QRS Class
QUALITAS REGISTER of SHIPPING

VOLUME IV

Hull

The present edition of Hull, Volume IV has been approved by the General Manager and will enter in force on May 15, 2023.

The present edition of Hull is based on the 2016 edition taking into account the amendments developed immediately before publication.

HULL

Volume IV

Contents

HULL

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1 Amended paragraph/ sections	Information on amendments	Entry-into-force date
	Hull – Volume IV has been reorganized to facilitate its use for all concerned parties (Purely Editorial Context)	01.02.2023
1.7.4.6	Requirements have been specified considering the experience in application of the Rules	01.02.2023
2.2.4 (c)	Requirement regarding the thickness of adjoining strakes has been specified	21.02.2023
2.2.4 (d)	Requirement regarding the thickness of the bottom shell plating has been specified	05.01.2015
2.10.4 (g)	Requirements of the rules have been specified	05.01.2015
	Several Existing Terms have been specified for ease of reading	

Section

1   General requirements for hull construction

2   General requirements for hull structures

3   Requirements for structures of ships of special design

SECTION 1
General

1.1   Application

The present Chapter of the Rules applies to steel ships facilities of welded construction, from 24 to 350 m.

1.1.2   Scope of supervision

a) The general provisions for supervision of the hull are set forth in *General Regulations for Classification*.

b) All hull structures regulated by the present Chapter of the Rules shall be subjected to supervision of QRS Class.

c) During manufacture, the structures regulated by the present Chapter of the Rules are to be submitted to inspection for compliance with the requirements of materials in the relevant Chapter and for compliance with the approved technical documentation.

d) The tightness tests of ship's hull are to be carried out according to the provisions of *Annex 1*.

Dimensions and draught
Length of ship L is the distance, in m, measured on the summer load waterline from the fore side of the stem to the after side of rudder post, or to the center of the rudder stock if there is no rudder post, or the distance equal to 96 per cent of the ship's length on the summer load waterline from the fore side of the stem to the after side of after end of ship, whichever is the greater. However, L shall not be taken greater than 97 per cent of the ship's length on the summer load waterline.
Breadth B is the maximum breadth, in m, measured amidships between the outer sides of the hull.
Depth D is the vertical distance measured amidships from the top of the plate keel or from the point where the inner surface of shell plating abuts upon the bar keel, to the top of the upper deck beam at side. In ships having a rounded gunwale the depth is measured to the point of intersection of the moulded lines of upper deck and side, the lines extending so as if the gunwale were of angular design.
Draught d is the vertical distance measured amidships from the top of the plate keel, or the point where the inner surface of the shell plating abuts upon the bar keel, to the summer load waterline. In ships with timber freeboard the draught shall be measured at side to the summer timber load waterline

Decks and platforms
Upper deck is the uppermost continuous deck extending the full length of the ship.
Strength deck is the deck forming the upper flange of the hull girder. The uppermost continuous deck or the deck of a midship superstructure.
Bulkhead deck is the deck to which the main transverse watertight bulkheads are carried.
Freeboard deck is the deck from which the freeboard is calculated.
Lower decks are the decks located below the upper deck. Where the ship has several lower decks, they shall be called: second deck, third deck, and so on., counting from the upper deck.
Platform is a lower deck extending over portions of the ship's length or breadth.
Superstructure deck is a deck forming the top of a tier of superstructure. Where the superstructure has several tiers, the superstructure decks shall be called as follows: first tier superstructure deck, second tier superstructure deck, and so on., counting from the upper deck.

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Erections

Superstructure is a decked structure on the upper deck extending from side to side of the ship.

Deckhouse is a decked structure on the upper deck or superstructure deck having doors, windows and other similar openings in the outer bulkheads and with its side plating, on one side at least.

Quarter deck is the aftermost part of the upper deck which raises to a height, not greater than the tween deck height.

Trunk is a structure on the upper deck limited by a deck in the upper part with is side plating, on one side at least.

Basic notions

Forward and after perpendiculars are vertical lines run through the foremost and aftermost ends of the length L, respectively, taken at the center line.

Midship section is the hull section at the middle of ship's length L.

Midship region is the part of the ship's length equal to 0,4L (0,2L forward and aft of amidships), unless expressly provided otherwise.

Machinery space aft corresponds to the position of the mid-length of the machinery space beyond 0,3L aft of amidships.

Explanations

Summer load waterline is the waterline on the level of the center of the load line ring for the ship's position without heel and trim.

Block coefficient C_b is the coefficient at draught d corresponding to summer load waterline, based on length L and breadth B, determined from formula:

$$= \frac{\left(\quad\right)}{}$$

$g = 9{,}81$ m/s² - acceleration due to gravity

$\rho = 1{,}025$ t/m³ - density of sea water

v_o - ship's specified speed, in knots

Tight structure is a structure impervious to water and other liquids.

Normal frames are vertical elements of the side reinforcement, placed at the floor or at the bilge brackets level at frame spacing between each one of them.

Intermediate frames are additional frames located between the aforementioned.

Spacing

Standard spacing is the distance a_o between frames/longitudinals, in m, obtained from the formula:

$$a_o = 0{,}002L + 0{,}48$$

Variation from the standard spacing is allowed to be ± 25 per cent. In the fore and after peaks the spacing of frames is not to exceed 0,6 m; between the fore peak bulkhead and 0,2L aft of the forward perpendicular is not be more than 0,7 m. Variations from these values are to be subject to special consideration by QRS Class.

In all cases the spacing of frames/longitudinals is not to exceed 1 m.

1.1.4 Basic provisions for determining the scantlings of hull members

a) The scantlings of hull members are to be regulated based upon the Rule design loads, calculation methods and safety factors by the middle of service life of a ship and taking into consideration maximum thickness reductions per structural member as stated in this Chapter.

b) Determination of the scantlings of hull members in the Rules is based on structural idealization using beam models subject to bending, shear, longitudinal loading, and torsion having regard to the effect of adjacent structures.

c) For material selection and calculations of structural materials to be used in vessels of New Constructions, please contact QRSHO.

d) The requirements for strength of structural members and structures as a whole aiming at determining their scantlings and strength characteristics is set forth in the Rules by assigning the specified values of permissible stresses.

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For design normal stresses

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For shear stresses

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where: k_σ = factor of permissible normal stresses;
          k_τ = factor shear stresses.

The values of k_σ and $k\tau$ are given in the relevant chapters of the Rules.

e) The buckling strength requirements are imposed upon the structural members subject to the action of considerable compressive normal and/or shear stresses as indicated in this Chapter.

f) The thicknesses of the structural members of the hull, determined according to the requirements of the present Chapter of the Rules are to be not less than the minimum thicknesses specified for particular structures as indicated in this Chapter. The minimum thicknesses are given for structural members of ordinary carbon steel. When higher strength steel is used, the minimum thickness may be reduced with the authorization of QRSHO once they have carried out the relevant calculations. This reduction does not apply to the minimum thicknesses of the center girder, side girders and floors of Group I ships and to the minimum thicknesses of the structures within the cargo and ballast tanks of Group II ships, as well as to the plating and framing of tanks in ships of Groups I and II. In all cases, unless expressly provided otherwise, the thickness of hull members is to be not less than 4 mm.

g) The requirements for determining the scantlings of hull members in the present Chapter of the Rules assume that measures are taken during construction and operation of the ship for corrosion protection of the hull in compliance with the standards and other regulating documents in force recognized by QRS Class.

1.1.5   Allowances for wear and corrosion

a) Allowances for wear and corrosion Δs, in mm, shall be determined from the formula:

$\Delta s = u\ (T - 12)$

where: u = average annual reduction of the member thickness, in mm per annum, due to corrosion wear or tear.
          T = planned service life of structure, in years; if service life is not specially prescribed, T should be taken equal to 24.

For the structures whose planned service life is less than 12 years, $\Delta s = 0$.

b) Division of all ships may be divided into two groups depending on corrosion wear conditions:
Group I: dry cargo ships and similar ships depending on service conditions.
Group II: tankers, bulk carriers, and similar ships depending on service conditions.
        If necessary (at the Owner's request), a decrease of thicknesses and dimensions of the hull elements maybe agreed with QRS Class. The decrease of thicknesses and dimensions are to be indicated in the hull structure plans, which are to be submitted to QRS Class.
        The ships for which QRS Class permits decrease of the stiffener dimensions, shall receive a special mark in the Classification Certificate.

c) The fore and after peaks bulkheads and bulkheads of the machinery space and the stern tubes in cargo ships.

Hull

.1 The fore peak bulkhead is to be watertight up to the freeboard deck. This bulkhead is to be located at a distance from the forward perpendicular of not less than 5 per cent of the length of the ship or 10 m, whichever is the less.

.2 Where a long forward superstructure is fitted the collision bulkhead is to be extended weathertight to the deck next above the freeboard deck.

.3 The number of openings in the extension of the fore peak bulkhead, above the freeboard deck; is to be restricted to the minimum compatible with the design and normal operation of the ship.

.4 The stern tubes are to be finished in a watertight compartment (or compartments) of low volumes. To reduce to the most the danger of water leaking in a ship due to a damage in stern tubes some measures could be taken.

Please find below the Maximum Permissible Diminution Levels required for Hull members on tables 1800 and 1900.

Table 1800
Maximum Permissible Diminution Levels of Individual Plates and Stiffeners

STRUCTURAL ITEL	CATEGORY I SHIPS	CATEGORY II SHIPS
Hull Envelope: Individual plates, shell and deck plating recorded along the strake.	20%	30%
Hull Envelope: Transverse section plates. (deck and sheer/bottom and side).	20%	30%
Longitudinal Structural Members (including deck and shell longitudinal stiffeners, longitudinal bulkhead plating and stiffeners, inner bottom plating and stiffeners, hopper sloping plating and stiffeners.	*(Plating)* 20% *(Stiffeners)* 25%	*(Plating)* 30% *(Stiffeners)* 25%
Transverse structural members in C.O. and W.B. Tanks (Including web frame plating and face plates).	20%	25%
W.T. and O.T. transverse bulkheads	*(Plating)* 25% *(Stiffeners & Corrugated Bulkhead Plating)* 25%	*(Plating)* 30% *(Stiffeners & Corrugated Bulkhead Plating)* 25%
Miscellaneous structural members (including deck plating inside the line of cargo hatch openings)	*(Plating)* 25% *(Stiffeners)* 25%	*(Plating)* 30% *(Stiffeners)* 25%
Cargo holds transverse frames and brackets	20%	25%

Notes
Note 1: Additional Bulk Carrier diminution criteria:
   (a) Corrugated parts within cargo holds designed to be fully filled with salt water ballast (deep tank) – 25%
   (b) Corrugated parts within cargo holds designed to be partially filled with salt water ballast – 15%
   (c) Corrugated parts of the aft transverse bulkhead of the forward cargo hold – 15%
   (d) Corrugated parts of the remaining transverse bulkheads in cargo holds – 20%
   (e) All plain transverse bulkhead plating – 25%

Note 2: The maximum diminutions are for the average thickness measured over the plate area or over the length between supports.

Table 1900

Maximum Permissible Diminution Topside and Bottom Areas

Structural Item		Category 1 Ships		Category 2 Ships		Category 3 Ships	
		over 0.5L amidships	at 0.075L from ends	over 0.5L amidships	at 0.75L from ends	over 0.5L amidships	at 0.75L from ends
Topside Area	Plating	10%	20%	10%	30%	15%	30%
	Longitudinals	15%	25%	15%	25%	20%	30%
Bottom Side	Plating – Single bottom construction	10%	20%	10%	30%	15%	30%
	Plating – Double bottom construction	15%	20%	15%	30%	20%	30%
	Longitudinales	15%	25%	15%	25%	20%	30%

NOTES

1) Intermediate values to be obtained by linear interpolation.
2) Topside area comprises deck, stringer and sheer strake together with associated longitudinals.
3) Bottom area comprises keel, bottom and bilge plating together with associated logitudinals.
4) Greater diminutions may be permitted under certain circumstances after verification by QRSHO.
5) Ship categories are defined as follows:
   Category 1: Oil tankers, chemical tankers, dry bulk cargo ships and liquified gas ships of 90 meters or more LOA.
   Category 2: All other ship types not defined above of 90 meters or more.
   Category3:   All ships having an LOA of less than 90 meters.

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d)   Double bottom in cargo ships other than tankers.

.1   A double bottom shall be fitted extending from the collision bulkhead to the after peak bulkhead, as far as this is practicable and compatible with the design and proper working of the ship.

.2   The double bottom depth shall be in conformity with *2.4.4 (a)* , and the inner bottom shall be continued out to the ship's side in such a manner as to protect the bottom to the turn of the bilge.

.3   Small wells constructed in the double bottom, in connection with the drainage arrangements of holds shall not extend in depth more than necessary. A well extending to the outer bottom may, however, be permitted at the after end of the shaft tunnel of the ship. Other wells may be permitted if the arrangements give protection equivalent to that afforded by a double bottom complying with the present paragraph.

.4   A double bottom need not to be fitted in way of watertight compartments used exclusively for the carriage of liquids, provided the safety of the ship in the event of bottom damage is not thereby impaired.

1.2   Materials

1.2.1   General

The materials used for hull structures regulated by this Chapter, are to comply with the relevant materials requirements.

1.2.2   Steel for hull structures

a)   This Chapter requires for the construction of hull structures the use of normal strength structural steel of grades A, B, D and E with upper yield stress MPa and high strength structural steel of grades A32, D32, E32 and F32 with $R_{eH} = 315$ MPa; steel of grades A36, D36, E36 and F36 with $R_{eH} = 355$ MPa and A40, D40, E40 and F40 with $R_{eH} = 390$ MPa. The use of steels of grades D, E and F with $R_{eH} > 420$ MPa, shall be specially considered by QRSHO.

b)   In case of high local stresses in the thickness direction, steel with improved thickness properties is to be used for the construction of structural members having a thickness more than 18 mm.

c)   Where clad steel is used, its mechanical properties are to be not lower than those required for steel grade specified in *1.2.3*.

1.2.3   Selection of steel grades for hull structures

a)   Steel grades for structural members, including those intended for prolonged exposure to low service temperatures, are to be selected according for various categories of structural members based on the adopted design thickness of the structure determined by a method approved by QRSHO.

b)   The design temperature of hull structures located within the refrigerated cargo spaces is to be assumed equal to the temperature in the refrigerated cargo space.

c)   The design temperature of the structures forming boundaries of the refrigerated cargo spaces is to be assumed as follows:
–With no insulation fitted on the side of the refrigerated cargo space, the temperature in this space. With insulation fitted on the side of the refrigerated cargo space and with no insulation on the other side, the temperature on the uninsulated side of the boundary in the space. With insulation fitted on both sides, mean of the temperatures in the adjacent spaces.

d)   For structures with high level of stress concentration, subject to dynamic loads (for example when mooring at sea) or being in combined stress state, the use of Grade D or Grade E steel may be required. Steel of Grade A is not permitted.

1.2.4 **Anticorrosive protection and coatings.**

a) Effective protective coatings complying with the requirements shall be applied to ballast tanks.
   It is recommended to protect the inner spaces of cofferdams, duct keels, supports of transverse bulkheads and other similar void spaces of oil tankers and bulk carriers with approved protective coatings.

b) Anti-fouling coatings of ship hulls, in case of their application, shall also be approved materials.

c) For cargo tanks of oil tankers of 5000 t deadweight and over carrying crude oil, one of the following effective measures on corrosion protection shall be implemented:

-applying protective coatings in compliance with IMO resolution MSC.288(87).
-using alternative means of protection or corrosion resistant materials to maintain the required structural integrity for 25 years in accordance with IMO resolution MSC.289(87).

1.3 **Design load**

1.3.1 **General requirements**

a) This Chapter contains the basic formulas for determining the design weather loading on hull, ship acceleration at motions as well as loading from dry and liquid cargoes.

b) Wave impacts loading on the forward portion of the bottom and flare, loading from vehicles and deck heavy cargo as well as emergency loading are given in the chapters of the Rules pertaining to the appropriate structures.

c) Rules for determining the value and the load point of the design loading are specified in the appropriate chapters of the Rules pertaining to structures. In the absence of such provisions the loading is assumed to be on the lower edge of the plate, at the middle of design span of the member or at the center of the area taking up distributed pressure.

d) The basic parameter of design loading and accelerations on ship's hull exposed to weather is the wave factor determined from the formula:

$$C_w = 0,0856 \cdot L \qquad \text{For} \quad L \geq 90 \text{ m}$$
$$C_w = 0,0856 \cdot L$$

$$= \qquad \frac{\qquad}{\qquad} \qquad \text{for} \quad 90 < L < 300 \text{ m}$$

$$C_w = 10,75 \qquad \text{for} \quad 300 \leq L \leq 350 \text{ m}$$

1.3.2 **External loading on ship's hull exposed to weather**

a) The design pressure p, in kPa, acting on ship's hull exposed to weather is determined from the formula:
For the points of application of the loads below the summer load waterline:

$$p = p_{st} + p_w$$

For the points of application of the loads above the summer load waterline:

$$p = p_w$$

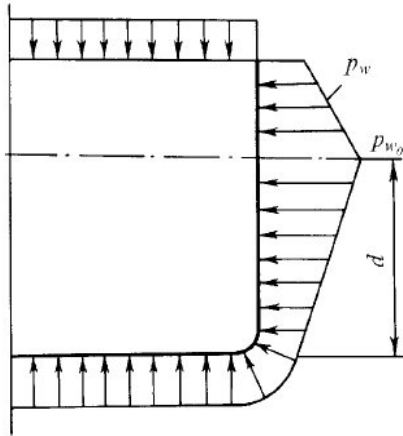where: p_{st} = static pressure, in kPa, determined

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from the formula:

$$p_{st} = \rho \cdot g \cdot z_i;$$

z_i = distance of the point of application of the load from the summer load waterline, in m;

p_w = as defined in this section.

b)   For design pressure calculations due to ship's hullmotion about wave contour, please contact QRSHO.

Figure 100 Cargo distribution by the contour of the transversal section

For the areas above the summer load waterline the pressure is not to be taken less than ⎯ +   or 5 Mpa, whichever is the greater.

The   distribution of the load p_w, over the hull section contour is shown in *fig 100*.

1.3.4   Cargo, fuel and ballast loading

a)   Design pressure p_r, in kPa, on the grillages of cargo decks, platforms and double bottom from general cargo is to be determined having regard to inertia forces from the formula:

$$= \quad (+ \ / \ )$$

but not less than 20 kPa.

where: h = design stowage height, m;
ρ_r = density of the cargo carried, in t/m³;

$$a_z = \sqrt{ + \ + }\ \sqrt{ + \ + }\ ,$$
in m/s²;

b)   The design pressure on the structures forming boundaries of the compartments intended for the carriage of liquid cargoes and ballast in oil tankers, the ballast tanks in dry cargo ships as well as oil fuel is determined depending on their dimensions, the extent of filling and the height of air pipe. By   compartment it is meant a tank or a portion of a tank confined between the effective bulkheads. Both watertight and wash bulkheads with the total area of openings not over 10 per cent of the bulkhead area are considered effective bulkheads.

.1   With compartment length $l \leq 0,15L$ and maximurn compartment breadth $b \leq 0,75B$ (*l* and *b* are measured at mid-height of compartment), the design pressure p_c, in kPa, is to be determined for the case of complete filling of a compartment from the formula:

$$= \quad (\quad + \quad) \quad + (\quad + \quad) \quad + \quad (\quad + \quad)$$

but not less than:

$$= \quad (\quad + \quad) \qquad = \quad (\quad + \quad)$$

where: $=$ density of liquid cargo, t/m³;

a_z $=$ as defined in *1.3.4;*

z_i $=$ distance of the concerned member from the deck level in the center line forming   boundaries   of   the compartment,   in   m;   when determining the design pressure on wash bulkheads, $z_i = 0$;

x_i $=$ distance of the concerned member from the transverse vertical plane passing through the center of gravity of the compartment volume in a balanced position in still water, in m;

y_i $=$ distance of the concerned member from the longitudinal vertical plane passing through the center of gravity of the compartment volume in a balanced position in still water, m.

.2   With compartment length $l > 0,15L$ and/or compartment breadth $b > 0,75B$ or where, proceeding from service conditions, the compartment is to be filled partially only (irrespective of size), the design pressure shall be determined by a special procedure approved by *QRS Class*. For approximate determination of design pressures on the transverse and longitudinal bulkheads the following formula may be used:

For transverse bulkhead over an area of width *0,25b* from the center line on starboard and port:

$$= \quad (\quad + \quad + \quad)$$

For longitudinal bulkhead as well as transverse bulkhead over an area of width *0,25b* from the line of intersection of longitudinal and transverse bulkheads:

$$= \quad (\quad + \quad + \quad)$$

where: $=$ as defined in *1.3.4*;

l $=$ distance of the concerned member from free surface level of liquid in a balanced position in still water, in m.

.3   The design pressure on ballast tank structures of dry cargo ships as well as the tanks for oil fuel and lubricating oil shall be determined from the formula:

$$= \quad (\quad + \quad) \quad = \quad (\quad + \quad)$$

where: $\mathbf{1}$ $=$ density of sea water and lubricating oil depending on tank purpose, in t/m³;

$=$ height of air pipe above the tank top, in m;

z_i = as defined in *1.3.4*.

c) The design pressure p_r, in kPa, on structures forming boundaries of the hold for bulk cargo shall be determined from the formula:

$$= \qquad (\quad + \quad)$$

but not less than 20 kPa.

where: ρ_r = as defined in *1.3.4*.

$$= (\quad) \left(\qquad \right) + (\quad) \qquad = (\quad) \left(\qquad \right) + (\quad)$$

where: $\smile$ = angle of web inclination to horizon, in deg.; $k_c = 1$ at $|\alpha - 57,3 \cdot \theta| < 10°$;

$\smile$ = for transverse bulkheads $\theta = 0$;

= angle of internal friction of the bulk cargo, in deg.;

a_z = as defined in *1.3.4*;

z_i = vertical distance from the point of application of load to the cargo free surface level, in m.

The pressure on inner bottom is to be determined from the *formula* in section *1.3.4* (c), where $k_c = 1$.

d) The design pressure on the structures in horizontal plane is determined with regard for inertia forces. When determining accelerations, the acceleration in the horizontal-transverse direction is determined from the formula:

$$= \sqrt{ \quad + \left(\quad + \quad \right) }$$

and in the horizontal-longitudinal direction:

$$= \sqrt{ \quad + \left(\quad + \quad \right) }$$

1.4 Longitudinal strength

1.4.1 General provisions and definitions

a) The present requirements apply to ships with _____ m.

b) Special consideration by QRS Class is to be required for ships with:
.1 Ratios of main dimensions:

$L/B \geq 5.$
$B/D \leq 2,5$

.2 Block coefficient $C_b < 0,6$.
.3 specified speed v_o exceeding the value υ, in knots, determined from the formula:

$$\upsilon = k \cdot \sqrt{L}$$

where: $\quad k = \quad$ 2,2 for $L \leq 100$ m;

$\qquad k = \quad 2,2 - 0,25 \cdot \dfrac{L-100}{100}$ for $L > 100$ m.

Special consideration will also be given to ships carrying heated cargoes and ships of unusual design and/or type.

c) For **Longitudinal Strength** calculation, design loads shall include still water bending moments and shear forces, wave bending moments and shear forces, and ships with large flare, bending moments due to wave impacts on the flare as well. Design wave and impact loads may be determined both from formula given in the Rules and by an approved calculation method taking into consideration the rolling in waves, long-term distribution of wave conditions and areas of navigation.

d) Downward shear forces are assumed to be taken as positive values and upward shear forces as negative values. The hogging bending moments are assumed to be taken as positive values and sagging bending moments as negative values. For the calculation of still water bending moment and shear force, transverse loads are to be integrated in the forward direction from the aft end of the length; in this case downward loads are assumed to be taken as positive values.

1.4.2 Symbols

a) The following symbols have been adopted:

L_1 : Length of the compartment considered, in m..

B_1 : Breadth of the compartment considered, in m.

C_{WL} : Waterplane coefficient in forward part of the summer load waterline from the forward perpendicular to midship section.

A_F : Difference between the area of horizontal upper deck projection (including forecastle deck) and summer load waterline on a length up to $0,2L$ aft from the perpendicular, in m^2.

z_F : Vertical distance from the summer load waterline to the upper deck (forecastle deck included), measured on the froward perpendicular, in m.

I : Actual inertia moment of the hull about the horizontal neutral axis of the hull section concerned, in cm^4.

S : Actual statical moment about the neutral axis of the portion of the hull section concerned, located above or below the level on which the thickness of the web is determined, in cm^3.

x : Distance of the hull section concerned from the aft perpendicular, in m.

1.4.3 Still water bending moments and shear forces

a) The still water bending moments and shear forces are to be calculated for all possible cases of weight distribution over the length of the ship including full-load and ballast conditions for departure and arrival of the ship.

As a rule, when determining the scantlings of framing members, consideration is to be given to the following loading conditions:

.1 For dry cargo ships, ships with large deck openings, ro-ro ships, refrigerated cargo ships, bulk carriers and ore carriers:

Homogeneous loading conditions at max. draught.

Ballast condition.

Special loading conditions, for example light load conditions at less than the maximum draught, heavy cargo, empty holds or non-uniform distribution of loading, deck cargo conditions, where applicable.

Short voyage, where applicable.

Loading and unloading transitory conditions.

Docking condition afloat.

.2   For oil tankers:

Homogeneous loading condition (excluding empty compartments and ballast tanks destined to that purpose).

Partly loaded and ballast conditions for both departure and arrival.

Specified non-uniform distribution of loadings.

Mid-voyage conditions relating to tank cleaning or other similar operations where these differ significantly from the ballast conditions.

Loading and unloading transitory conditions.

Docking condition afloat.

.3   Ballast loading conditions where forepeak, afterpeak and/or other ballast tanks are partly filled at the departure, arrival or mid-voyage, shall not be considered as the design loading conditions. The exception shall be the cases where partial fillings of the tank does not exceed the permissible strength limitations.

Where there are several partly loaded tanks, then all the combinations comprising empty, full and partly filled tanks shall be considered.

For ore carriers with large side ballast tanks in cargo area for the case where empty or full loading of one or maximum two pairs of these ballast tanks causes a trim exceeding at least one of the values mentioned below, then it shall be sufficient to demonstrate compliance with maximum, minimum and assigned partial filling levels of these one or maximum two pairs of side tanks, so that actual trim does not exceed these trim values. Fill up levels for the rest side ballast tanks shall be considered between full and empty. The abovementioned trim values are as follows:

trim by the stern for 3 per cent of ship length;

trim by the bow for 1,5 per cent of ship length;

trims at which propeller depth axis constitutes 25 % of its diameter.

Maximum and minimum filling levels of the abovementioned one or maximum two pairs of side ballast tanks shall be included to the Loading Manual.

In cargo loading conditions, the requirements of the present paragraph apply to the peak tanks only.

However, bending moment and shear force calculations for each ballasting or deballasting stage in the ballast water exchange sequence shall be included in the Loading Manual or Ballast Water Management Plan of ships that intend to employ the sequential ballast water exchange method.

b)   The maximum absolute values of sagging and hogging bending moments M_{SW}, and shear force N_{SW}, are to be determined for sections along ship length for all the still water loading conditions, which are possible in service:

The values M_{sw}, in sagging and hogging of the ship.

The maximun absolutes wove shear force N_{sw}.

c)   Where no longitudinal bulkheads are fitted in ships with non-uniform distribution of loading and some cargo holds are empty, the shear force curves plotted by integrating the load may be corrected for the bottom and side girders response.

d)   Where provision is made in ship's design for loading conditions resulting in regular change of a sign of the still water bending moment (in fully loaded and ballast conditions on direct and return voyages), its components at the section with the maximum range of bending moment are to be determined for use in the calculations.

1.4.4   Wave bending moments and shear forces

For calculations of Wave bending moments and shear forces for New Buildings or Existing Vessels, please contact QRSHO.

1.4.5   Bending moment   due to wave impacts on the flare.

In case of Bending Moment Calculations due to wave impact on ship´s Flare for New Buildings or Existing Vessels when required, please contact QRSHO.

1.4.6   Hull section modulus and moment of inertia

a)   The requirements of this paragraph regulate the hull section modulus and moment of inertia about the horizontal neutral axis.

b)   The hull section modulus (for deck and bottom) W, in cm^3, at the section concerned is not to be less than:

$$W = \frac{M_T}{\sigma} \cdot 10^3 \qquad\qquad (1.4.6.2)$$

where: M_T =   design bending moment, in kNm, at the section concerned equal to the the maximum absolute value of algebraic sum of M_{sw} and M_w components at this section:

$$M_T = \left| M_{sw} + M_w \right|$$
$$M_T = \left| M_{sw} + M_w \right|;$$

M_{sw} =   see *1.4.3*, in kN.m;

M_w =   see *1.4.4*;

σ =   normal stress, in MPa, determined by formula:

c)   In cases specified by *1.4.3.4* the section modulus W is to be multiplied by the factor m obtained from the formula:

$$= + \frac{}{\qquad} \quad \frac{+}{\left(\quad + \quad \right)} \qquad\qquad = + \frac{}{\qquad} \quad \frac{+}{\left(\quad + \quad \right)}$$

where: M_{sw}^{min}, =   absolute values of hogging and sagging bending moments at the maximum range section, in kNm.

M_{sw}^{max}

The factor m is not to be taken less than 1.

d)   The hull section modulus determined from *1.4.6* for maximum value of design bending moment is to be maintained within 0,4L amidship. However, if the maximum design bending moment occurs outside 0,4L amidships, the steady section modulus requirement is to be applicable along the ship's length up to the section where maximum design bending moment acts.

The   section   modulus is to be gradually reduced towards the ship's ends outside the region at which it is being maintained.

e)   For sharp-lined ships without middlebody, deviation from the requirements of *rule 1.4.6.5* may be permitted on agreement with *QRS Class*.

f)   The hull section modulus (for deck and bottom) amidships, in cm^3, is not to be less than:

$$= \qquad \left(\quad + \quad \right)$$

where: C_w = as given in *1.3.1*.

For ships of restricted area of navigation the minimum hull section modulus W_{min} is to be multiplied by factor φ_o, determined from *table 2000*.

Table 2000 Coefficient φ_o

Area of navigation	φ_o
I	$0,95 - 6 \cdot L \cdot 10^{-4}$
II	$0,92 - 8 \cdot L \cdot 10^{-4}$
III	$0,86 - 15 \cdot L \cdot 10^{-4}$

Scantlings of all continuous longitudinal members of hull girder based on the section modulus requirement in *1.4.6* are to be maintained within 0,4L amidships. However, in special cases, based on consideration of type of ship, hull forms and loading conditions, the scantlings may be gradually reduced towards the ends of the 0,4L part, bearing in mind the desire not to inhibit the vessel's loading flexibility.

g)   The moment of inertia of hull section I, in cm^4, within the midship region is not to be less than:

$$= \left(\quad + \quad \right)$$

where: C_w = as determined from *1.3.1*.

For ships of restricted area of navigation I_{min} is to be multiplied by factor given in *table 2000*.

h)   As a minimum, hull longitudinal strength checks shall be carried out at the following locations outside amidships:
-In way of the forward end of the engine room;
-In way of the forward end of the foremost cargo hold;
-Where there are significant changes in the hull cross-section;
-Where there are changes in the framing system.
The following shall be made outside amidships: buckling strength of members contributing to the longitudinal strength and subjected to compressive and shear stresses shall be checked, in particular in regions where changes in the framing system or significant changes in the hull cross-section occur in compliance with 1.6.5;

Continuity of structure shall be maintained throughout the length of the ship. Where significant changes in structural arrangement occur, adequate transitional structure shall be provided;

For ships with large deck openings such as containerships, sections at or near to the aft and forward quarter length positions shall be checked.

For such ships with cargo holds aft of the superstructure, deckhouse or engine room, strength checks of sections in way of the aft end of the aft-most holds, and the aft end of the deckhouse or engine room shall be performed.

1.4.7   Thickness of side shell and continuous longitudinal bulkheads

a)   The thickness of side shell s, in mm at the section
concerned lengthwise and depthwise, in the absence of longitudinal bulkheads is not to be less than:

$$= \frac{\left(\quad + \quad \right)}{} - \qquad = \frac{\left(\quad + \quad \right)}{} - \qquad \qquad (1.4.7.1)$$

---

where: N_{sw} = as defined in *1.4.3.2*, in kN;

         N_w = see *1.4.4*;

         τ = $110/\tau$, in MPa.

b)   The thickness of side shell s_s and the thickness of longitudinal bulkheads s_l, in mm, at the section under consideration for ships with two plane longitudinal bulkheads are not to be less than:

$$s_s = \frac{N_{sw} + N_w}{\tau} \cdot \frac{S}{I} \cdot \alpha_s \cdot 10^2 \qquad (1.4.7.2\text{-}1)$$

$$s_l = \frac{N_{sw} + N_w}{\tau} \cdot \frac{S}{I} \cdot \alpha_l \cdot 10^2 \qquad (1.4.7.2\text{-}2)$$

where: N_{sw} = see *1.4.7*;

         N_w = see *1.4.7*;

         τ = see *1.4.7*;

         α_s = $0,16 + 0,08 \cdot \dfrac{s_s}{s_l}$;

         α_l = $0,34 - 0,08 \cdot \dfrac{s_s}{s_l}$.

1.4.8 Calculation of actual hull section modulus

a)   The hull section modulus is to be determined:

for strength deck W_d, at moulded deck line at side (lower edge of deck stringer);

for bottom W_b, at moulded base line (top of keel plate).

For ships with continuous longitudinal strength members above deck including trunk and continuous hatch side coamings, W_d shall be calculated by dividing the moment of inertia of the hull section about the horizontal neutral axis by z_t determined from the formula:

$$z_T = z + y$$

where: z = distance from neutral axis to the top of continuous strength member above deck included in the calculation of W_d, in m;

         y = horizontal distance from center line of the ship to the top of continuous strength member above deck included in the calculation of W_d, in m.

z and y are to be measured to the point giving the largest value of z_T.

b)   When calculating the hull section modulus, all continuous longitudinal strength members are to be considered, including continuous hatch side coamings, and, where the ship's design provides for multiple hatchways - the longitudinal deck strips between them on condition the deck strips are effectively supported by longitudinal bulkheads, including the topside tank bulkheads (inner skins).

Continuous hatch side coamings in ships with single hatches not above the mentioned structures, may be included in the calculation of the hull section modulus only if the calculation has been specially approved by this effect.

The sectional area of longitudinal deck strips, each being of a uniform width throughout the length, including deck plating with longitudinal framing members and hatch side coamings not supported by longitudinal bulkheads, is to be included with reduction coefficient ξ, determined from the formula:

$$= \quad + \quad \frac{\overline{}}{ + +}$$

where:

m = 0,10 at $n = 1$
0,12 at $n = 2$;

n = number of longitudinal strips over ship's breadth;

Σl_H = total length of longitudinal deck strips, in m;

Δl_1, Δl_2 = lengths of end attachments of longitudinal deck strips aft and forward, in m.

If the end of the longitudinal deck strip is effectively attached to continuous deck and/or longitudinal bulkhead, the parameters $\Delta l_{1,2}$ shall be determined by the formula:

$$\Delta l_{1,2} = \frac{4 \cdot f}{B_{1,2} \cdot s_{d1,2}} \qquad \Delta l_{1,2} = \frac{4 \cdot f}{B_{1,2} \cdot s_{d1,2}}$$

where:

f = sectional area of one longitudinal deck strip, in cm²;

$B_{1,2}$ = breadth of ship in way of longitudinal deck strip termination, m;

$s_{d1,2}$ = average thickness of the portion of deck plating between the extension of longitudinal deck strip and ship's side along the effective attachment, in mm.

Where a longitudinal deck strip terminates at the transverse deck strip, provided $10 \cdot b'' \cdot s_d' \geq n \cdot f$ and $b'' > b'$, the parameters $\Delta l_{1,2}$ shall be determined by the formula:

$$= \quad \frac{\overline{}}{} \quad - \quad +$$

where:

s_d' = average plate thickness of the transverse deck strip, in mm;

υ = distance between the longitudinal edge of the hatch opening and symmetry plane of the longitudinal deck strip, in m;

υ = length of transverse deck strip, in m.

c) Large openings, i.e. openings exceeding 2,5 m in length and/or 1,2 m in breadth, and scallops, where scallop-welding is applied, are to be deducted from the sectional areas used in the section modulus calculation.

Smaller openings (manholes, lightening holes, single scallops in way of seams) need not be deducted, if the following conditions are met:
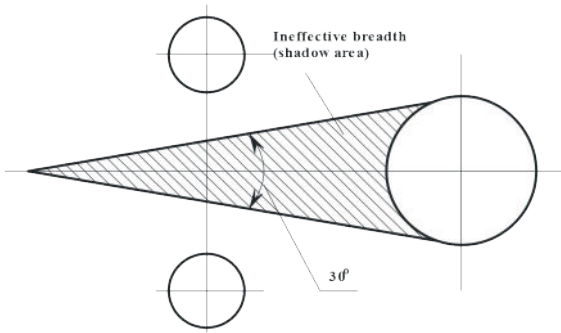
Figure 200 Total breadth of the openings and the ineffective areas in a hull transversal section

The sum of their breadth and shadow area (*fig. 200*) in one transverse section of the hull does not exceed $\left(\quad \right)$ (where $\sum b \sum b$ is the total breadth of large openings) or does not reduce the section modulus at deck or bottom by more than 3 per cent. The height of lightening holes, draining holes and single scallops in longitudinal members does not exceed 25 per cent of the web depth, and the height of scallops is not over 75 mm.

d)   Where continuous longitudinal members are built of high strength steel, they are to extend so far beyond amidships towards the ends as to provide a hull section modulus in way where the yield stress changes not less than required for an identical hull of normal strength steel.

e)   The continuous longitudinal members at a distance from horizontal neutral axis of hull section greater than:

$$ - \frac{\qquad}{\quad} = $$

are to be made of steel with the same yield stress as the strength deck (continuous hatch coaming) or bottom.

where: z =   distance of strength deck (upper face plate of continuous hatch side coaming) or bottom from neutral axis, in m;

          =   factor for the members of the remainder of hull section;

$W_a \, W_a$ =   actual section modulus and Rule section modulus with $\eta = 1$ for the deck (continuous hatch coaming) or bottom, respectively.
$W_{\eta=1}$
$W_{\eta=1}$

1.4.9   Loading Manual and Instrument

a)   *Loading Manual* and loading instrument are means of which it can be ascertained that the still water bending moments, shear forces, and the still water torsional and lateral loads, where applicable, in load or ballast conditions will not exceed the specified permissible values.

b)   Ships to be provided with loading manual and loading instrument are categorized as follows:
  Category I: all ships independent of length with large deck opening where combined stresses due to vertical and horizontal hull girder bending and torsional and lateral loads must be considered.
  Category II: ships the design of which consider uneven distribution of cargo or ballast (for example alternation of empty and loaded holds), except ships of less than 120 m in length which belong to category IV.
  Category III: chemical tankers and gas carriers except those of less than 65 m in length which belong to category IV.

Category IV: ships with arrangement giving small possibilities for variation in the distribution of cargo and ballast, and ships on regular and fixed trading pattern where the Loading Manual gives sufficient guidance and in addition those exceptions given under categories II and III.

c)   A *Loading Manual* is a document approved by *QRS Class* which describes:
  The loading conditions on which the design of the ship has been based;
  Permissible limits of still water bending moment and shear force and where applicable, limitations due to torsional and lateral loads;
  The results of the calculations of still water bending moments and shear forces for loading conditions stated in *1.4.3 (a)*;
  The allowable local loadings for the structure (hatch covers, decks, double bottom, and so on.).

d)   A loading instrument is an instrument approved by *QRS Class*, which is either analog or digital by means of which the still water bending moments, shear forces and torsional and lateral loads, where required, in load or ballast conditions can be easily and quickly checked at specified readout points. The number and position of sections and permissible still water bending moments and shear forces as well as the limitations due to torsional and lateral loads are to be approved by *QRS Class*. Single point loading instruments are not acceptable. An approved operational manual is to be provided for the loading instrument.

e)   All ships are to be provided with an approved Loading Manual. In addition, ships of categories I, II and III are to be equipped with a loading instrument approved by *QRS Class*.

f)   For ore carriers having a length of 150 m and more, additional requirements for strength control during loading are given in 3.3.6.

g)   Information (booklet) on Stability and Strength during Loading, Unloading and Stowage of BulkCargoes Other than Grain.
        To prevent excessive hull stresses, provision shall be made for Information (booklet) on Stability and strength during Loading, Unloading and Stowage of BulkCargoes other than Grain to be carried on board, including the following as a minimum:

  .1 stability data required.
  .2 data on the capacity of ballast tanks and of equipment for their filling and emptying;
  .3 maximum permissible load upon a unit of double-bottom plating surface;
  .4 maximum permissible cargo hold load;
  .5 instructions concerning loading and unloading and pertinent to hull strength, including limitations due to the worst operating conditions during loading, unloading, handling of water ballast, and during the voyage;
  .6 special limitations, for instance, those due to the worst operating conditions, where applicable;
  .7 where necessary — strength calculations:
maximum permissible forces and moments affecting the hull during loading, unloading and the voyage.
    The Information (booklet) shall be prepared in a language understood by the ship officers, and in English.

h)   When developing the Loading Manual and Information (booklet) on Ship Stability and Strength During Loading, Unloading and Stowage of Bulk Cargoes Other Than Grain, one shall be guided by the recommendations contained in Collection of Regulating Documents of the Register, Book9.

1.5   Vibration of hull structures. Vibration standards

1.5.1   General

a)   This Chapter regulates the procedure of calculating the main and local hull vibration of ships being designed and the values of the maximum permissible limits of the main hull vibration of the ship under way and local vibration of hull structures. Procedure for conducting vibration measurements in ships in service specifying the scope of required measurements and their sequence is to be approved by *QRS Class*.

b)   Irrespective of the results of vibration calculation for the first ship of the series, as well as for single buildings, the measurements of vibration are to be taken allowing to estimate their vibration characteristics proceeding from the standards of permissible vibration parameters given in *1.5.7*.

c)   The standards   of   allowable parameters of the main hull vibration of ships under way and local vibration of hull structures are the basic criterion for objective estimate of their vibration characteristics. The standards have been established proceeding from the condition of ensuring the strength of hull structures.

Application of the present standards does not dispense from compliance with the sanitary standards and the requirements of the *Health Authorities* concerning the admissible parameters of vibration at the working positions and in the ship's accommodation, service and other spaces.

1.5.2   Application

a)   The requirements of this Chapter specifying the procedure of performing the calculations of the main hull vibration apply to sea-going displacement ships with metal hull of 90 meters in length and over.

1.5.3   Definitions and explanations

a)   In the present Subsection are given the following definitions:

.1   **Main hull vibration:** Means vibration of ship's hull generated by the forces involved on account of operation of propeller, main engine or caused by the action of waves.

.2   **Vibration of superstructures and deckhouses:** Vibration of superstructures and deckhouses about the hull generated by its vibrations.

.3   **Local vibration:** Means vibration of hull structures (plates, stiffeners, framing members, grillages, and so on.) generated by propeller, unbalanced machinery located near these structures or by the main hull vibration of the ship under way.

.4   **Exciting forces:** External forces or moments of forces acting on vibrating system and causing its vibration.

.5   **First-order frequency:** Means frequency of exciting forces variation equal to the propeller speed. Forced vibration of the system arising at this frequency is called first-order vibration.

.6   **Top-order frequencies:** Means frequencies of exciting forces variation equal to the doubled, trebled, and so on. propeller speed. Forced vibration of the system arising at such frequencies multiple to propeller speed is called vibration of the second, third, and so on. order, respectively. In this case, frequency of exciting force variation equal to the product of propeller speed by the number of blades is called first-blade (or blade), frequencies multiple to it are called second-blade, third-blade, and so on., and vibration arising at these frequencies, for example, in case of four-bladed propeller is called blade vibration of the fourth order, second-blade vibration of the eighth order, and so on., respectively.

.7   **Main order frequencies of exciting forces generated by internal combustion engines:** Means frequencies of variation of unbalanced forces and moments of inertia forces equal to the engine crankshaft speed (first order) or double speed (second order) as well as frequencies of variation of capsizing moments the order of which is equal to the cylinder number (two-stroke engines) or to half the number of cylinders (four-stroke engines).

1.5.4   Technical documentation

a)   Upon completion of mooring and delivery sea trials the technical conclusion on the results of vibration measurements is to be submitted to *QRS Class*. The technical conclusion is to be approved by the management of the organization conducting the measurements and is to contain the assessment of ship vibration characteristics proceeding from the existing standards. This document includes the   information on arrangements to be carried out with a view to reducing the vibration as well as on check (repeat) measurements used for confirmation of efficiency of the arrangements.

1.5.5   Calculation of main hull vibration of the ship under way

a)   Calculations   of frequencies   and basic modes of natural frequencies of hull vibration for ship being designed as well as estimation of parameters of its forced vibration under way are to be carried out according to the procedure approved by *QRS Class*.

b)   Calculations of main hull vibration of the ship under way are to be carried out for the main operating loading conditions. The calculation of natural (resonant) frequency spectra of hull vibration in vertical and horizontal-transverse directions within the range of excitation forces frequency variation to the blade frequency inclusive is to be made.

___

c) When calculating the natural frequency of vibration, it is recommended to consider the interaction of hull and added large masses (grillages, deckhouses, and so on.). In addition, the amplitude estimation of vibration displacement of the hull forced vibration (including resonant) is to be carried out in the aftermost section at the point where vibration is normalized. Such estimation is to be carried out for the main specified running conditions. The obtained values shall be compared with the values specified in *1.5.7*.

1.5.6   Calculation of local vibration of hull structures

a) The local vibration strength of the hull structures subject to vibration loads is to be checked by the appropriate calculations performed at the designing stage according to the procedure approved by *QRS Class*. The basic condition of ensuring the vibration strength of hull structures in way of influence of vibration loading is to prevent the possibility of origination of their resonance oscillations for the main operating conditions of the ship.

b) To prevent origination of the resonance vibration, natural frequencies of the first mode hull structure vibration are to exceed the relevant frequencies of the excitation forces at least 1,5 times for the plates and 1,3 times for the framing members and stiffeners.

c) Permissible Main hull and superstructure vibration and local vibration of ship structures is considered permissible if they are negligible. In case of Vibration issues, a study may be carried out by QRSHO upon request.

1.6 Requirements for scantlings of hull structural members

1.6.1   General

a) This Chapter contains requirements for plating and framing.

b) Plate structure means a portion of plating bounded by stiffening members. By plate structures are meant portions of the deck, platform and inner bottom plating and portions of the bottom, side, bulkhead plating as well as girder webs.

c) In the present Chapter of the rules the term "framing" includes primary members and deep members (webs) strengthening the plate structures. Deep members also serve as supporting structures for primary members. Primary members are deck longitudinals, side longitudinals, bulkhead longitudinals, inner bottom plating and bottom longitudinals, as well as vertical and horizontal stiffeners of bulkheads, frames, beams, reverse and bottom frames of bracket floors, and so on. Deep members are deck transverses, deck girders, web frames, side stringers, floors, side girders, center girder, vertical webs and horizontal girders of bulkheads.

d) The scantlings of primary and deep members are based on the required section modulus, moment of inertia, web sectional area, thicknesses of web and face plate, as well as width of the face plate.

e) The geometric properties of the member section, unless provided otherwise, are determined considering the effective flange. If the member is so arranged that it is not normal to the effective flange, the section modulus is to be increased in proportion to $I / cos\,\alpha$ (where is the angle, in degrees, between the member web and the perpendicular to the effective flange at the section considered). If $\alpha \le 15°$, no increase of section modulus is required.

f) Rounding off the required scantlings of structural members is to be made in the direction of increase. Plate thickness is to be rounded off the nearest 0,5 or integer of millimetres.

1.6.2 Symbols

Shall be adopted the following symbols:

z_i : Vertical distance from horizontal neutral axis of ship to the center of section area of the longitudinal considered, in m.

I : Actual moment of inertia of the hull about neutral axis corresponding to the adopted scantlings less wear and corrosion allowance by the middle of service life of ship, in cm^4.

h : Depth of the member web, in cm.

l : Span of concerned member, in m.

a : Spacing, in m, of concerned primary or deep members of longitudinal or transverse framing system; where this varies, a is a half sum of distances of adjacent members from the member concerned.

p : Design pressure at the point of load application determined in the relevant chapters on the present Chapter of the Rules, in kPa.

σ_n : Design specified yield stress for normal stresses, in MPa.

τ_n : Design specified yield stresses for shear stresses, in MPa.

Δs : Corrosion allowance, in mm.

1.6.3 Span and effective flange of member

a) The span of primary and deep members is to be measured along the member face plate as the distance between its span points. Unless provided otherwise, where the end brackets are fitted, the span points are to be taken at the mid-length of the bracket. In this case, the span point position is to be such that the height of the end bracket in it does not exceed the web depth of the member considered. For curvilinear members the span is to be taken equal to the chord connecting the span point center.

b) The thickness of the effective flanges shall be taken equal to its mean thickness in the considered section of the member.

c) The width of the effective flange a_f, in m, of primary members is to be taken equal to the lesser value obtained from the formula:

$a_f = l/6$

$a_f = 0{,}5. (a_1 + a_2),$ whichever is the smaller

where: a_1, a_2 = distance of the considered member from the nearest members of the same direction located on both sides of the aformentioned considered member, m.

d) The width of the effective flange of the webs c_f, in m, of primary members is to be determined from the formula:

$=$

where: $c = 0{,}5 \cdot (c_1 + c_2);$

c_1, c_2	=		distance of the considered web from the nearest webs of the same direction located on both sides of the considered web, m;
k	=		factor obtained *from table 2100* depending on c, given span l_b and number n of members supported by web.

Table 2100 Relationship l_b/c

Number of members n	k values at l_b / c equal to:						
	1	2	3	4	5	6	7 and more
6	0,38	0,62	0,79	0,88	0,94	0,98	1
3	0,21	0,40	0,53	0,64	0,72	0,78	0,8

For simply supported webs the given span $l_b = l$, and for fixed webs $l_b = 0{,}6\, l$.

The way in which the frame members are to be supported (simple supporting or fixing) is to be determined proceeding from the engineering principles with regard for the actual structure (presence of brackets, welding of webs, face plates, and so on.) and characterized by the presence or absence of bending moment effects in the span point of the member. The intermediate values of the distance $d_b = c$, of n and the factor k shall be determined by linear interpolation.

e) The width of the hatch coaming effective flange shall be taken equal to one-twelfth of their span but not more than half the distance between the cargo hatch and the ship's side for the side coaming and, accordingly, half the distance between a cargo hatch and a transverse bulkhead (or the beam nearest to the cargo hatch) for the transverse coaming of the cargo hatch.

f) The width of the effective flange of the webs, located normal to the direction of corrugations, is to be taken equal to 15s and 20s for trapezoidal and wave-shaped corrugations, respectively (s = thickness of corrugated plates, in mm) or 0,1 c *(c* = width of effective flange according to *1.6.3* (d) in mm, whichever is the less.

g) Where primary members parallel to deep members are fitted along the width of the effective flange of the latter, full cross-sectional areas of the above primary members shall be adopted for calculation when determining the inertia moment and section modulus of the deep members.

h) In case the area of the effective flange is less than that of the face plate, the determination of section module and moments of inertia of the webs is to be subjected to special consideration by *QRS Class*. This does not apply to webs of corrugated structures.

1.6.4 Scantlings of structural members

a) The section modulus W, in cm³, of primary members of rolled section is not to be less than:

$$ = \qquad = \qquad\qquad\qquad (1.6.4.1\text{-}1) $$

where:	W	=	section modulus of the considered member, in cm³;
		=	multiplier taking into account corrosion allowance.

The appropriate increase of the section modulus of the member is to be designated as ΔW.

b)   The section modulus of the member considered, in cm³, without considering corrosion allowance shall be determined from the formula:

$$W' = \frac{Q \cdot l \cdot 10^3}{m \cdot k_\sigma \cdot \sigma_n}$$

where: Q = transverse load on the member considered, in kN, calculated by the expression: $Q = p \cdot a \cdot l$;

m, k_σ = factors of bending moment and permissible stresses to be found in the corresponding Subsections.

c) The net sectional area (excluding openings) of the web of framing member f_w, in cm², is not to be less than:

$$= \frac{}{} +$$

where: N_{max}, = maximum shear force and factor of
k_τ permissible shear stress determined in the corresponding Subsections.

d) The thickness s, in mm, of the plates (deck or shell plating) under transverse loading is not to be less than:

$$s = m \cdot a \sqrt{\frac{k \cdot p}{k_\sigma \cdot \sigma_n}} + \Delta s$$

where: m, k_σ = see *1.6.4*;
k = 1 at $a_1 / a > 2$;
k = $0{,}16\ (\quad) + \quad$ at
$ \quad 1{,}5 < a_1 / a \le 2{,}0$;
k = $0{,}70\ (\quad) \quad$ at
$ \quad 1{,}0 \le a_1 / a \le 1{,}5$;
a, a_1 = shorter and longer sides of the plate element, in m.

e)   The   dimensions of the corrugated structures are to comply with the following requirements:

.1   The thickness of the trapezoidal corrugations is to be determined from *formula* in 1.6.4 (d), with the value a taken equal to b or c.
The following relation is to be observed:

$$\frac{b}{s} \le \frac{0{,}95}{\sqrt{R_{eH}}}$$

where: b = width of the panel parallel to the bulkhead plane, in m.

The angle is to be assumed not less than 40.
.2   The thickness of the wave-shaped corrugations, s, in mm, is not to be less than:

$$s = 22 \cdot \beta_o \cdot R \cdot \sqrt{\frac{p}{k_\sigma \cdot \sigma_n}} + \Delta s$$

where: β_o = one-half angle of the spread of corrugation in rad.

R = radius of corrugation, in mm;

k_σ = factor of permissible stresses determined in the corresponding Subsections.

In this case the following relation is to be observed:

$$\frac{R}{s} \le \frac{17}{R_{eH}}$$

.3 The section modulus of the corrugation shall be determined according to *1.6.4*, with $Q = pd_o l$.
The spacing and section modulus of corrugations must be determined.
The factor γ shall be obtained from the formula:

$$\gamma = 2 \cdot \frac{\beta_o + 2\beta_o \cdot cos^2 \beta_o - 1,5 \, sen \, 2\beta_o}{1 - cos \beta_o}$$

In calculating the factor , the angle β_o is to be taken in radians.

1.6.5   Buckling strength of structural members

a)   The buckling strength of longitudinals, shell plates and hull structure plating within the midship region in ships of 60 m in length and over is to be ensured under compressive stresses due to longitudinal bending of the hull.
The effective compressive stresses σ_c, in Mpa, are to be calculated by the following formula:

$$\sigma_c = \frac{M_T}{I} \cdot z_i \cdot 10^5$$

where: M_T = design bending moment, in kN.m, at the section under consideration equal to the maximum absolute value of the algebraic sum of the moment components:
for longitudinal members arranged below the neutral axis:
$M_T = |M_{sw} + M_w|$;
for longitudinal members arranged above the neutral axis:
$M_T = |M_{sw} + M_w + M_F|$;

M_{sw} = as defined in *1.4.3*, in kN.m;

M_w = as determined from *1.4.4;*

M_F = see *1.4.5.*

The maximum hogging bending moment is to be assumed as design value M_T for longitudinal members arranged below the neutral axis, and the maximum sagging bending moment- for longitudinal members arranged above the neutral axis.

The buckling strength of side shell and longitudinal bulkheads at the section considered is to be ensured under shear stresses τ_c, in Mpa, calculated by the following formula:

For side shell plating for ships without effective longitudinal bulkheads:

$$\tau_c = \frac{N_{sw} + N_w}{2 \cdot s} \cdot \frac{S}{I} \cdot 10^2$$

For side shell plating in ships with two effective longitudinal bulkheads:

$$\tau_c = \frac{N_{sw} + N_w}{s_s} \cdot \frac{S}{I} \cdot \alpha_s \cdot 10^2 \qquad \tau_c = \frac{N_{sw} + N_w}{s_s} \cdot \frac{S}{I} \cdot \alpha_s \cdot 10^2$$

For longitudinal bulkhead plating in ships with two effective longitudinal bulkheads:

$$\tau_c = \frac{N_{sw} + N_w}{s_l} \cdot \frac{S}{I} \cdot \alpha_l \cdot 10^2$$

where: N_{sw} = still water shear force at the section considered, defined in *1.4.3*, in kN;

N_W = wave vertical shear force determined from *1.4.4.2*;

s = actual thickness of side shell for ships having no longitudinal bulkheads, in mm;

s_s, s_l = actual thickness of side shell and longitudinal bulkhead at the section considered for ships with two longitudinal bulkheads, in mm;

S, I = as defined in *1.4.2*;

α_s, α_l = see *1.4.7*.

Where one or more than two continuous longitudinal plane bulkheads or longitudinal bulkheads with horizontal corrugations are fitted, the shear stresses are to be determined by a procedure approved by *QRS Class*.

b) The buckling strength of hull structural members is considered sufficient if the following conditions are met:

$$k \cdot \sigma_c \le \sigma_{cr}$$
$$k \cdot \tau_c \le \tau_{cr}$$

where: k = **1,0** for deck plating, single bottom, side shell framed longitudinally and longitudinal bulkheads;

k = **1,1** for inner bottom plating, bottom plating as well as side shell framed transversely;

k = **1,15** for longitudinals and hatch side coamings;

σ_c, = see *1.6.5*;

τ_c

σ_{cr}, τ_{cr} = critical normal and shear stresses, determined from *1.6.5*.

Permissible loss of buckling. strength of the plate structures shall be subjected to special consideration by *QRS Class*.

1.6.6   Aluminum alloy structures

The scantlings of aluminum alloy structures are to be determined by conversion of the scantlings relating to the corresponding steel structures. For design of aluminum structures, all calculations must be submitted to QRSHO for verification.

1.7 Welded structures and joints

1.7.1 General

a)   Changes in the shape or section of the members of welded hull structure is to take place gradually. All openings are to have rounded corners and smooth edges.

b)   The scantlings of sections and the thicknesses of plates used for longitudinal members are to change gradually throughout the ship's length. Changes of framing system and plating thicknesses used for the strength deck, bottom, side shell and longitudinal bulkheads, shall not be permitted in areas where mechanical properties of steel change.

c)   Continuity to be ensured for as many of main longitudinal members as possible, and a gradual change of their sections is required in way of the ends together with other arrangements, contributing to the reduction of stress concentration.

d)   In tight structures, as well as in non-tight structures subject to intense vibration, stiffeners and similar details are to be fitted to prevent hard spots in the plating at the toes of brackets and in way of face plates of the members passing through, or terminating at the above-mentioned structures.

e)   The length of unsupported plating between the end of a longitudinal and the nearest web normal to direction member is to be as short as possible, however, not more than 4 s or 60 mm, whichever is the lesser (s = plate thickness, in mm).

f)   For the purpose of this Chapter of the rules, the hull structures subject to intense vibration are those situated in way of machinery and equipment which constitute a source of vibration. Considered as regions with high level of vibration in all ships are the regions situated below the lower platform continuous within the machinery space and bounded:

  in aft end, by a section forward of the fore edge of propeller boss at twice the propeller diameter, but not less than to the after peak bulkhead;
  in the machinery space, by the bulkheads of this space.

   The bulkheads forming boundaries. of machinery space, the afterpeak bulkhead and the lower continuous platform in the above regions throughout the length of the ship are structures subject to intense vibration.

g)   In way of the ends of bulwark, bilge keels, and other details welded to the hull, as well as of gutter bars, their height is to decrease on a length of at least 1,5 times the heights of these members. The ends of bulwarks are to be tapered. This is also recommended for the portions of the ends of the gutter bars.

h)   Welded joints, welding consumables and procedures, testing and inspection methods of welded joints are to comply with relevant materials requirements.

1.7.2 Connections of framing members

a)   The framing members are to have butt-welded joints. Overlapping joints may be allowed on agreement with *QRS Class*, except in regions with high level of vibration, deep member connections and in way of heavy concentrated loads. Brackets are to be of the material with the same yield stress as the material of the members connected.

b)   Connections of primary members
.1   Unless provided otherwise, the size of brackets c, in cm, (except the bilge brackets) measured in accordance with *fig 300*, is to be determined by the following formula:

$$c = n \cdot \sqrt{\frac{W}{0,1 \cdot s}}$$

where: n = factor taken in accordance with the provisions of the respective Subsections of this Chapter;

W = Rule section modulus of the member attached, in cm³;

s = bracket thickness, in mm, taken equal to the thickness of the member web, unless provided otherwise.
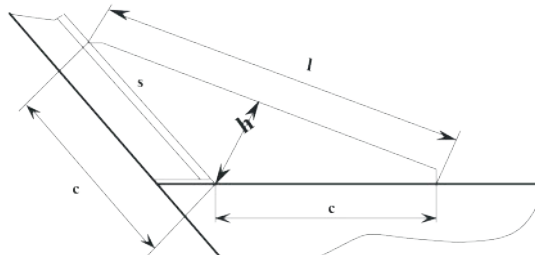
Figure 300   Dimensions of the brackets

The bracket height h (see *fig 300*) is to be not less than 0,7 times the required size c.

The size of brackets determined as indicated above, refers to the case when the members to be interconnected are not welded to each other or the member butts are not welded to the plating (decks). The allowable gap is not to exceed 40 mm or 25 per cent of size c, whichever is less. Otherwise, c may be required to be increased.

.2   The bracket is to have a face plate or flange if the length of free edge is greater than $45s$ *(s = thickness of the bracket, in mm)*. The width of the flange (face plate) is to be equal to $1/8c$ but not less than 50 mm.

.3   The sizes of brackets may be reduced:
by 10 per cent - where the framing members are welded to each other or to the plating (deck);
15 per cent - where a face plate or flange is provided;
by 25 per cent - where the framing members are welded to each other and the brackets are provided with a face plate or flange.

.4   In regions with high level of vibration the butt ends of framing members are to be connected, with the minimum dimensions of the plating portions unsupported by the framing.

.5   In way of side strengthening of ships mooring at sea as well as in forward region of category ICE2 ships, the bracket of the beam is to have a face plate or flange if there is a gap between the butt of beam and the frame.

c)   Deep members are recommended to be connected by rounded brackets with smooth change of web depth and face plate size.

.1   The height and width of brackets interconnecting the deep members, or attaching deep members to bulkheads, are, unless provided otherwise, to be not less than the member web (or the lesser of the web members connected). The bracket thickness is assumed equal to the lesser of the member web thicknesses. In deep member connections no gaps are permissible.

.2   The brackets connecting the deep members are to have a
face plate or flange along the free edge. In places of transition from the face plates of brackets to those of deep members, the width and thickness of the face plate along the free edge at different sizes of the deep member face plates are to change smoothly.
The area of face plate (or flange) of tripping bracket is to be taken not less than 0,8 times the area of the lesser face plate of the connected deep members.
If the length of the bracket free edge exceeds 1700 mm, a stiffener is to be fitted parallel to the face plate (flange) at a distance of about 1/4 of the bracket height or 35 times the thickness of the bracket (whichever is the less) the moment of inertia of which is regulated by *1.6.5*.
Depending on the sizes and form of the brackets additional stiffeners and brackets are to be fitted for their stiffening.

3.   The radius of rounding is not to be less than the depth of the smaller member forming the connection.
The webs and face plates are to be supported by stiffeners and tripping brackets in way of rounding (*fig 400*).

d) The constructions used for the attachment of longitudinals/frames to deep members are to comply with existing standards.
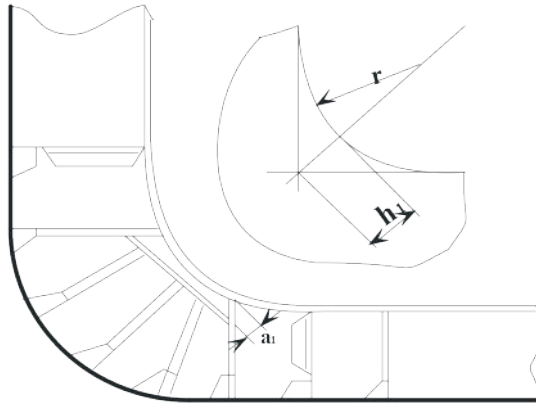

Figure 400 Reinforcement at the rounding area

1.7.3 Construction of deep members

a) The depth h and thickness s_w, of girder webs (as well as of built-in longitudinals/frames) and their sectional area are regulated by the relevant Subsections of this Chapter of the Rules.

The width of girder face plate b, in mm, as measured from its web, is not to be more than:

$$= \frac{}{\sqrt{}} \qquad = \frac{}{\sqrt{}}$$

where: $s_{f.p}$ = thickness of girder face plate, in mm.

$s_{f.p}$

The thickness of face plate is not to exceed a triple thickness of the web plate.

b) With $\qquad$ (for h and s_w s_w, in mm, see *1.7.3*), the webs of girders (except those whose buckling strength is to be checked in accordance with *1.6.5*) should be stiffened by tripping brackets and stiffeners.

1. At $\qquad$ the webs of the girders are to be stiffened by stiffeners fitted parallel to the girder face plate and arranged at a distance a_1 not more than $= \sqrt{}$ from each other, or from the face plate, or the plating.

At $\qquad$ stiffening may be effected. Spacing a_2, in mm, of the stiffeners fitted normal to the girder face plate is not to exceed $\sqrt{}$.

In way of portions equal to 0,2l l, but not less than 1,5 h from supports (l and h - are the span and the depth of girder web, respectively) the spacings a_1 and a_2 are to be reduced one and a half times.

The stiffeners fitted normal to the face plate of the girder supporting main hull members (for example longitudinals, bulkhead stiffeners, frames, and so on.) are to be fitted not further than in line with every second member in question.

The smaller size b of the panel of the double bottom floor web is not to be more than:

$$b = \frac{1600 s_w}{\sqrt{R_{eH}}} \qquad b = \frac{1600 s_w}{\sqrt{R_{eH}}}$$

The variation of the stated spacings of the stiffeners may be permitted based on the results of calculation analysis.

2. The thickness of stiffeners is not to be less than 0,8 s_w s_w .

    The moments of inertia of the stiffeners are determined according to *1.6.5*.

3. The tripping brackets stiffening deep members are to be fitted at the ends of knees securing the girders in way of roundings and struts as well as in way of span of the girder. The spacing of brackets is not to exceed 3,0 m or 15 $b_{f.p}$ ($b_{f.p}$ = full width of face plate, in mm), whichever is the less.

    The thickness of the tripping brackets is to be not less than required for the girder web. The brackets are to be extended to the face plate of the girder and be welded to it if the width of the face plate exceeds 150 mm, as measured from the girder web to the free edge of face plate..
    Where the width of symmetric face plates exceeds 200 mm, small brackets are to be fitted at the opposite side of the web in line with the tripping bracket.
    The width of the tripping brackets, measured at the base is to be not less than half their depth. The bracket is to have a face plate or flange if the length of free edge $l > 60s$ (s = thickness of bracket, in mm). The cross sectional area, in cm^2, of the face plate or flange is to be $s \geq 0,01l$. The width of the face plate or flange is not to be less than l/s.

c) Lightening   holes for the passage of framing
Members are permitted in the girder webs.

    Total height of openings cut in the same section is not to exceed 0,4 of the girder depth. For deck transverses, deck girders and web girders of watertight bulkheads in dry cargo ships, this value may be increased to 0,6 of the girder depth.

    The distance from the edges of all openings in deep members to the edges of slots for the passage of framing members is not to be less than the depth of these members. The holes in girder webs, except for the slots for passage of the framing members, are to be located at a distance not less than half the girder depth from the toes of brackets attaching this girder. Where it is impossible to satisfy this requirement, compensation is to be provided by local thickening of the web, fitting of collars, and so on.

1.7.4   Details of welded structures

a) The face plates and/or webs at the member ends are to be sniped depending on the construction used for attachment of members.

b) The width of flange (face plate) of brackets is to be not less than 8 bracket thicknesses unless expressly provided otherwise in the relevant Subsections of this Chapter of the Rules.

c) The edges of brackets, face plates and webs of the members shall be welded all round and shall have no craters. This requirement also applies to air and drain holes and slots for the passage of framing members and welded joints.

d) Welded joints are to be arranged in least stressed structural sections, as far as practicable from abrupt changes of sections, openings and details which were subject to cold forming.

e) The butt joints of face plates of the intersection girders in regions with high level of vibration are to be made with smooth transition by means of diamond plates.

f) It is recommended   that   local   concentration of welds, crossings of welds at an acute angle, as well as close locations of parallel butts or fillet welds and butt welds, be avoided.

g) The angle between two butt welds is not to be less than 60.

h) The butts (seams) in assembling joints of the plating shall be located at a distance not less than 200 mm from bulkheads, decks, inner bottom plating, web members fitted parallel to the above-mentioned joints. In assembling joints, the welded butts of built-up material shall be arranged so that the butts of a member web are not less than 150 mm from the butts of this member face plate. On agreement with *QRS Class*, the butts of webs and face plates may be arranged in the same plane provided that:
Full penetration welding is ensured at the connection of the web to face plate on a length of at least 100 mm each side of the butt
by non-destructive testing of the welded butt in every third member;

Overlapping of the butt by the framing elements (knees, brackets, and so on., fitted in line with the web) is ensured on a length not less than the face plate width each side of the butt.

1.7.5 Types and dimensions of fillet welds

a) The designed throat thickness a, in mm, of fillet welds for tee-connections for manual and semiautomatic welding is not to be less than:

$$a = \alpha \cdot \beta \cdot S \qquad\qquad (1.7.5.1)$$

where:

	=	weld factor taken. For structures inside cargo tanks of tankers α is to be increased by 0,05;
	=	factor depending on the ratio of weld pitch t, in mm, to weld length l, in mm;
s	=	thickness of the lesser of the parts joined.

The relationship between the leg length of the fillet weld and the height of the isosceles triangle inscribed into the cross-section of the weld is to be assumed as $k = 1,4a$ or $a = 0,7k$.

When automatic welding is employed instead of the proposed manual welding, the weld throat or leg length, whichever is adopted in calculation, may be reduced in height for single-run welds by not more than 30 per cent.

For multirun welds the percentage of the above reduction is to be subjected to special consideration by *QRS Class*.

If the thickness of the thinner of the items to be joined is less than half the thickness of the thicker item, then the leg lengths are to be subjected to consideration by *QRS Class*.

The throat thickness a of a fillet weld is not to be less than:

$a = 2,5$ mm with s 4 mm;
$a = 3,0$ mm with 4 s 10 mm;
$a = 3,5$ mm cuando 10 s 15 mm;
$a = 0,25s$ cuando s 15 mm.

The dimensions of fillet welds taken from calculations shall not exceed the following values:
a $0,7s$, $(k$ $s)$.

b) Overlapping connections, if allowed, are to be welded all round by continuous weld with factor 0,4.

The length of overlap, in mm, is to be not less than $b = 2\,s + 25$, but not more than 50 mm *(s thickness of the thinner of the plates joined)*.

c) The primary members (beams, deck longitudinals, frames, bulkhead stiffeners, and so on.) are to be connected to supporting members (deck girders, deck transverses, side stringers, horizontal girders, and so on.) by welds with factor 0,35.

The sectional area f, in cm^2, of the welds connecting the primary members to supporting members shall be not less than determined from the formula:

$$f = \frac{25 \cdot p \cdot a \cdot l}{\sigma_n}$$

where:

p	=	pressure, kPa, specified in appropriate chapters of this Part of the Rules;
a	=	spacing between members, in m;
l	=	span of members, in m;

σ_n = Contact QRSHO.

The weld sectional area f is determine y summing up the results obtained by multiplying the throat thickness by the weld length of each portion of the connection of member web to the girder.

d) The framing members cut at intersection with other structure are to be in good alignment. Nonalignment is not to exceed half the thickness of the member. Where continuity is obtained by directing welding of the members to the structure involved, the throat thickness s of the weld is to be determined considering the thicknes of the member concerned. Otherwise, through penetration welding is to be performed. If the thickness of the thinner of the parts joined is less than 0,7 of the thickness of the other part, the throat thickness is to be calculated with regard to the particular loading conditions in way of the intersection.

Where longitudinals are cut at transverse bulkheads, the construction used for their attachment is to comply with the following requirements:

.1   When the brackets are fitted in line on both sides of the bulkhead, the area f_1 in cm², of the weld connecting the brackets (and the longitudinal butt ends, if they are welded) to transverse bulkheads is not to be less than determined from the formula:

$$S_1 = 1,75 \cdot S_o$$

where: S_o = cross-sectional area of the longitudinal (effective flange excluded), in cm².

.2   If one continuous bracket plate welded in the appropriate slot cut in the bulkhead plating is fitted, the sectional area of the bracket at the bulkhead is not to be less than $1,25\ S_0$.

.3   The arm length l_{br}, of the bracket, in mm, over the longitudinals is not to be less than determined from the formula:

$$l_c = \frac{1,75 \cdot S_o - S_1}{2 \cdot a} \cdot 10^2$$

where: S_1 = area of weld connecting longitudinal butt ends to transverse bulkheads, in cm²;

a = accepted design thickness of fillet weld connecting bracket to longitudinal, mm.

e)   Where plate thickness exceeds 18 mm, for connections made by fillet welds in which excessive stress in Z-direction may be caused by welding process or by external loads Z-steel is to be used or structural measures are to be taken to prevent lamellar tearing. In all cases reducing of residual stress level is to be provided.

f)   Double continuous welds are to be used in the following regions:

.1   Within *0,25L* from forward perpendicular in ships with *L ≥ 30 m,* for connection of framing members to bottom shell, and in case of only a single bottom in this region, also for welding of the webs of center girder, side girders and floors to face plates of these members;

.2   Within the ice belt of ships of categories YAA, YA and Al, as well as in forward region of category A2 ships, for connection of side framing to shell plating;

.3   In way of foundations for machinery and equipment which may constitute a source of vibration for connection of framing members to bottom and inner bottom platings, deck framing to deck plating;

.4   For the structures in the after peak;

.5   In way of supports and member ends, for connection of framing members to the plating;

.6   In tanks (including double bottom tanks), exclusive the tanks for oil fuel or lubricating oil.

.7   For structures providing tightness.

g)   Single continuous welds are not to be used:

.1   Within *0,2L* from F.P. for connection of side framing to shell plating, and within *0,25L* from F.P. for connection of bottom framing to shell plating;

.2   For structures subject to intense vibration;

.3   For welding of side framing in ships mooring alongside other ships at sea or offshore units;

.4   For connections where the angle between a member web and the plating differs by more than 10º from a right angle.

h) For all types of intermittent joints the weld length is not to be less than *15a*, (for a, see *1.7.5*) or 50 mm, whichever is the greater.

The spacing of welds (*t - l* - for chain welds and scalloped framing, and $(t - 2 \cdot l)/2$ -for staggered welds) is not to exceed *15s* (*s* = plate thickness or we!) thickness, whichever is the less). The spacing of welds or scallop length, where scalloped frames are used, is not to exceed 150 mm,

Intermittent or single continuous welds connecting the framing members to the plating are to be substituted in way of supports and member ends bv double continuous welds having the same throat thickness as the intermittent or single continuous welds of the remaining part of the members. The length of joints welded from both sides is to be not less than the sum of bracket arm and the web depth, if a bracket is fitted, and is to be twice the web depth if no bracket is fitted.

Where the framing members pass through supporting structures (deck transverses, deck girders, floors, and so on.), the aforesaid reinforcement is to be provided on both sides of supporting member.

Where single continuous welds are used, back runs at least 50 mm long and spaced not more than 500 mm apart are to be welded on the reverse side of the detail joined. The throat thickness of back weld is to be the same as that of the continuous single weld.

i) Staggered spot welds and single intermittent welds may be used in the structures of deckhouses and superstructures of the second tier, on decks inside first tier houses and superstructures, casings, enclosures inside the hull, not subject to intense vibration and impact loads and not affected by active corrosion, provided that the maximum plate or member web thickness is not more than 7 mm.
.

j) Scalloped construction is not to be used:

.1   For side framing within *0,2L* from F.P. and for connection of framing members to bottom shell plating within *0,25L* from F.P.;

.2   In regions with high level of vibration;

.3   For side and bottom framing and for side framing in ships mooring at sea alongside other ships or offshore units;

.4   For connection of bottom center girder to plate keel;

.5   For deck and inner bottoin framing in locations where containers, trailers and vehicles may be stowed and for upper deck framing under deckhouses in way of their ends at a distance less than 0,25 of the deckhouse height from the intersection of deckhouse side and end.

k) In scalloped construction the welding is to be carried round the ends of all lugs. The depth of scallop in member web is not to exceed 0,25 of the member depth or 75 mm, whichever is the lesser. The scallops are to be rounded with radius not less than 25 mm. The spacing of lugs is to be not greater than the length of the scallop. Scallops in frames, beams, stiffeners and similar structures are to be kept clear of the ends of structures, as well as intersections with supporting structures (decks, side stringers, deck girders, and so on.) by at least twice the member depth, and from the toes of the brackets by at least half the member depth.

l) In way of cut-outs for air and drain water, slots for the passage of framing members and welded joints, the joints are to be welded as double welds for a length of 50 mm on both sides of the cut-out.

m)   Where welding of tee-joints by fillet welds is impracticable, tenon welds or plug welds may be used.

For plug welding, the slots are to be of circular or linear form, with throat thickness of weld equal to 0,5 of plate thickness. The ends of slots in plug welding are to be made semicircular. The linear slots are to be arranged with longer side in the direction of the parts to be joined.

Complete filling of slot is not permitted.

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In regions of high level of vibration welded joints with complete root penetration and permanent backing ring are recommended instead of tenon welds or plug welds.

SECTION 2
General requirements for hull structures

2.1   General

2.1.1   Application

a) The requirements of this Section apply to sea-going ships of all types and purposes, having regard to additional provisions of *Section 3*.

b) The Section specifies the requirements for hull structures: shell plating, platings, framing members, pillars, stems, sternframes and seatings.

2.1.2   Symbols

L_1 : Length of the compartment, in m, measured as follows:
  - **with plane bulkheads**, as the distance between bulkhead platings.
  - **with corrugated bulkheads**, as the distance between corrugation axes or the axes of trapezoidal stools at the inner bottom level;
  - **with cofferdam bulkheads**, as the distance between middle cofferdam axes.

B_1 : Breadth of the compartment, in m, measured at its mid-length as follows:
  - **for single skin construction**, as the distance between the sides or between the side and the longitudinal bulkhead at the upper edge of the floor.
  - **for double skin construction**, as the distance between inner skins or between the inner skin and the longitudinal bulkhead.
  - **where hopper side tanks are fitted**, as the distance between hopper tanks at the inner bottom level or between the longitudinal bulkhead and the hopper side tank.
  - **where several longitudinal bulkheads are fitted**, as the spacing of longitudinal bulkheads or as the distance between the longitudinal bulkhead nearest to the side and the appropriate side.

l : Span of framing member in accordance with *1.6.3*, unless provided otherwise.

h : Depth of the member web, in cm;

s : Plate thickness, mm;

W : Section modulus of members, in cm^3.

I : Moment of inertia of members, in cm^4.

a : Spacing of framing members concerned (longitudinal or transverse framing); where the spacing varies, a is the half-sum of the distances of adjacent members from the member concerned;

s : Corrosion allowance to the plate thickness, in mm.

___

: Factor taking account of corrosion allowance to the section modulus of members.

2.2   Shell plating

2.2.1   General and symbols

a) This Chapter specifies the requirements for the thickness of bottom and side shell plating, the thickness and width of sheer-strake, plate keel, garboard strakes as well as those for the minimum structural thicknesses of these members and construction of openings therein.

The requirements are applicable to all regions along the ship's length and depth.

Special requirements for strengthening of bottom and side plating at the ends are stated in *2.8*.

b). Symbols:

p_{st} : Design static pressure according to *1.3.2*.

p_w : Design pressure due to the motion of the ship's hull about wave contour according to *1.3.2*.

p_r : Design pressure from carried liquid cargo, ballast or oil fuel according to 1.3.4.

r : Radius of the opening, m.

2.2.2   Structure

a). No openings are to be cut in the upper edge of the sheer-strake.

If necessary, circular openings only may be cut in the sheer-strake. The center of the opening is to be not less than two diameters of the larger opening of two adjacent openings distant from the upper edge of the sheer-strake or from other openings. When the diameter of circular openings in the sheer-strake exceeds 20 times the thickness of the sheer-strake, or 300 mm, whichever is the lesser, thickened insert plates or horizontal stiffeners are to be fitted above and below the opening.

The insert plates or stiffeners are to extend for not less than 2r in either direction from the center of the opening, and their area is to be gradually reduced towards the ends.

Rectangular openings cut in the side shell plating (for cargo ports, sea-chests, and so on.) located below the sheer-strake are to have corners rounded with a radius of curvature 0,l of the opening height, but not less than 50 mm.
In all cases when the openings may result in considerable reduction of longitudinal or local strength of the ship, provision is to be made for reinforcement of such areas. It is recommended that insert thickened plates be used. The reinforcement of these openings is to be approved by *QRS Class*.

b) The transition of the sheer-strake to the deck stringer may be rounded. The radius of curvature of the sheer-strake, in this case, is to be not less than 15 times the thickness of the sheer-strake.

2.2.3 Loading on shell plating

The design pressure *p*, in kPa, on the bottom and side shell plating in dry cargo ships and tankers is the external pressure determined from the formula:

$p = p_{st} + p_w$ on

For tankers having no double bottom and double skin construction the internal pressure $p = p_c$, is additionally determined from Formula in section 1.3.4 (b). If $p_{st} > p_w$ the counter pressure is to be included in the calculation of the internal pressure

$$p = p_r - \left(p_{st} - p_w \right)$$

To be taken as the design pressure is the external or internal pressure, whichever is the greater.

2.2.4 Scantlings of plates of shell plating

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a). The thickness of bottom and side shell plating is not to be less than determined from Formula 1.6.4 (d) taking

$m = 22,4$;

$$k_\sigma = k_\sigma' + k_L \cdot \frac{x_1}{L}$$

where: k_L = see *table 2200*;

k_σ' = see *table 2200*.

x_1 = distance of the center of the plate considered from the midship section, m:

at $\frac{x_1}{L} \leq 0,2$ take 0,2;

at $\frac{x_1}{L} \geq 0,4$ take 0,4.

Table 2200

Framing system	Bottom		Side	
	k_σ'	k_L	k_σ'	k_L
Longitudinal	0,9	0,75	1,0	0,5
Transverse	0,3	2,25	0,4	2,0

The reduction of the side shell plating away from the base line is not to exceed 20 per cent of the thickness of the strake above bilge.

b). The buckling strength of the bottom plating, strake above bilge, sheer-strake and strake below in midship region of ships over 60 m in length is to be checked according to *1.6.5*.

c). The thickness of bilge strake shall not be less than that of adjacent strakes of bottom or side shell plating calculated according to 2.2.4 (a), whichever is the greater.

d). The width of keel plate b_k, in mm, is not to be less than determined from the formula:

$$b_q = 800 + 5 \cdot L$$

in this case bk need not exceed 2000 mm.
The thickness of keel plate is to exceed the adopted thickness of bottom shell plating in midship region by the value
= + , but not more than 3 mm.
Where the bottom plating thickness exceeds 22 mm, the plate keel thickness may not exceed 25 mm, but is not to be less than that of the bottom plating.
The thickness of the keel plate within 0,15L from the after perpendicular may be 10 per cent less than that of the midship region.

e). The width of the sheer-strake b_s, in mm, is not to be less than determined from Formula in 2.2.4 (d) taking b, not more than 2000 mm.
The sheer-strake thickness in midship region is not to be less than that of adjoining strakes of side shell or deck plating (stringer plate), whichever is the greater. At ends the sheer-strake thickness may be equal to that of the side plating in this area.

f). The shell plates adjoining the sternframe as well as the plates to which the arms of propeller shaft brackets are attached are to have a thickness s, in mm, not less than determined from the formula:

$$s = 0,1 \cdot L + 4,4 \qquad \text{for } L < 80 \text{ m}$$
$$s = 0,055 \cdot L + 8 \qquad \text{for } L \geq 80 \text{ m}$$

The aforesaid thickness is to be ensured after hot bending, if it was used.

g). The thickness, in mm, of shell strakes adjoining the bar keel (garboard strakes) for 0,7L from the forward perpendicular is not to be less than determined from the formula

$$s = 0,08 \cdot L + 6$$

The thickness of the garboard strakes abaft the specified area may be reduced by 15 per cent. The width of the garboard strake b, in mm, is not to be less than determined from the formula:

$$b = 400 + 2,5 \cdot L$$

in this case, $b \leq 1000$ mm.

h). The thickness of shell plating s, in mm, is not to be less than determined from the formula:

$$s_{min} = 0,04 \cdot L + 6 \qquad \text{for } L \geq 80 \text{ m};$$
$$s_{min} = 0,05 \cdot L + 5,2 \qquad \text{for } 30 \geq L < 80 \text{ m};$$
$$s_{min} = 0,12 \cdot L + 3,1 \qquad \text{for } L < 30 \text{ m}.$$

Reduction of minimum thickness in proportion to the ratio of the adopted spacing to standard spacing is allowed for ships with L ≤ 60 m, but not more than 10 per cent.

i). The sectional area of stiffener or a thickened plate 'or reinforcement of openings in the sheer-strake is not to be less than $0,7s_s r$ where s_s, is the thickness of the sheer-strake, in mm. The thickness of insert plates for reinforcement of openings in the shell plating (excluding sheer-strake) is not to be less than 1,5 times that of the plate to be reinforced.

2.3   Single bottom

THIS CHAPTER IS ONLY APPLICABLE HAVING CNSIDERED REGULATION 19 OF MARPOL IN ITS ENTIRETY.

2.3.1   General and symbols

a). The Chapter specifies the requirements for the bottom framing in ships having no double bottom and in way where it is omitted, as well as for the floors, bottom center girder, bottom longitudinals, and elements of their connection, i. e. knees and brackets.

b).   Symbols:

I_v :   Moment of inertia of the floor, in cm^4.

I_q :   Moment of inertia of the keel, in cm^4.

I_c :   Moment of inertia of the side girder, en cm^4.

2.3.2   Structure

a)   In tankers of 80 *m* in length and more longitudinal framing is to be provided in the single bottom.

b)   The bottom center girder is to extend throughout the ship's length as far as practicable. In ships over 60 m in length, a continuous center girder between transverse bulkheads is recommended. In tankers the center girder web is to be stiffened on both sides by flanged brackets fitted midway between the bottom transverses and between a bottom transverse and a

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    transverse bulkhead. Where horizontal stiffeners are fitted along the bottom center girder, the brackets are to be carried to the second horizontal stiffener from below. In case of vertical stiffeners, the brackets are to be carried to the face plate of bottom center girder. Breadth wise, the brackets are to extend to the nearest bottom longitudinal and are to be welded thereto.

c)   In dry cargo ships floors are to be fitted at every frame. Where the floors are cut at the bottom center girder, the face plates of floors are to be butt welded to the face plate of the center girder. In this case, the width of the floor face plate, where it is attached to the center girder face plate, is to be doubled, or horizontal knees of adequate sizes are to be fitted. The floor webs are to be welded to the center girder face plate. The floor face plates may be substituted by flanges. Flanged floors are to be fitted in way of machinery space, in the after peak, and in ships with $L \geq 30$ m, also for 0,25L from forward perpendicular.

d)   In tankers the spacing of bottom transverses is not to exceed *0,02L* or 3,75 m, whichever is the greater. Increase in spacing of bottom transverses by more than 5 m may be allowed on special agreement with *QRS Class*.

e)   In dry cargo ships the spacing of side girders and the distance from the center girder or the ship's side to the side girder is. not to exceed 2,2 m.

The side girder plates are to be cut at floors and welded thereto.

The face plates of side girders are to be welded to those of floors.

f)   In tankers the side girders, if fitted, in association with vertical stiffeners on transverse bulkheads and continuous deck girders are to form a ring system.

g)   Deep side girders having the same depth as the center girder web as well as conventional side girders having the same web depth as that of the bottom transverse, with $L_1/B_1 < 1$ are to run continuous from one transverse bulkhead to another.

h)   The center girder may be dispensed with in the machinery space, if the longitudinal girders under engine seating extend from the fore to the after bulkhead of the engine room and terminate with brackets beyond the bulkheads according to *2.3.5 (a)*.

i)   In tankers the webs of center girder and side girders are to be strengthened by stiffeners according to 1.6.5, and the bottom transverses - according to *1.7.3*.

2.3.3 Single bottom loads

a)   The design pressure on single bottom structures of dry cargo ships is the external pressure determined from Formula in section 2.2.3 for a ship in the ballast condition. When determining p_t of formula in section 2.2.3, the ballast draught may be taken as 0,6 of the summer draught. If a dry cargo ship is intended to navigate in fully loaded conditions with separate empty holds, the static pressure p_t of formula in section 2.2.3 for these holds is to be determined at the summer draught.

b)   The design pressure on single bottom structures of tankers- is the external pressure determined from formula in section 2.2.3 at the summer draught or the total pressure from Formula in section 2.2.3, whichever is the greater.

2.3.4 Scantlings of single bottom members

a). The bottom framing of dry cargo ships is to comply with the following requirements:

.1   The depth of floors in the center line is not to be less than *0,055B₁*. B_1 is not to be taken less than *0,6B_x* where B_x is the ship's breadth in the section concerned. Allowable reduction of floor depth is not to be more than 10 per cent, the required section modulus of the floor being also ensured. In the engine room the height of floor web between longitudinal girders under seatings is not to be less than 0,65 of the required depth at the center line. In this case, the reduction of section modulus by more than 10 per cent as against that required by this paragraph is not permitted.

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The depth of floors at a point located as far as 3/8 of the breadth B_x from the center line is not to be less than 50 per cent of that specified for center line floors.

The section modulus of floors is not to be less than determined from *1.6.4*, taking:

p - according to *2.3.3*;

$l = B_1$;

$m = 11,5$;

$k_\sigma = 0,8$ and $0,75$ - for floors with a face plate and flange, respectively.

The thickness of the floors web s, in mm, is not to be less than:

$$s = 0,01 \cdot h + 3,5$$

where: h = depth of the floor in the centerline, in mm.

.   The thickness of the floor need not exceed the thickness of the bottom plating.

On lengths of $0,05B_x$ (counting from the sides) the floor web area f_w in cm^2, is not to be less than determined from the formula:

$$= \quad (\quad + \quad)$$

Where bilge brackets are fitted, their sectional area may be included in the computation of the value f_w..

The thickness of floor face plate s, in mm, is not to be less than determined from the formula:

$$s = s_1 + \Delta s_1$$

where: s_1 = thickness of the floor web, in mm;

Δs_1 =		
2 mm	for L 50 m	
1 mm	for L < 50 m	
0 mm	for L < 30 m	

The width of floor face plate is not to be less than 75 mm. For $0,2L$ from forward perpendicular, as well as under the engine seatings and boiler bearers, the face plate area of floors is to be doubled.

Where flanged floors are fitted, the flange width is not to be less than 10 times the floor thickness but not greater than 18 times the floor thickness.

.2   The thickness of the center girder plate, s, in mm, in the midship region is to be determined from the formula:

$$s = 0,06 \cdot L + 6$$

The thickness of the center girder plate at $0,1L$ from the forward and after perpendiculars may be assumed 1 mm less than required for the midship region but not less than the thickness of floors in this region.

The thickness of the center girder face plate is to be taken 2 mm greater than that of the center girder plate.

.3   The plate thickness s, in mm, of side girders in the midship region is to be determined from the formula:

$$s = 0,05 \cdot L + 5$$

The plate thickness of side girders for $0,1L$ at the ends may be adopted 1 mm less than required for the midship region.

The thickness of side girder face plate is to be 2 mm greater than that of the side girder plate.

b).   The bottom framing of tankers in way of cargo tanks is to satisfy the following requirements:

.1   The section modulus of bottom longitudinals is not to be less than determined from *1.6.4*, taking:

p - according to *2.3.3*;

$m = 12$;

$k_\sigma = 0,20 + \dfrac{x_1}{L}$;

where: x_1 = distance from the mid-span of longitudinal to midship section, in m:

at $\dfrac{x_1}{L}$ 0,2 take: 0,2

at $\dfrac{x_1}{L}$ 0,4 take: 0,4

In ships having the length L 60 m, the buckling strength of bottom longitudinals in midship regios shall en ensured according to *1.6.5*.

.2 The bottom transverse depth is not to be less than $0,13B_1$..
The section modulus of bottom transverse is not to be less than determined from *1.6.4*, taking $l=B_1$.

If a deep side girder is fitted in the wing tank, the section modulus of bottom transverse is to be determined as for the center tank.

.3 The cross-section area of bottom transverse, in cm², excluding openings, is not to be less than determined from Formula in 1.6.4 (c) at $k_\tau = 0,55$:
in the center tank:

.4 The section modulus of center girder in the absence of side girders is not to be less than determined from *1.6.4*, taking:

$$a = \dfrac{B_1}{2};$$

$$l = L_1 - 0,3 \cdot h_c$$

where: h_c = is the depth of docking girder

$$k_\sigma = 0,25;$$

.5 The section modulus of side girder is not to be less than determined from *1.6.4*, taking:

$$a = \dfrac{a_2}{2}$$
$$l = L_1;$$
$$k_\sigma = 0,25;$$

.6 The thickness of webs and face plates of the center girder, bottom transverses, side girders, stiffeners and tripping brackets for strengthening the deep members in question, as well as the thickness of webs (and face plates) of bottom longitudinals, in mm, are not to be less than:

$$s_{min} = 0,035 \cdot L + 5,7 \text{ for L} < 80 \text{ m}$$
$$s_{min} = 0,025 \cdot L + 6,5 \text{ for 80 L 200 m}$$
$$s_{min} = 0,020 \cdot L + 7,5 \text{ for L} > 200 \text{ m}$$

In this case, s_{min} may not exceed 13,5 mm for bottom web framing or 11,5 mm for bottom longitudinals, stiffeners and tripping brackets.

c). In the machinery space the plate thickness of bottom transverses and side girders is not to be less than the thickness of the center girder. If the side girder acts also as a vertical plate of engine seating, it shall have a thickness not less than that of the vertical plate of engine seating. The depth of bottom transverses is to be increased in proportion to the height of installation of machinery seatings.

2.3.5 Special requirements

a). Attachment of the ends of the bottom members and strengthening of the deep member webs is to satisfy the following requirements:

.1   The center girder and side girders are to be attached to transverse bulkheads by brackets. For sizes of brackets, see *1.7.2*.

.2   In dry cargo ships the height of brackets is not to be less than half the depth of the center girder if the face plate of the center girder is welded to the transverse bulkhead. The brackets need not be fitted in case the face plate of the center girder **is** widened to at least twice the width of the normal face plate in way of abutting upon the transverse bulkhead. If the center girder is dispensed with in the machinery space, the center girder at breaks is to terminate beyond the bulkhead with a gradually tapered bracket of a length equal to double depth of the center girder, but not more than three frame spaces.

.3   In tankers the bottom transverses are to be attached to side transverses and/or vertical webs of longitudinal bulkheads by brackets. For sizes of brackets, see *1.7.2*.
      For the attachment of bottom transverses to the continuous center girder the brackets are to be carried to this girder face plate and welded thereto.

.4   In dry cargo ships less than 40 m in length (except within *0,25L* from F.P.) the side girders without vertical plates, made of welded T-section or other sections welded to the floor face plates, may be fitted.
      In this case, the sectional area *f*, in cm², of members acting as side girders is to be not less than determined from the formula:

$$f = 0,8 \cdot (B + 10)$$

      Sections acting as face plates of side girders without vertical plates are to be welded to bulkheads and are to have brackets of a height not less than the given section.

b). In dry cargo ships holes cut in the floors are to be of a diameter not exceeding half the floor depth in the given area. The distance between the hole edge and the floor face plate is to be not less than 0,25 times the depth of the floor in the given area. The distance between the edges of adjacent holes is not to be less than the floor depth. Floor plates provided with holes are to be strengthened with vertical stiffeners.

c). The webs of side girders and floors are to be provided with drain holes.

2.4   Double bottom

2.4.1   General

a)   This Chapter specifies the requirements for the double bottom structures including the bottom framing up to the top of the bilge rounding, inner bottom plating and framing, bottom center girder and duct keel, side girders and half-depth girders, margin plate with stiffeners for their strengthening, brackets, knees and intermediate vertical stiffeners in double bottom space, sea chests and drain wells.

2.4.2   Structure

a)   In tankers with L ≥ 80 m, ships for the carriage of bulk cargoes and ore carriers the double bottom is to be framed longitudinally.

b)   The center girder is to be extended as far as possible fore and aft to the stem and sternframe, and is to be attached to them, whenever possible. The center girder is to be continuous within at least *0,6L* amidships. Where longitudinal framing of the double bottom is adopted, brackets are to be fitted on both sides of the center girder, spaced not more than 1,2 m apart and be extended to the nearest longitudinal or the lightened side girder and welded thereto.

c) Instead of the bottom center girder a duct keel may be fitted consisting of two plates arranged on both sides from the center line. The distance, in m, between the side plates of the duct keel bk is to be determined from the formula:

$$b_q = 0,004 \cdot L + 0,7$$

The width of duct keel exceeding 1,9 m is subject to special consideration by QRS *Class*. Brackets or frames with knees are to be fitted at every frame on the bottom and inner bottom plating between the side plates of the duct keel. In case of longitudinal framing, on both sides of the duct keel at every frame brackets are to be fitted similar to those used for the center girder. Where the duct keel fitted only over a part of the ship's length breaks and transfers to the center girder, the plates of the duct keel and the center girder are to overlap over a length of at least one frame spacing and are to terminate in brackets with face plates. In this case, the length of the brackets is not to be less than three frame spaces, if the area of the transition is within 0,6L amidships, and not less than two frame spaces elsewhere.

d) The structures of side girders and margin plate are to satisfy the following requirements:
.1 The number of side girders on either side within midship region is not to be less than indicated in *Table 2.4.2.4.1.*

Table 2300

Framing system	Breadth, *B*, m	Number of side girders
Transverse	8 B 16	1
	16 B 25	2
	25 B	3
Longitudinal	10 B 18	1
	18 B 28	2
	28 B	3

Where transverse framing is adopted in the double bottom, the spacing of side girders is not to exceed 4 m.
.2 Where longitudinal framing is adopted in the double bottom, the lightened side girders may be fitted instead of longitudinals on bottom and inner bottom.

.3 Where there are two tunnels symmetrical with regard to the center line, their structure is subject to special consideration by *QRS Class*.

.4 In the machinery space the arrangement of the side girders is to be coordinated with that of the engine, boiler and thrust block seatings, so that at least one of the longitudinal girders under the seating will be fitted in line with the side girder. An additional side girder is to be provided, in this case, in line with the second longitudinal under the seating.
Where side girders cannot be arranged in line with longitudinal girders under the seatings, additional side girders are to be fitted under each longitudinal girder.
Additional side girders may be replaced by half depth side girders welded only to the inner bottom plating and floors, if approved by *QRS Class*.
.5 The inclined margin plate, if fitted, is to extend throughout the length of the double bottom and is to retain its width not less:
$$b = 0,0035\,L + 0,40$$
Where the margin plate is fitted horizontally, it shall be 50 mm thicker than the bilge bracket plus the frame section height.

e) The arrangement and structure of floors are to satisfy the following requirements:
.1 For transverse framing of double bottom plate floors are to be fitted at every frame:
In engine and boiler room;
At the fore end within *0,25L* from F.P.;
In the holds intended for the carriage of heavy cargo and ore, as well as in the holds from which cargo is regularly discharged by grabs;
In ships which may happen to be aground due to ebb-tide in ports.

In other regions it is permitted to fit the plate floors at the distances not greater than stated in *2.3.2*. In this case, provision is to be made for open floors (bracket or lightened).

Bracket floors consist of bottom and reverse frames connected by brackets at the center girder, side girders and margin plate.

Lightened floors consist of plate panels 'having large openings of the smooth shape between side girders.

.2 For longitudinal framing of double bottom, the spacing of plate floors is not to exceed *0,2L* or 3,75 m, whichever in the greater. Where lightened side girders are fitted instead of bottom nd inner bottom longitudinals, tha above spacing may be increased, but not more than twice.

For longitudinal framing the spacing of plate floors is not to exceed two frame spaces:

In engine and boiler room;

In the holds intended for the carriage of heavy cargoes and ore as well as in the holds from which cargo is regularly discharged by grabs;

At the fore end within *0,25L* from F.P.;

In ships which may happen to be aground due to ebb-tide in ports.

Brackets are to be fitted at every frame between plate floors along the margin plate and are to be extended to the nearest longitudinals in double bottom and inner bottom or to the nearest additional side girder and are to be welded to them.

Plate floors under the seating of the main engine are to be fitted at every frame and are to be carried to the nearest side girder outside the main engine seating.

.3 Plate floors are to be fitted:

Under pillars and the ends of longitudinal partial bulkheads;

Under bearers and the ends of boiler bearers;

Under transverse bulkheads and sloping plates of low trapezoidal stools of the corrugated bulkheads;

Under the ends of brackets of deep tank bulkhead stiffeners (in transversely framed double bottom);

Under block bearing seatings.

In the above cases the floors need not be fitted throughout the ship's breadth. Partial floors may be fitted and carried to the side girder nearest to the strengthened structure.

f)   Arrangement of the stiffeners on the center girder and duct keel, side girders and floors is to satisfy the following requirements:

.1 The stiffeners are to be provided for transverse framing and the plate floors of more than 900 rnrn in depth. The spacing of stiffeners is not to exceed 1,5 in. The spacin g of vertical stiffeners of lightened floors is not to exceed 2,2 m.

For longitudinal framing the stiffeners on plate floors are to be fitted in line with bottom and inner bottom longitudinals. The stiffeners are to be carried to the longitudinals and welded thereto.

The stiffeners are to be fitted under the pillars, at the toes of brackets of the end stiffeners of longitudinal partial bulkheads, and so on.

.2 Watertight floors are to be fitted with vertical stiffeners spaced not more than 0,9 in apart.

g)   Holes and manholes are to satisfy the following requirements:

.1 An adequate number of holes (manholes) is to be provided in the inner bottom plating, side girders and floors for access to all parts of the double bottom. Sizes of all holes (lightening holes included) are to satisfy the requirements of the standards or other regulating documents recognized by *QRS Class*.

.2 The holes in the center girder; side girders and floors are to be of the smooth rounded shape. The minimum allowable heights of the plate adjoining the bottom plating or inner bottom plating are indicated in *Table 2400*. Besides, the minimum height of the plate of the lightened side girder in way of the hole is not to be less than 1/8 of its length.

The plate heights indicated in *Table 2400* may be reduced if suitable stiffening is fitted.

Table 2400

Member	Minimum allowable plate height (parts of member height)
Center girder	0,3
Side girders	0,25
Lightened girders	0,15
Floors:	
Plate	0,25
Lightened	0,2

.3 The distance between the edges of adjacent openings in the center girder, side girders and plate floors is not to be less than half the length of the larger opening.

The distance of the opening edges in the floors from the longitudinal bulkheads, center girder, side girders, inclined margin plate and inner edges of hopper side tanks is not to be less than hall the depth of the center girder in this region. The distance of the opening edge in the lightened floor from the side girders is not to be less than one-quarter of the depth of the center girder.

Deviation from this requirement may be permitted in exceptional cases.

.4 One or more consecutive openings may be allowed in the lightened side girder web between the adjacent floors and lightened floor web between the adjacent side girders. In the latter case, vertical stiffeners are to be fitted between openings. The length of one opening is not to exceed 1,2 times the accepted depth of the center girder and 0,7 times the spacing between floors (side girders) or between the floor (side girder) and the vertical stiffener, whichever is the less. The distance of the opening edges in the lightened side girders and floors is not to be less than half the depth of the center girder in this region.

.5 Openings are not to be permitted:

In the center girder over a length of *0,75L* from F.P.

In the center girder and side girders (lightened side girders) under pillars and at sections adjoining transverse bulkheads (between the bulkhead and extreme floor in the case of transverse framing and over a length equal to the inner bottom depth in the case of longitudinal framing).

In floors under pillars and at the longitudinal partial bulkheads.

In floors at the ends of brackets supporting the seatings of main machinery in transverse direction.

In floors between the side (inner side) and the nearest lightened side girder provided the spacing of floors is increased.

In exceptional cases, openings in the above-mentioned members may be permitted provided the webs in way of the openings are suitably stiffened.

.6 In brackets circular lightening openings are permitted with a diameter not more than 1/3 of the width or height of the bracket, whichever is the less.

2.4.3 Double bottom loads

a) The external pressure on double bottom structures from sea is the external pressure p determined from Formula in section 2.2.3.

b) For the design ballast condition the value z_i is to be counted from the design waterline corresponding to operation in ballast condition.

c) Double bottom loading from inside:

.1 Design pressure on the double bottom from general cargo is determined from *1.3.4*.
.2 Design pressure on the double bottom from liquid cargo or ballast is determined from *1.3.4*.
.3 Design pressure on the double bottom from bulk cargo is determined from *1.3.4*.
.4 Test loads
$p = 7,5h_p$

where h_p = vertical distance, in m, from inner bottom plating to the top of air pipe;

.5 loads due to the emergency flooding of double bottom compartments

$$p= 10,5(d-h)$$

where h = actual depth of double bottom, in m.

d) The total design pressure on the double bottom is determined as the difference between the external pressure p and cargo (ballast) pressure p_c from inside. If the hold may be empty during operation, the external pressure p, is to be taken as the design pressure.

2.4.4 Scantlings of double bottom members

a) The double bottom depth h, in m, at the center girder is not to be less than determined from the formula:

$$h = \frac{L-40}{570} + 0,04B + 3,5\frac{d}{L}$$

but not less than 0,65 m.

b) The center girder and side girders are to satisfy the following requirements:
.1 The cross-sectional area f_w in cm², of the web of the center girder and side girders (excluding openings) is not to be less than determined from Formula in 1.6.4 (c) taking k_t = 0,9;

.2 The thickness of the center girder (duct keel) s_{min} in mm, is not to be less than determined from the formula:

$$s_{min} = 0,035 \cdot L + 6,5$$

The thickness of the side girder web s_{min}, in mm, for transverse framing is not to be less than determined from the formula:

$$S_{min} = 0,035 \cdot L + 5$$

For longitudinal framing, the thickness of the side girder web is determined in conformity with *2.4.4*.
.3 The buckling strength of the web of center girder and side girders as well as that of longitudinal stiffeners fitted on them is to be provided in accordance with *1.6.5*.
.4 At the ends the thickness of the center girder at *0,1L* from the perpendiculars may be 10 per cent less than that of the center girder in midship region, calculated for steel used at the ends but not less than the minimum thickness as determined from Formula above for thickness of the center girder (duct keel).

The thickness of watertight portions of the center girder and side girders is not to be less than required for watertight floors in this region.
The thickness of side plates of the duct keel is not to be less than 0,9 times the thickness required for the center girder in this region.

c) Floors are to satisfy the following requirements:

.1 The cross-sectional area f, in cm², of plate floors (excluding openings) is not to be less than determined from the formula in 1.6.4 (c).

.2 The floor shall be stiffened according to *1.7.3*.
Between the fore peak bulkhead and 0,25L from the forward perpendicular, in the machinery space and peaks, and in the holds of ship which may happen to be aground due ebb-tide or from which cargo is regularly discharged by grabs, the thickness of plate floors s_{min}, in mm, is not to be less than:
For transverse framing:

$$s_{min} = 0,035 \cdot L + 5$$

For longitudinal framing:

$$s_{min} = 0,035 \cdot L + 6$$

.3   The thickness of watertight floors is not to be less than determined from *formula* 1.6.4 (d) and is not to be less than required for the plate floors in this region of the ship.

  d)   Inner bottom plating and margin plate are to satisfy the following requirements:

.1   The thickness of the inner bottom plating including the margin plate is not to be less than determined from *formula* 1.6.4 (d).

.2   The thickness of the inner bottom plating s_{min} D Equation , in mm, is not to be less than:
$$s_{min} = 0,05 \cdot L + 3,8 \qquad \text{for } L < 80 \text{ m}$$
$$s_{min} = 0,035 \cdot L + 5 \qquad \text{for } L\ 80 \text{ m}$$

  The thickness of the inner bottom plating in the holds which may be filled with water ballast as well as in the cargo (ballast) tanks of tankers is not to be less than determined from *formula* in section 2.3.4 (b)(6).

  In the engine room and holds under cargo hatches, if no wood sheathing is provided, s_{min} is to be increased by 2 mm.
  In the holds, if no wood sheathing is provided and cargo is discharged by grabs, s_{min} is to be increased by 4 mm.

  e)   Bottom and inner bottom longitudinals and frames are to satisfy the following requirements:
.1   The section modulus of the bottom and inner bottom longitudinals as well as bottom and reverse frames of the bracket floors and the duct keel is not to be less than determined from *1.6.4*.

.2   If intermediate struts are fitted between bottom and inner bottom longitudinals at the mid-span, the section modulus of these longitudinals may be reduced in half.

.3   If the ratio of the span of longitudinal on the bottom or inner bottom to its depth is less than 10, the sectional area of longitudinal web is not to be less than determined from *formula* in 1.6.4 (c):
    taking $N_{max} = 0,5 \cdot p \cdot a \cdot l\ N_{max} = 0,5 \cdot p \cdot a \cdot l$, in kN;
  $k_\tau = 0,70$;

where: p = design pressure of the longitudinal
                according to *2.4.4*;
          l = design span of the longitudinal
                according to *2.4.4*.

4.   In the midship region of the ship having the length $L\ 60$ m, the buckling strength of bottom and inner bottom longitudinals should comply with *rule 1.6.5*.

  f)   The stiffeners on the watertight portions of the center girder (duct keel), side girders and floors are to satisfy the following requirements:

1.   The section modulus of vertical stiffeners on watertight portions of the center girder (duct keel), side girders and floors is not to be less than determined from *rule 1.6.4*.
    In this case:
    l - span of the stiffener determined as the spacing of longitudinals to which the stiffener is welded or as the double bottom depth if the stiffener is not in line with bottom and inner bottom longitudinals, in m;
    $m = 8$ and 10 - for the stiffeners sniped at ends and welded to the bottom and inner bottom longitudinals, respectively;
    $k_\sigma = 1$.

.2   The section modulus of horizontal stiffeners on the center girder (duct keel) and side girders is not to be less than determined from *1.6.4*.

In this case:

$p = p_d$ - as defined in *2.4.3* at the level of the horizontal stiffener concerned;

l - distance between floors or between floors and brackets, m;

$m = 12$;

$k_\sigma = 0,7$.

.3   In the mid-ship region of the ship having the length L 60 m, the buckling strength of horizontal stiffeners on the center girder (duct keel) and side girders is to comply with *1.6.5*.

2.4.5   Special requirements

a)   The partial double bottom and strengthening in way of changing depth of double bottom are to satisfy the following requirements:

.1   In areas where the double bottom ends, gradual tapering of longitudinal members of the double bottom into those beyond the double bottom is to be provided.

The inner bottom plating is to be tapered (on a length of at least three frame spaces) into the face plates of the center girder and side girders of the single bottom. The width of these face plates at the double bottom boundary is to be not less than half the distance between the adjacent side girders.

The margin plate is to extend beyond the double bottom as a bracket with a height equal to the margin plate width and a length equal to not less than three frame spaces, with a face plate or flange along its free edge.

.2   Where the double bottom depth changes in the form of a knuckle, one end of the knuckle shall be at a transverse bulkhead and the other - on a plate floor.

However, both knuckles may be arranged at plate floors, but, in this case, the construction is subject to special consideration by *QRS Class*.

.3   Where the double bottom depth changes in the form of a step, the step shall be arranged at a transverse bulkhead.

At the step, the inner bottom plating of the lower portion shall extend for a length of three frame spaces, with L 80 m, and for two frame spaces, with $L< 80$ m. Forward (or aft) of the end of the extension the requirements for the partial double bottom are to be complied with.

Where the step is located beyond $0,5L$ amidships, as well as where the height of step is less than 660 mm, the construction of double bottom in way of the extension shall, in every case, be subject to special agreement with *QRS Class*.

.4   Continuity and reduction of stress concentration is to be provided in way of step where there is a change in the depth of center girder, side girders, margin plate and inner bottom longitudinals (for longitudinal framing system).

b)   Bilge wells, sea chests and ice boxes are to satisfy the following requirements:

.1   Bilge wells are to satisfy as far as possible the requirements of this Chapter.

The thickness of walls and bottom plates of a bilge well is to exceed that of watertight floors by not less than 2 mm.

.2   The thickness of floors, side girders and inner bottom plating forming the walls of sea chests is to be 2 mm greater than required by *2.4.4 (b)*, with the test head according to *Appendix 1, item 9*.

The thickness of sea chest and ice box walls is to be not less than it is required by *2.2.4 (a)* for. the shell plating in the region under consideration.

c)   Besides general provisions for the arrangement of the oil fuel tanks, for the arrangement of the double bottom tanks for oil fuel storage the manholes in the tank top arranged within the engine and boiler room for access to the tanks are to be provided with coamings not less than 0,l m in height.

d)   The bed plate of main engine and the thrust block are seated directly on the inner bottom plating, insert plates of a thickness not less than stated in *2.11.4 (a)* are to be welded into the plating under the supporting parts of the bed plate and thrust block. The dimensions of welded inserts shall be such as to provide adequate arrangement of supports and attachment of machinery and shall be not less than the supporting parts of the bed plate. Where the engine bed plate and the thrust block are fitted on the inner bottom plating, two girders, or one such girder and a half-depth girder, shall be fitted in way of their arrangement along each welded insert plate. The upper part of the girder webs shall have the same

thickness as the welded insert for at least 0,2 of the girder depth, or alternatively, the thickness of the webs for the full depth shall be as required by *2.11.4* for the vertical plates of seatings.

A horizontal stiffener of a size required in the foregoing for the upper part of girder webs shall be fitted between the girders, account being taken of the holes for holddown bolts of the bed plate.

With the consent of *QRS Class*, for engines of smaller power, only one side girder is permitted to be fitted under the welded insert plate.

e) The plating of recess under the engine crankcase, as well as the side girders and floors confining it, are to have a thickness 2 mm greater than that of inner bottom plating in that region. The minimum distance from the recess plating to the bottom shell plating is not to be less than 460 mm.

f) The inner bottom plating under the corner fittings of containers or in way of stowage bottom pockets is to be increased in thickness and strengthened by means of stiffeners, knees or brackets. This also applies to strengthening of bottom plating in way of lashing pots.

2.5   Side framing

2.5.1   General and symbols

a) This Subsection specifies the requirements for the side frames, web frames (side transverses), side longitudinals, side stringers, cross ties connecting the side transverses to vertical webs on longitudinal bulkheads in tankers.

b) Symbols:
 l :   Span of side longitudinal, in m, measured as follows:
.1   In **dry cargo ships**:
     For main and web frames - between the top edge of the tank top or floor and the lower edge of the deck at side , the value of l being not less than 3 m and 3,5 m for main frames in single-deck and multi-deck ships, respectively.
     For between deck frames - between the decks, but not less than 2,6 m.
     For stringers - between web frames or between a web frame and the nearest transverse bulkhead, whichever is the greater.

.2   In **tankers**:
     For frames - between side stringers, or between a stringer and the mid-height of a bilge bracket, whichever gives the greatest measurement of the frame.
     For side longitudinals - between side transverses or between the side transverse and the transverse bulkhead, whichever is the greater.
     For side transverses - between the top edge of bottom transverse and the lower edge of deck transverse.
     For side stringers - between transverse bulkheads, including bilge brackets, and, if side transverses are fitted - between side transverses or between side transverse and transverse bulkhead.
.3   Determination of the design span of vertical and horizontal diaphragms of double skin is subject to special consideration by *QRS Class*.

2.5.2   Structure

a) In tankers with transversely framed sides provision shall be made for side stringers which are recommended to be connected by cross ties to horizontal girders on longitudinal bulkheads. The cross ties are to be arranged in line with every side transverse. Side stringers are to be fitted so that they are spaced not more than 3,5 m apart and at intervals not more than 3,5 m from the deck or base line. Where the distance between transverse bulkheads exceeds 10 m, side transverses are to be fitted in line with deck and bottom transverses. Where the ship's side is framed longitudinally, side transverses are to be fitted.

b) Web frames and vertical webs are to be fitted between the sides of double skin construction in the framing system. These structures are to be attached to plate floors and deck transverses. With transversely framed sides side stringers and horizontal girders or plate platforms are also to be fitted between the side plating and the inner skin. For access to all structures inside double skin appropriate openings (manholes) are to be provided in vertical diaphragms and platforms. Openings in diaphragms and platforms are to be arranged with their long axis parallel to side plating. The edges of openings situated at least 1/4 of span from the cross-sections at supports are to be reinforced by collars or stiffeners. The distance between the edges of neighboring openings is not to be less than the opening length.

In platforms for a length not less than three frame spaces or 1,5 times the distance between side plating and inner skin (whichever is the lesser) from transverse bulkheads. Openings, except for air and drain holes, are not permitted:

In vertical diaphragms for a length not less than 1,5 times the distance between side plating and inner skin from the lower and upper ends of the diaphragm.

c) The side framing in the machinery space and tanks is to be strengthened by means of web frames and side stringers. The web frames are to be spaced not more than five frames spaces apart or 3 m, whichever is the less. The web frames are to be arranged taking into account the location of the main engine, i.e. they are to be fitted at least at the extremities of the engine. The web frames are to be carried to the nearest continuous platform in way of the machinery space. Deck transverses are to be fitted in line with the web frames. Side stringers in the machinery space are to be fitted so that the distance measured vertically between the stringers and that between the side stringer and the deck or the tank top (the upper edge of floors) at side is not to exceed 2,5 m.

2.5.3 Side loading

a) The design pressure on side plating is the external pressure p determined from *formula* in section 2.2.3.
In way of tanks, the pressure determined in accordance with *1.3.4.* should additionally be taken into consideration.
The design pressure on inner skin is to be taken not less than 25 kPa.

b) In case of double skin construction the design pressure on inner skin forming the boundaries of the compartment intended for the carriage of liquid cargoes and ballast is determined from *1.3.4.* The design pressure on inner skin from bulk cargo is determined according to *1.3.4.* The design pressure on inner skin as well as on watertight portions of vertical diaphragms and horizontal platforms inside the double skin is not to be taken less than the test head determined from *Appendix 1*.

2.5.4 Scantlings of side members

a) The section modulus of main frames of dry cargo ships and side frames of tankers for transverse framing is not to be less than determined from *1.6.4*. In this case:

p - as defined in 2.5.3.1, but not less than the hydrostatic head from the mid-span of the frame to the upper deck at side.
m - factor equal to:
16,0 and **17,5** for main frames of dry cargo ships with single deck, two decks, three and more decks, respectively;
11,0 for side frames of tankers;
k_σ - factor equal to:
1,00 for main frames of dry cargo ships;
0,70 for side frames of tankers.

b) The section modulus of tween deck and superstructure frames is to be not less than determined from *1.6.4*. In this case:

p - as defined in 2.5.3.1 (for tween deck frames, not less than the hydrostatic head from the mid-span of the frame to the upper deck at side);
m - factor taken equal to:
4,2 for tween deck of two-deck ships;
6,4 for lower tween decks of multi-deck ships;

4,7 for upper tween deck of multi-deck ship and superstructure;

k_σ - factor taken equal to:

0,8 for lower tween decks of multi-deck ships;

1,2 for two-deck ship tween deck and upper tween deck of multi-deck ship and superstructure;

$\omega_c = 1$ for superstructures.

This requirement applies to the case where the lower end of 'tween deck frame is not attached by a bracket. If the lower end of the frame is attached by a bracket of a height not less than $0,1l$ and the section modulus of the frame at the deck taking into account the bracket is not less than 1,75 of the section modulus determined above, the section modulus of 'tween deck frame may be reduced by 30 per cent.

The section modulus of tween deck or superstructure frame is to be taken not less than 12 cm^3.

c) The section modulus of side longitudinals of all ships is not to be less than determined from 1.6.4. Taking:

p - according to *2.5.3 (a)*

$m = 12$.

k_σ - according to *table 2500.*

Table 2500 Coefficient k

Arrangement of longitudinals along the ship's depth	k	
	Dry cargo ships	Tankers
Within 0,25D from the deck	0,45	0,45
At mid-depth between 0,25D from the deck and 0,25D from the bottom	0,55	0,50
Within 0,25D from the bottom	0,45	0,45

In the midship region of the ship having the length L 60 m, the buckling strength of three upper and three lower longitudinals is to comply with *1.6.5*.

c) The section modulus of side   stringers   in a transversely framed side is not to be less than determined from 1.6.4. In this case:

$k_\sigma = 0,50$.

p - as defined in *2.5.3*.

m - factor taken equal to:

18,4 without cross ties;

29,0 and **37,0** with one, two and more cross ties fitted, respectively.

If side transverses are fitted and if they are connected by cross ties to the longitudinal bulkhead, the section modulus of side stringers is to be determined at $m = 8,9$. The depth of the side stringer web is not to be less than $0,08l$.

d) The section modulus of web frames in the hold of dry cargo ships is to be determined from *2.5.4 (a)* and in tween decks - from *2.5.4 (b)* with required increase of obtained values by 30 per cent.

The section modulus of side transverses of tankers is not to be less than determined from 1.6.4. In this case:

p - as defined in *2.5.3*.

m - factor taken equal to:

21 in absence of rosters;

29, **35** and **42** with one, two and three cross ties fitted, respectively;

$k_\sigma = 0,50$.

The depth of side transverse web may be tapered towards the top end, with the difference in depth at the top and bottom ends permitted up to 10 per cent of the mean value of the web depth.

e) The side framing of the machinery space and tanks should comply with the following requirements:

f)   In ships with $L < 30$ m the web frames and side stringers required by *2.5.2.3* may be omitted in the machinery space on condition the main frame has a section modulus W, in cm³, not less than obtained from the formula:

$$W = W_1 + 0,5 \cdot \frac{W_2}{n+1}$$

where: W_1 =   section modulus of the main frame according to *2.5.4 (a)*, cm³;
           W_2 =   section modulus of the web frame according   to   for   maximum permissible spacing of web frames, in cm³;
           n =   number of main frames between web frames.

g)   In way of ballast and oil fuel tanks of dry cargo ships with $L \geq 30$ m, the side framing is to be strengthened by the side stringers arranged in line with horizontal girders on bulkheads. When fitting one or two side stringers the section modulus of frames may be reduced by 10 or 20 per cent, respectively, as compared with that required by *2.5.4 (a)*. The section modulus of side stringers, as well as the width and thickness of the web plates are determined in the same way as for horizontal girders on bulkheads of tanks.

h)   The depth of web frames is not to be less than 0,l times the span, and the thickness is not to be less than 0,01 times the depth of the web, plus 3,5 mm. The thickness of the face plate is to be at least 2 mm greater -than that of the web plate.

i)   The width of a side stringer is to be equal to the depth of a web frame. The thickness of a side stringer may be assumed to be I mm less than that of a web frame. The side stringer face plate thickness is to be taken equal to the face plate thickness of a web frame.

j)   The minimum thickness s_{min} of tank side framing is to be determined from formula in section 2.7.4 (a).

k)   Where large openings (the width of which exceeds 0,7 times the breadth of the ship) are provided in the deck, on agreement with QRS Class strengthening of frames of the inner skin and side plating as well as vertical diaphragms may be required as a result of the upper deck pliability and determined by calculation.

l)   The inner skin framing of tankers is to satisfy the requirements of *2.7*. Structural members of side framing in tanks (cargo and ballast) of tankers and in holds which can be filled with water ballast are to have the thickness not less than determined from *formula* in section 2.3.4 (b)(6). The minimum thickness of primary members need not exceed 11,5 mm.

2.5.5   Special requirements

a) Attachment of the lower ends of main frames is to satisfy the following requirements:
.1   In dry cargo ships the bilge bracket connecting the main frames to the margin plate (or the floor, if the inner bottom is absent) is to have a height of not less than 0,1l as measured from the upper edge of the floor (where l = main frame span, in m).
.2   With an inclined margin plate, the height of brackets may be reduced, if the section modulus of the frame, determined according to *2.5.4 (a)* is multiplied by the factor:

—   —

where: h =   accepted height of the bracket, in m.

.3   With a horizontal margin plate, the section modulus W_o, in cm³, shall, in way of the connection of frame to margin plate, be not less than determined by the formula:

$$W_o = 2,5 \cdot W$$

where: W =   section modulus of main frame according to *2.5.4 (a)*, in cm^3.

The design section shall include: welded joint along the perimeter of the frame and the bilge bracket (if the latter is fitted), as well as the effective flange of the shell plating.

The connection of the frame and bilge bracket is assumed to be made by welding with weld factor 0,35.
In way of the connection of the frame (including the bilge bracket, if fitted) to margin plate by full penetration welds, the section modulus W_o, in cm^3, is to be not less than:

$$W_o = 1,44 \cdot W$$

The height of a bilge bracket in way of horizontal margin plate is not to be less than its width measured from the face plate of the frame.

.4   The thickness of bilge brackets is to be not less than the thickness of floor in that region. The free edge of bilge brackets is to be provided with a flange or a face plate having a width equal to ten times the thickness of the bracket, but is not to exceed 120 mm. Holes cut in the tank side brackets are to be such that the width of plating outside the hole is nowhere less than 1/3 of the width of the bracket.

b)   In tankers with transversely framed sides the ends of side frames located outside the line of the bottom and deck transverses are to be connected to the deck and bottom by brackets.

The vertical arm length of bilge brackets, in m, is not to be less than:

$$l = 0,08 \cdot D + 0,35 \text{ for D } 10 \text{ m;}$$
$$l = 0,04 \cdot D + 0,75 \text{ for D} > 10 \text{ m;}$$

but not in excess of 1,5 m.
The bilge brackets are to cover the entire round of the bilge.
The brackets are to be welded to the nearest deck and bottom longitudinals:
The deck brackets are to have the vertical arm length not less than:

$$l = 0,04 \cdot D + 0,3$$

but not more than 1,1 m.

c)   The upper ends of frames in 'tween decks and superstructures are to be carried to the deck with minimum gaps, while the beams are to be extended to the inner edge of the frames. The scantlings of brackets connecting the upper ends of frames with beams are to comply with the requirements of *1.7.2 (b)*, assuming $n = 1,8$.

Uppermost decks of ships (except for ships securing alongside other ships at sea) may be designed with beams carried to the shell plating with minimum gaps, and frames carried to the beams.

In transverse side framing and longitudinal deck framing, the brackets attaching the upper ends of frames are to be carried to the nearest deck longitudinal and welded thereto. In this case, the height of the knee measured from the deck is not to be less than twice the depth of the frame.

d)   Where the frames are cut at decks, their lower ends are to be attached by brackets.

e)   Side stringers are to be attached to side transverse by means of brackets carried to the side transverse face plates and welded thereto.

f)   In way of connection of double skin to double bottom the inner bottom plating shall pass continuous through the inner skin up to the shell plating, and in line with inner skin provision shall be made for a side girder or festoon plates.

2.6 Decks and platforms

2.6.1 General and symbols

a) This Chapter specifies the requirements for the structures of decks and platforms of the ships where the width of the opening for a single cargo hatch does not exceed 0,7 times the breadth of the ship abreast the opening. Additional requirements for the decks and platforms of ships where the opening width is greater and the length exceeds 0,7 times the spacing of centers of transverse deck strips between openings as well as for decks and platforms of ships with twin or triple openings are specified in *3.1*.
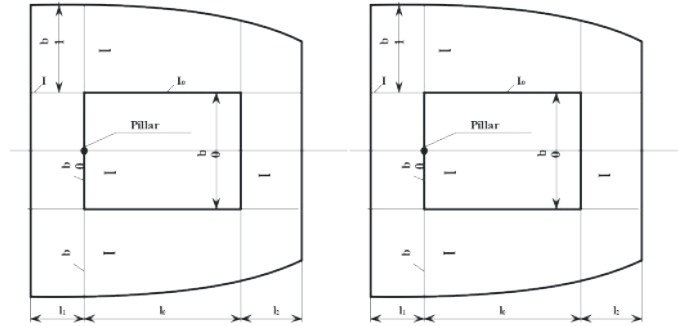
Figure 500 Deck and platforms

The present Chapter covers the requirements for the plating and framing members of decks and platforms: deck longitudinals, beams, deck transverses, deck girders, hatch end beams, hatch side coamings and hatch end coamings, wash plate in tanks of tankers.

b) Symbols (*fig 500*):

l_o : Maximum span of deck girder measured between the supports (hatch end beams, pillars), m;

l_1, l_2 : Span of deck girder measured from the bulkhead to the hatch end beam, m;

l_o^b : Span of hatch end beam measured within the width of hatch opening, m.

l_1^δ : Span of hatch end beam from the ship's side to the deck girder, m.

I : Moment of inertia of the deck girder, in cm^4.

l_o^b : Moment of inertia of hatch end beam within the width of hatch opening, in cm^4.

W, W_d^a : Rule section modulus at $\eta = 1$ and actual hull section modulus at deck according to *1.4.6* and *1.4.8*, respectively.

l_1^b : Moment of inertia of the hatch end beam on the length between the ship's side and the hatch opening, in cm^4.

I_o : Moment of inertia of the hatch side coaming acting as a deck girder, in cm^4.

2.6.2 Structure

a) In tankers with $L \geq 80$ m, ships for the carriage of bulk cargoes and ore carriers longitudinal framing is to be adopted at the strength deck in way of cargo holds (tanks). Where longitudinal framing is adopted, the spacing of deck transverses is not to exceed the spacing of bottom transverses specified in *2.3.2*.

b) Provision is to be made for the structural continuity of deck girders of strength deck in the midship region. If the deck girders are cut at transverse bulkheads, their web plates are to be welded to transverse bulkheads and attached to them by brackets. The web plates of hatch end coamings, deck transverses and hatch end beams as well as of wash plates are to be strengthened by stiffeners and brackets.

c) Connection of face plates of deck girders and hatch end beams is to be effected by means of diamond plates. The diamond plate thickness of the deck girder -hatch end beam is to be equal to the greater of the thicknesses used for the face plates connected.

d) The ends of side coamings at the corners of hatchways on the strength deck are to be either bent along the line of hatch corner rounding and butt welded to the hatch end beam or extended in the form of a bracket beyond the corner of the hatchway. Provision is to be made for gradual transition of the bracket to the deck girder web. The upper edges of coamings acting as deck girders are to be stiffened by face plates and the lower edges of coamings are to be rounded.

e) The deck girders and deck transverses are to be strengthened by stiffeners or by tripping brackets in way of pillars.

2.6.3 Deck loading

a) The design pressure on weather decks is the wave pressure p_w according to *1.3.2 (b)*.

b) For weather decks designed to carry deck cargoes (except timber and coke), the design pressure is taken equal to the cargo pressure p_c, determined from *formula* in section 1.3.4. For weather decks designed to carry timber and coke, the value h in is taken equal to 0,7 times the height of stowage of timber and coke on deck. For lower decks and platforms the design pressure should be taken according to *1.3.4*. For decks where cargo is suspended from beams or deck, the design pressure value is to be suitably increased.

c) The design pressure on structures of decks and platforms forming boundaries of compartments intended for the carriage of liquids is determined from *1.3.4*.

2.6.4 Scantlings of deck members

a)   Thickness of deck plating:

.1 The thickness of strength deck plating outside the line of hatch openings taking into account deck longitudinals is to be that necessary to give hull section modulus at strength deck required by *1.4.6*.

The adopted thickness of strength deck plating within midship region is to comply with the requirements for the buckling strength (see *1.6.5*).

.2 For ships of 60 m in length and over the sectional area of strength deck F_l, in cm^2, at ends for 0,1L from forward and after perpendiculars is not to be less than determined from the formula:

$$F_1 = 4 \cdot B \cdot s_{min} \quad F_1 = 4 \cdot B \cdot s_{min}$$

where: s_{min} = as determined from t*able 2600*.

.3   With the engine room located aft, the thickness of deck plating and the scantlings of longitudinals at the poop (aft deckhouse) front is to be maintained abaft the poop (deckhouse) front for a length of at least the width of machinery casing opening.

.4   If the distance from the fore edge of the casing opening to the poop (deckhouse) front is less than the width of the opening, additional strengthening of the deck may be required in this area.

.5   If the thickness of strength deck plating is taken less than the side thickness, a deck stringer is to be provided. The width of the stringer plate for strength deck b, in mm, is not to be less than obtained from the formula:

___

$$b = 5 \cdot L + 800 \leq 1800$$

and the thickness of stringer plate is not to be less than that of side shell plating.

.6 The thickness of deck plating and platform in way of tanks is to be determined as for the plating of the bulkheads forming boundaries of tanks. This thickness is not to be less than required for the plating of the appropriate deck..

b) The thicknesses of deck and platform plating are not to be less than specified in *table 2600*.

The thickness of plating and deck structural elements (including perforated members) s_{min}, in mm, in way of tanks is not to be less than:

$$s_{min} = 0,03 \cdot L + 4,5$$
$$6,0 \; s_{min} \; 7,5$$

Table 2600 Thickness of deck plating or platform

Deck and platform	s_{min}, in mm, in deck zone	
	Between ship's side and the line of large openings [1]	Inside the line of large openings and at the ends
Strength deck: for $L < 80$ m for L 80 m	0,055 L + 3,8 0,04 L + 5,0	0,055 L + 3,3 0,015 L + 6,5
Second deck: for $L < 80$ m for $L > 80$ m	0,055 L + 3,3 0,015 L + 6,5	0,04 L +3,5 0,015 L + 5,5
Third deck and platforms: for $L < 80$ m for L 80 m	0,04 L + 3,5 0,015 L + 5,5	
NOTE: Where frame spacing is greater/less than the standard spacing, minimum thicknesses of deck plating shall/may be amended in proportion to the ratio of actual spacing to a_o. [1] For tankers, deck plating in way of the tanks.		

c) The sectional area of longitudinal members of strength deck F_o, in cm², within midship region in ships of less than 60 m in length is not to be less than:

$$= \quad \left(\quad + \quad \right) \qquad = \quad \left(\quad + \quad \right)$$

where: s_{min} = minimum thickness of deck plating at

s_{min} ends as determined from the formula:

$$s_{min} = 0,055 \cdot L + 3,3;$$

$$c_1 = \quad + \quad \sqrt{} \quad - \quad n;$$

$$c_2 = \quad + \quad - \quad .$$

The thickness s, in mm, of strength deck plating within midship region in ships of less than 60 m in length for transverse framing system is not to be less than:

$$= \frac{}{(\quad) \sqrt{\quad}} \sqrt{\quad}$$

where: F_o = sectional area of the deck required, at = 1, in cm²;

          F = actual sectional area of longitudinal members of strength deck, in cm².

d)   The section modulus of deck longitudinals is not to be less than determined from *1.6.4*. In this case:

p - as defined in *2.6.3*.

$m = 12$.

k_σ - factor equal to:

For strength deck:

$$k_\sigma = 0{,}2 + \frac{x_1}{L}$$

where: x_1 = distance from mid-point of span of longitudinal to midship, in m;.

          at $\frac{x_1}{L} \leq 0{,}2$ take 0,2;

          at $\frac{x_1}{L} \geq 0{,}4$ take 0,4.

For the second deck and the decks below as well as for the platforms:

$k_\sigma = 0{,}6$.

The bluckling strength of strength deck longitudinals in the midship region is to comply with *1.6.5*.

e)   With transverse framing of decks and platforms, the section modulus of beams is not to be less than determined from *1.6.4*, taking p according *2.6.3*, $rn = 10$, $k_\sigma = 0{,}7$.

f)   The scantlings of deck transverses are to satisfy the following requirements:

.1   For dry cargo ships the section modulus of deck transverses in case of longitudinal framing of deck is not to be less than determined from *1.6.4* taking:

     p according to *2.6.3*

     $m = 10$

     $k_\sigma = 0{,}7$

.2   For tankers the section modulus of deck transverses W, in cm³, in the center tank with a deck center-line girder is not to be less than determined according to *1.6.4* at:

     $Q = p \cdot a \cdot L_1$.

     $l = B_1$

       $m = 40$ with four and less deck transverses in the tank;

      $m = 35$ with more than four deck transverses in the tank;

      $k_\sigma = 0{,}50$

     p - as defined in *2.6.3*

.3   In wing tanks of tankers and in topside tanks of ships for the carriage of bulk cargoes the section modulus of deck transverses is not to be less than determined from *1.6.4* taking:

     p according to *2.6.3*

     $m = 12$

     $k_\sigma = 0{,}50$.

g) Deck girders and hatch side coamings are to satisfy the following requirements:

.1 The section modulus of deck girder W, in cm^3, is not to be less than determined according to *1.6.4* at:

$$Q = p \cdot a_2 \cdot l_o$$

p = as defined in *2.6.3*

$l = l_o$

m - factor to be determined depending on the bottom grillage model (see fig 500) and the relative stability parameter , as well as on the span ratio l_1 / l_0 (where $l_1 \neq l_2$, the greater of the deck girder span values l_1 and l_2 is adopted for calculation.

$$= \quad \text{—} \quad \text{—}$$

k - factor determined from *table 2700.*

Where pillars are fitted at intersections of the hatch end beam with the deck girder, = 0.

k_σ = 0,60 and 0,70 - for the deck girder of strength deck, lower decks and platforms, respectively.

a_2 = breadth of the deck (including hatchways) supported by a deck girder; a_2 a_2 is measured at the section for $\dfrac{l_1 + l_o + l_2}{2}$

from the bulkhead, in m.

Outside the cargo hatch region, the section modulus of a girder is determined according to *1.6.4* with $m = 12$, k_σ = 0,6 and 0,7 for girders of strength deck and lower decks and platforms, respectively.

When determining the scantling of deck girders, the following requirements are to be complied with:

The web depth is not to be less than 0,05 times the girder span, for ships of 80 m in length and more, and not less than 0,04 times the girder span, for ships of 60 m in length and less. Intermediate values should be determined by linear interpolation.
The web thickness s, in mm, is not to be less than:

$$= \qquad + \qquad\qquad\qquad (2.6.4.7.1)$$

where: h_w = assumed depth of web plate, in mm.

In ships of less than 30 m in length, the web plate thickness nees not exceed the thickness of deck plating.
Deck girders are to be stiffened according to *1.7.3*. The buckling strength of strength deck girders in the midship region of ships 60 m in length and over shall be checked according to *1.6.5*.

.2 Where the side coaming acts as a deck girder, its section modulus is to be increased by 20 per cent.
The thickness s, in mm, of vertical plate of hatch coamings of the upper deck is not to be less than:
For dry cargo ships of less than 30 m in length
$s = 0,2L + 3$
But it shall be at least 1 mm greater than the thickness of deck plating.
For dry cargo ships of 60 m in length and over
$s = 11$ mm
For intermediate ship lengths, the thickness of vertical plates is to be determined by linear interpolation.
Side coamings are to be stiffened according to *1.7.3*. The buckling strength of side coamings in the midship region of ships 60 m in length and over shall be checked according to *1.6.5*.

Table 2700 Coefficient *k* depending on the span ratio

Deck	Hatch end beam construction	*k* values at l_1^b / l_0^b equal to:		
		0,25	**0,50**	**0,75**
Upper deck	Without pillars	0,139	0,640	1,626
	Pillar in the center line	0,033	0,065	0,098
Lower deck and platforms	Without pillars	0,022	0,150	0,0478
	Pillar in the center line	0,009	0,031	0,053
NOTE: For intermediate values of l_1^b / l_0^b, *k* is determined by linear interpolation.				

.3 If side coamings of strength deck terminate by brackets, the extension l_{br}, of this bracket over the deck shall be:

$$\text{at } R_{eH} \leq 315, \text{ in MPa;}$$

$$\text{at } R_{eH} = 390, \text{ in MPa;}$$

where: h_c = coaming height above the deck, in m.

For intermediate values of R_{eH} R_{eH} the extension of the bracket is determined by linear interpolation.

.4 Where containers or other cargo is envisaged to bestowed on the covers of cargo hatches, the scantlings of stiffeners for the vertical plates of coaming are to be calculated so that both the horizontal and vertical components of inertia forces at rolling are considered.

.5 In tankers with two longitudinal bulkheads there shall be fitted a deck center-line girder having a depth of not less than twice the depth of the deck transverse and a thickness not less than that of the deck transverse web. The deck center-line girder is to be reinforced along its free edge by a face plate with the same sectional area as that of the deck transverse face plate.

.6 The section modulus of the strengthened deck longitudinals fitted in the wing and center tanks of tankers is not to be less than 0,9 times the section modulus of the deck transverses.

h) Structural elements of framing of deck forming boundaries of tanks (cargo and ballast) of the tankers and holds which may be filled with water ballast are to have the thickness not less than determined from *formula* 2.3.4 (b)(6). In this case, the minimum thickness of the beams and deck longitudinals need not exceed 11,5 mm.

2.6.5 Special requirements

a) The requirements for hatch openings given below apply to single hatches.

1. It is supposed that the greater side of the openings shall have the fore-and-aft direction. Otherwise, the design of the corners in openings is subject to special consideration by *QRS Class*.
2. It is recommended to avoid penetration of welds to longitudinal edges of the openings.
3. Where the deck plating stops at the hatch coaming (or the machinery casing) and is welded thereto, full penetration welds are to be used. Where the deck plating extends inside the coaming, the free edges of the plating within the hatchways are to be smooth and free of weld attachments.
4. Where the side coamings of the cargo hatch terminates in a bracket, the bracket end is not to coincide with the butt joint of the deck plating.

5. With longitudinal framing, the deck plating between hatch end coamings shall be additionally strengthened by transverse intercostal stiffeners at every frame.

6. Single openings in the strength deck and the deck below between the side and the line of hatch openings are to have the minimum possible sizes and are to be arranged well clear of corners of cargo hatchways, engine and boiler casing openings as well as the ends of' superstructures.

7. No openings are permitted in thickened plates of the deck stringer at the ends of superstructures and at the toes of brackets at the end of side coamings.

8. Rectangular and circular openings in strength deck plating having a width (diameter) less than 20 times the thickness of plate, or 300 mm (wichever is less) may be without reinforcement. Openings having greater sizes are to be reinforced.

9. Openings (including rectangular) are not to be reinforced when located inside the line of large hatch openings not further than $0,25b$ from the center line and $0,5b$ from the transverse edges of the cargo hatch opening (where b is the width of the cargo hatch, in m).

10. If the distance between the edge of opening on the strength deck and ship's side (or a side coaming) is less than twice the opening width, appropriate reinforcement is to be provided irrespective of the width and shape of the opening. The aforesaid distance shall be not less than 75 mm.

11. The corners of rectangular openings are to be rounded along the radius. $r_{min} = 0,1b$ (where b is the width of the opening, in m). The minimum radius of curvature is not to be taken less than two times the thickness of the plating in way of the opening or 50 mm, whichever is the greater.

12. The thickness of coamings on superstructure decks of the first tier, located outside the limits of $0,25L$ from F.P., may be reduced by 10 per cent as compared to that required for coamings on the freeboard deck and raised quarter deck.

13. Where the thickness of the deck plating is less than 10 mm, a welded insert or doubling plate shall be fitted in way of the coaming with a thickness equal to at least 10 mm and length and breath not less than twice the diameter or twice the length of the greater of the coaming sides.

14. In case of an efficient interconnection between the coaming and deck framing a welded insert or doubling plate is not needed.

15. Where the coaming of ventilating cowls or cowl ventilators exceeds 0,9 m in heigth and is not supported by adjacent hull structures, brackets are to be fitted attaching the coaming to the deck.

16. The structure of the coamings of companionways and skylights is to be of a strength equivalent to that of the cargo hatches; the thickness of coamings is not to be taken less than 7 mm but need not be thicker than the deck plating at the coaming.

2.7 Bulkheads, propeller shaft tunnel

2.7.1 General and symbols

a) This Chapter contains the requirements for the number of watertight bulkheads, thicknesses of plating, bulkhead stiffeners and girders.

b) The total number of transverse watertight bulkheads, including the fore and after peak bulkheads, is not to be less than specified in *table 2800*. These requirements apply to cargo ships only and are minimum. A reduced number of bulkheads may be admitted by QRSHO. In this case the distance between two adjacent watertight bulkheads is not to exceed 30 m. Increase of this distance shall, in each case, be a matter of special consideration by QRS Class. All the transverse watertight bulkheads located between the fore and after peak bulkheads are to be carried to the freeboard deck.

c)   In ships intended for the carriage of liquid cargoes in bulk, a wash bulkhead is to be fitted at mid-length of a tank if the tank exceeds 0,1*L* or 15 m, whichever is the greater.

d)   In tanks more than 9m wide and/or long, longitudinal and/or transverse wash bulkheads (plates) are to be fitted.

Table 2800 Total number of the transversal bulkhead, including after peak and fore peak bulkhead.

L, in m	Total number of bulkheads	
	Machinery amidships	Machinery aft [1]
Not exceeding 65	4	3
65 to 85	4	4
85 to 105	5	5
105 to 125	6	6
125 to 145	7	6
145 to 165	8	7
165 to 185	9	8
Exceeding 185	Upon agreement with QRS Class	Upon agreement with QRS Class
[1] After peak bulkhead forming the after boundary of the machinery space.		

2.7.2   Structure

a)   The watertight bulkheads may be either plane or corrugated. Wash bulkheads with openings are to be only plane.

b)   The structure of longitudinal watertight bulkheads, partial watertight bulkheads, as well as log and depth sounder wells, escape trunks, propeller shaft tunnel, and so on. shall be subject to the same requirements as the transverse watertight bulkheads. Watertight steps and recesses in bulkheads are permitted. Longitudinal bulkheads throughout the cargo tank area (including pump rooms and cofferdams) are to be tight except for the third bulkhead at the center line which is to be constructed as a wash bulkhead. At intersections of longitudinal and transverse bulkheads, structural continuity of longitudinal bulkheads shall be ensured. The termination of longitudinal bulkheads is to be smooth.

c)   Corrugated longitudinal bulkheads are to have horizontal arrangement of corrugations. Transverse bulkheads may leave both vertical and horizontal arrangement of corrugations.

d)   Plane bulkheads are to be strengthened by vertical or horizontal stiffeners. Vertical and horizontal stiffeners of plane bulkheads as well as vertical and horizontal corrugations of corrugated bulkheads may be supported by horizontal girders or vertical webs, respectively.

e)   In tanks filled partially during operation the horizontal girders are to be arranged so that the span of vertical web does not exceed 3 m. Vertical webs and horizontal stiffeners of the watertight bulkheads are to have their ends bracketed. The brackets attaching the stiffeners to the deck plating, or the inner bottom plating (for transverse framing) are to be extended to the beam or floor nearest to the bulkhead and welded to them.

f)   It is permitted to attach the lower ends of bulkhead stiffeners by brackets fitted parallel to the bulkheads provided they are of equivalent strength.

g)   The watertight bulkhead stiffeners (excluding collision bulkhead) in the upper 'tween deck space and in ships where the depth does not exceed 3m may be sniped at ends. The vertical stiffeners on collision bulkhead are to be bracketed. The construction of the collision bulkhead with the ends of stiffeners welded to that bulkhead and no brackets fitted may be permitted only in the portion of the bulkhead above the freeboard deck.

h)   In the upper tween deck space, the brackets need not be welded to the nearest transverse member. The ends of horizontal stiffeners are to be attached to the ship's sides or bulkheads by brackets which are to be carried to the nearest frame or vertical stiffener and welded thereto.

i) Vertical webs and horizontal girders are to have their ends bracketed. In the absence of side stringers, the brackets attaching the horizontal girders are to be carried to the nearest frame and welded thereto.

j) The ends of stiffeners of the propeller shaft tunnel are to be attached by brackets similarly to watertight bulkhead stiffeners and tank bulkheads.

2.7.3   Bulkhead loading

a) The design pressure on watertight bulkhead structures must be calculated.

b) The design pressure on the bulkheads of cargo tanks and holds filled with water ballast is determined from *1.3.4* but not less than the test pressure according to *Appendix*. The bulkheads of tanks are to be additionally tested by design pressure corresponding to the head up to the tank top and the test head according to *Appendix*. Design pressure on bulkheads forming boundaries of holds to be loaded with heavy bulk cargoes is determined from *1.3.4*. special requirements

2.7.4   Scantlings of bulkhead members

a) The thickness of the bulkhead plating is to be not less than determined from *formula* 1.6.4 (d):
p - according to *2.7.3*.
$m = 15,8$.
k_σ - according to *table 2900*.

Table 2900 Coefficient k_σ

Bulkheads	k
Watertight (emergency) bulkheads	0,85
Collision bulkhead	0,60
Bulkheads of cargo tanks of tankers and holds to be filled with water ballast	0,80
Bulkheads of tanks under the head:	
up to the top of air pipe	0,90
up to the tank top	0,50
Bulkheads of holds of ships for the carriage of bulk cargoes	0,70

In ships under 50 m in length, the thickness, of watertight bulkhead plating may be 0,5 mm less and in ships under 40 m in length, 1 mm less. The intermediate values of permissible thickness reduction are determined by linear interpolation.

The thickness of top and bottom strakes of longitudinal bulkheads in tankers is to satisfy the requirements for the side shell plating (see *2.2.4*).

The thickness of plating, in mm, of the watertight bulkheads and lubricating oil tanks s_{min} s_{min}, in mm, is not to be less than:

$$s_{min} = 5 \cdot a + 2,5$$

but not less than 5 mm;
The thickness of bottom plates of bulkheads shall be 1 mm greater than obtained from the formula, but at least 6 mm.
In bulkheads forming boundaries of the tanks (except the lubricating oil tanks) the thickness of face plates and webs of the framing members as well as the plating thickness s_{min}, in mm, shall not be less than:

$$s_{min} = 0,03 \cdot L + 4,5$$

$6,0 \quad s_{min} \quad 7,5$

Bulkhead plating may have a thickness not exceeding the thickness of the corresponding strokes of shell plating, where the spacings and yield stress values are identical. The same applies to thickness relation of bulkhead bottom strakes and inner bottom plating (bottom shell plating).

The thickness of stiffeners and girders as well as plating of the bulkheads of cargo and ballast tanks of tankers and holds filled with water ballast is not to be less than determined from *formula* 2.3.4 (b)(6). The minimum thickness of vertical and horizontal stiffeners need not exceed 11,5 mm.

b)   The section modulus of bulkhead stiffeners is not to be less than determined from *1.6.4*, taking:

p - according to *2.7.3*.
k - according to *table 3000*.
m - coefficient equal to:

Table 3000 Coefficient k_σ

Bulkheads and stiffeners	k_σ
Watertight (emergency) bulkheads [1]	0,85
Collision bulkhead	0,65
Bulkheads of tanks of tankers, holds filled with water ballast and holds loaded with bulk cargo:	
Horizontal stiffeners of longitudinal bulckheads within midship region for 0,15D from the deck and the bottom.	0,75
Other horizontal stiffeners at the ends of the longitudinal bulkheads as well as longitudinal and transverse bulkhead stiffeners.	0,80
Bulkheads of tank [1] under the head:	
Up to the top of air pipe	0,80
Up to the tank top	0,45
[1] Vertical and horizontal stiffeners.	

2.7.5   Special requirements

a)   The plating thickness *s*, in mm, of plane bulkheads separating cargo tanks from segregated ballast tanks is to be not less than:

$$s = 3,33 \cdot a \cdot \sqrt[4]{p} + 4$$

where: p = as defined in *2.7.3*.

In way of passage of the stern tubes, the thickness of the bulkhead plating is to be doubled.

b)   The breadth of the bottom strake of the bulkhead measured from the inner bottom plating, or where no double bottom is provided, from the ship's bottom shell plating, shall be not less than 0,9 m in ships of 40 m in length and more, and not less than 0,4 m in ships of 12 m in length. For the intermediate lengths, the breadth of the aforesaid strake should be determined by linear interpolation. If the double bottom reaches the bulkhead only from one side, the bottom strake of bulkhead plating shall extend for not less than 0,3 m above the inner bottom plating. In the boiler room, the bottom strake of the bulkhead is to extend not less than 0,6 m above the flooring. The upper edge of the bottom strake of transverse bulkheads in cargo tanks of tankers is to be at least 100 mm above the upper toes of brackets of the bottom longitudinals. The breadth of top and bottom strakes of longitudinal bulkhead plating is not to be less than 0,1*D* but not more than 1,8 m.

c)   The scantlings of the center-line partial bulkheads are to satisfy the following requirements:

.1   The thickness of plating of the center-line partial bulkhead is not to be less than 7 mm in holds and not less than 6 mm in tweendecks, but not more than the thickness of the plates of adjacent watertight transverse bulkheads with equidistant stiffeners.

.2   The stiffeners of partial bulkheads supporting deck transverses and hatch end beams are to satisfy the requirements for the appropriate pillars.

.3   Two-sided vertical stiffeners symmetrical about the center line are to be fitted under the hatch end beams, as well as under superstructure end bulkhead and are to be connected to the deck and the bottom by flanges brackets or other equivalent means.

d)   The scantlings of wash bulkheads and wash plates in tanks are to satisfy the following requirements:

.1   The total area of openings in wash bulkheads is to be 10 per cent of non-perforated bulkhead area. The number and scantlings of the openings in the top and bottom strakes of bulkheads are to be minimum.
The plating thickness and the strake breadth of wash bulkheads are to be taken in accordance with the requirements for the tank bulkhead plating.
For a wash bulkhead, the section module of the framing elements (vertical and horizontal stiffeners, vertical webs and horizontal girders) shall be assumed to be 50 per cent of those required for the bulkheads of tanks.
The ends of framing elements are to be bracketed.

.2   For fuel tanks, the depth of the wash plate measured from the crown of a tank is to be not less than 1/2 of the height of tank and not less than 1/3 of the height of tank for all other tanks:
The wash plate thickness shall be not less than that of the top strake in the bulkheads forming boundaries of the tank.
A horizontal stiffener or face plate shall be fitted along the free edge of the wash plate. The stiffener (face plate) section modulus, in cm³, shall be not less than determined by the formula:

$$W = 3 \cdot h \cdot l^2$$

where: h = wash plate height, in m;
                     l = wash plate span, in m.

Wash plates are to be strengthened by stiffeners or horizontal girders spaced not more than 0,75~m apart.

e)   The cofferdam bulkheads adjoining the cargo tanks are to have tight structure. The cofferdam bulkheads which do not adjoin the cargo tanks, may have a lightened structure if the cofferdams are not filled with water. In this case, the thickness of bulkhead plating and sizes of stiffening elements are to comply with requirements for the watertight bulkheads. In cofferdams and pump rooms, openings are permitted to be cut in bulkheads, provided the corners of these openings are rounded and the edges are suitably reinforced. Stitch openings shall not be made in top and bottom strakes of

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longitudinal bulkheads. Cofferdam scantlings are to be so selected as to make them accessible for inspection and repair. The structure and scantlings of the walls bordering the cofferdams should be the same as those of the walls bordering the tanks.

f)   Corrugated structures of trapezoidal section as well as of wave-shaped section with vertical or horizontal corrugations may be used for the watertight.
   The member scantlings and the corrugated bulkhead structure are to be in compliance with the following:

.1   The thickness of corrugations is determined from *1.6.4 (e)*

.2   The section modulus of corrugation is not to be less than determined from *2.7.4* at $m = 13$ for continuous corrugations and $m = 10$ for corrugations cut at girder webs.

.3   The requirements for web members of corrugated bulkheads are to be similar to those for plane bulkheads. In this case the section with minimum depth is assumed to be the design cross-section of the web member, and the width of the effective flange is to be taken according to a *1.6.3*.

.4   In way the corrugated bulkhead with horizontal corrugations is attached to the bottom and the deck, and the corrugated bulkhead with vertical corrugations is attached to the sides and longitudinal bulkheads, transitional plane areas are to be provided the thickness and strengthening of which are to comply with the requirements of *rules 2.7.4*.

g)   The thickness of the vertical sides and top plating of shaft tunnels is to be equal to that required for plates of watertight bulkheads according to *2.7*. In case of a curved top, the plating thickness may be reduced by 10 per cent.   The shaft alley recess is to satisfy the requirements for the watertight bulkheads in accordance with *2.7.4 (a)*, whereas the beams are to satisfy the requirements of *2.6* and are to have section modulus not less than required for recesses of watertight bulkheads. The thickness of the top plating under cargo hatchways is to be increased in accordance with requirements of *2.4.4*. If the tunnels pass through the tanks, the scantlings of stiffeners and the thickness of plating are not to be less than required for the bulkheads of tanks.

2.8   Fore and after ends

2.8.1   General and symbols

a) This Chapter contains the requirements for the following structures:
  Fore peak with bulb (if the latter is provided).
  Bottom within $0,3L$ aft from the forward perpendicular.
  Side within $0,2L$ aft from the forward perpendicular.
  Open deck areas within $0,2L$ aft from the forward perpendicular.
  Structure located aft from after peak bulkhead.
       In this Chapter it is assumed that watertight deck and platform arranged directly above the summer load waterline form the upper boundary of fore and after peaks.
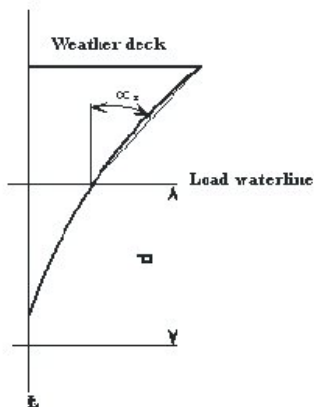

Figure 600 Determination of angle α_x,

b) For the purpose of this Chapter, the following symbols have been adopted:
  B_x : Breadth of ship at the section concerned, in m.

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B_x

d_1 : Minimum design draught measured at the section at 0,1*L* aft from the forward perpendicular, in m.

α_x : Angle, in deg., between the vertical and straight line connecting intersection points of summer load lines and weather deck with ship's side at cross section for 0,005 $v_o L$ from the forward perpendicular (*fig 600*).

β_x : Angle, in deg., between the tangent to waterline at vertical mid-distance between summer load lines and weather deck on the forward perpendicular and the line parallel to center line at cross section for 0,005 $v_o v_o L$ from the forward perpendicular (*fig 700*).

a_1 : Half-sum of distances between member concerned and two adjacent members, in m.

a_2 : Half-sum of distances between floor considered and two adjacent floors, in m.

$h_{c.g}$: Depth of center girder in the portion of ship's length considered, in m.
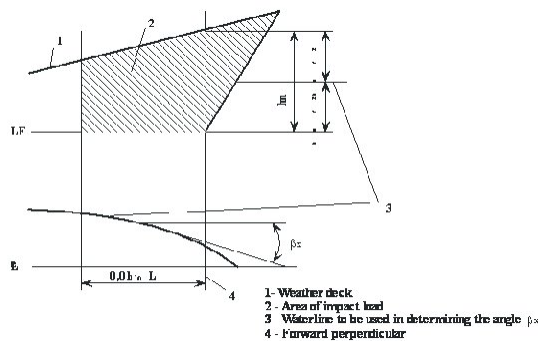
$h_{c.g}$

1 - Weather deck
2 - Area of impact load
3 - Waterline to be used in determining the angle β_x
4 - Forward perpendicular

Figure 700 Determination of angle β_x

2.8.2 Structure

a) Provision is made for the following end framing systems:
Transverse - for the bottom in the fore and after peaks.
Transverse or longitudinal - for other structures.

b) Fore peak floors are to be fitted at every frame and are to have a face plate or a flange. With $L \geq 30$ m, floors with flanged edges are not permitted. Floor webs are to be stiffened according to *1.7.3*.
In way of the holds the intercostal girder with a face plate is to be fitted as an extension of bottom center girder.
The height and thickness of girder plates, as well as the thickness and width of face plate are to equal to those of the floors.
Where the webs of the girders cannot be arranged, the floor face plates are to be interconected in center line by angle, tee section, and so on. the flanges of which have similar width and thickness.

c) In transverse framing of the fore peak side, the side stringers are to be fitted at least up to the deck immediately above the summer load waterline. Side stringers are to be fitted so that the distance measured vertically is not to exceed 2m. Side stringers shall be strengthened by panting beams fitted at alternate frames and shall, where possible, be supported at the center line by a longitudinal bulkhead. Frames without panting beams shall be attached to the stringers by knees having arm lengths not less than half the width of the stringer plate.

Instead of panting beams the side stringers may be supported by the web frames spaced not more than 3 m apart.

It is recommended to fit nontight platforms instead of side stringers with panting beams or web frames. Beams of nontight platforms are to be fitted at every frame.

If in the structure with panting beams or web frames the distance from the base plane to the nearest deck or platform exceeds 9 m, the nontight platform is to be fitted at the middle of this length, in which the total area the middle of this length, in which the total area of openings is not to exceed 10 per cent of its area.

With longitudinally framed fore peak, the spacing of web frames is not to exceed 2,4 m. Deck transverses are to be provided in way of passage or attachment of web frames on decks and platforms.

Floors without web frames in line are to be attached by knees to the nearest side longitudinals.

If the fore peak acts as a tank, the wash bulkhead or plate are to be fitted at the center line.

In tanks in way of 0,15L from the forward perpendicular (including the fore peak tank) the length of which exceeds 0,06L or 6 m, whichever is the greater, provision shall be made for the transverse wash plate.

d) The bulb shall be strengthened by horizontal diaphragm plates spaced not more than 2 m apart. The horizontal plates are to be supported by transverses fitted at every frame. If the length of bulb forward of the forward perpendicular exceeds 0,03L, a nontiglit bulkhead shall be fitted at the center line, with stiffeners arranged at every frame. If the length of the bulb is less than 0,03L, the bulb may be strengthened by a girder fitted at the center line in continuation of the center girder. The construction of ship's forward end shall provide for the anchor to be lowered freely past the bulb, with the ship listed 5 degrees either side. In way of eventual touching of the bulb, the shell plating is to be increased and intermediate frames fitted.

e) The bottom structure in way of the fore end outside the fore peak in a ship with single bottom is to comply with the requirements of *2.3.2*, *2.3.4* and those given below.

.1 Within 0,25L from forward perpendicular the spacing of side girders, as well as the distance from the center girder or the ship's side to the side girder is not to exceed 1,1 m.

In cargo tanks of tankers at minimum fore draught less than 0,035L midway between the bottom transverses there shall be fitted an additional transverse with face plate along free edge. The depth of this transverse shall be not less than that of the bottom longitudinals.

.2 Forward of cargo tanks:

With transverse framing system intercostal side girders with face plate along free edge are to be fitted in continuation of every second bottom longitudinal, extending forward as far as possible. The depth and thickness of side girder webs, as well as the size of face plates are to be taken as for the bottom transverses.

With a longitudinal framing system, the spacing of bottom transverses shall not exceed 2,8 m. Between the center girder and longitudinal bulkhead an intercostal side girder with the same scantlings as the bottom transverses is to be fitted on either side of the ship.

f) The double bottom structure in way of the fore end outside the fore peak is to comply with the requirements of *2.4.2* and those given below.

Within 0,25L from forward perpendicular 2,2 m.

In this region, with transverse framing system, the additional half-depth girders are to be fitted and welded to the bottom and floors.

The distance between side girders and half-depth girders is not to exceed 1,1 m.

These half-depth girders are to be extended as far forward as possible, whereas their free edges are to be reinforced by flanges or face plates.

The floors are to be strenghened with stiffeners in line with every half-depth girder and every bottom longitudinal for longitudinal framing.

g) With transversely framed side in the fore end outside the fore peak at the level of fore peak stringers, there shall be fitted the intercostal side stringers. The depth and thickness of the stringer plate are to be equal to the depth and thickness of the frame. The intercostal brackets fitted as stringer plates are to be welded to shell plating and, at both ends, to the webs of the frames, and shall have along the free edge a face plate (flange). The face plate width shall be not less than 10 times the thickness of the bracket, however, it need not be greater than 100 mm. The stringer face plate (flange) should not be welded to the face plate of the frame. Intercostal stringers are to be attached to the bulkheads by brackets.

h) In ships having characteristic ($v_o / \sqrt{L}$ $v_o / \sqrt{L}$) 1,5or large bow flare, provision shall be made for web frames and side stringer supported by them. The spacing of web frames shall not exceed 5 frme spaces. With longitudinally frame side in the fore end outside the fore peak, the spacing of web frames shall not exceed 3 m. In holds of all ships as well as in 'tween decks and superstructures of ships with characteristic ($v_o / \sqrt{L}$) 1,5 or with large bow flare provision shall be made for vertical intercostal member having the same scantlings as those of side longitudinals, fitted between web frames. The structure of the member considered shall be similar to the structure of the intercostal side stringer required for transverse framing system. Every second side longitudinal is to be attached to web frames by brackets extended to the frame face plate.

i) Within 0,1L from the forward perpendicular the span of deck transverses of weather decks is not to exceed 3 m, and the span of deck girders is not to exceed 3,6 m.

j) The   structure   located   aft   from   the after peak bulkhead is to be sufficiently rigid in vertical and horizontal planes. For this purpose fitting of additional longitudinal bulkheads or platforms, thickening of deck plating and shell plating, as well as connection of the bottom and upper deck longitudinals with pillars or struts may be required. If the stern overhang is large or the after peak width at sections exceeds 20 m, the additional longitudinal nontight bulkheads are recommended to be fitted on port or starboard. If there is a flat of the bottom, the additional strengthening may be required to take loads due to slamming.

k) The floors in the after peak shall comply with the requirements stated in *2.8.2* and shall be secured by stiffeners spaced not more than 600 mm apart. In single-screw ships the floors are to be carried to above the stern tube, but to a height not less than 0,8 m. If this is impracticable, tie plates with face plates on both edges shall be fitted transverse at every frame above the stern tube. The thickness of the tie plates shall be not less than that of floors.

l) Brackets above the stern tube are compulsory. The brackets should be carried to the sternpost. The brackets need not be fitted, if a wash plate is located above the floors, with the lower edges extending to at least 0,8 m below the face plates of floors. The openings in floors for passing the stern tube shall be reinforced by face plates along the edges. Below the stern tube the openings in floors shall be reinforced by face plates or stiffeners.

m) With transverse side framing of the after peak, the panting beams and side stringers, beam knees, attachment of frames to side stringers, arrangement and construction of web frames and nontight platforms are to satisfy the requirements of Section 2.   The vertical distance between side stringers is not to exceed 2,5 m, the frame span measured on the side plating is not to exceed 3,5 m.

n) In twin-screw ships having a cruiser or transom stern, the distance between the stringers as measured on the side plating, is not to exceed 2 m; the stringer is to be fitted in way of the top edge of the propeller shaft bossing, or in line with the shaft bracket. Where the web frames are fitted, their, spacing is not to exceed 2,4 m.

o) The ends of the members of the after peak (including deck, platform and bulkhead framing), as well as the ends of horizontal and, where possible, vertical stiffeners of floors are to be attached.

p) The spacing of normal or bevel frames may be as in midship region, but is not to exceed 750 mm. A bottom girder of the same depth as that of floors is to be fitted in the center line. In case of transom sterns and (or) flat of the bottom, the side girders are to be spaced not more than 2 m apart.

q) The side stringers in the fore and after peak tanks are to be provided with a flange along the free edge or a face plate. If the after peak acts as a tank, the longitudinal wash bulkhead and/or plate is to be fitted in the center line.

r) In way of impact loads only the minimum required holes are permitted in the center girder, side girders and floors. In ships 80 m in length and more the holes are to be reinforced by a face plate along the edge or stiffened.

2.8.3   Loading on structures at ends

a). The design pressure on the structures at ends is determined under the action of the working loads specified in *Subs 2.2-2.7*, as well as the extreme loads specified in this section for the structures in way of impact loads.

b) The extreme values of design hydrodynamic pressures p, in kPa, under wave impacts on the bottom at the fore end are to be determined from the formula:

$$= \qquad \underline{\qquad} \quad \underline{\quad} \qquad = \qquad \underline{\qquad} \quad \underline{\quad}$$

where: c_1 =   For L 200 m:
$$c_1 = \sqrt{L}$$
For L > 200 m:
$$c_1 = 5 \cdot \sqrt{10 - \frac{L}{100}};$$

c_2 = $0,16 \cdot \dfrac{v_o}{\sqrt{L}} \cdot \left(1 - 18 \cdot \dfrac{d_1}{L}\right);$

d_1 = as determined from *2.8.1*, but not more than 0,055L, m;

φ_r = $\varphi_r = 1$ for ships unrestricted service;

b_x = breadth of ship at the considered cross section at the level of 0,04B from the base plane but not more than 0,8B, m;

x = distance of the considered cross section of the ship from the forward perpendicular ($x_1 \le l_g$), in m;

l_g = $\left(\quad + \quad \right)$ - extent of exposure to hydrodynamic pressures under wave impacts on the bottom along the ship's length aft from the forward perpendicular, m.

Effect of hydrodynamic pressures extends over 0,04B from the base plane.

c) The extreme values of design hydrodynamic pressures p, in kPa, under wave impacts on the side at the fore end are to be determined from the formula:

$$p = 0,9 \cdot c_3 \cdot c_4^2$$

where: c_3 = $+$;

c_4 = $\quad \underline{\quad} \quad \underline{\qquad} \quad + \quad \sqrt{\quad}\,;$

L_o =   For L 250 m:
$$L_o = L$$
For L > 250 m:
$$L_o = 250.$$

Impact loads act over the height on the side portion located above the ballast waterline and for the length on the side portion extending aft up to the cross section at $0,01 \cdot v_0 \cdot L$ from the forward perpendicular and forward up to the intersection of the upper deck with the stem (see *fig 700*).

2.8.4   Scantlings of structural members at ends

a). The scantlings of structural members under the action of working loads determined from *2.8.3* should not be less than those determined in accordance with *1.6.4*, taking:

$N_{max} = n \cdot p \cdot a \cdot l$, in kN

k_σ - see *table 3100;*

n - see *table 3200;*

k_τ - 0,8 for web frames and deck tranverses of dry cargo ships;

k - 0,65 for side transverses of tankers;

k according to *2.3* and *2.4* for bottom framing members.

In this case the thickness of shell plating and scantlings of associated framing at the after end shall be prescribed as for steel with R_{eH} = 235 MPa, irrespective of the yield stress of the steel adopted for use.

b). The scantlings of bottom and side structural members at the fore end in way of exposure to extreme loads determined from *2.8.3* are to satisfy the following requirements:

.1   The thickness of shell plating *s*, in mm, is not to be less than determined from the formula:

$$s = 13 \cdot k_1 \cdot a \cdot \sqrt{\frac{p}{R_{eH}}} + \Lambda s$$

where: a = length corresponding to the shorter sides of the plate, in m;

b = length corresponding to the longer sides of the plate, in m;

k_1 =   At $\frac{a}{b} > 0,5$:

$k_1 = 1,25 - 0,5 \cdot \frac{a}{b}$

At $\frac{a}{b} \leq 0,5$:

$k_1 = 1$.

.2   The section modulus *W*, in cm³, of framing members is not to be less than:

$= \overline{\qquad}$

where: p =   design pressure according to *2.8.3*;

k_2 = $\dfrac{3}{3 - (a_1 / l)^2}$;

k_3 =   Where framing members pass continuous through the girder webs: 1,0

.3   The sectional area *f*, in cm², of the member or that of the weld attaching the ends of intercostal to the girder webs shall be not less than obtained from the formula:

$$f = \frac{8,7 \cdot k_4 \cdot p \cdot a_1 \cdot l}{R_{eH}} + 0,05 \cdot h_1 \cdot \Delta s \quad f = \frac{8,7 \cdot k_4 \cdot p \cdot a_1 \cdot l}{R_{eH}} + 0,05 \cdot h_1 \cdot \Delta s$$

where:

$k_4 = 1 - 0,5 \cdot \dfrac{a_1}{l};$

$h_1 = $ perimeter of the member section, in cm;

$p = $ see *2.8.4*.

The cross sectional area of the member includes the web area as well as the area of the effective flange of width $b_1 = 3s$ (where s is the thickness of effective flange, in mm). The face plate of the member of bulb flat is completely included in the cross-sectional area. The face plate of the member of "T" section is included in the cross-sectional area similarly to the effective flange.

c). The thickness of the floors, s_f, in mm, is not to be less than determined from the formula:

$$= \frac{\left(\quad \right)}{\left(\quad \right)\left(\quad + \quad + \quad \right)} +$$

where:

$n = 0,01 \cdot L_o \cdot (3 + a_2)/a_2 - 0,6 \cdot (1 - 2/a_2)$

$p = $ as defined in *2.8.3* (b);

$h_{c.g} = $ depth of the center girder in the given portion of the ship's length, in m;

$L_o = $ L it should be taken not less than 80 m and not more than 160 m;

$h_f\ h_f = $ depth of the floor in the given portion of the ship's length at $L/40$ from the center line to the side but not less than the depth of the side girder nearest to the side, excluding the height of opening if provided in the considered floor plate between the side girder and the half-depth girder, m;

$= $ sum of depths of side girders in the given portion of the ship's length within $L/40$ from the center line towards the side, excluding the heights of openings, if provided, in m;

$= $ sum of depths of half-depth girders in the given portion of the ship's length within $L/40$ from the center line towards the side, excluding the heights of openings, if provided, in m.

The thickness of side girder web, web and face plate of half-depth girders is to be equal to the thickness of floors, and the thickness of the web of center girder is to be increased at least by 20 per cent as compared to the floor thickness.

d). With transverse framing, the depth of bottom transverses h, in mm, forward of cargo tanks is not to be less than determined from the formula $h = 7L + 100$. The face plates of bottom transverses are to have a thickness 2 mm greater than the web thickness and a width not less than 10-fold thickness of face plates.

e) In the fore peak, the depth of bottom transverses (as measured from the center line or steam) is not to be less than $1/8B_x$, and their thickness is to be equal to 0,01 of the depth. However, they need not be thicker than the bottom plating in the area considered. The face plate thickness of bottom transverses is not to be less than web thickness, and the width of a face plate (flange) is to be ten times its thickness.

Table 3100 Coefficient *k*

Structural members	Coefficient *k*
Plates	1,2
Deck and side framing members (excluding deck transverses in cargo tanks of tankers and deck girders)	0,6
Deck transverses in cargo tanks of tankers and deck girders	According to *2.6*
Bottom framing members	According to *2.3* and *2.4*

Table 3200 Coefficient *n*

Structure	Framing members	Coefficient *n*
Deck	Decks transverses of dry cargo ships	0,73
Side	Web frames of dry cargo ships	0,5
	Side transverses of tankers:	
	Without cross ties	0,33
	With one cross tie	0,23
	With two and more cross ties	0,21
Bottom	All framing members	According to *2.3* and *2.4*

f) The scantlings of the frames within the area of the stern counter are to be not less than those in the after peak, if their spacing does not exceed 2,5 in. At greater spacings the frame scantlings are to be accordingly increased. The thickness of the floors and side girders is not to be less than required by *2.8.2 (b)*.

g) The width *b* and thickness *s* of the side stringers in the fore and after peaks with transverse framing are not to be less than:
For *L* 80 m:
$$b = 0,005L + 0,24$$
For L > 80 m:
$$b = 0,003L + 0,4$$
$$s = 0,025L + 5,75$$

h) The scantlings of panting beams as well as the beams of nontight platforms fitted instead of panting beams are determined from Section *2.9.4*. In this case, the sectional area and section modulus of beams of nontight platforms are determined taking into account the effective flange.

i)   The thickness of shell plating in way of the bulb is not to be less than $0,08L + 6$, but need not be taken more than 25 mm. In this case, the thickness of shell plating at the lower part of the bulb is not to be less than determined from formula 2.8.4 (b)(1) for the hull girder section at the forward perpendicular.

2.9   Pillars and panting beams

2.9.1   General and symbols

a) The Chapter contains the requirements for the scantlings of pillars fitted in the hull, superstructures and deckhouses and the requirements for the panting beams in peaks.

b)   Symbols:

l : Length of pillar (panting beam), in m, measured:

For the pillar-between the face plate of the deck girder (or the deck transverses, if the latter.

For the panting beam-betwen the inner edges of the starboard and port frames or from the inner edge of the frame to a strong support in the center line.

f : Sectional area of the pillar (panting beam), cm^2.

I : The least moment of inertia of the pillar (panting beam), in cm^4.

$i = \sqrt{\dfrac{I}{f}}$: The least radius of inertia of the pillar (panting beam), cm.

$\lambda = \dfrac{l}{i}$: Slenderness ratio of the pillar (panting beam), in m/cm.

s : Wall thickness of the pillar, mm.

d_o : Outer diameter of the pillar, mm.

2.9.2   Structure

a)   The pillar axes in 'tween deck spaces and holds are to be fitted in the same vertical line. The pillars are to be fitted on plate floors or side girders. With the load exceeding 250 kN, the pillars are to be fitted at the intersection of plate floors and side girders, otherwise the plate floor (side girder) is to be strengthened with brackets attached to the adjacent floors (side girders). A doubling plate is to be fitted on the inner bottom or deck plating (if no brackets, cones, inserts for load distribution are fitted) under the heel of a pillar with $d_o > 125$ mm. The doubling plate is to be welded all round by continuous weld. The pillars in tanks are to be of open built-up sections.

2.9.3   Design loads

a)   Loading on the pillar P, in kN, is determined from the formula:

$$ =   + \left(\qquad \right) =   + \left(\qquad \right) $$

where: p = design pressure on the above deck according to *2.6.3*, kPa;

l_m = distance measured along the deck girder between mid-points of their spans,,m

b_m = mean breadth of deck area (including the hatchways in the region concerned) supported by the pillar, m;

$$\sum_i \left(p \cdot l_m \cdot b_m \right)_i$$ = sum of loads from the pillars fitted above, determined having regard to *2.6.3*, which may be transferred on the pillar considered, in kN.

b) Loading on the panting beam P, in kN, is determined from the formula:

$$= \qquad =$$

where: p = $p = p_{st} + p_w$ $P = p_{st} + p_w$ - design pressure on the ship's side in way of installation of the panting beam, determined from *1.3.2 (a) y (b)*, kPa;

  a = spacing of frames on which panting beams are fitted, m;

  c = half-sum of frame spans measured vertically above and under the beam considered, m.

2.9.4 Scantlings of pillars and panting beams

a)   The sectional area of the pillars and panting beams f, in cm², is not to be less than determined by the iterative method according to the formula:

$$= \frac{\left(+ \right)}{n}$$

where: p = load upon pillar or panting beam according to *2.9.3*;

  k = 1,0 and 1,15 for pillars and panting beams, respectively;

  σ_{cr} = critical stress determined from 1.6.5 depending on $\sigma_e = \dfrac{203}{\lambda^2}$ as a first approximation, $\lambda = \dfrac{0{,}4}{\eta}$ may be assumed.

b) The wall thickness s, in mm, of tubular pillars is not to be taken less than:

$$s = \frac{d_o}{50} + 3{,}5$$

The wall thickness of built-up pillars (box-shaped, made of channels or I-beams) s, in mm, is not to be less than:

$$s = \frac{h_n}{50}$$

where: h_p = width of the pillar wall, mm.

The wall thickness of a pillar is not to be taken less than 6 mm.

In small ships the thickness of the pillar walls may, on agreement with QRS Class, be reduced to 5 mm, provided the Rule sectional area of the pillar is maintained.

c) The thickness s, in mm, of doubling plate under the lower end of the pillar is not to be less than:

$$s = 3,3 \cdot 10^{-3} \cdot p + 10$$

where: p = as defined in *2.9.3 (a)*.

The diameter of a doubling plate is to exceed the pillar diameter by a value equal to about $6s$.

2.9.5 Special requirements

a) For built-up pillars the width of the face plate measured from the wall is not to exceed that given in *1.7.3*.

2.10 Stems, stern frames, keels, rudder horn, propeller shaft brackets, fixed nozzles of propellers

2.10.1 General and symbols

a) The Chapter contains the requirements for the construction and scantlings of the stem, sternframe (rudder post, propeller post), sole piece of the sternframe, rudder horn of semi-spaced rudders, propeller shaft brackets, bar keel, fixed nozzles of propellers.

b) Symbols:

l_s : Length of the cross-section of the stem, in mm.

b_s : Width of the cross-section of the stems and keels, in mm.

h_s : Depth of the cross-section of the keel, in mm.

z_s : distance of the design section of the rudder horn of semi-spade rudder from the lower support of the rudder, in m (*fig 1100*).

x_s
x_s : Distance of the given section of the sole piece from the center of the rudder turning axis, in m.

R_4 : Reaction force of lower support of the rudder, in kN (see *2.10.3*).

R_p : Radius of the propeller, in mm.

D_o : Outer diameter of fixed nozzle of propeller, in mm.

D_o

2.10.2 Structure

a) Stem is to be efficiently connected to the bar or plate keel and, whenever possible, to the bottom center girder. The welded stem plates are to be strengthened by horizontal webs. Arrangement of horizontal webs of the stem shall, as far as possible, be agreed with the hull framing. Horizontal webs strengthening the stem plates are fitted not more than 1 m apart below and not more than 1,5 m above the summer load waterline. The brackets are to overlap the joints of the stem with the shell plating and are to be extended and welded to the nearest frames. The brackets which cannot be extended to the framing shall have their rear edge made along a smooth curve. In case of a full bow or where the radius of curvature of the stem exceeds 200 mm at the level of the summer load waterline, a centerline stiffener with face plate along free edge is to be fitted from the keel to the level of $0,15d$ above the summer load waterline. A special web is to be provided in cast stems for attachment to the center girder at the stem foot. A cast stem is to be reinforced by horizontal webs the arrangement of which in the casting is to be agreed with the hull framing.

b) Sternframe is to be provided with horizontal webs (welded sternframe) and webs (cast sternframe). The webs are to be spaced at least 1m apart. The arrangement of webs and horizontal webs is to be agreed with the hull framing.

c) The lower part of the sternframe of single-screw ship shall be extended forward from the propeller post and shall be attached to at least three floors in ships with $L > 120$ m and at least two floors in ships with $80 < L \leq 120$ m. In ships with $L \leq 80$ m the sternframe may be attached to one floor only. Where the propeller post of single-screw ship and the rudder post are made as one piece, it shall be extended aft from the axis of the rudder stock for at least three standard frame spaces. The lower part of the sternframe of twin-screw ship is to be extended forward from the propeller post and is to be attached to at least two main floors.

d) The rudder post is to be extended over the counter to a height sufficient for its efficient attachment to the transom floor, but not less than three times the length of the propeller post section. In ships of 80 m in length and over and in ships with cruiser stern, the propeller post is to be also extended upwards to a distance sufficient for effective attachment to the additional transom floor.

e) The rudder horn of semi-spade rudder is to be efficiently connected to the respective floors of the after peak and its center line wash bulkhead. The welded rudder horn of steel plates is to be provided with a sufficient number of horizontal webs and its main supporting structures are to be extended to the nearest deck or platform.

f) The struts of two-strut shaft brackets are to form an angle of approximately 90° to each other. Their axes are to intersect at the axis of the propeller shaft. The construction of propeller shaft brackets with struts arranged at an angle less than 80° and greater than 100°, additional strengthening of the hull within the area of these brackets are subject to special consideration by *QRS Class*.

g) The stern frames of single-screw and triple-screw ships are to have such geometrical dimensions as to provide the clearances between sternframe and propeller, and between propeller and rudder (*fig 800*), not less than indicated in *table 3300*.

Table 3300 Clearance dimensions

Dimensions	a	b	c	d	e
Clearances, mm	$0{,}2\,R_p$	$0{,}42\,R_p$	$0{,}36\,R_p$	$0{,}08\,R_p$	200-250
	$0{,}2\,R_p$	$0{,}42\,R_p$			

In twin-screw ships and for side propeller shafts of triple-screw ships, the clearance between the blade tip and the ship's hull should be as great as possible, and not less than $0{,}5R_p$.

h) The outer and inner plating of propeller nozzle is to be strengthened by stiffeners.

The transverse web plates are to be arranged in line with the floors of the after peak.

In way of attachment of the nozzle to the hull smooth transition from the nozzle to the ship hull is to be provided. The bottom part of the nozzle is to be connected to the hull. If the propeller nozzle is attached to the hull by means of brackets, provision is to be made for an efficient connection of the brackets with the framing in aft end and the framing inside the nozzle. The construction of brackets is to satisfy the requirements of *2.10.2 (d)*.

Drain plugs of non-corrosive material are to be fitted in the top and bottom parts of outer plating.

2.10.3 Design loading

a) Design loading for the structures of the sole piece and rudder horn of semi-spade rudders is taken equal to the reaction force of lower support of the rudder.

2.10.4 Scantlings of stem, sternframe, rudder horn of semi-spade rudder and propeller shaft bracket, bar keel and fixed nozzle of propeller

a) The scantlings l_s and b_s in mm, of a solid rectangular bar stem, from the keel to the summer load waterline, are not to be less than:

$l_s = 0,95 \cdot L + 100$

$b_s = 0,40 \cdot L + 15$, but not more than 100 mm

Upwards from the summer load waterline the sectional area of the stem may be gradually tapered to 70 per cent of the area obtained from the scantlings stated above.

b) Where the stem is welded of steel plates, the thickness of the plates $s = 0,1L + 4$, but not less than 7 mm. When determining the thickness of the welded stem for ships with $L > 200$ m, L should be taken equal to 200 m.
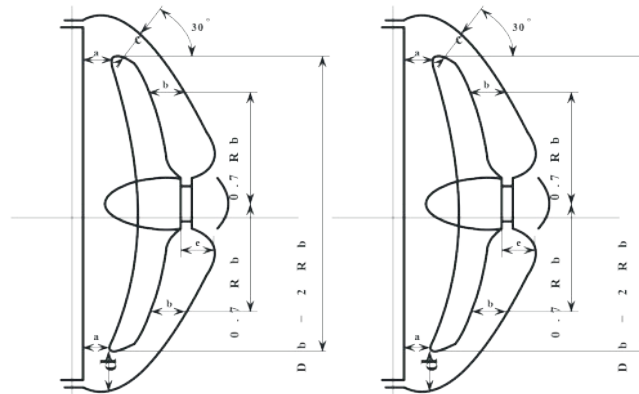
Figure 800 Geometric scathing of the post

At $d / L \geq 0,065$ $d / L \geq 0,065$ the thickness of welded stem is to be multiplied by the factor $0,35 + 10 \cdot d / L$.

The adopted plate thickness, however, is not to be less than the thickness of the plate keel in way of attachment to the stem foot. Above the summer load waterline the plate thickness may be gradually tapered to the thickness of shell plating at ends.

The length of cross-section of the fabricated stem is recommended to be not less than twice that of the bar stem.

The thickness of webs strengthening the plate stem is taken equal to that of the shell plating adjoining the stem. The thicknesses of the stiffener web and face plate fitted in the center line of the stem are not to be less than those adopted for the horizontal webs.

When the distance between the webs is reduced by 0,5 m, a reduction in plate thickness of stems by 20 per cent is permissible as compared with the above requirements. The plate thickness, however, is not to be less than that of the adjoining shell plating. The thickness of webs strengthening the cast sternframe is to be at least 50 per cent greater than that of the shell plating adjoining the sternframe. Spacing of horizontal webs is not to exceed 0,75 m at the thickness of horizontal webs taken 20 per cent greater than that of the shell plating adjoining the sternframe.

c) The *scantlings* l_s and b_s, in mm, of a rectangular solid propeller post of single-screw ship are not to be less than determined from the formula:

$$= \sqrt{}$$

$$= \sqrt{} \qquad = \sqrt{}$$

The length of the rudder post cross-section may be reduced by 10 per cent as compared with that of the propeller post. Above the counter the sectional area of sternframe may be gradually tapered to 40 per cent of sectional area of the propeller post. The sole piece in a solid rectangular cross-section is to be not less than 10 per cent higher and not less than 40 per cent wider than the propeller post cross-section.

The finished thickness of the propeller boss is to be not less than 60 per cent of the propeller post width or 30 per cent of the shaft diameter, whichever is the greater.
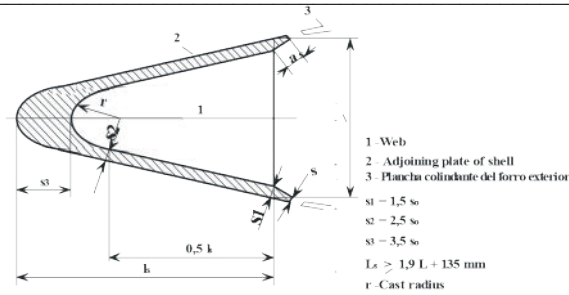
hic.12
Figure 900 Transversal section of the rudder post, of the post welded to the shell plating

d) In single-screw ships, a sternframe with no rudder post, or a sternframe designed with a rudder axle, may have the propeller post with the section as required by *2.10.4 (c)*.
   The section modulus W, in cm³, of sections of the sole piece, as related to the vertical axis, is not to be less than:

$$W = 8 \cdot R_4 \cdot x_s$$

   The sectional area of the solepiece is not to be less than the area corresponding to the scantlings specified in *2.10.4 (c)*.

e) The scantlings of the propeller post of a cast sternframe, with the rudder having top and bottom supports are to be determined in accordance with fig 900 depending on the value $s_o = 0,1 \cdot L + 4,4$, in mm.
   The thickness s of sternframe edges welded to the shell plating and the length of transition a_s, are to be in conformity with existing for welding of parts having different thickness.

f) The scantlings of the propeller post section of a welded sternframe with the rudder having top and bottom supports are to be determined according to *fig 1000*, where $s_o s_o$ is to be assumed in compliance with *2.10.4 (e)*.
   For ships of more than 150 m in length, the thickness s of the plate structures may be reduced to $1,5s_o$.

g) The strength of sternframes when bending and cutting is not to be lower than that of the sternframe with a solid cross-section made in accordance with *2.10.4 (c)*; the centerline web of the sternframe is not included in the specified area.

h) The scantlings of the sternframe of triple-screw ship are to be the same as those of single-screw ship of equal dimensions.

i) In twin-screw ships, the length ls and width bs of a solid rudder post with rectangular cross-section are assumed to be not less than those obtained from the following formula, with gradual reduction of the sternframe section above the counter by 50 per cent:

$$l_s = 24 \cdot \sqrt{L} - 30$$
$$b_s = 13 \cdot \sqrt{L} - 45$$

   The thickness of components of a cast sternframe with a shaped cross-section and of a welded sternframe may be 15 per cent less than those for a single-screw ship, provided the horizontal webs are spaced not less than 1,0 and 0,75 m apart, respectively..

s=1,6 So
k > 2,5L+180 mm
R Bending radius
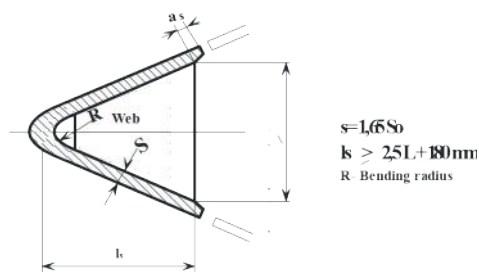
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Figure 1000 Main scantling of the transversal section of the propeller post welded to the shell plating

j) For rudders with one gudgeon upon the horn, the
section modulus, in cm³, of the rudder horn about the longitudinal axis in way of attachment to hull (*fig 1100*) is not to be less than:

$$W = 12 \cdot R_4 \cdot z_s$$

Where a fabricated rudder horn is used, the thickness of the plates is to be at least $1,6s_o$.

k) The sectional area of either strut of two-strut shaft brackets is to be equal to not less than 60 per cent of the propeller shaft section in the bracket plane, the strut thickness - to not less than 45 per cent, and the boss thickness -to not less than 35 per cent of the propeller shaft diameter.
The strength of the fabricated shaft brackets and their attachment to the hull is not to be less than that specified above. The plate thickness adopted for shaft brackets is not to be less than $1,5s_o$.

The weld area of rivets attaching each strut to the hull is to be not less than 25 per cent of the propeller shaft sectional area. Where the struts are attached by means of flanges, the thickness of the latter is to be not less than 25 per cent of the propeller shaft diameter.

l) The scantlings of the bar keel crosssection h_s and b_s, in mm, are not to be less than determined from the formula:

$$h_s = 1,30 \cdot L + 100$$
$$b_s = 0,70 \cdot L + 8 \quad \text{for } L < 60 \text{ m}$$
$$b_s = 0,40 \cdot L + 26 \text{ for } L \geq 60 \text{ m}$$

m) The thickness of outer and inner plating of a fixed propeller nozzle is to comply with requirements is to meet the following conditions:
width of mid-belt of inner plating is to be not less than the distance from $0,03D_o$ forward, and $0,07D_o$ aft, of the propeller blade tips;
thickness of forward part of the inner and outer plating is to be not less than required for side shell plating.
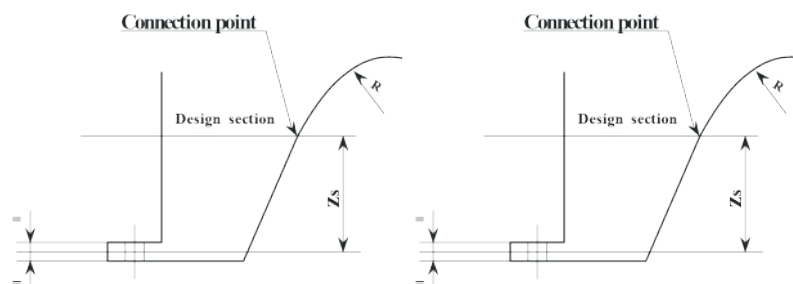
Figure 1100 Transversal section of the semi-spade rudder

_____

      The width of attachment is to be at least $0,15D_o$.

      The sectional area of the joint is to be not less than required by *2.10.4 (c)* for the solepiece.

      If the solepiece acts as support of the rudder, the connection of the nozzle to the solepiece will be subject to special consideration by *QRS Class*.

      For twin-screw ships when the propeller nozzle is not secured to the hull at its bottom part, the width of attachment at the top part is to be not less than $0,3D_o$.

2.10.5   Special requirements

a)   The thickness of the floors to which the propeller post and rudder post of single-screw ship are attached is to exceed by 3-5 mm (depending on the ship's dimensions), and by 2 mm for twin-screw ship, the value which is required for the after peak floors. The floors are to be extended to the nearest deck or platform.

b) The thickness of the floors to which the rudder horn of semi-spade rudder is connected is to be increased by 50 per cent as compared to the thickness of the floors s_{min}, determined from *2.4.4 (c)*.

2.11   Seatings of machinery and boilers

2.11.1   General and symbols

a) The Chapter contains the requirements for the seatings of main machinery and boilers and for those of deck machinery, cargo-handling gear, auxiliary machinery, and so on.

b)   Symbols:
   Q : Mass of machinery (boiler) in working condition, t.
   N : Specified power of the engine, kW.

2.11.2   Constructions of seatings

    a)   A seating shall comprise continuous vertical plates (girder webs), and top horizontal plates (face plates) to which the machinery is to be attached directly. Longitudinal vertical plates shall be fitted in line with the side girders. The seating shall be so designed that the plating beneath is accessible for inspection.

2.11.3   Loading

    a)   Dimensions of structural components of the seating are taken as a function of the mass of machinery (boiler) or specified power of the engine.

2.11.4   Dimensions of structures of seatings

    a) The thickness s, in mm, of structural components of a seating is not to be less than determined from the following formula:
- for low-speed engine:

$$s = k_0 \cdot \sqrt[3]{Q} + k_1$$

- for mean-speed engine:
$$s = k_2 \cdot \sqrt[3]{N}$$

where: k_o = factor the values of which are given
                     in *table 3400*;
            k_1 = factor depending on the machinery

mass taken according to *table 3500*;

k_2 = factor equal to 2,3 for the top plate; 1,6 for inner plate and 1,3 for outer plate, bracket, knee.

2.11.5   Special requirements

a) Where the seatings are installed on the strength deck of ships with L60 m within 0,6L amidships, the following requirements are to be met:

Where the longitudinal supports of the seating are welded to the deck or a rounded sheer-strake, thev shall be arranged in

the same plane as the longitudinal members of deck framing, otherwise sufficient strengthening shall be fitted. A smooth transition shall be provided from longitudinal supports of the seating to the longitudinal framing members.
Attachment of the seating to the upper edge of sheer-strake is subject to special agreement with *QRS Class*.
Access shall be provided to permit the deck plating under the seating to be inspected and measures shall be taken to prevent water from accumulating under the seating.
In particular cases agreed with QRS Class, a hermetic construction of the seating mav be admitted, the inner space of the seating being filled with some chemically neutral material with good adhesion properties.

Table 3400 Coeficient k_o

Seating of machinery (boiler)	k_o		
	top plates	vertical plates [1]	brackets and knees
Main internal combustion engine Main geared turbine set, main diesel generator and electric propelling	4,65	3,0	2,50
motor	4,15	2,70	2,70
Boiler	3,65	2,40	2,40
[1] In a seating the thickness of the outer plate of the two vertical plates either side of the seating may be taken equal to the thickness of brackets and knees.			

Table 3500 Coeficient k_1

Mass of machinery (boiler), t	20	>20 50	>50 100	>100 200	>200
k_1	4	3	2	1	0

f) Equipment and fittings may   be installed on shell plating, tight portions of decks and platforms, tight bulkheads (inclusive of the tank bulkheads and crowns), inner bottom and shaft tunnel platings on condition they are attached to the framing members and stiffeners or fitted on cantilevers secured to the framing members or stiffeners. Attachment of small-sized machinery and fittings directly to the above-mentioned structure with the help of welded pads is not permitted.

Hull

2.12   Superstructures, deckhouses and quarter decks

2.12.1   General provisions, definitions and symbols

a)   The requirements of the present Chapter apply to both short and long superstructures extending from side to side of the ship as well as to short midship superstructures which do not extend to the sides of the ship, forecastle, poop, long forecastle and poop extending to ship's sides, short deckhouses and quarter decks.

The applicability of the requirements contained in this Chapter to long superstructures not extending from side to side of the ship as well as to long deckhouses are to be specially agreed with *QRS Class*.

b) **Definitions**

Short midship superstructure: Superstructure of a length not more than:

$$= \quad — + \quad —— \qquad\qquad (2.12.1.2\text{-}1)$$

Long midship superstructure: A midship superstructure which is not a short midship superstructure.
Short deckhouse: A deckhouse with the length more than:

$$= \left(\; + \; \right) — \quad = \left(\; + \; \right) — \qquad\qquad (2.12.1.2\text{-}2)$$

Long deckhouse: A deckhouse (or part thereof) located on the strength deck within portion l_2 amidship which is not a short deckhouse.
Long forecastle (poop): A forecastle (poop) of a length more than:

$$—— + \quad — + \quad — \qquad\qquad (2.12.1.2\text{-}3)$$

where: B_2 =   is measured at a distance of $3h$ from the end of forecastle or poop.

Quarter deck: The after part of upper deck stepped up to a portion of 'tween deck height.
Ends of superstructures and deckhouses: The ends of the length counting from the end bulkheads:
- for superstructures:

$$— + \quad — \qquad\qquad (2.12.1.2 \text{-} 4)$$

- for deckhouse:

$$\left(\; + \; \right) —$$

Ratio $\dfrac{W_d^a}{W} \; \dfrac{W_d^a}{W}$ is not to be taken more than 1,5.

The superstructures and deckhouses of ships under 60 m in length are considered as short.

c). Symbols:

B_2 : Double breadth of the superstructure deck from the side to the line of large openings of superstructure deck, or ship's breadth B_x B_x with no openings in the deck, m; en ausencia de las aberturas, in m.

B_x : Ship's breadth at the level of the upper deck at the section concerned, m.

b : Breadth of the deckhouse, m.

b_1 : Half-width of continuous top plating between the sides, m.

c_1 : Width of projecting part of deckhouse top, m.

l : Span of stiffener determined as the distance between decks, m.

h : Height of the lower tier of superstructure or deckhouse, in m.

l_2 : Length of the portion of the upper deck within midship region;

l_1 : Length of superstructure (deckhouse) measured between the end bulkheads along the ship's side for stiperstructure, and along the deckhouse side for deckhouse, m; the length of forecastle or poop is measured accordingly from the forward or after perpendicular to the end bulkhead of the forecastle or poop

c : Relative length of superstructure:

$$c = \frac{l_1}{\dfrac{B_2}{2} + h}$$

W : Rule section modulus at $=l$ according to *1.4.6* .

W_d^a : Actual hull section modulus at deck according to *1.4.8*.

2.12.2 Construction

a) Short midship superstructures are to have the same plate thickness of side and deck throughout the length. The bottom strake of side plating shall be of a steel grade not lower than required, and with the yield stress not less than used for the strength deck in than region.

b) Long midship superstructures are constructed with different thicknesses of side plating and deck plating for the ends and mid-length of superstructure. The bottom strake of side plating at the ends shall have the same thickness as the side plating in mid-length of the superstructure, and the width shall be not less than one half of the height. Provision should be made for a smooth transition from the thickness of plates in mid-portion of superstructure to the thicknesses at the ends. The bottom strake of side and longitudinal bulkhead plating at the ends of superstructure is to be of a steel grade not lower than required, and with the yield stress not less than used for the strength deck in that region.

c) A deckhouse (or part thereof) situated on the strength deck within the portion l_2 amidships and having a length $(\quad + \quad)$ $(\quad + \quad)$ is to have the bottom strake of side plating made of a steel grade not lower than required and the yield stress not less than adopted for the strength deck in that region. With the deckhouse length this requirement applies only to the ends of the deckhouse $(\quad + \quad) \quad / \quad$, this requirement applies only to the ends of the deckhouses.

d) The ends of stiffeners of the end bulkheads of the superstructures and deckhouses and sides of deck lidless are to be welded to the decks. Side stiffeners of 1st tier houses may be attached to the deck by brackets. However, where inside the

deckhouse partial bulkheads are fitted according to *2.12.2 (e)* spaced not more than 8 m apart, the ends of stiffeners may be welded to the deck.

e)   Bulkheads in deckhouses and superstructures are to be strengthened by web frames and partial bulkheads according to the requirements given below.

.1 Web frames and vertical webs or partial bulkheads are to be fitted in superstructures and deckhouses in such a way as to be in line with girder webs or bulkheads located below.

The spacing between partial bulkheads or web frames and side stiffeners in superstructures and deckhouses is not to exceed 10 m. This should also apply to the arrangement of vertical webs at the superstructure and deckhouse end bulkheads.

.2 Where the superstructure end bulkhead is not in line with the transverse bulkhead of the. ship, partial bulkheads are to be fitted in the tween deck below the end transverse bulkhead, or the side framing is to be strengthened and beam knees are to be increased.

.3 Where the end of a long deckhouse with no expansion or sliding joints is located within the length *l* amidships, and the end bulkhead is not in line with the transverse bulkhead below, short deck girders are to be fitted under the deckhouse sides to extend further for three frame spaces forward and aft of the ends of deckhouse.

.4 Where the end bulkheads of superstructures and deckhouses rest on the longitudinals and the sides of deckhouses on the transverse deck structures fitted below (bulkheads, partial bulkheads, deck girders, deck transverses, and so on.), the webs of the said deck structures are to be strengthened to exclude hard points by knees or brackets fitted in line with the superimposed bulkheads of superstructures and deckhouses.

.5 Adequate strengthening is to be provided for the deckhouse sides and top in way of boats and davits.

f)   Flexible attachment of the deckhouses to the deck may be permitted on agreement with *QRS Class*.

2.12.3   Design loading

a)   Pressure on the end bulkheads of superstructures and deckhouses as well as on sides of deckhouses *p*, in kPa, is determined from the formula:

$$= \qquad (\qquad)$$

where: n = factor determined from *table 3600*;

c_2 = $0,3 + 0,7 . {}^{b}\!/_{B_x}$,   in   this   case

$c_2 \geq 0,5$;

at $x_1 / L \leq 0,45$:

$$= \quad + \quad \frac{\diagup}{+}$$

at $x_1 / L > 0,45$:

$$= \quad + \quad \frac{\diagup}{+} \quad \text{tion} ;$$

c_b = is not to be taken less than 0,6 and more than 0,8; for aft ends forward of amidships $c_b = 0,8$.

For the sides of deckhouses the factor k is assumed to vary for the length of bulkhead. For this purpose the deckhouse is subdivided into parts of approximately equal length not exceeding 0,15*L* each, and x, is taken as the distance between the after perpendicular and the middle of

the part considered;

z_o = as given in *table 3700*;

z_1 = vertical distance from the summer load waterline to the mid-width of the plate considered or mid-span of the stiffener.

The above-stated values of factor n apply to a ship having the freeboard equal to minimum tabular freeboard of type "B" ships, and a standard height of superstructures.

If the deck of the tier considered is situated higher than the standard position due to an increase of freeboard, as against the tabular value, then the appropriate factor n may be determined by linear interpolation between the values of that factor for superstructures with standard and actual positions of decks under the superstructures.

b) The design pressure is not to be taken less than indicated in *table 3800*.

2.12.4   Scantlings of structures of superstructures, deckhouses and quarter decks

a) The thickness of side and deck plating of forecastle and poop s, in mm, is not to be less than:

$$= \left(\quad + \quad \right) \qquad = \left(\quad + \quad \right)$$

where: n = factors obtained from *table 3900*;
            m = factors obtained from *table 3900*;
                = factor determined from *table 4000*.

Table 4000 Coefficient

d/D	
0,8	1
$0{,}65 \, d/D {<} 0{,}8$	$d/D {+} 0{,}2$
${<}0{,}65$	0,85

Table 3600 Bulkhead structure

Structure			n
Bulkhead front	Unprotected	1st tier	$2 + L_0/120$
		2nd tier	$1 + L_0/120$
		3rd tier	
	Protected		$0{,}5 + L_0/150$ [1]

Hull

Bulkhead aft end	Aft of amidships	+ / /
		+ / /
	Forward of amidships	+ / /
		+ / /

L_o - is the ship's length (to be taken not more than 300 m for calculation purposes).
x_1 - is the distance of the given end bulkhead from the after perpendicular, in m.
[1] Formula is also used for the sides of deckhouses.

Table 3700 Values of z_o

L, m	z_o, m	L, m	z_o, m
20	0,87	180	9,85
40	2,59	200	10,25
60	4,07	220	10,55
80	5,42	240	10,77
100	6,60	260	10,92
120	7,69	280	11,00
140	8,63	300	11,03
160	9,35	350	11,05

Table 3800 Design pressure

| L, m | Presión de cálculo p, en kPa | |
	for 1st tier of unprotected fronts	elsewhere
50	30	15
50<L<250	$25+\dfrac{L}{10}$	$12,5+\dfrac{L}{20}$
250	50	25

Table 3900 Values of coefficients *m* and *n*

| Structure | Side plating | | Deck plating | |
	m	n	m	n
forecastle	0,045	4,0	0,03	3,5
poop	0,040	4,0	0,03	3,5

For ships of less than 40 m in length, the thickness of side and deck plating is to be determined as for ships of 40 m in length. Where the spacing of stiffeners a, in m, is greater (lesser) than the value a_o, the thickness of side and deck plating shall be accordingly increase (reduced) by the value $= \dfrac{(\quad)}{\quad}$. However, the thickness reduction of side and deck plating shall not exceed 15 per cent of the value required by *formula 2.12.4* (a). in the magnitude, in mm.

No reduction of thickness is allowed at $a<a_o$ within regions of 0,2L and less from the forward perpendicular and above the after peak. The thickness of side plating of superstructure need not exceed that of ship's shell plating in the aforesaid region.

The thickness of the side plating of the forecastle and poop is not to be less than required by *2.2.4 (a)*.

The reduction of thickness for side and deck plating, where high strength steel is used, will be a subject of special consideration by *QRS Class*.

Where the steel plating is covered by a coating, the plate thickness may be reduced upon agreement with *QRS Class*.

Long forecastle (pool)) shall be treated as midship superstructure with the length equal to:

—— , in m.

b) The thickness s, in mm, of the deck and side plating at the mid-length of the long superstructure between the end portions shall not be less than determined from the formula:

$s = s_1$ at c 3

= —— + —— = —— + —— at *3<c<4,5*

$s = s_2$ at c 4,5

where: s_1 = thickness of side or deck plating determined as for the forecastle according to *2.12.4* (a), mm

s_2 = thickness of side plating according to *2.2.4 (a)* and (b) and deck plating according to *2.6.4 (a)* based on the assumption that superstructure deck is the strength deck, mm.

c) The plate thickness s, in mm of the bulkheads at the ends of forecastle, midship superstructure, poop, sides and end bulkheads of deckhouses is to be determined from the formula:

$$s = 14,7 \cdot a \cdot \sqrt{\frac{p}{R_{eH}}}$$

where: p = as defined in *2.12.3 (a)*.

The thickness of bottom plates of end bulkheads in superstructures of 1st tier is to be increased by l mm as compared with the design thickness. The width of bottom plate is to be not less than 0,5 m.

If the deckhouse front extends in a fair convex form beyond the intersection with the deckhouses sides, the thickness of plating may be taken 0,5 mm less as compared with the design value.

d) The plating thickness of side and end bulkheads of superstructures, as well as that of bulkheads of deckhouses is not to be less than 0,01L+5 mm for lower tier and 0,01L+4 mm for upper tiers, but not less than 5 min.

The thickness of deck plating in superstructures and deckhouses is not to be less than 5 mm. The minimum thickness of the deck and bulkhead plating may be reduced to 4 mm in ships with L < 50 m and to 3 mm in ships with L < 20 m. This does not apply to front bulkhead in the lower tier of midship superstructure and unprotected poop of ships with L ≥ 20 m.

e) Framing of the sides, decks and end bulkheads of the forecastle, poop and midship superstructure, quarter deck and deckhouse is to satisfy the following requirements:

.1 Side framing of the forecastle, poop and midship superstructure is to comply with the requirements of *2.5.4 (b)* as well as the applicable requirements of *2.8*.
The beams are to be fitted at every frame. The section modulus of deck longitudinals of superstructures and deckhouses is to satisfy the requirements of *2.6.4* when $c = 1$.

.2 The section modulus W, in cm³, of stiffeners of the end bulkkheads of forecastle, poop, midship superstructure and deckhouses, deckhouse sides is not to be less than determined from the formula:

$$W = 85 \cdot \frac{a \cdot p \cdot l^{\,2}}{R_{eH}}$$

where: p = as defined in *2.12.3 (a)*.

.3 The value of section modulus "W" refers to the construction with the ends of stiffeners welded to the deck.
.4 Where the lower ends of stiffeners are attached to the deck by brackets the scantlings of which satisfy the requirements of *2.7.2.3*, the stiffener section modulus may be reduced by 20 per cent.

2.12.5 Special requirements

a) Minimum thickness of the upper deck plating within l_2 amidships tinder the superstructure extending for more than ⸺ +

⸺ + at the portion between sections at ⸺ + from the superstructure ends may be reduced from the value s'_{min} determined from *table 2600* for the strength deck to the value determined from *table 2600* for the second deck, with the following relationship being complied with:

$$s_{min} = s'_{min} - k \cdot \left(s'_{min} - s''_{min} \right)$$

where: k = 0 at
k = $1,0$ at $c \angle$ ⌐
For intermediate values of c, k is to be determined by linear interpolation..

The reduction of thickness of the strength deck plating under the long deckhouse is subject to special consideration by *QRS Class*.

b) The structures at the ends of superstructures located within the portion l_2 amidships are to satisfy the following requirements:
.1 At the ends of a midship superstructure, the superstructure side plating is to be extended beyond the superstructure with smooth tapering into the ship's side on a length d_l, in m, determined from the formula:

/ (+) / (+)

The blunted ends of projecting plates are to be machined flush with the deck.
The value of d_l is taken not greater than $1,5h$. With $L < 60$ m, the ratio F_o / F F_o / F has been substituted for the ratio W / W_d^a W / W_d^a (see *2.6.4*).

.2 The bottom strakes of superstructure side plating projecting beyond the ends are to have a thickness exceeding that of side plating in mid-length of superstructure by a value Δ determined in per cent from the formula:

$$= (\quad) / \qquad = (\quad) /$$

The free edge of side plating projecting beyond the ends of superstructure is to be stiffened by the flat bar carried down for 50 mm from the edge. The lower end of that bar is to be sniped.

The projecting plates are to be attached to the bulwark by means of flexible joints. Welding shall not be used to attach flexible joints to projecting plate.

Openings in side plating projecting beyond the ends of a midship superstructure are not permitted.   Where, however, such openings are necessary, their arrangement and construction shall be specially agreed upon with *QRS Class*.

.3   Where d_1 is greater than $1,5h$, $d_1 = 1,5h$ the sheer-strake thickness at the end of midship superstructure is to be increased, as compared to that beyond the superstructure, bv Δ_1 determined in per cent from the formula:

$$= (\quad)$$

$_1 = 0$ at $c<2$.

Relative increase of deck stringer plate is not to be taken less than 70 per cent of Δ_1.

.4   At the ends of forecastle and poop, the projecting plates of side plating are to be constructed as required for the end of a midship superstructure, with

$$= \frac{\overline{\quad\quad}}{\quad / \quad +} \qquad = \frac{\overline{\quad\quad}}{\quad / \quad +}$$

In cases where the distance between the ends of forecastle (poop) and midship superstructure is less than

$$\quad\quad + \quad / \quad ,$$ the strengthening of upper deck sheer-strake and stringer plate in way of adjacent ends of those superstructures and strengthening of side plating projecting beyond the superstructures shall be specially considered by *QRS Class*.

.5   At the ends of a short midship superstructure not extending from side to side of ship the attachment of the side to the strength deck shall be made similarly to the attachment required by *2.12.5 (c)* for deckhouse, otherwise gussets are to be used to provide a smooth transition from the side to a local deck girder fitted in line with that side, the deck stringer plate shall be strengthened according to formula in Point 3 above.

c) The structures at the ends of superstructures arranged beyond the length l_2 amidships are to satisfy the following requirements:
 Where the end of superstructure (forecastle, poop) is within $0,1L$ from the forward or after perpendicular, the side plating at the ends of superstructure need not be increased in thickness. However, the requirements of d_1 for structural arrangement of the

projecting plate of bottom strake shall be fulfilled, taking d_1 $\quad\quad + \quad$ or d_1 $0,5$, whichever is the greater. Where the end

of superstructure (forecastle, poop) is located between the end point of the portion amidships and $0,1L$ from the forward (after) perpendicular, the value d_1 and thickness increase for superstructure side plating are to be determined by linear interpolation.

d)   Attachment of sides of the deckhouse arranged on the upper deck within the portion l_2 amidships to the end bulkheads (front and aft end) shall be performed by rounding to radius r, in m, determined from the formula:

$$= \overline{\quad} \quad + \quad - \qquad = \overline{\quad} \quad + \quad -$$

---

d) Rectangular openings in sides and top plating of deckhouse with $\left(\ + \ \right) \underline{\quad}$ $\left(\ + \ \right) \underline{\quad}$ shall have their

corners well rounded and shall be substantially framed. Doors cut in the sides of a deckhouse (or a part thereof) having the length

$\left(\ + \ \right) \underline{\quad}$ and situated on strength deck within l_2 amidships shall be additionally strengthened bv thickened plates fitted

above and below the opening, and for a deckhouse of lesser length or beyond the length l_2 amidships, only below the opening.

Where the distance between the expansion or sliding joints is less than a triple height of the deckhouse, it is sufficient to provide the rounding of corners. Openings for side scuttles shall have the tipper and lower edges strengthened by horizontal stiffeners.

e) The present requirements apply to the strengthening at break in ships less than 90 m in length. from the deckhouse end situated on the strength deck within the portion l_2,amidships.

.1 The steel plating of upper deck in way of the break is to extend abaft the break for three frame spaces in ships of 60 m in length and more, and for two frame spaces in ships less than 60 in length. The upper deck plating.

In the sides of a deckhouse (or part thereof) with $l_1 > 6 \cdot \left(b_1 + c_1 \right) \cdot \dfrac{W}{W_d}$ rectangular openings are not permitted for a length not less

than the height of the deckhouse counted if ships less than 40 m in length need not extend abaft the break.

.2 The upper deck stringer is to extend abaft the steel plating for three frame spaces, with $L \geq 60$ m, and for two frame spaces, with $L < 60$ m.
   The deck stringer so arranged shall be tapered from its full width to a width equal to the depth of frame to which it is welded.

.3 The stringer of raised quarter deck is to extend forward in the form of a knee gradually tapered into ship's side on a length of three frame spaces. The knee is to be adequately stiffened and its free edge shall have face plate or flange.

.4 The sheer-strake of raised quarter deck shall extend forward of the deck stringer plate projecting beyond the break bulkhead for at least 1,5 times the height of break and be tapered into the tipper edge of ship's sheer-strake.

.5 Diaphragm plates spaced not more than 1,5 m apart are to be fitted over the ship's breadth between the overlapping decks in way of the break. The thickness of diaphragms shall be not less than the thickness of the break bulkhead plating. The diaphragm plates are to be strengthened by vertical stiffeners. Continuous welds are to be used to attach the horizontal edges of diaphragm plates to the decks, and the vertical edges to break bulkhead on one side, and on the other side to an extra supporting bulkhead made of a continuous plate welded to the decks over the breadth of ship. The plate thickness of that bulkhead is to be not less than the thickness of break bulkhead plating, and may have openings between diaphragms

.6 Where a supporting bulkhead is fitted the diaphragm plates shall be secured by knees fitted to their ends.

.7 Where a raised quarter deck is adjoining a midship superstructure, it shall extend into that superstructure for two frame spaces beyond the break, the extension being, not less than the elevation of superstructure above the quarter deck.
   The quarter stringer plate shall extend forward for two frame spaces with the width gradually tapered.
   Strengthening of the overlapping decks in way of break is to comply with requirements of *2.12.5* depending on the location of the break within ship's length.
   The superstructure side plates extending aft of the superstructure are to be gradually tapered into the sheer-strake on a length of at least 1,5 times the height of break.
   Strengthening in case where the break bulkhead is located within 0,25L from after perpendicular shall comply with the following requirements:
   In ships of more than 60 m in length, the supporting bulkhead fitted over the breadth of ship may be omitted. The free edges of diaphragm plates are, in this case, to be stiffened by face plates or flanges of a width equal to at least ten thicknesses of the diaphragm plate.
   In ships of 60 m in length and less, the upper deck plating need not extend aft of the break over the breadth of ships, however, the upper deck stringer and the raised quarter deck stringer and sheer strake shall be extended forward and aft.
   In ships of more than 90 m in length, the strengthening at break shall be specially dealt with by *QRS Class*.

___

e)   The use of aluminum alloys for the construction of deckhouses is permitted. Decks of accommodation and service spaces situated above the machinery and cargo spaces shall be made of steel.

The scantlings of aluminum deckhouses shall be determined 'according to *1.6.6*.

The minimum scantlings shall be the same as specified for steel deckhouses.

Determination of degree to which the deckhouse of aluminum alloys promotes longitudinal bending of the hull and stresses in ship's hull and deckhouse shall be performed according to the procedure' approved by QRS Class.

2.13   Machinery casings

2.13.1   General

a)   Openings in decks and platforms over machinery spaces are to be protected by strong casings. The casings may be omitted only in cases where the space on the deck or platform is part of the machinery space.

b)   Where the part of machinery casing located below the bulkhead deck is included into subdivision calculation as a watertight construction, its strength shall be not less than that of the transverse watertight bulkheads on the same level as the above-mentioned part of the casing.

2.13.2   Structure

a)   Where there are large openings in the deck in way of machinery space, additional pillars and deck transverses are to be fitted for strengthening of the deck in way of machinery casing. In ships with $L > 60$ m the lower plate of the casing side plating adjoining the strength deck within the portion *l* amidships shall be of the same steel as the strength deck plating in that portion.

b)   Where the machinery casings extend throughout the length of machinery space and support the decks in that region, their structures are to be suitably strengthened. The extent of strengthening is subject to special consideration by QRS Class.

c)   Where the opening for machinery casing is arranged in the strength deck, the requirements of *2.6.5* regarding the design of corners and compensation for openings shall be complied with.

2.13.3   Loading

a)   To be taken as design loads for the plating and framing of machinery casing are the loads on the parts of watertight bulkheads at the appropriate height or sides of deckhouses in this region.

2.13.4   Scantlings of machinery casing structures

a)   In the machinery casing located on the weather deck or the raised quarter deck, the thickness of plating is to be 15 per cent, and the section modulus of stiffeners 50 per cent, greater than required for a deckhouse in the same position. The thickness of plating of the portion of machinery casing located on the weather deck at the level of 2nd and subsequent tier deckhouse shall be taken 10 per cent, and the stiffener section modulus 20 per cent, greater than required for a deckhouse of the corresponding tier. The lower plate of the casing side plating adjoining the upper deck shall be increased in thickness by 1 mm.

b)   Where the part of machinery casing located below, the bulkhead deck is not included into the subdivision calculation, the thickness of the plating in way of the 'tween decks shall be 6 mm, and that of the coaming, 7 mm. In particular cases, the thickness of casings in ships of 100 m in length and less may be reduced maximum to 5 mm, and that of the coaming, to 6 mm.

c)   The sides of casings are to be strengthened by vertical stiffeners spaced not more than 0,9 m apart. The scantlings of the stiffeners are to be such as to give a section modulus not less than 70 per cent of that required for the stiffeners of a corresponding height placed on watertight transverse bulkheads. Where d/D 0,70 the scantlings of the casing stiffeners in

upper tween deck space may be reduced but so, that their section modulus is not less than 55 per cent of that required for the corresponding stiffeners of watertight bulkheads.

d) For casings inside the midship superstructure, poop or deckhouse, the thickness of plating may be 0,5 mm less than required for casings in way of the tween decks, but not less than 4,5 mm for the plating and 5,5 mm for the coamings.

e) The scantlings of stiffeners may be adopted such as required for casings in way of the tween decks with the ratio $d/D <$ 0,70.

2.14   Bulwarks
2.14.1   General

a) Bulwarks of strong construction are to be provided. The construction of bulwarks in midship region of ships of 80 m in length and more shall be such that the bulwark is not involved into longitudinal bending of the hull.

2.14.2   Structure

a) The bulwark is to be stiffened by stays spaced not more than 1,8 m apart. In the region of uprights for timber deck cargo fastening to bulwarks, as well as in the fore end to $0,07L$ aft from forward perpendicular, the spacing of stays shall be not more than 1,2 m. In ships with large flare of sides and in ships with minimum assigned freeboard, stays may require to be fitted at every frame within the region considered. In particular cases, the spacing of stays may be increased, provided adequate strength requirements are complied with.

b) The stays are to be fitted in line with deck beams, knees and other structures and are to be welded to the rail section, bulwark plate and deck. The attachment of stays to bulwark shall be ensured on a length not less than half-height of the bulwark. In welding the stays to the deck, provision shall be made for sufficient holes in the stays to allow free passage of water to the scuppers. The welded connection of the beam to deck plating in way of stay shall not be weaker than the attachment of stay to deck. Immediately under the lower ends of stays no cuts in deck beams and no gaps between frame ends and the deck are permissible. The dimensions of lightening holes in stays are not to exceed half the stay width of sections of the stay. The free edges of stays are to be stiffened by face plates or flanges. As a rule, the flanges (face plates) or stays are not to be welded to deck plating and rail section. The face plates (flanges) on the outer edge of the stay are not to be welded to horizontal stiffener (flange) of lower edge of the bulwark in way of continuous cut.

c) In case where the bulwark is welded to the sheer-strake (in ships of 60 m in length which do not secure alongside other ships at sea and in ships of 60 m in length and more, beyond $0,6L$ amidships), the openings cut in bulwarks shall be so designed as to ensure a smooth transition (by 100 mm radius, at least) from the bulwark plate to the edge of sheer-strake. Within $0,07L$ from forward perpendicular the bulwark is to be welded to the sheer-strake.

d) The lower edge of bulwark shall be stiffened by a horizontal stiffener or a flange in way of continuous cuts. Bulwarks are to be additionally strengthened in way of mooring pipes, fairleads and eyeplates or cargo gear.

2.14.3   Scantlings of bulwark structures

a) The thickness of the bulwark platings is to be not less than $s = 0,065L + 1,75$ for $L \leq 60$ m and $s = 0,025L + 4,0$ for $L > 60$ m, but not less than 3,0 and not more than 8,5 mm. The thickness of bulwark plating of a superstructure located beyond 1/4 of the ship's length from the forward perpendicular, as well as that of bulwark plating of 2nd tier deckhouses or superstructures may be reduced by 1 mm. For 3rd and above tiers of the deckhouses the thickness of the bulwark plating need not exceed the thickness required for the plating of sides of 3rd tier deckhouse.

b) The thickness of rail section shall, as a rule, beat least 1 mm greater than that of the bulwark plating. The width of rail section shall be not less than 75 mm, with bulwark thickness 3 mm and not less than 150 mm, with bulwark thickness 8,5 mm. The intermediate values of the rail section width are to be determined by linear interpolation.

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c) The thickness of stays is to be 1 mm greater than that of the bulwark plates. Where the bulwarks are cut to joints, the thickness of stays at the ends of these openings or expansion joints is to exceed the bulwark thickness by 25 per cent.

d) The width of the lower end of the stay measured at the welded joint is not to be less than:

$$b = \left(0{,}65 \cdot L + 190\right) \cdot \sqrt{a}$$

where: =   spacing of stays, m.
a=

However, b need not be assumed greater than 360 mm.

For ships carrying deck cargoes, as well as within the fore end, b shall be determined with a = 1,8 m, irrespective of the actual spacing of stays.

If the bulwark is attached to the sheer-strake, then b may be reduced by 20 per cent (except within 0,07L from the forward perpendicular). Where the height of the bulwark exceeds 1 m, the width of the lower end of stay is to be increased in proportion to the height. The width of stay at the upper end shall be equal to that of the rail section.

SECTION 3
Requirements for structures of ships of special design

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3.1 Open-type ships

3.1.1 General

a) The requirements of this Chapter are additional to those of *Sections 1* and *2* and apply to ships (including container ships) with single, twin and triple cargo hatchways which are considered to form a large deck opening meeting the following conditions:

$$b\big/B \geq 0{,}7 ; \quad l\big/l_m \geq 0{,}7$$

     The requirements of the Chapter are to be applicable throughout the entire cargo hatch region including the engine room, provided it is located between the cargo holds.

b) Symbols:
   b : Breadth of deck opening determined as the distance between the outer longitudinal edges of hatchway openings at ship's sides, in m;
   l : Length of hatchway opening, in m.
   l_m : Distance between centers of transverse deck strips at each end of opening, in m;
   c : Distance between transverse edges of adjoining openings, in m.
   W : Rule hull section modulus at $\eta = 1$ and actual value in way of deck according to *1.4.6* and *1.4.8*.
   W_d^a : Rule hull section modulus at $\eta = 1$ and actual value in way of deck according to *1.4.6* and *1.4.8*.
   n : Total number of 20-ft containers carried by the ship.

3.1.2 Structure

a) For ships with $L \geq 80$ m longitudinal framing system of the deck and bottom is provided.

b) Upper deck and side longitudinals are to be continuous within the region stated in *3.1.1*.

c) Ends of cargo hold continuous side coamings are to be attached in compliance with the requirements of *1.7* and *2.6.2*. It is not recommended that continuous side coamings be attached to the front bulkhead of the aft superstructure and the aft bulkhead of the forecastle.

d) Abrupt. changes of the cross-section and shape of the important members over the ship's length are not permitted. Where such changes are necessary, arrangements are to be such as to minimize the creation of stress concentration and attention is to be paid to provision of buckling strength.

e) The attachment of the forward end of the longitudinal strip to the deck where there is a cargo hold single opening forward of the attachment is to be specially considered by *QRS Class*.

f) It is recommended that transverse and longitudinal deck strips have a box-shaped cross-section.

g) Transverse deck strips are to be efficiently attached to the underdeck framing members and web frames in line with which they are fitted. Where the plating of the deck strips is arranged in line with the upper flanges of continuous side coamings of cargo hatches, the attachment of the deck strips to the deck and side shell is to be specially considered by *QRS Class*.

h) Openings in the deck plating in immediate proximity to the attachments of transverse and longitudinal deck strips are not permitted.

i) Openings in open-type ships:
.1   Adjacent corners of openings in the upper deck arranged in one line are to be rounded form a gangway or provision is made for expansion with a radius r (*fig 1200*) not less than:

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$$= \quad \overline{\quad\quad}$$

$k = 0,025$ with $c/_b \le 0,04$

$k = 0,050$ with $c/_b \ge 0,2$

The intermediate values of k are obtained by linear interpolation.
In way of longitudinal deck strips the value r may be reduced by 40 %.
Given below are minimum radii of rounding of opening corners:
In way of a deck stringer plate:
$r_{min} = 30$ mm;
In way of longitudinal deck strips:
$r_{min} = 250$ mm.
In corners of openings insert plates of increased thickness are required (see *fig 1200*).

.2 In way of conjugations of open and enclosed parts of the hull (adjacent to the engine room, bow, and so on.) the radius of the batch corners is not to be more than:

$$= \quad \overline{\quad\quad} = \quad \overline{\quad\quad}$$

.3 Hatch corners in the areas where cargo hatchways arranged abreast change in number are to be authorized by *QRS Class*.
.4 For requirements imposed upon deck openings, see *2.6.5*.

j) The side girders are to be arranged under container corner seatings.

3.1.3 Design loads

a) The design still water bending moment is to be determined in compliance with *1.4.3*.
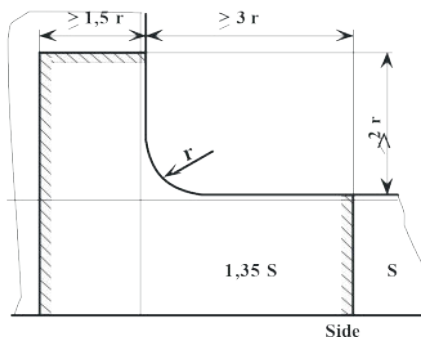
Figure 1200   Radius of the hatch corners

where:

$$k_h = \aleph \cdot \left(\frac{d}{B} + 0,3 \right);$$

$$\zeta = 1 - 4 \cdot \frac{d}{L};$$

$$\alpha_h = 0,5 \cdot \left(1 - cos \cdot \frac{2\pi \cdot x}{L} \right);$$

$$c_w = \text{see } 1.3.1;$$

$$= \qquad\qquad (3.1.3.3)$$

b) Kinematic parameters of warping are to be determined.

      The elongation of hatch opening diagonal under the effect of hull warping is not to exceed 35 mm. Where such elongation obtained by calculation is in excess of 35 mm, measures specially agreed with *QRS Class* are to be taken for opening edge reinforcements. The calculation is to be made in accordance with the procedure approved by *QRS Class*.

c) Adequate buckling strength of the longitudinal deck strip between the supports as well as that of its items as regards the compressive stresses due to longitudinal bending are to be ensured.

d) Where the ratio of the length of the hatch opening to the width of the deck portion from the side shell to the longitudinal edge of the nearest hatch opening exceeds 10, calculation of shape deformation of the deck portion concerned in the horizontal plane in accordance with the procedure approved by QRS Class and use of the results obtained in assessment of the deck stressed state, design of hatch covers and side framing may be required.

3.2 Roll-on/roll-off ships

3.2.1 General and symbols

a) The requirements of this Chapter apply to roll-on/roll-off ships and are additional to those of *Sections 1* and *2*.

      These requirements also apply to decks and double bottoms of ships carrying wheeled vehicles for use in cargo handling.

b) Symbols:

Q_o : Static load on the axle of the wheeled vehicle, in kN.

n_o : Number of wheels on the axle.

n : Number of wheels forming a group (for a single wheel $n = 1$).

u : Size of a tire print, normal to the axis of rotation.

v_1 : Size of a tire print, parallel to the axis of rotation, in m.

v : Size of a tire print, parallel to the axis of rotation, in m, used as a parameter in determination of loads; for a single wheel $v = v_1$; for a group of wheels v is a tire print size with regard to the wheel spacing.

e : Spacing between adjacent wheels, in m.

l_b : Print size of a wheel or a group of wheels, parallel to the larger side of the panel or along framing members, in m.

$l_a\ l_a$: Print size of a wheel or a group of wheels, parallel to the smaller side of the panel or athwart framing members, in m.

$l_{\Sigma a}$: Total length of tire prints, as measured along the larger side of the panel within its width or athwart framing members within their mean spacing a_1, in m.

$l_{\Sigma b}$: Total length of tire prints, as measured along the larger side of the panel or framing members within the panel length or design member span l, in m.

a : Smaller side of the panel, in m.

b : Larger side of the panel, in m.

a_1 : Mean distance between the deck girder under consideration and two adjacent deck girders, in m.

l : Span of the considered girder between supports.

3.2.2 Structure

a) Vehicle decks and double bottoms of ro-ro ships are to be longitudinally framed.

b) Movable decks fitted occasionally for the carriage of vehicles are to be so fixed as to prevent these decks from taking up longitudinal forces under hull longitudinal bending. The Rules provide for movable deck structure consisting of a top decking with a web structure and longitudinals welded thereto. Other forms of movable deck construction will be specially considered by *QRS Class*.

3.2.3 Deck loading from wheeled vehicles

a) The design loads are to be based on specification details of vehicles carried on board the ship and used for cargo handling. The design documentation submitted to *QRS Class* for consideration is to include statically load on vehicle axle, number of wheels on the axle, wheel spacing, tire print dimensions and tire type.

b) The design load is to be determined with regard to specific pressure on the print of one wheel, tire print dimensions and wheel spacing. Where a wheel spacing is, however, less than the print width of one wheel, such wheels may be considered as a group and the wheel spacings may be included in the tire print area. The design area of the wheel print or a group of wheels A_w, in m^2 must be calculated.

c) To be considered are the loads resulting from operation of vehicles during cargo handling operations and from stowage of vehicles on deck under conditions of ship's motions. Where distribution of the load between wheeled vehicle axles is not uniform, the maximum axle load is to be taken as the design load. For forklift trucks it is assumed that the total load is applied to the forward axle.

d) Where specifications on tire print dimensions are not available, the static specific pressure p_w, in kPa, is to be taken as given in *table 4100*.

Table 4100 Specific statical pressure p_w

Vehicle	p_w	
	Pneumatic tires	**Cast tires**
Cars	200	-
Lorries, motor vans	800	-
Trailers	800	1500
Fork trucks	800 (with $n = 1$)	1500
	600 (with n 2)	1500

The tire print dimension of a wheel or a group of wheels, parallel to the wheel axle v, in m, is to be determined from the formula:

$$v = \frac{A_w}{u} \text{ ion}$$

e) For each type of loads regulated by *3.2.3*, design loads are to be determined for two mutually perpendicular positions of vehicle wheels about the plate panel sides or framing members: when the wheel axle is parallel to the smaller side of the panel (normal to the framing members) and parallel to the larger side of the panel (parallel to the framing members).

The arrangement of wheel prints within the panel width or the framing member span is to comply with the following requirements, unless otherwise provided in the specification:
In case of odd number of prints, the center of middle print is to coincide with the middle of the smaller panel side or the middle of the framing member span.

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In case of even number of prints the following two cases are to be considered:

prints are to be arranged so that their total length along the smaller panel side or along the framing member is the greatest.

design number of prints is to be reduced by one and the center of the middle print is in line with the middle of the smaller side of the panel or with a mid-span of the framing member.

Wheel prints are to be so arranged that their total length along the larger side of the panel (in panel calculation) or athwart the framing members within the average spacing between the members (in calculation of framing members) is the greatest.

The design loads for side shell and permanent deck primary members are to be those required to satisfy the most severe stowage arrangement of all cargoes carried on decks (including package cargo, containers, wheeled vehicles, and so on.) and to allow for statically and inertia forces resulting from ship's motions.

Accelerations are to be determined as required by *1.3.3*.

3.3   Bulk carriers and oil or bulk dry cargo carriers

3.3.1   General

a)   The requirements of this Chapter apply to bulk carriers for the carriage of bulk cargoes and crude oil (oil products) in bulk of less than 90 m in length. Bulk carriers of 90 m in length and upwards, contract for construction of which was signed on April 1, 2006 and after, shall comply with the requirements of IACS, Common Structural Rules for Bulk Carriers.

b) The   scantlings of structural items within the cargo region are to be determined as required by *Sections 1* and *2* on assumption of the carriage of bulk or liquid cargo (ballast water) in the holds primarily designed for the purpose concerned. The value to be adopted is the greater of the appropriate strength characteristics of the item.

c) The requirements, for the items not mentioned in this Chapter are to be as given in *Sections 1* and *2*. The requirements for the hull and its items are not to be less stringent than those stated in *Sections 1* and *2*.

d) The   basic   structural type of ships referred to in *3.3.1* (a) is considered to be a single-deck ship with machinery aft, having a flat (or nearly a flat) double bottom in the holds (permissible slope of the inner bottom from the side to the center line is not over 3°), hopper side and topside tanks, single or double skin sides, transverse hold bulkheads of plane, corrugated or double-plate cofferdam type.

e) The descriptive notation Bulk Carrier and the distinguishing mark (ESP) shall be assigned to sea going self-propelled single deck ships with a double bottom, hopper side tanks and topside tanks and with single or double skin side construction intended for carriage of dry cargoes in bulk. Bulk carrier of single skin side construction means a bulk carrier where one or more cargo holds are bound by the side shell only or by two watertight boundaries, one of which is the side shell, which are:
- less than 760 mm apart in bulk carriers, the keels of which are laid or which are at a similar stage of construction before 1 January 2000;
- less than 1000 mm apart in bulk carriers, the keels of which are laid or which are at a similar stage of construction on or after 1 January 2000.

3.3.2   Structure

a) Longitudinal framing is to be adopted for the deck, the side shell in way of topside tanks and the sloped bulkheads of topside tanks. The deck plating between end coatings of adjacent cargo hatches is to be additionally strengthened by intercostal transverse stiffeners fitted at every frame. The double bottom is to be longitudinally framed. The double bottom construction with additional side girders in which all bottom and inner bottom longitudinals are replaced by side girders may be permitted. The single skin side between topside and hopper side tanks is to be transversely frame.

Longitudinal or transverse framing may be adopted for the double skin side and in hopper side tanks. The transverse watertight bulkheads may be plane with vertical stiffeners, corrugated with vertical corrugations or of a double-plate type.

b) A side hatch coaming is to be fitted with horizontal stiffeners. At every alternate frame the coaming is to be strengthened by vertical brackets fitted between the coaming flange and the deck.

c) The slope angle of topside tank walls to the horizontal axis is not to be less than 30 deg. Inside topside tanks, in line with transverse hold bulkheads, diaphragms are to be fitted, the plating of which may have drain and access holes of minimum size. The plating of transverse bulkheads inside topside tanks is to be strengthened with stiffeners. The ends of vertical stiffeners are to be bracketed. In topside tanks transverse beams are to be fitted in line with deck transverses. To strengthen the plates of the tank vertical walls which are in line with the cargo hatch side coaming, brackets are to be placed inside the tanks in line with every stay of the side coaming. These brackets are to be extended to the deck and tank sloped bulkhead longitudinals nearest to the center line. At every frame, in the lower corner of the tank, brackets are to be fitted in line with the brackets attaching the main frame to the sloped bulkhead of the tank. These brackets shall be carried to the ship's side and tank sloped bulkhead longitudinals nearest to the lower corner of the tanks and welded to them so as to extend beyond the brackets of frames.

d) The slope angle of hopper side tank walls to the horizontal is not to be less than 45 deg. The extension of the tank over the breadth of the ship at the inner bottom level is not to be less than $0,125B$ on one side. Transverse diaphragms shall be fitted in line with transverse bulkheads and every alternate plate floor. The diaphragms may have drains and access holes. The total height of openings at the section of diaphragm, in the direction along the normal to the tank plating, from a line drawn through the opening center perpendicularly to that normal, to the plating shall not exceed $0,5$ of the height of that section anywhere. The opening edges shall be reinforced with face plates or stiffeners. The diaphragm plating shall be stiffened as required by 1.7.3 for the floor stiffeners. Inside longitudinally framed tank, brackets shall be fitted in line with every frame. These brackets shall be carried to the sloped bulkhead and side longitudinals and welded to them so as to extend beyond the brackets of frames. At the outboard side girder forming hopper side tank wall, brackets are to be fitted in line with every frame. These brackets are to be carried to the nearest bottom longitudinal.

e) Within the cargo area, the single-side structure shall comply with the following requirements:

.1 the scantlings of side hold frames immediately adjacent to the collision bulkhead shall be increased in order to prevent excessive imposed deformation on the shell plating. As an alternative, supporting structures shall be fitted which maintain the continuity of fore peak stringers within the foremost hold;

.2 frame ends shall be attached with brackets. The vertical dimension of the lower and upper brackets, as measured at shell plating, shall not be less than $0,125$ of the frame span. On the level of the frame adjoining the bilge and underdeck tank, the breadth of the lower and upper brackets shall not be less than half the web height;

.3 frames shall be fabricated symmetrical sections with integral upper and lower brackets and shall be arranged with soft toes. The end brackets adjoining the underdeck and bilge tanks shall be blunted, and the flange ends shall be sniped. The side frame flange shall be curved at the connection with the end brackets. The radius of curvature shall not be less than *r,* in mm, determined by the formula:

$r = 0,4bbr\ lsbr$
where bbr = the flange width, in mm;
sbr = the thickness of brackets, in mm;
.
4 normal steel frames may be asymmetric. The face plates or flanges of brackets shall be sniped at both ends. The brackets shall be arranged with soft toes.

.5 where, a frame being connected to an underdeck tank, the frame or its bracket overlaps with a horizontal section of an inclined wall, provision shall be made for the bracket to go over the bent section, and the angle between the plane of the face plate (bracket) and the inclined tank wall shall not be less than 30°;
.6 the web depth to thickness ratio of frames shall not exceed the following values:
$60\sqrt{n}$ for symmetrically flanged frames;
$50\sqrt{n}$ for asymmetrically flanged frames;
.7 the outstanding flange shall not exceed $10\sqrt{n}$ $10\sqrt{n}$ times the flange thickness;

.8 in way of the foremost hold, side frames of asymmetrical section shall be fitted with tripping brackets which shall be welded to shell plating, webs and face plates of frames;

.9 double continuous welding shall be adopted for the connections of frames and brackets to side shell, hopper wing tank plating and web to face plates. For this purpose, the strength factor a for a weld is adopted equal to:

0,44 where frame webs shall be welded to shell plating on lengths equal to 0,25 of the frame span as measured from the upper and lower frame end, and where bracket webs shall be welded to the plating of underdeck and bilge tanks;

0,4 where frame webs shall be welded to shell plating outside the above end sections.

Where the hull form is such as to prohibit an effective fillet weld, edge preparation of the web of frame and bracket may be required, in order to ensure the same efficiency as the weld connection stated above.

f)   The ends of plane bulkhead stiffeners are to be bracketed to the inner bottom plating and to the deck structures.

g)   The cofferdam bulkheads shall satisfy the following requirements:

.1 the construction of cofferdam bulkheads, as stipulated under 2.7.1, shall consist of two tight platings, diaphragms and/or platforms. To stiffen the plating, vertical or horizontal stiffeners may be fitted;

.2 the vertical or horizontal stiffeners of both platings shall be identical, form a ring structure and pass continuous through the platforms or, accordingly, diaphragms. The vertical stiffeners of both platings shall be fitted in the same plane parallel to the centerline of the ship; the horizontal stiffeners shall be fitted in the same plane parallel to the base line of the ship.

Cross ties are permitted between the vertical or horizontal stiffeners of both platings, at the mid-span thereof;

.3 the diaphragms or platforms shall be stiffened in accordance with 1.7.3. The smaller side, in mm, of the panel of diaphragm or platform to be stiffened shall not exceed $100s\sqrt{n}$ $100s\sqrt{n}$, where s is the thickness of diaphragm or platform, in mm;

.4 for access to all parts of the cofferdam bulkhead an adequate number of openings (manholes) shall be provided in the diaphragms and platforms. The total width of openings in one section of the diaphragm or platform shall not exceed 0,6 of the cofferdam bulkhead thickness.

Openings other than the air and drain scuppers are not permitted:

in the platforms, at a distance not less than 1,5 times the cofferdam bulkhead thickness from the longitudinal bulkheads or side, which act as the platform supports;

in the diaphragms, at the same distance from the inner bottom plating or the upper point of the bulkhead bottom trapezoidal stool, and the upper deck plating or the lower point of the horizontal underdeck stiffener of rectangular or trapezoidal section, being the bulkhead top stool, which act as the diaphragm supports.

Edges of the openings cut in the diaphragms and platforms located within ¼ of the span from their supports shall be reinforced with face plates or stiffeners. The distance between the edges of adjacent openings shall be not less than the length of these openings.

h)   Transverse bulkheads with vertical corrugations shall have plane areas at ship's sides not less than 0,085 in width. The upper ends of these bulkheads shall be attached to the deck by horizontal stiffeners of rectangular or trapezoidal section, while the lower ends shall be attached directly to the inner bottom plating or to the stools of trapezoidal section fitted on the inner bottom. The bulkheads in heavy cargo holds shall be supported by trapezoidal stools. At lower end of corrugations there shall be fitted vertical and sloped plates so as to cover the concave portion of corrugations on each side of the corrugated bulkhead. The height of the covering plates in oil or bulk dry cargo carriers shall not be less than 0,1 of the corrugation span, and their thickness shall be not less than the lower strake thickness of the corrugation.

i)   Where lower ends of vertical corrugations are attached directly to the inner bottom plating, floors the thickness of which shall be not less than that of the bottom strake of the corrugated bulk heads shall be aligned with transverse faces (those directed athwart the ship). In this case, web plates (those directed along the ship) of rectangular corrugations shall be in line with inner bottom longitudinals or side girders. Side faces of trapezoidal corrugations shall be arranged so that in way of their intersection with inner bottom longitudinals hard spots are avoided.

j)   The construction of the transverse bulkhead bottom trapezoidal stool shall comply with the following requirements:

.1 the stool is fitted on the inner bottom athwart the ship under the bulkhead. It shall consist of a top horizontal plate having a width not less than the height of the bulkhead corrugations and two sloped plates resting upon the plate floors. The height of the stool shall not exceed 0,15Z). Stools of greater height are subject to special consideration by *QRS Class*;

.2 inner bottom longitudinal shall be cut at the floors giving support to the sloped plates of the bottom stools and to be attached to them by brackets. Brackets having a thickness not less than that of the floors, reinforced with stiffeners shall be fitted between the floors in line with the inner bottom longitudinal;

.3 diaphragms shall be fitted inside the bottom stools in line with the center girder and side girders. Drain and access holes may be cut in the diaphragms. Size of the openings, their runforcement as well as stiffening of diaphragms shall comply with similar requirements for the diaphragms of hopper side tanks;

.4 the horizontal and sloped plates inside the bottom stool shall be stiffened to form a ring structure, fitted in line with the inner bottom longitudinal.

k) The construction of the corrugated bulkhead top stool of rectangular or trapezoidal section shall comply with the following requirements:

.1 the top stool shall be fitted under the deck athwart the ship, over the bulkhead. It shall consist of a bottom horizontal plate having a width not less than the height of the bulkhead corrugations and two vertical or sloped plates. The height of the top stool shall be approximately equal to 0,1 of the distance between the topside tanks. The dimensions of the top stool shall be such as to provide access into that stool;

.2 the horizontal and vertical (sloped) plates inside the stool shall be stiffened.

The stiffeners may be fitted in line with the deck longitudinals forming ring structures with them.

Horizontal stiffeners may be fitted. In this case, webs giving intermediate support to these stiffeners as well as brackets ensuring efficient end attachment of corrugations shall be provided inside the top stool;

3.3.3   Design loads

a) For determining the depth of double bottom and scantlings of its members center girder, side girders, floors in the holds loaded with heavy bulk cargoes the design load is to be calculated for the heaviest of the anticipated bulk cargoes. When determining the above scantlings in the holds loaded with liquid cargo (ballast water) or remained empty, the design load is to be calculated where the hold is filled with liquid cargo or is to be assumed equal to the external pressure with no regard to the counterpressure, whichever is the greater.

b) The design pressure on the plating and longitudinals of the inner bottom in the holds loaded with heavy bulk cargo is to be calculated. In empty holds the design pressure is assumed equal to the test head given in the Appendix. For the holds loaded with liquid cargo (ballast water) the design pressure on the inner bottom is to be not less than that determined from *1.3.4*.

c) The design pressure on the plating and framing of the hopper side tank sloped sides in the holds loaded with heavy bulk cargo is to be determined as required by *1.3.4*, in the holds loaded with liquid cargo (ballast water) as stated in *1.3.4*. The design pressure on the sloped side is not to be taken less than the test head given in the *Appendix*.

d) For the holds loaded with heavy   bulk cargo the design pressure on the single skin side is to be determined as specified in *1.3.4*, and for the holds loaded with liquid cargo (ballast water) as given in *1.3.4*, no account being taken of the counterpressure from the sea. For empty holds an external pressure $p_{st} + p_w$ is to be assumed as the design pressure on the single skin side in accordance with *1.3.2*.

e) For ships having double skin construction to be taken as the design pressure on the inner skin is the pressure of the heavy bulk or liquid cargo (ballast water) as specified in 3.3.3 for a single skin side, no account being taken of the counterpressure from inter-skin tanks, but it is not to be assumed less than the test head for cargo and ballast tanks, given in the *Appendix*. For calculation of the scantlings of web frames and stringers of inner skin, to be taken as the design pressure is a pressure of bulk cargo or liquid cargo from the inside, or an external pressure as specified in *3.3.3* for single skin.

f) To be assumed as the design pressure on the topside tank sloped sides is a pressure of liquid cargo from the inside as required by *1.3.4* or the test head given in the *Appendix*, whichever is the greater.

g) The design pressure on the boundary bulkheads ofthe holds for heavy bulk cargo (including supporting structures) is to be determined as required by *1.3.4*. Where liquid cargo (ballast water) is likely to affect a bulkhead from one side, the design pressure on the bulkhead is to be determined as specified in *1.3.4*.

Hull

3.3.4   Scantlings of structural members

a)   The scantlings of double bottom members shall satisfy the following requirements:

.1 the scantlings of center girder, side girders and floors shall be determined on the basis of strength calculation made for bottom grillages using design pressure stated in 3.3.3 and the following permissible stress factors:

for center girder and side girders

$k_a = 0,3k_z^{0,6}$ in the midship region, when determining the shell plating stresses;

$k_a = 0,35k_z^{0,6}$ in the midship region, when determining the inner bottom plating stresses;

$k_{cr} = 0,6$ at the ship's ends within 0,1L from the fore or after perpendicular.

For regions between the midship region and the above portions of ship's ends, k_{cr} shall be determined by linear interpolation;

for floors

$k_a = 0,6$;

when the strength is verified using the shear stresses,

$k_T = 0,6$;

Where combinations of empty and loaded holds are envisaged, this shall be accounted for in the strength calculation made for the bottom grillage when determining the root flexibility factor of the center girder and side girders on the bearing contour line of the grillage. Account may be taken of the end root flexibility of floors owing to rotational stiffness of the hopper side tanks. The grillage shall be treated as a system of cross members (structural idealization using beam models);

.2 the section modulus of the bottom primary members shall be determined in accordance with 2.4.4 taking the following permissible stress factors:

for longitudinals

$k_a = 0,4k_z^{0,65}$ in the midship region;

$k_a = 0,65$ at the ship's ends within 0,1L from the fore or after perpendicular.

For regions between the midship region and the above portions of the ship's ends, k_a shall be determined by linear interpolation;

for transverse members

ka= 0,65;

.3 the section modulus of inner bottom primary members shall be determined in accordance with 2.4.4 at the design

pressure in accordance with 3.3.3 and the following permissible stress factors:

for longitudinals

$k_a = 0,5k_z^{0,75}$ in the midship region;

$k_a = 0,75$ at the ship's ends within 0,1L from the fore or after perpendicular.

For regions between the midship region and the above portions of the ship's ends, k_a shall be determined by linear interpolation;

for transverse members

ka= 0,75

b)   The scantlings of the hopper side tank members shall comply with the following requirements:

.1 the thickness of the sloped bulkhead plating shall not be less than that determined by the *Formula* 1.6.4 (d) taking:

$m = 15,8$;

p = design pressure as defined in 3.3.3;

The bottom strake thickness of the tank sloped bulkhead shall not be less than that of the inner bottom plate adjacent to it. The thickness of other strakes, in mm, shall not be less than:

$$S_{min} = (7 + 0,035L) \sqrt{n} \sqrt{n},$$

but not greater than the bottom strake thickness.

Where the hold and/or tanks used for the carriage of oil, oil products or water ballast, the thickness shall not be less than required by 3.5.4;

.2 the section modulus of primary members of the sloped bulkhead shall not be less than that determined in accordance with 1.6.4 taking:

p = design pressure as defined in 3.3.3;

$m = 10$ for transverse stiffeners;

$m = 12$ for longitudinal stiffeners;

k_a shall be taken as for the bulkhead stiffeners of tankers.

The longitudinal stiffeners shall comply with buckling strength requirements.

.3 the thickness of the diaphragm plating shall not be less than that of the abutting plate floors. Stiffening of the diaphragms with openings shall comply with the requirements for stiffeners of the floors, as specified in 1.7.3 (a).

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c) Where the frame ends are attached directly to the sloped bulkheads of the tanks (without transitional horizontal area) the section modulus of the section at support W_{sup}, in cm³, is to be not less than determined from the formula:

$$= \frac{\qquad}{\qquad}$$

where: W_o =   section modulus of the frame section normal to the side shell, cm³;

                       =   slope angle of the tank bulkhead to the horizontal axis, deg.

d) The scantlings of the frames shall be in accordance with the following requirements:
.1 the thickness of frame webs $S_{w\,min}$, in mm, shall not be less than:

$S_{wmin} = k\,(0,03L + 7)$

where: k =   1,15 for frame webs in way of yhe foremost hold need not to be adopted greater than 200 m.

            k =   1,0 for frame webs in way of other holds

.2 the thickness of the bracket connecting the lower end of frame to the bilge tank shall not be less than that of the frame web or s_{wmin} + 2 mm, whichever is greater. The thickness of the bracket connecting the upper end of frame to the underdeck tank shall not be less than that of the frame web;
.3 the section modulus of the frame and bracket or integral bracket, and associated shell plating, shall not be less than twice the section modulus required for the frame midspan area.

e) The scantlings of the topside tank members shall comply with the following requirements:
.1 the plating thickness of the vertical and sloped bulkheads of the topside tank shall not be less than determined by the *Formula* 1.6.4 (d) taking:
$m = 15,8$;
p = design pressure as defined in 3.3.3;
k_{σ} shall be taken as for the longitudinal bulkhead plating of tankers.
    The thickness, in mm, of the vertical bulkhead plating and of the adjoining sloped bulkhead plate shall not be less than:
$S_{min} = 10 + 0,025L$.
    The thickness of other sloped bulkhead plates shall be not less than that determined by the Formula in section 2.7.4 (a). Where the hold and/or tank is used for the carriage of oil, oil products or water ballast, the thickness shall be not less than that required by 3.5.4;

.2 the section modulus of longitudinal stiffeners of the vertical and sloped bulkheads shall not be less than that determined according to 1.6.4 taking:
p = design pressure as defined in 3.3.3, but not less than 25 kPa;
$m = 12$;
k_G shall be taken as for horizontal stiffeners of longitudinal bulkheads of tankers.
    The longitudinal stiffeners of the vertical and sloped bulkheads shall comply with buckling strength requirements of 1.6.5;
.3 the section modulus of the transverse web of the sloped bulkhead shall be not less than that determinate in 1.6.4

.4 the section modulus and sectional area of the deck transverse web inside the tank shall comply with the requirements of 2.6.4.
    The section modulus and sectional area of the side transverse web inside the tank shall comply with the requirements of 2.5.4 at $m = 10$.
    The section modulus and sectional area of vertical web plate of the tank vertical bulkhead shall be calculated as the mean of these values for the deck transverse and transverse web of the sloped bulkhead;

.5 the plate thickness of bulkheads inside the tanks fitted in line with the hold transverse bulkheads shall not be less than that of the latter at the same distance from the inner bottom plating. Stiffening of bulkhead plating shall comply with the requirements of 2.7.4 for the tank primary members;

.6 the thickness of brackets stiffening the tank vertical bulkhead and of brackets fitted at the lower corner of the tank shall not be less than 10 mm.

f) The hold bulkhead plating and corrugations shall have a thickness not less than 10 mm. The height of top rectangular (trapezoidal) stool, bottom trapezoidal stool and of double bottom is not included in the span of the hold bulkhead vertical corrugations.

g) The scantlings of the transverse bulkhead lower trapezoidal stool members shall comply with the following requirements:

.1 the thickness of the horizontal and sloped plate shall not be less than that determined by the *Formula* 1.6.4 (d) taking:

m = 15,8;
p = design pressure as defined in 3.3.3;
ka= 0,9.

The thickness of horizontal plate and top strake of the sloped plate shall not be less than that of the corrugation adjoining the stool. The thickness of the bottom strake of the sloped plate shall not be less than that of the inner bottom plating. The thickness of other stakes of the sloped plate shall not be less than that determined in section 3.3.4 (b). Where the hold and/or stool is used for the carriage of oil, oil products or

water ballast, the thickness shall be not less than that required by 3.5.4;

.2 the section modulus of the sloped plate stiffeners

shall not be less than that determined in accordance with 1.6.4 taking:

p = design pressure as defined in 3.3.3;
m =10;
ka= 0,75.

The section modulus of the horizontal plate stiffeners shall not be less than that of the sloped plate stiffeners;

.3 the thickness of diaphragm shall not be less than that of side girders. Size of the openings cut in diaphragms and their reinforcement shall comply with the requirements for openings and reinforcement of the hopper side tank diaphragms as specified in 3.3.4 (b-3).

h) The scantlings of the transverse bulkhead top rectangular or trapezoidal stool members shall comply with the following requirements:

.1 the thickness of the horizontal and vertical (or sloped) plates shall not be less than that determined by the Formula 1.6.4 (d) taking:

m = 15,8;
p = design pressure as defined in 3.3.3;
ka= 0,9.

The thickness of the horizontal plate and bottom strake of the vertical (sloped) plate shall not be less than that of the corrugation adjoining the top stool. Where the vertical plate is fitted in line with the hatch end coaming, its thickness shall not be less than that of this coaming as required by 3.3.4. The top strake of the sloped plate shall have the same thickness provided that its upper edge is at a distance of less than 0,4 m from the hatch end coaming. The thickness of the vertical or sloped plate shall not be less than that determined by the Formula in section 2.7.4 (a). Where the hold and/or interior of the top stool is used for the carriage of oil, oil products or water ballast, the thickness shall not be less

than that required by 3.5.4;

.2 the section modulus of the stiffeners of vertical or sloped plate shall not be less than that determined according to 1.6.4 taking:

p = design pressure as defined in 3.3.3, but not less than 25 kPa.
m = 12 for horizontal stiffeners;
m = 10 for other stiffeners;
ka= 0,75.

The section modulus of the stiffeners of horizontal plate shall not be less than that of the stiffeners of vertical or sloped plate;

.3 the section modulus of the vertical or sloped plate web to be fitted where horizontal stiffeners are provided, as stated in 3.3.2.11.2, shall not be less than that determined from 1.6.4, while the sectional area of the web plate shall not be less than determined according to 1.6.4 (c) taking:

Nmax = 0,5pal;
p = design loads as defined in 3.3.3, but not less than 25 kPa;
m =10;

Hull

$k_a = k_T = 0,75$.

The section scantlings of webs fitted on the horizontal plate and under the deck shall not be less than those required for the vertical (sloped) plate web;

.4 the thickness of the brackets fitted inside the top stool to ensure efficient upper end attachment of corrugations shall not be less than that of these corrugations in the upper part of the bulkhead.

i) The scantlings of the cofferdam bulkhead members shall comply with the following requirements:

.1 the thickness of the cofferdam bulkhead plating shall not be less than that determined by the Formula 1.6.4 (d) taking:

$m = 15,8$;

p = design pressure as defined in 3.3.3;

ka= 0,9.

The plating thickness shall not be less than that determined by the Formula in section 2.7.4 (a), whichever is the greater. Where the hold or interior of the cofferdam bulkhead is used for the carriage of oil, oil products or water ballast, the plating thickness shall be not less than that required by 3.5.4;

.2 the section modulus of primary members stiffening the plating of cofferdam bulkheads shall not be less than that determined from 1.6.4 taking:

p = design pressure as defined in 3.3.3 but not less than 25 kPa;

$m = 12$;

$k_a = 0,75$;

.3 where the construction of the cofferdam bulkhead incorporates only diaphragms or only platforms, their section modulus shall not be less than that determined from 1.6.4, and the sectional area is not less than that determined from 1.6.4 (c) taking:

N m a x = **0,5***pal* for platforms,

N m a x = 0,65pal for diaphragms;

p= design loads as defined in 3.3.3, but not less than 25 kPa;

l = span, in m, equal to:

for diaphragms — the distance between the deck plating and inner bottom plating, at the centerline;

for platforms — the ship's breadth in way of construction bulkhead for ships having single skin side construction, the distance between the inner skins for ships having double skin side construction;

$m = 10$;

$ka = kz = 0,75$;

.4 where the construction of the cofferdam bulkhead consists both the diaphragms and platforms, their thickness shall be determined on the basis of the calculation of the grillage as a system using beam models, with the loads specified in 3.3.3 but not less than 25 kPa and the permissible stress factors $k_a = k_T = 0,75$;

.5 The thickness of the cofferdam bulkhead diaphragms and platforms shall sufficient to comply with calculations in this Volume. Where the interior of the cofferdam bulkhead is used as a fuel oil or ballast tank, the thickness of the diaphragms and platforms shall not be less than that required by 3.5.4;

.6 stiffening of the diaphragms and platforms shall comply with the requirements of 1.7.3;

.7 the thickness of tight portions of the diaphragms and platforms and their stiffeners shall comply with the requirements of 2.7.4 for tank bulkheads

Where cross ties are fitted, the section modulus of the primary members of cofferdam bulkheads, as specified in 3.3.4 (i-2), may be reduced by 35 per cent.

j) The thickness of the hatch coamings shall not sufficient for requirements here indicated.

The thickness of the hatch side coamings, in mm, shall not be less than:

$s = $ **17***a* (3.3.4.10)

where a = vertical distance between horizontal stiffeners on coaming plate or between the lower stiffener and the deck plating, in m.

Stiffening of the coaming plates shall comply with the requirements of 1.7.3. The thickness of coaming plate stiffeners and brackets shall not be less than 10 mm.

The width of the coaming face plate shall comply with the requirements of 1.7.3.

k) The thickness of single-side shell plating located between hopper and upper wing tanks shall not be less than *smin,* in mm, determined by the formula

$S_{min} \sqrt{n}$

___

3.3.5 Special requirements

a) The thickness *s* of continuous side coamings of cargo hatches, in mm, is to be not less than determined from the formula:

$$= \quad - \quad = \quad -$$

where: a =   vertical distance between horizontal stiffeners on coaming plate or between the stiffener and the deck plating, in;

   η =   factor defined depending on coaming material.

the thickness of the hatch side and end coamings is to be not less than 15 mm.
The buckling strength of a continuous side coaming is to be assessed as required in *1.6.5*.

b) Inside cargo holds, provision should be made for an efficient corrosion protection coating (epoxy or equivalent) for all surfaces of side shell and transverse bulkhead structure including associated stiffening members and their end brackets. In the selection of coating due consideration to be given to the intended cargo and conditions expected in service.
In this context, transverse bulkhead includes bottom stool within 300 mm from the top of the stool. Likewise, side shell includes that part of upper and lower wing tank plating from the side shell to a distance 300 mm beyond the toe of frame brackets.

3.4 Ore carriers

3.4.1 General

a) The requirements of this Chapter apply to ships intended for the carriage of ore and other bulk cargoes.

b)   The requirements for structures not mentioned in this Chapter are to be as stated in *Sections 1* and *2*, having regard to those contained in *3.3* as regards structures exposed to the loads from heavy dry bulk and liquid cargoes. The requirements for the hull and its structures are not to be less stringent as those of *Sections 1* and *2*.

c)   The basic structural type of a ship is considered to be a single deck ship, with machinery aft, having longitudinal bulkheads separating the center ore compartment from the wing tanks and a double bottom throughout the entire breadth of the ship or the center part between the longitudinal bulkheads.

d)   Descriptive notation and distinguishing mark (ESP). The descriptive notation Ore carrier and the distinguishing mark (ESP) shall be assigned to sea-going self-propelled single deck ships having two longitudinal bulkheads and a double bottom throughout the cargo region and intended for the carriage of ore cargoes in the center holds only.

3.4.2 Structure

a) The deck and bottom (double bottom) are to be longitudinally framed. The side shell and longitudinal bulkheads may be framed either longitudinally or transversely. Deck plating between end coamings of adjacent cargo hatches is to be strengthened by transverse stiffeners.

b) Floors in the center hold and, in the wing-tanks are to be aligned and to form, in conjunction with side transverses, vertical webs of longitudinal bulkheads and deck transverses, a single transverse ring structure.

c) Where transverse bulkheads in the wing tanks are not aligned with center hold bulkheads, transverse ring structures are to be fitted in line with the latter bulkheads.

d) Longitudinal bulkheads are to be plane with horizontal or vertical stiffening. Longitudinal bulkheads may be slightly sloped or to have a knuckle.

e) Where a double bottom in wing tanks is omitted, loors are to be backed by substantial knees or brackets fitted in line with the inner bottom plating of the center hold.

3.4.3 Design loads

a) The design pressure on the center hold boundary structures is to be determined assuming that the center hold is loaded with ore or other heavy bulk cargo.

b) Structures which are likely to be subjected to one-sided pressure of a liquid cargo (ballast water) are to be examined for the design pressure of the liquid cargo.

3.4.4 Scantlings of structural members

a) The depth of the double bottom in the center hold is to be determined as required by *2.4.4*.

b) The scantlings of the bottom center girder and side girders in the center hold are to be determined according to *2.4.4*, and those of floors according to *2.4.4 (c)* with the design pressure as required by *2.4.3* for the heaviest cargo of those anticipated and n_o being within the limits stipulated for tankers.

c) Bottom framing in wing tanks where a double bottom is omitted is to comply with the requirements of *2.3.4.2* for tankers.

d) The thickness of the inner bottom plating is to comply with the requirements of *3.3.4 (e)*, stiffeners of the plating are to be as required by *3.3.4 (f)*.

e) The thickness of the outer shell, where double bottom is omitted is to be determined according to *2.2.4 (a)* with the design pressure derived from *2.2.3* for tankers having no double bottom and no double skin construction.

f) Side framing is to comply with the requirements of *2.5.4* for tankers. Requirements for longitudinal bulkheads, see *3.3.4*.

g) The thickness of transverse bulkhead plating and corrugations in the center hold and of longitudinal bulkheads is to be as required in *3.3.4 (e)* The plating thickness of transverse bulkheads in wing tanks is to be determined as stipulated in *2.7.4 (a)* is for cargo and ballast tanks of tankers.

h) The section modulus of vertical and horizontal stiffeners of bulkheads and corrugations in tile center hold is to be as required by *3.3.4.19*. The section modulus of transverse bulkheads in wing tanks is to comply with the requirements of *2.7.4* as for cargo and ballast tank bulkheads in tankers.

i) The section modulus of vertical webs and horizontal girders of wing tank bulkheads is to be as required by *2.7.4 (b)* for bulkheads of cargo and ballast tanks in tankers.

3.5 Tankers

3.5.1 General

a) The requirements of this Chapter apply to tankers, as well as to oil recovery ships, as applicable, with machinery aft, having a single or a double bottom arrangement and one, two or three longitudinal bulkheads. Hull structural members of tanker,-, not covered by this Chapter are to comply with the requirements of *Sections 1* and *2*.

b) Double hull oil tankers of 150 m and over in length, which contract for construction is signed on 1 April 2006 or later, shall comply with the requirements of IACS "Common Structural Rules for Double Hull Oil Tankers".

c) Descriptive notation and distinguishing mark (ESP).

d) The descriptive notation Oil tanker and the distinguishing mark (ESP) shall be assigned to sea-going self-propelled ships having integral tanks and intended for the carriage of oil in bulk. The above mentioned descriptive notation and distinguishing mark shall be assigned to tankers of both single and double skin side construction.

e) The descriptive notation Chemical tanker and the distinguishing mark (ESP) shall be assigned to sea-going self-propelled ships having integral tanks in tended for the carriage of chemicals in bulk. This descriptive notation shall be assigned to tankers of both single or double skin side construction, as well as tankers with alternative structural arrangements.

3.5.2   Structural configuration

a) The maximum permissible dimensions of cargo tanks are to comply with the requirements of *2.7.1*. The width of vertical cofferdams is to be equal to one frame spacing, but not less than 0,6 m, the height of horizontal cofferdams, not less than 0,7 m. The dimensions of cofferdams are to be selected so that access therein is to be provided for repairs and maintenance.

c) Longitudinal bulkheads, except for the third bulkhead located on the center line of the ship, are to be tight within the entire cargo tank region. Corrugated bulkheads are permitted in ships under 180 in length. Longitudinal corrugated bulkheads are to have horizontally arranged corrugations, and their upper and lower strakes for $0,1D$ from the deck and bottom, respectively, are to be plane. In way of connections between longitudinal and transverse bulkheads, continuity of strength is to be maintained at the top and bottom strakes of the longitudinal bulkheads.

d) The deck and bottom in the cargo tank region are to be framed longitudinally, for the side shell and longitudinal bulkhead is, longitudinal or transverse framing may be adopted. The deck and bottom of ships under 80 m in length may be transversely framed. It is recommended that longitudinal framing be used for side shell and longitudinal bulkheads of ships exceeding 180 m in length. Where the longitudinal framing is adopted, spacing of transverse members is to correspond to that of bottom transverses.

e) The longitudinal scantlings of deck, bottom, side shell and longitudinal bulkheads within the midship portion of the ship are not to vary. Structural continuity of the above longitudinals is to be ensured within $0,1D$ from deck and bottom. In ships of 150 m and more in length, the above longitudinals are to pass through the transverse bulkheads without cutting.

f) The primary supporting members (bottom center-line girder, side girders, vertical webs on bulkheads, deck center-line girder, continuous deck girders, side and bottom transverses, side stringers and bulkhead horizontal girders) in wav of cargo tanks are to form a transverse ring structure, whenever possible.

g) Hull structural members are to be interconnected as required by *1.7.2*. The webs of primary supporting members are to be supported by horizontal or vertical stiffeners in accordance with *1.7.3*.

3.5.3   Design loads

a) Unless provided otherwise in this Chapter, the design loads on hull structures of tankers are to be taken according to *1.3* and relevant chapters of *Setion 2*.

Hull

3.5.4 Scantlings of structural members

a)   The scantlings of structural items of tankers are to be determined in compliance with *Section 2*, having regard to the provisions of this Chapter.

The thickness S_{min}, in mm, of structural members, forming the boundaries of cargo and ballast tanks as well as members fitted inside these tanks shall not be less than:

$s_{min} = 5,5 + 0,035L$ for $L < 80$ m;

$s_{min} = 6,7 + 0,02L$ for $L \geq 80$ m.

Where $L > 290$ m, L shall be taken as equal to 290 m. In this case, the minimum thickness of the primary members need not exceed 11,5 mm.

3.5.5 Special requirements

a) The number of openings for access to cofferdams, pump rooms, cargo and ballast tanks is to be kept to the minimum requires. They are to be as far distance as practicable from end bulkheads of superstructures. Hatches to wing tanks in line with a center tank hatch in the athwart direction are not permitted. Hatch opening are to be either circular or elliptical in shape, the elliptical openings having the major axis fore and aft. Structural continuity of deck girders and longitudinals is to be maintained. The thickness of cargo hatch coamings less than 750 mm high is to be 10 mm, while coamings 750 mm and more in height are to have a thickness equal to 12 mm. Coamings more than 750 mm in height, provided they are more than 1,25 m long, are to be stiffened.

b) Guard rails, bulwark, gangway or an equivalent arrangement are to be fitted. The gangway, if fitted, is not to contribute to longitudinal hull bending.

3.7 Special purpose ships

3.7.1 General and symbols

a)   The requirements of this Chapter apply to special purpose and cargo ships intended for processing, storage and transportation of catch.

b) The requirements for structures referred to in this Chapter are given in *Sections 1* and *2*. In no case should the requirements for the hull and hull structures be less stringent than those stipulated in *Sections 1* and *2*.

c)   The requirements for ships mooring at sea provide for a damping protection of the hull for which purpose pneumatic fenders or other equivalent damping arrangements may be used. The requirements assume that ships would be moored at a sea state not above 6.

d)   Symbols:

  b : Breadth of stern ramp, in m.

  G_1 : The greatest specified mass of the catch which can be handled by a special wheeled device or other transport means, t.

  G_2 : Mass of the moving part of a special wheeled device or other transport means, t.

  G : Mass of processing equipment, t.

  S_d : Factory deck area, in m².

  h : Distance of strengthening boundaries region from summer load lines and ballast waterline, in m.

  $A_1 -$: Regions of strengthening.
  A_7

  $E_1 -$: Regions of strengthening.
  E_7

  a : Spacing of framing members under consideration,

_____
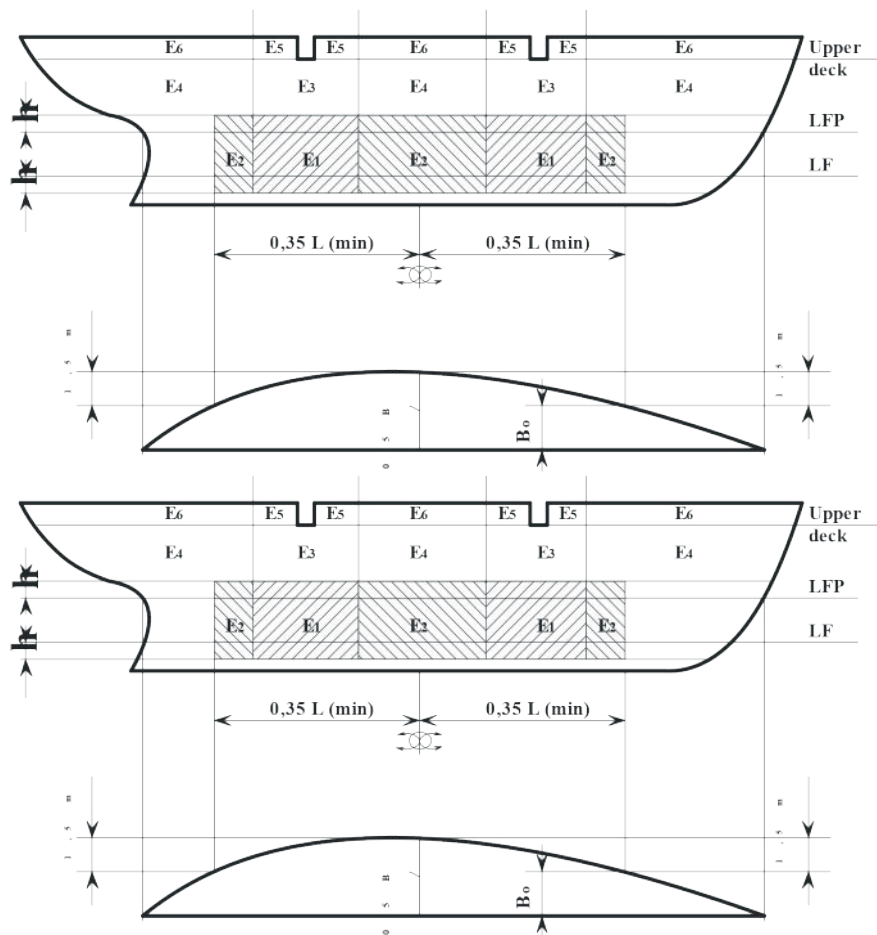
        in m;

l : Span of the member under consideration, in m;

   : Corrosion allowance added to the plate thickness, mm.

   : Factor taking account of corrosion allowance in the section modulus of framing members.

e) For vessels mooring at sea, the regions of side strengthening are to be as shown as in the figure here below:

3.7.2 Structure

a) The after-end structure of vessels having a stern ramp and/or stern trawling arrangements is to be strengthened by fitting additional longitudinal and transverse members (girders, transverses, cross ties, bulkheads and partial bulkheads. The stern ramp is to be so constructed is to be so constructed as to avoid flat of bottom in way of stern counter. The transom plating is to be protected from excessive wear by half-round steel bars at least 70 mm in diameter fitted inclined and welded to the transom plating.

    1. The connection of stern ramp sides to transom plating and of the ramp deck to bottom plating is to have a radius of rounding not less than 200 mm. This connection may be made by using a bar not less than 70 mm in diameter.

    2. In way rounded connection of stern ramp side to transom plating, the side strake is to be at least 20 mm thick for a minimum breadth of 700 mm. Strengthening by means of doubling plates is admissible. Lengthwise, forward of the end of the transom, half-round steel bars with a diameter at least 70 mm are to be welded to the ramp side plating.

3. Stern ramp sides are, to be carried downwards to the shell plating and forward to the after peak bulkhead and are to be smoothly tapered into deck girders and transverses.

4. Where the catch is dragged onto the deck, it is recommended that the stern ramp be longitudinally framed with transverses fitted at intervals not exceeding four frame spacing. The stern ramp longitudinals are to be spaced not more than 600 mm apart. In vessels where special transport means are used to carry the catch onto the deck, the stern ramp is to be framed transversely.

5. The extension of the thickened portions of stern ramp plating lengthwise shall be not less than the stern ramp breadth as measured forward of the stern ramp end in way of bottom rounding and not less than twice the stern ramp breadth in way of top rounding.

6. It is recommended that suitable devices be installed to preclude excessive wear of stern ramp plating with wire ropes dragging the catch. Where the rated pull of the winch exceeds 30 kN on each wire rope, such devices are compulsory.

7. Instead of devices preventing the plating from excessive wear, doubling plates may be fitted in the thickened regions of top and bottom rounding over the full breadth of the stern ramp, and doublings strips at least 400 mm wide may be fitted at the sides over the rest of the stern ramp length.

b) It is recommended that vessels more than 30 m in length having a side trawling arrangement be fitted up with a forecastle. Within the location of each gallows, determined as the distance between sections at three spacing forward and aft of the gallows ends the strengthening shall be as follows:

Intermediate frames are to be fitted extending from the upper deck down to a level not less than 0,5 m below the ballast waterline and having a section modulus not less than 75 per cent of that required by *2.5.4 (b)* for the frames in the tween deck space concerned.
The upper and lower ends of intermediate frames are to be secured to the decks, platforms and longitudinal intercostal members fitted between the main frames; longitudinal intercostal members are to have the same section as intermediate frames and be aligned with them; the upper longitudinal intercostal member is to be fitted not more than 350 mm below the upper deck.
Bulwark stays are to be fitted at every frame.
Bulwark, sheer-strake and shell plating above the ballast waterline are to be protected with steel bars of ogival section fitted inclined and secured by welding.

c) Where the number of bulkheads in the processing shops located above the bulkhead deck is less than specified in 2.7.1 and where the distance between the bulkheads forming the boundaries of that space exceeds 30 m, partial bulkheads extending inboard for not less than 0,5 m of the 'tween deck height are to be fitted on the bulkhead deck at each side of the vessel in line with watertight bulkheads. The thickness of the partial bulkhead plating is to be not less than that of the top strake of the corresponding watertight bulkhead below the deck where the considered processing shop is located. Partial bulkheads are to be strengthened with horizontal stiffeners in accordance with *1.7.3*. Strengthening with vertical stiffeners is permitted with fitting the horizontal stiffeners between the side shell and the nearest vertical stiffener. Partial bulkheads are to be interconnected with deck transverses supported by pillars in a required number. Alternative structural arrangements may be used if approved by *QRS Class* as equivalent. Where multi-tier deckhouses are arranged above the processing shops, the requirements of *2.12.2* for rigid members (bulkheads, partial bulkheads) to be fitted in such spaces are to be complied with.

d) Strengthening of ships mooring at sea:
.1 In regions strengthened for mooring at sea, transverse framing is to be adopted for the vessel's sides. In single-deck ships, the deck and the bottom in the above regions are also to be framed transversely.
In multi-deck ships, transverse framing is to be adopted for the deck situated at the level of fenders. Longitudinal framing of sides is permissible in the upper tween deck space only. In this case, the spacing of web frames is not to exceed three frame spacings or 2,4 m, whichever is less. In A1 and E1 regions of strengthening, intermediate frames are recommended.
.2 It is recommended that symmetrical sections be used and the minimum possible web depth be provided in conjunction with the required section modulus.

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.3   Between the vessel's side and the vertical stiffener nearest to it, transverse bulkheads are to have horizontal stiffeners with a section height not less than 75 per cent of the vertical stiffener height. In vessels with L 80 m, horizontal stiffeners are to be spaced not more than 600 m apart, and with L 150 m, not more than 800 mm apart.
    For vessels of intermediate lengths, linear interpolation may be used. The ends of horizontal stiffeners are to be welded to vertical stiffeners and sniped at the vessel's sides.

.4   The bulwark is to be inclined towards the center line of the vessel at not less than one-tenth or be fitted inboard of the vessel's side at not less than one-tenth of its height.

.5   Bilge keels of vessels with L 80 m are to be, as far as practicable, so arranged that a tangent drawn to the frame and passing through the outer free edge of the bilge keel would form an angle of not less than 15. For vessels with L 150 m this angle may be 0.
    For vessels of intermediate lengths, the above angle is to be obtained by linear interpolation.

.6   The lower end attachments of hold frames are to be as required by *2.5.5.1*.
    In tween decks, the attachments of frame lower ends are to comply with the requirements of 2.5.5.3. The frame ends are to be welded to the deck plating.
    The frame ends are to be welded to the deck plating.
    Upper ends of frames are to be carried to the deck plating and welded thereto. Beams are to be carried to the inner edges of frames with a minimal gap. Beam knees are to have a face palte or flange.
    The ends of intermediate frames are to be attached to longitudinal intercostals, decks or platforms.

.7   Side longitudinal are to be attached to transverse bulkheads with knees. The height and width of the knees are to comply with *1.7.2 (b)* assuming $n = 1,8$.

.8   Bulwark stays welded to sheer-strake are to be so constructed as to prevent the damage of deck plating in case of bumping

3.7.3   Design loads

a)   The design pressure p, in kPa, on the ramp sides and decks in vessels where the catch is dragged in is to be determined using the formula:

$$p = 6,5 \cdot b$$

    Where the breadth of the ramp varies along its length, the minimum breadth is to be taken as the design value.

    In vessels equipped with a special wheeled catch-transport arrangement, the design load P, in kN, for ramp deck plating is to be determined from the formula:

$$= \frac{+}{\qquad}$$

where: n_w n_w = number of the wheel axes of the arrangement.

b)   For factory decks, the design pressure p, in kPa, is to be determined from the formula:

$$= \overline{\quad}$$

3.7.4   Scantlings of structural members

a)   The section modulus of factory deck beams and longitudinals is to be determined as required by *2.6.4* with the design load according to *3.7.3* where it exceeds that required by *2.6.3*.

b)   The section modulus of longitudinals, beams and deck transverses of the stern ramp is to be determined according to 1.6.4. In this case:

p :   As obtained from *formula* above if the catch is dragged

in and from *formula* above if the catch is carried onto the deck by a wheeled arrangement

m : As determined from *table 4200* if the catch is dragged in:

if the catch is carried onto the deck by a wheeled arrangement:

$$m = 9,31^2 \cdot 4\sqrt{\frac{a}{l}} \; ;$$

$$k_\sigma = 0,6.$$

Table 4200 Coefficient *m*

Stern ramp framing	Special purpose ship
Deck longitudinals	7,9
Beams and deck transverses	8,8

c) The section modulus, in cm³, of stern,

$k_\sigma = 1,1, \quad m = 13,8$ and 18,5 for special purpose ships, respectively.

The stiffener span *l* is to be adopted equal to the maximum distance between the ramp deck and the nearest deck above or to the distance between two decks adjoining the ramp side, but is not to be less than 2,6 m:

$$= \quad\quad \text{—} \quad \text{——} \quad \text{—}$$

In no case shall the section modulus of stern ramp side stiffeners be less than required in *2.5.4 (b)* for the frames of upper tween deck and superstructure.

d) Whatever the mode of carrying the catch along the stern ramp, the thickness of ramp plating in vessels of all types is to be 2 mm greater than required by *2.2.4 (h)* for the shell plating. The above thickness is to be maintained on the length from the stern ramp end to a line at least 600 mm above the bulkhead deck within the particular section of the vessel length. Forward of this region the thickness of stern ramp plating is to be 2 mm greater than required in *table 2600* for the upper deck plating at ends.

e) On a length at least 1,0 m forward of the stern ramp edge and at least over the whole breadth of the stern ramp, the stern-counter plating shall be 1 mm thicker than stipulated by *2.2.4 (a)*.

f) In vessels over 30 m in length having a side trawling arrangement, the side plating and sheer-strake thickness within the vessel length between the gallows determined as the distance between the section three spacing forward of the fore end of forward gallows and the section three spacing abaft the after end of after gallows shall be 1 mm greater than stipulated by *2.2.4 (a)*. Within the location of each gallows, determined as the distance between sections at three spacing forward and aft of the gallows ends, the following strengthening is to be provided:
Sheerstrake thickness is to be increased by 2 mm.
Thickness of strake adjacent to sheer-strake is to be increased to equal that of the sheer-strake between gallows.
Deck stringer thickness is to be increased by 3 mm as compared to that required by *2.6.4 (a)*.

g) For ships mooring at sea and having the length L 80 m, the side plating and sheer-strake thickness shall be increased by 1 mm as compared to that stipulated by *2.2.4 (h)*.

h) When determining the sternframe scantlings requirements for vessels wit $L < 60$ m, the design length and width of solid rectangular propeller post are to be those stipulated by *2.10.4 (c)* increased by 10 per cent.

$$l \ = \quad \text{frame span as measured along the chord between the upper edge of inner bottom plating or floor face plate and the lower edge of deck at side (side stringer where web frames are fitted), in m.}$$

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3.8 Supply vessels

3.8.1 General

a) The requirements of this Chapter apply to vessels specially designed for the carriage of specialized cargoes (stores and equipment) to mobile offshore drilling units and other offshore installations.

b) The requirements are additional to the requirements of *Sections 1* and *2*. Structural items not covered by this Chapter are to comply with the requirements of *Sections 1* and *2*.

3.8.2 Structure

a) Provision is to be made for longitudinal fenders. At the fore end sloped fenders are to be fitted between the longitudinal fenders.

b) Inner bulwarks (coamings) and other similar structures protecting deck cargoes are to be properly secured to deck framing members. The scantlings of the above structures are to be agreed with *QRS Class*.

c) Shell in way of stern rollers and in other high load areas is to be suitably reinforced.

d) In deck areas where concentrated loads are applied (e. g. drilling rig anchors), extra strengthening of decks is to be provided.

e) The sides of superstructures and the bulwark are to be included to the center line of the vessel at not less than one tenth or to be fitted in board from the vessel's side at not less than one tenth of their height.

f) The lower ends of stiffeners of the first-tier front bulkheads are to be connected to the underdeck framing members by brackets. The lower ends of other stiffeners are to be welded to the decks. The upper ends of stiffeners are to be connected to the deck beams by means of brackets.

g) The stays of the bulwark welded to the sheer-strake are to be so constructed as to prevent damage of deck plating is case of bumping.

h) Extra strengthening of a flat portion of the bottom in way of the stern may be required to take up loads induced by slamming.

3.8.3 Design loads

a) Design loads on hull structures of supply vessels are to be taken in compliance with *Sections 1* and *2*.

3.8.4 Scantlings of structural members

a) The thickness of the side shell plating is to be 1 mm greater than required by *2.2.4*. In no case is the thickness of the side shell plating to be taken less than 9,0 mm.

b) The thickness of deck plating is to be determined from *2.6.4*, but it is not to be less than 8,0 mm.

c) The scantlings of deck framing members are to be obtained as required by *2.6.4* with a design load corresponding to the specified value but not less than 35 MPa.

d) The scantlings of girders and pillars supporting these girders are to be suitable for the weight of the deck cargo, as well as for loads induced by towing winches, supports of separate cargo platforms and other concentrated loads. Account is to be also taken of a vertical and a horizontal components of inertia forces due to the vessel's motions.

f) The section modulus of hold, tween deck and forecastle frames is to be sufficient to meet all requirements of this Volume.

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g) The section modulus of stiffeners of the fronts, sides and after ends of the deckhouses situated on the forecastle deck is to be not less than that required in Section 2.12.4. The assumed head p, in kPa, is not to be taken less than given in *table 4300*.

Table 4300 Conventional pressure p

Deckhouse tier	p, kPa		
	Front bulkhead	Side bulkhead	After bulkhead
First	90	60	25
Second and above	75	50	25

h) The plate thickness of the fronts, sides and after ends is to be taken not less than 6,5 mm for the first-tier front bulkhead and 6,0 mm for other bulkheads.

i) The plate thickness of the bulwark is to be at least 7 mm, and the width of the stiffener lower end measured along the weld is to be not less than 360 mm. The distance between stays is not to exceed two spacing or 1,3 m, whichever is the lesser.

3.8.5   Special requirements

a) In vessels having a double skin construction, structures and scantlings of the inner skin framing are to comply with *2.5*.

3.9   Tugs

3.9.1   General and symbols

a)   The requirements of this Chapter apply to tugs of all purposes and service areas.

b)   Structural items not covered by this Chapter are to comply with the requirements of *Sections 1* and *2*.

c)   Symbols:
   b_s :   Width of stem cross section, in mm.
   l_s :   Length of stem cross section, in mm.

3.9.2   Structure

a) Plate floors are to be fitted at every frame. Where the double bottom is omitted, the floors are to have a symmetrical face plate.

b) Where a main frame span exceeds 3,0 m, load distributing side stringers are to be fitted along the length of the vessel, except for the engine room.

c) Web frames in the engine room are to be fitted at a distance not exceeding four spacing from the inner bottom (floor face plates) to the upper deck. It is recommended that web frames be fitted at the engine ends.

d) A fender is to be fitted at the level of the upper deck and long forecastle deck.

e) In places where concentrated loads are applied (e. g. due to towing winches) extra strengthening is to be provided.

f) The sterns of harbor tugs above the summer load waterline are to have rounded shapes.

3.9.3   Design loads

a) Design load on hull structures of tugs are to be assumed in compliance with the requirements of *Sections 1* and *2*.

3.9.4   Scantlings of structural members

     a) The minimum plating thickness of shell and upper deck as well as watertight bulkheads is to be not less than 5 mm. The thickness of the shell plating in way of the engine room, when located aft, is to be not less than required for; the midship region.

     b) The scantlings of load distributing side stringers are to be determined as required by *2.8.2 (c)*.

     c) Rectangular solid bar stems are to have scantlings (from the keel to the summer load waterline) not less than those determined from the formula:

$$l_s = 1{,}6 \cdot L + 100$$
$$b_s = 0{,}5 \cdot L + 25$$

     The scantlings and positioning of brackets for strengthening of the stem are to be as required by *2.10.4*
     The stem is to be extended abaft the fore peak bulkhead for not less than three spacings.
     Ship-handling tugs are not permitted to have reduced cross-section and scantlings of the stem (if constructed of steel plates) above the summer load waterline.
     The steel plates of the stem are to be strengthened over their length by horizontal brackets spaced not more than 0,6 m apart, the plate thickness of the stem determined according to *2.10.4* being not reduced.

     g) The thickness of the bulwark plating shall not be less than 4 mm.
     The bulwark stays are to be fitted not farther than at alternate frames. The bulwark is to be inclined to the center line of the vessel at not less than 7 deg. The stays of the bulwark welded to the sheer-strake plate may have a structure with a flexible element.

3.9.5   Special requirements

     a) For unrestricted service tugs more than 40 m in length the number of watertight bulkheads is to be not less than four.

ANNEX 1
Tightness test of ship's hull

In the course of construction, the hull of very ship is to be tested for tightness according to provisions of this table and methods approved by *QRS Class*

Nos.	Items to be tested	Test methods and required test heads	Notes
1	2	3	4
1	Fore and after peaks:		
1.1	Used as water compartments.	By filling with water to a head up to the top of air pipe, but not less than 0,9 m above the upper deck or forecastle (poop) deck [1]	The after peak is to be pressure tested with the stern tube and rudder trunk fitted.
1.2	Not intended to be filled with water	By filling with water to a head of 0,3 m above the bulkhead deck, and hose tested above this level. [1]	If the hatch coamings of the fore and after peaks (not intended to be filled with.
2	Double bottom compartments (including the duct keel)	By filling with water to a head up to the bulkhead deck or top of the air pipe, whichever is the greater [1]	
3	Double-skin compartments:		
3.1	Intended for carrying liquids.	By filling with water to a head up to the top of air pipe, but not less than 2,5 m from the deck forming the upper boundary of the compartment [1]	
3.2	Not intended for carrying liquids.	In double-bottomed ships. [1,2] by hose testing above the level of the double bottom [1,2] In single-bottomed ships: by filling with water to a head of 1,0 m from the bottom shell plating at the keel plate and hose testing above this level.	
4	Cargo holds in dry cargo ships, engine and boiler rooms, electric propulsion motor rooms:		
4.1	For double-bottomed ships.	By hose testing of the entire surface above the level of double bottom [2]	
4.2	For single-bottomed ships.	By filling with water to a head of 1,0 m from the bottom shell plating at a keel plate and hose testing above this level	

1	2	3	4
5	'Tween deck spaces.	By hose testing. [2]	
6	Tanks located beyond the double bottom, including the tanks for ship's liquid fuel stores, lubricating oil and daily service tanks. Tanks (in dry cargo ships and special purpose ships) for storage of vegetable oil, whale oil and other liquid cargoes.	By filling with water to a head up to the top of air pipe, but not less than 2,5 m from the plating forming the crown of the tank. [1]	For tanks with air pipes led into a manifold the test head is taken to the top of the manifold, but not less than 2,5 m from the crown of the tank.
7	Cargo tanks of tankers and cargo holds of dry cargo ships which can be filled with liquid cargo or ballast.	By filling with water to a head up to the top of expansion trunk, but not less than 2,5 m from the deck forming the crown of the tank (hold). [1]	If pressure testing is impracticable while on berth or in dry dock, it may be carried out with the ship afloat. Before the ship is launched all cargo tanks (holds) are to be leak tested by air pressure. When afloat, one center and two side tanks selected by the Surveyor, are to be pressure tested using water. These tanks are to be tested simultaneously; the relative position of the tanks tested shall correspond to most severe loading condition. If, during the test, structural defects or leaks are revealed, the Surveyor may require more tanks 8or all of them) to be tested by filling with water.
8	Cofferdams:		
8.1	With fittings to permit filling with water.	By filling with water to a head up to the top of air pipe, but not less than 2,5 m from the plating forming upper boundary of the cofferdam. [1]	Cofferdams arranged within the double bottom are to be tested as the double-bottom compartments (see item 2 of this table).
8.2	Without fittings to permit filling with water.	By filling with water to a head up to the top of hatch coaming above the cofferdam or to the top of air pipe (whichever is the greater). In the absence of hatch coming or air pipe, the head will be taken up to 0,6 m above the highest point of deck (platform) in way of cofferdam. [1]	

1	2	3	4
9	Sea inlet and ice boxes.	By filling with water to a head up to 1,25 times the ship's depth, but not less than the pressure in the clearing system..	When testing the ice boxes (where heated by steam), the test head is to be always not less than the design pressure of the heating system.
10	Shaft tunnels, recesses and escape trunks, as well as tight trunks (including machinery casings, boiler uptakes and funnel casings), vent ducts located inside the hull, superstructures and deckhouses.	Hose testing. ²	In the shaft tunnel or the trunks pass through compartments which are pressure tested, the appropriate part of the tunnel and the trunks are checked during the tests of the compartments. Vent ducts may be tested similarly, unless provided otherwise in the relevant specification.
11	Chain lockers:		
11.1	Located abaft the collision bulkhead.	By filling with water to a head of 0,6 m from the locker bottom and hose testing above this level. ²	Chain locker structures (or part thereof) located forward of the collision bulkhead, which were pressure tested at the same time as the for peak, need not be subjected to hose testing.
11.2	Located forward of the collision bulkhead.	Hose testing. ²	
12	Spaces inside the stern counter.	By filling with water to a head up to the level of load waterline; hose testing above said level. ²	
13	Superstructures and deckhouses (including exposed parts of machinery and funnel casings).	Water pressure blasting. ²	
14	Exposed parts of decks (inclusive of the deck	Hose testing. ²	On tankers, the parts of exposed decks in cargo tanks region are to be tested simultaneously with the compartments located immediately below them (see *item 7* of this table)
15	Hatchway and ventilator coamings on exposed parts of upper deck, as well as decks of superstructures and deckhouses	Hose testing. ²	

1	2	3	4
16	Closing appliances for openings in tight structures of ship's hull: Doors in subdivision bulkheads. Doors in outer bulkheads of superstructures and deckhouses. Cargo ports. Covers of skylights and companionways. Scuttles in upper deck and ship sides, as well as decks and sides of superstructures and deckhouses. Covers in manholes in tight decks, platforms and bulkheads. Outer closures of rubbish shoots. Steel covers of cargo hatchways.	Hose testing. [2]	Closing appliances for openings in tight structures located inside the ship, in superstructures located inside the ship, in superstructures and deckhouses may be tested for leak by means of air jet. Closing appliances of openings (for example covers of manholes, hatchways, sluice valves) as well as closures of air, sounding and similar pipes in tween decks and other spaces tested by filling with water are to be tested at the same times as these spaces. If separately tested, they are to be subjected to a pressure head corresponding to the test head used for the space concerned. Doors of subdivision bulkheads are to be pressure tested to a head up to the bulkhead deck, but not less than 49 kPa either before or after the door is fitted in place.
17	Anchor hawses and chain pipes.	Hose testing. [2]	
18	Spaces in double-plated (streamlined) rudders, spaces between outer and inner plating of fixed and steering nozzles, hollow elements of foil structure.	By filling with water the pressure p, in kPa [1], (m of water head), obtained from formula: $\quad = \quad + \text{——}$ where : d = load draught, in m; $\quad\quad v$ = ships's speed, in knots. [2]	
19	Independent water, fuel and lubricating oils tanks.	By filling with water to a head up to the top of air or overflow pipes. [1] For fuel and lubricating oil tanks the head is to be at least 2,5 m from the highest point of the tank. [1]	Independent tanks are to be tested twice: before and after installation in the ships, with all piping connected.
20	Sewage tanks.	By filling with water to a head equal to 1,5 times the height from the tank bottom to the lower toilet bowl. [1]	
21	Thruster compartments, buoyancy spaces, log and echo sounder trunks.	By filling with water to a head up to the bulkhead deck. [1]	

NOTES:

I   In ships with the depth less than 5 m, the structures indicated in *3*, *6*, *7*, *8* and *9* may be tested to a head equal to 0,5 of the ship's depth, but not less than 1,5 m.

II   the tightness test methods and standard values used during repairs and special surveys of ships are to meet the requirements of this table.

III   For special surveys, the test head may be determined based on the filling of tanks:
   1. For water and fuel tanks, up to the top of the air pipes, or overflow pipes, if fitted;
   2. For cargo tanks and cofferdams of tankers, up to the top edge of expansion trunks of hatches.

When tested in dock, filling with water is permitted to the level of light waterline, and up to the top coaming when afloat.

The amount of testing during repair is to be established with regard to the type of repair work and must be approved by the Surveyor.

On agreement with *QRS Class*, tests by filling with water may be substituted by an air test with excessive pressure of 30 kPa.

For welded joints (except overlap connections) hose testing may be substituted by wetting with kerosine.

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