not to be less than the greater of the two following values:

$$p_{req1} = \frac{2M_Y}{d_m^2 \ell \pi \mu_0} 10^3 \quad (N/mm^2)$$

$$p_{req2} = \frac{6M_b}{\ell^2 d_m} 10^3 \quad (N/mm^2)$$

Where:

M_Y : Design yield moment of rudder stock, as defined in **3.8.3-2** (*N-m*)

d_m : Mean cone diameter (*mm*) (*See* **Fig. C3.7**)

ℓ : Cone length (*mm*)

μ_0 : Frictional coefficient, equal to 0.15

M_b : Bending moment in the cone coupling (e.g. in case of spade rudders) (*N-m*)

It has to be proved by the designer that the push-up pressure does not exceed the permissible surface pressure in the cone. The permissible surface pressure is to be determined by the following formula:

$$p_{perm} = \frac{0.8\sigma_Y\left(1-\alpha^2\right)}{\sqrt{3+\alpha^4}}$$

Where:

σ_Y : Minimum yield stress (*N/mm²*) of the material of the gudgeon

$$\alpha = \frac{d_m}{d_a}$$

d_m : Mean cone diameter (*mm*) (*See* **Fig. C3.7**)

d_a: Outer diameter of the gudgeon (*See* **Fig. C3.7**) (*mm*) to be not less than 1.5 d_m.

3 Push-up length

The push-up length $\Delta\ell$ (*mm*) is to comply with the following formula:

$$\Delta\ell_1 \le \Delta\ell \le \Delta\ell_2$$

Where:

$$\Delta\ell_1 = \frac{p_{req} d_m}{E\left(\frac{1-\alpha^2}{2}\right)c} + \frac{0.8R_{tm}}{c}$$

$$\Delta\ell_2 = \frac{1.6\sigma_Y d_m}{\sqrt{3+\alpha^4} E c} + \frac{0.8R_{tm}}{c}$$

R_{tm} : Mean roughness (*mm*) taken equal to about 0.01 *mm*

c : Taper on diameter according to **3.8.4-1**

Notwithstanding the above, the push up length is not to be less than 2 *mm*.

Note: In case of hydraulic pressure connections the required push-up force P_e for the cone (*N*) may be determined by the following formula:

$$P_e = p_{req} d_m \pi \ell \left(\frac{c}{2} + 0.02\right)$$

The value 0.02 is a reference for the friction coefficient using oil pressure. It varies and depends on the mechanical treatment and roughness of the details to be fixed.

Where due to the fitting procedure a partial push-up effect caused by the rudder weight is given, this may be taken into account when fixing the required push-up length, subject to approval by the Society.

3.~~8~~9 Pintles

3.~~8~~9.1 Diameter of Pintles

The diameter of pintles d_p is not to be less than the dimension obtained from the following formula.

$$d_p = 0.35\sqrt{BK_p} \quad (mm)$$

Where:

B: Reaction force in bearing (*N*)

K_p: Material factor for pintles as given in **3.1.2**

3.~~8~~9.2 Construction of Pintles

1 Tapering

Pintles are to be constructed as taper bolts with a taper on the diameter not exceeding the following values, and capable of being fitted to the cast parts of the rudders. The nuts fixing the pintles are to be provided with efficient locking devices.

(1) For pintles to be assembled and locked with slugging nuts: 1:8～1:12

(2) For pintles mounted with hydraulic arrangements (oil injection and hydraulic nut, etc.): 1:12～1:20

2 Push-up pressure for pintle bearings

The required push-up pressure for pintle bearings (N/mm^2) is to be determined by the following formula:

$$p_{req} = 0.4\frac{Bd_0}{d_m^2 \ell}$$

Where:

B : As defined in **3.9.1**

d_m, ℓ: As defined in **3.8.4-2**

d_0: Pintle diameter (*mm*) (*See* **Fig. C3.7**)

The push up length is to be calculated similarly as in **3.8.4-3**, using required push-up pressure and properties for the pintle bearing.

~~2~~3 The minimum dimensions of the threads and the nuts of pintles are to be determined by applying the requirements in ~~**3.7.2-2**~~**3.8.3-3** correspondingly.

~~3~~4 The taper length of the pintle is not to be less than the maximum actual diameter of the pintle.

~~4~~5 Pintles are to be properly protected from corrosion.

3.~~9~~10 Bearings of Rudder Stocks and Pintles

3.10.1 Sleeves and Bushes

1 Rudder stock bearing

Sleeves and bushes are to be fitted in way of bearings. The minimum thickness of sleeves and bushes is to be equal to:

- $t_{min} = 8\ mm$ for metallic materials and synthetic material
- $t_{min} = 22\ mm$ for lignum material

2 Pintle bearing

The thickness of any sleeve or bush is neither to be less than:

$$t = 0.01\sqrt{B} \quad (mm)$$

Where:

B: As specified in **3.9.1**

nor than the minimum thickness defined in **-1**.

3.~~9.1~~10.2 Minimum Bearing Surface

The bearing surface A_b (defined as the projected area: *length* × *outside diameter of sleeve*) is not to be less than the value obtained from the following formula.

$$A_b = \frac{B}{q_a} \quad (mm^2)$$

Where:

B: As specified in **3.~~8~~9.1**

q_a: Allowable surface pressure (N/mm^2)

The allowable surface pressure for the various bearing combinations is to be taken from **Table C3.~~2~~3**. When verified by tests, however, values different from those in this Table may be taken.

Table C3.23 Allowable surface pressure q_a

Bearing material	q_a (N/mm^2)
Lignum vitae	2.5
White metal (oil-lubricated)	4.5
Synthetic material with hardness between 60 and 70, Shore D (Note 1)[1]	5.5[2]
Steel (Note 2)[3], bronze and hotpressed bronze graphite materials	7.0

Notes:

1: Indentation hardness test at the temperature of 23°C and the humidity of 50%, is to be carried out according to a recognized standard. Synthetic bearings are to be of the type as deemed appropriate by the Society.

2: Surface pressures exceeding 5.5 N/mm^2 may be accepted in accordance with bearing manufacturer's specification and tests, but in no case more than 10 N/mm^2.

23: Stainless and wear-resistant steel in an approved combination with a stock liner.

3.9.210.3 ~~Length of Bearings~~ Bearing Dimensions

The length/diameter ratio of the bearing surface ~~is not to be less than 1.0. However, the ratio~~ is not to be greater than 1.2 ~~unless specially approved by the Society~~.

The bearing length L_p of the pintle is to be such that

$$d_{p0} \le L_p \le 1.2 d_{p0}$$

Where:

d_{p0}: As specified in **2.2.7**

3.9.310.4 Bearing Clearances

With metal bearings, clearances are not to be less than d_{bs} /1000+1.0 (mm) on the diameter. d_{bs} is the inner diameter of the bush.

If non-metallic bearing material is used, the bearing clearance is to be specially determined considering the material’s swelling and thermal expansion properties. This clearance is not to be taken as less than 1.5 mm on the bearing diameter unless a smaller clearance is supported by the manufacturer’s recommendation and there is documented evidence of satisfactory service history with a reduced clearance.

3.101 Rudder Accessories

3.101.1 Rudder Carriers

Suitable rudder carriers are to be provided according to the form and the weight of the rudder, and care is to be taken to provide efficient lubrication at the support.

3.101.2 Prevention of Jumping

A suitable arrangement is to be provided to prevent the rudder from jumping due to wave shocks.

Chapter 20 HATCHWAYS, MACHINERY SPACE OPENINGS AND OTHER DECK OPENINGS

20.1 General

Paragraph 20.1.3 has been deleted.

~~20.1.3 Renewal Thickness of Steel Hatchway Covers and Hatchway Coamings for Ships in Operation~~

~~Structural drawings for hatch covers and hatch coamings complying with the requirements of **20.2** are to indicate the renewal thickness ($t_{renewal}$) for each structural element given by the following formula in addition to the as built thickness ($t_{as\text{-}built}$). If the thickness for voluntary addition is included in the as built thicknesses, the value may be at the discretion of the Society.~~

~~$t_{renewal} = t_{as\text{-}built} - t_e + 0.5$ (*mm*)~~

~~t_e: Corrosion additions specified in **Table C20.1**~~

~~Where corrosion addition t_e is 1.0 (*mm*), renewal thickness may be given by the formula $t_{renewal} = t_{as\text{-}built} - t_e$ (*mm*)~~

20.2 Hatchways

Paragraph 20.2.1 has been amended as follows.

20.2.1 Application

(-1 and -2 are omitted.)

3 When the requirements for hatchways in **Part CSR-B&T** apply to the hatchways of ships which are not subject to the application of **Part CSR-B&T**, the corrosion additions for hatch coamings, hatch coaming stays and stiffeners may be taken as 1.5*mm*.

(-4 is omitted.)

Paragraph 20.2.3 has been amended as follows.

20.2.3 Net Scantling Approach

(-1 to -3 are omitted.)

4 The corrosion addition t_c is to be taken as specified in **Table C20.1** according to ship type, the type of structure and structural members of steel hatchway covers, steel pontoon covers and steel weathertight covers (hereinafter referred to as "steel hatch covers"). However, the corrosion additions for structural members that make up hatchway coamings are to be as deemed appropriate by the Society when their t_c values are not specified in **Table C20.1**.

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

Table C20.1 Corrosion Additions

Type of ship	Type of structural member		Corrosion addition t_c (*mm*)
Container carriers and car carriers	Steel hatch covers		1.0
	Hatchway coamings		1.5
Ships other than those specified above and subject to the application of this section	Single plating type hatch cover		2.0
	Double plating type hatch cover	Top, side and bottom plating	1.5
		Internal structures	1.0
	Hatchway coamings, hatch coaming stays and stiffeners		1.5

Paragraph 20.2.4 has been amended as follows.

20.2.4 Design Loads

The design loads for steel hatchway covers, steel pontoon covers, steel weathertight covers, portable beams and hatchway coamings applying the requirements in **20.2** are specified in following **(1)** to **(5)**:

((1) is omitted.)

(2) Design horizontal wave load P_H (kN/m^2) is not to be less than that obtained from the following formulae. However, P_H is not to be taken less than the minimum values given in **Table C20.3**. P_H need not be included in the direct strength calculation of the hatch cover, expect where structures supporting stoppers are assessed.

$$P_H = ac(bC_1 - y)$$

a: As given by the following:

$20 + \frac{L'}{12}$ for unprotected front coamings and hatch cover skirt plates

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

$5 + \frac{L'}{15}$ for side and protected front coamings and hatch cover skirt plates

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

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

L': Length of ship L_1 (*m*). However, where L_1 exceeds 300*m*, L' is to be taken as 300*m*.

L_1: Length of ship specified in **2.1.2, Part A ~~of the Rules~~** (*m*). However, L_1 need not to be greater than 97% of the total length on the summer load waterline.

C_1: As given by the following formulae:

$10.75 - \left(\frac{300 - L_1}{100}\right)^{1.5}$ for $L_1 \leq 300m$

10.75 for $300 < L_1 \leq 350m$

$$10.75 - \left(\frac{L_1 - 350}{150}\right)^{1.5} \quad \text{for } 350 < L_1$$

c_L: Coefficient to be taken as 1.0

b: As given by the following formulae:

$$1.0 + \left(\frac{0.45 - \frac{x}{L_1}}{C_{b1} + 0.2}\right)^2 \quad \text{for } \frac{x}{L_1} < 0.45$$

$$1.0 + 1.5\left(\frac{\frac{x}{L_1} - 0.45}{C_{b1} + 0.2}\right)^2 \quad \text{for } \frac{x}{L_1} \geq 0.45$$

x: Distance (m) from the hatchway coamings or hatch cover skirt plates to after perpendicular, or distance from the mid-point of the side hatchway coaming or hatch cover skirt plates to after perpendicular. However, where the length of the side hatchway coaming or hatch cover skirt plates exceeds $0.15L_1$, the side hatchway coaming or hatch cover skirt plates are to be equally subdivided into spans not exceeding $0.15L_1$ and the distance from the mid-point of the subdivisions to the after perpendicular is to be taken.

C_{b1}: Block coefficient. However, where C_b is 0.6 or under, C_{b1} is to be taken as 0.6 and where C_b is 0.8 and over, C_{b1} is to be taken as 0.8. When determining scantlings of the aft ends of coamings and aft hatch cover skirt plates forward of amidships, C_{b1} does not need to be taken as less than 0.8.

c: As given by the following formula. However, where $\frac{b'}{B'}$ is less than 0.25, $\frac{b'}{B'}$ is to be taken as 0.25.

$$0.3 + 0.7\frac{b'}{B'}$$

b': Breadth (m) of hatchway coamings at the position under consideration

B': Breadth (m) of ship on the exposed weather deck at the position under consideration

y: Vertical distance (m) from the designed maximum load line to the mid-point of the span of stiffeners when determining the scantlings of stiffeners and to the mid-point of the plating when determining the thickness of plating

Table C20.3 Minimum Value of P_H (kN/m^2)

	Unprotected front coamings and hatch cover skirt plates	others
$L \leq 250$	$25 + \frac{L_1}{10}$	$12.5 + \frac{L_1}{20}$
$L > 250$	50	25

(3) The load on hatch covers due to cargo loaded on said covers is to be obtained from the following **(a)** and **(b)**. Load cases with partial loading are also to be considered.

(a) Distributed load due to cargo load P_{cargo} (kN/m^2) resulting from heave and pitch (i.e., ship in upright condition) is to be determined according to the following formula:

$$P_{cargo} = P_C(1 + a_V)$$

P_C: Static uniform cargo load (kN/m^2)

a_V: Vertical ~~A~~acceleration addition given by the following formula:

$$a_V = \frac{0.11mV'}{\sqrt{L_1}}$$

m: As given by the following formulae:

$$m_0 - 5(m_0 - 1)\frac{x}{L_1} \quad \text{for } 0 \le \frac{x}{L_1} \le 0.2$$

$$1.0 \quad \text{for } 0.2 < \frac{x}{L_1} \le 0.7$$

$$1 + \frac{m_0 + 1}{0.3}\left(\frac{x}{L_1} - 0.7\right) \quad \text{for } 0.7 < \frac{x}{L_1} \le 1.0$$

m_0: As given by the following formula:

$$m_0 = 1.5 + \frac{0.11V'}{\sqrt{L_1}}$$

V': Speed of ship (*knots*) specified in **2.1.8, Part A~~ of the Rules~~**. However, where V' is less than $\sqrt{L_1}$, V' is to be taken as $\sqrt{L_1}$.

x and L_1: As specified in **(2)** above

(b) Point load F_{cargo} (kN) due to a single force resulting from heave and pitch (i.e., ship in upright condition) ~~(e.g. in the case of containers)~~ is to be determined by the following formula. ~~When the load case of a partially loaded container is considered, the point load is at the discretion of the Society.~~ However, container loads are to comply with the provisions of **(4)** below.

$$F_{cargo} = F_S(1 + a_V)$$

F_S: Static point load due to cargo (kN)

a_V: As specified in **(a)** above

(4) Where containers are stowed on hatch covers, cargo loads determined by following **(a)** ~~and **(b)**~~ to **(c)** are to be considered:

(a) Cargo loads (kN) acting on each corner of a container stack due to heave, pitch and roll motion of the ship (i.e., ship in heel condition) are to be determined by the following formulae ~~are to be considered~~ (see **Fig. C20.1**). When the load case of a partially loaded container is considered, the cargo load is at the discretion of the Society.

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

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

$$B_Y = 2.4M$$

M: Maximum designed mass of container stack (t)

$$M = \sum W_i$$

h_m: Design height of the centre of gravity of the stack above hatch cover ~~supports~~ top plates (m) may be calculated as the weighted mean value of the stack, where the centre of gravity of each tier is assumed to be located at the centre of each container

$$h_m = \sum \frac{(z_i W_i)}{M}$$

z_i : Distance from hatch cover top plate to the centre of *i*th container (m)

W_i : weight of *i*th container in (t)

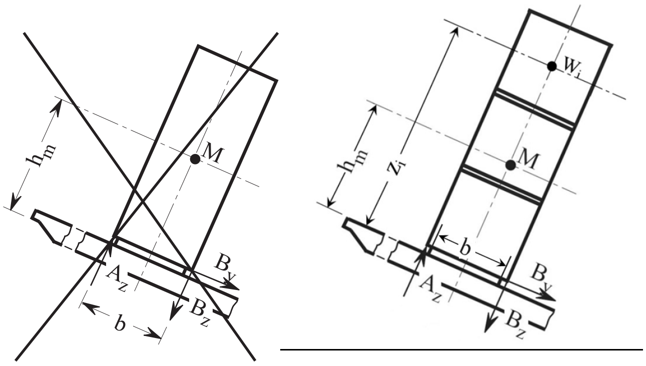
b: Distance between midpoints of foot points (m)

A_Z and B_Z : Support forces in vertical direction at the forward and aft stack corners (kN)

B_Y : Support force in transverse direction at the forward and aft stack corners (kN)

a_V : As specified in **(3)** above

Fig C20.1 Forces due to Container Loads



(b) Details of the application of **(a)** above are to be in accordance with the following:

i) For the maximum design mass of container stack M and the design height of the centre of gravity of the stack above hatch cover supports h_m, it is recommended to apply the values which are used for the calculations of cargo securing (container lashing). If different assumptions are made for M and h_m, sufficient data which show that the hatch cover structure is not loaded by less than the recommended values is to be submitted.

ii) When the strength of a hatch cover structure is assessed FEM analysis using shell or plane strain elements, h_m may be taken as the design height of the centre of gravity of the stack above the hatch cover top plate by grillage analysis according to **20.2.5-5.**, h_m and z_i need to be taken measured from hatch cover supports, not hatch cover top plates. Force B_Y does not need to be considered in this case.

iii) The values of M A_Z and h_m B_Z applied for the assessment of hatch cover strength are to be shown in the drawings of the hatch covers.

iii) It is recommended that container loads, as calculated in **(a)** above, be considered as the limit for foot point loads of container stacks in cargo securing (container lashing) calculations.

iv) In the case of container stacks secured to lashing bridges or carried in cell guides, the forces acting on the hatch covers may be specially considered by the Society.

v) Container loads may be applied based on accelerations calculated by an individual acceleration analysis for the lashing system being used as deemed appropriate by the Society.

(c) Stack load P_{stack} (kN), acting on each corner of a container stack, due to heave and pitch (i.e., ship in upright condition) is to be determined by the following formula.

$$P_{stack} = 9.81\frac{M}{4}(1 + a_V)$$

a_V : As specified in **(3)** above

M : As specified in **(a)** above

(5) In addition to the loads specified in **(1)** to **(4)** above, when the load in the ship's transverse direction by forces due to elastic deformation of the ship's hull is acting on the hatch covers, the sum of stresses is to comply with the permissible values specified in **20.2.5-1(1)**.

Paragraph 20.2.5 has been amended as follows.

20.2.5 Strength Criteria of Steel Hatch Covers and Hatch Beams

1 Permissible stresses and deflections

(1) The equivalent stress σ_E (N/mm^2) in steel hatchway covers and steel weathertight covers is to comply with the criteria in the following **(a)** and **(b)**:

(a) For ~~beam element calculations and~~ grillage analysis:

$$\sigma_E = \sqrt{\sigma^2 + 3\tau^2} \le 0.8\sigma_F$$

σ : Nominal stress (N/mm^2)

τ : Shear stress (N/mm^2)

σ_F : Minimum upper yield stress (N/mm^2) or proof stress (N/mm^2) of the material. However, when material with a σ_F of more than 355 N/mm^2 is used, the value for σ_F is to be as deemed appropriate by the Society.

(b) For FEM calculations, in cases where the calculations use shell or plane strain elements, the stresses are to be taken from centre of the individual element.

$\sigma_E = \sqrt{\sigma_x^2 - \sigma_x\sigma_y + \sigma_y^2 + 3\tau^2} \le 0.8\sigma_F$ when assessed using the design load specified in **20.2.4(1)**

$\sigma_E = \sqrt{\sigma_x^2 - \sigma_x\sigma_y + \sigma_y^2 + 3\tau^2} \le 0.9\sigma_F$ when assessed using any other design loads

σ_x : Normal stress (N/mm^2) in the x-direction

σ_y : Normal stress (N/mm^2) in the y-direction

τ : Shear stress (N/mm^2) in the x-y plane

x, y: Coordinates of a two dimensional Cartesian system in the plane of the considered structural element

σ_F : As specified in **(a)** above

(2) The equivalent stress σ_E (N/mm^2) in steel pontoon covers and hatch beams is not to be greater than $0.68\sigma_F$, where σ_F is as specified in **(1)** above.

(3) For FEM calculations, equivalent stress σ_E (N/mm^2) in girders with unsymmetrical flanges of steel hatchway covers and steel weathertight covers is to be determined according to the following **(a)** or **(b)**:

(a) FEM calculations using the stress obtained for fine mesh elements; or

(b) FEM calculations using the stress at the edge of the element or the stress at the centre of the element, whichever is greater.

(~~3~~4) Deflection is to comply with following **(a)** and **(b)**:

(a) When the design vertical wave load specified in **20.2.4(1)** is acting on steel hatchway covers, steel pontoon covers, steel weathertight covers and portable beams, the vertical deflection of primary supporting members is not to be taken as more than that given by the following:

$0.0056l$ for steel hatchway covers and steel weathertight covers

$0.0044l$ for steel pontoon covers and hatch beams

l: Span of primary supporting members (*m*)

(b) Where steel hatch covers are arranged for carrying containers and mixed stowage is allowed, i.e., a 40-foot container is stowed on top of two 20-foot containers, particular attention is to be paid to the deflections of hatch covers. In addition the possible contact of deflected hatch covers with in hold cargo has to be observed.

2 Local net plate thickness of steel hatch covers

(1) The local net thickness t_{net} (*mm*) of steel hatch cover top plating is not to be less than that obtained from the following formula, and it is not to be less than 1% of the spacing of the stiffeners or 6 *mm*, whichever is greater:

$$t_{net} = 15.8 F_p S \sqrt{\frac{P_{HC}}{0.95\sigma_F}}$$

F_p: Coefficient given by the following formula:

$1.9\ \sigma/\sigma_a$ (for $\sigma/\sigma_a \geq 0.8$, for the attached plate flange of primary supporting members)

1.5 (for $\sigma/\sigma_a < 0.8$, for the attached plate flange of primary supporting members)

σ: Maximum Nnormal stress (N/mm^2) of the attached plate flange of primary supporting members (see **Fig. C20.2**). ~~The normal σ may be determined at a distance *S* from the webs of adjacent primary supporting members perpendicular to secondary stiffeners and at a distance *S*/2 from the web of an adjacent primary supporting member parallel to secondary stiffeners, whichever is greater (see **Fig. C20.2**). The distribution of normal stress σ between two parallel girders is to be in accordance with **20.2.5-6.(3)(c)**.~~

σ_a: Permissible stress (N/mm^2) is to be as given by following formula:

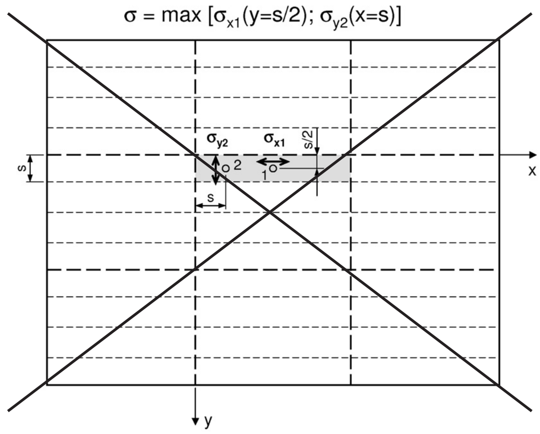
$$\sigma_a = 0.8\sigma_F$$

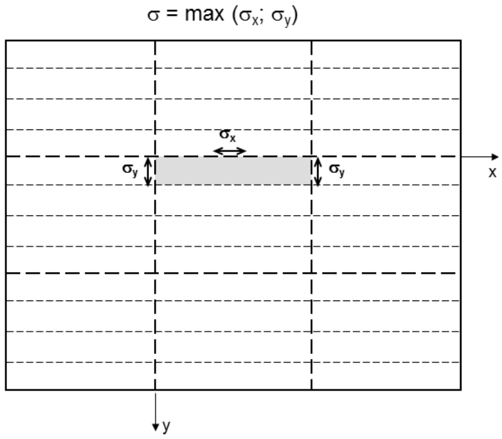
S: Stiffener spacing (*m*)

P_{HC}: Design load (kN/m^2) specified in **20.2.4(1)** and **20.2.4(3)(a)**

σ_F: Minimum upper yield stress (N/mm^2) or proof stress (N/mm^2) of the material

Fig.C20.2 Determination of the Normal Stress of Hatch Cover Plating





(2) The net thickness of double skin hatch covers and box girders is to be obtained in accordance with **-5** below taking into consideration of the permissible stresses specified in **20.2.5-1(1)**

(3) ~~In addition to **(2)** above, w~~When the lower plating of double skin hatch covers is taken into account as a strength member of the hatch cover, the net thickness t_{net} (mm) of the lower plating is not to be less than 5 *mm*. ~~that obtained from following formulae:~~

~~$t_{net} = 6.5S$~~

~~$t_{net} = 5$~~

~~S : As specified in **(1)** above~~

(4) When lower plating is not considered to be a strength member of the hatch cover, the thickness of the lower plating is to be determined as deemed appropriate by the Society.

(5) When cargo likely to cause shear buckling is intended to be carried on a hatch cover, the net thickness t_{net} (mm) is not to be less than that obtained from the following formulae. In such cases, "cargo likely to cause shear buckling" refers particularly to large or bulky cargo lashed to the hatch cover, such as parts of cranes or wind power stations, turbines, etc. Cargo that is considered to be uniformly distributed over the hatch cover (e.g., timber, pipes or steel coils) does not need to be considered.

$t_{net} = 6.5S$

$t_{net} = 5$

S : As specified in **(1)** above

3 Net scantling of secondary stiffeners

(1) The net section modulus Z_{net} (cm^3) of the secondary stiffeners of hatch cover top plates, based on stiffener net member thickness, is not to be less than that obtained from the following formula. The net section modulus of the secondary stiffeners is to be determined based on an attached plate width that is assumed to be equal to the stiffener spacing.

$Z_{net} = \frac{104 S P_{HC} l^2}{\sigma_F}$ for the design loads specified in **20.2.4(1)** above

$Z_{net} = \frac{93 S P_{HC} l^2}{\sigma_F}$ for the design loads specified in **20.2.4(3)(a)** above

l : Secondary stiffener span (m) is to be taken as the spacing of primary supporting members or the distance between a primary supporting member and the edge support, as applicable.

S: Stiffener spacing (m)

P_{HC}: Design load (kN/m^2) as specified in **-2(1)** above

σ_F : Minimum upper yield stress (N/mm^2) or proof stress (N/mm^2) of the material

(2) The net shear sectional area A_{net} (cm^2) of the secondary stiffener webs of hatch cover top plates is not to be less than that obtained from the following formula:

$$A_{net} = \frac{10SP_{HC}l}{\sigma_F}$$

$$A_{net} = \frac{10.8SP_{HC}l}{\sigma_F}$$ for the design loads specified in **20.2.4(1)** above

$$A_{net} = \frac{9.6SP_{HC}l}{\sigma_F}$$ for the design loads specified in **20.2.4(3)(a)** above

l, S and P_{HC} : As specified in **(1)** above

(3) For flat bar secondary stiffeners and buckling stiffeners, the following formula is to be applied:

$$\frac{h}{t_{W,net}} \le 15\sqrt{k}$$

h: Height (mm) of the stiffener

$t_{W,net}$: Net thickness (mm) of the stiffener

$k = 235/\sigma_F$

σ_F : As specified in **(1)** above

(4) Stiffeners parallel to primary supporting members and arranged within the effective breadth according to **20.2.5-5(2)** are to be continuous at crossing primary supporting member and may be regarded for calculating the cross sectional properties of primary supporting members.

(5) The combined stress of those stiffeners induced by the bending of primary supporting members and lateral pressures is not to exceed the permissible stresses according to **20.2.5-1(1)**.

(6) For hatch cover stiffeners under compression, sufficient safety against lateral and torsional buckling according to **20.2.5-6(3)** is to be verified.

(7) For secondary stiffeners of the lower plating of double skin hatch covers, the requirements in **(1)** and **(2)** above do not need to be applied due to the absence of lateral loads.

(8) The net thickness (mm) of a stiffener (except for U-type stiffeners) web is not to be taken as less than 4 mm.

(9) Single-side welding is not permitted for secondary stiffeners, except for U-type stiffeners.

(10) The requirements in this **-3** do not need to be applied to stiffeners of the lower plating of double skin hatch covers in cases where the lower plating is not considered to be a strength member.

(-4 is omitted.)

5 Strength calculation

(1) Strength calculation for steel hatch covers may be carried out by either using beam theory, grillage analysis or FEM. Net scantlings are to be used for modeling. Strength calculations for double skin hatch covers or hatch covers with box girders are to be assessed using FEM, as specified in **20.2.5-5(3)**.

(2) Effective cross-sectional properties for calculation by beam theory or grillage analysis are to be determined by the following **(a)** to **(e)**:

(a) The effective breadth of the attached plating e_m of the primary supporting members specified in **Table C20.5** according to the ratio of l and e is to be considered for the calculation of effective cross-sectional properties. For intermediate values of l/e, e_m is to be obtained by linear interpolation.

(b) Separate calculations may be required for determining the effective breadth of one-sided or non-symmetrical flanges.

(c) The effective cross sectional areas of plates is not to be less than the cross sectional area of the face plate.
(d) The cross sectional area of secondary stiffeners parallel to the primary supporting member under consideration within the effective breadth may be included in the calculations (see **Fig. C20.5**).
(e) For flange plates under compression with secondary stiffeners perpendicular to the web of the primary supporting member, the effective width is to be determined according to **20.2.5-6(3)**.

(3) General requirements for FEM are as follows:
(a) The structural model is to be able to reproduce the behaviour of the structure with the highest possible fidelity. Stiffeners and primary supporting members subject to pressure loads are to be included in the modelling. However, buckling stiffeners may be disregarded for stress calculation.
(b) Net scantlings which exclude corrosion additions are to be used for modeling.
(c) Element size is to be suitable to take effective breadth into account.
(d) In no case is element width to be larger than stiffener spacing. The ratio of element length to width is not to exceed 4.
(e) The element height of the webs of primary supporting members is not to exceed one-third of the web height.
(f) Stiffeners may be modelled using shell elements, plane stress elements or beam elements.

Table C20.5 Effective Breadth e_m of Plating of Primary Supporting Members

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

(Notes)
e_{m1}: Effective breadth (*mm*) to be applied where primary supporting members are loaded by uniformly distributed loads or by not less than 6 equally spaced single loads
e_{m2}: Effective breadth (mm) to be applied where primary supporting members are loaded by 3 or less single loads
l: Length between zero-points of bending moment curve taken equal to:
For simply supported primary supporting members: l_0
For primary supporting members with both ends constant: $0.6l_0$
l_0: Unsupported length of the primary supporting members
e: Width of plating supported, measured from centre to centre of the adjacent unsupported fields

6 Buckling strength of steel hatch covers

The buckling strength of the structural members of steel hatch covers is to be in accordance with the following **(1)** to **(3)**:

(1) The buckling strength of a single plate panel of the top and lower steel hatch cover plating is to comply with the following formulae:

$$\left(\frac{|\sigma_x|C_{sf}}{\kappa_x\sigma_F}\right)^{e1}+\left(\frac{|\sigma_y|C_{sf}}{\kappa_y\sigma_F}\right)^{e2}-B\left(\frac{\sigma_x\sigma_y C_{sf}^2}{\sigma_F^2}\right)+\left(\frac{|\tau|C_{sf}\sqrt{3}}{\kappa_\tau\sigma_F}\right)^{e3}\leq 1.0$$

$$\left(\frac{\sigma_x C_{sf}}{\kappa_x\sigma_F}\right)^{e1}\leq 1.0$$

$$\left(\frac{\sigma_y C_{sf}}{\kappa_y\sigma_F}\right)^{e2}\leq 1.0$$

$$\left(\frac{|\tau| C_{sf}\sqrt{3}}{\kappa_\tau \sigma_F}\right)^{e3} \leq 1.0$$

(omitted)

C_{sf}: Safety factor taken as equal to:

$C_{sf} = 1.25$ for hatch covers when subjected to design vertical wave loads according to **20.2.4(1)**

$C_{sf} = 1.10$ for hatch covers when subjected to loads according to **20.2.4~~(2)~~(3)** to **(5)**

(omitted)

((2) is omitted.)

(3) The buckling strength of partial and total fields included in the structural members of steel hatch covers is to comply with the following **(a)** to **(e)**:

(a) The buckling strength of longitudinal and transverse secondary stiffeners is to comply with following **(d)** and **(e)**~~:~~. For U-type stiffeners, however, the requirements in **(e)** below may be omitted.

((b) and (c) are omitted.)

(d) For lateral buckling, longitudinal and transverse stiffeners are to comply with following **i)** to **iii)**:

i) Secondary stiffeners subject to lateral loads are to comply with the following criteria:

$$\frac{\sigma_a + \sigma_b}{\sigma_F} C_{sf} \leq 1$$

σ_a : Uniformly distributed compressive stress (N/mm^2) in the direction of the stiffener axis, given by the following formula:

$\sigma_a = \sigma_x$ for longitudinal stiffeners

$\sigma_a = \sigma_y$ for transverse stiffeners

σ_b : Bending stress (N/mm^2) in the stiffeners, given by the following formula:

$$\sigma_b = \frac{M_0 + M_1}{Z_{st} 10^3}$$ ~~with $\sigma_x = \sigma_n$ and $\tau = \tau_{SF}$~~

(omitted)

((e) is omitted.)

Paragraph 20.2.9 has been amended as follows.

20.2.9 Hatch Coaming Strength Criteria

(-1 is omitted.)

2 Scantlings of hatch coamings are to be in accordance with the followings.

((1) to (4) are omitted.)

(5) The net scantlings of hatch coaming stays are to be in accordance with following **(a)** to **~~(d)~~(c)**:

(a) For hatch coaming stays considered to be simple beams (see **Examples 1** and **2** of **Fig. C20.8**), ~~T~~the net section modulus Z_{net} (cm^3) of such stays at their deck connections ~~with a height of less than 1.6*m*~~ and the net scantling $t_{w,net}$ (mm) of their webs ~~is~~ are not to be less than those obtained from following formulae:

$$Z_{net} = \frac{526 H_C^2 S P_H}{\sigma_F}$$

$$t_{w,net} = \frac{2H_C S P_H}{\sigma_F \, h}$$

H_C: Hatch coaming stay height (m)
h: Hatch coaming stay depth (m)
S: Hatch coaming stay spacing (m)
σ_F and P_H: As specified in **(1)** above

(b) ~~The scantlings of hatch coaming stays with a height of 1.6 *m* and over are to be determined by direct calculations. The effective breadth of the coaming plate is to be in accordance with **20.2.5-5(2)** and stresses in hatch coaming stays are to comply with the criteria specified in **20.2.5-1**.~~For coaming stays other than those in **(a)** above (see **Example 3** of **Fig. C20.8**), stresses are generally to be determined through grillage analysis or FEM, and the calculated stresses are to satisfy the permissible stress criteria of **20.2.5-1**.

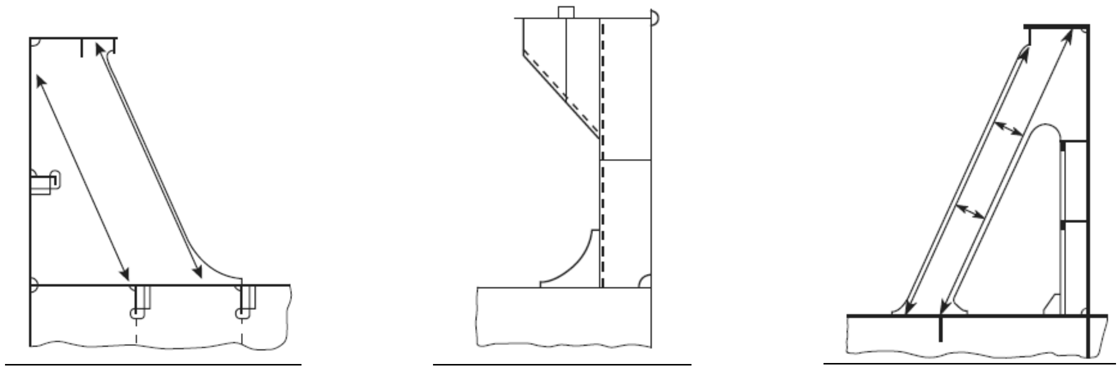
(c) For calculating the net section modulus of coaming stays, the area of their face plates is to be taken into account only when it is welded with full penetration welds to the deck plating and an adequate underdeck structure is fitted to support the stresses transmitted by them.

~~(d) The net scantling $t_{w,net}$ (mm) of hatch coaming stay webs is not to be less than that obtained from the following formula:~~

$$t_{w,net} = \frac{2H_C S P_H}{\sigma_F \, h}$$

~~h : Hatch coaming stay depth (m)~~
~~H_C, S, P_H and σ_F : As specified in **(a)** above~~

Fig. C20.8 Examples of coaming stays

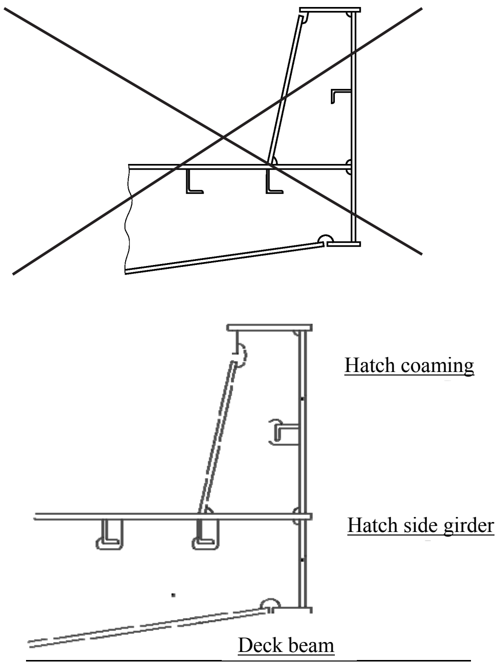


Example1 Example2 Example3

(-3 and -4 are omitted.)

5 Coaming plates are to extend to the lower edge of the deck beams; moreover, they are to be flanged or fitted with face bars or half-round bars (see **Fig. C20.8**), except where specially approved by the Society.

Fig. C20.~~8~~9 Example for the extension of coaming plates



(-6 is omitted.)

Paragraph 20.2.10 has been amended as follows.

20.2.10 Closing Arrangements

(-1 is omitted.)

2 The securing devices of hatch covers, on which cargo is to be lashed, are to be designed for a lifting force resulting from the loads according to **20.2.4(4)** (see **Fig. C20.~~9~~10**). Unsymmetrical loading, which may occur in practice, is to be considered. Under such loading, the equivalent stress (N/mm^2) in securing devices is not to be greater than that obtained from the following formula. Anti-lifting devices may be dispensed with at the discretion of the Society.

$$\sigma_E = \frac{150}{k_l}$$

k_l: As obtained from the following formula:

$$k_l = \left(\frac{235}{\sigma_F}\right)^e$$

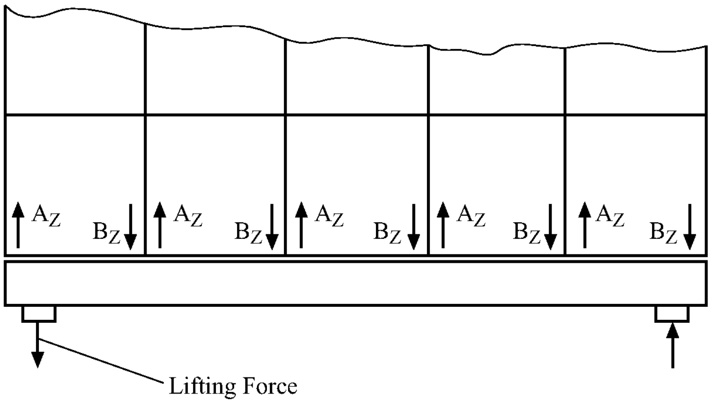
σ_F : Minimum upper yield stress (N/mm^2) or proof stress (N/mm^2) of the material

e: As given below:

0.75 for $\sigma_F > 235$

1.00 for $\sigma_F \leq 235$

Fig. C20.~~9~~10 Lifting forces at a hatch cover



Paragraph 20.2.11 has been amended as follows.

20.2.11 Hatch Cover Supports, Stoppers and Supporting Structures

Hatch cover supports, stoppers and supporting structures subject to the provisions of **20.2** are to comply with the following **(1)** to **(3)**:

(1) For the design of the securing devices for the prevention of shifting, the horizontal mass forces F obtained from the following formula are to be considered. Acceleration in the longitudinal direction, a_X, and in the transverse direction, a_Y, does not need to be considered as acting simultaneously.

$F = ma$

m: Sum of mass of cargo lashed on the hatch cover and mass of hatch cover

a: Acceleration obtained from the following formula:

$a_X = 0.2g$ for longitudinal direction

$a_Y = 0.5g$ for transverse direction

(2) The design load for determining the scantlings of stoppers is not to be less than that obtained from **20.2.4(2)** and **(1)**, whichever is greater. Stress in the stoppers is to comply with the criteria specified in **20.2.5-1(1)**.

(3) The details of hatch cover supporting structures are to be in accordance with the following **(a)** to **(g)**:

(a) The nominal surface pressure (N/mm^2) of hatch cover supports is not to be greater than that obtained from the following formula:

$p_{n\max} = dp_n$ in general

$p_{n\max} = 3p_n$ for metallic supporting surface not subjected to relative displacements

d: As given by the following formula. Where d exceeds 3, d is to be taken as 3.

$d = 3.75 - 0.015L_1$

$d_{\min} = 1.0$ in general

$d_{\min} = 2.0$ for partial loading conditions

L_1: Length of ship specified in **2.1.2, Part A~~ of the Rules~~** (m). However, L_1 need not to be greater than 97% of the total length at the summer load waterline.

p_n: As obtained from **Table C20.10**

Table C20.10 Permissible nominal surface pressure p_n

Material	p_n when loaded by	
	Vertical force	Horizontal force
Hull structure steel	25	40
Hardened steel	35	50
Plastic materials in steel	50	-

(b) Where large relative displacements of the supporting surfaces are to be expected, the use of material having low wear and frictional properties is recommended.

(c) Drawings of the supports are to be submitted. In these drawings, the permitted maximum pressure given by the material manufacturer ~~related to long time stress~~ is to be specified.

(d) ~~Sufficient abrasive strength may be shown by tests demonstrating an abrasion of support surfaces of not more than 0.3 *mm* per year in service at a total distance of shifting of 15,000 *m* per year when deemed necessary by the Society.~~ When the manufacturer of the vertical hatch cover support material can provide proof that the material is sufficient for the increased surface pressure, not only statically but under dynamic conditions, the permissible nominal surface pressure $p_{n\max}$, as specified in **(a)** above, may be relaxed at the discretion of the Society. However, realistic long term distributions of spectra for vertical loads and relative horizontal motion between hatch covers and hatch cover stoppers are to be as deemed appropriate by the Society.

(e) Irrespective of the arrangement of stoppers, the supports are to be able to transmit the following force p_h in the longitudinal and transverse direction.

$$p_h = \mu \frac{p_v}{\sqrt{d}}$$

p_v : Vertical supporting force

μ : Friction coefficient generally to be taken as 0.5. For non-metallic or low-friction materials, the friction coefficient may be reduced as appropriate by the Society. However, in no case μ is to be less than 0.35.

(f) Stresses in supporting structures are to comply with the criteria specified in **20.2.5-1(1)**.

(g) For substructures and adjacent constructions of supports subjected to horizontal forces p_h, special consideration is to be given to fatigue strength.

EFFECTIVE DATE AND APPLICATION (Amendment 1-2)

1. The effective date of the amendments is 1 July 2016.

2. Notwithstanding the amendments to the Rules, the current requirements may apply to ships for which the date of contract for construction* is before the effective date.

* "contract for construction" is defined in the latest version of IACS Procedural Requirement (PR) No.29.

IACS PR No.29 (Rev.0, July 2009)

1. The date of "contract for construction" of a vessel is the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. This date and the construction numbers (i.e. hull numbers) of all the vessels included in the contract are to be declared to the classification society by the party applying for the assignment of class to a newbuilding.

2. The date of "contract for construction" of a series of vessels, including specified optional vessels for which the option is ultimately exercised, is the date on which the contract to build the series is signed between the prospective owner and the shipbuilder.
For the purpose of this Procedural Requirement, vessels built under a single contract for construction are considered a "series of vessels" if they are built to the same approved plans for classification purposes. However, vessels within a series may have design alterations from the original design provided:
(1) such alterations do not affect matters related to classification, or
(2) If the alterations are subject to classification requirements, these alterations are to comply with the classification requirements in effect on the date on which the alterations are contracted between the prospective owner and the shipbuilder or, in the absence of the alteration contract, comply with the classification requirements in effect on the date on which the alterations are submitted to the Society for approval.
The optional vessels will be considered part of the same series of vessels if the option is exercised not later than 1 year after the contract to build the series was signed.

3. If a contract for construction is later amended to include additional vessels or additional options, the date of "contract for construction" for such vessels is the date on which the amendment to the contract, is signed between the prospective owner and the shipbuilder. The amendment to the contract is to be considered as a "new contract" to which **1.** and **2.** above apply.

4. If a contract for construction is amended to change the ship type, the date of "contract for construction" of this modified vessel, or vessels, is the date on which revised contract or new contract is signed between the Owner, or Owners, and the shipbuilder.

Note:
This Procedural Requirement applies from 1 July 2009.

GUIDANCE FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

Part C Hull Construction and Equipment

GUIDANCE

2016 AMENDMENT NO.1

Notice No.39 30th June 2016

Resolved by Technical Committee on 5th February 2016

Notice No.39 30th June 2016
AMENDMENT TO THE GUIDANCE FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS

"Guidance for the survey and construction of steel ships" has been partly amended as follows:

Part C HULL CONSTRUCTION AND EQUIPMENT

Amendment 1-1

C20 HATCHWAYS, MACHINERY SPACE OPENINGS AND OTHER DECK OPENINGS

C20.3 Machinery Space Openings

Paragraph C20.3.5 has been amended as follows.

C20.3.5 Miscellaneous Openings in Machinery Casings

In applying the requirements of **20.3.5-1, Part C** of the Rules, the ~~height of~~ ventilator coamings above the upper surface of the deck is to ~~be at least~~ extend more than 4.5*m* above the surface of the deck in Position I ~~for the freeboard deck, raised quarter decks and superstructure decks forward of $0.25L_f$ aft of the bow~~, and more than 2.3*m* above the surface of the deck in Position II specified in **20.1.2, Part C** of the Rules ~~for other superstructure decks~~. Ventilator openings are not to be fitted with weathertight closing appliances. However, ventilator openings are to be fitted with closing means specified in **20.3.5-3, Part C of the Rules**.

C23 BULWARKS, GUARDRAILS, FREEING ARRANGEMENTS, CARGO PORTS AND OTHER SIMILAR OPENINGS, SIDE SCUTTLES, RECTANGULAR WINDOWS, VENTILATORS AND GANGWAYS

C23.6 Ventilator

C23.6.7 Ventilators for Emergency Generator Room

Where it is not practicable for the height of ventilator coamings to comply with **23.6.7, Part C** of the Rules, they are to comply with the following requirements **(1)** or **(2)** instead.

(1) Where the emergency generator room is located in an enclosed superstructure, the ventilators are to have coamings in compliance with **23.6.1, Part C** of the Rules, and are to be fitted with weathertight closing appliances in combination with other suitable arrangements to ensure adequate ventilation.

Sub-paragraph (2) has been amended as follows.

(2) In cases other than **(1)** above, where the emergency generator room has no opening leading to a space below the freeboard deck, the height of coamings of ventilators to supply air to the emergency generator room, above the upper surface of the deck, is to be at least 900*mm* above the surface of the deck in Position I ~~for the freeboard deck, raised quarter decks and superstructure decks forward of 0.25~~~~L_f~~ or 760*mm* above the surface of the deck in Position II specified in **20.1.2, Part C** of the Rules ~~for other decks~~. In addition, these ventilator openings are to be fitted with suitable protection devices such as louvers to prevent the intrusion of sea-water. Openings on the boundaries of the emergency generator room are to be treated in a similar manner.

EFFECTIVE DATE AND APPLICATION (Amendment 1-1)

1. The effective date of the amendments is 30 June 2016.

Amendment 1-2

C23 BULWARKS, GUARDRAILS, FREEING ARRANGEMENTS, CARGO PORTS AND OTHER SIMILAR OPENINGS, SIDE SCUTTLES, RECTANGULAR WINDOWS, VENTILATORS AND GANGWAYS

C23.5 Side Scuttles and Rectangular Windows

Paragraph C23.5.1 has been amended as follows.

C23.5.1 General Application

1 With respect to the provisions of **23.5, Part C of the Rules**, side scuttles with round or oval openings having areas exceeding 0.16m^2 are to be treated as windows.

2 With respect to the provisions of **23.5.1-1, Part C** of the Rules, the design pressures of windows in the fore end bulkheads of superstructures and deckhouses above the third tier located above the freeboard deck and forward of 0.5*L* are not to be less than the minimum design pressures given in **Table C23.5, Part C** of the Rules. However, this requirement may be dispensed with if the height of the highest deck at the fore end is not less than 22*m* above the designed maximum load line, or if cargo, etc. is regularly loaded onto exposed decks in front of the windows (e.g., container carriers).

~~2~~3 With respect to the provisions of **23.5.1-2, Part C** of the Rules, windows on the navigation bridge up to the third tier above the freeboard deck permitted to be rectangular according to the provisions of **23.5.6, Part C** of the Rules may be other than those of Class *E* or Class *F* subject to the following **(1)** and **(2)**.

(1) The navigation bridge is to be separated from spaces below the freeboard deck and spaces within enclosed superstructures by the followings
  (a) Weathertight closing devices
  (b) Two or more cabin bulkheads or doors

  The height of the doorway sill to the navigation bridge is not to be less than that required for closing devices at the position of such a doorway.

(2) The design pressure of such windows is not to be less than the value specified in **23.5.8, Part C** of the Rules. The frame of the window is to conform to Class *E* or Class *F* according to the location it is installed, and the window is to have appropriate weathertightness.

EFFECTIVE DATE AND APPLICATION (Amendment 1-2)

1. The effective date of the amendments is 30 June 2016.

2. Notwithstanding the amendments to the Guidance, the current requirements may apply to ships the keels of which were laid or which were at *a similar stage of construction* before the effective date.
(Note) The term "*a similar stage of construction*" means the stage at which the construction identifiable with a specific ship begins and the assembly of that ship has commenced comprising at least 50 *tonnes* or 1% of the estimated mass of all structural material, whichever is the less.

Amendment 1-3

C2 STEMS AND STERN FRAMES

C2.2 Stern Frames

Paragraph C2.2.5 has been amended as follows.

C2.2.5 Rudder Horns

In the application of **2.2.5, Part C of the Rules**, the bending moment, shear force, torque and stresses to be considered are to be determined by direct calculation or by a simplified approximation method. For direct calculation, the data to be used is to be according to **C3.4.1**. A simplified approximation method is to be as specified in the following **(1)** or **(2)**:

(1) Rudder horn of 1 elastic support

(a) Bending moment M at the section considered is to be obtained from the following formula. (*See* **Fig. C2.2.5-1**)

$$M = Bz \quad (M_{max} = Bd) \quad (N\text{-}m)$$

B: Supporting force in the pintle bearing (N) as given in **3.4.1 of the Rules**.

(b) Torsional moment T_h at the section considered is to be obtained from the following formula. (*See* **Fig. C2.2.5-1**)

$$T_h = Bc(z) \quad (N/mm^2)$$

(c) Bending stress σ_b, shear stress τ and torsional stress τ_t acting on the rudder horn are to be obtained from the following formulae respectively:

Bending stress: $\sigma_b = \dfrac{M}{Z_x}$ (N/mm^2)

Shear stress: $\tau = \dfrac{B}{A_h}$ (N/mm^2)

Torsional stress: $\tau_t = \dfrac{1000T_h}{2A_t t_h}$ (N/mm^2)

Where:

M, B and T_h: As specified in **(a)** and **(b)** above

A_t: Area in the horizontal section enclosed by the rudder horn (mm^2)

t_h: Plate thickness of the rudder horn (mm)

Z_x: As specified in **2.2.5-1(1), Part C of the Rules**

A_h: As specified in **2.2.5-1(2), Part C of the Rules**

(2) Rudder horn of 2 conjugate elastic support

(a) Bending moment

Bending moment (N) acting on the generic section of the rudder horn is to be obtained (N-m) from the following formulae:

・ between the lower and upper supports provided by the rudder horn:

$M = F_{A1} z$

・ above the rudder horn upper-support:

$M = F_{A1} z + F_{A2} (z - d_{lu})$

Where:

F_{A1}: Support force at the rudder horn lower-support (N) to be obtained according to

Fig. C3.4.1-7, and taken equal to B_1

F_{A2}: Support force at the rudder horn upper-support (N) to be obtained according to **Fig. C3.4.1-7**, and taken equal to B_2

z : Distance (m) defined in **Fig. C2.2.5-2**, to be taken less than the distance d (m) defined in the same figure

d_{lu} : Distance (m) between the rudder-horn lower and upper bearings (according to **Fig. C3.4.1-7**, $d_{lu} = d - \lambda$).

(b) Shear force

The shear force B acting on the generic section of the rudder horn is to be obtained (N) from the following formulae:

- between the lower and upper rudder horn bearings:

$B = F_{A1}$

- above the rudder horn upper-bearing:

$B = F_{A1} + F_{A2}$

Where:

F_{A1}, F_{A2} : Support forces (N).

(c) Torque

The torque acting on the generic section of the rudder horn is to be obtained (N-m) from the following formulae:

- between the lower and upper rudder horn bearings:

$T_h = F_{A1}\, e_{(z)}$

- above the rudder horn upper-bearing:

$T_h = F_{A1}\, e_{(z)} + F_{A2}\, e_{(z)}$

Where:

F_{A1}, F_{A2} : Support forces (N)

$e_{(z)}$: Torsion lever (mm) defined in **Fig. C2.2.5-2**.

(d) Shear stress and tortional stress calculation

i) For a generic section of the rudder horn, located between its lower and upper bearings, the following stresses are to be calculated:

τ : Shear stress (N/mm^2) to be obtained from the following formula:

$$\tau = \frac{F_{A1}}{A_h}$$

τ_t : Torsional stress (N/mm^2) to be obtained for hollow rudder horn from the following formula:

$$\tau_t = \frac{T_h 10^3}{2F_T t_h}$$

For solid rudder horn, τ_T is to be considered by the Society on a case by case basis.

ii) For a generic section of the rudder horn, located in the region above its upper bearing, the following stresses are to be calculated:

τ : Shear stress (N/mm^2) to be obtained from the following formula:

$$\tau = \frac{F_{A1} + F_{A2}}{A_h}$$

τ_t : Torsional stress (N/mm^2) to be obtained for hollow rudder horn from the following formula:

$$\tau_t = \frac{T_h 10^3}{2F_T t_h}$$

For solid rudder horn, τ_t is to be considered by the Society on a case by case basis

Where:

F_{A1}, F_{A2}: Support forces (N)

A_h: Effective shear sectional area of the rudder horn (mm^2) in Y-direction

T_h: Torque (N-m)

F_T: Mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn (m^2)

t_h: Plate thickness of rudder horn (mm). For a given cross section of the rudder horn, the maximum value of τ_t is obtained at the minimum value of t_h.

(e) Bending stress calculation

For the generic section of the rudder horn within the length d the following stresses are to be calculated:

σ_b : Bending stress (N/mm^2) to be obtained from the following formula:

$$\sigma_b = \frac{M}{Z_X}$$

M: Bending moment at the section considered (N-m)

Z_X: Section modulus (cm^2) around the X-axis (see **Fig. C2.2.5-2**).

Fig. C2.2.5-1 has been added as follows.

Fig. C2.2.5-1 Geometry of rudder horn (1 elastic support)

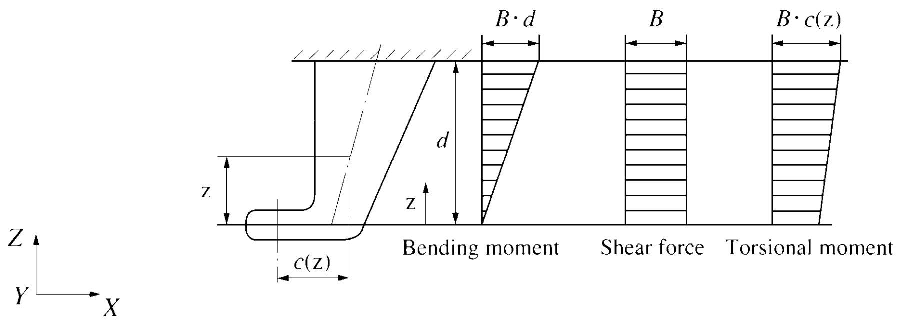
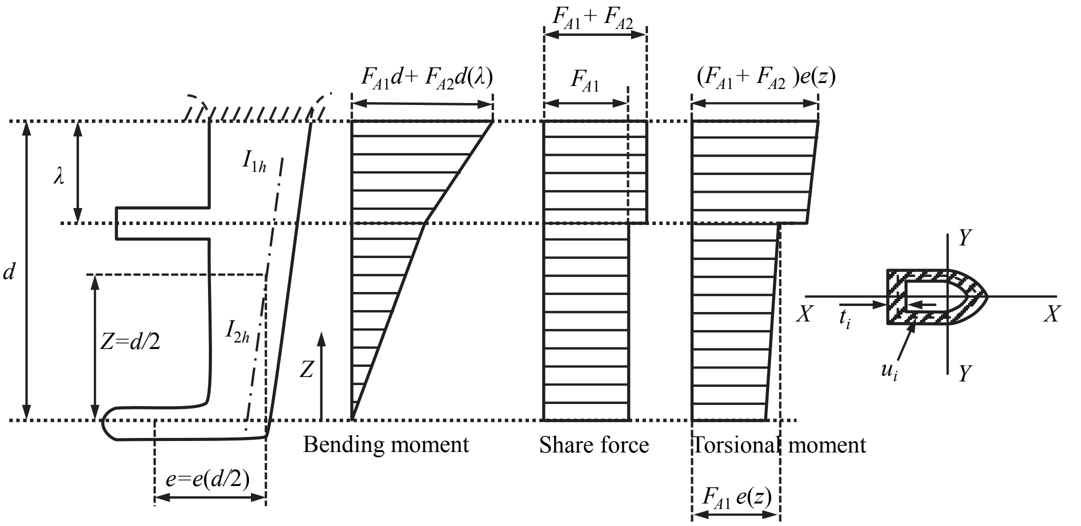


Fig. C2.2.5-2 has been added as follows.

Fig. C2.2.5-2 Geometry of rudder horn (2 conjugate elastic supports)



C3 has been amended as follows.

C3 RUDDERS

C3.1 General

C3.1.1 Application

1 Rudders having three or more pintles

The scantling of each member of rudders having three or more pintles is to be determined in accordance with the requirements in **Chapter 3, Part C** of the Rules. However, the moment and force acting on each member are to be determined by the direct calculation method, in accordance with the requirements in **C3.4**~~ of the Guidance~~.

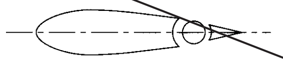
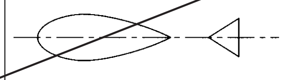
2 Rudders having a special shape or sectional form

~~Rudders with flaps, fish tail rudders and n~~Nozzle rudders are to be as specified ~~in **(1)** and **(2)**~~ below, unless the rudder force and rudder torque are required to be determined by tests or detailed theoretical calculation. In other rudders, the scantling of each member is to be determined by obtaining the rudder force and rudder torque through tests or detailed theoretical calculations, and correspondingly applying the requirements in **Chapter 3, Part C** of the Rules. Results of tests or theoretical calculations are to be submitted to the Society.

~~(1) Rudders with flaps and fish tail rudders~~

~~The scantling of each member of rudders with flaps or fish tail rudders is to be determined in accordance with the requirements in **Chapter 3, Part C** of the Rules. However, in applying the Rules, values of factor K_2 in **3.2** and values of factor α in **3.3, Part C** of the Rules are to be as specified in **Table C3.1.1-1**. K_2 and α in astern condition are to be to the discretion of the Society.~~

~~Table C3.1.1-1 Factor K_2 and α~~

Profile type	K_2 Ahead Condition	α Ahead Condition
Rudders with flaps 	1.7	0.45
Fish tail rudders 	1.4	0.45

~~(2)~~ Nozzle rudders

The scantling of each member of nozzle rudders is to be determined in accordance with the requirements in **Chapter 3, Part C** of the Rules. In applying the Rules, the total rudder area and the rudder area ahead of the centreline of the rudder stock are to be calculated as follows:

Total rudder area A:

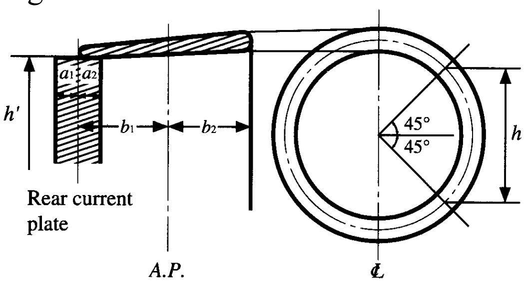
$$2h(b_1+b_2)+h'(a_1+a_2) \quad (m^2)$$

Rudder area ahead of the centreline of the rudder stock A_f :

$$2hb_2 \quad (m^2)$$

Where:
a_1, a_2, b_1, b_2, h and h' : Refer to **Fig. C3.1.1-1**

Fig. C3.1.1-1 Area of Nozzle Rudder



3 Rudders designed for helm angles exceeding 35°

The scantling of each member of rudders designed for helm angles exceeding 35° is to be determined in accordance with the requirements in **Chapter 3, Part C** of the Rules, on the basis of the rudder force and rudder torque obtained through tests or detailed theoretical calculations. The results of tests and theoretical calculations are to be submitted to the Society.

C3.1.2 Materials

1 If the diameter of the rudder stock is small, cast carbon steel is not to be used.

2 Rolled bar steel (*KSFR*45) may be treated in the same way as *KSF*45.

C3.4 Rudder Strength Calculation

C3.4.1 Rudder Strength Calculation

1 General

The bending moment, shear force, and supporting force acting on the rudder and rudder stock may be evaluated using the basic rudder models shown in **Fig. C3.4.1-1** to **Fig. C3.4.1-~~5~~7**.

2 Moments and forces to be evaluated

The bending moment M_R and the shear force Q_1 acting on the rudder body, the bending moment M_b acting on the bearing, and the bending moment M_s acting on the coupling between the rudder stock and the rudder main piece and the supporting forces B_1, B_2, B_3 are to be obtained ~~from C3.4.1-3~~. These moments and forces are to be used for analyzing the stresses in accordance with the requirements in **Chapter 3, Part C** of the Rules.

3 Method of evaluating moments and forces

The method of evaluating moments and forces is to be as in the following **(1)** to **(3)** below. Notwithstanding the above, for Type *D* rudders with 2-conjugate elastic supports by rudder horns, the method of evaluating moments and forces is to be as in **-4**.

(1) General data

Data on the basic rudder models shown in **Fig. C3.4.1-1** to **Fig. C3.4.1-~~5~~6** is as follows:

$l_{10} \sim l_{50}$: Lengths (m) of individual girders of the system

$I_{10} \sim I_{50}$: Moments (cm^4) of inertia of these girders

For rudders supported by a shoe piece, the length l_{20} is the distance between the lower edge of the rudder body and the centre of the shoe piece and I_{20} is the moment of inertia of the pintle in the shoe piece.

h_c is the vertical distance (m) from the mid-point of the length of that pintle to the centroid of the rudder area.

(2) Direct calculation

The standard data to be used for direct calculation are as follows:

Load acting on rudder body (Type *B* ~~and *C*~~ rudders)

$$P_R = \frac{F_R}{1000 l_{10}} \quad (kN/m)$$

Load acting on rudder body (Type *C* rudders)

$$P_R = \frac{F_R}{1000 l_{10}} \quad (kN/m)$$

Notwithstanding the above, the value is as follows for rudders with rudder trunks supporting rudder stocks.

$$P_R = \frac{F_R}{1000(l_{10} + l_{20})} \quad (kN/m)$$

Load acting on rudder body (Type *A* rudder)

$$P_{R10} = \frac{F_{R2}}{1000 l_{10}} \quad (kN/m)$$

$$P_{R20} = \frac{F_{R1}}{1000 l_{30}} \quad (kN/m)$$

Load acting on rudder body (Type *D* and *E* rudders)

$$P_{R10} = \frac{F_{R2}}{1000 l_{10}} \quad (kN/m)$$

$$P_{R20} = \frac{F_{R1}}{1000 l_{20}} \quad (kN/m)$$

Where:

F_R, F_{R1}, F_{R2}: As specified in **3.2** and **3.3**, **Part C** of the Rules

k: Spring constant of the supporting point of the shoe piece or rudder horn respectively, as shown below

For the supporting point of the shoe piece:

$$k = \frac{6.18 I_{50}}{l_{50}^{\ 3}} \quad (kN/m)$$

(*See* **Fig. C3.4.1-1** and **Fig. C3.4.1-2**)

Where:

I_{50} : The moment (cm^4) of inertia of shoe piece around the Z-axis

l_{50} : Effective length (m) of shoe piece

For the supporting point of rudder horn:

$$k = \frac{1}{f_b + f_t} \quad (kN/m)$$

(*See* **Fig. C3.4.1-1**, **Fig. C3.4.1-4** and **Fig. C3.4.1-5**)

Where:

f_b: Unit displacement of rudder horn due to a unit force of 1 kN acting in the centre of support as shown below.

$$f_b = 1.3 \frac{d^3}{6.18 I_n} \quad (m/kN)$$

Where:

I_n: The moment (cm^4) of inertia of rudder horn around the X-axis

f_t: Unit displacement due to torsion, as shown below.

$$f_t = \frac{dc^2 \Sigma u_i / t_i}{3.14 F_T{}^2} \times 10^{-8} \quad (m/kN)$$

F_T: Mean sectional area (m^2) of the rudder horn

u_i: Breadth (mm) of the individual plates forming the mean sectional area of the rudder horn

t_i: Plate thickness (mm) within the individual breadth u_i

For c and d, see **Fig. C3.4.1-4** and **Fig. C3.4.1-5**. (For the rudder horn of Type A rudders, the same values are to be also applied.)

(3) Simplified method

The moments and forces for rudders of each type may be obtained from the following formulae.

(a) Type A rudders

$$M_R = \frac{B_1^2(l_{10}+l_{30})}{2F_R} \quad (N\text{-}m)$$

$$M_b = \frac{B_3(l_{30}+l_{40})(l_{10}+l_{30})^2}{l_{10}^2} \quad (N\text{-}m)$$

$$M_s = B_3 l_{40} \quad (N\text{-}m)$$

$$B_1 = \frac{F_R h_c}{l_{10}} \quad (N)$$

$$B_2 = F_R - 0.8B_1 + B_3 \quad (N)$$

$$B_3 = \frac{F_R l_{10}{}^2}{8l_{40}(l_{10}+l_{30}+l_{40})} \quad (N)$$

(b) Type B rudders

$$M_R = \frac{B_1^2 l_{10}}{2F_R} \quad (N\text{-}m)$$

$$M_b = B_3 l_{40} \quad (N\text{-}m)$$

$$M_s = \frac{3M_R l_{30}}{l_{10}+l_{30}} \quad (N\text{-}m)$$

$$B_1 = \frac{F_R h_c}{l_{10}+l_{30}} \quad (N)$$

$$B_2 = F_R - 0.8B_1 + B_3$$

$$B_3 = \frac{F_R(l_{10}+l_{30})^2}{8l_{40}(l_{10}+l_{30}+l_{40})} \quad (N)$$

(c) Type C rudders

$$M_b = F_R h_c \quad (N\text{-}m)$$

$$B_2 = F_R + B_3 \quad (N)$$

$$B_3 = \frac{M_b}{l_{40}} \quad (N)$$

Notwithstanding the above, the value is as follow, for rudders with rudder trunks supporting rudder stocks.

M_R is the greatest of the following values:

$M_R = C_{R2} (\ell_{10} - CG_{2Z})$

$M_R = C_{R1} (CG_{1Z} - \ell_{10})$

where A_1 and A_2 are the rudder blade area which are above the lower bearing and below respectively and symbols are as follows (*See* **Fig. C3.4.6**)

F_{R1} : Rudder force over the rudder blade area A_1

F_{R2} : Rudder force over the rudder blade area A_2

CG_{1Z}: Vertical position of the centre of gravity of the rudder blade area A_1

CG_{2Z}: Vertical position of the centre of gravity of the rudder blade area A_2

$M_b = F_{R2} (\ell_{10} - CG_{2Z})$

$B_2 = F_R + B_3$

$$B_3 = \frac{M_b + M_{FR1}}{\ell_{20} + \ell_{40}}$$

(d) Type *D* rudders

$$M_R = \frac{F_{R2} l_{10}}{2} \quad (N\text{-}m)$$

$$M_b = \frac{F_R {l_{10}}^2}{10(l_{20} + l_{30})} \quad (N\text{-}m)$$

$$M_s = \frac{2 M_R l_{10} l_{30}}{(l_{20} + l_{30})^2} \quad (N\text{-}m)$$

$$B_1 = \frac{F_R h_c}{l_{20} + l_{30}} \quad (N)$$

$$B_2 = F_R - B_1, \min B_2 = F_R / 4 \quad (N)$$

$$B_3 = \frac{M_b}{l_{40}} \quad (N)$$

$$Q_1 = F_{R2} \quad (N)$$

(e) Type *E* rudders

$$M_R = \frac{F_{R2} l_{10}}{2} \quad (N\text{-}m)$$

$$M_b = \frac{F_R {l_{10}}^2}{10 l_{20}} \quad (N\text{-}m)$$

$$B_1 = \frac{F_R h_c}{l_{20}} \quad (N)$$

$$B_2 = F_R - B_1, \min B_2 = F_R / 4 \quad (N)$$

$$B_3 = \frac{M_b}{l_{40}} \quad (N)$$

$$Q_1 = F_{R2} \quad (N)$$

4 Method of evaluating moments and forces (Type *D* rudders with 2-conjugate elastic support)

For Type *D* rudders with 2-conjugate elastic supports by rudder horns, the method of evaluating moments and forces is to be as in **(1)** and **(2)** below.

(1) General data

K_{11}, K_{22}, K_{12}: Rudder horn compliance constants calculated for rudder horn with

2-conjugate elastic supports (**Fig. C3.4.1-7**). The 2-conjugate elastic supports are defined in terms of horizontal displacements, y_i, by the following equations:

at the lower rudder horn bearing:

$y_1 = -K_{12} B_2 - K_{22} B_1$

at the upper rudder horn bearing:

$y_2 = -K_{11} B_2 - K_{12} B_1$

Where

y_1, y_2 : Horizontal displacements (m) at the lower and upper rudder horn bearings, respectively

B_1, B_2 : Horizontal support forces (kN) at the lower and upper rudder horn bearings, respectively

K_{11}, K_{22}, K_{12} : Obtained (m/kN) from the following formulae:

$$K_{11} = 1.3 \cdot \frac{\lambda^3}{3EI_{1h}} + \frac{e^2 \lambda}{GI_{th}}$$

$$K_{12} = 1.3 \left[\frac{\lambda^3}{3EI_{1h}} + \frac{\lambda^2 (d - \lambda)}{2EI_{1h}} \right] + \frac{e^2 \lambda}{GI_{th}}$$

$$K_{22} = 1.3 \left[\frac{\lambda^3}{3EI_{1h}} + \frac{\lambda^2 (d - \lambda)}{EI_{1h}} + \frac{\lambda (d - \lambda)^2}{EI_{1h}} + \frac{(d - \lambda)^3}{3EI_{2h}} \right] + \frac{e^2 d}{GI_{th}}$$

d : Height of the rudder horn (m) defined in **Fig. C3.4.1-7**. This value is measured downwards from the upper rudder horn end, at the point of curvature transition, till the mid-line of the lower rudder horn pintle

λ : Length (m) as defined in **Fig. C3.4.1-7**. This length is measured downwards from the upper rudder horn end, at the point of curvature transition, till the mid-line of the upper rudder horn bearing. For $\lambda = 0$, the above formulae converge to those of spring constant Z for a rudder horn with 1-elastic support, and assuming a hollow cross section for this part

e : Rudder-horn torsion lever (m) as defined in **Fig. C3.4.1-7** (value taken at $z = d/2$)

I_{1h} : Moment of inertia of rudder horn about the x axis (m^4) for the region above the upper rudder horn bearing. Note that I_{1h} is an average value over the length λ (see **Fig. C3.4.1-7**)

I_{2h} : Moment of inertia of rudder horn about the x axis (m^4) for the region between the upper and lower rudder horn bearings. Note that I_{2h} is an average value over the length $d - \lambda$ (see **Fig. C3.4.1-7**)

I_{th} : Torsional stiffness factor of the rudder horn (m^4)

For any thin wall closed section

$$I_{th} = \frac{4F_T^2}{\sum_i \frac{u_i}{t_i}}$$

F_T : Mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn (m^2)

u_i : Length (mm) of the individual plates forming the mean horn sectional area

t_i : Thickness (mm) of the individual plates mentioned above.

Note that the I_{th} value is taken as an average value, valid over the rudder horn height.

(2) Direct calculation

The standard data to be used for direct calculation are as follows:
Load acting on rudder body

$$P_{R10} = \frac{F_{R2}}{1000 l_{10}} \quad (kN/m)$$

$$P_{R20} = \frac{F_{R1}}{1000 l_{20}} \quad (kN/m)$$

F_R, F_{R1}, F_{R2} : As defined in **3.3.2**

Fig. C3.4.1-1 Type *A* Rudder

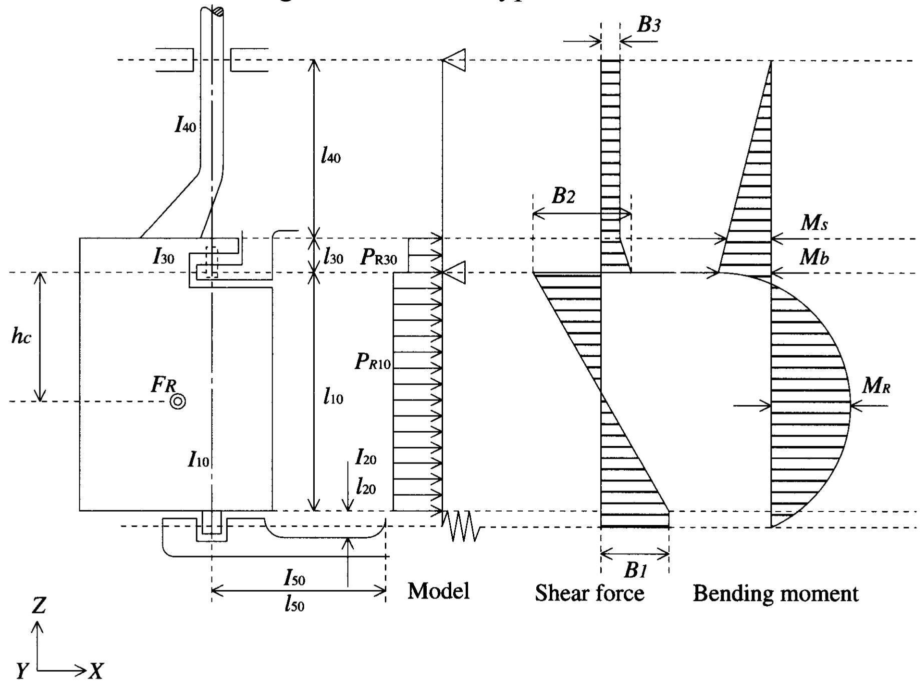


Fig. C3.4.1-2　Type *B* Rudder

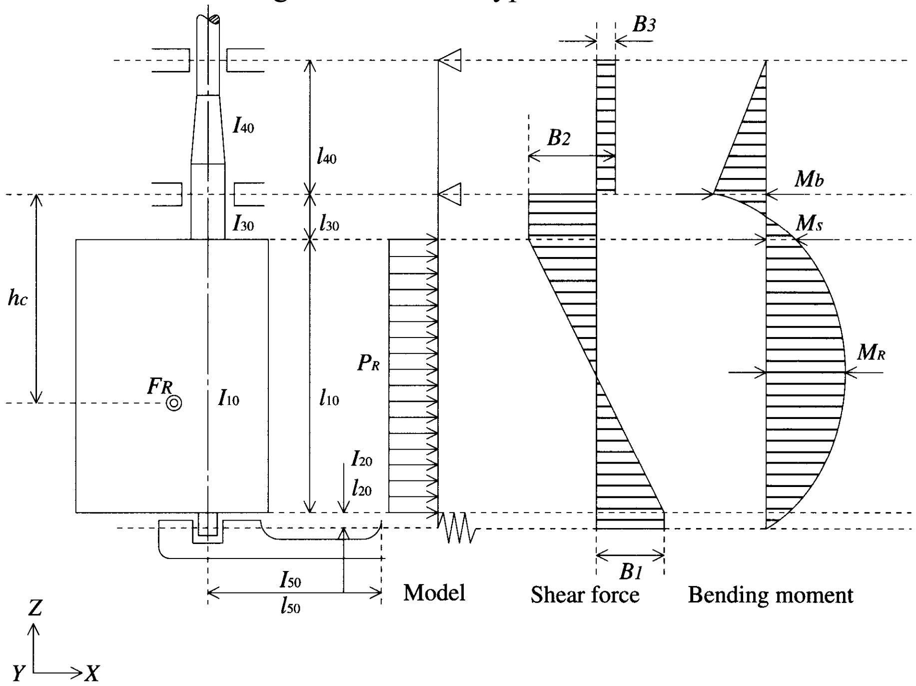


Fig. C3.4.1-3　Type *C* Rudder

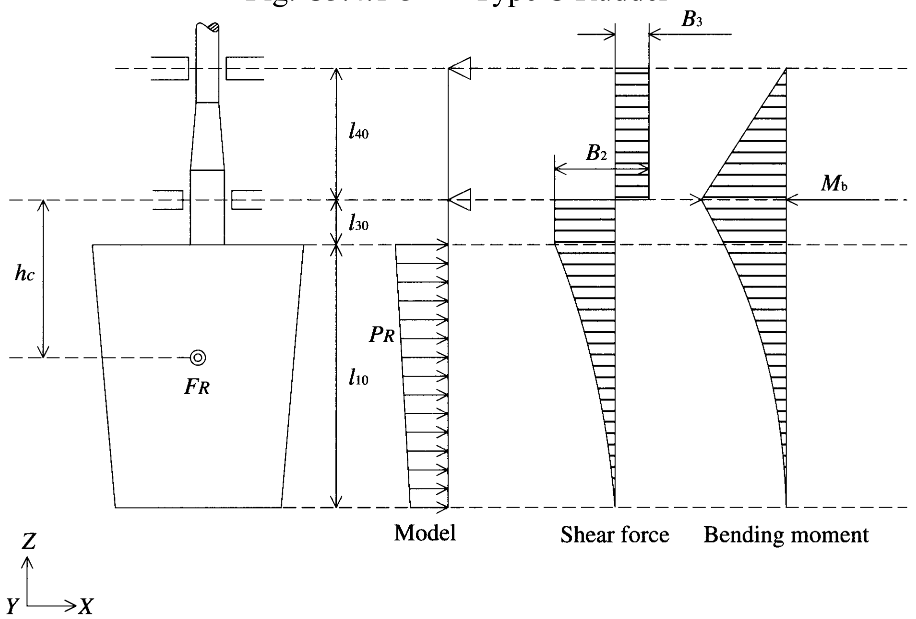


Fig. C3.4.1-4 Type *D* Rudder

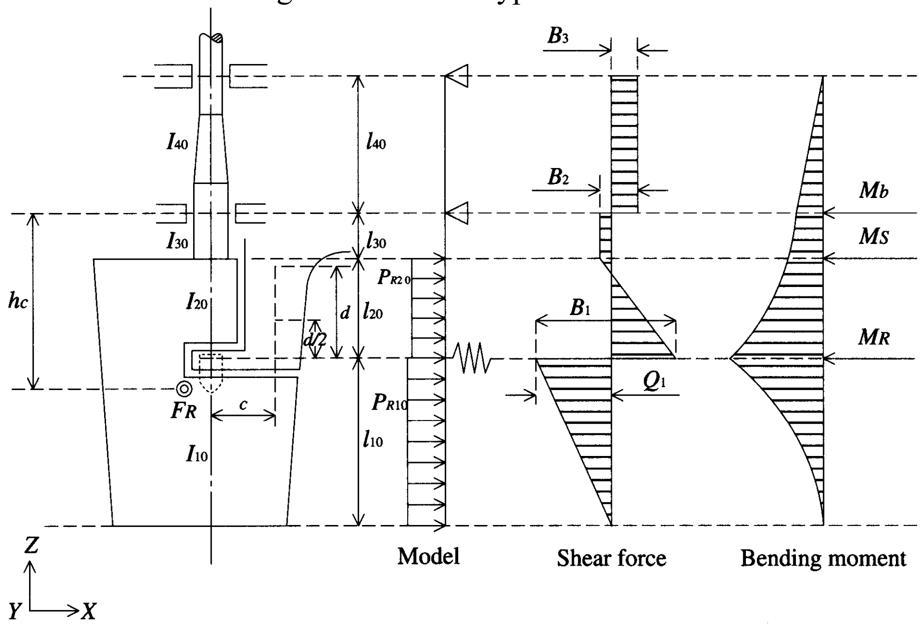


Fig. C3.4.1-5 Type *E* Rudder

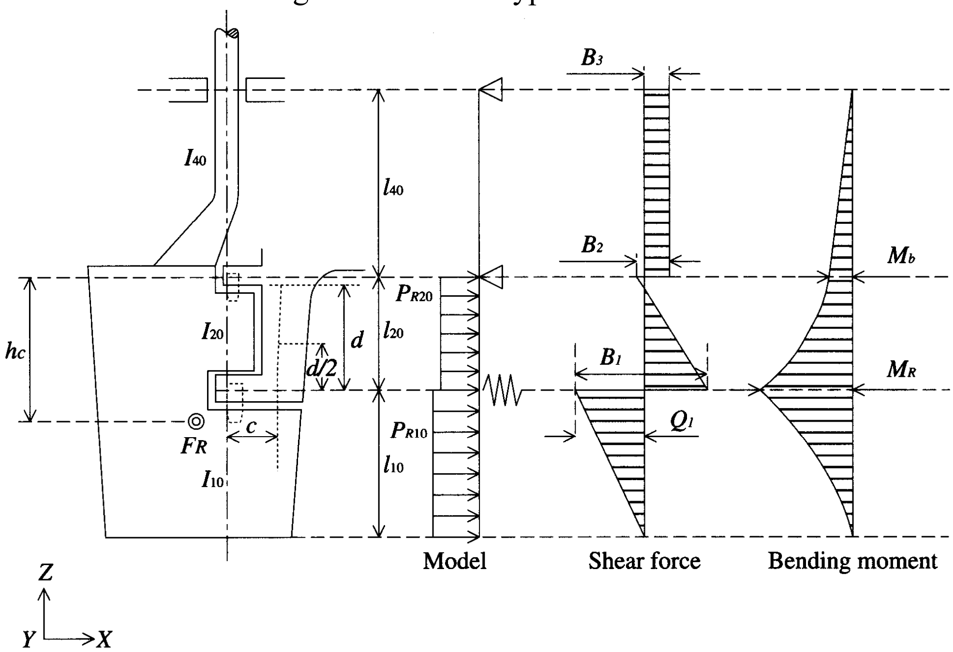


Fig. C3.4.1-6 Type *C* Rudder with rudder trunk supporting rudder stock

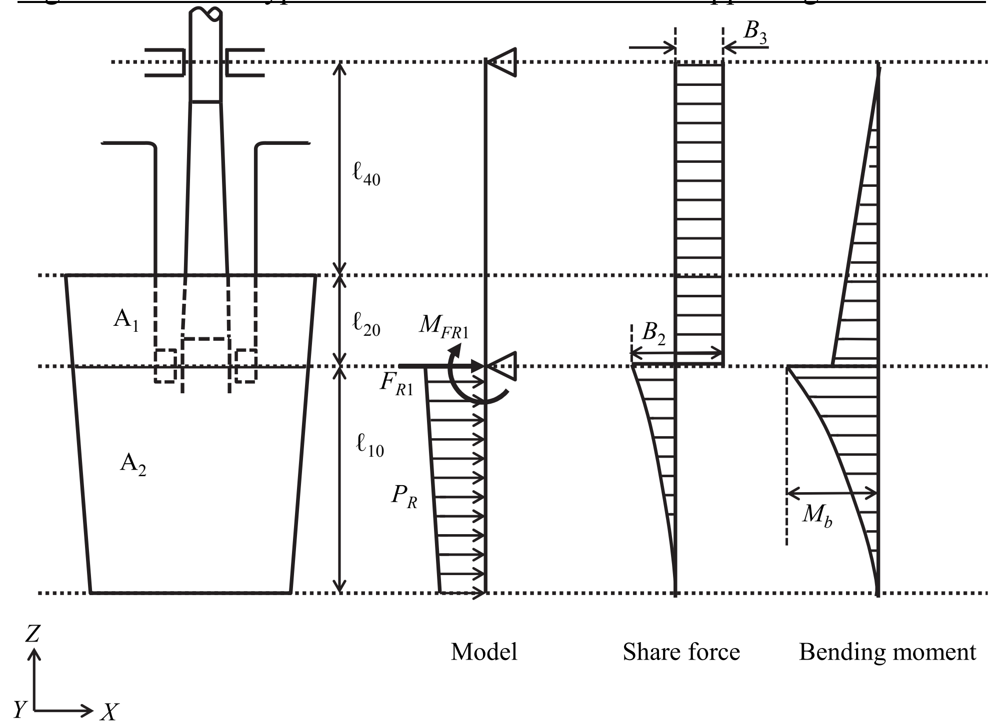
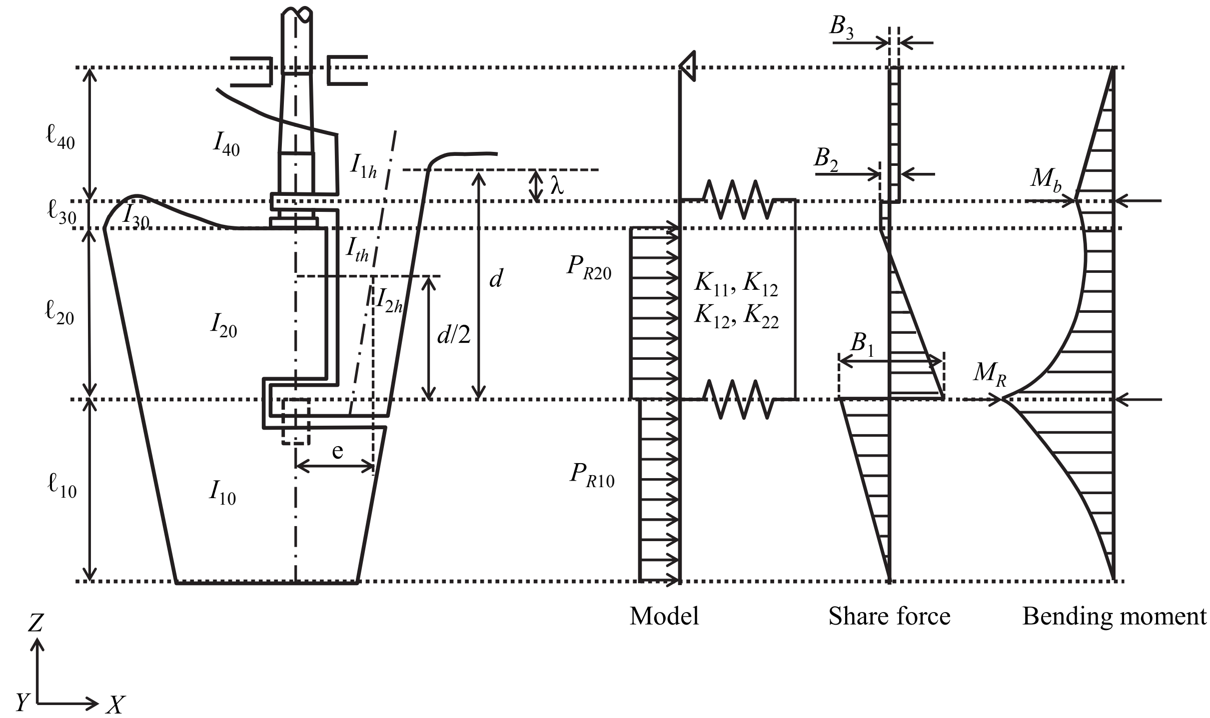


Fig. C3.4.1-7 Type *D* Rudder with 2-conjugate elastic supports



C3.5 Rudder Stocks

C3.5.1 Upper Stocks

1 Taper of upper stock at joint with tiller

Where the upper stocks are tapered for fitting the tiller, the taper is not to exceed 1/25 of the radius or 1/12.5 of the diameter.

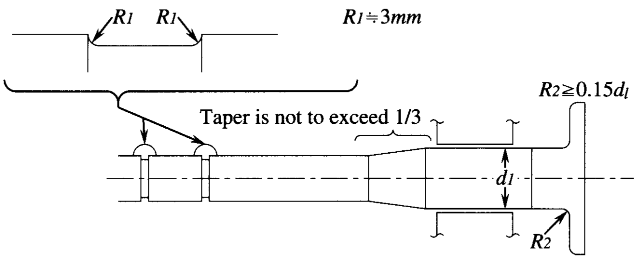
2 Keyways

(1) The depth of the keyway may be neglected in determining the diameter of the rudder stock.

(2) All corners of keyways are to be properly rounded.

3 Each part of the rudder stocks of Type *B*, *C* and *D* rudders specified in **3.5, Part C** of the Rules is to be so constructed as shown below.

Fig. C3.5.1-1 Rudder Stock of Type *B*, *C* and *D* Rudder



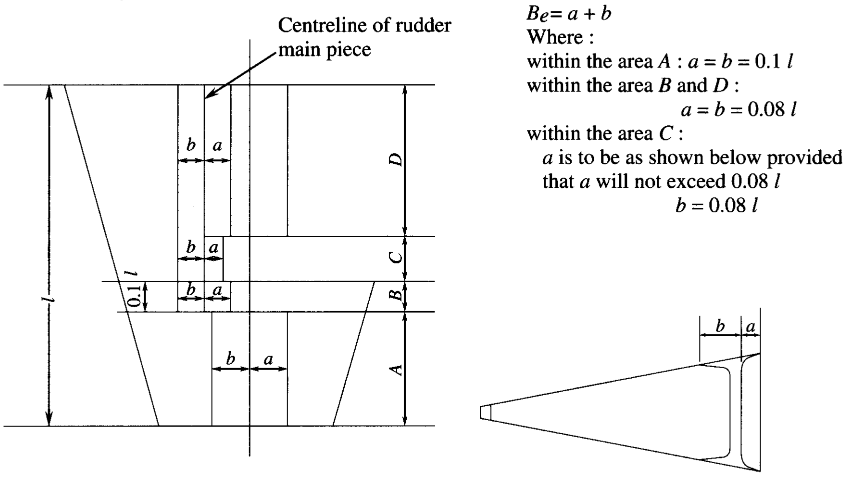
C3.6 Rudder Plates, Rudder Frames and Rudder Main Pieces

C3.6.3 Rudder Main Pieces

1 In Type *D* and Type *E* rudders, the effective breadth of the rudder plate B_e to be included in the section modulus of the main piece is to be as shown in **Fig. C3.6.3-1**. However, the cover plate which is removed to lift up the rudder is not to be included in the section modulus. These requirements also apply to Type *A* rudders.

2 Material factor K_m is to be for the lowest strength material among the materials used in the section considered.

Fig. C3.6.3-1 Effective Breadth of Rudder Plate



C3.6.4 Connections

~~1 The rudder plate is to be connected to rudder frames by spot welding as far as is practicable. **Fig. C3.6.4-1** is to be referred to as the standard for spot welding.~~

~~2~~ In principle, edge bars are to be fitted to the aft end of the rudder. However, considering the size and form of the rudder, weldability, etc., edge bars and/or chill plates may be omitted. (*See* **Fig. C3.6.4-~~2~~1**)

~~Fig. C3.6.4-1 Slot Welding~~

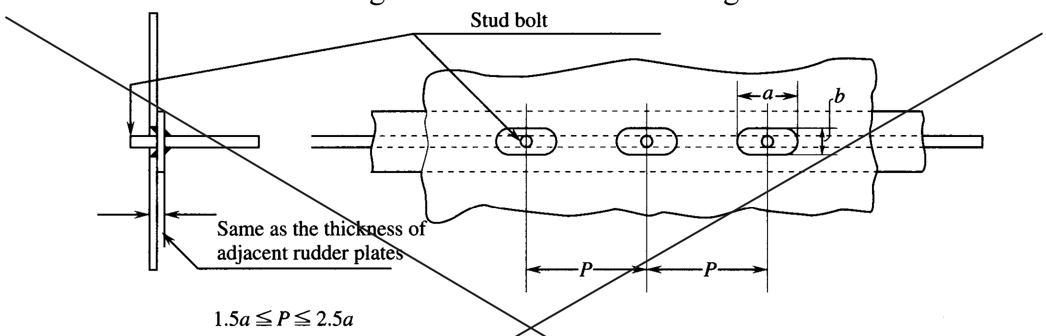
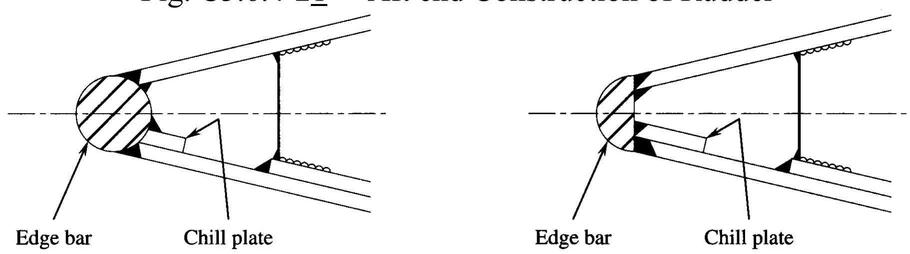


Plate thickness (*mm*)	Dimensions (*mm*)		Kind of fillet weld
	a	*b*	
Up to 6	65	35	*F*1
7~18	75	40	
19 or more	85	45	

Fig. C3.6.4-~~2~~1 Aft end Construction of Rudder



C3.~~7~~8 Couplings between Rudder Stocks and Main Pieces

C3.~~7~~8.1 Horizontal Flange Coupling

1 Diameters of coupling bolts in Type *A* and Type *E* rudders

In the application of **3.~~7~~8.1-1, Part C** of the Rules, the diameter of the coupling bolt d_l in Type *A* and Type *E* rudders is to be determined in accordance with the requirements in **3.5.2, Part C** of the Rules, assuming that the lower stock is cylindrical.

2 Locking device for nuts of coupling bolts

The nuts of coupling bolts are to have locking devices. They may be split pins.

C3.~~7.3~~8.2 Vertical Flange Couplings

1 Diameter of coupling bolts in Type *A* and *E* rudders

In the application of **3.~~7.3~~8.2-1, Part C** of the Rules, the diameter of the coupling bolt d_l in Type *A* and *E* rudders is to be determined in accordance with **3.5.2, Part C** of the Rules, assuming that the lower stock is cylindrical.

2 Locking devices for nuts of coupling bolts

The nuts of coupling bolts are to have locking devices. They may be split pins.

C3.~~7.2~~8.3 Cone Couplings with Key

1 General

(1) The lower stock is to be securely connected to the rudder body with slugging nuts or hydraulic arrangements. Shipbuilders are to submit data on this connection to the Society.

(2) Special attention is to be paid to corrosion of the lower stock.

(3) The thickness t_B of the cast steel part of the rudder body (*See* **Fig. C3.~~7.2~~8.3-1**) is not to be less than 0.25 *times* the required diameter of the lower stock.

(4) In the application of **3.~~7.2~~8.3-1** and **-~~2~~3, Part C** of the Rules, actual values are to be used for d_0, d_g and d_e.

2 ~~Keys provided on the cone coupling for rudder stocks fitted into the rudder body and secured by a nut:~~ In the application of **3.8.3-5**, the scantlings of the key are as follows in cases where all rudder torque is considered to be transmitted by the key at the couplings.

(1) The shear area A_k of keys is not to be less than:

$$A_k = \frac{30 T_R K_k}{d_k} \quad (mm^2)$$

Where:

d_k: Rudder stock diameter (*mm*) at the mid-point of length of the key

K_k: Material factor for the key as given in **3.1.2, Part C** of the Rules

T_R: Rudder torque obtained from **3.3, Part C** of the Rules

(2) The abutting surface area A_c between the key and rudder stock or between the key and rudder body, respectively, is not to be less than:

$$A_c = \frac{10 T_R K_{\max}}{d_k} \quad (mm^2)$$

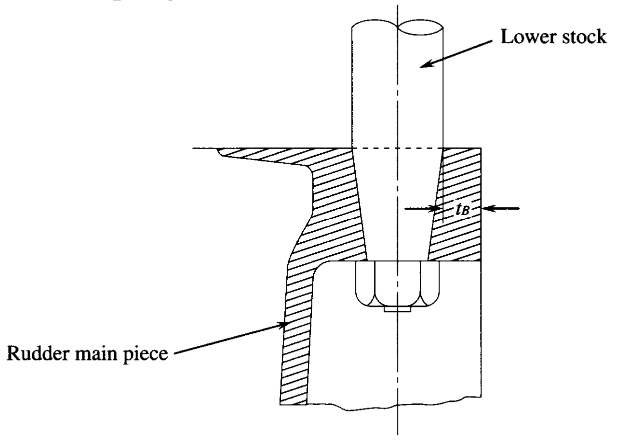
Where:

$K_{\max}$: The greater of the material factors (given in **3.1.2, Part C** of the Rules) between the rudder stock and the key it is in contact with or the greater of the material factors between the rudder body and the key it is in contact with

d_k and T_R: As specified in **(1)**

~~**3** "It is considered that rudder torque is transmitted by friction at the couplings" prescribed in **3.7.2-3, Part C** of the Rules refer to those cases in which 50% of the rudder torque is transmitted by friction at the coupling. In such cases, the value of the shear area of the key, the abutting surface area between the key and rudder stock or between the key and rudder body specified in **-2** above may be reduced to half respectively.~~

Fig. C3.~~7.2~~8.3-1 Coupling Between Lower Stock and Rudder Main Piece



C3.~~8~~9 Pintles

C3.~~8~~9.2 Construction of Pintles

1 Locking device for pintle nut

Split pins are not recommendable as the locking device for pintle nuts. Locking rings or other equivalent devices are to be used, as shown in **Fig. C3.~~8~~9.2-1**.

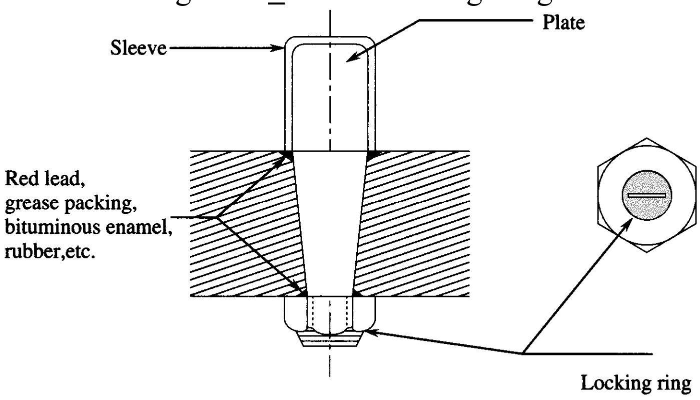
2 Preventing corrosion of pintles

To prevent corrosion of pintles, the end of the sleeve is to be filled with red lead, grease packing, bituminous enamel, rubber, etc. as shown in **Fig. C3.~~8~~9.2-1**.

3 Combination of pintle and rudder frame in monoblock

In ships exceeding 80 *m* in length, combining the pintle and rudder frame into a monoblock is not recommended.

Fig. C3.~~8~~9.2-1 Locking Ring



C3.~~9~~10 Bearings of Rudders Stock and Pintles

C3.~~9~~10.1 Minimum Bearing Area

1 Where a metal bush is used, the sleeve is to be of a different material from the bush (for example, sleeve of *BC*3 and bush of *BC*2).

2 "The type as deemed appropriate by the Society" stipulated in **Table C3.2, Part C** of the Rules means that approval is to be made in accordance with the requirements of **Chapter 5, Part 4 of Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use**.

C3.~~9~~10.3 Bearing Clearance

Where a bush is non-metal, the standard bearing clearance is to be 1.5~2.0 *mm* in diameter.

C3.1~~0~~1 Rudder Accessories

C3.1~~0~~1.1 Rudder Carriers

1 Materials of rudder carriers and intermediate bearings

Rudder carriers and intermediate bearings are to be of steel. They are not to be of cast iron.

2 Thrust bearing of rudder carrier

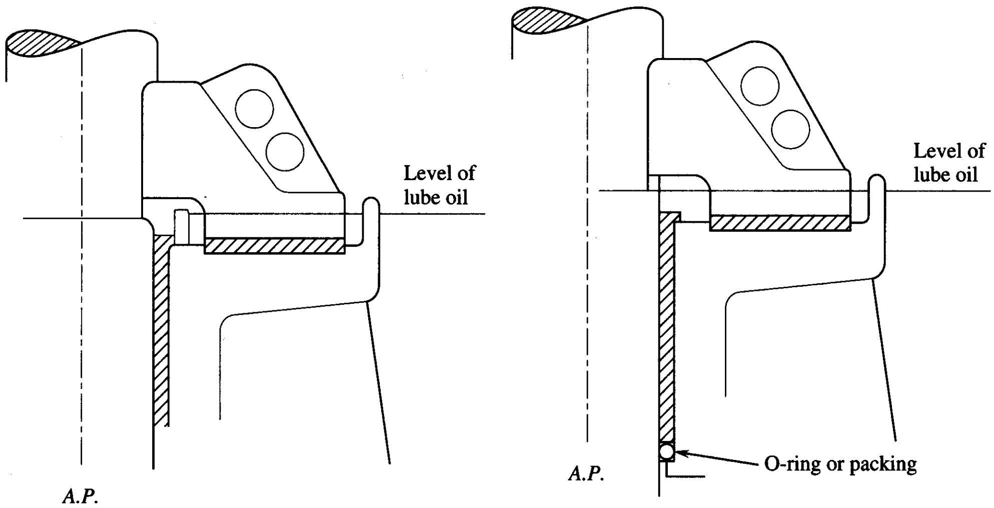
(1) The bearing is to be provided with a bearing disc made of bronze or other equivalent materials.

(2) The calculated bearing pressure is not to exceed 0.98 *MPa* as a standard. In calculating the weight of the rudder, its buoyancy is to be neglected.

(3) The bearing part is to be well lubricated by dripping oil, automatic grease feeding, or a similar method.

(4) The bearing is to be designed to be structurally below the level of lubricating oil at all times. (*See* **Fig C3.1~~0~~1.1-1**)

Fig. C3.1~~0~~1.1-1 Rudder Carrier



3 Watertightness of rudder carrier part

(1) In rudder trunks which are open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline, two separate stuffing boxes are to be provided.

(2) It is recommended that the packing gland in the stuffing box have an appropriate clearance from the rudder stock corresponding to the position of the stuffing box. The standard clearance is to be 4 *mm* for the stuffing box provided at the neck or intermediate bearing, and 2 *mm* for the stuffing box at the upper stock bearing.

4 Assembly of rudder carriers

In split type rudder carriers, at least two bolts are to be used on each side of the rudder for assembly.

5 Installation of rudder carriers

(1) In ships exceeding 80 *m* in length, it is recommended that the rudder carrier is directly installed

on the seat on the deck.

(2) A spigot type seat is not recommended to be installed on the deck.

(3) The hull construction in way of the rudder carrier is to be suitably reinforced.

6 Bolts securing rudder carriers and intermediate bearing

(1) At least one half of the bolts securing the rudder carrier and the intermediate bearing are to be reamer bolts. If stoppers for preventing the rudder carrier from moving are to be fitted on the deck, all bolts may be ordinary bolts. In using chocks as stoppers, they are to be carefully arranged so that they are not driven in, in the same direction. (*See* **Fig C3.1~~0~~1.1-2**)

(2)

(a) In ships provided with electrohydraulic steering gears, the total sectional area of the bolts securing the rudder carriers or the bearing just under the tiller to the deck is not to be less than that obtained from the following formula:

$0.1d_u^2$ (mm^2)

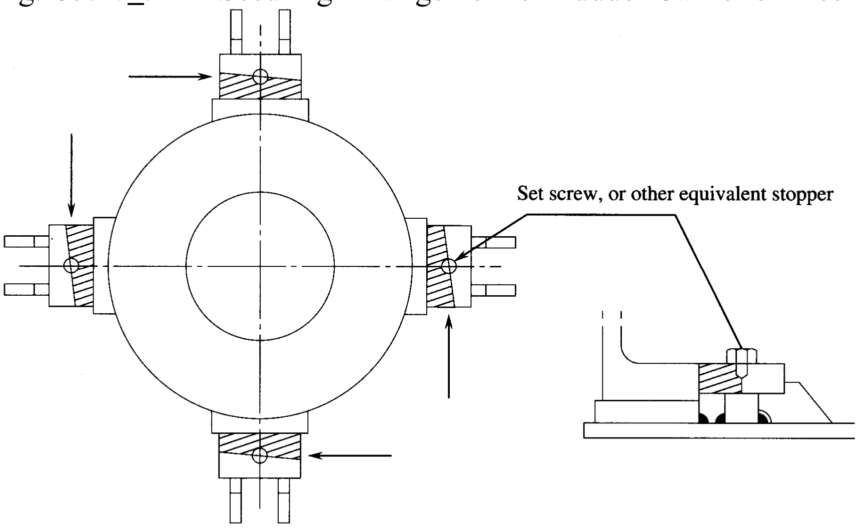
Where:

d_u: Required diameter of upper stock (*mm*)

(b) Where the arrangement of the steering gear is such that each of the two tiller arms is connected with an actuator and two actuators function simultaneously, or is of any other type where the rudder stock is free from horizontal force, the total sectional area of bolts securing the rudder carrier to the deck may be reduced to 60% of the area required in **(a)**.

(c) Where all the bolts securing the rudder carrier to the deck are reamer bolts, the total sectional area of bolts may be reduced to 80% of the area required by **(a)** and **(b)**.

Fig. C3.1~~0~~1.1-2 Securing Arrangement of Rudder Carrier on Deck



C3.1~~0~~1.2 Prevention of Jumping

A 2 *mm* clearance between the jumping stopper and ~~the rudder carrier~~ its contact surface is deemed as standard. ~~In ships provided with power-operated steering gears, this clearance is not to exceed 2 *mm*.~~

C20 HATCHWAYS, MACHINERY SPACE OPENINGS AND OTHER DECK OPENINGS

C20.2 Hatchways

Paragraph C20.2.4 has been amended as follows.

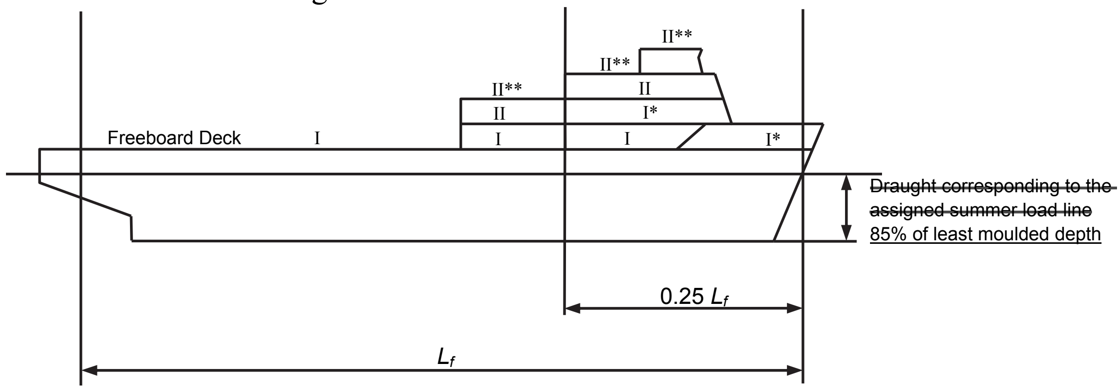
C20.2.4 Design Load

1 Design vertical wave load P_V as specified in **20.2.4(1), Part C** of the Rules is to comply with the following requirements.

(1) Positions I and II may be determined in accordance with Fig. **C20.2.4-1** and **-2**.

(2) Where an increased freeboard is assigned, the design load for hatch covers according to **20.2.4(1), Part C** of the Rules on the actual freeboard deck may be as required for a superstructure deck, provided the summer freeboard is such that the resulting draught will not be greater than that corresponding to the minimum freeboard calculated from an assumed freeboard deck situated at a distance at least equal to one superstructure standard height (as per Regulation 33 of the "*International Convention on Load Lines,* 1966 *and Protocol of* 1988 *relating to the International Convention on Load Lines,* 1966") below the actual freeboard deck (see **Fig. C20.2.4-2**).

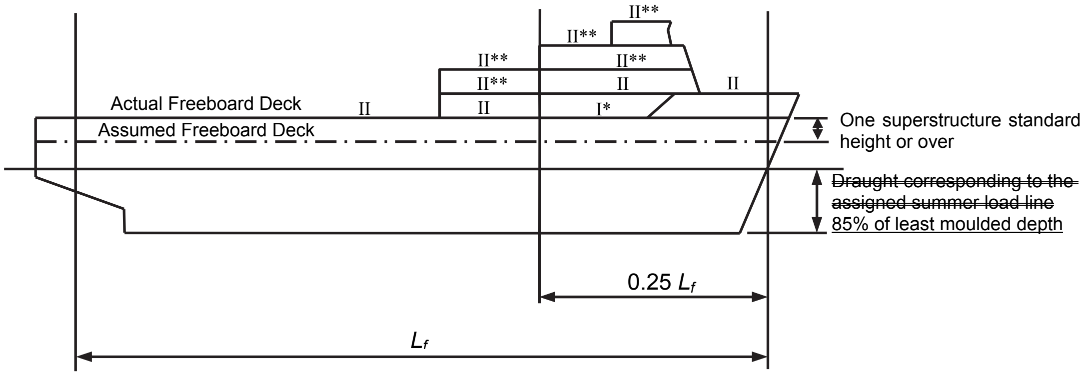
Fig. C20.2.4-1 Position I and II



* Exposed superstructure decks located at least one superstructure standard height above the freeboard deck

** Exposed superstructure decks of vessels having length L_f of greater than 100*m* located at least one superstructure standard height above the lowest Position II deck

Fig. C20.2.4-2 Position I and II for an increased freeboard

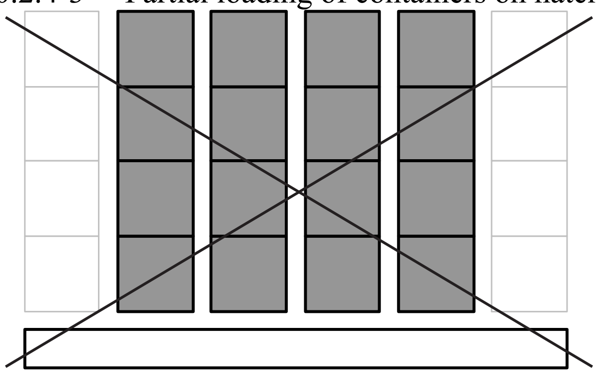


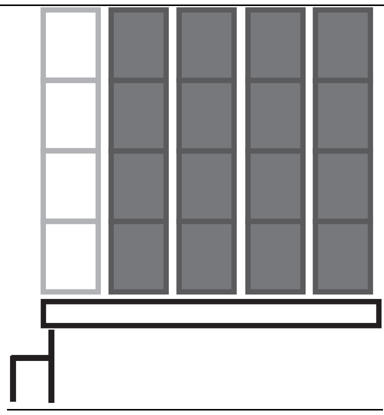
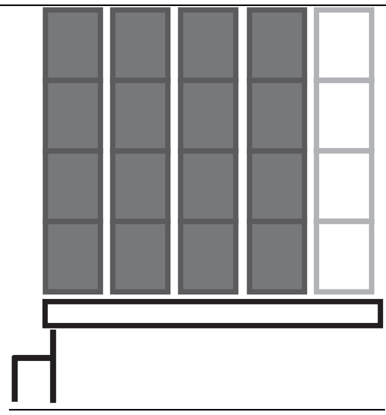
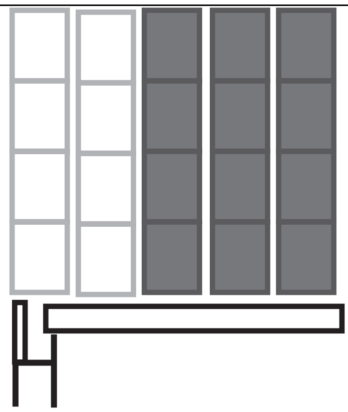
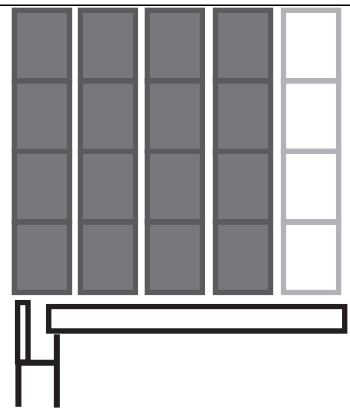
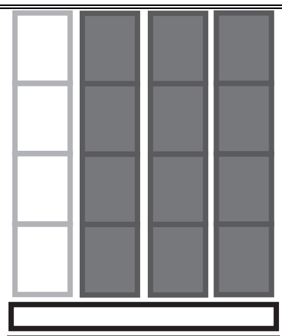
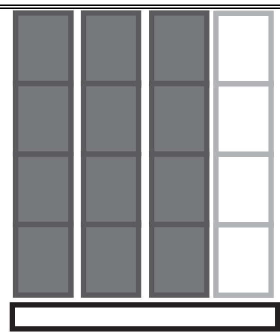
* Exposed superstructure decks located at least one superstructure standard height above the freeboard deck

** Exposed superstructure decks of ships having length L_f of greater than 100m located at least one superstructure standard height above the lowest Position II deck

2 In the application of the requirements of **20.2.4~~(3)~~(4)(a)** and **~~(4)~~(c)**, **Part C** of the Rules, load cases with the partial loading of containers on hatch covers are to be considered ~~may be evaluated using a simplified approach, in cases where the hatch cover is loaded without the outermost stacks~~ (see **Fig. C20.2.4-3**). However, where deemed necessary by the Society, load cases other than those specified in **Fig. C20.2.4-3** are to be separately considered.

Fig. C20.2.4-3 Partial loading of containers on hatch covers



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

3 The partial load cases specified in **Fig. C20.2.4-3** may not cover all partial load cases critical for the hatch cover lifting specified in **20.2.10-2, Part C**.

4 In the case of mixed stowage (e.g., 20-*foot* + 40-*foot* container combined stacks), the foot point forces at the fore and aft ends of the hatch cover are not to be higher than those resulting from the design stack weight for the 40-*foot* containers, and the foot point forces at the middle of the cover are not to be higher than those resulting from the design stack weight for the 20-*foot* containers.

C32 CONTAINER CARRIERS

C32.3 Torsional Strength

Paragraph 32.3.1 has been amended as follows.

C32.3.1 General

1 The torsional strength of the hull is to comply with the following **(1)** or **(2)**:

(1) The torsional strength of the hull at each sectional position from the collision bulkhead to the watertight bulkhead at the fore end of the machinery space is to be such that the following relationship is satisfied.

$$\sqrt{(0.75\sigma_V)^2 + \sigma_H^2 + \sigma_\omega^2} + \sigma_S \leq \frac{1000}{5.72K}$$

Where

σ_S, σ_V and σ_H : As obtained from the following formula

However, warping stress is to be added to σ_S when torsional moment is generated in the ship by unbalanced loading of cargoes.

$$\sigma_S = 1000\frac{|M_S|}{Z_V}$$

$$\sigma_V = 1000\frac{M_W}{Z_V}$$

$$\sigma_H = 1000\frac{M_H}{Z_H}$$

~~M_S : As specified in **15.2.1-1, Part C of the Rules**~~

~~M_W : M_W (+) or M_W (-) as specified in **15.2.1-1, Part C of the Rules** whichever is of the same sign as M_S~~

M_S, M_W : Vertical still water bending moment and vertical wave induced bending moment for the load cases "hogging" and "sagging" as specified in **32.2.3-8, Part C of the Rules**

M_H : As obtained from the following formula:

$0.45C_1L^2d(C_b + 0.05)C_H$ (kN-m)

C_H : Coefficient, as given in **Table C32.3.1-1**, based on the ratio of L to x, where x is the distance (m) from the aft end of L to the section under consideration. Intermediate values are to be determined by interpolation.

Z_V : Section modulus (cm^3) of strength deck with respect to longitudinal bending of the hull at the position of the section under consideration

Z_H : Section modulus (cm^3) of hatch side with respect to horizontal bending of the hull at the position of the section under consideration

C_1 : As specified in **15.2.1-1, Part C of the Rules**

Table C32.3.1-1 Coefficient C_H

x/L	0.0	0.4	0.7	1.0
C_H	0.0	1.0	1.0	0.0

σ_ω : Warping stress (N/mm^2) due to torsion of the hull calculated according to the following formula for ships of ordinary construction using the dimensions and scantlings at the midship section.

Values for other types are to be in accordance with the discretion of the Society.

$$\sigma_\omega = 0.000318 \frac{\omega l_C M_T}{I_\omega + 0.04 l_C^2 J}$$

M_T : As given by the following formula:

$$M_T = 7.0 K_2 C_w^2 B^3 \left(1.75 + 1.5 \frac{e}{D_S} \right) \quad (kN\text{-}m)$$

C_w : Water plane area coefficient

e : As given by the following formula:

$$e = e_1 - \frac{d_0}{2}$$

e_1 : As given by the following formula:

$$e_1 = \frac{(3D_1 - d_1) d_1 t_d + (D_1 - d_1)^2 t_S}{3 d_1 t_d + 2(D_1 - d_1) t_S + B_1 t_b / 3}$$

d_0 : Height of double bottom (m)

d_1 : Breadth of double hull side (m)

D_1 : As given by the following formula:

$$D_1 = D_S - \frac{d_0}{2}$$

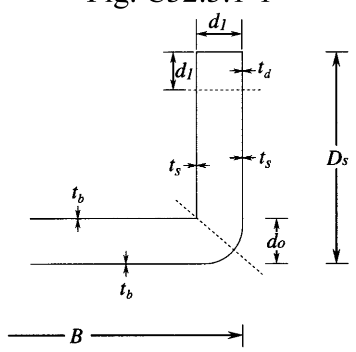
B_1 : As given by the following formula:

$$B_1 = B - d_1$$

t_d, t_s, t_b : Mean thickness (m) of deck, ship side, and bottom specified in **Fig. C32.3.1-1**

Mean thickness may be determined by including all the longitudinal strength members located within this range.

Fig. C32.3.1-1



K_2 : As given by the following formulae:

$$K_2 = \sqrt{1 - \left(\frac{300 - L_1}{300}\right)^2} \quad \text{for ships with } L_1 < 300\ m$$

1.0 for ships with $L_1 \geq 300\ m$

ω : As given by the following formula:

$$\omega = \frac{B_1}{2}(D_1 - e_1) + \frac{d_1}{2}(D_1 + e_1)$$

l_C : Distance (m) from the collision bulkhead to watertight bulkhead of the fore end of the machinery room

I_ω : As given by the following formula:

$$I_\omega = B_1^2 \{d_1 t_d I_d + (D_1 - d_1) t_S I_S + B_1 t_b I_b\}$$

I_d : As given by the following formula:

$$I_d = (D_1 - e_1)\left\{\frac{3}{2}(D_1 - e_1) - d_1\right\} + \frac{d_1^2}{3}$$

I_S : As given by the following formula:

$$I_S = (D_1 - d_1)\left\{\frac{1}{3}(D_1 - d_1) - e_1\right\} + e_1^2$$

I_b : As given by the following formula:

$$I_b = \frac{e_1^2}{6}$$

J : As given by the following formula

However, the mean thicknesses of t'_d, t'_S, t'_b are to be calculated using only the strength deck, side shell, bottom shell, inner bottom and longitudinal bulkhead plating. Other longitudinal strength members are not to be included.

$$J = \frac{2\{Bd_0 + 2(D_S - d_0)d_1\}^2}{3d_1 / t'_d + 2(D_1 - d_1)/t'_S + B_1 / t'_b}$$

K : Coefficient corresponding to the kind of steel

e.g., 1.0 for mild steel, the values specified in **1.1.7-2(1) of the Rules** for high tensile steel

(2) Torsional strength assessments are to be carried out in accordance with the **"Guidelines for Hull Girder Torsional Strength Assessment"** in the **"Guidelines for Container Carrier Structures"** In such cases, the vertical wave induced bending moment to be considered is specified in **32.2.3-6 of the Rules**.

2 Notwithstanding the requirements of **-1** above, torsional strength assessments specified in **-1(2)** above are to be carried out for any of the following cases. ~~may be required when deemed necessary by the Society.~~

(1) Ships not less than 290 m in length L_1;

(2) Ships exceeding 32.26 m in breadth B; or

(3) When deemed necessary by the Society.

C35 MEANS OF ACCESS

C35.2 Special Requirements for Oil Tankers and Bulk Carriers

Paragraph C35.2.3 has been amended as follows.

C35.2.3 Means of Access to Spaces

(-1 to -5 are omitted.)

6 With respect to the provisions of **35.2.3-4(2)**, **(4)**, **-5(3)** and **(7), Part C of the Rules**, adjacent sections of a vertical ladder are to be in accordance with following **(1)** to **(3)**. (Refer to **Fig. C35.2.3-1**, **Fig. C35.2.3-2** and **Table C35.2.3**)

(1) The minimum "lateral offset" between two adjacent sections of a vertical ladder is the distance between the sections, upper and lower, so that the adjacent stringers are spaced of at least 200 *mm*, measured from half thickness of each stringer.

(2) Adjacent sections of vertical ladder are to be installed so that the upper end of the lower section is vertically overlapped, in respect to the lower end of the upper section, to a height of 1,500 *mm* in order to permit a safe transfer between ladders.

(3) No section of the access ladder is to be terminated directly or partly above an access opening.

Fig. C35.2.3-1 Vertical ladder – ladder passing through linking platform

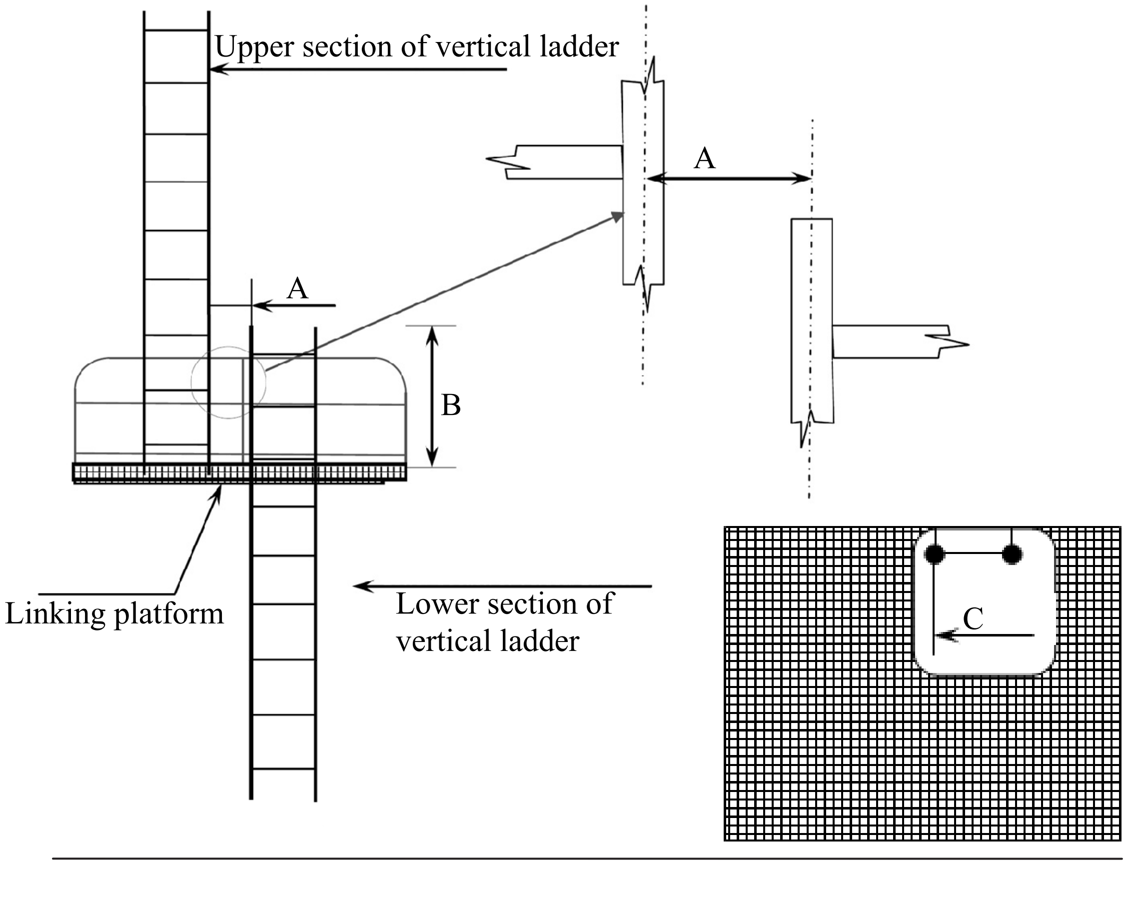


Fig. C35.2.3-2 Vertical ladder - side mount

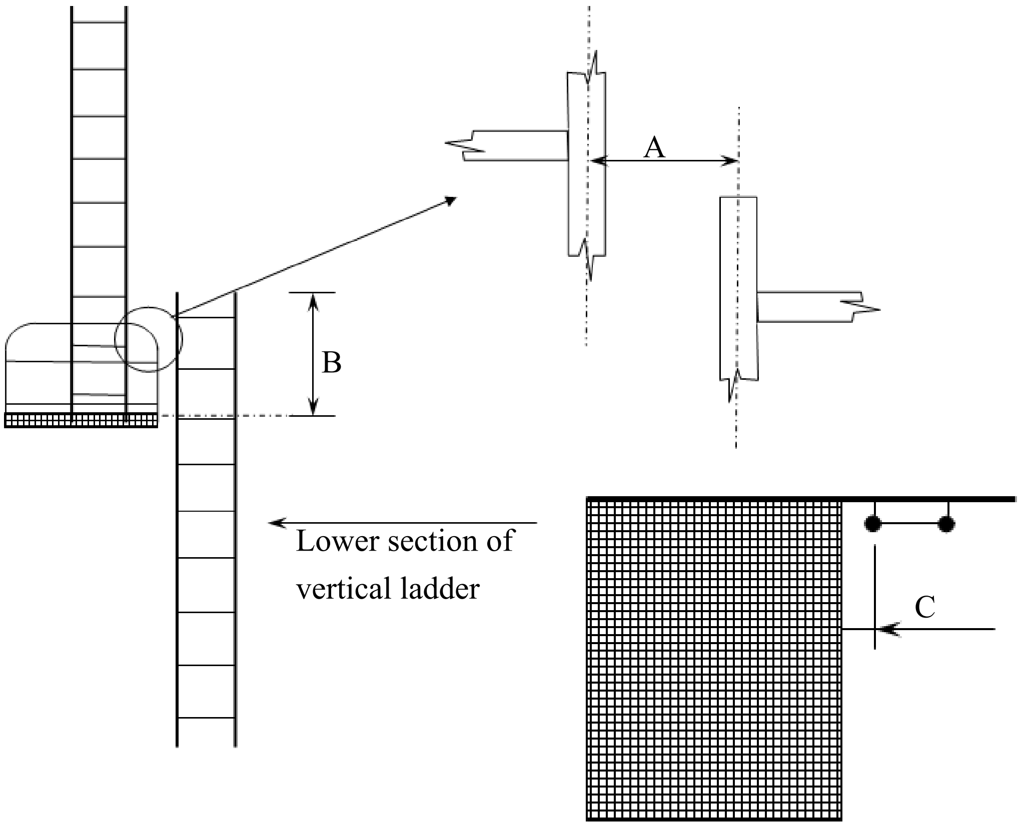


Table C35.2.3 Dimensions

A	Horizontal separation between two vertical ladders, stringer to stringer	≥ 200 *mm*
B	Stringer height above landing or intermediate platform	≥ 1,500* *mm*
C	Horizontal separation between ladder and platform	100 *mm* ≤ C < 300 *mm*
Note * : the minimum height of the handrail of resting platform is 1,000 *mm*		

Appendix C1 REFERENCE DATA FOR DESIGN

Title of Section 1.2 has been amended as follows.

1.2 Connection of Rudder Stock and Rudder Main Piece using Cone Coupling (3.~~7.2~~8.3, Part C of the Rules)

Paragraph 1.2.1 has been amended as follows.

1.2.1

~~Where the rudder stock is connected to the main piece using the keyless cone coupling with hydraulic arrangement for mounting and dismounting the coupling (mounting with oil injection and hydraulic nut)~~ Where the rudder stock is connected to the main piece using the cone coupling with a slugging nut and key and all of the rudder torque is transmitted by the key, the standard necessary push-up force and the push-up length are as determined by the following formulae;

Push-up force (F):

$$F = \frac{2T_R f_{s1}}{\mu_2 d_m}\left(\mu_1 + \frac{1}{2k}\right) \quad (kN)$$

Push-up length (Δl):

$$\Delta l = 4k\left(\frac{T_R f_{s1} \times 10^3}{\pi E \mu_2 d_m l\left(1-c^2\right)} + R_t\right) \quad (mm)$$

Permissible push-up length (Δl_{perm}):

$$\Delta l_{perm} = 2k\left(\frac{d_m \sigma_Y}{E\sqrt{3+c^4}\, f_{s2}} + 2R_t\right) \quad (mm)$$

Where:

$c = d_m / d_c$

d_m : Mean diameter (mm) of cone

d_c : Outer diameter (mm) of gudgeon at middle height of cone

μ_1 : Coefficient of friction against push-up, may normally be taken as ~~0.02~~0.14

μ_2 : Coefficient of friction against slip, may normally be taken as 0.15

R_t : Mean roughness of the contact surface, may normally be taken as 0.01 *mm*

k : Inverse number of cone taper on diameter (12～20)

E : Young's modulus of the materials of rudder stock and gudgeon, be taken as 2.06×10^5 (N/mm^2) for steel

σ_Y : Yield stress (N/mm^2) of the material of gudgeon

f_{s1} : ~~Safety factor against slip~~ Coefficient, to be taken as ~~3.0~~0.5 or over

f_{s2} : Safety factor against strength of the gudgeon, to be taken as not less than 1.25
Special consideration is to be made for couplings that are under a large bending moment in addition to the rudder torque such as those of rudder type *C*.

l : Taper length (mm) of cone

Paragraphs 1.2.2 and 1.2.3 have been deleted.

~~**1.2.2**~~

~~Where the rudder stock is connected to the main piece using the cone coupling with a slugging nut and key and all of the rudder torque is transmitted by the key, the necessary push-up force and the push-up length may be determined by applying the formulae mentioned in **1.2.1** above, taking μ_1 as 0.14 and f_{s1} as 0.5.~~

~~**1.2.3**~~

~~Where the rudder stock is connected to the main piece using a cone coupling with a key and it is considered that 50% of the rudder torque is transmitted by friction at the coupling, the necessary push-up force and the push-up length may be determined by applying the formulae mentioned in **1.2.1** above, taking μ_1 and f_{s1} as follows according to the applied method for mounting and dismounting the coupling.~~

~~f_{s1} as 1.5: in the case of hydraulic arrangements (e.g. oil injection and hydraulic nut)~~

~~μ_1 as 0.14 and f_{s1} as 1.5: in the case of a slugging nut~~

Section 1.3 has been amended as follows.

1.3 Thickness of Sleeves and Bushes (3.~~3~~10, Part C of the Rules)

1.3.1

As for the thickness of sleeves and bushes at the pintle bearing part and neck bearing part, their standard thicknesses are to be as obtained from the following formulae, where sleeves are metallic and bushes are of lignum vitae or synthetic resin. The thicknesses of sleeves and bushes are ~~not to be less than 7.5 *mm* and 10 *mm* respectively~~ as in **3.10.1, Part C of the Rules**.

(1)

(a) Thickness of pintle sleeve

$0.03 d_{po} + 5 \quad (mm)$

Where:

d_{po}: Diameter (mm) of pintle measured at outside of sleeve

(b) Thickness of bush of pintle bearing

$d_{po} < 300$: $0.05 d_{po} + 5 \quad (mm)$

$d_{po} \geq 300$: $0.03 d_{po} + 11 \quad (mm)$

Where:

d_{po} :As per **(1)(a)** above

(2)

(a) Thickness of rudder stock sleeve at neck bearing

$0.03 d_l + 3 \quad (mm)$

Where:

d_l: Diameter of lower stock (mm)

(b) Thickness of bush of neck bearing

$d_l < 300$: $0.05 d_l + 2 \quad (mm)$

$d_l \geq 300: \ 0.03d_l + 8 \quad (mm)$

Where:

d_l: As per **(2)(a)** above

EFFECTIVE DATE AND APPLICATION (Amendment 1-3)

1. The effective date of the amendments is 1 July 2016.

2. Notwithstanding the amendments to the Guidance, the current requirements may apply to ships for which the date of contract for construction* is before the effective date.

* "contract for construction" is defined in the latest version of IACS Procedural Requirement (PR) No.29.

IACS PR No.29 (Rev.0, July 2009)

1. The date of "contract for construction" of a vessel is the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. This date and the construction numbers (i.e. hull numbers) of all the vessels included in the contract are to be declared to the classification society by the party applying for the assignment of class to a newbuilding.

2. The date of "contract for construction" of a series of vessels, including specified optional vessels for which the option is ultimately exercised, is the date on which the contract to build the series is signed between the prospective owner and the shipbuilder.

For the purpose of this Procedural Requirement, vessels built under a single contract for construction are considered a "series of vessels" if they are built to the same approved plans for classification purposes. However, vessels within a series may have design alterations from the original design provided:

(1) such alterations do not affect matters related to classification, or

(2) If the alterations are subject to classification requirements, these alterations are to comply with the classification requirements in effect on the date on which the alterations are contracted between the prospective owner and the shipbuilder or, in the absence of the alteration contract, comply with the classification requirements in effect on the date on which the alterations are submitted to the Society for approval.

The optional vessels will be considered part of the same series of vessels if the option is exercised not later than 1 year after the contract to build the series was signed.

3. If a contract for construction is later amended to include additional vessels or additional options, the date of "contract for construction" for such vessels is the date on which the amendment to the contract, is signed between the prospective owner and the shipbuilder. The amendment to the contract is to be considered as a "new contract" to which **1.** and **2.** above apply.

4. If a contract for construction is amended to change the ship type, the date of "contract for construction" of this modified vessel, or vessels, is the date on which revised contract or new contract is signed between the Owner, or Owners, and the shipbuilder.

Note:

This Procedural Requirement applies from 1 July 2009.