BUREAU VERITAS MARINE & OFFSHORE

RULE NOTE

HULL STRUCTURE AND ARRANGEMENT FOR THE CLASSIFICATION OF **CARGO SHIPS LESS THAN 65M AND NON CARGO SHIPS LESS THAN 90M**

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These rules are provided within the scope of the Bureau Veritas Marine & Offshore General Conditions, enclosed at the end of Part A of NR467, Rules for the Classification of Steel Ships. The latest version of these General Conditions is available on the Bureau Veritas Marine & Offshore website.

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CHAPTER 1
GENERAL

Section 1 General

1 Application criteria

1.1 Types of ships covered by the present Rules

1.1.1 General

The present Rules contain the requirements for the evaluation of the hull scantlings (fore, central and aft parts of the ship) and structure arrangement applicable to the following type of ships of normal form, speed and proportions and built in steel, aluminium, or composite materials:

- Cargo ships with a length L less than 65 m
- Non cargo ships with a length L less than 90 m.

Note 1: For definition of cargo ships and non cargo ships, refer to [2.1.3].

1.1.2 Hull shape

In the present Rules, the hull loadings are estimated considering the hull shape of the two following types of hull:

- Displacement hull: hull designed to be mainly supported by the pressure of water displaced by the hull
- Planing hull: hull designed to use hydrodynamic lift to rise up and glide on the surface of the water when the hull speed exceeds a critical value. Under this critical speed value, the hull behaviour is to be considered as a displacement hull.

1.1.3 Navigation notations and operating area notations

Any ships covered by the present Rules, except those having the service notation **launch** or **seagoing launch**, are to be assigned one of the following navigation notations:

- **unrestricted navigation**
- **summer zone**
- **tropical zone**
- **coastal area**
- **sheltered area**,

as defined in NR467 Steel Ships, Pt A, Ch 1, Sec 2, [5.2].

Additional specific operating area notations may be granted as specified in NR467 Steel Ships, Pt A, Ch 1, Sec 2, [5.3]. (See also [2.2.2])

1.1.4 Additional requirements applicable to specific ships

a) Ships in aluminium:

Specific additional requirements applicable to ships built in aluminium materials are defined in NR561 Aluminium Ships.

b) Ships in composite materials:

Specific additional requirements applicable to ships built in composite, plywood and/or polyethylene high density (HDPE) materials are defined in NR546 Composite Ships.

1.2 Types of ships not covered by the present Rules

1.2.1 Liquefied gas carrier

Ships having the service notation **liquefied gas carrier** are not covered by the present Rules and are to be in accordance with NR467 Steel Ships, Part B and Part D, Chapter 9.

1.2.2 Cargo ships with alternate light and heavy cargo loading conditions

For ships having the additional service feature **nonhomload** and designed for alternate light and heavy cargo loading conditions, the scantling check is to be carried out in accordance with NR467 Steel Ships, Part B instead of the present Rules.

1.2.3 High speed craft

Ships having:

- one of the service notations **HSC-CAT A**, **HSC-CAT B**, **HSC**, **light ship**, **Crew Transfer Vessel**, and
- a navigation notation corresponding to sea areas defined on the basis of sea states characterised by a significant wave height,

are not covered by the present Rules.

1.3 Particular cases

1.3.1 Hull scantling

The Society reserves its right, whenever deemed necessary, to apply the requirements defined in NR467 Steel Ships (Rules dedicated to ships greater than 65 m in length) in lieu of the present Rules (see Sec 3, [3]).

1.3.2 Subdivision, compartment arrangement, arrangement of hull openings and freeing ports

The requirements to be applied for the subdivision of the hull, the compartment arrangement and the arrangement of hull openings are defined in Ch 2, Sec 2, Tab 1.

2 General

2.1 Wording

2.1.1 Rules

In the present Rules, the references to other Rules of the Society are defined in Tab 1.

Table 1 : References to other Rules of the Society

Reference	Rules
NR467 Steel Ships	NR467 Rules for the Classification of Steel Ships
NR566	NR566 Hull Arrangement, Stability and Systems for Ships less than 500 GT
NR546 Composite Ships	NR546 Hull in Composite, Plywood and High Density Polyethylene Material
NR561 Aluminium Ships	NR561 Hull in Aluminium Alloys, Design Principles, Construction and Survey
NR216 Materials and Welding	NR216 Rules on Materials and Welding for the Classification of Marine Units

2.1.2 Interested Party

Party, other than the Society, having responsibility of the classification and/or certification of the ship, such as the Owner or his representatives, or the Shipbuilder, or the engine Builder, or the Supplier of parts to be tested

2.1.3 Ship groups: Cargo ships and non cargo ships

In the present Rules, the wording “cargo ships” and “non cargo ships” means:

- Cargo ships:

  Ships liable to carry cargoes and having a deadweight greater than 30% of the total displacement. These ships are fitted with cargo holds, tanks and lateral ballast tanks used in non loaded conditions (i.e. bulk or ore carriers, oil or chemical tankers, container ships, general cargo ships,...). As a rule, the value of the block coefficient is greater than 0,75
- Non cargo ships:
  - Type of ships other than cargo ships defined here above, or
  - Ships having a deadweight greater than 30% of the total displacement but:
    - not fitted with lateral ballast tanks used in non loaded navigation condition
    - whose arrangement provides small possibilities for variation in the distribution of cargo.

2.1.4 Multihull

In the present Rules, “multihull” means a ship with two hulls (floats) connected to a platform structure.

A multihull with more than two floats is to be considered on a case-by-case basis.

Two types of multihulls are considered in the present Rules:

- Catamaran:

  Multihull which may be of displacement hull type or planing hull type, according to its design
- Swath (Small Waterplane Area Twin Hull ship):

  Multihull with two submerged floats connected to the platform structure by narrow struts.

  As a rule, a swath is not to be considered as ship having a planing hull and is not subjected to slamming impacts on bottom.

2.1.5 Planing hull

In the present Rules, “planing hull” defines a ship having a planing hull shape and able to sail:

- in planing mode, when the actual sea state is adapted to reach planing speeds without exceeding the expected design vertical acceleration resulting from hydrodynamic lift and slamming phenomenon on bottom, and
- in displacement mode, when the actual speed and sea state do not allow to sail in planing mode without exceeding the expected design vertical acceleration.

The Designer defines whether both the ship is designed to sail in planing mode and bottom slamming impacts are expected to occur.

In this case, the design vertical acceleration at L_{CG} , to be defined by the Designer, is to correspond to the highest accelerations obtained from a relationship between the actual ship speed and the sea state conditions expected by the Designer.

Planing hulls for which $V \geq 10\ L_{WL}^{0,5}$ are individually considered by the Society, where:

V : Maximum ahead service speed, in knots

L_{WL} : Waterline length, as defined in [4.2.5].

Note 1: As a guidance, a ship may be considered as able to sail in planing hull mode when:

$V \geq 7,16\ \Delta^{1/6}$

with:

Δ : Displacement of the ship, as defined in [4.6.1].

2.2 Classification

2.2.1 General

Ships complying with the requirements of the present Rules are to comply with the requirements of NR467 Steel Ships, Part A for assignment and maintenance of Class.

2.2.2 Service notations and corresponding additional service features

The service notations define the type and/or service of the ship which have been considered for its classification, according to the request for classification signed by the Interested Party.

A service notation may be completed by one or more service features, giving further precision regarding the type of service of the ship, for which specific rule requirements are applied.

At least one service notation is to be assigned to every classed ship according to NR467 Steel Ships, Pt A, Ch 1, Sec 2, [4].

The assignment of any service notation and any additional service feature is subject to compliance with the general requirements laid down in the present Rules and especially with the additional requirements laid down in Ch 6, Sec 1, as applicable.

2.2.3 Additional class notations

An additional class notation expresses the classification of additional equipment or specific arrangement which has been requested by the Interested Party.

The different additional class notations which may be assigned to a ship are listed in NR467 Steel Ships, Pt A, Ch 1, Sec 2, [6].

The assignment of such an additional class notation is subject to the compliance with additional rule requirements, which are detailed in:

- NR467 Steel Ships, Part F, and
- Ch 5, Sec 2, [16] for the additional class notation **STRENGTHBOTTOM** and for additional class notations assigned to ships strengthened for navigation in ice infected waters

3 Navigation coefficient

3.1 Ships with a navigation notation

3.1.1 The navigation coefficient n, depending on the assigned navigation notation as defined in NR467 Steel Ships, Part A, Chapter 1, Sec 2, [5.2], is given in Tab 2.

Table 2 : Navigation coefficient n

Navigation notation	Navigation coefficient n
unrestricted navigation	1,00
summer zone	0,90
tropical zone	0,80
coastal area	0,80
sheltered area	0,65

3.2 Sea going launch and launch

3.2.1 For ships having the service notation **sea going launch** or **launch**, as defined in NR467 Steel Ships, Part A, Chapter 1, Sec 2, [4.15.2], the navigation coefficient n is as given in Tab 3.

Table 3 : Navigation coefficient n

Service notation	Navigation coefficient n
sea going launch	$0,65 + 0,008\ L_w \leq 0,80$
launch	0,65
Note 1: L_w : Length as defined in [4.2.6].	

4 Definitions

4.1 Moulded base line

4.1.1 The moulded base line is the horizontal line located at the upper face of the bottom plating or at the intersection between the upper face of the bottom plating and the solid bar keel.

For ships designed with a rake of keel, the base line is to be as defined above, at a point located at the midship section.

4.2 Lengths

4.2.1 Rule length L

The rule length L is the distance, in m, measured on the waterline at the scantling draught, from the fore side of the stem to the after side of the rudder post, or to the centre of the rudder stock where there is no rudder post.

L is to be taken not less than 96%, and need not exceed 97%, of the extreme length on the summer load waterline.

4.2.2 Ends of the rule length

The fore end (FP) of the rule length L is the perpendicular to the waterline at the scantling draught at the fore side of the stem.

The aft end (AP) of the rule length L is the perpendicular to the waterline at the scantling draught at a distance L aft of FP.

4.2.3 Midship L_{CG}

The midship L_{CG} is the perpendicular to the waterline at scantling draught at a distance 0,5 L aft of FP.

4.2.4 Hull length L_{HULL}

The hull length L_{HULL} is equal to the distance, in m, measured from the fore end of the hull to the aft end of the hull.

4.2.5 Waterline length L_{WL}

The waterline length L_{WL} is equal to the distance, in m, measured from the intersection between the waterline at the scantling draught and the fore end of the hull to the aft end of the hull.

4.2.6 Length L_w

The length L_w is to be taken equal to:

$L_w = 0,5\ (L_{WL} + L_{HULL})$

4.3 Breadth

4.3.1 Moulded breadth B

The moulded breadth B is the greatest moulded breadth, in m, measured amidships at the scantling draught.

4.3.2 Waterline breadths B_{WL} and B_{ST}

The waterline breadth B_{WL} is the breadth of the hull, in m, measured 0,5 L_{WL} at the scantling draught.

For a catamaran, the waterline breadth B_{WL} is to be measured at 0,5 L_{WL} at one float at the scantling draught.

For a swath, the waterline breadth B_{ST} is to be measured at 0,5 L_{WL} at one strut at the scantling draught.

4.3.3 Breadth B_E between multihull floats

The breadth B_E between the floats of a multihull is the distance, in m, measured between the longitudinal planes of symmetry of the floats. As a rule, the longitudinal plane of symmetry of a float is located at 0,5 B_{WL} or 0,5 B_{ST}.

4.3.4 Breadth B_{SF} of swath submerged float

The moulded breadth B_{SF} of a swath submerged float is the greatest moulded breadth of the submerged float, in m, measured at 0,5 L_{WL}.

4.4 Depth D

4.4.1 The depth D is the distance, in m, measured vertically on the midship transverse section, from the moulded base line to the top of the deck beam at side on the uppermost continuous deck.

In the case of ships with a solid bar keel, the moulded base line is to be taken at the intersection between the upper face of the bottom plating and the solid bar keel at midship L_{CG}.

4.5 Scantling draught T

4.5.1 The scantling draught T is the distance, in m, measured vertically on the midship transverse section, from the moulded base line to the waterline at which the strength requirements for the scantlings of the ships are met. It represents the full load condition and is to be not less than that corresponding the assigned freeboard.

In the case of ships with a solid bar keel, the moulded base line is to be taken as defined in [4.4.1].

4.6 Total block coefficient C_B

4.6.1 The total block coefficient C_B is to be taken equal to:

- for monohull:

$$C_B = \frac{\Delta}{1,025 L_{WL} B_{WL} T}$$

- for catamaran:

$$C_B = \frac{\Delta}{1,025 L_{WL} 2 B_{WL} T}$$

- for swath:

$$C_B = \frac{\Delta}{1,025 L_{WL} 2 B_m T}$$

with:

$$B_m = \frac{B_{SF} D_{SF} + B_{ST}(T - D_{SF})}{T}$$

where:

Δ : Moulded displacement, in tonnes, at draught T, in sea water (density ρ = 1,025 t/m^3)

L_{WL} : Waterline length, in m, as defined in [4.2.5]

B_{WL}, B_{SF}, B_{ST} :Breadths, in m, measured amidships, as defined in [4.3.2] and [4.3.4]

D_{SF} : Depth, in m, of the submerged float amidships

T : Scantling draught, as defined in [4.5.1].

4.7 Chine and bottom

4.7.1 Chine

For hulls without a clearly identified chine, the chine is the hull point where the tangent to the hull is inclined by 50° compared to the horizontal.

4.7.2 Bottom

The bottom is the part of the hull between the centre line of the hull or the float and the chines.

4.8 Lightweight

4.8.1 The lightweight is the displacement, in t, without cargo, fuel, lubricating oil, ballast water, fresh water and feed water, consumable stores and passengers and crew and their effects, but including liquids in piping.

4.9 Deadweight

4.9.1 The deadweight is the difference, in t, between the displacement, at the summer draught in sea water of density ρ = 1,025 t/m^3, and the lightweight.

4.10 Freeboard deck

4.10.1 The freeboard deck is defined in Regulation 3 of the 1966 International Convention on Load Lines, as amended.

4.11 Bulkhead deck

4.11.1 Designation

a) Passenger ship:

The bulkhead deck in a passenger ship means the uppermost deck at any point in the subdivision length L_S to which the main bulkheads and the ship shell are carried watertight. In a cargo ship, the freeboard deck may be taken as the bulkhead deck.

b) Cargo ship:

The bulkhead deck in a cargo ship may be taken as the freeboard deck.

Note 1: The subdivision L_S of a ship is the greatest projected moulded length of that part of the ship at or below deck or decks limiting the vertical extent of flooding with the ship at the deepest subdivision draught.

4.12 Superstructure

4.12.1 General

A superstructure is a decked structure connected to the freeboard deck, extending from side to side of the ship or with the side plating not being inboard of the shell plating more than 0,04 B.

4.12.2 Superstructure deck

A superstructure deck is a deck forming the upper boundary of a superstructure.

4.12.3 Deckhouse

A deckhouse is a decked structure other than a superstructure, located on the freeboard deck or above.

4.12.4 Standard height of superstructure h_S

The standard height of superstructure h_S is defined in Tab 4.

Table 4 : Standard height of superstructure h_S

Load line length L_{LL} , in m	Standard height h_S, in m	
	Raised quarterdeck	All other superstructures
$L_{LL} \le 30$	0,90	1,80
$30 < L_{LL} < 75$	$0{,}9 + 0{,}00667 (L_{LL} - 30)$	1,80
$75 \le L_{LL} < 90$	$1{,}2 + 0{,}012 (L_{LL} - 75)$	$1{,}8 + 0{,}01 (L_{LL} - 75)$

4.12.5 Tiers of superstructures and deckhouses

The lowest tier is the tier located immediately above the freeboard deck.

The second tier is the tier located immediately above the lowest tier, and so on.

4.13 Multihull platform

4.13.1 A multihull platform is a strength structure connecting the hulls by primary transverse cross structure elements. These transverse elements may be cross beams or cross bulkheads.

The part of the platform directly exposed to sea effect is designed as platform bottom.

The upper part of the platform together with the upper decks are defined as platform deck.

5 Reference co-ordinate system

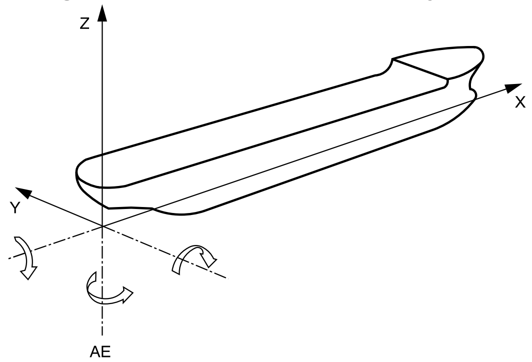
5.1 General

5.1.1 The ship's geometry, motions, accelerations and loads are defined with respect to the following right-hand co-ordinate system (see Fig 1):

- Origin: at the intersection between the longitudinal plane of symmetry of ship, the aft end of L and the baseline
- X axis: longitudinal axis, positive forwards
- Y axis: transverse axis, positive towards portside
- Z axis: vertical axis, positive upwards.

5.1.2 Positive rotations are oriented in anti-clockwise direction about the X, Y and Z axes.

Figure 1 : Reference co-ordinate system



6 Stability

6.1 General

6.1.1 For information, intact stability and damage stability are to comply with the following Rules:

- For non-propelled ships and ships of less than 500 GT:
  - **passenger ship** with unrestricted navigation: NR467 Steel Ships
  - **ro-ro passenger ship** with unrestricted navigation: NR467 Steel Ships
  - **chemical tanker**: NR467 Steel Ships
  - **fishing vessel**: NR467 Steel Ships
  - ships with other service notations: NR566
- For ships of 500 GT and over:
  NR467 Steel Ships.

7 Documentation to be submitted

7.1 Documentation to be submitted

7.1.1 Plans and documents to be submitted for approval

The plans and documents to be submitted to the Society for approval are listed in Tab 5.

Structural plans are to show details of connections of the various parts and to specify the materials used, including their manufacturing processes (see also Chapter 7).

7.1.2 Plans and documents to be submitted for information

In addition to those in [7.1.1], the following plans and documents are to be submitted to the Society, for information:

- general arrangement
- capacity plan indicating, for all the compartments and tanks, their volume and the position of their centre of gravity
- lightweight distribution.

Moreover, when direct calculation analyses are carried out by the Designer according to the rule requirements, they are to be submitted to the Society.

Table 5 : Documentation to be submitted for approval for all ships

Plan or document	Containing also information on
Midship section Transverse sections Shell expansion Decks and profiles Double bottom Pillar arrangements Framing plan Deep tank and ballast tank bulkheads, wash bulkheads	Class characteristics Main dimensions Minimum ballast draught Frame spacing Maximum ahead service speed Density of cargoes Design loads on decks and double bottom Steel grades Location and height of air vent outlets of various compartments Corrosion protection Openings in decks and shell and relevant compensations Boundaries of flat areas in bottom and sides Details of structural reinforcements and/or discontinuities Bilge keel with details of connections to hull structures

Plan or document	Containing also information on
Watertight subdivision bulkheads Watertight tunnels	Openings and their closing appliances, if any
Fore part structure	Location and height of air vent outlets of various compartments
Transverse thruster, if any, general arrangement, tunnel structure, connections of thruster with tunnel and hull structures	
Aft part structure	Location and height of air vent outlets of various compartments
Machinery space structures Foundations of propulsion machinery and boilers	Type, power and r.p.m. of propulsion machinery Mass and centre of gravity of machinery and boilers
Superstructures and deckhouses Machinery space casing	Extension and mechanical properties of the aluminium alloy used (where applicable)
Bow doors, stern doors and inner doors, if any, side doors and other openings in the side shell	Closing appliances Electrical diagrams of power control and position indication circuits for bow doors, stern doors, side doors, inner doors, television system and alarm systems for ingress of water
Hatch covers, if any	Design loads on hatch covers Sealing and securing arrangements, type and position of locking bolts Distance of hatch covers from the summer load waterline and from the fore end
Movable decks and ramps, if any	
Windows and side scuttles, arrangements and details	
Bulwarks and freeing ports	Arrangement and dimensions of bulwarks and freeing ports on the freeboard deck and superstructure deck
Helicopter decks, if any	General arrangement Main structure Characteristics of helicopters: maximum mass, distance between landing gears or landing skids, print area of wheels or skids, distribution of landing gear loads
Rudder and rudder horn **(1)**	Maximum ahead service speed
Stern frame or sternpost, stern tube **(1)** Propeller shaft boss and brackets	
Derricks and cargo gear Cargo lift structures	Design loads (forces and moments) Connections to the hull structures
Sea chests, stabiliser recesses, etc.	
Hawse pipes	
Plan of outer doors and hatchways	
Plan of manholes	
Plan of access to and escape from spaces	
Plan of tank testing	Testing procedures for the various compartments Height of pipes for testing
Plan of watertight doors and scheme of relevant manoeuvring devices	Manoeuvring devices Electrical diagrams of power control and position indication circuits
Equipment calculation	Geometrical elements for calculation List of equipment Construction and breaking load of steel wires Material, construction, breaking load and relevant elongation of synthetic ropes

(1) Where other steering or propulsion systems are adopted (e.g. steering nozzles or azimuth propulsion systems), the plans showing the relevant arrangement and structural scantlings are to be submitted.

Section 2 Materials

1 General

1.1 Application

1.1.1 This Section defines the main characteristics to take into account for steels, aluminium alloys or composite materials within the scope of the evaluation of the hull scantling as defined in the present Rules.

1.1.2 Materials and products such as parts made of iron castings, where allowed, products made of copper and copper alloys, rivets, anchors, chain cables, cranes, masts, derrick posts, derricks, accessories and wire ropes are to comply with the applicable requirements of NR216 Materials and Welding.

1.1.3 Materials with different characteristics may be considered, provided their specification (manufacture, chemical composition, mechanical properties, welding,...) is submitted to the Society for approval.

2 Steels for hull structure

2.1 General

2.1.1 Characteristics of materials

The characteristics of steels to be used in the construction of ships are to comply with the applicable requirements of NR216 Materials and Welding.

2.1.2 Testing and manufacturing process

Materials are to be tested in compliance with the applicable requirements of NR216 Materials and Welding.

The requirements of this Section presume that welding and other cold or hot manufacturing processes (parent material types and welding, preheating, heat treatment after welding,...) are carried out in compliance with current sound working practices and the applicable requirements of NR216 Materials and Welding.

2.1.3 Steel material grades and mechanical properties

Normal strength steels having a minimum yield strength R_{eH}=235 N/mm^2 are divided into four grades A, B, D and E. The letters A, B, D and E mean impact properties at +20°C, 0°C, −20°C and −40°C, respectively.

Higher strength steels are divided into four grades identified by the letters AH, DH, EH and FH followed by a number related to the yield strength level. The letters AH, DH, EH and FH mean impact properties at 0°C, −20°C, −40°C and −60°C, respectively.

Tab 1 gives the mechanical properties of steels commonly used in the construction of ships.

Higher strength steels other than those indicated in Tab 1 are considered by the Society, on a case-by-case basis.

When steels with a minimum specified yield stress R_{eH} other than 235 N/mm^2 are used for a ship, the hull scantlings are to be determined considering the material factor k defined in [2.1.4].

Table 1 : Mechanical properties of hull steels

Steel grades t ≤ 100 mm	Minimum yield stress R_{eH} , in N/mm^2	Ultimate minimum tensile strength R_m , in N/mm^2
A-B-D-E	235	400 - 520
AH32-DH32- EH32-FH32	315	440 - 590
AH36-DH36- EH36-FH36	355	490 - 620
AH40-DH40- EH40-FH40	390	510 - 650
Note 1: Refer to NR216 Materials and Welding, Ch 3, Sec 2, [1.8].		

2.1.4 Material factor k for scantling

To take into account the steel materials, a material factor k is used in the scantling formulae, as a function of the minimum specified yield stress R_{eH}.

As a rule, the scantling of the structure elements is based on a steel material having a minimum yield stress R_{eH} equal to 235 N/mm², corresponding to k = 1.

Unless otherwise specified, the values of material factor k are defined in Tab 2.

For intermediate values of R_{eH} , k may be obtained by linear interpolation.

Steels having a yield stress higher than 390 N/mm² are considered by the Society on a case-by-case basis.

For steel having a yield stress lower than 235 N/mm², the material factor may be taken equal to $235/R_{eH}$, where R_{eH} is the minimum yield stress, in N/mm², of the considered material.

Table 2 : Material factor k

R_{eH} , in N/mm²	k
235	1,00
315	0,78
355	0,72
390	0,68

2.1.5 Minimum yield stress for scantling criteria of hull structure

The minimum yield stress of steel R_y , in N/mm², used for the scantling criteria of the hull structure is to be taken, unless otherwise specified, equal to:

$R_y = 235 / k$

where:

k : Material factor defined in [2.1.4].

2.1.6 Steel grades

Materials in the various strength members are not to be of lower grade than those corresponding to the following material classes and grades:

a) General requirements:

As defined in NR467 Steel Ships, Part B, Ch 4, Sec 1, Tab 3 and Tab 9.

For ships less than 65 m in length, the material class and grade defined for the outside 0,4L amidships area in Table 3 is to be considered along the full length of the ship.

Note 1: Steel having a specified minimum yield stress equal to 235 N/mm² is denoted ‘NSS’. Steel having a higher specified minimum yield stress is denoted ‘HSS’.

b) Ships with ice strengthening:

As defined in NR467 Steel Ships, Part B, Ch 4, Sec 1, Tab 8, for plates of ice strengthening area.

c) Ships structures exposed to low air temperature:

As defined in NR467 Steel Ships, Part B, Ch 4, Sec 1, [2.4] and in Tables 10 to 13.

For ships less than 65 m in length, the material class and grade defined for the outside 0,4L amidships area in Table 10 is to be considered along the full length of the ship.

d) Structure within or adjacent to refrigerated spaces:

As defined in NR467 Steel Ships, Part B, Ch 4, Sec 1, [2.5].

e) Single-side of bulk carriers, ore carrier and combination carrier:

As defined in NR467 Steel Ships, Part B, Ch 4, Sec 1, Tab 7 for lower bracket of ordinary side frame and side shell strakes.

2.1.7 Through thickness properties

Where normal tensile loads induce out-of-plane stress greater than 0,5 R_y in steel plates:

- for plates with $t < 15$ mm, ultrasonic testing is to be performed
- for plates with $t \geq 15$ mm, Z-quality steel is to be used or ultrasonic testing is to be performed,

in order to prevent laminar tearing.

The ultrasonic testing is to be performed, before and after welding, on the area of the plate located within 50 mm or t, whichever is the greater, around the weld, in accordance with NR216 Materials and Welding, Ch 3, Sec 11.

3 Aluminium alloys for hull structure

3.1 Characteristics and testing

3.1.1 The characteristics of aluminium alloys to be used in the construction and their testing and manufacturing process are to comply with the applicable requirements of the following Rules:

- NR216 Materials and Welding
- NR561 Aluminium Ships.

Aluminium alloys with different characteristics may be accepted, provided their specification (manufacture, chemical composition, mechanical properties, welding,...) is submitted to the Society for approval.

3.1.2 Minimum yield stress for scantling criteria of hull structure

The minimum yield stress of aluminium R_y, in N/mm², used for the scantling criteria of the hull structure is to be taken, unless otherwise specified, equal to:

$R_y = R'_{lim}$

where:

R'_{lim} : Minimum yield stress of the aluminium alloys considered, to be taken equal to the minimum value, in welded condition, between $R'_{p0,2}$ (proof stress) and 0,7 R'_m (tensile strength), where $R'_{p0,2}$ and R'_m are defined in NR561 Aluminium Ships.

3.1.3 Material factor k for scantling

To take into account the minimum yield stress of the aluminium alloy in welded condition, the material factor k used in the scantling formulae is to be taken equal to:

$k = 100 / R'_{lim}$

4 Composite, plywood and HDPE material for hull structure

4.1 Characteristics and testing

4.1.1 The characteristics of the composite, plywood and HDPE material and their testing and manufacturing process are to comply with the applicable requirements of NR546 Composite Ships, in particular for the:

- raw materials
- laminating process
- mechanical tests and raw material homologation.

4.2 Application

4.2.1 Attention is drawn to the use of composite, plywood and HDPE materials from the point of view of structural fire protection.

The Flag Administration may request that international convention be applied instead of the present requirements, which may entail in some cases a limitation in the use of these materials.

Section 3 Scantling Principles

Symbols

L_{WL} : Waterline length, in m, as defined in Sec 1, [4.2.5].

1 General principles

1.1 General

1.1.1 Design life

The design life is the period during which the ship is assumed to be exposed to operating conditions.

1.1.2 Strength assessments

Strength assessments refer to the assessments aiming at covering strength checks in seagoing, harbour and flooded conditions.

1.1.3 Wave environment

Unless otherwise specified, the rule requirements are based on north Atlantic wave environment for the strength assessments.

1.1.4 Probability levels for strength assessments in sea-going conditions

The strength assessment in sea-going conditions are based on loads corresponding to the probability level of 10^{-5} over 25 years design life.

1.1.5 Design temperatures

The structural assessment of hull strength members is assumed to be valid for the following design temperatures:

- lowest mean daily average temperature in air: −10°C
- lowest mean daily average temperature in seawater: 0°C.

Ships intended to operate in areas with lower mean daily average temperature, e.g. regular service during winter seasons to Arctic or Antarctic waters, are subject to specific requirements.

In the present requirement, the following definitions apply:

- daily average: Average during one day and one night
- mean: Statistical mean over an observation period (at least 20 years)
- lowest: The lowest value during one year.

For seasonally restricted service, the lowest value within the period of operation applies.

2 Main scantling principles

2.1 General

2.1.1 The present Section defines the main scantling principles considered in the present Rules.

2.2 Type of ships

2.2.1 General

The motions and accelerations of a ship are calculated in relation to its group defined in Sec 1, [2.1.3] (cargo ship or non cargo ship).

Their longitudinal distribution along the ship length is split into four different areas, as follows (see Fig 1):

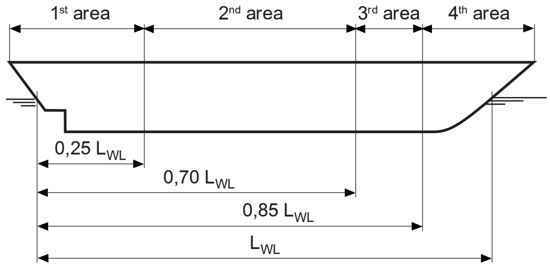
- first area: from the aft part to 0,25 L_{WL}
- second area: from 0,25 L_{WL} to 0,70 L_{WL}
- third area: from 0,70 L_{WL} to 0,85 L_{WL}
- fourth area: from 0,85 L_{WL} to the fore part.

The motions and accelerations of each area are calculated in the middle of the area and considered as a constant along the area.

As a rule, the ship motions and accelerations are calculated:

- for monohull: in head sea condition
- for multihull: in head sea and quartering sea conditions

Figure 1 : Definition of the longitudinal areas



2.2.2 Specific case of planing hull

The structure of a planing hull is to be examined, resulting from its two navigation modes, both:

- as cargo ship or non cargo ship, as applicable, when the ship sails in displacement mode (when the actual sea state does not allow to sail in planing mode with an actual vertical acceleration compatible with the vertical acceleration taken into account for the ship structure design), and
- as planing hull, when the ship sails in planing mode (when the actual vertical acceleration induced by the actual sea state and speed to reach planing mode is compatible with the vertical acceleration taken into account for the ship structure design).

The global and local loads, and the permissible stresses considered to check the structure are specific to each case of navigation modes.

2.3 Corrosion addition

2.3.1 Ships in steel or aluminium alloys

As a rule, the scantlings obtained by applying the criteria specified in the present Rules for steel and aluminium structures are gross scantling, i.e. they include additions for corrosion.

2.3.2 Ships in composite materials

The scantlings obtained by applying the criteria specified in the present Rules for composite structures include a rule partial safety factor C_V which takes into account the ageing effect on the laminate mechanical characteristics.

2.4 Rounding off

2.4.1 The rounding off of plate thicknesses on metallic hulls is to be obtained from the following procedure:

a) the thickness is calculated in accordance with the rule requirements

b) the rounded thickness is taken equal to the value rounded off to the nearest half-millimetre.

Stiffener section moduli as calculated in accordance with the rule requirements are to be rounded off to the nearest standard value. However, no reduction may exceed 3%.

3 Hull analysis approach

3.1 Global hull girder strength and local strength

3.1.1 General

As a rule, the global hull girder strength and the local strength are examined independently in the present Rules, as follows:

- the longitudinal scantling of the hull girder and the transverse scantling of the platform of catamaran are examined on the basis of a maximum permissible stress and a buckling check of the elements contributing to the global strength in the cases listed in Ch 4, Sec 2, [1.1.3]
- the local scantling is examined on the basis of the local permissible stresses defined in relation to the type of local loads applied and the type of structure elements.

3.1.2 Particular case

a) Ship in steel and aluminium alloys:

When the global stress, in N/mm^2, calculated according to Ch 4, Sec 2 (excluding the cases of additional specific wave hull girder loads defined in Ch 3, Sec 2, [6]) is greater than 0,35 R_y, the global and local stresses are to be combined to check the scantlings of the structure elements contributing to the hull girder strength according to Ch 4, App 2.

Where:

R_y : As defined in Sec 2, [2.1.5] for steel structure and in Sec 2, [3.1.2] for aluminium structure.

Note 1: At the request of the Interested Party, NR467 Steel Ships, Part B, Chapter 7 may be fully applied.

b) Ship in composite materials:

When deemed necessary by the Society, the analysis of the composite structure, taking into account the global hull girder loads and the local loads, is to be carried out as defined in NR546 Composite Ships, according to the safety factors defined in Ch 2, Sec 3, [3.2].

CHAPTER 2
STRUCTURE DESIGN PRINCIPLES, GENERAL ARRANGEMENT AND SCANTLING CRITERIA

Section 1 Structure Design Principles

1 General

1.1 Application

1.1.1 Steel structure

The requirements of the present Section apply to longitudinally or transversely framed structure arrangement of hulls built in steel materials for:

- structural continuity of hull
- single and double bottoms
- sides and decks
- transverse and longitudinal structures
- superstructures and deckhouses
- special features.

Any other arrangement may be considered, on a case-by-case basis.

1.1.2 Aluminium structure

Equivalent arrangement for hulls built in aluminium alloys is defined in NR561 Aluminium Ships.

1.1.3 Composite, plywood and HDPE structure

Equivalent arrangement for hulls built in composite, plywood and HDPE material is defined in NR546 Composite Ships.

1.1.4 Additional specific structure design principles in relation to the service notation or service feature

Additional specific structure design principles in relation to the service notation or feature assigned to of the ship are to be taken into account as defined in Ch 6, Sec 1.

2 Structural continuity of hull girder

2.1 General principles for longitudinal hull girder

2.1.1 Attention is to be paid to the structural continuity:

- in way of changes in the framing system
- at the connections of primary supporting members and secondary stiffeners.

2.1.2 The longitudinal members contributing to the hull girder longitudinal strength are to extend continuously over a sufficient distance towards the ends of the ship.

The secondary stiffeners contributing to the hull girder longitudinal strength are generally to be continuous when crossing primary supporting members. Otherwise, the detail of connections is considered by the Society on a case-by-case basis.

2.1.3 Where stress concentrations may occur in way of structural discontinuity, adequate compensation and reinforcements are to be provided.

2.1.4 Openings are to be avoided, as far as practicable, in way of highly stressed areas.

Where necessary, the shape of openings is to be specially designed to reduce the stress concentration factors.

Generally, the radius of opening corners is to be not less than 50 mm. In way of highly stressed areas, the radius is to be taken as the greater of 50 mm and 8% of the opening width.

2.1.5 Primary supporting members are to be arranged in such a way that they ensure adequate continuity of strength. Abrupt changes in height or in cross-section are to be avoided.

2.2 General principles for multihull platform

2.2.1 Attention is to be paid to the structural continuity of the primary transverse cross structure of the platform ensuring the global transverse resistance of the multihull.

The primary transverse cross structure of catamaran is generally to be continuous when crossing float structures.

The connection between the transverse cross structures of swath and struts is to be examined by direct calculation.

The general continuity principles defined in [2.1] apply also to the primary transverse cross structure of the platform.

2.3 Insert plates and doublers

2.3.1 A local increase in plating thickness is generally to be achieved through insert plates. Local doublers, normally allowed only for temporary repair, may however be accepted by the Society on a case-by-case basis.

In any case, doublers and insert plates are to be made of materials of a quality at least equal to the quality of the plates on which they are welded.

2.3.2 Doublers having a width, in mm, greater than:

- 20 times their thickness, for thicknesses equal to or less than 15 mm
- 25 times their thickness, for thicknesses greater than 15 mm

are to be fitted with slot welds, to be effected according to Chapter 7.

2.3.3 When doublers fitted on the outer shell and strength deck within 0,6 L amidships are accepted by the Society, their width and thickness are to be such that slot welds are not necessary according to the requirements in [2.3.2]. Outside this area, the possibility of fitting doublers requiring slot welds will be considered by the Society on a case-by-case basis.

2.4 Connection between steel and aluminium

2.4.1 Any direct contact between steel and aluminium alloy is to be avoided.

Heterogeneous jointing system is considered by the Society on a case-by-case basis.

The use of transition joints made of aluminium/steel-clad plates or profiles is to be in accordance with NR216 Materials and Welding.

3 Local reinforcement

3.1 General principles

3.1.1 Where stress concentration may occur in way of structural discontinuities, adequate compensation and reinforcement are to be provided.

3.1.2 Reinforcements at knuckles

Knuckles are in general to be stiffened to achieve out-of-plane stiffness by fitting ordinary stiffeners or equivalent means in line with the knuckle. Arrangements without stiffener may be accepted on a case-by-case basis depending on the knuckle angle and stress level.

4 Bottom structure arrangement

4.1 General arrangement

4.1.1 The bottom structure is to be checked by the Designer to make sure that it withstands the loads resulting from the dry-docking of the ship or the lifting by crane, when applicable. This check under such loading cases is not within the scope of classification.

4.1.2 Provision is to be made for the free passage of water from all the areas of the bottom to the suctions, by means of scallops in floors and bottom girders.

4.1.3 Additional girders and floors may be fitted in the engine room to ensure adequate rigidity of the structure, according to the recommendations of the engine supplier.

4.1.4 If fitted, solid ballast is to be securely positioned. If necessary, intermediate girders and floors may be required. The builder is to check that the solid ballast material is compatible with the hull material.

4.1.5 Where face plates of floors and girders are at the same level, the face plate of the stiffer member is generally to be continuous. Butt welds of the face plates are to provide strength continuity.

4.1.6 As a rule, bottom girders are to be fitted in way of each line of pillars. If it is not the case, local longitudinal members are to be provided.

4.2 Longitudinal framing arrangement of single bottom

4.2.1 As a general rule, hull with a longitudinally framed single bottom is to be fitted with a continuous or an intercostal centre girder welded to the floors.

4.2.2 Where side girders are fitted locally in lieu of the centre girder, they are to be extended over a sufficient distance beyond the ends of the centre girder and an additional stiffening of the bottom in the centreline area may be required.

4.2.3 Centre and side bottom girders are to be extended as far as possible towards the ends of the hull.

4.2.4 Cut-outs fitted in the web of floors for the crossing of bottom longitudinals are to be taken into account for shear analysis of the floors.

4.3 Transverse framing arrangement of single bottom

4.3.1 In general, the height, in m, of the floors at the centreline should not be less than B/16. In the case of ships with considerable rise of floors, this height may be required to be increased so as to ensure a satisfactory connection to the frames.

4.3.2 The ends of the floors at side are to be aligned with the side transverse members.

It may be accepted, on a case-by-case basis, that the floor ends at side be welded on a primary longitudinal member of the side shell or of the bottom.

4.3.3 Openings and cut-outs in the web of bottom girders for the crossing of floors are to be taken into account for shear analysis of the floors.

4.4 Double bottom arrangement

4.4.1 Double bottom height

As a general rule, the double bottom height is to be:

- sufficient to ensure access to any part of the bottom, and
- not less than 0,76 m in way of the centre girder.

4.4.2 Where the height of the double bottom varies, the variation is generally to be made gradually and over an adequate length.

The knuckles of inner bottom plating are to be located in way of floors.

Where this arrangement is not possible, suitable longitudinal structures such as partial girders, longitudinal brackets etc., fitted across the knuckle, are to be fitted.

4.4.3 Adequate continuity is to be provided between double bottom area and single bottom area.

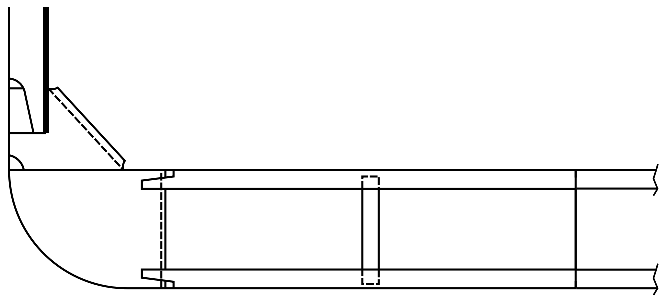
4.4.4 Floors are to be fitted:

- watertight in way of the transverse watertight bulkheads
- reinforced in way of the double bottom steps.

4.4.5 Watertight floors are to be fitted with stiffeners having a section modulus not less than that required for tank bulkhead vertical stiffeners.

4.4.6 In case of open floors consisting of a frame connected to the bottom plating and a reverse frame connected to the inner bottom plating, the construction principle is to be as shown in Fig 1.

Figure 1 : Open floor



4.4.7 Double bottom compartment

Arrangement of the double bottom compartments is to be in accordance with Sec 2, [4].

4.4.8 Duct keel

Where a duct keel is arranged, the strength continuity of the structure of the floors is to be ensured.

4.4.9 Bilge wells

Bilge wells arranged in the double bottom are to be formed by steel plates having a thickness not less than the greater of that required for watertight floors and that required for the inner bottom.

4.5 Inner bottom of cargo holds intended to carry dry cargo

4.5.1 The inner bottom thickness calculated as defined in Ch 4, Sec 3, [2] is to be increased by 2 mm unless it is protected by a continuous wooden ceiling.

4.6 Arrangement, scantlings and connections of bilge keels

4.6.1 Arrangement

Bilge keels may not be welded directly on the shell plating. An intermediate flat, or a doubler, is required on the shell plating.

The thickness of the intermediate flat is to be equal to the thickness of the bilge strake.

The ends of the bilge keels are to be sniped at an angle of 15° or rounded with a large radius. They are to be located in way of a bilge transverse stiffener. The ends of the intermediate flat are to be sniped at an angle of 15°.

The arrangement shown in Fig 2 is recommended.

The arrangement shown in Fig 3 may also be accepted.

4.6.2 Materials

The bilge keel and the intermediate flat are to be made of steel having the same yield stress and grade as the steel of the bilge strake.

4.6.3 Welding

Welding of the bilge keel with the intermediate flat is to be in accordance with Ch 7, Sec 2.

Figure 2 : Recommended bilge keel arrangement

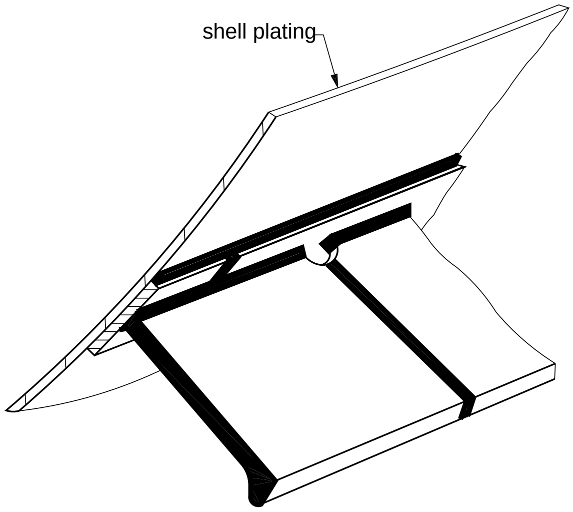
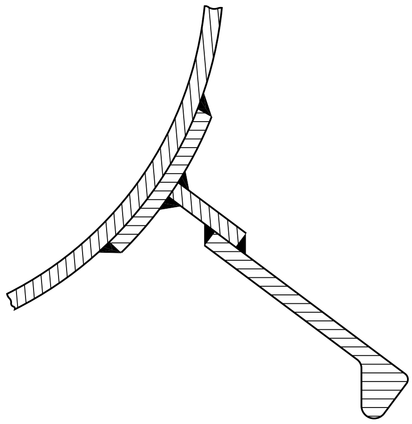


Figure 3 : Accepted bilge keel arrangement



5 Side structure arrangement

5.1 General

5.1.1 In a transverse framing system, the side structure is made of secondary transverse frames, possibly supported by horizontal stringers.

5.1.2 In a longitudinal framing system, the side structure is made of secondary longitudinal stiffeners supported by vertical primary supporting members.

5.1.3 Where the connection between side shell and deck plate is rounded, the radius, in mm, is to be not less than 15 t_S, where t_S is the thickness, in mm, of the sheerstrake.

5.2 Stiffener arrangement

5.2.1 In general, the section modulus of 'tweendeck frames is to be not less than that required for the frames located immediately above.

5.2.2 Transverse web frames and secondary side frames are to be attached to floors and deck beams by brackets or any other equivalent structure (see Ch 4, Sec 6).

5.2.3 For transverse framing system, the attention of the Designer is drawn on the risk of buckling of the side shell plate panels in way of the frame ends. Extra-thickness or additional intercostal stiffeners may be requested in these areas on the side shell.

5.3 Openings in the side shell plating

5.3.1 Openings in the side shell are to be well rounded at the corners and located, as far as practicable, well clear of the superstructure ends.

5.3.2 Large size openings are to be adequately compensated by means of insert plates of increased thickness. Such compensation is to be partial or total, depending on the stresses occurring in the area of the openings.

5.3.3 Secondary stiffeners cut in way of openings are to be attached to local structural members supported by the continuous adjacent secondary stiffeners, or any other equivalent arrangement.

5.3.4 The sea chest thickness is generally to be equal to the thickness of the local shell plating.

5.3.5 Openings for stabilizer fins are considered by the Society on a case-by-case basis.

6 Deck structure arrangement

6.1 General

6.1.1 Adequate continuity of decks (plates and stiffeners) is to be ensured in way of:

- stepped or knuckled strength decks
- changes in the framing system
- large openings.

6.1.2 Deck supporting structures under cranes and windlass are to be adequately stiffened.

6.1.3 Pillars or other supporting structures are generally to be fitted under heavy concentrated loads on decks.

6.1.4 Stiffeners are also to be fitted in way of the ends and corners of deckhouses and partial superstructures.

6.1.5 Beams fitted at sides of a deck hatch are to be effectively supported by at least two deck girders located at each side of the deck opening.

6.2 Opening arrangement

6.2.1 The deck openings are to be as much spaced apart as possible.

As practicable, they are to be located as far as possible from the highly stressed deck areas or from the stepped deck areas.

6.2.2 Extra thickness or additional reinforcements may be requested where deck openings are located:

- close to the primary transverse cross structure of the multihull platform
- in areas of deck structural singularity (cockpit, stepped deck,...)
- in way of the fixing of out-fittings.

6.2.3 As a rule, all the deck openings are to be fitted with radiused corners. Generally, the corner radius is not to be less than:

- 5% of the hatch width, where a continuous longitudinal deck girder is fitted below the hatch coaming
- 8% of the hatch width, where no continuous longitudinal deck girder is fitted below the hatch coaming.

6.2.4 Corner radiusing, in the case of two or more openings athwart ship in one single transverse section, is considered by the Society on a case-by-case basis.

6.3 Hatch supporting structures

6.3.1 Hatch side girders and hatch end beams of reinforced scantling are to be fitted in way of cargo hold openings.

In general, hatch end beams and deck transverses are to be in line with bottom and side transverse structures, so as to form a reinforced ring.

Adequate continuity of strength of longitudinal hatch coamings is to be ensured.

The details of connection of deck transverses with longitudinal girders and web frames are to be submitted to the Society for approval.

6.4 Pillar arrangement under deck

6.4.1 Pillars are to be connected to the bottom at the intersection of girders and floors and to any deck at the intersection of deck beams and deck girders.

Where it is not the case, an appropriate local structure is to be fitted to support the pillars.

6.4.2 Pillars are to be attached at their heads and heels by continuous welding.

Heads and heels of pillars are to be attached to the surrounding structure by means of brackets, insert plates or doubling plates so that the loads are well distributed.

In general, the thickness of the insert plates or doubling plates is to be not less than 1,5 times the thickness of the pillar.

6.4.3 If tensile stress is expected in the pillar, an insert plate is to be fitted in place of a doubling plate and head and heel brackets or equivalent arrangement are to be provided.

6.4.4 In tanks and in spaces intended for products able to procure explosive gases, solid or open section pillars are to be fitted.

6.4.5 Manholes may not be cut in the web of primary supporting structures in way of the heads and heels of pillars.

6.4.6 Tight or non-tight bulkheads may be considered as pillars, provided their scantlings comply with Ch 4, Sec 7.

6.4.7 The pillar scantlings are to comply with the requirements of Ch 4, Sec 7.

6.5 Deck structure in way of launching appliances used for survival craft or rescue boats

6.5.1 Attention is drawn on any possible specific requirements that could be issued by a Flag Administration with respect to local structure reinforcements in way of launching appliances used for survival craft or rescue boats.

6.6 Deck reinforcements in way of superstructures

6.6.1 Stiffeners are to be fitted in way of the ends and corners of deck houses and partial superstructures.

7 Bulkhead structure arrangement

7.1 General

7.1.1 Plane bulkheads may be horizontally or vertically stiffened.

Stiffening of horizontally framed bulkheads consists of horizontal secondary stiffeners supported by vertical primary supporting members.

Stiffening of vertically framed bulkheads consists of vertical secondary stiffeners which may be supported by horizontal stringers.

The structural continuity of the vertical and horizontal primary supporting members with the surrounding supporting hull structures is to be carefully ensured.

7.1.2 As a general rule, the transverse bulkheads are to be stiffened, in way of bottom and deck girders, by vertical stiffeners in line with these girders or by any equivalent system.

Where a deck girder is not continuous, the bulkhead vertical stiffener supporting the end of the deck girder is to be strong enough to sustain the bending moment transmitted by the deck girder.

7.2 Watertight bulkheads

7.2.1 Crossing, through watertight transverse bulkheads, of bottom, side shell or deck longitudinal stiffeners is to be closed by watertight collar plates.

7.2.2 The stiffener ends of watertight bulkheads are to be aligned with the hull structure members and are to be fitted with end brackets.

Where this arrangement is made impossible due to hull lines, any other solution may be accepted, provided embedding of the bulkhead secondary stiffeners is satisfactorily achieved.

7.2.3 The secondary stiffeners of watertight bulkheads in 'tweendecks may be snipped at ends, provided their scantling is increased accordingly.

7.2.4 Watertight doors

The thickness of watertight doors is to be not less than the thickness of the adjacent bulkhead plating, taking into account the actual spacing of the stiffeners.

Where bulkhead stiffeners are cut in way of a watertight door, reinforced stiffeners are to be fitted and suitably overlapped; cross-bars are to be provided to support the interrupted stiffeners.

7.3 Non-tight bulkheads

7.3.1 As a rule, non-tight bulkheads not acting as pillars are to be provided with vertical stiffeners having a maximum spacing equal to:

- 0,9 m, for transverse bulkheads
- two frame spacings, without exceeding 1,5 m, for longitudinal bulkheads.

7.3.2 Wash bulkheads

As a rule, the total area of the openings in wash bulkheads fitted in tanks is to be between 10% and 30% of the total area of the wash bulkhead.

7.4 Corrugated bulkheads

7.4.1 General

The main dimensions a, b, c, d and t of the corrugated bulkheads are defined in Fig 4.

Unless otherwise specified, the following requirement is to be complied with:

$a \leq 1,2\ d$

Moreover, in some cases, the Society may prescribe an upper limit for the ratio b / t.

In general, the bending internal radius R_i , in mm, is to be not less than:

- for normal strength steel:

  $R_i = 2,5\ t$

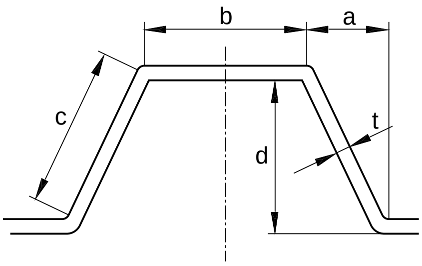
- for high tensile steel:

  $R_i = 3,0\ t$

When welds, in a direction parallel to the bend axis, are provided in the zone of the bend, the welding procedures are to be submitted to the Society for approval, as a function of the importance of the structural element.

In general, where girders or vertical primary supporting members are fitted on corrugated bulkheads, they are to be arranged symmetrically.

Figure 4 : Corrugated bulkhead



7.4.2 Structural arrangement

Strength continuity of the corrugated bulkheads is to be ensured at the ends of the corrugations.

Where corrugated bulkheads are cut in way of primary supporting members, attention is to be paid to ensure correct alignment of the corrugations on each side of the primary supporting members.

The connection of the corrugated bulkheads with the deck and the bottom is to be carefully designed and specially considered by the Society.

In general, where vertically corrugated bulkheads are welded on the inner bottom:

- plate floors are to be fitted in way of the flanges of corrugations in the case of transverse bulkheads, and
- girders are to be fitted in way of the flanges of corrugations in the case of longitudinal bulkheads.

However, other arrangements ensuring adequate structural continuity may be accepted by the Society.

In general, the upper and lower parts of horizontally corrugated bulkheads are to be flat over a depth equal to 0,1 D.

Where stools are fitted at the lower part of transverse bulkheads, the thickness of the adjacent plate floors is to be not less than that of the stool plating.

7.4.3 Bulkhead stool

In general, plate diaphragms or web frames are to be fitted in bottom stools in way of the double bottom longitudinal girders or plate floors, as the case may be.

Brackets or deep webs are to be fitted to connect the upper stool to the deck transverses or hatch end beams, as the case may be.

The continuity of the corrugated bulkhead with the stool plating is to be adequately ensured. In particular, the upper strake of the lower stool is to be of the same thickness and yield stress as those of the lower strake of the bulkhead.

7.5 Bulkheads acting as pillars

7.5.1 As a rule, bulkheads acting as pillars (i.e. those designed to sustain the loads transmitted by a deck structure) are to be provided with vertical stiffeners spaced, at a maximum, two frames apart.

7.5.2 A vertical stiffening member is to be fitted on the bulkhead in line with the deck supporting member transferring the loads from the deck and is to be checked as defined in Ch 4, Sec 7, [2.4].

7.6 Bracketed stiffeners

7.6.1 The bracket scantlings at ends of bulkhead stiffeners are to be defined by direct calculation, taking into account the bending moment and shear forces acting on the stiffener in way of the bracket as defined in Ch 4, Sec 6.

8 Superstructures and deckhouses

8.1 Connection of superstructures and deckhouses with the hull structure

8.1.1 Superstructure and deckhouse frames are to be fitted, as far as practicable, in way of deck frame structure and are to be efficiently connected.

Ends of superstructures and deckhouses are to be efficiently supported by bulkheads, diaphragms, webs or pillars.

Where hatchways are fitted close to the superstructure ends, additional strengthening may be required.

8.1.2 Construction details

The vertical stiffeners of the superstructure and deckhouse walls of the first tier (directly located above the freeboard deck) are to be attached to the decks at their ends.

Brackets are to be fitted at the lower end, and preferably also the upper end, of the vertical stiffeners of the exposed front bulkheads of engine casings and superstructures.

8.1.3 Connection to the hull deck of the corners of superstructures and deckhouses is considered by the Society on a case-by-case basis. Where necessary, local reinforcements may be required.

8.1.4 As a general rules, the side plating at ends of superstructures is to be tapered into the side shell bulwark or the sheerstrake of the strength deck.

Where a raised deck is fitted, the local reinforcement in way of the step is to extend, as a general rule, over at least three-frame spacings.

8.2 Structural arrangement of superstructures and deckhouses

8.2.1 Web frames, transverse partial bulkheads or other equivalent strengthening of each tier (superstructure and deckhouses) are to be arranged, where practicable, in line with the transverse reinforced structure below.

Web frames are also to be arranged in way of the large openings, tender davits, winches, provision cranes and other areas subjected to local loads.

Web frames, pillars, partial bulkheads and similar strengthening are to be arranged, in conjunction with the deck transverses, at ends of superstructures and deckhouses.

8.2.2 Openings

The arrangement of superstructure and deckhouse openings is to be as defined in Ch 5, Sec 1.

The attention of the Shipowners, Shipyards and Designer is drawn on the fact that the Flag Administration may request the application of National Rules.

8.2.3 Access openings and doors

Access openings cut in side bulkheads of enclosed superstructures are to be fitted with doors having a strength equivalent to the strength of the surrounding structure.

Special consideration is to be given to the connection of the doors to the surrounding structure.

Securing devices which ensure watertightness are to include tight gaskets, clamping dogs or other similar appliances, and are to be permanently attached to the bulkheads and doors. These doors are to be operable from both sides.

Section 2 Subdivision, Compartment Arrangement and Arrangement of Hull Openings

Symbols

L_{LL} : Load line length, in m, as defined in [2.1]

FP_{LL} : Forward freeboard perpendicular. FP_{LL} is to be taken at the forward end of L_{LL} and is to coincide with the forward side of the stem on the waterline on which the length L_{LL} is measured.

1 General

1.1 Application

1.1.1 The present Section is applicable to cargo ships and to non cargo ships as defined in Ch 1, Sec 1, [2.1.3], in accordance with the scope of application defined in Tab 1.

Table 1 : Scope of application

Gross tonnage	< 500 GT **(1)**	≥ 500 GT **(2)**
Subdivision arrangement	NR566	[3]
Compartment arrangement	NR566	[4]
Access arrangement	[5]	[5]
Hull opening arrangement	NR566	NR467 Steel Ships

(1) Except ships ships having the following service notations:
- **passenger ship** with **unrestricted navigation**
- **ro-ro passenger ship** with **unrestricted navigation**
- **fishing vessel**
- **chemical tanker**

(2) And ships having the service notations defined in (1), whatever their tonnage

1.1.2 Additional specific arrangement in relation to the service notation or service feature

Additional specific arrangement in relation to the service notation or feature assigned to the ship are to be taken into account as defined in Ch 6, Sec 1.

1.1.3 Openings in superstructures and deckhouses

Arrangement of openings in superstructures and deckhouses are defined in Ch 5, Sec 1.

2 Definition

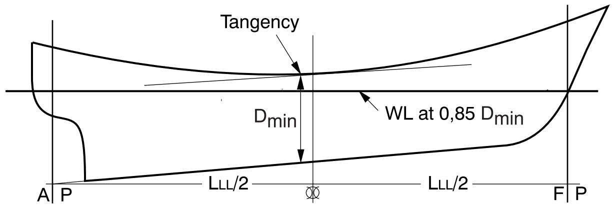
2.1 Load line length L_{LL}

2.1.1 The load line length L_{LL} is the distance, in m, on the waterline at 85% of the least moulded depth from the top of the keel, measured from the forward side of the stem to the centre of the rudder stock. L_{LL} is to be not less than 96% of the total length on the same waterline.

In ship design with a rake of keel, the waterline on which this length is measured is parallel to the designed waterline at 85% of the least moulded depth D_{min} found by drawing a line parallel to the keel line of the ship (including skeg) tangent to the moulded sheer line of the freeboard deck.The least moulded depth is the vertical distance measured from the top of the keel to the top of the freeboard deck beam at side at the point of tangency (see Fig 1).

For ships without a rudder stock, the length L_{LL} is to be taken as 96% of the waterline at 85% of the least moulded depth.

Figure 1 : L_{LL} of ships with a rake of keel



2.2 Machinery spaces of category A

2.2.1 Machinery spaces of category A are those spaces or trunks to such spaces which contain:

- internal combustion machinery used for main propulsion, or
- internal combustion machinery used for purposes other than propulsion where such machinery has in the aggregate a total power output of not less than 375 kW, or
- any oil fired boiler or fuel oil unit.

3 Subdivision arrangement

3.1 Number of transverse watertight bulkheads

3.1.1 General

All ships, in addition to complying with the requirements of [3.1.2], are to have at least the following transverse watertight bulkheads:

- one collision bulkhead
- one after peak bulkhead for ships having the service notation **passenger ship** or **ro-ro passenger ship**
- two bulkheads forming the boundaries of the machinery space for ships with machinery amidships, or one bulkhead forward of the machinery space for ships with machinery aft. In the case of ships with an electrical propulsion plant, both the generator room and the engine room are to be enclosed by watertight bulkheads.

3.1.2 Additional bulkheads

As a rule, for ships not required to comply with subdivision regulations, the number of transverse bulkheads adequately spaced are to be at least as indicated in Tab 2.

Additional bulkheads may be required for ships having to comply with subdivision or damage stability criteria.

Table 2 : Number of transverse bulkheads

Ship length, in m	Ships with aft machinery	Other ships
$L < 65$	3	4
$L \geq 65$	4	5

3.2 Water ingress detection

3.2.1 General

When a ship is fitted, below the freeboard deck, with a single cargo hold or with cargo holds not separated by at least one bulkhead made watertight up to the freeboard deck, a water ingress detection system is to be fitted according to NR467 Steel Ships, Pt C, Ch 1, Sec 10, [6.12.2].

3.2.2 Bulk carriers

For ships granted with the service notation **bulk carrier**, **bulk carrier ESP**, **ore carrier ESP**, **combination carrier/OBO ESP** or **combination carrier/OOC ESP**, the water ingress detection system is to be fitted according to NR467 Steel Ships, Pt C, Ch 1, Sec 10, [6.12.1].

3.3 Collision bulkhead

3.3.1 A collision bulkhead, made watertight up to the bulkhead deck, is to be fitted. This bulkhead is to be located at a distance from FP_{LL} not less than 5 per cent of the length L_{LL} and, except as may be permitted by the Society, not more than 8 per cent of L_{LL} or 5 per cent of L_{LL} + 3 m, whichever is the greater.

Note 1: For ships not covered by the SOLAS Convention, L_{LL} need not be taken less than 50 m, unless otherwise required by the National Authorities.

3.3.2 Where any part of the ship below the waterline extends forward of the forward perpendicular, e.g. a bulbous bow, the distances, in metres, stipulated in [3.3.1] are to be measured from a point located either:

- at mid-length of such an extension, or
- at a distance equal to 1,5 per cent of the length L_{LL} forward of the forward perpendicular

whichever gives the smallest measurement.

3.3.3 The bulkhead may have steps or recesses, provided they are within the limits specified in [3.3.1] or [3.3.2].

No door, manhole, ventilation duct or any other opening is to be fitted in the collision bulkhead below the bulkhead deck.

3.3.4 At the Owner's request and subject to the agreement of the flag Administration, the Society may accept, on a case-by-case basis, a distance from the collision bulkhead to the forward perpendicular FP_{LL} greater than the maximum limit specified in [3.3.1] and [3.3.2], provided that subdivision and stability calculations show that, when the ship is in upright condition on full load summer waterline, flooding of the space forward of the collision bulkhead will not result in any part of the freeboard deck becoming immersed, or in any unacceptable loss of stability.

In such a case, the attention of the Owner and the Shipyard is drawn to the fact that the flag Administration may impose additional requirements and that such an arrangement is, in principle, formalised by the issuance of a certificate of exemption under the SOLAS Convention provisions. Moreover, in case of change of flag, the taking Administration may not accept the exemption.

3.3.5 Where a long forward superstructure is fitted, the collision bulkhead is to be extended weathertight up to the next deck above the bulkhead deck. This extension need not be fitted directly above the bulkhead below, provided that:

- it is located within the limits specified in [3.3.1] or [3.3.2], considering the exemption given in [3.3.6], and
- the part of the deck which forms the step is made effectively weathertight.

3.3.6 Where bow doors are fitted and a sloping loading ramp forms part of the extension of the collision bulkhead above the freeboard deck, the part of the ramp beyond 2,3 m above the freeboard deck may extend forward of the limit specified in [3.3.1] or [3.3.2]. The ramp is to be weathertight over its full length.

3.3.7 The number of openings in the extension of the collision bulkhead above the freeboard deck is to be restricted to the minimum compatible with the design and normal operation of the ship. All such openings are to be capable of being closed weathertight.

3.4 After peak bulkheads, machinery space bulkheads and sterntubes

3.4.1 General

Bulkheads are to be fitted to separate the machinery space from the cargo and accommodation spaces forward and aft, and made watertight up to the bulkhead deck. In passenger ships, an after peak bulkhead is also to be fitted and made watertight up to the bulkhead deck. The after peak bulkhead may, however, be stepped below the bulkhead deck, provided the degree of safety of the ship as regards subdivision is not thereby impaired.

3.4.2 Sterntubes

In all the cases, sterntubes are to be enclosed in watertight spaces of moderate volume. In passenger ships, the stern gland is to be located in a watertight shaft tunnel or other watertight space separate from the sterntube compartment and of such a volume that, if flooded by leakage through the stern gland, the bulkhead deck will not be immersed. In cargo ships, other measures to minimise the danger of seawater ingress in case of damage to the sterntube arrangement may be taken at the discretion of the Society.

3.5 Height of transverse watertight bulkheads other than collision bulkhead and after peak bulkheads

3.5.1 Transverse watertight bulkheads are to extend watertight up to the bulkhead deck. In exceptional cases and at the Owner's request, the Society may allow transverse watertight bulkheads to terminate at a deck below the freeboard deck, provided that deck is at an adequate distance above the full load summer waterline.

3.5.2 Where it is not practicable to arrange a watertight bulkhead in one plane, a stepped bulkhead may be fitted. In this case, the part of the deck which forms the step is to be watertight and equivalent in strength to the bulkhead.

3.6 Openings in watertight bulkheads and decks

3.6.1 Ships greater than 500 GT

The requirements for openings in watertight bulkheads and decks for ships having a service notation other than **passenger ship** or **ro-ro passenger ship** are defined in NR467 Steel Ships, Pt B, Ch 2, Sec 1, [6].

The openings in watertight bulkheads below the bulkhead deck of ships having the service notation **passenger ship** or **ro-ro passenger ship** are to comply with NR467 Steel Ships, respectively Part D, Chapter 11 and Part D, Chapter 12.

3.6.2 Ships less than 500 GT

The requirements for openings in watertight bulkheads and decks are defined in NR566, Ch 1, Sec 2 [1.4].

4 Compartment arrangement

4.1 Definitions

4.1.1 Cofferdam

A cofferdam means an empty space arranged so that compartments on each side have no common boundary. A cofferdam may be located vertically or horizontally. As a rule, a cofferdam is to be properly ventilated and of sufficient size to allow for inspection.

4.2 Cofferdam arrangement

4.2.1 Cofferdams are to be provided between:

- fuel oil tanks and lubricating oil tanks
- compartments intended for liquid hydrocarbons (fuel oil, lubricating oil) and compartments intended for fresh water (drinking water, water for propelling machinery and boilers)
- compartments intended for liquid hydrocarbons (fuel oil, lubricating oil) and tanks intended for the carriage of liquid foam for fire-extinguishing systems.

4.2.2 Cofferdams separating:

- fuel oil tanks from lubricating oil tanks
- lubricating oil tanks from compartments intended for fresh water or boiler feed water
- lubricating oil tanks from those intended for the carriage of liquid foam for fire-extinguishing systems,

may not be required, when deemed impracticable or unreasonable by the Society in relation to the characteristics and dimensions of the spaces containing such tanks, provided that:

a) General case:
   - the common boundary plate thickness of the adjacent tanks is increased, with respect to the thickness obtained according to Ch 4, Sec 3, by:
     - 2 mm in the case of tanks carrying fresh water or boiler feed water, and
     - 1 mm in all the other cases
   - the sum of the throat thicknesses of the weld fillets at the edges of these plates is not less than the thickness of the plates themselves
   - the structural test is carried out with a head increased by 1 m with respect to Ch 7, Sec 3.

b) Structure in composite materials:
   - the scantling check under test load and the structural test are carried out with a head increased by 1 m with respect to Ch 7, Sec 3.
   - the internal protection of each compartment is to be ensured by suitable protective coating.

4.2.3 Spaces intended for the carriage of flammable liquids are to be separated from accommodation and service spaces by means of a cofferdam. Where accommodation and service spaces are arranged immediately above such spaces, the cofferdam may be omitted only where the deck is not provided with access openings and is coated with a layer of material recognized as suitable by the Society.

The cofferdam may also be omitted where such spaces are adjacent to a passageway, subject to the conditions stated in [4.2.2] for fuel oil or lubricating oil tanks.

4.3 Double bottom

4.3.1 Except for ships with service notation **fishing vessel**, a double bottom is to 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.

4.3.2 Any part of a ship which is not fitted with a double bottom is to be capable of withstanding bottom damages as specified in NR467 Steel Ships, Pt B, Ch 3, Sec 3, [3.4].

4.3.3 Where a double bottom is required to be fitted, the inner bottom is to be continued out to the ship sides in such a manner as to protect the bottom to the turn of the bilge. Such protection is to be deemed satisfactory if the inner bottom, at any part, is not lower than a plane parallel to the keel line and located at a vertical distance h, measured from the keel line, not less than, in m:

$h = B / 20$ without being less than 0,760 m.

However, h need not be taken greater than 2 m.

4.3.4 Small wells constructed in the double bottom in connection with the drainage arrangement of holds are not to extend downward more than necessary. A well extending to the outer bottom is, however, permitted at the after end of the shaft tunnel of the ship. Other wells may be permitted by the Society if it is satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with [4.3]. In no case the vertical distance from the bottom of such a well to a plane coinciding with the keel line is to be less than 500 mm.

4.4 Compartments forward of the collision bulkhead

4.4.1 The fore peak and other compartments located forward of the collision bulkhead are not to be used for the carriage of fuel oil or other flammable products.

4.5 Minimum bow height

4.5.1 The minimum bow height F_b is to be as defined in:

- NR566, Ch 1, Sec 4, or
- NR467 Steel Ships, Part B, Ch 2, Sec 2 for ships greater than 500 GT.

4.6 Shaft tunnels

4.6.1 Shaft tunnels are to be watertight.

4.7 Watertight ventilators and trunks

4.7.1 Watertight ventilators and trunks are to be carried at least up to:

- the freeboard deck for ships other than passenger ships
- the bulkhead deck for passenger ships.

4.8 Fuel oil tanks

4.8.1 The arrangements for the storage, distribution and utilisation of the fuel oil are to be such as to ensure the safety of the ship and persons on board.

4.8.2 As far as practicable, fuel oil tanks are to be part of the ship structure and are to be located outside the machinery spaces of category A.

Where fuel oil tanks, other than double bottom tanks, are necessarily located adjacent to or within machinery spaces of category A:

- at least one of their vertical sides is to be contiguous to the machinery space boundaries
- they are preferably to have a common boundary with the double bottom tanks, and
- the area of the tank boundary common with the machinery spaces is to be kept to a minimum.

Where such tanks are located within the boundaries of machinery spaces of category A, they may not contain fuel oil having a flashpoint less than 60°C.

4.8.3 Fuel oil tanks may not be located where spillage or leakage therefrom can constitute a hazard by falling on heated surfaces.

Precautions are to be taken to prevent any oil that may escape under pressure from any pump, filter or heater from coming into contact with heated surfaces.

Fuel oil tanks in boiler spaces may not be located immediately above the boilers or in areas subjected to high temperatures, unless special arrangements are provided in agreement with the Society.

4.8.4 Where a compartment intended for goods or coal is located close to a heated liquid container, a suitable thermal insulation is to be provided.

4.8.5 Fuel oil tank protection

All ships with an aggregate oil fuel capacity of 600 m^3 are to comply with the requirements of Regulation 12 A of Annex I to MARPOL Convention, as amended.

4.9 Tanks containing fuel for auxiliary vehicles

4.9.1 General

Tanks containing fuel for auxiliary vehicles are to comply with the requirements of NR467 Steel Ships, Pt C, Ch 4, Sec 11, [3.1].

4.9.2 Tank protection and segregation

Tanks containing fuel for auxiliary vehicles are to be located in accordance with the requirements of NR467 Steel Ships, Pt C, Ch 4, Sec 11, [3.2].

5 Access arrangement

5.1 General

5.1.1 The number and size of small hatchways for trimming and of access openings to tanks or other enclosed spaces are to be kept to the minimum consistent with the access and maintenance of the space.

5.2 Double bottom

5.2.1 Manholes are to be provided in floors and girders so as to provide convenient access to any part of the double bottom.

5.2.2 Manholes may not be cut in the continuous centreline girder or in the floors and girders below pillars, except where allowed by the Society, on a case-by-case basis.

5.2.3 Inner bottom manholes are to be not smaller than 400 mm x 400 mm. Their number and location are to be so arranged as to provide convenient access to any part of the double bottom.

5.2.4 However, the size of manholes and lightening holes in floors and girders is, in general, to be less than 50 per cent of the local height of the double bottom.

Where manholes of greater size are needed, edge reinforcement by means of flat bar rings or other suitable stiffeners may be required.

5.2.5 Inner bottom manholes are to be closed by watertight plate covers.

Doubling plates are to be fitted on the covers, where secured by bolts.

Where no ceiling is fitted, covers are to be adequately protected from damage caused by the cargo.

5.3 Access arrangement to, and within, spaces in, and forward of, the cargo area

5.3.1 General

The requirements defined in [5.3.2] for access to tanks, in [5.3.3] for access within tanks and in [5.3.4] for construction of ladders are not applicable to:

- ships with service notation **oil tanker ESP** (see NR467 Steel Ships, Part D, Chapter 7)
- spaces in double bottom and double side tanks.

Additional specific requirements, defined in NR467 Steel Ships, Part D, are applicable to the following service notations:

- **livestock carrier**: see NR467 Steel Ships, Part D, Chapter 3
- **bulk carrier**: see NR467 Steel Ships, Part D, Chapter 4
- **ore carrier**: see NR467 Steel Ships, Part D, Chapter 5
- **combination carrier**: see NR467 Steel Ships, Part D, Chapter 6
- **oil tanker**: see NR467 Steel Ships, Part D, Chapter 7
- **chemical tanker**: see NR467 Steel Ships, Part D, Chapter 8
- **passenger ship**: see NR467 Steel Ships, Part D, Chapter 11
- **ro-ro passenger ship**: see NR467 Steel Ships, Part D, Chapter 12.
- **tug**: see NR467 Steel Ships, Part E, Chapter 1
- **supply**: see NR467 Steel Ships, Part E, Chapter 3
- **oil recovery**: see NR467 Steel Ships, Part E, Chapter 5
- **diving support**: see NR467 Steel Ships, Part E, Chapter 7
- **standby rescue**: see NR467 Steel Ships, Part E, Chapter 10

5.3.2 Access to tanks

Tanks and subdivisions of tanks having lengths of 35 m and above are to be fitted with at least two access hatchways and ladders, as far apart as practicable longitudinally.

Tanks less than 35 m in length are to be served by at least one access hatchway and ladder.

The dimensions of any access hatchway are to be sufficient to allow a person wearing a self-contained breathing apparatus to ascend or descend the ladder without obstruction and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the tank. In no case is the clear opening to be less than 600 mm x 600 mm.

When a tank is subdivided by one or more wash bulkheads, at least two hatchways are to be fitted, and these hatchways are to be so located that the associated ladders effectively serve all subdivisions of the tank.

5.3.3 Access within tanks

Where one or more wash bulkheads are fitted in a tank, they are to be provided with openings not less than 600 mm x 800 mm and so arranged as to facilitate the access of persons wearing a breathing apparatus or carrying a stretcher with a patient.

To provide ease of movement on the tank bottom throughout the length and breadth of the tank, a passageway is to be fitted on the upper part of the bottom structure of each tank or, alternatively, manholes having at least the dimensions of 600 mm x 800 mm are to be arranged in the floors at a height of not more than 600 mm from the bottom shell plating.

The passageways located in the tanks are to be as follows:

a) They are to have a minimum width of 600 mm, considering the requirement for the possibility of carrying an unconscious person. Elevated passageways are to be provided with guard rails over their entire length. Where guard rails are provided on one side only, foot rails are to be fitted on the opposite side. Shelves and platforms forming a part of the access to the tanks are to be of non-skid construction, where practicable, and be fitted with guard rails. Guard rails are to be fitted to bulkhead and side stringers when such structures are being used for recognised access.

b) Access to elevated passageways from the ship bottom is to be provided by means of easily accessible passageways, ladders or treads. Treads are to provide lateral support for the foot. Where rungs of ladders are fitted against a vertical surface, the distance from the centre of the rungs to that surface is to be at least 150 mm.

c) When the height of the bottom structure does not exceed 1,50 m, the passageways required in a) may be replaced by alternative arrangements having regard to the bottom structure and requirement for ease of access of a person wearing a self-contained breathing apparatus or carrying a stretcher with a patient.

Where manholes are fitted, as indicated in [5.2.4], access is to be facilitated by means of steps and hand grips with platform landings on each side.

Guard rails are to be 900 mm in height and consist of a rail and intermediate bar. These guard rails are to be of substantial construction.

5.3.4 Construction of ladders

In general, the ladders are not to be inclined at an angle exceeding 70°. The flights of ladders are not to be more than 9 m in actual length. Resting platforms of adequate dimensions are to be provided.

Ladders and handrails are to be constructed of steel of adequate strength and stiffness and securely attached to the tank structure by stays. The method of support and length of stay are to be such that vibration is reduced to a practical minimum.

Provision is to be made for maintaining the structural strength of the ladders and railings taking into account the corrosive effect of the cargo.

The width of ladders is not to be less than:

- 350 mm for vertical ladders
- 400 mm for inclined ladders.

The treads are to be equally spaced at a distance apart measured vertically not exceeding 300 mm. They are to be formed of two square steel bars of not less than 22 mm by 22 mm in section fitted to form a horizontal step with the edges pointing upward, or of equivalent construction. The treads are to be carried through the side stringers and attached thereto by double continuous welding.

All sloping ladders are to be provided with handrails of substantial construction on both sides, fitted at a convenient distance above the treads.

5.4 Shaft tunnels

5.4.1 Tunnels are to be large enough to ensure easy access to shafting.

5.4.2 Access to the tunnel is to be provided by a watertight door fitted on the aft bulkhead of the engine room in compliance with [3.6].

5.5 Access to steering gear compartment

5.5.1 The steering gear compartment is to be readily accessible and, as far as practicable, separated from machinery spaces.

Suitable arrangements to ensure working access to steering gear machinery and controls are to be provided.

These arrangements are to include handrails and gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

Section 3 Scantling Criteria

Symbols

R : Minimum yield stress, in N/mm² to be taken equal to:

- for steel structures: R_y as defined in Ch 1, Sec 2, [2.1.5]
- for aluminium structures: R_y as defined in Ch 1, Sec 2, [3.1.2]
- for HDPE structures: R as defined in NR546 Composite Ships, Sec 10.

1 General

1.1 Application

1.1.1 The requirements of the present Section define:

- the permissible stresses considered for the check of steel and aluminium structures (see [2])
- the permissible safety factors considered for the check of composite and plywood structures. (see [3] and [4]) and the permissible stresses for HDPE (see [5]).

1.2 Global and local stresses

1.2.1 General

As a rule, the global hull girder stresses and the local stresses are examined independently.

However, according to the global stress level, the hull structure under local stresses may be checked taking into account the global hull girder stresses (see Ch 1, Sec 3, [3.1.2]).

When a three-dimensional model of the primary structure, simultaneously loaded by global external loads and local loads, is submitted to the Society by the designer, the checking criteria are to be in accordance with [2.3].

1.3 Stress notation

1.3.1 As a rule, the notations used for the stresses are:

σ : Bending, compression or tensile stress

τ : Shear stress.

The following indexes are used depending on the type of stress considered:

am : Rule permissible stress value

gl : Stresses resulting from a global strength analysis as defined in Ch 4, Sec 2

loc : Stresses resulting from a local strength analysis as defined from Ch 4, Sec 3 to Ch 4, Sec 5

VM : Combined stress calculated according to the Von Mises criteria.

2 Steel and aluminium alloy structures

2.1 General case

2.1.1 Permissible stresses under global loads

When the global hull girder strength is examined as required in Ch 4, Sec 2, [1.1.3], the permissible global stresses for plating and for secondary and primary stiffeners, and the safety factors for the buckling check of the structure submitted to global loads are defined in Tab 1.

2.1.2 Permissible stresses under local loads

a) Plating and secondary stiffeners

The permissible local stresses for the check of plating and secondary stiffeners submitted to local loads, in relation to the type of structure element and the type of local loads, are defined in Tab 2 and Tab 3.

b) Primary stiffeners

- Bending and shear stresses of primary stiffeners:

  The check of primary stiffeners submitted to local loads, in relation to the type of structure element and the type of local loads, is to be carried out taking into account the following permissible stresses:

- for analysis through an isolated beam calculation:
  σ_{locam} and τ_{locam}
- for analysis through a three-dimensional structure beam or a finite element model:
  σ_{vmam}

where:

σ_{locam} , τ_{locam} : Permissible local stresses, in N/mm², defined in Tab 4

σ_{vmam} : Permissible local Von Mises equivalent stresses, in N/mm², defined in Tab 4.

- Buckling of the attached plating of primary stiffeners:

  When deemed necessary by the Society, the buckling of the attached plating induced by the bending of primary stiffeners under local loads is to be checked along the primary stiffener span.

  In this case, the buckling of the attached plating is to comply with the following criteria defined in Ch 4, App 1, [3.3.7].

2.2 Finite element calculation

2.2.1 When the hull structure analysis under global loads or local loads is carried out by a finite element calculation submitted to the Society according to Ch 4, Sec 2, [5] or Ch 4, Sec 5, [1.3] respectively, the permissible stresses and buckling safety factors defined in Tab 1 and in Tab 4 are to be respectively increased and reduced by 10%.

Table 1 : Permissible global stresses and buckling safety factors for plating and for secondary and primary stiffeners under global loads

<table>
<tr><th rowspan="2">Structure element</th><th rowspan="2">Stress and safety factor</th><th colspan="2">Material</th></tr>
<tr><th>Steel</th><th>Aluminium</th></tr>
<tr><td rowspan="2">Plating
Secondary stiffeners
Primary stiffeners</td><td>σ_{glam} (1)</td><td colspan="2">0,60 R</td></tr>
<tr><td>τ_{glam} (1)</td><td colspan="2">0,40 R</td></tr>
<tr><td>Plating</td><td>SF_{buck} (2)</td><td>1,35</td><td>1,35</td></tr>
<tr><td>Secondary stiffeners</td><td>SF_{buck} (2)</td><td>1,45</td><td>1,30</td></tr>
<tr><td>Primary stiffeners</td><td>SF_{buck} (2)</td><td>1,25</td><td>1,15</td></tr>
<tr><td colspan="4">(1) Permissible stresses may be increased by 15% for:
• planing hull, when the actual global stresses are calculated with the moment in planing mode defined in Ch 3, Sec 2, [6.1]
• swath, when the actual global stresses are calculated with the moment acting on twin hull defined in Ch 3, Sec 2, [6.2.2]
(2) Permissible buckling safety factor may be decreased by 15% for:
• planing hull, when the actual global stresses are calculated with the moment in planing mode defined in Ch 3, Sec 2, [6.1]
• swath, when the actual global stresses are calculated with the moment acting on twin hull defined in Ch 3, Sec 2, [6.2.2]</td></tr>
</table>

Table 2 : Permissible local stresses σ_{locam} for plating under local loads

<table>
<tr><th rowspan="2">Loading case</th><th rowspan="2">Plating</th><th rowspan="2">Framing</th><th colspan="2">Permissible value of σ_{locam}</th></tr>
<tr><th>for steel structure</th><th>for aluminium structure</th></tr>
<tr><td rowspan="4">Local sea and internal pressures</td><td rowspan="2">Plating not contributing to the global strength</td><td>transverse</td><td rowspan="2">0,70 R</td><td rowspan="2">0,70 R</td></tr>
<tr><td>longitudinal</td></tr>
<tr><td rowspan="2">Plating contributing to the global strength</td><td>transverse</td><td>0,50 R</td><td>0,45 R</td></tr>
<tr><td>longitudinal</td><td>0,60 R</td><td>0,65 R</td></tr>
<tr><td rowspan="2">Local dynamic sea pressures (bottom slamming for planing hull, or bottom impact pressure for flat bottom forward area, or side shell impact)</td><td>All type of plating</td><td rowspan="2">all type of framing</td><td>0,75 R</td><td>0,75 R</td></tr>
<tr><td>Flat forward bottom plating</td><td>0,90 R</td><td>0,90 R</td></tr>
<tr><td rowspan="5">Flooding loads</td><td rowspan="2">Plating not contributing to the global strength</td><td>transverse</td><td>0,75 R</td><td rowspan="2">0,80 R</td></tr>
<tr><td>longitudinal</td><td>0,85 R</td></tr>
<tr><td rowspan="2">Plating contributing to the global strength</td><td>transverse</td><td>0,60 R</td><td>0,45 R</td></tr>
<tr><td>longitudinal</td><td>0,70 R</td><td>0,70 R</td></tr>
<tr><td>Collision bulkhead</td><td>all type of framing</td><td>0,70 R</td><td>0,70 R</td></tr>
<tr><td>Testing loads</td><td>All type of plating</td><td>all type of framing</td><td>0,85 R</td><td>0,90 R</td></tr>
<tr><td colspan="5">Note 1: The platings contributing to the global strength are the continuous platings located between 0,3 L and 0,7 L and the continuous platings located in the platform of multihull.</td></tr>
</table>

Table 3 : Permissible local stresses for secondary stiffeners under local loads

Loading case	Structure element	Stress	Permissible value
Local sea and internal pressures	Stiffeners contributing to the global strength	σ_{locam}	0,55 R
	Stiffeners not contributing to the global strength	σ_{locam}	0,80 R
	All stiffeners	τ_{locam}	0,45 R
Local dynamic sea pressures (bottom slamming for planing hull, or bottom impact pressure for flat bottom forward area, or side shell impact)	All stiffeners	σ_{locam}	0,90 R
		τ_{locam}	0,50 R
	Flat forward bottom stiffeners	σ_{locam}	0,90 R
		τ_{locam}	0,55 R
Flooding loads	Stiffeners contributing to the global strength	σ_{locam}	0,60 R
	Stiffeners not contributing to the global strength	σ_{locam}	0,85 R
	All stiffeners	τ_{locam}	0,45 R
	Stiffeners on collision bulkhead	σ_{locam}	0,65 R
		τ_{locam}	0,40 R
Testing loads	All stiffeners	σ_{locam}	0,85 R
		τ_{locam}	0,50 R

Note 1: In this Table, "stiffeners" means "secondary stiffeners".
Note 2: The stiffeners contributing to the global strength are the continuous longitudinal stiffeners located between 0,3 L and 0,7 L and the continuous transverse stiffeners located in the platform of multihull.

2.3 Permissible stresses of primary stiffeners under global and local loads

2.3.1 General

The requirements of this Article apply to the structure check of primary stiffeners analysed through a three-dimensional structural beam or a finite element model, loaded simultaneously by global loads (as defined in Ch 3, Sec 2, [4] and Ch 3, Sec 2, [5]) and by local loads induced by external sea pressures and internal loads (as defined in Ch 3, Sec 3, [2] and Ch 3, Sec 3, [3]).

As a rule, the dynamic loads defined in, Ch 3, Sec 3, [3], the testing loads defined in Ch 3, Sec 4, [5] and the flooding loads defined in Ch 3, Sec 4, [6] need not be combined with global loads.

2.3.2 Checking criteria

It is to be checked that the stresses deduced from the model are in compliance with the following criteria:

$$\sigma_{VM} \leq \frac{R}{SF}$$

$$\sigma \leq \frac{\sigma_c}{SF_{buck}}$$

where:

σ_{VM} : Von Mises equivalent stresses, in N/mm^2, deduced from the model

σ_c : Critical buckling stresses of the attached plating, in N/mm^2, calculated as defined in Ch 4, App 1

σ : Actual compressive stress in the attached plating, in N/mm^2, deduced from the model calculation

SF : Safety factor to be taken equal to 1,25

SF_{buck} : Safety factor defined in Tab 4.

2.3.3 Calculation hypothesis

The calculation models are to be as defined in:

- Ch 4, Sec 5, [1.2.2] for two- or three dimensional beam model
- Ch 4, Sec 5, [1.3] for finite element model.

The corrosion coefficient λ is to be taken equal to 1.

Note 1: These hypothesis are equivalent to a theoretical calculation considering:

- a corrosion coefficient λ taken equal to 1,1 and,
- permissible stresses increased 10% over values given in Tab 4 for an isolated beam calculation to account for the accuracy of the 2D/3D or finite element calculations.

Table 4 : Permissible local stresses for primary stiffeners under local loads

Loading case	Structure element	Stress / Safety factor	Permissible value
Local sea and internal pressures	Bottom and side girders contributing to the global strength	σ_{locam}	0,45 R
		τ_{locam}	0,40 R
		σ_{vmam}	0,45 R
	Other primary stiffeners contributing to the global strength	σ_{locam}	0,55 R
		τ_{locam}	0,45 R
		σ_{vmam}	0,55 R
	Primary stiffeners not contributing to the global strength	σ_{locam}	0,80 R
		τ_{locam}	0,45 R
		σ_{vmam}	0,80 R
	All primary stiffeners	SF_{buck} (steel)	1,45
		SF_{buck} (aluminium)	1,3
Local dynamic sea pressures (bottom slamming for planing hull, or bottom impact pressure for flat bottom forward area)	All primary stiffeners	σ_{locam}	0,90 R
		τ_{locam}	0,50 R
		σ_{vmam}	0,90 R
Flooding loads	Primary stiffeners on collision bulkhead	σ_{locam}	0,70 R
		τ_{locam}	0,50 R
		σ_{vmam}	0,70 R
	Primary stiffeners contributing to the global strength	σ_{locam}	0,60 R
		τ_{locam}	0,50 R
		σ_{vmam}	0,60 R
	Primary stiffeners not contributing to the global strength	σ_{locam}	0,85 R
		τ_{locam}	0,50 R
		σ_{vmam}	0,85 R
Testing loads	All primary stiffeners	σ_{locam}	0,90 R
		τ_{locam}	0,50 R
		σ_{vmam}	0,90 R
Note 1: The primary stiffeners contributing to the global strength are the continuous primary stiffeners located between 0,3 L and 0,7 L and the continuous transverse primary stiffeners located in the platform of multihull.			

3 Composite material structure

3.1 General

3.1.1 Principle of design review

The design review of composite structures is based on safety factors which are to be in compliance with the following criteria:

- Minimum stress criteria in layers:

$$\frac{\sigma_{bri}}{\sigma_{iapp}} \geq SF$$

- Critical buckling stress criteria:

$$\frac{\sigma_c}{\sigma_A} \geq SF_B$$

- Combined stress criteria in layers:

$$SF_{CS} \geq SF_{CSiapp}$$

where:

σ_{bri} : In-plane theoretical individual layer breaking stresses defined in NR546 Composite Ships, Sec 5, [5]

σ_c : Critical buckling stress of the composite element considered calculated as defined in NR546 Composite Ships, Sec 6, [4].

σ_{iapp} : In-plane individual layer applied stresses

σ_A : Compressive stress applied to the whole laminate considered

SF, SF_B , SF_{CS}:Rule safety factors defined in [3.2.3]

SF_{CSiapp} : Actual combined safety factor applied in layer as calculated in NR546 Composite Ships, Sec 2, [1.3.3].

Note 1: The breaking stresses directly deduced from mechanical tests (as requested in NR546 Composite Ships) may be taken over from the theoretical breaking stresses if the mechanical test results are noticeably different from the expected values.

3.1.2 Types of stress considered

The following different types of stress are considered, corresponding to the different loading modes of the fibres:

a) Principal stresses in the individual layers

- Stress σ_1

  These stresses, parallel to the fibre (longitudinal direction), may be tensile or compressive stresses and are mostly located as follows:

  - in 0° direction of unidirectional tape or fabric reinforcement systems
  - in 0° and 90° directions of woven roving

- Stress σ_2

  These stresses, perpendicular to the fibre (transverse direction), may be tensile or compressive stresses and are mostly located as follows:

  - in 90° direction of unidirectional tape or combined fabrics when the fibres of the set are stitched together without criss-crossing

- Shear stress τ_{12} (in the laminate plane)

  These shear stresses, parallel to the fibre, may be found in all type of reinforcement systems

- Shear stresses τ_{13} and τ_{23} (through the laminate thickness)

  These shear stresses, parallel or perpendicular to the fibre, are the same stresses than the interlaminar shear stresses τ_{IL2} and τ_{IL1}

- Combined stress (Hoffman criteria)

b) Stresses in the whole laminate

- Compressive and shear stresses in the whole laminate inducing buckling.

3.1.3 Theoretical breaking criteria

Three theoretical breaking criteria are used in the present Rules:

a) the maximum stress criteria leading to the breaking of the component resin/fibre of one elementary layer of the full lay-up laminate

b) the Hoffman combined stress criteria with the hypothesis of in-plane stresses in each layer

c) the critical buckling stress criteria applied to the laminate.

The theoretical breaking criteria defined in items a) and b) are to be checked for each individual layer.

The theoretical breaking criteria defined in item c) is to be checked for the global laminate.

3.1.4 First ply failure

It is considered that the full lay-up laminate breaking strength is reached as soon as the lowest breaking strength of any elementary layer is reached. This is referred to as “first ply failure”.

3.2 Rule safety factors

3.2.1 General

a) General consideration:

   The rule safety factors to be considered for the composite structure check are defined in [3.2.3], according to the partial safety factors defined in [3.2.2].

b) Additional considerations:

   Rule safety factors other than those defined in [3.2.3] may be accepted for one elementary layer when the full lay-up laminate exhibits a sufficient safety margin between the theoretical breaking stress of this elementary layer and the theoretical breaking stress of the other elementary layers.

c) Finite element model analysis:

   Finite Element Model analyses are examined on a case by case basis by the Society. As a rule, when the structure is checked with a Finite Element Model, the rule safety factors defined in [3.2.3] and [3.2.4] are to be reduced by ten per cent.

3.2.2 Partial safety factors

As a general rule, the minimum partial safety factors considered are to be as follows:

a) Ageing effect factor C_V

C_V takes into account the ageing effect of the composites and is generally taken equal to:

C_V = 1,2 for monolithic laminates (or for face-skins laminates of sandwich) and strip planking

C_V = 1,1 for sandwich core materials

b) Fabrication process factor C_F

C_F takes into account the fabrication process and the reproducibility of the fabrication and is generally taken equal to:

C_F = 1,10 in case of a prepreg process

C_F = 1,15 in case of infusion and vacuum process

C_F = 1,25 in case of a hand lay-up process and strip planking

C_F = 1,00 for the core materials of sandwich composite

c) Type of load factor C_i

C_i takes into account the type of loads and is generally taken equal to:

C_i = 1,0 for local external sea pressures and internal pressures or concentrated forces

C_i = 0,8 for dynamic sea pressures (slamming loads on bottom and impact on flat bottom on forward area) and for test pressures and flooding loads

C_i = 0,6 for impact pressure on side shell and on platform bottom of multihull

d) Type of stress factor C_R

C_R takes into account the type of stress in the fibres of the reinforcement fabrics and the cores and is generally taken equal to:

1) For fibres of the reinforcement fabrics:
   - for tensile or compressive stress parallel to the continuous fibre of the reinforcement fabric:

     C_R = 2,1 for unidirectional tape, bi-bias, three-unidirectional fabric

     C_R = 2,4 for woven roving
   - for tensile or compressive stress perpendicular to the continuous fibre of the reinforcement fabric:

     C_R = 1,25 for unidirectional tape, bi-bias, three-unidirectional fabric
   - for shear stress parallel to the fibre in the elementary layer and for interlaminar shear stress in the laminate:

     C_R = 1,6 for unidirectional tape, bi-bias, three-unidirectional fabric

     C_R = 1,8 for woven roving
   - for mat layer:

     C_R = 2,0 for tensile or compressive stress in the layer

     C_R = 2,2 for shear stress in the layer and for interlaminar shear stress

2) For core materials:
   - for tensile or compressive stress for cores:
     - in the general case:

       C_R = 2,1 for tensile or compressive stress
     - for balsa:

       C_R = 2,1 for tensile or compressive stress parallel to the wood grain

       C_R = 1,2 for tensile or compressive stress perpendicular to the wood grain
   - for shear stress, whatever the type of core material:

     C_R = 2,5

3) For wood materials for strip planking:

   C_R = 2,4 for tensile or compressive stress parallel to the continuous fibre of the strip planking

   C_R = 1,2 for tensile or compressive stress perpendicular to the continuous fibre of the strip planking

   C_R = 2,2 for shear stress parallel to the fibre and for interlaminar shear stress in the strip planking.

3.2.3 Rule safety factors

The rule safety factors SF, SF_{CS} and SF_B to be considered for the composite structure check are defined according to the type of hull structure calculation, as follows:

a) For structure checked under local loads:

The local loads considered are defined in Ch 3, Sec 3 and Ch 3, Sec 4:

1) Minimum stress criterion in layers:

   $SF = C_V C_F C_R C_i$

   with:

   C_V, C_F, C_R, C_i:Partial safety factors defined in [3.2.2]

2) Combined stress criterion in layers:

$SF_{CS} = C_{CS}\ C_V\ C_F\ C_i$

with:

C_{CS} : Partial safety factor, to be taken equal to:

- C_{CS} = 1,7 for unidirectional tape, bi-bias, three-unidirectional fabric
- C_{CS} = 2,1 for the other types of layer

C_V, C_F, C_i: Partial safety factors defined in [3.2.2]

b) For structure element contributing to the global strength checked under global hull girder loads:

The global hull girder loads considered are defined in Ch 3, Sec 2.

The minimum stress criterion in layers and the combined stress criterion in layers are to be taken as defined in a) with a value of C_i equal to 1,4.

The critical buckling stress criterion is to be taken equal to:

$SF_B = C_{Buck}\ C_V\ C_F\ C_i$

with:

C_{Buck} : Partial safety factor to be taken equal to 1,45

C_F : Partial safety factor defined in [3.2.2]

C_V : Partial safety factor to be taken equal to 1,2

C_i : Partial safety factor to be taken equal to 1,2

c) For structure element contributing to the global strength checked under global loads combined with local loads:

The global hull girder loads combined with local loads considered are:

- global loads: As defined in Ch 3, Sec 2, [4] and Ch 3, Sec 2, [5]
- local loads: As defined in: Ch 3, Sec 3, [2], Ch 3, Sec 4, [3] and Ch 3, Sec 4, [4].

The minimum stress criterion in layers and the combined stress criterion in layers are to be taken as defined in a) with a value of C_i equal to 0,8.

The critical buckling stress criterion is to be taken as defined in b) with a value of C_i equal to 0,8.

3.2.4 Rule safety factors for structural adhesive joints

The mechanical structural adhesive characteristics are to be as defined in NR546 Composite Ships, Sec 4 [5].

As a general rule, the rule safety factor SF considered in the present Rules and applicable to the maximum shear stress in adhesive joints is to be calculated as follows:

a) General case:

$SF \geq 2,4\ C_t\ C_v\ C_F\ C_{t°}\ C_i$

Taking into account the following partial safety factors:

C_t : Value discrepancies of the shear breaking stresses determined by mechanical tests, to be taken equal to 1,2

C_v : Ageing effect, to be taken equal to 1,2

Note 1: When the joint is exposed to UV and/or to sea water, a greater value of C_v is to be considered on the basis of test.

C_F : Factor taking into account the gluing process (with final control defined on a case by case basis) and generally taken as follows:

- C_F = 1,15 in case of a vacuum or infusion process
- C_F = 1,25 in case of manual process

$C_{t°}$:
- When the adhesive joint is tested in laboratory for the different ranges of temperature provided in service: $C_{t°}$ = 1
- When the characteristics of the adhesive joint for the different ranges of temperature provided in service are extrapolated from technical datasheets of the adhesive supplier: $C_{t°}$ = 1,2

C_i : Partial safety factor defined in [3.2.2] c).

b) For joint of minor importance, the failure of which might induce only localised effect:

$SF \geq 2,0\ C_t\ C_v\ C_F\ C_{t°}\ C_i$

Taking into account the following partial safety factors:

C_t : As defined in a) or, when the shear breaking stress are determined on the basis of datasheets for appropriate adherents, to be taken equal to 1,5

C_v : As defined in a)

C_F : As defined in a) or when provided without final control, to be taken equal to:

- C_F = 1,3 in case of a vacuum or infusion process
- C_F = 1,5 in case of manual process

$C_{t°}$: As defined in a)

C_i : Partial safety factor defined in a).

4 Plywood structure

4.1 Principal of design review

4.1.1 Characteristics of plywood

The mechanical characteristics of plywoods are to be estimated as defined in NR546 Composite Ships.

4.1.2 Principle of design review

The design review of plywood structure is based on one of the two following methods as defined in NR546 Composite Ships:

- global approach, when mechanical characteristics of plywood are defined, or
- ply by ply approach, based on the same calculation process than composite.

For each method, the safety factors (defined as the ratio between the applied stresses, calculated on the basis of the present rules, and the theoretical breaking criteria of the plywood or elementary layers of the plywood) are to be greater than the minimum rule safety factors defined in [4.2].

4.2 Rule safety factors

4.2.1 Homogeneous material approach

As a general rule, the rule safety factor SF to be taken into account in the global formula used to determine the plating thickness or the permissible stress in stiffeners is to be equal to, or greater than, 4,0.

4.2.2 Ply by ply approach

As a general rule, the rule safety factor SF applicable to the maximum stress in each layer of the plywood is to be calculated as follows:

a) Minimum stress criterion in layers

$SF = C_R\ C_i\ C_V$

with:

C_R : Factor taking into account the type of stress in the grain of the plywood layer. Generally:

- C_R = 3,7 for tensile or compressive stress parallel to the grain of the ply considered
- C_R = 2,4 for tensile or compressive stress perpendicular to the grain of the ply considered
- C_R = 2,9 for shear stress

C_i : Factor taking into account the type of loads. Generally:

- C_i = 1,0 for local external sea pressures and internal pressures or concentrated forces
- C_i = 0,8 for dynamic sea pressures (slamming loads on bottom, impact on flat bottom in forward area), and for test pressures and flooding loads
- C_i = 0,6 for impact pressure on side shell and on platform bottom of multihull

C_V : Factor taking into account the ageing effect of the plywood, to be taken at least equal to 1,2

b) Critical buckling stress criterion

As a general rule, the rule safety factor SF_B applicable to the critical buckling stress criterion is to be calculated as follows:

$SF_B = C_{Buck}\ C_V\ C_i$

with:

C_{Buck} , C_V : Partial safety factors, to be taken equal to 1,35 and 1,2 respectively for the check of the global hull girder structure.

C_i : Partial safety factor to be taken equal to 1,2.

Note 1: For planing hull, when the global stress is calculated with the minimum bending moments defined in Ch 3, Sec 2, [6.1], C_i may be taken equal to 0,8.

5 HDPE structure

5.1 Permissible stresses

5.1.1 The structure check of plating, secondary and primary stiffeners is to be carried out as defined in NR546 Composite Ships, Sec 10, taking into account the permissible stresses defined in Tab 5.

Table 5 : Permissible stresses for HDPE structure

Loading cases	Structure element	Stress **(1)**	Permissible value
Local sea and internal pressures	Plating	σ_{locam}	0,45 R
	Secondary stiffener	σ_{locam}	0,50 R
		τ_{locam}	0,30 R
	Primary stiffener	σ_{locam}	0,55 R
		τ_{locam}	0,30 R
		σ_{vmam}	0,55 R
Local dynamic sea pressure (side shell impact, bottom slamming for planing hull)	Plating	σ_{locam}	Bottom slamming: 0,75 R Side shell impact: 0,85 R
	Secondary stiffener	σ_{locam}	Bottom slamming: 0,70 R Side shell impact: 0,90 R
		τ_{locam}	Bottom slamming: 0,40 R Side shell impact: 0,50 R
	Primary stiffener **(2)**	σ_{locam}	0.85 R
		τ_{locam}	0,45 R
		σ_{vmam}	0,85 R
Flooding loads	Plating	σ_{locam}	0,50 R
	Secondary stiffener	σ_{locam}	0,55 R
		τ_{locam}	0,30 R
	Primary stiffener	σ_{locam}	0,55 R
		τ_{locam}	0,30 R
		σ_{vmam}	0,55 R
Testing loads	Plating	σ_{locam}	0,60 R
	Secondary stiffener	σ_{locam}	0,65 R
		τ_{locam}	0,35 R
	Primary stiffener	σ_{locam}	0,70 R
		τ_{locam}	0,40 R
		σ_{vmam}	0,70 R
Global loads	All structure elements	SF_{buck}	1,3

(1) Stress as defined in NR546 Composite Ships, Sec 10 [1.3]
(2) Not applicable for side shell impact analysis

NR600

Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m

CHAPTER 3
DESIGN LOADS

Section 1 General

1 Application

1.1 General

1.1.1 As a general rule, the wave loads and the ship motions and accelerations defined in the present Chapter are based on wave environment as defined in Ch 1, Sec 3, [1.1.3] corresponding to a probability level as defined in Ch 1, Sec 3, [1.1.4].

1.1.2 As an alternative to the present Chapter, the Society may accept the values of ship motions and accelerations derived from direct calculations or obtained from model tests, when justified on the basis of the ship characteristics and intended service. In general, the values of ship motions and accelerations to be determined are those which can be reached with the probability level defined in [1.1.1]. In any case, the model tests or the calculations, including the assumed sea scatter diagrams and spectra, are to be submitted to the Society for approval.

1.1.3 Additional specific design loads in relation to the service notation or service feature

Additional specific design loads in relation to the service notation or feature assigned to the ship are to be taken into account as defined in Ch 6, Sec 1.

2 Definition

2.1 Hull girder loads

2.1.1 Hull girder loads (still water loads, wave loads and dynamic loads) are forces and moments which result from the effects of local loads acting on the ship as a whole and considered as a beam.

These loads are considered for the hull girder strength check and are defined in Sec 2.

2.2 Local external pressures

2.2.1 The local external pressures are local pressures (still water, wave and dynamic) applied to the individual local structure (plating, secondary stiffeners and primary supporting members).

These local external pressures are considered for the local structure check and are defined in Sec 3.

2.3 Local internal pressures and forces

2.3.1 The local internal pressures and forces are local pressures (still water and inertial pressure) applied to the local internal structure (plating, secondary stiffeners and primary supporting structure) and include liquid loads, dry cargoes (bulk, uniform or unit), wheeled loads and accommodation deck loads.

Flooding pressures induced by damage and testing pressures are also considered as local internal pressures.

These local internal pressures and forces are considered for the local internal structure check and are defined in Sec 4.

3 Local pressure application

3.1 Application

3.1.1 The local pressures to be used in the scantling checks of plating, secondary stiffeners and primary supporting members are the following ones:

a) For an element of the outer shell: the local external pressures (still water and wave) considered as acting alone, without any counteraction from the ship internal loads in ship full load condition.

   However, for an element of the outer shell adjacent to a liquid compartment, the local load to be used in the scantling checks of plating, secondary stiffeners and primary supporting members of the shell is to be taken equal to the greater value between:

   - the local load as defined just above, and
   - for cargo ship:

     $p = p_{int} - 10 (T_B - h_1 - z)$

     with:

     $T_B - h_1 - z \geq 0$

- for non cargo ship:
  $p = p_{int} - 10 (T - h_1 - z)$
  with:
  $T - h_1 - z \geq 0$

where:

p_{int} : Local internal pressure, in kN/m², as defined in Sec 4
T : Draught as defined in Ch 1, Sec 1, [4.5], in m.
T_B : Draught in ballast condition, in m, measured from the base line
When T_B is unknown, T_B may be taken equal to 0,03 L_{WL}
h_1 : Ship relative motion in the considered area, in m, as defined in Sec 3, [2.1]
z : Load point calculation as defined in [4].

b) For an element inside the hull: the local internal pressures, the adjacent compartments being considered individually loaded, without any counteraction

c) For testing conditions: the internal testing pressures considered as acting alone, without external load counteraction

d) For flooding conditions: the internal flooding pressures on internal watertight elements considered without any counteraction on the internal watertight element considered.

3.1.2 Ship draught

The ship draught to be considered for the combination of the local loads is to correspond to:

- the full load condition: when one or more cargo compartments (oil tank, dry cargo hold, vehicle spaces) are considered as being loaded and the ballast tanks empty
- the light ballast condition: when one or more ballast tanks are considered as loaded and the cargo compartments empty (in the absence of more precise information, the ship's draught in light ballast condition, in m, may be taken equal to 0,03 L_{WL}).

4 Local load point location

4.1 General case for structures made of steel or aluminium alloys

4.1.1 Still water and wave loads

Unless otherwise specified, the local loads are to be calculated:

- for plate panels: at the lower edge of the plate panels
- for horizontal stiffeners: at mid-span of the stiffeners
- for vertical stiffeners: at the lower and upper vertical points of the stiffeners.

4.1.2 Dynamic loads

Unless otherwise specified, the dynamic loads are to be calculated:

- for plate panels: at mid-edge of the plate panels
- for longitudinal and transverse stiffeners: at mid-span of the stiffeners.

4.2 General case for structures made of composite materials

4.2.1 Still water and wave loads

Unless otherwise specified, the local loads are to be calculated:

- for plate panels:
  - at the lower edge of the plate panels for monolithic, and
  - at the middle of the plate panels for sandwich
- for horizontal stiffeners: at mid-span of the stiffeners
- for vertical stiffeners: at the lower and upper vertical points of the stiffeners.

4.2.2 Dynamic loads

Unless otherwise specified, the dynamic loads are to be calculated:

- for plate panels: at mid-edge of the plate panels
- for longitudinal and transverse stiffeners: at mid-span of the stiffeners.

4.3 Superstructures and deckhouses

4.3.1 For superstructures and deckhouses, the lateral pressures are to be calculated, for all type of materials:

- for plating: at mid-height of the bulkhead
- for horizontal and vertical stiffeners: at mid-span of the stiffeners.

Section 2 Global Hull Girder Loads

Symbols

B_{WL} : Waterline breadth, in m, as defined in Ch 1, Sec 1, [4.3.2]

B_{ST} : Waterline breadth of struts of swath, in m, as defined in Ch 1, Sec 1, [4.3.2]

B_{SF} : Moulded breadth of the submerged float of swath, in m, as defined in Ch 1, Sec 1, [4.3.4]

C_B : Total block coefficient as defined in Ch 1, Sec 1, [4.6]

As a rule, the value of C_B is to be taken at least equal to 0,4 in the present Section

Δ : Full load displacement, in t, at scantling draught in sea water (ρ = 1,025 t/m^3)

Δ_{light} : Lightship weight, in t. For the purpose of the present Section, the lightship weight includes lubricating oil, fresh and feed water

Δ_b : Total displacement of the ship in ballast condition, in t

D_W : Maximum deadweight of the ship, in t, equal to the difference between the full load displacement and the light ship weight

g : Gravity acceleration taken equal to 9,81 m/s^2.

L_{WL} : Length at waterline at full load, in m

L_{HULL} : Length of the hull from the extreme forward part to the extreme aft part of the hull, in m

n : Navigation coefficient depending on the assigned navigation notation, defined in Ch 1, Sec 1, [3]

T : Draught, in m, as defined in Ch 1, Sec 1, [4.5]

1 General

1.1 Hull girder loads

1.1.1 General

The hull girder loads considered in the present Rules are the:

- still water loads: induced by the longitudinal distribution of the lightship, the internal loads (cargo and ballast) and the buoyancy in still water condition
- wave loads: induced by the encountered waves in head sea condition and, in addition for multihull, in quartering sea condition
- impact loads: induced by the bottom impact in waves (for planing hull only)
- digging in wave loads: induced by the encountered waves when the fore part of each float is burying into the waves (for multihull only)
- waves acting on the twin hull (for swath only).

1.1.2 Combination

These different hull girder loads are to be combined as defined in [3] in order to check:

- the longitudinal hull girder scantlings, and
- in addition for multihull, the transverse structure of platform and the longitudinal float girder scantlings.

1.1.3 Ships fitted with a wind propulsion system

When the wind propulsion system arrangement induces significant global hull girder bending moments and shear forces, these moments and forces are to be combined with the still and wave global hull girder loads to carry out the strength check of the hull girder structure.

The values of the global bending moments and shear forces induced by the wind propulsion system arrangement in operation are to be defined by the Designer. These values may be reduced by 30% when they are calculated on the basis of the moments and forces deduced from the 3D finite element model defined in NR206 Wind Propulsion Systems, Sec 8.

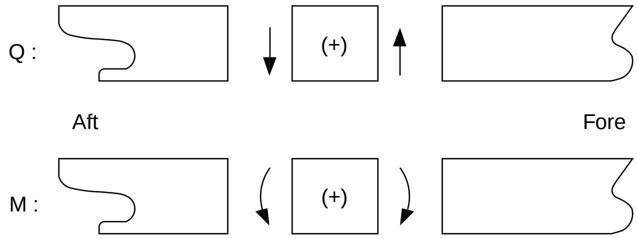
2 Calculation convention

2.1 Sign conventions of global bending moments and shear forces

2.1.1 The sign conventions of bending moments and shear forces, at any ship transverse section, induced by the hull girder loads are as shown in Fig 1, namely:

- the bending moment M is positive when it induces tensile stresses in the strength deck (hogging bending moment); it is negative in the opposite case (sagging bending moment, inducing compression stresses in the strength deck)
- the vertical shear force Q is positive in the case of downward resulting forces preceding, and upward resulting forces following, the ship transverse section under consideration; it is negative in the opposite case.

Figure 1 : Sign conventions of bending moments and shear forces



2.2 Designation of global bending moments and shear forces

2.2.1 Global bending moments

The designation of the bending moments is as follows:

- Bending moments in still water condition:
  - M_{SWH} for hogging conditions
  - M_{SWS} for sagging conditions
- Wave bending moments induced by head sea condition:
  - M_{WH} for hogging conditions
  - M_{WS} for sagging conditions
- Wave bending moments induced by quartering sea condition (for multihull only):
  - M_{WQH} for hogging conditions
  - M_{WQS} for sagging conditions
- Minimum combined bending moments induced by bottom impact in wave and still water conditions (for planing hull only):
  - Vertical moments:
    - M_{minH} for hogging conditions
    - M_{minS} for sagging conditions
  - Transverse torsional moment (for multihull only):
    - M_{ttmin}
- Bending moment induced by digging in wave (for multihull only):
  - M_{DWL} for bending moment applied to the floats of multihull
  - M_{DWT} for bending moment applied to the primary transverse structure of the platform of multihull
- Transverse bending moment acting on twin-hull connection (for swath only):
  - M_Q

2.2.2 Vertical shear forces

The vertical shear forces Q are designed with the same suffixes as those defined for the bending moments in [2.2.1].

3 Combination of hull girder loads

3.1 Hull girder load combinations

3.1.1 The bending moments and the combinations to be considered for the hull girder analysis are defined in Tab 1.

The shear forces and the combinations to be considered for the hull girder analysis are based on the same principle than the combinations of the bending moments defined in Tab 1.

Table 1 : Hull girder load combinations for ship in displacement mode

Ship condition		Monohull ship	Multihull ship
		All type of ship	
Head sea condition	(hogging)	$M_{SWH} + M_{WH}$	
	(sagging)	$M_{SWS} + M_{WS}$	
Quartering sea condition	(hogging)	NA	$M_{SWH} + M_{WQH}$
	(sagging)	NA	$M_{SWS} + M_{WQS}$
Digging in wave (sagging)		NA	M_{DWL}
		In addition, for ship in planing mode	
Head sea condition (hogging or sagging)		M_{minH} or M_{minS}	M_{minH} or M_{minS} **(1)**
Quartering sea condition		NA	M_{ttmin} **(1)**
		In addition, for swath	
Transverse moment		NA	M_Q

Note 1: NA = Not applicable.
(1) Not applicable to swath.

3.2 Hull girder loads distribution

3.2.1 The hull girder loads defined in [3.1.1] are to be applied along the ship from 0,3 L_{WL} from the aft end to 0,7 L_{WL} from the aft end.

Note 1: As a rule, the distribution of hull girder loads from the aft perpendicular to 0,3 L_{WL} and from 0,7 L_{WL} to the fore perpendicular are overlooked and considered as equal to zero.

4 Still water loads

4.1 General

4.1.1 The values of the still water bending moments and shear forces and their longitudinal distribution are to be defined by the Shipyard for the final design assessment.

The Shipyard is to supply the data necessary to verify the calculations of the still water loads.

When these values are not available, the values defined in [4.2] or [4.3] may be considered as a guideline for preliminary assessment only.

4.2 Cargo ships

4.2.1

a) General

As a rule, for cargo ships as defined in Ch 1, Sec 1, [2.1.3], the longitudinal distribution of still water bending moments and shear forces for homogeneous loading conditions at full load displacement and for ballast condition, subdivided into departure and arrival conditions, is to be submitted to the Society.

The data necessary to calculate the still water bending moments and shear forces are to be submitted to the Society for information.

b) Still water load specification

The longitudinal distribution of still water bending moments and shear forces is a basis for the hull girder strength review. The values of these still water bending moments and shear forces considered for the structure review (rule or designer values) are to be indicated on the midship section drawing.

4.2.2 For ships having alternate light and heavy cargo loading conditions, see Ch 1, Sec 1, [1.2.2].

4.2.3 Particular types of ship

Supply vessels, barges, fishing vessels, and all types of ship not considered as cargo ships as defined in Ch 1, Sec 1, [2.1.3] but liable to carry loading or equivalent loads, may be however examined, for a hull girder load in still water point of view, with the present requirements for cargo ships, when deemed necessary by the Society.

4.2.4 Still water bending moments and shear forces

a) Hogging conditions

In hogging conditions, the maximum bending moment M_{SWH}, in kN·m, and the maximum shear force Q_{SWH}, in kN, may be calculated, in ballast condition, as follows:

$$M_{SWH} = 5\ [0{,}28\ L_{WL}\ \Delta_{light} + \Sigma\ (x_i\ D_{Wloci}) - 0{,}198\ L_{WL}\ \Delta_b]$$

$$Q_{SWH} = \frac{4M_{SWH}}{L_{WL}}$$

where:

D_{Wloci} : Weight, in t, of the ballasts considered

x_i : Distance, in m, between the midship perpendicular and the centre of gravity of the considered ballasts (the sign of x_i is always to be considered positive)

Note 1: When the value of M_{SWH} is negative, M_{SWH} is to be considered as a minimum sagging moment (in this case, the ship is always in sagging condition in still water).

b) Sagging conditions

In sagging conditions, the maximum bending moment M_{SWS}, in kN·m, and the maximum shear force Q_{SWS}, in kN, may be calculated, in full load condition (for homogeneous loading case only), as follows:

$$M_{SWS} = 5\ [0{,}28\ L_{WL}\ \Delta_{light} + X\ D_W - 0{,}225\ L_{WL}\ \Delta]$$

$$Q_{SWS} = \frac{4M_{SWS}}{L_{WL}}$$

where:

X : Distance, in m, taken equal to:

$$X = \frac{(0,5L_{WL} - X_1)^2 + (X_2 - 0,5L_{WL})^2}{2(X_2 - X_1)}$$

X_1, X_2 : Distances, in m, between the aft perpendicular of the ship and, respectively, the aft boundary and the fore boundary of the cargo holds.

Note 2: When the value of M_{SWS} is positive, M_{SWS} is to be considered as a minimum hogging moment (in this case, the ship is always in hogging condition in still water).

Note 3: These formulae are to be used only for ships having their machinery space and superstructure located in the ship aft part.

c) Hogging and sagging conditions for catamaran and swath considered as cargo ships

For catamaran and swath considered as cargo, the maximum values of bending moments and shear forces in hogging and sagging conditions calculated according to item a) and item b) are to be reduced by 50%.

4.3 Non cargo ships

4.3.1 Still water bending moments and shear forces

a) Hogging conditions for monohull and catamaran

In hogging conditions, the maximum bending moment M_{SWH}, in kN·m, and the maximum shear force Q_{SWH}, in kN, may be calculated as follows:

$$M_{SWH} = 0{,}8\ (0{,}25\ C_W\ L_W^2\ B_{WL}\ C_B)$$

$$Q_{SWH} = \frac{4M_{SWH}}{L_{WL}}$$

where:

L_W, C_W : Wave length and wave parameter, respectively, as defined in [5.2.2]

b) Sagging conditions for monohull and catamaran

In sagging conditions, the maximum bending moment M_{SWS}, in kN·m, and the maximum shear force Q_{SWS}, in kN, may be taken equal to:

$$M_{SWS} = Q_{SWS} = 0$$

c) Hogging and sagging conditions for swath

In hogging and sagging conditions, the maximum bending moments and the maximum shear forces for swath are to be calculated as defined in item a) and item b), using the breadth B_{SF} instead of B_{WL} in the formulae.

For ships having a superstructure distribution all along the ship length or located in the midship area from 0,3 L to 0,7 L from the aft end, the maximum bending moments and the maximum shear forces in hogging conditions may be reduced by 40%.

5 Wave loads

5.1 General

5.1.1 Ship in displacement mode

Wave loads induced by the encountered waves in head sea condition are defined in [5.2.2].

As an alternative, the Society may accept the values of wave induced loads derived from direct calculations, when justified on the basis of the ship characteristics and intended service. The calculations are to be submitted to the Society for approval.

5.1.2 Ship in planing mode

In addition to the calculation to be carried out as defined in [5.1.1], the combined bending moments and shear forces induced by impact loads are to be calculated according to [6.1] for planing hull.

As an alternative, the Society may accept the values of impact loads derived from direct calculations, when justified on the basis of the ship characteristics and intended service. The calculations are to be submitted to the Society for approval.

5.1.3 Additional wave loads for multihull

Wave loads induced by the encountered waves in quartering sea condition are defined in [5.3.1].

As an alternative, the Society may accept the values of wave induced loads and impact loads derived from direct calculations, when justified on the basis of the ship characteristics and intended service. The calculations are to be submitted to the Society for approval.

In addition to the moment defined in head sea condition, the torsional moments applied to the platform of multihull (inducing bending moment and shear force in the floats and in the primary transverse cross structure of the platform) are to be calculated according to the following hypotheses:

- For multihull:
  - in quartering sea condition: the forward perpendicular of one float and the aftward perpendicular of the other float are on the crest of the wave (see [5.3])
  - digging in wave: the fore part of each float buries into the wave down to a depth as defined in [6.2.1]
- In addition, for swath:
  - wave acting on twin hull (see [6.2.2]).

5.2 Wave loads in head sea condition

5.2.1 Wave loads in head sea condition

The bending moments and shear forces induced by wave in head sea condition are calculated according to [5.2.3], considering the following hypotheses:

- the forward and aftward perpendiculars of the hull are on the crest (sagging conditions), or
- the forward and aftward perpendiculars of the hull are on the trough (hogging conditions).

The values obtained are to be applied along the ship from 0,3 L to 0,7 L from the aft end.

When deemed necessary by the Society, a distribution of the bending moments and shear forces as defined in NR467 Steel Ships, Ch 5, Sec 2, [4] may be considered.

5.2.2 Wave characteristics for head sea condition

The characteristics of the encountered waves to be considered in head sea condition (equivalent static wave) are as follows:

- sinusoidal type
- wave length L_W , in m, equal to:

  $L_W = 0,5 (L_{WL} + L_{HULL})$
- wave parameter C_W , in m, equal to:

  $C_W = 0,625 (118 - 0,36 L_W) L_W \cdot 10^{-3}$

5.2.3 Wave bending moments and shear forces

a) Hogging conditions for monohull ship

In hogging conditions, the maximum bending moment M_{WH} , in kN·m, and the maximum shear force Q_{WH} , in kN, along one float in head sea condition, are obtained from the following formulae:

$M_{WH} = 0,20 n C_W L_W^2 B_{WL} C_B$

$Q_{WH} = 0,65 n C_W L_W B_{WL} C_B$

b) Sagging conditions for monohull ship

In sagging conditions, the maximum bending moment M_{WS} , in kN·m, and the maximum shear force Q_{WS} , in kN, along one float in head sea condition, are obtained from the following formulae:

$M_{WS} = - 0,25 n C_W L_W^2 B_{WL} C_B$

$Q_{WS} = - 0,75 n C_W L_W B_{WL} C_B$

where:

L_W , C_W : Wave length and wave parameter, respectively, as defined in [5.2.2]

B_{WL} : Breadth at waterline, in m, of one float.

c) Hogging and sagging conditions for catamaran

The maximum values of the wave bending moments and shear forces for catamaran are to be calculated as defined in items a) and b), increased by 10%.

d) Hogging and sagging conditions for swath

The maximum values of the wave bending moments and shear forces for swath are to be calculated as defined in item c), using the breadth B_{ST} instead of B_{WL} in the formulae.

5.3 Wave loads in quartering sea condition for multihull

5.3.1 Wave characteristics for quartering sea condition

The characteristics of the encountered waves to be considered in quartering sea condition (equivalent static wave) are as follows:

- sinusoidal type
- wave length L_{WQ} , in m, resulting from the quartering wave position and defined as follows (see Fig 2):

$$L_{WQ} = \frac{2 L_W B_E}{\sqrt{L_W^2 + B_E^2}}$$

where:

L_W : Wave length, in m, as defined in [5.2.2]

B_E : Distance, in m, between the float axes (see Fig 2)

- wave parameter C_{WQ} , in m, equal to:

$C_{WQ} = 0,625\ (118 - 0,36\ L_{WQ})\ L_{WQ} \cdot 10^{-3}$

5.3.2 Wave bending moments and shear forces for multihull

a) Hogging and sagging conditions for catamaran

The bending moments M_{WQH} and M_{WQS} , in kN·m, and the shear forces Q_{WQH} and Q_{WQS} , in kN, are to be calculated as follows:

- in hogging conditions:

  $M_{WQH} = n\ C_{WQ}\ L_W^2\ B_{WL}\ C_B$

  $Q_{WQH} = 1,60\ n\ C_{WQ}\ L_W\ B_{WL}\ C_B$

- in sagging conditions:

  $M_{WQS} = -\ n\ C_{WQ}\ L_W^2\ B_{WL}\ C_B$

  $Q_{WQS} = -\ 1,60\ n\ C_{WQ}\ L_W\ B_{WL}\ C_B$

where:

C_{WQ} : Wave parameter as defined in [5.3.1]

L_W : Wave length, in m, as defined in [5.2.2].

b) Hogging and sagging conditions along the floats and in the platform for catamaran

The bending moments and the shear forces along the floats as well as those in the primary transverse cross structure of the platform are to be determined by a beam model as defined in Ch 4, Sec 2, [4.3].

The beam model is to be loaded by forces F, in kN, as shown on Fig 3, where F is successively equal to:

$F = M_{WQH} / L_{WL}$

$F = M_{WQS} / L_{WL}$

where:

M_{WQH} , M_{WQS} : Bending moments, in kN·m, as defined in item a).

L_{WL} : Length at waterline at full load, in m

c) Hogging and sagging conditions along the floats and in the platform for swath

The bending moments and the shear forces along the floats and in the platform are to be calculated as defined in item b), using the breadth B_{ST} instead of B_{WL} in the formulae of bending moments M_{WQH} and M_{WQS} .

Figure 2 : Wave length L_{WQ} for multihull

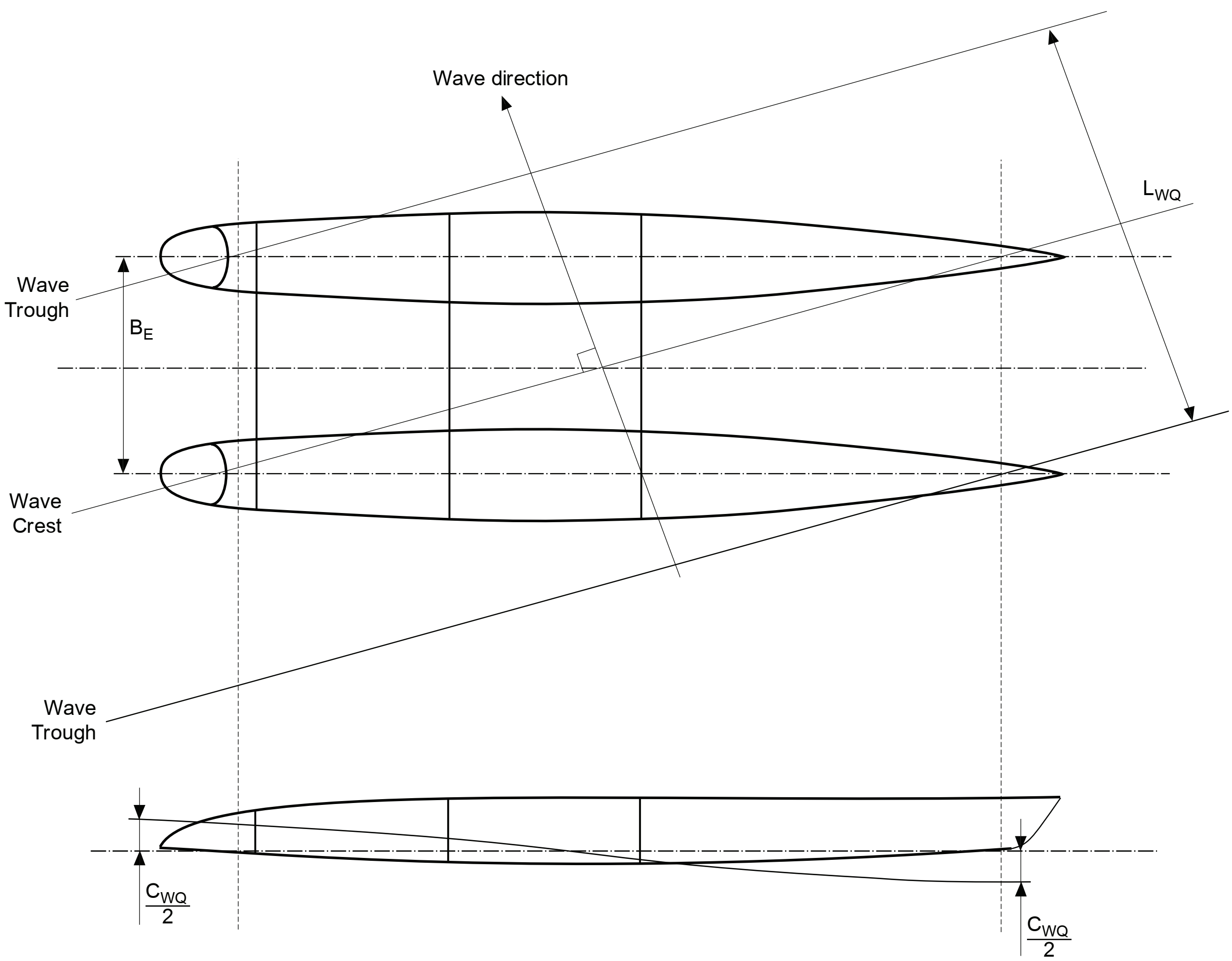
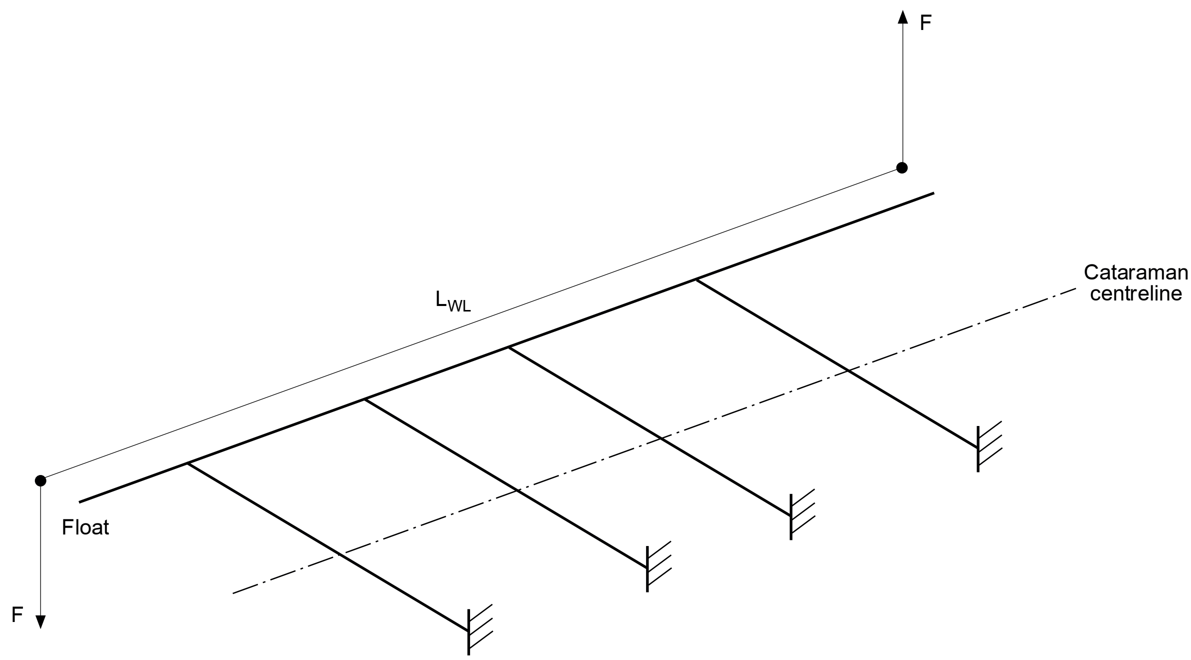


Figure 3 : Wave loads for catamaran platform



6 Additional specific wave hull girder loads

6.1 Additional wave loads for planing hull

6.1.1 Minimum bending moments and shear forces in head sea condition

a) Hogging and sagging conditions for monohull

For monohull planing hull as defined in Ch 1, Sec 1, [2.1.5], the minimum combined bending moments M_{minH} and M_{minS} , in kN·m, and the minimum shear forces Q_{minH} and Q_{minS} , in kN, in planing hull mode (due to still water plus wave induced loads plus impact loads) are to be not less than the following values:

- in hogging conditions:

$$M_{minH} = 0,55\ \Delta\ L_{WL}\ (C_B + 0,7)\ (1 + a_{CG})$$

$$Q_{minH} = \frac{3,2 M_{minH}}{L_{WL}}$$

- in sagging conditions:

$$M_{minS} = -\ 0,55\ \Delta\ L_{WL}\ (C_B + 0,7)\ (1 + a_{CG})$$

$$Q_{minS} = \frac{3,2 M_{minS}}{L_{WL}}$$

where:

a_{CG} : Vertical design acceleration at $L_{CG,}$ expressed in g, as defined in Sec 3, [3.3.4]

The minimum water bending moments and shear forces are to be applied along the ship from 0,3 L to 0,7 L from the aft end.

b) Hogging and sagging conditions for catamaran

For catamaran planing hull as defined in Ch 1, Sec 1, [2.1.5], the minimum combined bending moments M_{minH} and M_{minS} , in kN·m, and the minimum shear forces Q_{minH} and Q_{minS} , in kN, in planing hull mode (due to still water plus wave induced loads plus impact loads) applied to one float are to be taken equal to the values defined in [6.1.1] reduced by 50%.

As an alternative to items a) and b), the Society may accept the values of hull girder bending moments induced by still water plus wave loads plus impact loads in the fore body area derived from direct calculation or obtained by model test.

6.1.2 Minimum bending moments and shear forces in quartering sea condition (catamaran only)

a) Bending moment

For catamaran designed with planing hull as defined in Ch 1, Sec 1, [2.1.5], the minimum transverse torsional moment M_{ttmin} , in kN·m, due to wave induced loads plus impact loads is not to be less than:

$$M_{ttmin} = 0,125\ \Delta\ L_{WL}\ a_{CG}\ g$$

where:

a_{CG} : Design vertical acceleration as defined in Sec 3, [3.3.4]. In the above formula, a_{cg} need not be taken greater than 1,0 g.

b) Bending moments and shear forces along the floats and in the platform

The bending moments and the shear forces along the floats as well as those in the primary transverse cross structure of the platform are to be determined by a beam model as defined in Ch 4, Sec 2, [4.3].

The beam model is to be loaded by forces F, in kN, as shown on Fig 3, where F is successively equal to:

$$F = M_{ttmin} / L_{WL}$$

$$F = -\ M_{ttmin} / L_{WL}$$

6.2 Additional wave loads for multihull

6.2.1 Digging in wave loads

a) Application

The digging in wave loads correspond to the situation where the multihull sails in quartering sea condition and has the fore end of the floats burying into the encountered waves.

b) Bending moment and shear force for catamaran

As a rule, the bending moment due to digging in wave may be not calculated and overlooked for catamaran having a front platform located at a distance from the forward end of floats less than 5% of L_{WL} .

The bending moment M_{DWL} , in kN.m, and the shear force Q_{DWL} , in kN, in the floats and in the platform of the catamaran are to be calculated by a beam model as defined in Ch 4, Sec 2, [4.3], taking into account the following fore float linear loads, in kN/m, (see Fig 4):

- for the float the more sunk in the wave:

$$F_{vm} = \frac{8F'}{3L_W}$$

$$F_{hm} = \frac{8F''}{3L_W}$$

- for the float the less sunk in the wave:

$$F_{vl} = \frac{4F'}{3L_W}$$

$$F_{hl} = \frac{4F''}{3L_W}$$

where:

L_W : Wave length, in m, as defined in [5.2.2].

F' : Vertical Archimedian overpressure force, in kN, equal to:

$$F' = \frac{1,8g\Delta dA_p}{\delta_1 + \delta_2} \cdot n$$

F'' : Horizontal Archimedian overpressure force, in kN, equal to:

$F'' = F' \cos 80°$

d : Length, in m, of digging in wave, equal to the distance between the extreme fore end of each float and the forward part of the platform

A_p : Pitch amplitude, in rad, as defined in Sec 4, [2.1.5]

δ_1 , δ_2 : Vertical heights of the digging in wave, in m, of a point located at d/2 abaft fore end of each float, calculated as follows:

$$\delta_1 = \frac{1}{3} L_W A_p$$

$$\delta_2 = \frac{1}{6} L_W \tan 16°$$

The vertical and horizontal linear loads F_v and F_h are to be applied from the fore part of the floats on a distribution length, in m, equal to L_{WL} / 4 without being taken greater than d, as shown on Fig 4.

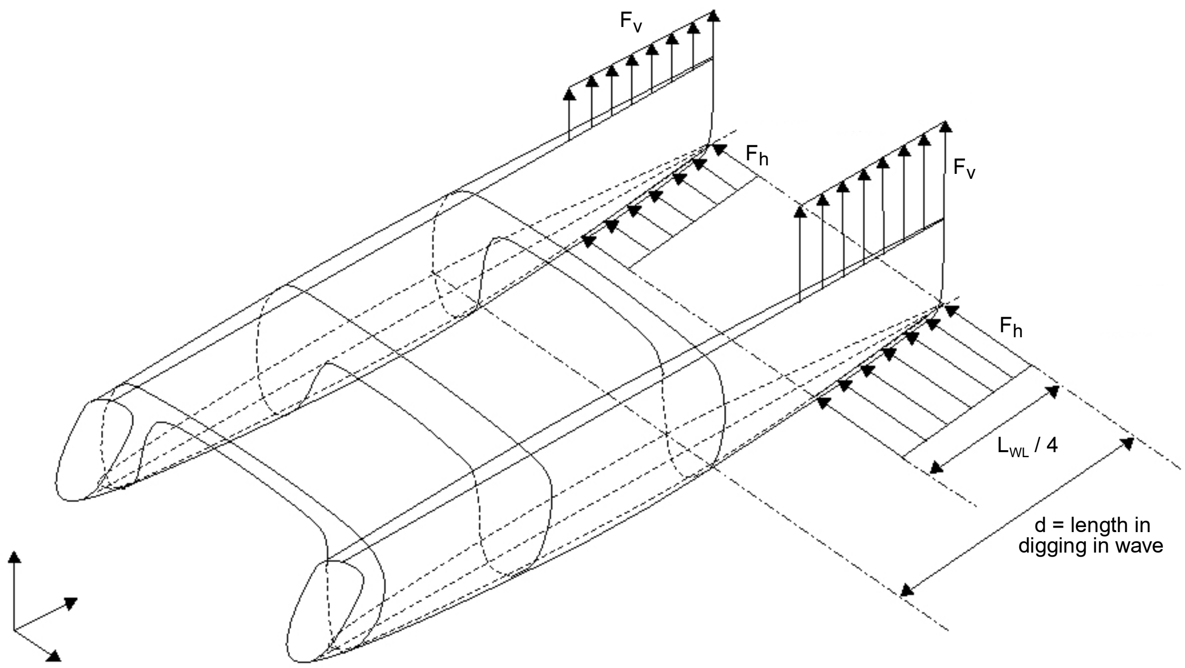
Note 1: For non conventional location of the fore part of the platform, the Society may decide to consider another load distribution, on a case-by-case basis.

c) Bending moments and shear forces for swath

The bending moment M_{DWL} , in kN·m, and the shear force Q_{DWL} , in kN, in the floats and in the platform of the swath are to be calculated as defined in item b), taking into account a vertical Archimedian overpressure F′, in kN, equal to:

$$F' = \frac{1,5g\Delta(0,2L_{WL})A_p}{\delta_1 + \delta_2} \cdot n$$

Figure 4 : Multihull loads due to digging in wave



6.2.2 Bending moment acting on twin-hull connections of swath

The bending moment M_Q , in kN·m, applied along the platform structure of swath is to be taken equal to:

$M_Q = h_M F_q$

where:

h_M : Half the draught T, in m, plus the distance from the waterline at draught T to the midpoint of the platform structure (see Fig 5)

F_q : Side beam force, in kN, equal to:

$F_q = 12,5\ n\ T\ \Delta^{2/3}\ d_q\ L_S$

with:

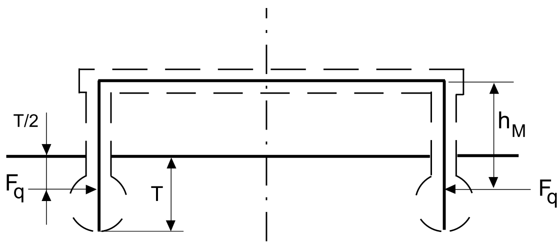
$d_q = 1,55 - 0,75 \tanh (\Delta / 11000)$

$L_S = 2,99 \tanh (\lambda) - 0,725$

$\lambda = 0,137\ A_{lat} / (T\ \Delta^{1/3})$

A_{lat} : Lateral surface, in m², projected on a vertical plane of one hull with that part of strut or struts below the waterline at draught T.

Figure 5 : Side beam force



Section 3 Local External Pressures

Symbols

Base Line: As a rule, the base line is a fictive line located at the lower point of the hull bottom where z = 0 (see Fig 1)

C_B : Total block coefficient as defined in Ch 1, Sec 1, [4.6]

$C_W = 0,625\ (118 - 0,36\ L_W)\ L_W\ 10^{-3}$

D : Depth, in m, as defined in Ch 1, Sec 1, [4]

Δ : Full load displacement, in t, at scantling draught in sea water (ρ = 1,025 t/m^3)

g : Gravity acceleration taken equal to 9,81 m/s^2

L_{WL} : Length at waterline at full load, in m

L_{HULL} : Length of the hull from the extreme forward part to the extreme aft part of the hull, in m

$L_W = 0,5\ (L_{WL} + L_{HULL})$

n : Navigation coefficient depending on the assigned navigation notation, defined in Ch 1, Sec 1, [3]

ρ : Sea water density, taken equal to 1,025 t/m^2

T : Draught as defined in Ch 1, Sec 1, [4.5]

T_B : Draught, at ballast displacement, in m, measured from the base line.
If T_B is unknown, T_B may be taken equal to 0,03 L_{WL}

V : Maximum ahead service speed, in knots.

z : Z co-ordinate, in m, at the calculation point as defined in Sec 1, [4]

1 Definitions

1.1 General

1.1.1 The local external pressures to be considered are:

a) Sea pressure

Still water loads (due to hydrostatic external sea pressure in still water), and wave loads (due to wave pressure and ship motions).

b) Dynamic sea pressures

The dynamic sea pressures are loads which have a duration shorter than the period of wave loads and are constituted by:

- side shell impacts and, for multihull, platform bottom impact: to be calculated for the plating and the secondary stiffeners only (see [3.1])
- bottom impact pressure on flat bottom forward area: to be calculated for the structural elements of forward bottom, where applicable (see [3.3])
- bottom slamming pressure: to be calculated for the structural elements of the bottom of planing hull as defined in Ch 1, Sec 1, [2.1.5] (see [3.3]) where slamming may occur.

Note 1: Side shell primary stiffeners and platform bottom primary stiffeners are, as a general rule, examined with sea pressures only, without taking into account the side shell and platform bottom impacts.

c) Local internal pressure

Local internal pressures are loads induced by liquid cargoes, dry cargoes, accommodations, testing loads and flooding loads.

d) Wheel loads on deck, when applicable.

2 Sea pressures

2.1 Ship relative motions

2.1.1 General

Ship motions are defined, with their sign, according to the reference co-ordinate system in Ch 1, Sec 1, [5] and are assumed to be periodic.

The ship relative motions h_1 are the vertical oscillating translations of the sea surface on the ship side. It is measured, with its sign, from the waterline at draught T and may be assumed as being:

- symmetrical on the ship sides (upright ship conditions)
- with an amplitude equal to the half of the crest to through of the encountered wave.

The ship relative motions h_1, in m, are to be calculated for cargo and non cargo ships as defined in Tab 1.

2.2 Sea pressures

2.2.1 Bottom and side shell

The sea pressure on bottom and side shell in the different longitudinal parts of the hull are obtained, in kN/m², as follows:

- for bottom structure:

$$P_S = \rho g(T + h_1 + h_2 - z_0)$$

Note 1: In case of important deadrise angle, the bottom sea pressure may be calculated as defined for the side shell structure.

- for side shell structure:

  the greater value obtained from the following formulae, without being taken greater than the sea pressure calculated for the bottom:

$$P_S = \rho g(T + h_1 + h_2 - z)$$

$$P_S = \rho g\left(T + \frac{0,8B_1}{2}\sin A_R - z\right)$$

$$P_S = P_{dmin}$$

where:

z_0 : Distance, in m, between the base line and the hull bottom in the considered section (see Fig 1). z_0 is to be taken negative if the hull bottom in the considered section is located below the base line

z : Distance, in m, between the base line and the calculation point in the considered section (see Fig 1)

P_{dmin} : Minimum sea pressure on exposed deck, in kN/m², as defined in [2.2.2], in the considered section, with φ_1 and φ_3 taken equal to 1,00

h_1 : Ship relative motion, in m, in the different longitudinal parts of the hull as defined in Tab 1

A_R : Roll angle, in deg, to be taken equal to:

- for monohull cargo ship: $A_R = 20°$
- for monohull non cargo ship: $A_R = 25°$
- for catamaran: $A_R = 10°$
- for swath: $A_R = 5°$

h_2 : Parameter, in m, equal to:

- for monohull: $h_2 = 0$
- for catamaran:
  - for bottom, internal side shell and platform bottom:

$$h_2 = \frac{B_{WLi}(T + h_1)C_B}{B_E - B_{WLi}}$$

  - for external side shell: $h_2 = 0$
- for swath:
  - for bottom, internal side shell and platform bottom:

$$h_2 = \frac{B_{STi}(T + h_1)C_B}{B_E - B_{STi}}$$

  - for external side shell: $h_2 = 0$

B_1 : Reference breath to be taken as follows:

- for monohull: $B_1 = B_{WLi}$
- for catamaran: $B_1 = B_E + B_{WLi}$
- for swath: $B_1 = B_E + B_{STi}$

where:

B_{WLi}, B_E, B_{STi}:Moulded breaths as defined in Ch 1, Sec 1, [4.3], measured at the middle of the area considered.

Table 1 : Ship relative motion h_1

Location	Relative motion h_1, in m, for cargo ship	Relative motion h_1, in m, for non cargo ship
from aft part to 0,25 L_{WL}	$h_{1,A} = 0,63\left(\frac{4,35}{\sqrt{C_B}} - (3,25)\right)h_{1,m} \geq h_{1,m}$	$h_{1,A} = 1,1h_{1,m}$
from 0,25 L_{WL} to 0,70 L_{WL}	$h_{1,m} = 0,36nC_W(C_B + 0,7)$ **(1)**	$h_{1,m} = (0,38C_W + 0,3)n$ **(2)**
from 0,70 L_{WL} to 0,85 L_{WL}	$h_{1,E} = h_{1,m} + 0,125h_{1,FE} \leq h_{1,FE}$	$h_{1,E} = \frac{1,4h_{1,m} + 0,7h_{1,FE}}{2}$
from 0,85 L_{WL} to fore part	$h_{1,FE} = 1,2h_{1,m}\left(\frac{4,35}{\sqrt{C_B}} - 3,25\right)C_H$	$h_{1,FE} = 1,7h_{1,m}\left(\frac{7,6}{C_B^{0,1}} - 6,4\right)C_H$

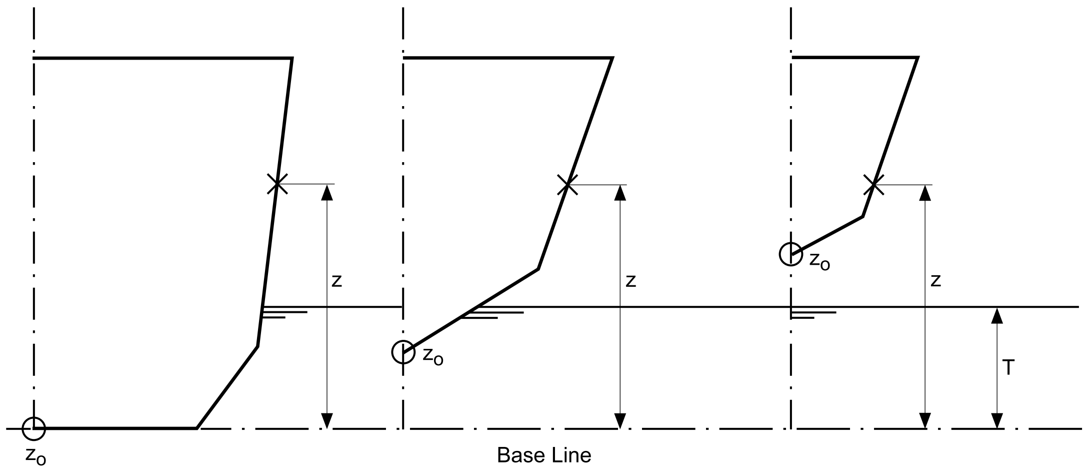
Note 1:

C_H : Coefficient, to be taken as follows:
- for monohull: C_H = 1,00
- for catamaran: C_H = 1,20
- for swath: C_H = 0,75

(1) The value of $h_{1,m}$ is not to be taken greater than the minimum of T and (D – 0,9 T_B).

(2) The value of $h_{1,m}$ is not to be taken greater than T.

Figure 1 : Z co-ordinate at the calculation point



2.2.2 Exposed deck

The local external loads due to green sea, in kN/m², on exposed decks are obtained from the following formula:

$p_d = (p_0 - 10\ z_d)\ \varphi_1\ \varphi_2\ \varphi_3 \geq p_{dmin}$

where:

p_0 : Sea pressure, in kN/m², in the considered section calculated at the base line according to [2.2.1] (z_0 taken equal to 0)

z_d : Vertical distance, in m, between the deck and the base line at the considered transverse section

φ_1 : Coefficient for pressure on exposed deck, equal to:
- for freeboard deck: φ_1 = 1,00
- for top of lowest tier: φ_1 = 0,75
- for top of second tier: φ_1 = 0,56
- for top of third tier: φ_1 = 0,42
- for top of fourth tier and above: φ_1 = 0,32

φ_2 : Coefficient taken equal to:

$$\varphi_2 = \frac{L_{WL}}{120} \geq 0,42$$

φ_3 : Reduction coefficient, equal to:
- when the deck is partially protected (not directly exposed to green sea effect): φ_3 = 0,70
- in the other case: φ_3 = 1,00

Note 1: A deck may be considered as partially protected when the deck is located directly behind a transversal aft wall of a superstructure or a roof. In this case, the surface of the deck to be considered as partially protected may be taken equal to 60% of the vertical aft wall superstructure or roof surface.

p_{dmin} : Minimum sea pressure on deck, in kN/m², equal to:

- from aft part to 0,70 L_{WL}: $p_{dmin} = 17{,}5\ n\ \varphi_1\ \varphi_2\ \varphi_3 > 5$
- from 0,70 L_{WL} to fore part: $p_{dmin} = 19{,}6\ n\ \varphi_1\ \varphi_2\ \varphi_3 > 7$

2.2.3 Exposed deck with cargo

As a rule, for exposed deck supporting cargo, the local external load, in kN/m², to consider for the scantling of stiffeners are the combination of the:

- cargo load as defined in Sec 4, [3] on the area where the deck is loaded by the cargo, and
- external load due to green sea as defined in [2.2.2] in the area where the deck is not protected by the cargo and subject to green seas.

2.2.4 Other type of exposed deck

The local external loads of exposed deck not directly exposed to sea pressure and not accessible to the passengers and/or crew may be taken equal to 1,3 kN/m².

The local external loads on superstructures decks are defined in Ch 5, Sec 1.

Local forces on deck induced by containers, lashing, wheel loads, etc, are to be calculated as defined in Sec 4.

3 Dynamic sea pressures

3.1 Side shell impact and platform bottom impact

3.1.1 General

The side shell impact and the platform bottom impact (for multihull) are local loads and represents the local wave impact acting on the hull, independently of the ship motion.

These impacts are considered as locally distributed like a water column of 0,6 m diameter and is to be applied above the scantling draught for:

- the side shell and bulwarks: on all the length of the ship
- the lowest tier of side walls of superstructure, where the side wall is in the prolongation of the side shell as defined in Ch 5, Sec 1, [1.2.7].

The side shell impact and platform bottom impact (for multihull) may be disregarded for ships having the service notation **launch** or **sheltered water** or having an operating area notation assigned to ships intended to operate only within 5 miles from shore.

3.1.2 Impact calculation on side shell

The impact pressure p_{ssmin}, in kN/m², acting on the side shell is not to be less than:

$p_{ssmin} = C_i\ n_1$

where:

C_i : Dynamic load, in kN/m² defined in Tab 2.

n_1 : Coefficient depending on the assigned navigation notation or operating area notation, to be taken equal to:

- 1 for **unrestricted navigation**
- 0,9 for **summer zone**
- 0,8 for **tropical zone**
- 0,7 for **coastal area** or operating area notation assigned to ships intended to operate only within 20 miles from shore
- 0,6 for **sea going launch**.

Table 2 : Dynamic load C_i on side shell

	from T to T+1, in m	from T+1 to T+3, in m	above T+3, in m
from aft part to 0,70 L_{WL}	55	40	30
from 0,70 L_{WL} to fore part	70	55	30

3.1.3 Impact calculation on internal side shell and platform bottom of multihull

The impact pressure p_{ssmin}, in kN/m², acting on the internal side shell and on the platform bottom is not to be less than:

$p_{ssmin} = C_i\ n_1$

where:

C_i : Dynamic load, in kN/m² defined in Tab 3.

Table 3 : Dynamic load C_i on internal side shell and on platform bottom of multihull

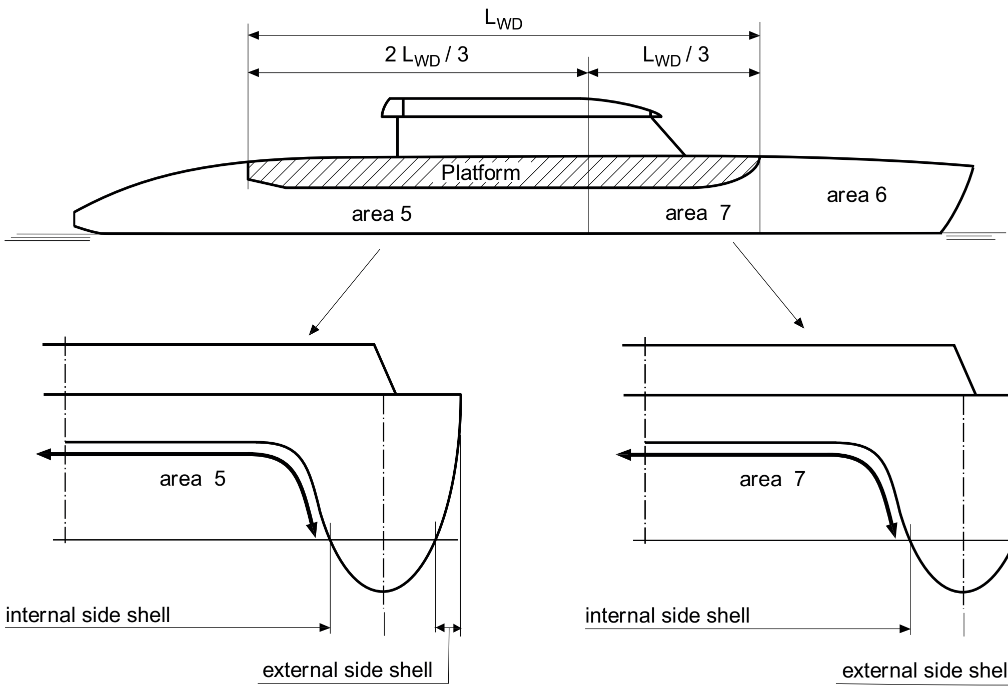
Areas (see Fig 2)	from T to T+1, in m	from T+1 to T+3, in m	above T+3, in m
Area 5	55	40	30
Area 6	70	55	30
Area 7	80	70	50

n_1 : Coefficient depending on the assigned navigation notation or operating area notation, to be taken equal to:

- 1 for **unrestricted navigation**
- 0,9 for **summer zone**
- 0,8 for **tropical zone**
- 0,7 for **coastal area** or operating area notation assigned to ships intended to operate only within 20 miles from shore
- 0,6 for **sea going launch**.

When the platform of multihull is extended up to the fore float, the fore area 6 is to be considered as area 7 (see Fig 2).

Figure 2 : Load areas for impact pressure on multihull



3.2 Bottom impact pressure for flat bottom forward area

3.2.1 Application

The present requirements are applicable for ships having:

- a navigation notation other than **sheltered area**
- a flat bottom shape on the forward hull body, and
- a minimum forward draught, in m, in ballast condition or in partial loading operation less than 0,04 L.

Note 1: For pontoon shaped ships, when a reduction of the speed is provided in relation with the sea state to avoid bottom impact pressure for flat bottom area, the present requirements are not applicable.

Note 2: For ships having the navigation notation **coastal area**, a reduction of 20% may be applied on the bottom impact pressure, on a case-by-case basis.

3.2.2 Area to be considered

The flat bottom area is considered as the area limited to:

- longitudinally: area in aft of the fore end, from 0,05 L_{WL} to 0,25 (1,6 – C_B) L_{WL} , without being taken less than 0,2 L_{WL} nor greater than 0,25 L_{WL}
- transversely and vertically: over the whole flat bottom and the adjacent zones up to a height from the base line not less, in mm, than 2 L_{WL} , limited to 300 mm.

3.2.3 Bottom impact pressure for flat bottom area

a) Plating and secondary stiffeners

The bottom impact pressure p_{BI} in kN/m², for the plating and secondary stiffeners is to be obtained from the following formula:

$$p_{BI} = 62 C_1 L_{WL}^{0,6}$$

where:

- general case:

$$C_1 = \frac{119 - 2300\frac{T_{Fmin}}{L_{WL}}}{78 + 1800\frac{T_{Fmin}}{L_{WL}}}$$

with $0 < C_1 \leq 1$

- non propelled units:

$$C_1 = \frac{119 - 2300\frac{T_{Fmin}}{L_{WL}}}{156 + 3600\frac{T_{Fmin}}{L_{WL}}} + 0,09$$

with $0 < C_1 \leq 0,59$

where:

T_{Fmin} : Minimum forward draught, in m.

b) Primary stiffeners

The bottom impact pressure in kN/m², for the primary stiffeners is to be taken equal to 0,3 p_{BI} , where p_{BI} is the bottom impact pressure for plating and secondary stiffeners calculated in item a).

3.3 Bottom slamming for planing hull

3.3.1 General

Slamming phenomenon on bottom area, induced by heave acceleration in planing hull mode, is to be considered on planing hull as defined in Ch 1, Sec 1, [2.1.5].

As a rule, bottom slamming loads are to be calculated on bottom area, up to the limit of bilges or hard chines, and from the transom to the fore end, for monohull and catamaran.

3.3.2 Bottom slamming pressures

The slamming pressure p_{sl} , in kN/m², considered as acting on the bottom of planing hull is to be not less than:

$$P_{sl} = P_{sl1}\ K_2$$

where:

K_2 : Area factor defined in [3.3.3], item b)

P_{sl1} : Design bottom slamming pressure, in kN/m², equal to: $P_{sl1} = 100\ T\ K_1\ K_3\ a_{CG}$

K_1 : Distribution factor defined in [3.3.3], item a)

K_3 : Bottom shape factor defined in [3.3.3], item c)

a_{CG} : Vertical design acceleration at L_{CG} , expressed in g, defined in [3.3.4].

3.3.3 Dynamic load factors K_i

The dynamic load factors K_i are to be calculated as follows:

a) Distribution factor K_1

The longitudinal slamming pressure distribution factor K_1 for the calculation of the design bottom slamming pressure in planing hull mode is defined in Tab 4.

b) Area factor K_2

The area factor K_2 is a coefficient taking into account the dimension and the material of the structure element submitted to bottom slamming load. This factor is defined by the following formula:

$$K_2 = 0,455 - 0,35\frac{u^{0,75} - 1,7}{u^{0,75} + 1,7} \geq K_{2min}$$

where:

$$u = 100\frac{s_a}{S_r}$$

s_a : Area, in m², supported by the element (plating, stiffener, floor or bottom girder)

For plating, the supported area is the spacing between the stiffeners multiplied by their span (the span is not to be taken more than three times the spacing between the stiffeners)

S_r : Reference area, in m², equal to:

$$S_r = 0,7\frac{\Delta}{T}$$

Note 1: For catamaran, Δ is to be taken as half of the total displacement.

K_{2min} : Minimum values of K_2 , taken equal to:

- for steel, aluminium and HDPE structure:
  - $K_{2min} = 0,50$ for plating
  - $K_{2min} = 0,45$ for secondary stiffeners
  - $K_{2min} = 0,35$ for primary stiffeners
- for composite and plywood structure:
  - $K_{2min} = 0,15$ for plating and for secondary stiffeners
  - $K_{2min} = 0,35$ for primary stiffeners.

c) Bottom shape factor K_3

The bottom shape and deadrise factor K_3 for the calculation of the design bottom slamming load is defined by the following formula:

$$K_3 = \frac{70 - \alpha_d}{70 - \alpha_{dCG}} \leq 1$$

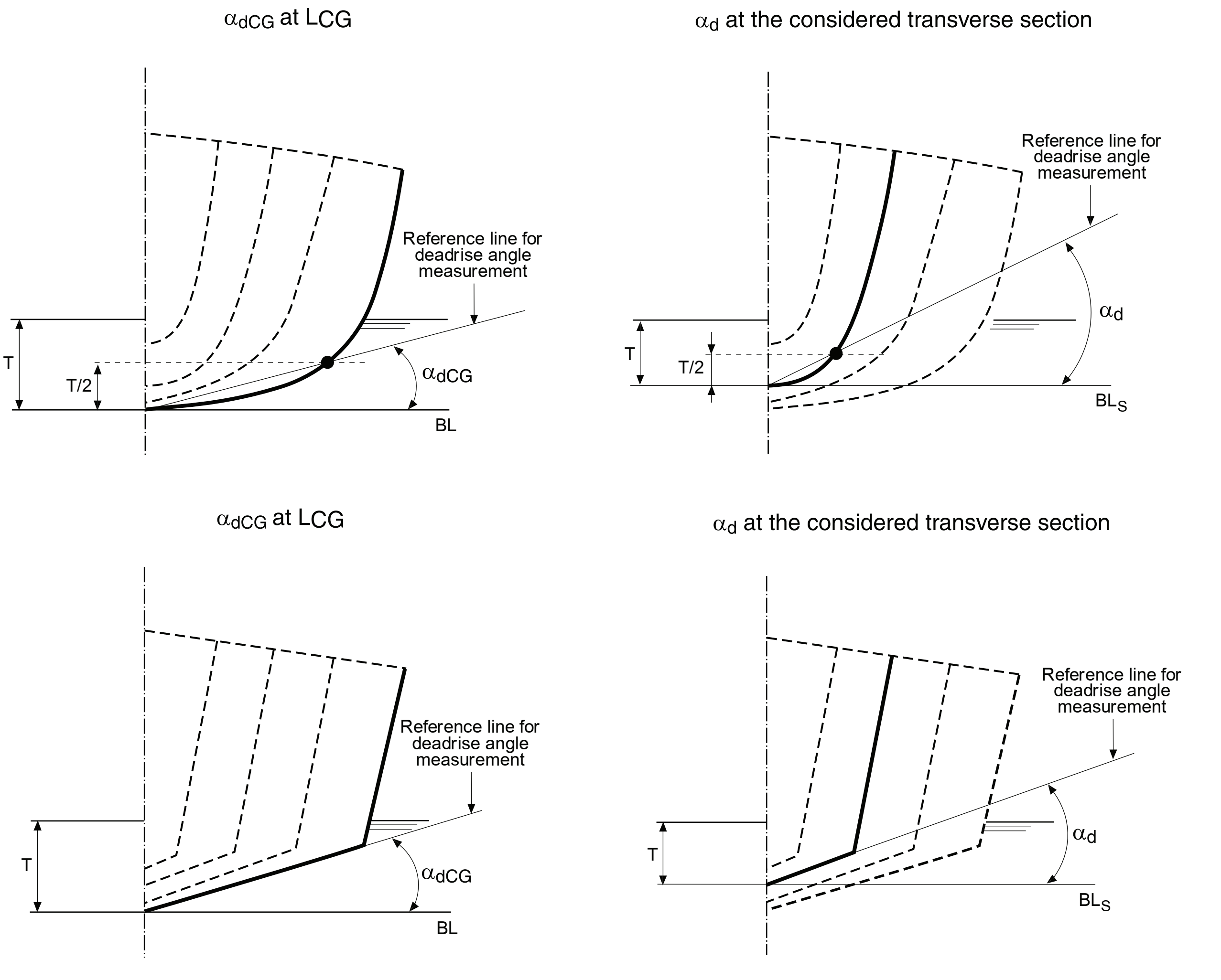
where:

α_d : Deadrise angle at the considered transverse section, in deg (see Fig 3)

α_{dCG} : Deadrise angle, in deg, measured at the ship longitudinal centre of gravity L_{CG} (see Fig 3).

The values taken for α_d and α_{dCG} are to be between 10° and 50°.

Figure 3 : Deadrise angles α_{dCG} and α_d



BL : Base line at L_{CG} ; BL_S : Base line at the considered transverse section

Table 4 : Longitudinal slamming pressure distribution factor K_1

Location	K_1
from aft part to 0,25 L_{WL}	0,60
from 0,25 L_{WL} to 0,70 L_{WL}	0,90
from 0,70 L_{WL} to 0,85 L_{WL}	1,00
from 0,85 L_{WL} to fore part	0,75

3.3.4 Design vertical acceleration a_{CG} at L_{CG}

a) Design vertical acceleration

The design vertical acceleration a_{CG} calculated at L_{CG} is to be defined by the Designer and is to correspond to the highest accelerations deduced by the relationship between instantaneous ship speeds associated to wave heights encountered at the different considered speeds.

The design vertical acceleration a_{CG} is to be considered as a relative acceleration, expressed in g, in addition to the gravity acceleration.

b) It is the Designer responsibility to specify the range of speeds where the ship is in planing hull mode and to define a relation between the speed and the height of the wave that provides a maximum vertical acceleration less than the design value considered for the hull structure review. This relation may be determined on the basis of the results of model tests or full-scale measurements.

c) Vertical acceleration specification

The value of the vertical acceleration at L_{CG} is a basis for the structure scantling review within the scope of classification. The value of the maximum vertical acceleration a_{CG} , expressed in g, considered for the structure review is to be specified on the midship section drawing.

3.3.5 Information in relation to the design vertical acceleration

a) Information for vertical acceleration

For information only, when the Designer value of the vertical acceleration is not available, the following value of a_{CG} , expressed in g, may be used taking into account the type of service and the navigation notation as defined in Ch 1, Sec 1, [1.1.3]:

$$a_{CG} = foc \cdot soc\frac{V}{\sqrt{L_{WL}}}$$

where:

foc, soc : Values given, respectively, in Tab 5 and Tab 6.

b) Information about relation between instantaneous speeds and associated wave heights

For information only, where the relation between the speeds and the associated wave heights is not defined by the Designer, the following formula may be used between instantaneous speeds V_x and associated wave heights H_S in planing hull mode compatible with the design acceleration considered for the hull structure check:

$$a_{CG} = \frac{(50-\alpha_{dCG})\left(\frac{\tau}{16}+0,75\right)}{3555C_B}\left(\frac{H_S}{T}+0,084\frac{B_W}{T}\right)K_{FR}K_{HS}$$

where:

H_S : Associated wave height, in m, to the considered speed V_x

a_{CG} : Design vertical acceleration, in g, considered for the structure scantling review

V_x : Speed considered, in knots

α_{dCG} : Deadrise angle, in deg, at L_{CG} . In this formula, α_{dCG} is to be taken between 10° and 30°

τ : Trim angle during navigation, in deg, to be taken not less than 4°

B_W : Maximum breadth at full load waterline. For catamarans, B_W is to be taken as the sum of the breadth of each hull

K_{FR} , K_{HS} : Coefficients defined as follows:

- for planing hull for which $V/L^{0,5} \geq 3$ and $\Delta/(0,01L)^3 \geq 3500$:

$$K_{FR} = \left(\frac{V_x}{\sqrt{L_{WL}}}\right)^2$$

$K_{HS} = 1$

- for planing hull for which $V/L^{0,5} < 3$ or $\Delta/(0,01L)^3 < 3500$:

$$K_{FR} = 0,8+1,6\frac{V_x}{\sqrt{L_{WL}}}$$

$K_{HS} = H_S / T$

Table 5 : Values of foc

Type of service	Passenger, Ferry, Cargo	Supply, Fishing	Pilot, Patrol	Rescue
foc	0,666	1,000	1,333	1,666
Note 1: As a rule, foc is to be taken equal to 0,666 for **launch** and **sea going launch**.				

Table 6 : Values of soc

Navigation notation	**Unrestricted navigation**	**Summer zone**	**Tropical zone** or **coastal area (3)**	**Sheltered area (4)**
Wave height (for information only) **(1)**	$H_s \geq 4{,}0$ m or $2{,}5$ m $\leq H_s < 4{,}0$ m		$0{,}5$ m $< H_s < 2{,}5$ m	$H_s \leq 0{,}5$ m
soc	C_F **(2)**	0,30	0,23	0,14

(1) Wave heights, given for information only, in relation with the navigation notations are wave heights which are exceeded for an average of not more than 10% of the year.

(2) For passenger, ferry and cargo ship, their seaworthiness in this condition is to be ascertained. In general, the value of soc should not be less than the values given in this Table, with:

$$C_F = 0,2 + \frac{0,6}{V/\sqrt{L_{WL}}} \geq 0,32$$

(3) Not applicable to ships having the type of service "Rescue".

(4) Not applicable to ships having the type of service "Pilot, Patrol" or "Rescue".
As a rule, applicable to ships having the navigation notation **sea going launch** or **launch**.

The formula of H_S is only valid if all the following relationships are simultaneously complied with:

- $3500 < \Delta / (0{,}01\ L_{WL})^3 < 8700$
- $3 < L_{WL} / B_W < 5$
- $10° < \alpha_{dCG} < 30°$
- $0{,}2 < H_S / B_W < 0{,}7$
- $3{,}0 < V / (L_{WL})^{0{,}5} < 10{,}9$

3.4 Bottom slamming pressure of ships fitted with a wind propulsion system

3.4.1 Ships fitted with a wind propulsion system and having a hull shape similar to a monohull sailing yacht is to be examined on a case by case basis where bottom slamming may occur on the bottom. In this case, the bottom slamming pressures is to be determined as defined in NR500 Yacht, Ch 4, Sec 3, [3.2.2] item b) calculated for cruise sailing yacht, considering:

- a soc coefficient as defined in Tab 6
- deadrise angles as defined in [3.3.3], reduced by 20°, without being less than 0°, in order to account for the heel angle while sailing.

Section 4 Local Internal Pressures and Forces

Symbols

a_z : Vertical acceleration, in m/s², defined in [2.2]
B : Moulded breadth, in m, as defined in Ch 1, Sec 1, [4.3.1]
B_{WL} : Waterline breadth, in m, as defined in Ch 1, Sec 1, [4.3.2]
B_E : Breadth between multihull floats, in m, as defined in Ch 1, Sec 1, [4.3.3]
B_{SF} : Moulded breadth, in m, of the submerged float of swath, as defined in Ch 1, Sec 1, [4.3.4]
C_W : $C_W = 0{,}625\ (118 - 0{,}36\ L_W)\ L_W\ 10^{-3}$
C_B : Total block coefficient as defined in Ch 1, Sec 1, [4.6]
g : Gravity acceleration taken equal to 9,81 m/s²
L_{WL} : Length at waterline at full load, in m
L_{HULL} : Length of the hull from the extreme forward part to the extreme aft part of the hull, in m
L_W : $L_W = 0{,}5\ (L_{WL} + L_{HULL})$
n : Navigation coefficient as defined in Ch 1, Sec 1, [3]
ρ : Sea water density, taken equal to 1,025 t/m³.
V : Maximum ahead service speed, in knots

1 Application

1.1 General

1.1.1 The local internal pressures and forces are based on the ship accelerations calculated on the basis of the present Section.

1.1.2 Definition

Local internal pressures are loads induced by liquid cargoes, dry cargoes, accommodations, wheeled loads when applicable, testing loads and flooding loads.

1.1.3 Planing hull

As a rule, the local internal pressures and forces for planing hull are to be calculated taking into account the accelerations in planing hull mode condition and in displacement hull mode condition.

2 Ship accelerations

2.1 Reference values

2.1.1 The reference values of the vertical and transverse accelerations, and the amplitude taken into account in the present Section are considered equal to the values given in the present Article.

2.1.2 As an alternative, the Society may accept the values of ship accelerations derived from direct calculations or obtained from model tests, when justified on the basis of the ship characteristics and the intended service.

2.1.3 The motions and accelerations are defined:

- in displacement mode: in [2.1.4] to [2.1.7] and in [2.2.1]
- in planing mode: in [2.2.2].

2.1.4 Motion and acceleration parameter

The motions and accelerations are based on a parameter a_B to be taken equal to:

$$a_B = n\left(0{,}76F + 2{,}5\frac{C_W}{L_{WL}}\right)$$

where:

F : Froude's number equal to:

$$F = 0{,}164(V/\sqrt{L_{WL}}) \le 0{,}33$$

Note 1: At a preliminary design stage when V is unknown, F may be taken equal to 0,33.

2.1.5 Heave

The heave acceleration a_H, in m/s², is obtained from the following formulae:

- for cargo ships: $a_H = a_B\, g$
- for non cargo ships: $a_H = 1{,}25\, a_B\, g$

2.1.6 Pitch

The pitch acceleration α_p, in rad/s², is obtained from the following formula:

$$\alpha_p = A_p \left(\frac{2\pi}{T_p}\right)^2 n$$

where:

A_p : Pitch amplitude A_p, in rad, equal to: $A_p = (1 - L_{WL}\, 10^{-3})\, C_{Ap}$

with:

- for cargo ships:

  $C_{Ap} = 0{,}14$ for monohull

  $C_{Ap} = 0{,}16$ for catamaran

  $C_{Ap} = 0{,}21$ for swath

- for non cargo ships:

  $C_{Ap} = 0{,}16$ for monohull

  $C_{Ap} = 0{,}16$ for catamaran

  $C_{Ap} = 0{,}21$ for swath

T_p : Pitch period, in s:

- for cargo ships:

  $T_p = 0{,}56\, (L_{WL})^{0,5}$ for monohull

  $T_p = 0{,}51\, (L_{WL})^{0,5}$ for catamaran

  $T_p = 0{,}69\, (L_{WL})^{0,5}$ for swath

- for non cargo ships:

  $T_p = 0{,}52\, (L_{WL})^{0,5}$ for monohull

  $T_p = 0{,}51\, (L_{WL})^{0,5}$ for catamaran

  $T_p = 0{,}69\, (L_{WL})^{0,5}$ for swath.

2.1.7 Roll

The roll acceleration α_R, in rad/s², is obtained from the following formula:

$$\alpha_R = A_R \left(\frac{2\pi}{T_R}\right)^2 n$$

where:

A_R : Roll amplitude, in rad:

- for cargo ships:

  $A_R = 0{,}35$ for monohull

  $A_R = 0{,}17$ for catamaran

  $A_R = 0{,}08$ for swath

- for non cargo ships:

  $A_R = 0{,}43$ for monohull

  $A_R = 0{,}17$ for catamaran

  $A_R = 0{,}08$ for swath

T_R : Roll period, in s, equal to:

$$T_R = 2,2\frac{\delta}{\sqrt{GM}}$$

with:

- for cargo ships:
  - for monohull:
    $GM = 0,13\ B_{WL}$ and $\delta = 0,35\ B$
  - for catamaran:
    $GM = 1,8\ B_E$ and $\delta = 0,35 B_E$
  - for swath:
    $GM = 0,9\ B_E$ and $\delta = 0,35 B_{SF}$
- for non cargo ships:
  - for monohull:
    $GM = 0,22\ B_{WL}$ and $\delta = 0,35\ B$
  - for catamaran:
    $GM = 1,8\ B_E$ and $\delta = 0,35 B_E$
  - for swath:
    $GM = 0,9\ B_E$ and $\delta = 0,35 B_{SF}$

2.2 Vertical accelerations

2.2.1 Cargo and non cargo ship

The vertical acceleration a_z , in m/s², to be taken into account in relation to the ship location areas is to be as defined in Tab 1.

Table 1 : Vertical acceleration a_z

Location	a_z , in m/s²	
	Cargo ship	Non cargo ship
from aft part to 0,25 L_{WL}	$\sqrt{a_H^2 + \alpha_p^2(0,40L_{WL})^2}$	$\sqrt{a_H^2 + \alpha_p^2(0,30L_{WL})^2}$
from 0,25 L_{WL} to 0,70 L_{WL}	$\sqrt{a_H^2 + \alpha_p^2(0,20L_{WL})^2}$	$\sqrt{a_H^2 + \alpha_p^2(0,20L_{WL})^2}$
from 0,70 L_{WL} to 0,85 L_{WL}	$\sqrt{a_H^2 + \alpha_p^2(0,40L_{WL})^2}$	$\sqrt{a_H^2 + \alpha_p^2(0,30L_{WL})^2}$
from 0,85 L_{WL} to fore part	$\sqrt{a_H^2 + \alpha_p^2(0,55L_{WL})^2}$	$\sqrt{a_H^2 + \alpha_p^2(0,50L_{WL})^2}$

2.2.2 Planing hull

The vertical acceleration a_z , in m/s², to be taken into account in relation to the ship location for planing hull in planing mode is to be taken equal to the following values:

a) At speed in displacement mode:

a_z as defined in [2.2.1] for cargo or non cargo ships, as applicable

b) At maximum speed in planing mode:

$a_z = g\ a_V$

where:

$a_V = K_V\ a_{CG}$

with:

K_V : As defined in Tab 2

a_{CG} : Design vertical acceleration at L_{CG} as defined in Sec 3, [3.3.4]

L_{CG} : Midship perpendicular as defined in Ch 1, Sec 1, [4.2.3].

Table 2 : Value of K_V

Location	K_V
from aft part to 0,25 L_{WL}	1,00
from 0,25 L_{WL} to 0,70 L_{WL}	1,20
from 0,70 L_{WL} to 0,85 L_{WL}	1,55
from 0,85 L_{WL} to fore part	1,85

3 Internal loads

3.1 Internal load calculations

3.1.1 Vertical acceleration parameters

The vertical acceleration parameters to take into account for the internal load calculations are as follow:

a) for displacement hull:
- vertical acceleration a_z, in m/s²: As defined in [2.2.1]
- vertical acceleration coefficient η: To be taken equal to 1

b) for planing hull:
- vertical acceleration a_z, in m/s²: As defined in [2.2.2]
- vertical acceleration coefficient η: To be taken equal to 0,4

3.1.2 Internal load calculations

The local internal pressures p, in kN/m², to be considered in the present Article are to be calculated as follow:

a) for displacement hull:

According to [3.2] and [3.3] with a_z and η as defined in [3.1.1] a)

b) for planing hull:

The greater value of the value calculated:
- According to [3.2] to [3.3] with a_z and η as defined in [3.1.1] b)
- According to a) as defined for displacement hull.

3.2 Liquids

3.2.1 Watertight bulkheads

The local internal pressure p, in kN/m², on watertight bulkheads, bottom and top of liquid capacity is to be taken equal to the greater value obtained from the following formulae, taking into account [3.1.2]:

$$p = \rho_L\left[0,15\eta g\frac{\ell_b}{2} + a_z\eta(z_{TOP} - z) + g(z_L - z)\right]$$

$$p = \rho_L(g + a_z\eta)(z_{TOP} - z) + 100p_{pv} + 0,15\eta g\rho_L\frac{\ell_b}{2}$$

where:

ρ_L : Density of the liquid considered, in t/m³

a_z, η : Vertical acceleration parameters defined in [3.1.1]

ℓ_b : Longitudinal distance, in m, between the transverse capacity boundaries or the transverse wash bulkheads, if any, satisfying the requirements in [3.2.2]

z_{TOP} : z co-ordinate, in m, of the highest point of the capacity (see Fig 1)

z : z co-ordinate of the calculation point, as defined in Sec 1, [4]

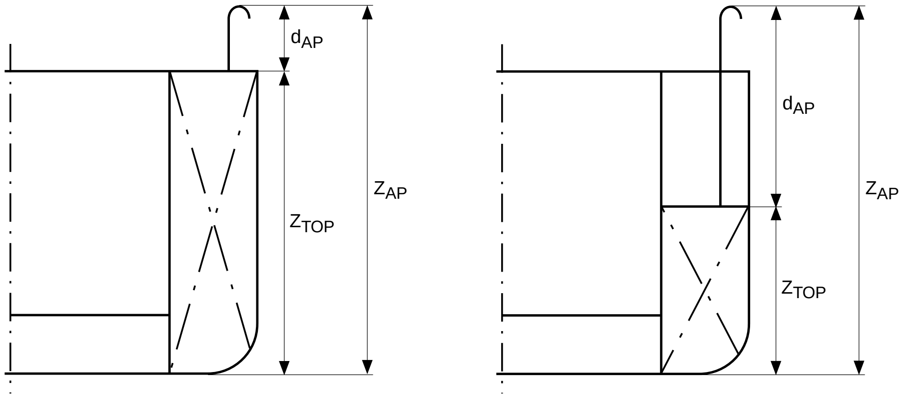
p_{pv} : Setting pressure, in bar, of safety valves, if any

z_L : $z_L = z_{TOP} + 0,5\,(z_{AP} - z_{TOP})$

with:

z_{AP} : z co-ordinate, in m, of the top of air pipe (see Fig 1).

Figure 1 : z co-ordinates



3.2.2 Wash bulkheads

The local internal pressure p, in kN/m², acting on wash bulkheads is obtained as follows:

- for transverse wash bulkheads:
  $p = 4,4\ \rho_L\ n\ \ell_c\ (1 - \alpha)\ 0,15$
- for longitudinal wash bulkheads:
  $p = 4,4\ \rho_L\ n\ b_c\ (1 - \alpha)\ 0,35$

with $p \geq 0,8\ g\ d_0$

where:

ρ_L : Density of the liquid considered, in t/m³

ℓ_c : Longitudinal distance, in m, between transverse bulkheads (watertight or wash)

b_c : Transverse distance, in m, between longitudinal bulkheads (watertight or wash)

α : Ratio of lightening hole area to the total bulkhead area, not to be taken greater than 0,3

d_0 : Distance, in m, to be taken equal to: $d_0 = 0,02\ L \leq 1,00$

3.3 Dry cargoes

3.3.1 Dry uniform cargo

The pressure p, in kN/m², transmitted to the structure by dry uniform cargo is to be taken equal to the following formula, taking into account [3.1.2]:

$$p = p_s\left(1 + \frac{a_z \eta}{g}\right)$$

where:

p_s : Design pressure given by the Designer
When this value is not defined, p_s may be taken equal to $6,9\ h_{TB}$, where h_{TB} is the compartment height at side

a_z, η : Vertical acceleration parameters defined in [3.1.1]

3.3.2 Dry bulk cargo

The pressure p, in kN/m², transmitted to the structure by dry bulk cargo is to be taken equal to the greater value obtained from the following formulae, taking into account [3.1.2]:

$$p = p_{DB}\left(1 + \frac{a_z \eta}{g}\right)$$

$$p = \rho_B (g + a_z \eta)(h_b + h_t - h_z) K_B$$

where:

ρ_B : Density of the dry bulk carried, in t/m³

p_{DB} : Design pressure on the double bottom, in kN/m², given by the Designer

a_z, η : Vertical acceleration parameters defined in [3.1.1]

h_b : Height, in m, from the bottom cargo hold, of the rated surface of the bulk, to be taken equal to:

$$h_b = \frac{M_c}{\ell_c b_c \rho_B}$$

with:

M_c : Total mass of cargo, in t, in the considered hold

ℓ_c : Longitudinal distance, in m, between transverse hold bulkheads

b_c : Transverse distance, in m, between longitudinal hold bulkheads

h_t : Height, in m, of the bulk cargo upper surface, to be taken equal to:

$$h_t = \frac{b_c}{4}\tan\frac{\varphi}{2}$$

with:

φ : Angle of repose, in deg, of the bulk cargo considered drained and removed (in absence of precise evaluation, φ may be taken equal to 30°)

h_z : Vertical distance, in m, from the bottom hold to the calculation point

K_B : Coefficient, taken equal to:

- K_B = 0,4 when the dry bulk pressure is applied on a vertical structure element
- K_B = 1,0 in the other cases.

3.3.3 Dry unit cargo

The forces transmitted to the hull structures are to be determined on the basis of the forces F_z, in kN, calculated as follows, taking into account [3.1.2]:

$$F_z = M\,(g + a_z\,\eta)$$

where:

M : Total mass, in t, of the dry unit cargo considered

a_z, η : Vertical acceleration parameters defined in [3.1.1]

Where deemed necessary by the Society for dry unit cargo located above the water line level, the horizontal and vertical forces applied to the dry unit cargo, in kN, induced by roll may be taken into account in addition to F_z.

In this case, the forces F_T and F_V, in kN, transmitted to the hull structure and to be added to F_z may be calculated as follows:

- transverse force: $F_T = 0{,}7\ M\ \alpha_R\ (z - T_{min})$
- vertical force: $F_V = 0{,}7\ M\ \alpha_R\ y$

where:

M : Mass, in t, of the dry unit cargo considered

α_R : Roll acceleration, in rad/s^2, as defined in [2.1.7]

y, z : Transverse and vertical co-ordinates of the centre of gravity of the dry unit considered

T_{min} : Minimum draught of the ship, in m.

4 Loads on deck

4.1 Deck load calculations

4.1.1 Vertical acceleration parameters

The vertical acceleration parameters to take into account for the deck load calculations are defined in [3.1.1].

4.1.2 Deck load calculations

The pressure on deck p, in kN/m^2, to be considered in the present Article are to be calculated as follow:

a) for displacement hull:

According from [4.2] to [4.4] with a_z and η as defined in [3.1.1] a)

b) for planing hull:

The greater value of the value calculated:

- According from [4.2] to [4.4] with a_z and η as defined in [3.1.1] b)
- According from a) defined for displacement hull.

4.2 Accommodation deck

4.2.1 The pressure on accommodation deck is obtained, in kN/m^2, from the following formula, taking into account [4.1.2]:

$$p = p_s\left(1 + \frac{a_z\eta}{g}\right)$$

where:

a_z : Reference value of the vertical acceleration defined in [2.2]

η : As defined in [3.3.1]

p_s : Pressure defined by the Designer, to be taken at least equal to the values given in Tab 3.

For the assessment of primary supporting members and pillars, the application extent of the pressure p_s may be limited so as to reach the maximum intended deck load (e.g. maximum number of passengers) at positions considered as the most critical.

Table 3 : Minimum values of p_s

Accommodation deck	p_s , in kN/m²
Large public spaces such as restaurants, halls, cinema, lounges	5,0
Large rooms such as rooms with fixed furniture, games and hobbies rooms, hospitals	3,0
Cabins	3,0
Other compartments	2,5

4.3 Specific loads on deck

4.3.1 Machinery spaces

The pressure on decks and platforms located in the machinery spaces is obtained, in kN/m², from the following formula, taking into account [4.1.2]:

$$p = p_s\left(1 + \frac{a_z\eta}{g}\right)$$

where:

a_z : Reference value of the vertical acceleration defined in [2.2]

η : As defined in [3.3.1]

p_s : Pressure defined by the Designer

When this value is not defined, p_s may be taken equal to 10 kN/m².

4.4 Wheeled loads

4.4.1 Local forces

Caterpillar trucks and unusual vehicles are considered by the Society on a case-by-case basis.

The load supported by the crutches of semi-trailers, handling machines and platforms is considered by the Society on a case-by-case basis.

The forces transmitted through the tyres are comparable to the pressure uniformly distributed on the tyre print, the dimensions of which are to be indicated by the Designer together with the information concerning the arrangement of wheels on axles, the load per axle and the tyre pressures.

For vehicles on rails, all the forces transmitted are to be considered as concentrated.

The forces F_W , in kN, transmitted to the hull structure are to be determined as follows:

- in the general case:

  $F_W = M (g + \alpha\, a_z)$
- in harbour conditions, for fork-lift trucks and vehicles on external ramp:

  $F_W = 1,1\, M\, g$

where:

M : Force, in t, applied by one wheel and calculated as follows:

$$M = \frac{Q_A}{n_W}$$

with:

Q_A : Axle load, in t. For fork-lift trucks, Q_A is to be taken equal to the total mass of the vehicle, including the mass of the cargo handled, applied to one axle only

n_W : Number of wheels for the axle considered

α : Coefficient taken equal to:

- in the general case: $\alpha = 0,5$
- for landing gears of trailers: $\alpha = 1,0$

a_z : Reference value of the vertical acceleration defined in [2.2].

4.5 Exposed deck

4.5.1 The local external loads, in kN/m², on exposed deck are to be as defined in Sec 3, [2.2.2].

5 Testing loads

5.1 General

5.1.1 The testing loads acting on the structures subject to tank testing are obtained, in kN/m², from the formulae in Tab 4. Compartments not defined in Tab 4 are to be tested in accordance with NR467 Steel Ships, Pt B, Ch 5, Sec 6.

Table 4 : Testing load values

Compartment or structure to be tested	Still water pressure p_{ST}, in kN/m²	Remarks
Double bottom tanks	The greater of the following: • $p_{ST} = 10\ [(z_{TOP} - z) + d_{AP}]$ • $p_{ST} = 10\ [(z_{TOP} - z) + 2,4]$ • $p_{ST} = 10\ (z_{BD} - z)$	For Non-SOLAS ships, 2,4 is to be replaced by 0,3D + 0,76 metres above the top of the tank, without being taken greater than 2,4 m
Double side tanks	The greater of the following: • $p_{ST} = 10\ [(z_{TOP} - z) + d_{AP}]$ • $p_{ST} = 10\ [(z_{TOP} - z) + 2,4]$ • $p_{ST} = 10\ (z_{BD} - z)$	
Independent tanks, and Other tanks than those listed elsewhere in this Table	The greater of the following: • $p_{ST} = 10\ [(z_{TOP} - z) + d_{AP}]$ • $p_{ST} = 10\ [(z_{TOP} - z) + 2,4]$	
Peak tanks	The greater of the following: • $p_{ST} = 10\ [(z_{TOP} - z) + d_{AP}]$ • $p_{ST} = 10\ [(z_{TOP} - z) + 2,4]$	
Fuel oil tanks	The greater of the following: • $p_{ST} = 10\ [(z_{TOP} - z) + d_{AP}]$ • $p_{ST} = 10\ [(z_{TOP} - z) + 2,4]$ • $p_{ST} = 10\ [(z_{TOP} - z) + 10\ p_{PV}]$ • $p_{ST} = 10\ (z_{BD} - z)$	
Cargo oil tanks	The greater of the following: • $p_{ST} = 10\ [(z_{TOP} - z) + d_{AP}]$ • $p_{ST} = 10\ [(z_{TOP} - z) + 2,4]$ • $p_{ST} = 10\ [(z_{TOP} - z) + 10\ p_{PV}]$	
Integral or independent cargo tanks of ships with service notation **chemical tanker**	The greater of the following: • $p_{ST} = 10\ [(z_{TOP} - z) + 2,4]$ • $p_{ST} = 10\ [(z_{TOP} - z) + 10\ p_{PV}]$	
Ballast holds of ships with service notation **bulk carrier** or **bulk carrier ESP**	The greater of the following: • $p_{ST} = 10\ [(z_{TOP} - z) + d_{AP}]$ • $p_{ST} = 10\ (z_h - z)$	z_h is the Z co-ordinate, in m, of the top of hatch coaming
Chain locker	• $p_{ST} = 10\ (z_{CP} - z)$	z_{CP} is the Z co-ordinate, in m, of the top of chain pipe
Ballast ducts	The greater of the following: • $p_{ST} = 10\ [(z_{TOP} - z) + 10\ p_{PV}]$ • the ballast pump maximum pressure	

Note 1:

z_{TOP} : Z co-ordinate, in m, of the deck forming the top of the tank excluding any hatchways.
z : z co-ordinate of the calculation point
z_{BD} : Z co-ordinate, in m, of the bulkhead deck
d_{AP} : Distance, in m, from the top of air pipe to the top of the compartment
p_{pv} : Setting pressure, in bar, of the safety relief valves, where relevant.

6 Flooding loads

6.1 General

6.1.1 The internal pressure p_{fl} to be considered on the structure of boundaries of watertight compartments not intended to carry liquids (bulkheads and decks with exception for bottom and side shell structures) is to be obtained, in kN/m², from the following formula:

$p_{fl} = n \rho g d_f$

without being taken less than $0,8 g d_0$

where:

d_f : Height, in m, from the calculation point to the bulkhead deck (or freeboard deck when there is no bulkhead deck). For non Solas ship, where the results of damage stability calculations are available, the deepest equilibrium waterline may be considered in lieu of the bulkhead deck

d_0 : Distance, in m, to be taken equal to:

$d_0 = 1$ if $L_{WL} \leq 50$ m

$d_0 = 0,02 L_{WL}$ if $L_{WL} > 50$ m

CHAPTER 4
HULL SCANTLING

Section 1 General

1 Materials

1.1 General

1.1.1 General

The requirements for the evaluation of the hull scantlings defined in the present Chapter are applicable to ship hull made totally or partly of:

- steel (ordinary or high tensile)
- aluminium alloys
- composites materials
- wood (strip planking or plywood).
- high density polyethylene (HDPE)

Ships built with different hull materials are to be specifically considered on a case-by-case basis.

The offered scantling is to be greater than, or equal to, the required scantlings based on requirements provided in this Chapter.

Attention is drawn to the selection of building materials which is not only to be determined from strength consideration, but should also give consideration to structural fire protection and associated class requirements or Flag Administration requirements where applicable.

1.1.2 Characteristics of materials

The main characteristics of materials to consider for hull scantlings are defined in Ch 1, Sec 2.

1.1.3 Additional hull scantling requirements in relation to the service notation or service feature

Additional hull scantling requirements in relation to the service notation or feature assigned to the ship are to be taken into account as defined in Ch 6, Sec 1.

2 Structure scantling approach

2.1 General

2.1.1 General case

As a rule, the global hull girder strength and the local strength are examined independently.

2.1.2 Particular cases

The combination of global hull girder strength and the local strength may be carried out as defined in Ch 1, Sec 3, [3.1.2].

2.2 Global strength analysis

2.2.1 Analysis

The global hull girder longitudinal strength and the global strength of multihull are to be checked according to Sec 2, taking into account the:

- global loads as defined in Ch 3, Sec 2, and
- permissible stresses and safety factors as defined in Ch 2, Sec 3.

2.2.2 Check

The global strength analysis is carried out in order to check, for the elements contributing to the global hull strength, the hull girder stresses in relation to:

- the maximum permissible global stress, and
- buckling criteria.

2.3 Local scantling analysis

2.3.1 Analysis

The local scantling of panels, secondary stiffeners and primary stiffeners is to be checked according to Sec 3 for plating, Sec 4 for secondary stiffeners and Sec 5 for primary stiffeners, taking into account the:

- local loads as defined in Ch 3, Sec 3 for external pressure, Ch 3, Sec 4 for internal pressure and Ch 5, Sec 1 for superstructures, and
- permissible stresses and safety factors as defined in Ch 2, Sec 3.

The type of local lateral pressures to be considered are:

- wave loads
- dynamic loads:
  - bottom slamming pressures for planing hull, when slamming may occur
  - side shell impacts (and platform bottom impacts for multihull) for all types of ships, where applicable (see Ch 3, Sec 3, [3.1])
- deck loads and superstructure pressures
- bulkhead and tank loads
- wheeled loads.

2.3.2 Check

The local strength analysis is carried out in order to check, for the plating, secondary and primary stiffeners, the local stresses in relation to:

- the maximum permissible local stress, and
- local buckling criteria, where applicable.

2.4 Specific cases

2.4.1 Specific scantling criteria in relation to the service notation of the ships are defined in Ch 6, Sec 1.

Section 2 Global Strength Analysis

1 General

1.1 Application

1.1.1 The global strength analysis is to be carried out in order to check the hull girder stress in relation to maximum permissible stress and buckling stress (see [2.2] and [2.3]).

1.1.2 Material

The global strength analysis of monohull and multihull is to be carried out taking into account:

- for steel structure: the present Section
- for aluminium structure: the present Section and NR561 Aluminium Ships
- for composite structure: the present Section and NR546 Composite Ships.

1.1.3 Application

a) Monohull ships and float of multihull:

For monohull ships and for floats of multihull, the global hull girder longitudinal strength is to be examined in the following cases:

- ships with length greater than 40 m, and 30 m for ship built in composite material, or
- ships having large openings in decks or significant geometrical structure discontinuity at bottom or deck, or
- ships with transverse framing systems, or
- ships with deck structure built with large spacing of secondary stiffeners, or
- cargo ship as defined in Ch 1, Sec 1, [2.1.3], or
- where deemed appropriate by the Society.

For ships not covered by the above cases, the hull girder strength is considered satisfied when local scantlings are in accordance with requirements defined in Sec 3 and in Sec 4.

b) Platform structure of multihull:

As a rule, the global transverse strength of platform of multihull is to be examined for all types of multihull.

1.2 Global strength calculation

1.2.1 General

The global strength of monohull and multihull are to be calculated according to:

- [3] and [4] for monohull and catamaran respectively, or
- finite element calculation according to [5], or
- an equivalent alternative calculation approach submitted by the designer

1.2.2 Where a member contributing to the longitudinal and/or transversal strength is made in material other than steel with a Young's modulus E equal to 2,06 10^5 N/mm², the steel equivalent thickness area that may be included for the calculation of the inertia of the considered section is obtained, in mm², from the following formula:

$$t_{SE} = \frac{E}{2{,}06{,}10^5} t_M$$

where:

t_M : Thickness, in mm², of the member under consideration

E : Young modulus, in N/mm², of the considered member.

1.2.3 Finite element calculation

The global strength analysis may also be examined with a Finite Elements Analysis submitted by the Designer. In this case, and where large openings are provided in side shell and/or in primary transverse cross structure of platform of multihull for windows, doors..., a special attention is to be paid to ensure a realistic modelling of the bending and shear strength of the jambs between openings.

2 Global strength check

2.1 General

2.1.1 The global analysis check is to be successively carried out taking into account the scantling criteria based on maximum stress check (see [2.2]) and on buckling check (see [2.3]).

The global analysis check is to be carried out in the following areas of the hull:

- in head sea condition (for monohull and multihull):
  - along the ship from 0,3L to 0,7L from the aft end
  - along the ship outside the area from 0,3L to 0,7L from the aft end whenever deemed appropriate by the Society.
- in quartering sea (for multihull only):

  Along the float from aft to fore end, and in way of each primary transverse cross structure of the platform.

2.2 Maximum stress check

2.2.1 Steel and aluminium structure

It is to be checked that the actual normal stresses σ_A, in N/mm², and the actual shear stresses τ_A, in N/mm², calculated according to [3] and, for multihull, to [4] are in compliance with the following criteria:

$$|\sigma_A| \leq \sigma_{glam}$$

$$|\tau_A| \leq \tau_{glam}$$

where:

σ_{glam} : Global bending permissible stress, in N/mm², as defined in Ch 2, Sec 3

τ_{glam} : Global shear permissible stress, in N/mm², as defined in Ch 2, Sec 3.

2.2.2 Composite structure

It is to be checked that the actual normal stresses and shear stresses, calculated according to [3] and, for multihull, to [4] are in compliance with the criteria defined in Ch 2, Sec 3, [3.1].

2.3 Buckling check

2.3.1 Steel and aluminium structure

It is to be checked that the actual normal stresses σ_A and shear stresses τ_A calculated according to Article [3] and, for multihull, to Article [4] are in compliance with the criteria defined in App 1.

2.3.2 Composite structure

a) Stress check:

   It is to be checked that the actual normal stresses σ_A and shear stresses τ_A calculated according to Article [3] and, for multihull, to Article [4] are in compliance with the following criteria:

$$|\sigma_A| \leq \frac{\sigma_c}{SF_B}$$

$$|\tau_A| \leq \frac{\tau_c}{SF_B}$$

   where:

   σ_c, τ_c, : Critical buckling stress, in N/mm², in compression and in shear in the whole panel as defined in NR546 Composite Ships

   SF_B : Permissible safety factor defined in Ch 2, Sec 3, [3.2.3].

b) Midship section of inertia:

   As a rule, the midship section moment of inertia is to be in accordance with NR546 Composite Ships [4.4],

2.3.3 HDPE structure

According to NR546 Composite Ships, Sec 10 [1.2.2] for ships able to sail in planning mode, it is to be checked that the actual normal stresses and shear stresses induced by loading cases defined in Ch 3, Sec 2, [6.1] and calculated according to Article [3] are in compliance with the criteria defined in App 1.

3 Calculation of global strength for monohull ship

3.1 General

3.1.1 The calculation of the hull girder strength characteristics is to be carried out taking into account all the longitudinal continuous structural elements of the hull.

A superstructure extending over at least 0,4 L may be considered as contributing to the longitudinal strength.

The transverse sectional areas of openings such as deck hatches, side shell ports, side shell and superstructure doors and windows, in the members contributing to the longitudinal hull girder strength, are to be deducted from the considered transverse section.

Lightening holes, draining holes and single scallops in longitudinal stiffeners need not be deducted if their height is less than 0,25 h_W without being greater than 75 mm, where h_W is the web height, in mm, of the considered longitudinal.

Bilge keels may not be included in the hull girder transverse sections, as they are considered not contributing to the hull girder sectional area.

3.2 Strength characteristics

3.2.1 Section modulus

The section modulus in any point of a transverse section along the hull girder is given, in m³, by the following formula:

$$Z_A = \frac{I_Y}{|z - N|}$$

where:

I_Y : Moment of inertia, in m⁴ of the transverse section considered, calculated taking into account [1.2.2] and all the continuous structural elements of the hull contributing to the longitudinal strength as defined in [3.1], with respect to the horizontal neutral axis

z : Z co-ordinate, in m, of the considered point in the transverse section above the base line

N : Z co-ordinate, in m, of the centre of gravity of the transverse section, above the base line.

3.2.2 Section moduli at bottom and deck

The section moduli at bottom and deck are given, in m³, by the following formulae:

- at bottom:

$$Z_{AB} = \frac{I_Y}{N}$$

- at deck:

$$Z_{AD} = \frac{I_Y}{V_D}$$

where:

I_Y, N : Defined in [3.2.1]

V_D : Vertical distance, in m, equal to:

$V_D = z_D - N$

z_D : z co-ordinate, in m, of the deck, above the base line.

3.3 Overall stresses

3.3.1 Overall stresses

a) General case:

The overall bending and shear stresses, in N/mm², in any point of a transverse section of a member contributing to the longitudinal and/or transversal global strength is obtained by the following formula:

$$\sigma_A = \frac{M_V}{Z_A} 10^{-3}$$

$$\tau_A = \frac{Q_v S_v V}{I_y t}$$

where:

M_V, Q_v : Overall bending moments, in kN.m, and shear forces, in kN, induced by the loading cases considered combined as defined in Ch 3, Sec 2, [3]

Z_A : Section modulus, in m³, calculated according to [3.2].

S_v : Vertical section, in m², located above the point considered in the section taking into account [1.2.2]

V : Vertical distance, in m, between the centre of gravity of the vertical section S_v and the centre of gravity of the whole transverse section

I_y : Moment of inertia, in m^4 as defined in [3.2.1]

t : Thickness, in mm, of the element where the shear stress is calculated.

b) Overall stress for element other than steel:

For element other than steel, the stresses σ_A and τ_A calculated according to a) are to be corrected by the ratio between the Young modulus of the considered element and the steel Young modulus taken equal to $2{,}06.10^5$ N/mm² for σ_A, and by the ratio between the Shear modulus of the considered element and the steel Shear modulus taken equal to $7{,}93.10^4$ N/mm².

c) Simplified method for the calculation of the shear stress:

When the inertia of a section is not determined, the shear stress in a section may be calculated as follow:

- the total shear section S_A of the section may be considered as equal to the sum of the vertical sections of the:
  - for longitudinal strength analysis: Side shells and longitudinal bulkheads contributing to the global strength of the hull girder
  - for transversal strength analysis of catamaran: Transversal bulkheads contributing to the global strength of the platform.
- the shear stress may be taken equal to:

$$\tau_A = \frac{Q_v}{S_A} 10^{-3}$$

- Where a member is made in material other than steel with a shear modulus G equal to $7{,}93.10^4$ N/mm², the steel equivalent thickness that may be included for the calculation of the section S_A of the considered section is obtained, in mm, from the following formula:

$$t_{SE} = \frac{G}{7{,}93 \cdot 10^4} t_M$$

where:

t_M : Thickness, in mm, of the member under consideration

G : Shear modulus, in N/mm², of the considered member.

The shear stresses τ_A are to be corrected by the ratio between the shear modulus of the considered element and the steel shear modulus taken equal to $7{,}93.10^4$.

4 Calculation of global strength for multihull

4.1 General

4.1.1 Global strength approach for multihull

The global strength of multihull is to be successively examined:

- in head sea conditions, according to Article [3]
- In quartering sea conditions: By combining the stress analysis carried out in head sea conditions according to [3], considering only the bending moment in still water conditions, and in quartering sea conditions according to [4.3.4] b) combined as defined in Ch 3, Sec 2, [3]
- in digging in waves conditions, according to [4.3] b)
- in addition for swath, in transverse bending moment, according to [4.4].
- in addition for planing hull, according to [4.5]

The global strength of multihull having more than two floats is to be examined on a case-by-case basis.

4.2 Global strength in head sea condition

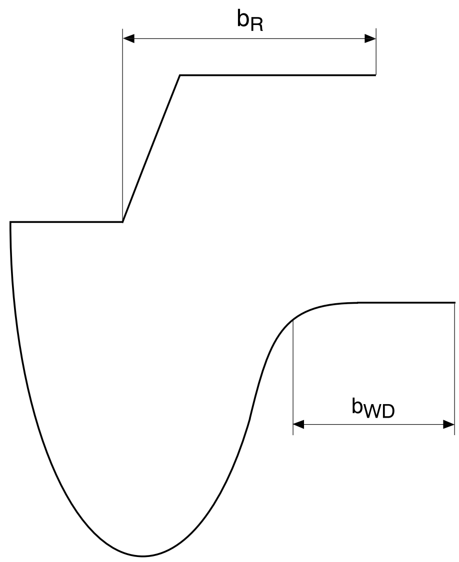
4.2.1 General

The global strength in head sea condition is to be checked as defined in Article [3].

The moment of inertia I_Y is to be calculated for only one float. A platform extending in length over at least 0,4 L_{WL} is to be considered for the calculation of the inertia of the float with a breadths b_R and b_{WD} as defined in Fig 1, limited to 10% of the platform longitudinal length.

For swath, struts extending in length over at least 0,4 L_{WL} is to be considered for the calculation of the inertia of the float.

Figure 1 : Hull girder strength Areas to be taken into account for continuous members (plates and stiffeners)



4.3 Global strength in quartering sea and in digging in waves

4.3.1 General

The global strength of multihull in quartering sea is to be examined according to:

- the present sub article for multihull built in steel material
- the present sub article and NR561 Aluminium Ships for multihull built in aluminium alloys
- the present sub article and NR546 Composite Ships for multihull built in composite materials.

The global strength analysis may be carried out by a beam model as shown in Fig 2, taking into account the bending and shear stiffness of the primary transverse cross structure of the platform and of one float.

The transverse cross beams are fixed in the model in way of the inner side shell of the other float.

Any other justified global analysis submitted by the Designer may be considered.

4.3.2 Primary transverse cross structure model

Each primary transverse cross structure in the platform is considered as a beam in the global model, taking into account:

- its bending inertia about an horizontal axis (depending mainly on the web height of the transverse cross beam or bulkhead, and the thickness of the bottom and deck platform
- its vertical shear inertia (depending on the web height of the transverse cross beams or bulkheads and their thickness)
- its span between inner side shell of floats.

4.3.3 Float model

The float is modelled as a beam having, as far as practicable:

- vertical and horizontal bending inertia, and
- a shear inertia, and
- a torsional inertia about longitudinal float axis

close to the actual float values.

4.3.4 Loading of the model

The two following loading cases are to be considered:

a) Loads in quartering sea condition as shown on Fig 3, where the torsional moment exerted on the platform and induced by encountered waves in quartering sea is represented by two vertical forces F defined in Ch 3, Sec 2, [5.3.2].

Note 1: As a general rule, two successive loading cases are to be taken into account: the case as shown in Fig 3 and the same case with forces in opposite direction.

b) Loads in digging in waves condition as shown on Fig 4, where the torsional moment induced by the digging in wave is represented by the vertical linear forces F_{VD} and horizontal linear forces F_{HD}, in kN/m, equal to:

$F_{VD} = F_{vm} - F_{vl}$

$F_{HD} = F_{hm} - F_{hl}$

where:

F_{vm}, F_{vl}, F_{hm}, F_{hl}: Fore float loads defined in Ch 3, Sec 2, [6.2.1] b)

The vertical and horizontal linear loads F_{VD} and F_{HD} are to be applied from the fore part of the modelled float on a distribution length, in m, equal to L_{WL} / 4 without being taken greater than d, where:

L_{WL} : Length at waterline at full load, in m

d : Length, in m, of digging in wave, equal to the distance between the extreme fore end of each float and the forward part of the platform.

4.3.5 Main structure check

The global bending moments and shear forces distribution in the float are as shown in Fig 5, and in the primary transverse cross structure as shown in Fig 6.

The bending stresses σ_A and the shear stresses τ_A in the float and in the platform of the multihull are to be directly deduced from the beam model calculation and are to be in compliance with the criteria defined in Article [2].

For the primary transverse cross structure, the bending stresses and shear stresses are to be calculated in way of the modelled float.

Particular attention is to be paid to:

- shear buckling check of cross bulkheads
- compression/bending buckling check of platform bottom and platform deck platings in areas where the bending moment is maximum.

Figure 2 : Model principle

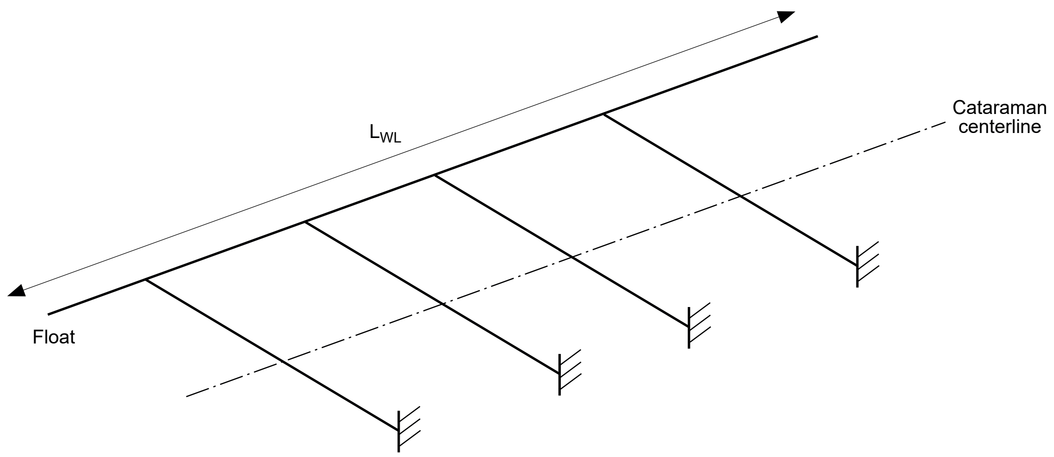


Figure 3 : Primary transverse cross structure of multihull - Loading in quartering sea condition

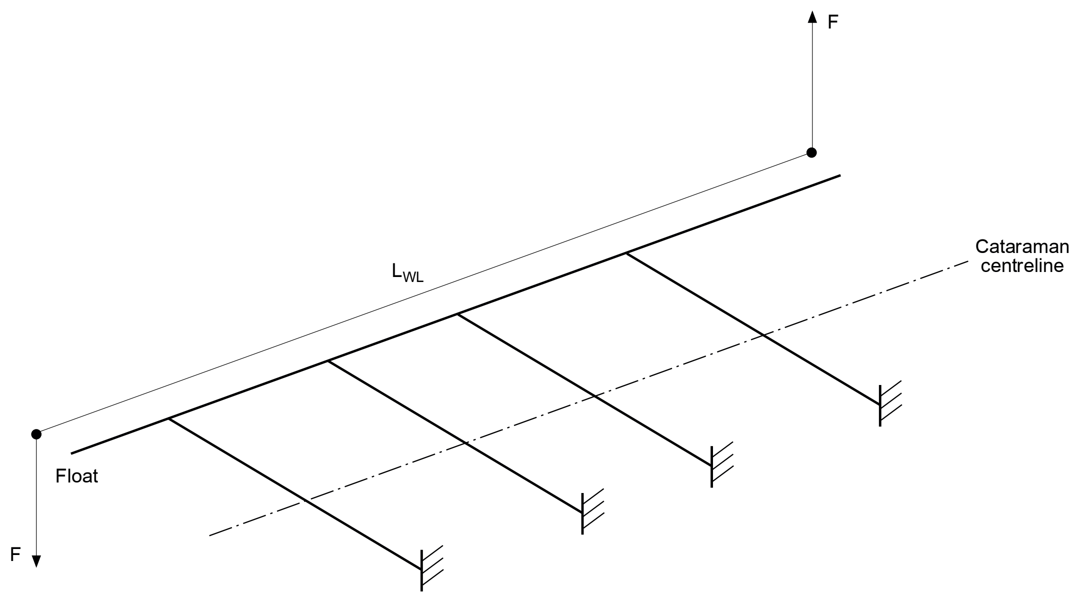


Figure 4 : Primary transverse cross structure of multihull - Loading in digging in wave condition

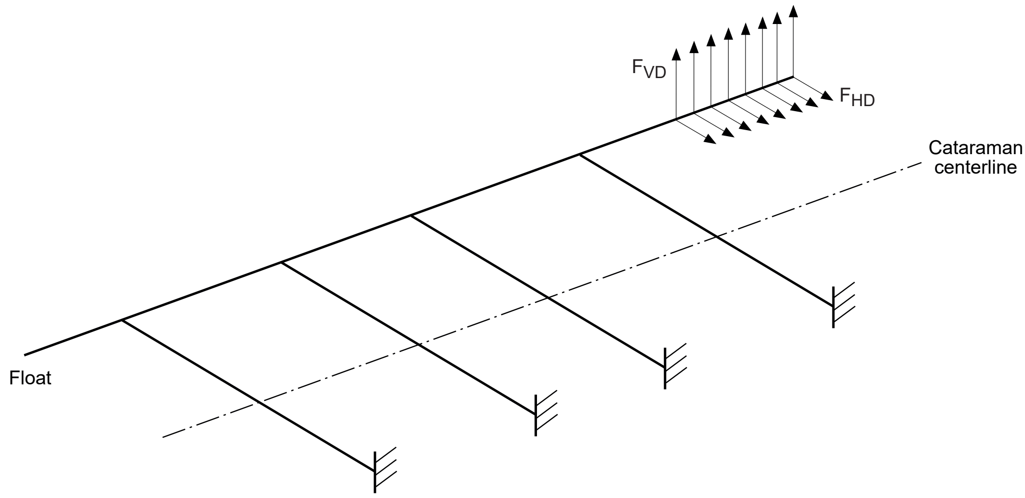


Figure 5 : Longitudinal distribution of the bending moment and shear force along the float

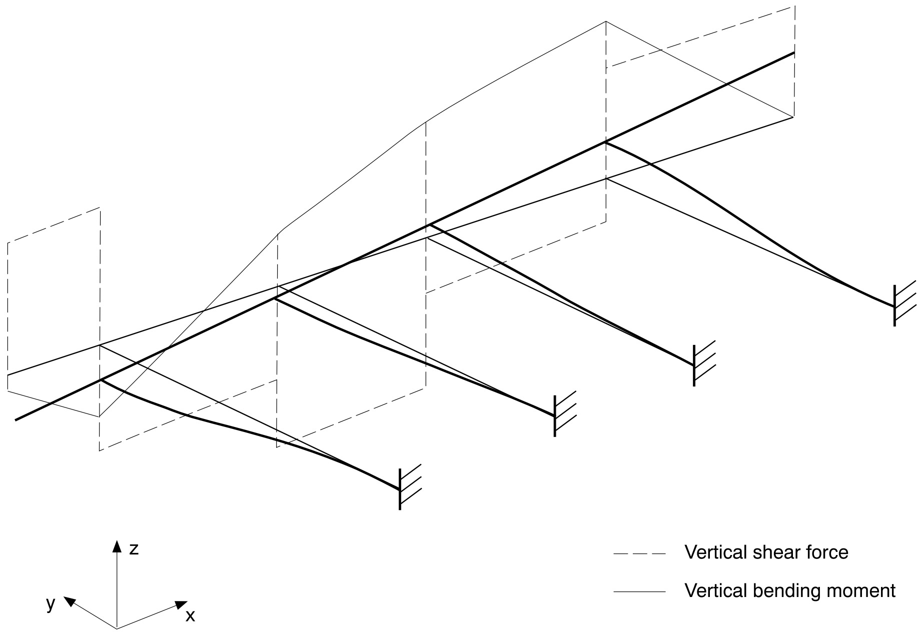
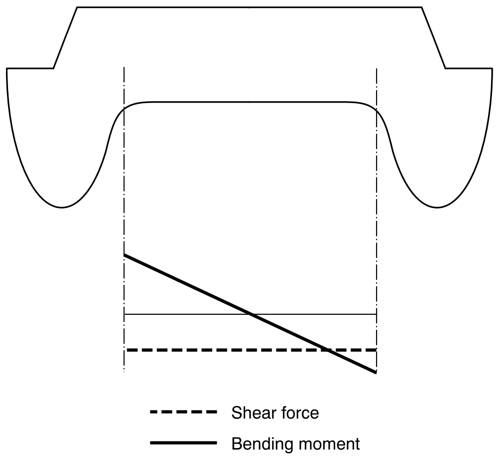


Figure 6 : Transverse distribution of bending moments and shear forces



4.4 Transverse bending moment acting on twin-hull connections of swath

4.4.1 The global transversal strength analysis of the primary structure of the platform of swath is to be carried out by a direct calculation.

The bending moment M_Q, in kN.m, and the shear force F_Q, in kN, applied along the platform structure of swath is to be taken equal to:

$M_Q = h_M \cdot F_Q$

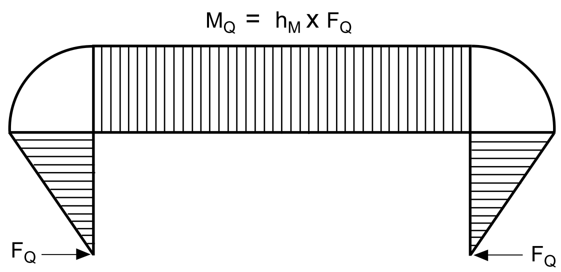
where:

h_M : Half the draught T, in m, plus the distance from the waterline at draught T to the midpoint of the platform structure (see Ch 3, Sec 2, Fig 5)

F_Q : Beam side force, in kN, defined in Ch 3, Sec 2, [6.2.2].

The bending moment distribution is to be as shown on Fig 7. The shear force is to be considered as constant along the struts of the swath.

Figure 7 : Bending moment distribution



4.5 Global strength for planing hull

4.5.1 The global strength analysis of multihull planing hull is to be carried out:

a) In head sea condition:

according to [3.3] taking into account:

- Bending moments and shear forces defined in Ch 3, Sec 2, [6.1.1]
- A section modulus based on a moment of inertia I_Y calculated for only one float. A platform extending in length over at least 0,4 L_{WL} is to be considered for the calculation of the inertia of the float with a breadths b_R and b_{WD} as defined in Fig 1, limited to 10% of the platform longitudinal length.

b) In quartering sea conditions:

according to [4.3], in quartering sea only, taking into account the minimum transverse torsional moment along the float and in the platform defined in Ch 3, Sec 2, [6.1.2].

5 Global strength analysis for monohull and catamaran by finite element calculation

5.1 General

5.1.1 This Article is a guidance for the stress check (maximum and buckling stresses) of hull girder and platform structure loaded under global hull girder loads only using a finite element complete ship model.

5.2 Steel and aluminium structure

5.2.1 Structural model

a) General:

The complete ship is to be modeled so that the elements contributing to global strength or leading to shear deformation are properly taken into account.

Long superstructures are to be modeled in order to also reproduce the correct hull global strength, in particular the contribution of each superstructure deck to the hull girder longitudinal strength.

Special attention is to be brought to the following structural elements which are to be correctly represented:

- deck structure, with particular attention to deck openings
- transverse and longitudinal bulkheads, with particular attention to door openings
- transverse web frames
- pillars
- vertical stiffeners in way of windows
- ends of superstructure and their fixation to deck
- side shell openings.

The following structural elements may be disregarded:

- small deck openings (less than typical size of elements)
- openings in webs of primary supporting members when their height is less than 50% of the web height, provided that a detailed analysis is performed for the assessment of these primary supporting members according to Sec 5, [3.2].

b) Finite elements:

The shell element mesh is to follow the stiffening system as far as practicable, hence representing the actual plate panels between stiffeners.

Shell elements are to be used to represent plating. As a rule, the aspect ratio of shell elements is generally not to be greater than 2, and in no case greater than 4.

Angles of quadrilateral elements are to be greater than 60° and less than 120°. Angles of triangular elements are to be greater than 30° and less than 120°.

Ordinary stiffeners are to be modeled with bar elements and may be grouped at regular intervals.

Webs of primary structure are to be modeled with shell elements.

Face plates of primary structure may be modeled with rod or bar elements.

Pillars may be modeled by bar elements. Their bending properties and their connections to deck are to be accurately represented.

In order to account for the shear deformation of deckhouses and superstructure sides, at least three elements in each direction of the strips between the windows are to be modeled.

5.2.2 Loads distribution

Hull girder loads distributions are divided in still water hull girder load distributions and wave hull girder load distributions.

Hull girder load distributions are obtained by applying fictitious vertical loads at specific longitudinal locations.

The structural elements selected for the application of such loads are to be chosen such as to avoid fictive local stress and generally to be those of high vertical stiffness.

Hull girder load distributions are to target the bending moments and shear forces distributions defined in Ch 3, Sec 2.

Detailed justifications of the loading distributions may be requested by the Society to verify the values of the actual global bending moments and shear forces applied to the model.

5.2.3 Boundary conditions

The finite element calculation is to be performed with displacement restrictions applied to nodes of the model. Rotations of these nodes are to be free.

As a rule, these nodes are to be located outside the model areas where global stress checks are carried out.

Detailed justifications may be requested by the Society to verify that the forces reactions applied to these nodes do not affect the global bending moments and shear forces applied to the model.

5.2.4 Stress check

a) Stress components:

Stress components are generally identified with respect to the element co-ordinate system. The orientation of the element co-ordinate system in relation to the reference co-ordinate system of the model is to be specified.

The following stress components to be considered and calculated at the centroid of each element are:

- the normal stresses σ_1 and σ_2 in the directions of element co-ordinate system axes
- the shear stress τ_{12} with respect to the element co-ordinate system axes

b) Stress check

The maximum stresses and buckling stresses are to be calculated as follow:

- Maximum stress check:

  The Von Mises equivalent stress, σ_{eq}, in N/mm², is to be derived as follows:

  $$\sigma_{eq} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1 \sigma_2 + 3\tau_{12}^2}$$

  Where σ_1, σ_2 and τ_{12} are defined in b).

- Buckling stress check:

  Where the buckling panel is meshed by several finite plate elements, the stresses of the buckling panel are obtained by the following methodology:

  - For each plate finite element, the stresses ($\sigma_{\xi\,\varepsilon}^*$, $\sigma_{\psi\,\varepsilon}^*$, τ_{ε}^*) expressed in the element co-ordinate system are projected in the co-ordinate system of the buckling panel to obtained the stresses ($\sigma_{\xi\,\varepsilon}$, $\sigma_{\psi\,\varepsilon}$, τ_{ε}).
  - For the buckling panel, the stresses are calculated according to the following formula:

$$\sigma_x = \frac{\sum_i^n A_i \sigma_{x\,e_i}}{\sum_i^n A_i} \geq 0$$

$$\sigma_y = \frac{\sum_i^n A_i \sigma_{y\,e_i}}{\sum_i^n A_i} \geq 0$$

$$\tau = \frac{\sum_i^n A_i \tau_{e_i}}{\sum_i^n A_i} \geq 0$$

where:

$\sigma_{\xi\,\varepsilon\iota}$, $\sigma_{\psi\,\varepsilon\iota}$: Stresses, in N/mm², of the plate finite element i, taken equal to 0 in case of tensile stress

τ_{ei} : Shear stress, in N/mm², of the plate finite element i

A_i : Area, in mm², of the plate finite element i.

5.2.5 Scantling criteria

The maximum actual stresses and buckling stresses are to fulfill the permissible global stresses and buckling safety factors defined in Ch 2, Sec 3, Tab 1 taking into account Ch 2, Sec 3, [2.3].

5.3 Composite structure

5.3.1 General

The structural model, the global loads distribution and the boundary conditions are to fulfill the general requirements defined in [5.2].

5.3.2 Stress check

The stress check is to be carried out as defined in Ch 2, Sec 3, [3.1].

5.3.3 Scantling criteria

The rule safety factors to be considered are defined in Ch 2, Sec 3, [3.2] taking into account Ch 2, Sec 3, [3.2.1] c).

Section 3 Local Plating Scantling

Symbols

k : Material factor, defined in Ch 1, Sec 2, [2] for steel and in Ch 1, Sec 2, [3] for aluminium alloys

ℓ : Length, in m, of the longer side of the plate panel

λ : Corrosion coefficient taken equal to:

- for steel plating: $\lambda = 1{,}10$
- for aluminium plating: $\lambda = 1{,}05$

μ : Aspect ratio coefficient of the elementary plate panel, equal to:

$$\mu = 1{,}21\sqrt{1 + 0{,}33\left(\frac{s}{\ell}\right)^2} - 0{,}69\frac{s}{\ell} \leq 1$$

s : Length, in m, of the shorter side of the plate panel

σ_{locam} : Local permissible bending stress, in N/mm², as defined in Ch 2, Sec 3, in relation to the type of load

τ_{locam} : Local permissible shear stress, in N/mm², as defined in Ch 2, Sec 3, in relation to the type of load.

1 General

1.1 General

1.1.1 The local plating scantling is to be carried out according to:

- for steel structure: the present Section
- for aluminium structure: the present Section and the NR561 Aluminium Ships
- for composite and HDPE structure: see [2.3].

1.1.2 The scantling of platings contributing to the overall longitudinal strength of the hull girder and to the overall transverse strength of transverse multihull platform are also to be checked as defined in Sec 2.

1.2 Local loads

1.2.1 Local load types

The local lateral pressures to be considered are:

- for bottom platings: sea pressures, bottom slamming pressures (when slamming may occur for planing hull) and bottom impact pressures on flat bottom forward area when applicable
- for side shell and, for multihull, platform bottom platings: sea pressures and side shell impacts
- for deck platings: external or internal loads, minimum loads and, when applicable, wheeled loads
- for all platings, when applicable: internal pressure.

The platings subject to local compression loads are also to be checked against buckling criteria as defined in App 1, [2.1.2], item b).

1.2.2 Local load point calculation

The location of the point of the plating where the local loads are to be calculated in order to check the scantling are defined in:

- Ch 3, Sec 1, [4.1] for steel and aluminium plates
- Ch 3, Sec 1, [4.2] for composite panels
- Ch 3, Sec 1, [4.3] for superstructure panels.

2 Plating scantling

2.1 General

2.1.1 Loading cases and permissible stresses

The scantling of plating is obtained considering successively the different loads defined in [1.2.1] sustained by the plate (combined as defined in Ch 3, Sec 1, [3.1] if relevant), and the associated permissible stresses defined in Ch 2, Sec 3.

2.1.2 Deck plating protected by wood sheathing or deck composition

The thickness of deck plating protected by wood sheathing, deck composition or other arrangements deemed suitable by the Society may be reduced on a case by case basis. In any case this thickness is to be not less than the minimum value defined in [2.2.1].

The sheathing is to be secured to the deck to the satisfaction of the Society.

2.2 Scantling for steel and aluminium plating

2.2.1 Minimum thickness

a) As a rule, the thickness t, in mm, of plates calculated according to the present Section are not to be less than:
   - for steel plate:
     The greater value obtained from the following formulae:
     - cargo ship: $t = 0,05\ L_W\ k^{1/2} + 3,5 \geq 5$ mm
     - non-cargo ship: $t = 0,05\ L_W\ k^{1/2} + 3,0 \geq 5$ mm
     - for **sea-going launch** and **launch**: t = 3,0 mm
   - for aluminium plate: t = 4,0 mm
   - for aluminium extruded panel: t = 3,0 mm.

   where:

   L_w : $L_w = 0,5\ (L_{WL} + L_{HULL})$

b) Bottom plating
   As a rule, the thicknesses of bottom plating are not to be lesser than the thickness of side shell.

c) Additional specific minimum thicknesses in relation to the service notation or service feature assigned to the ship are defined in Ch 6, Sec 1.

2.2.2 General case

a) As a rule, the thickness of plating subjected to lateral pressure is to be not less than the value obtained, in mm, from the following formula:

$$t = 22,4 \lambda n_p \mu s \sqrt{\frac{p}{\sigma_{locam}}}$$

   where:

   p :
   - local sea pressures or internal pressures, in kN/m², as defined in Ch 3, Sec 3 and Ch 3, Sec 4, or
   - bottom impact pressure for flat bottom forward area, in kN/m², as defined in Ch 3, Sec 3, [3.2], or
   - bottom slamming pressure for planing hull, p_{sl}, in kN/m², as defined in Ch 3, Sec 3, [3.3]

   n_p : Coefficient to be taken equal to:
   - local sea pressures or internal pressures:
     - for longitudinally framed steel plating: $n_p = 0,67$
     - for transversely framed steel plating: $n_p = 0,77$
     - for steel transverse bulkhead: $n_p = 0,67$
     - for aluminium plating, whatever the frame system: $n_p = 1,00$
   - bottom impact pressure for flat bottom forward area and for bottom slamming pressure for planing hull:
     - for steel plating: $n_p = 0,77$
     - for aluminium plating: $n_p = 0,85$

b) For steel plating, where the thickness t calculated according to item a) is greater than 20 mm, the rule thickness, in mm, may be taken equal to:

   $0,9\ t + t_c$,

   where t_c is to be taken equal to the sum of the corrosion addition for each exposed side of the plating as defined in NR467 Steel Ships, Pt B, Ch 4, Sec 3.

c) The thickness of sidescuttles located on the side shell are to be examined according to Ch 5, Sec 1, [7.3], taking into account the value of P defined in the present requirement.

2.2.3 Plating of side shell under impact pressure

As a rule, the thickness of side shell plating and of platform bottom plating for multihull subjected to impact pressure is to be not less than the value obtained, in mm, from the following formulae:

- if s ≤ 0,6 m

$$t = 17,3 \sqrt{\frac{1}{\ell_{ssi}}} \lambda n_p \mu s \sqrt{\frac{p}{\sigma_{locam}}}$$

- if s > 0,6 m

$$t = 13,4\sqrt{\frac{1,5s^2 - 0,18}{\ell_{ssi} s}}\lambda n_p \mu \sqrt{\frac{p}{\sigma_{locam}}}$$

where:

p : Pressure, in kN/m², to be taken equal to: $p = C_p P_{ssmin}$

p_{ssmin} : Impact pressure on side shell and, for multihull, on platform bottom, in kN/m², as defined in Ch 3, Sec 3, [3.1.2] and/or Ch 3, Sec 3, [3.1.3]

C_p : Pressure coefficient equal to: $C_p = -0,98s^2 + 0,3s + 0,95 \geq 0,8$

n_p : Coefficient to be taken equal to:
- for steel plating: $n_p = 0,77$
- for aluminium plating: $n_p = 0,85$

ℓ_{ssi} : Length, in m, equal to: $\ell_{ssi} = 0,6\ (1 + s) \leq \ell$

The thickness of sidescuttles located on the side shell and submitted to side shell impact are to be examined according to Ch 5, Sec 1, [7.3], taking into account the value of P_{ssmin} defined in the present requirement where applicable (see Ch 3, Sec 3, [3.1]).

2.2.4 Plating subjected to wheeled loads

The thickness of plate panels subjected to wheeled loads is to be not less than the value obtained, in mm, from the following formula:

a) Single wheel or group of wheels:

$$t = 0,9 C_m C_{WL} \lambda \sqrt{F_W n k}$$

where:

k : Material factor, defined in Ch 1, Sec 2, [2] for steel and in Ch 1, Sec 2, [3] for aluminium alloys

n : Number of wheels on the plate panel:
- 1 in the case of single wheel
- the number of wheels in a group of wheels in the case of double or triple wheels

C_m : Coefficient equal to:
- 1,00 for steel
- 1,55 for aluminium alloy

C_{WL} : Coefficient to be taken equal to:

$$C_{WL} = 2,15 - 0,05\frac{\ell}{s} + 0,02\left(4 - \frac{\ell}{s}\right)\alpha^{0,5} - 1,75\alpha^{0,25}$$

where ℓ/s is to be taken not greater than 3

$$\alpha = \frac{A_T}{\ell s}$$

A_T : Tyre print area, in m². In the case of double or triple wheels, A_T is the print area of the group of wheels.
When the tyre print area is not known, it may be taken equal to:

$$A_T = 9,81\frac{nQ_A}{n_W p_T}$$

where:

Q_A : Axle load, in t

n_W : Number of wheels for the axle considered

p_T : Tyre pressure, in kN/m². When the tyre pressure is not indicated by the Designer, it may be taken as defined in Tab 1

n : Number of wheels on the plate panel, taken equal to:
- 1 in the case of a single wheel
- the number of wheels in a group of wheels in case of double or triple wheels

F_W : Wheeled force, in kN, as defined in Ch 3, Sec 4, [4.4].

b) Wheels spread along the panel length:

In the case where two to four wheels of the same properties (load and tyre print area) are spread along the plate panel length as shown on Fig 1, the thickness of deck plating is to be not less than the value obtained, in mm, from the following formulae:

$$t = t_1\sqrt{1 + \sum_{i=2}^{n}\beta_i}$$

where:

t_1 : Thickness obtained, in mm, from item a) with n = 1, considering one wheel located on the plate panel

n : Number of wheels on the plate panel, to be taken not less than 2

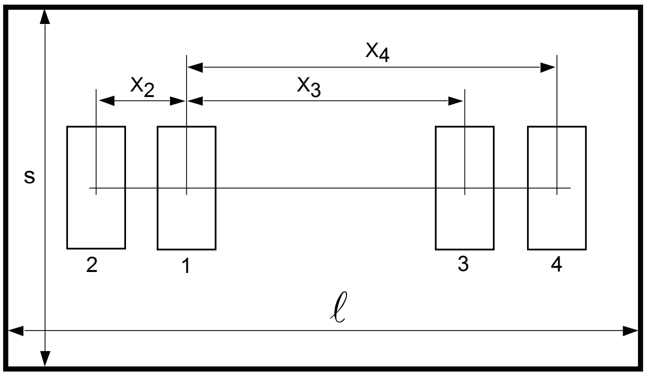
βi : Coefficients obtained from the following formula, by replacing i by 2, 3 or 4, respectively (see Fig 1):

- for $\alpha_i < 2$: $\beta_i = 0,8\ (1,2 - 2,02\ \alpha_i + 1,17\ \alpha_i^2 - 0,23\ \alpha_i^3)$
- for $\alpha_i \geq 2$: $\beta_i = 0$

α_i : $\alpha_i = x_i/s$

x_i : Distance, in m, from the wheel considered to the reference wheel (see Fig 1)

Figure 1 : Four wheels axle located on a panel length



c) Wheels spread along the panel breath:

In the case where two wheels of the same properties (load and tyre print area) are spread along the plate panel breadth as shown in Fig 2, the thickness of deck plating is to be not less than the value obtained, in mm, from the following formula:

$$t = t_2\sqrt{\delta}$$

where:

t_2 : Thickness obtained, in mm, from item a) with n = 2, considering one group of two wheels located on the plate panel

δ : Coefficient obtained from the following formula:

$\delta = (\delta_1 + \delta_2)/2$

$$\delta_1 = 1 - \left(\frac{w_s}{s - v}\right)$$

$$\delta_2 = 1 - \frac{3w_s^2 + 6w_s v}{3s^2 - 4v^2}$$

w_s : Distance between the two wheels, as shown in Fig 2

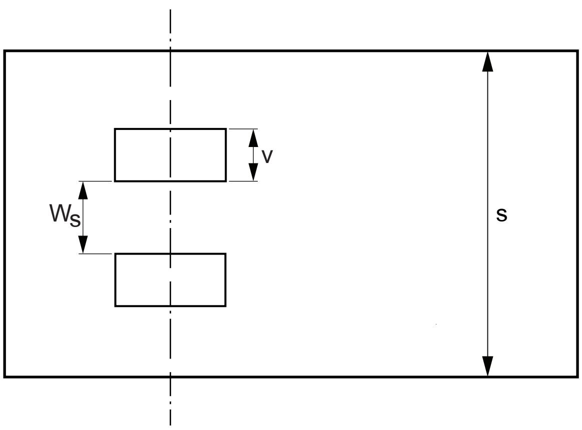
v : Individual wheel breadth, as shown in Fig 2.

Where this two-wheels arrangement is repeated several times over the panel length (2, 3 or 4 times), the required thickness t is to be multiplied by:

$$\sqrt{1 + \sum_{i=2}^{n} \beta_i}$$

as calculated in item b), where n is the number of two wheels groups.

Figure 2 : Wheels spread along the panel breath



d) Wheels larger than the plate panel:
In the particular case of wheels or group of wheels where u > s, the tyre print outside of the plate panel is to be disregarded. The load and the area to be considered are to be adjusted accordingly (see Fig 3).

Figure 3 : Tyre print with u > s

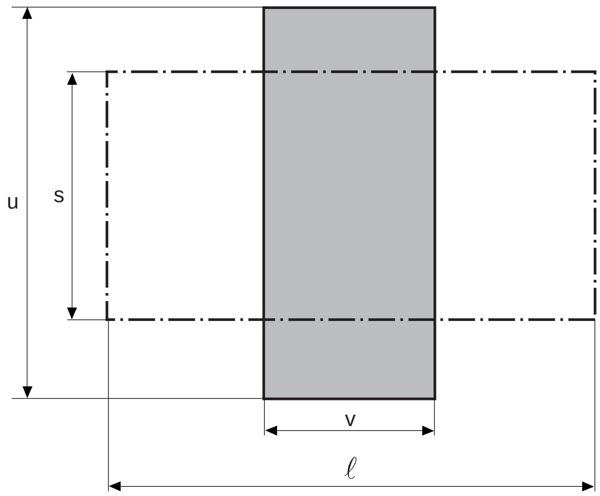


Table 1 : Tyre pressures p_T for vehicles

Vehicle type	Tyre pressure p_T, in kN/m²	
	Pneumatic tyres	Solid rubber tyres
Private cars	250	not applicable
Vans	600	not applicable
Trucks and trailers	800	not applicable
Handling machines	1100	1600

2.3 Scantling for composite, plywood and HDPE panels

2.3.1 The scantling of composite, plywood and HDPE panels is to be checked according to:

- the local loads defined in [1.2.1]
- the safety factor criteria defined in Ch 2, Sec 3, [3] for composite, Ch 2, Sec 3, [4] for plywood and Ch 2, Sec 3, [5] for HDPE, and
- the calculation methodology defined in NR546 Composite Ships

Section 4 Local Secondary Stiffener Scantling

Symbols

k : Material factor, defined in Ch 1, Sec 2

ℓ : Span, in m, of the secondary stiffener under consideration

λ : Corrosion coefficient to be taken equal to:
- steel structure:
  - for stiffener located in a dry compartment: $\lambda = 1,1$
  - for stiffener located in a liquid compartment: $\lambda = 1,2$
- aluminium structure: $\lambda = 1,05$.

m : End stiffener condition coefficient, defined in [1.4]

s : Spacing, in m, of the secondary stiffener under consideration

σ_{locam} : Local permissible bending stress, in N/mm^2, as defined in Ch 2, Sec 3, in relation to the type of load

τ_{locam} : Local permissible shear stress, in N/mm^2, as defined in Ch 2, Sec 3, in relation to the type of load

1 General

1.1 Local scantling

1.1.1 General

The local secondary stiffener scantling is to be carried out according to:
- for steel structure: the present Section
- for aluminium structure: the present Section and NR561 Aluminium Ships
- for composite and HDPE structure: see [2.3].

1.1.2 The scantling of secondary stiffeners contributing to the overall longitudinal strength of the hull girder and to the overall transverse strength of platform of multihull are also to be checked as defined in Sec 2.

1.2 Local loads

1.2.1 Local load types

The local lateral pressures to be considered are:
- for bottom secondary stiffeners: sea pressures, bottom slamming pressures (when slamming may occur for planing hull) and bottom impact pressures on flat bottom forward area when applicable
- for side shell and, for multihull, platform bottom secondary stiffeners: sea pressures and side shell impacts
- for deck secondary stiffeners: external or internal loads, minimum loads, and when applicable, wheeled loads
- for all stiffeners, when applicable: internal pressures.

1.2.2 Local load point calculation

The location of the point of the stiffener where the local loads are to be calculated in order to check the scantling are defined in Ch 3, Sec 1, [4].

1.3 Section modulus calculation

1.3.1 General case and attached plating width

As a rule, the inertia, section modulus and shear section of secondary stiffeners are to be determined by direct calculation.

The effective breadth b_p , in m, of the attached plating to be considered in the inertia and section modulus for the yielding check of a stiffener is to be obtained from the following formulae:
- where the plating extends on both sides of the stiffener:

  $b_p = \min (0,2\ \ell\ ;\ s)$
- where the plating extends on one side of the stiffener (i.e. stiffener bounding an opening):

  $b_p = \min (0,1\ \ell\ ;\ 0,5\ s)$

1.3.2 Bulb section for steel stiffeners

As a rule, the inertia, section modulus and shear section of bulb section of steel stiffener are to be determined taking into account the following equivalent dimensions of an angle profile:

$$h_w = h'_w - \frac{h'_w}{9,2} + 2$$

$$t_w = t'_w$$

$$b_f = \alpha\left[t'_w + \frac{h'_w}{6,7} - 2\right]$$

$$t_f = \frac{h'_w}{9,2} - 2$$

where:

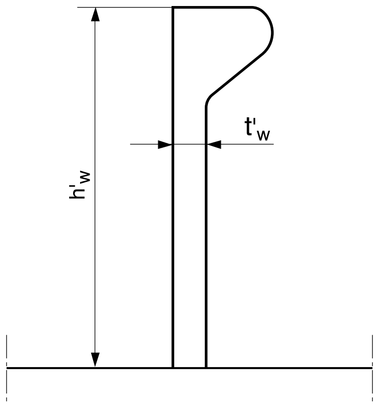
h'_w, t'_w : Height and thickness of the bulb section, in mm, as shown in Fig 1

α : Coefficient equal to:

$1,1 + \frac{(120 - h'_w)^2}{3000}$ for $h'_w \le 120$

$1,0$ for $h'_w > 120$

Figure 1 : Dimension of a steel bulb section



1.3.3 Stiffener not perpendicular to the attached plating

Where the stiffener is not perpendicular to the attached plating, the actual section modulus, in cm³, and the shear area, in cm², may be obtained from the following formula:

$$Z = Z_0 \sin\alpha$$

$$A_{sh} = A_0 \sin\alpha$$

$$I = I_0 \sin^2\alpha$$

where:

Z_0 : Actual section modulus, in cm³, of the stiffener assumed to be perpendicular to the plating

A_0 : Actual shear section in cm², of the stiffener assumed to be perpendicular to the plating

I_0 : Actual moment of inertia, in cm⁴, of the stiffener assumed to be perpendicular to the attached plating

α : The lowest angle between the stiffener web and the attached plating.

1.3.4 Bulb section for aluminium stiffeners

For aluminium secondary stiffeners, the equivalent dimensions of an angle bar are as defined in [1.3.2] are not applicable.

The dimensions of the bulb section are to be specified by the Shipyard.

1.3.5 Stiffeners in composite materials

The inertia, section modulus and shear section of secondary stiffeners in composite materials are to be determined as defined in the NR546 Composite Ships.

1.4 End stiffener conditions for section moduli calculation

1.4.1 The connection of secondary stiffeners with surrounding supporting structure is to be taken into account in the calculation of the rule stiffener section moduli.

The following three assumptions on end stiffener conditions are taken into consideration in the scantling formulae, using a coefficient m equal, successively, to:

- for fixed end condition: m = 12

The cross-section at the ends of the stiffener cannot rotate under the effect of the lateral loads (as a rule, the secondary stiffeners are considered with fixed ends).

The section modulus is to be checked at the ends of the stiffener.

- for simply supported end condition: m = 8

  The cross-section at the ends of the stiffener can rotate freely under the effect of the lateral loads.

  The section modulus is to be checked at mid span of the stiffener.

- for intermediate conditions: m = 10

  The cross-section at the ends of the stiffener is in an intermediate condition between fixed end condition and simply supported end condition.

  The section modulus is to be checked at mid span of the stiffener.

1.5 Span of stiffener

1.5.1 The span ℓ of the stiffeners considered in the scantling formulae is to be measured as shown in Fig 2 to Fig 4.

Figure 2 : Stiffener without brackets

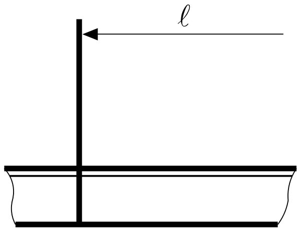


Figure 3 : Stiffener with a stiffener at one end

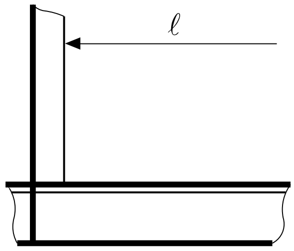
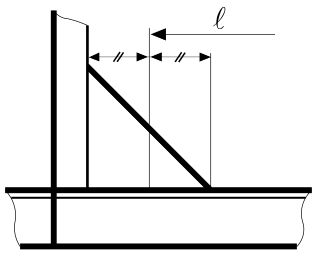
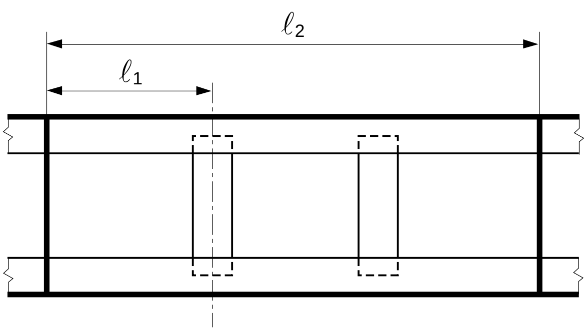


Figure 4 : Stiffener with a bracket and a stiffener at one end



1.5.2 For open floors, when a direct beam calculation taking into account all the elements of the open floor is not carried out, the span ℓ of the upper and lower secondary stiffeners connected by one or two strut(s) is to be taken equal to 0,7 ℓ_2 instead of ℓ_1 (see Fig 5).

Figure 5 : Span of stiffeners in case of open floors



1.6 Recommended proportions of secondary stiffeners

1.6.1 General

As a rule, the proportions of secondary stiffeners are to be as defined in:

- For steel stiffener: [1.6.2]
- For aluminium alloy stiffener: NR561 Aluminium Ships, [3.3].

Other proportions may be considered if the buckling assessment under local loads and axial loads is carried out according to App 1 for steel stiffeners or NR561 App 2 for aluminium stiffeners.

1.6.2 Proportion of secondary stiffener

As a rule, the thicknesses (web and flange) of stiffeners are to satisfy the following criteria:

a) Stiffener web plate:

$$t_w \geq \frac{h_w}{C_w}\sqrt{\frac{R_{eH}}{235}}$$

b) Stiffener flange:

$$t_f \geq \frac{b_{f-out}}{C_f}\sqrt{\frac{R_{eH}}{235}}$$

$$b_f \geq 0{,}25\ h_w$$

where:

C_w, C_f : Slenderness coefficients given in Tab 1.

t_w, t_f : Thickness, in mm, of the web and flange respectively

h_w, t_w, b_{f-out} :Dimensions of the stiffener, in mm, as defined in Fig 6.

Figure 6 : Stiffener scantling parameters

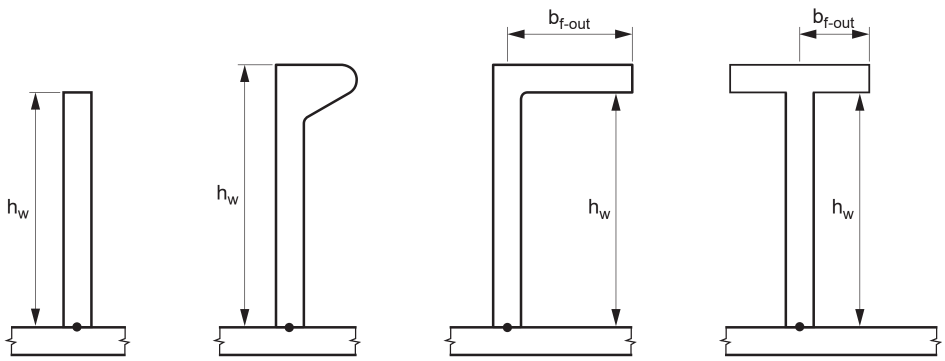


Table 1 : Slenderness coefficient

Type of stiffeners	C_w	C_f
Angle bars	75	12
T-bars	75	12
Bulb bars	45	–
Flat bars	22	–

2 Secondary stiffener scantling

2.1 General

2.1.1 Loading cases and permissible stresses

The scantling of secondary stiffener is obtained considering successively the different loads sustained by the stiffener defined in [1.2.1] (combined as defined in Ch 3, Sec 1, [3.1] if relevant) and the permissible stresses defined in Ch 2, Sec 3.

2.1.2 Weld section of secondary stiffener

Where no stiffener brackets are provided at the connection between the secondary stiffener and the primary supporting element, the resistant weld section A_w, in cm^2, is not to be less than twice the value of A_{sh} defined in [2.2].

2.2 Scantling for steel and aluminium secondary stiffener

2.2.1 General

a) Minimum section modulus:

As a rule, the minimum section modulus, in cm^3, of hull and decks secondary stiffeners calculated according to the present Section are not to be less than:

- for steel secondary stiffener: $0,2\ L_W\ k + 4$
- for aluminium secondary stiffener: $2\ L_W^{1/3}\ k$

where:

L_w : $L_w = 0,5\ (L_{WL} + L_{HULL})$

k : Material factor defined in Ch 1, Sec 2.

b) Welding between secondary stiffener and primary structure:

As a rule, the resistant weld section of the fillet weld connecting the secondary stiffener to the primary structure is to be as defined in:

- Ch 7, Sec 2, [2.6.7] for steel structure
- NR561 Aluminium Ships, Sec 3 for aluminium structure.

2.2.2 General case

As a rule, the section modulus Z, in cm^3, and the shear area A_{sh}, in cm^2, of the secondary stiffeners subjected to lateral local pressures and bottom slamming are to be not less than the values obtained from the following formulae:

- for horizontal stiffeners (longitudinal or transverse):

$$Z = 1000\lambda C_t \frac{ps\ell^2}{m\sigma_{locam}}$$

$$A_{sh} = 5\lambda C_t \frac{ps\ell}{\tau_{locam}}$$

where:

p : Local sea pressures or internal pressures, in kN/m^2, as defined in Ch 3, Sec 3 and Ch 3, Sec 4, or

Bottom impact pressure for flat bottom forward area, in kN/m^2, as defined in Ch 3, Sec 3, [3.2], or

Bottom slamming pressure for planing hull, p_{sl}, in kN/m^2, as defined in Ch 3, Sec 3, [3.3]

C_t : Reduction coefficient defined as follows:

- for sea pressures and internal pressure cases:

$$C_t = 1 - \frac{s}{2\ell}$$

to be taken greater than 0,50

- for other loading types (slamming pressure):

$C_t = 1,00$

- for vertical transverse stiffeners:

$$Z = 1000\lambda C_t \frac{p_1 s\ell^2}{m_b\sigma_{locam}}$$

$$A_{sh} = 10\lambda C_t \frac{p_2 s\ell}{m_s\tau_{locam}}$$

where:

p_1, p_2 : Equivalent pressure, in kN/m^2, as defined in Tab 2

m_b, m_s : End stiffener condition coefficients defined in Tab 2

C_t : Reduction coefficient defined as follows:

- for sea pressures and internal pressure cases:

$$C_t = 1 - \frac{s}{2\ell}$$

to be taken greater than 0,50

- for other loading types:

$C_t = 1,00$

Table 2 : Equivalent pressures

End stiffener condition	P_1	m_b	P_2	m_s
Both ends fixed	$2\ p_{Supper} + 3\ p_{Slower}$	60	$3\ p_{Supper} + 7\ p_{Slower}$	20
Lower end fixed, upper end supported	$7\ p_{Supper} + 8\ p_{Slower}$	120	$9\ p_{Supper} + 16\ p_{Slower}$	40
Both ends supported	$p_{Supper} + p_{Slower}$	16	$p_{Supper} + 2\ p_{Slower}$	6
Note 1: p_{slower}, p_{supper}: Sea pressure or internal pressure as defined in Ch 3, Sec 3 or Ch 3, Sec 4, in kN/m², calculated at lower end of the stiffener and at upper end of the stiffener respectively.				

2.2.3 Secondary stiffeners under side shell impacts

As a rule, the section modulus Z, in cm³, and the shear area A_{sh}, in cm², of the horizontal and vertical secondary stiffeners sustaining lateral side shell impacts are to be not less than the values obtained from the following formulae:

$$Z = 1000\lambda C_f \frac{P s \ell^2}{m \sigma_{locam}}$$

$$A_{sh} = 5\lambda C_t \frac{P s \ell}{\tau_{locam}}$$

where:

P : Pressure, in KN/m², to be taken equal to: $P = C_p\ P_{ssmin}$

C_p : Pressure coefficient equal to: $C_p = -0{,}98 s^2 + 0{,}3 s + 0{,}95 \geq 0{,}8$

s : Spacing of the stiffeners, in m, not to be taken greater than 0,6 m for the calculation of Z and A_{sh}

p_{ssmin} : Impact pressure on side shell and, for multihull, on platform bottom, in kN/m², as defined in Ch 3, Sec 3, [3.1.2] and/ or Ch 3, Sec 3, [3.1.3]

C_f, C_t : Reduction coefficients equal to:

$C_f = 0{,}3\ (3\ \ell^2 - 0{,}36) / \ell^3$ with $\ell \geq 0{,}6$ m

$C_t = 0{,}6 / \ell$ without being taken greater than 1.

2.2.4 Secondary stiffeners under wheeled loads

As a rule, the secondary stiffeners scantling under wheeled loads are checked by direct calculation. Single span and multi span stiffeners are considered.

The values of the bending stresses σ and shear stresses τ, in N/mm², calculated according to the following approaches are to be less than the permissible stresses defined in Ch 2, Sec 3.

a) Single span stiffeners

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \alpha_W K_S \frac{F_W \ell}{6 Z_a} 10^3$$

$$\tau = \alpha_W K_T \frac{10 F_W}{A_{Sha}}$$

where:

Z_a, A_{sha} : Actual section modulus, in cm³, and shear section, in cm², of the stiffener considered

F_W : Wheeled force, in kN, as defined in Ch 3, Sec 4, [4.4]

α_w : Coefficient taking into account the number of wheels per axle considered as acting on the stiffener, defined in Tab 3, without being taken less than 1,0

K_S, K_T : Coefficients taking into account the number of axles considered as acting on the stiffener, defined in Tab 4.

b) Multi span stiffeners

The maximum normal stress σ and shear stress τ are to be obtained by a direct calculation taking into account:

- the distribution of wheeled loads applying on the stiffener
- the number and position of intermediate supports (girders, bulkheads, etc.)
- the condition of fixity at the ends of the stiffener and at intermediate supports
- the geometrical characteristics of the stiffener on the intermediate spans.

Table 3 : Wheeled loads - Coefficient α_W

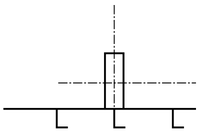
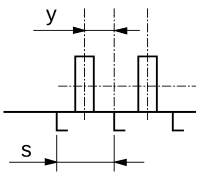
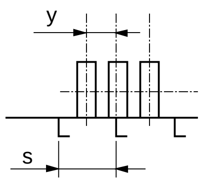
Single wheel configuration	Double wheels configuration	Triple wheels configuration
		
$\alpha_W = 1$	$\alpha_W = 2\left(1-\frac{y}{s}\right)$	$\alpha_W = 3-2\frac{y}{s}$
Note 1: y : Distance, in m, from the external wheel of a group of wheels to the stiffener under consideration, to be taken equal to the distance from the external wheel to the centre of the group of wheels.		

Table 4 : Wheeled loads - Coefficients K_S and K_T

Coefficient	Configuration	
	Single axle	Double axles
K_S	1	• if $d \le \ell/\sqrt{3}$ $\frac{172}{81}-\frac{4d}{3\ell}-\frac{d^2}{\ell^2}+\frac{d^4}{\ell^4}$ • if $d > \ell/\sqrt{3}$ $\frac{4}{3}-\frac{4d}{3\ell}+\frac{3d^2}{\ell^2}-\frac{8d^3}{3\ell^3}$
K_T	1	$2-\frac{d}{2\ell}-\frac{3d^2}{2\ell^2}+\frac{d^3}{\ell^3}$
Note 1: d : Distance, in m, between the two axles ℓ : Span, in m, of the secondary stiffener under consideration		

2.2.5 Struts for open floors

As a general rule, the scantling of the struts is to be checked by direct calculation, taking into account the compression and/or the tensile force Q, in kN, calculated as follows:

- compression force:

$$Q_c = \frac{s\ell_2}{4}(P_{Bottom} + P_{DBottom})$$

- tensile force:

$$Q_t = \frac{2s\ell_2 P_{Ballast}}{4}$$

where:

P_{Bottom} : Local loads (wave loads and/or dynamic loads), in kN/m², applied on the ship bottom, as defined in Ch 3, Sec 3

$P_{DBottom}$: Local loads, in kN/m², applied on the ship double bottom, as defined in Ch 3, Sec 4

$P_{Ballast}$: Ballast local loads at mid-height of the ship double bottom, in kN/m², as defined in Ch 3, Sec 4

ℓ_2 : Span of the upper and lower secondary stiffeners, as defined in Fig 5.

When deemed necessary by the Society, the buckling check of struts may be examined on a case-by-case basis.

2.3 Scantling of secondary stiffeners in composite, plywood and HDPE materials

2.3.1 The scantling of composite, plywood and HDPE stiffeners are to be checked according to:

- the local loads defined in [2.1.1]
- the safety factor criteria defined in Ch 2, Sec 3, [3] for composite, Ch 2, Sec 3, [4] for plywood and Ch 2, Sec 3, [5] for HDPE, and
- the calculation methodology defined in NR546 Composite Ships.

Section 5 Local Primary Stiffener Scantling

Symbols

λ : Corrosion coefficient to be taken equal to:
- steel structure:
  - for stiffener located in a dry compartment: $\lambda = 1,1$
  - for stiffener located in a liquid compartment: $\lambda = 1,2$
- aluminium structure: $\lambda = 1,05$.

σ_{VM} : Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma + 3\tau}$$

σ : Normal stress in the direction of the beam axis, induced by local loads

τ : Shear stress in the direction of the local loads applied to the beam

1 General

1.1 Local scantling

1.1.1 The local primary stiffener scantling is to be carried out according to:
- for steel structure: the present Section
- for aluminium structure: the present Section and NR561 Aluminium Ships
- for composite structure: the present Section and NR546 Composite Ships.

1.1.2 The scantling of primary stiffeners contributing to the overall longitudinal strength of the hull girder and to the overall transverse strength of platform of multihull are also to be checked as defined in Sec 2.

1.2 Structural beam models

1.2.1 Isolated beam model

a) The requirements for the scantling of primary stiffeners defined in the present Section apply for isolated beam calculation.

b) Local loads

The local lateral pressures to be considered are defined in [1.2.2], b).

c) Local load point calculation

The location of the point of the stiffener where the local loads are to be calculated in order to check the scantling are defined in Ch 3, Sec 1, [4].

d) Checking criteria

The bending stresses, shear stresses and combined stresses calculated by the model are to be in accordance with the permissible values defined in Ch 2, Sec 3.

1.2.2 Two- or three-dimensional beam model

When an isolated beam calculation of the primary structure is not possible due to an interaction of the primary stiffeners, a two- or three-dimensional structural model analysis including the different primary stiffeners is to be carried out as follows:

a) Model:

The structural model is to represent the primary supporting members, with their attached plating (as defined in [1.4.1]), of the structure area considered.

The extension of the structural model is to be such that the results in the areas to be analysed are not influenced by the unavoidable inaccuracy in the modelling of the boundary conditions.

b) Loading conditions:

The local lateral pressures to be considered are:
- for bottom primary stiffeners: sea pressures and bottom slamming pressures (when slamming may occur)
- for side shell and, for multihull, primary transverse cross structure of platform bottom: sea pressures (without taking into account side shell impact)
- for deck primary stiffeners: external or internal pressures, minimum loads and, when applicable, wheeled loads
- for all primary stiffeners, when applicable: internal pressures.

When deemed necessary, it may be taken into account of the counteraction between the internal and external loads in the most severe conditions (see Ch 3, Sec 1, [3.1.1]).

Note 1: When a bottom slamming pressure analysis is carried out for planing hull, the impact pressure p_{sl} defined in Ch 3, Sec 3, [3.3.2] is to be only applied on one floor of the model as a constant pressure. The other floors of the model are to be loaded by the bottom sea pressure defined in Ch 3, Sec 3, [2.2.1].

c) Local load point calculation:

The location of the point of the stiffener where the local loads are to be calculated in order to check the scantling are defined in Ch 3, Sec 1, [4].

d) Checking criteria:

It is to be checked that the equivalent stresses σ_{VM} deduced from the model are in compliance with Ch 2, Sec 3.

1.2.3 Curved beam model

The curvature of primary supporting members may be taken into account by direct analysis.

In case of two dimensional or three dimensional beam structural model, the curved primary supporting members may be represented by a number N of straight beams, N being adequately selected to minimize the spring effect in way of knuckles.

The stiffness of knuckle equivalent springs is considered as minor from the point of view of the local bending moment and the shear force distribution when the angle between two successive beams is not more than 3°.

1.3 Finite element model

1.3.1 General

This Subarticle is a guidance for the stress check of primary structure loaded under local load only using a finite element model.

1.3.2 Steel and aluminium structure

a) Finite elements:

In order to obtain an accurate representation of stresses in the areas of interest, the structural model is to be built on the basis of the following criteria:

- the mesh dimensions are to be such as to enable a faithful representation of the stress gradients
- quadrilateral elements are to have 90° angles as much as possible, or angles between 60° and 120°
- the use of linear triangular elements is to be avoided as much as possible in high stress area. When the use of a linear triangular element cannot be avoided, its edges are to have the same length
- the use of membrane and rod elements is only allowed when significant bending effects are not present; in the other cases, elements with general behaviour (quadratic finite element acting in traction, compression and bending and bar element acting also in bending) are to be used
- webs of primary members are to be modelled with at least three elements on their height
- the ratio between the longer side and the shorter side of elements is to be less than 3 in the areas expected to be highly stressed.
- large openings in web of primary supporting members and door openings in bulkheads are to be correctly represented taking into account local reinforcement when provided.

b) Load model:

The finite element model is to be loaded taking into account the local loads defined in Ch 3, Sec 3 and Ch 3, Sec 4.

Distributed loads are to be applied:

- to the plating panels when the platings are modelled by shell elements (quadratic finite element acting in traction, compression and bending) and the secondary stiffeners by bar elements (acting also in bending), or
- directly to the primary supporting members actually supporting the secondary stiffeners proportionally to the areas of influence of secondary stiffeners.

c) Boundary conditions:

The finite element calculation is to be performed with displacement restrictions applied to nodes of the model. Rotations of these nodes are to be free.

As a rule, these nodes are to be located outside the model areas where stress checks are carried out.

Detailed justifications may be requested by the Society to verify that the forces reactions applied to these nodes do not affect the bending moments and shear forces applied to the model.

d) Stress components:

Stress components are generally identified with respect to the element co-ordinate system. The orientation of the element co-ordinate system in relation to the reference co-ordinate system of the model is to be specified.

The following stress components to be considered and calculated at the centroid of each element are:

- the normal stresses σ_1 and σ_2 in the directions of element co-ordinate system axes
- the shear stress τ_{12} with respect to the element co-ordinate system axes

e) Stress check:

The maximum stresses and buckling stresses are to be calculated as follow:

- Maximum stress check:

  The Von Mises equivalent stress, σ_{eq}, in N/mm², is to be derived as follows:

$$\sigma_{eq} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 + 3\tau_{12}^2}$$

  Where σ_1, σ_2 and τ_{12} are defined in a).

- Buckling stress check:

  Where the buckling panel is meshed by several finite plate elements, the stresses of the buckling panel are obtained by the following methodology:

  - For each plate finite element, the stresses ($\sigma_{\xi\varepsilon}^*$, $\sigma_{\psi\varepsilon}^*$, τ_ε^*) expressed in the element co-ordinate system are projected in the co-ordinate system of the buckling panel to obtained the stresses ($\sigma_{\xi\varepsilon}$, $\sigma_{\psi\varepsilon}$, τ_ε).
  - For the buckling panel, the stresses are calculated according to the following formula:

$$\sigma_x = \frac{\sum_i^n A_i \sigma_{x\,e_i}}{\sum_i^n A_i} \geq 0$$

$$\sigma_y = \frac{\sum_i^n A_i \sigma_{y\,e_i}}{\sum_i^n A_i} \geq 0$$

$$\tau = \frac{\sum_i^n A_i \tau_{e_i}}{\sum_i^n A_i} \geq 0$$

  where:

  $\sigma_{\xi\,\varepsilon\iota}$, $\sigma_{\psi\,\varepsilon\iota}$: Stresses, in N/mm², of the plate finite element i, taken equal to 0 in case of tensile stress

  τ_{ei} : Shear stress, in N/mm², of the plate finite element i

  A_i : Area, in mm², of the plate finite element i.

f) Scantling criteria:

The maximum actual stresses and buckling stresses are to fulfill the permissible global stresses and buckling safety factors defined in Ch 2, Sec 3, Tab 4 taking into account Ch 2, Sec 3, [2.2].

1.3.3 Composite structure

a) General:

The structural model, the global loads distribution and the boundary conditions are to fulfill the general requirements defined in [1.3.2].

b) Stress check:

The stress check is to be carried out as defined in Ch 2, Sec 3, [3.1].

c) Scantling criteria:

The rule safety factors to be considered are defined in Ch 2, Sec 3, [3.2] taking into account Ch 2, Sec 3, [3.2.1] c).

1.4 Beam section modulus calculation

1.4.1 Attached plating

As a rule, the inertia, section modulus and shear section of primary stiffeners are to be determined by direct calculation.

The width b_p, in m, of the attached plating to take into account for the inertia and section modulus calculations are to be taken equal to the spacing between primary stiffeners (or half of the spacing between primary stiffeners when the plating extends on one side only), without being taken greater than $0,2\ell$ (or $0,1\ell$ when the plating extends on one side only), where ℓ is the length of the primary stiffener.

1.5 End stiffener conditions for calculation

1.5.1 Definition and calculation conditions

The assumptions on end stiffener conditions for the calculation of section moduli of primary stiffeners are defined in Sec 4, [1.4.1].

As a rule, the coefficient m is to be taken equal to 10 for an isolated beam calculation of primary stiffener.

2 Primary stiffener scantling analysed by isolated beam calculation under local loads

2.1 Scantling for steel and aluminium primary stiffeners under lateral loads

2.1.1 Scantling

The primary stiffener scantling check is to be carried out as defined for the secondary stiffener scantling in Sec 4, excepted otherwise specified, considering successively the different loads sustained by the primary stiffener defined in [1.2.1], item b) and the relevant permissible stresses defined in Ch 2, Sec 3.

The following parameters are to be taken into account in the section modulus and shear area formulae:

- Reduction coefficient $C_t = 1$
- Corrosion coefficient λ as defined in the present Section

The minimum section modulus for secondary stiffeners defined in Sec 4, [2.2.1] is not applicable to primary stiffeners.

The primary stiffener scantling check is also to be carried out for primary supporting members subjected to specific loads, such as concentrated loads.

2.1.2 Additional check of primary stiffeners

In addition to [2.1.1], the primary stiffeners are also to be examined taking into account the following requirements:

a) Buckling of attached plating:

Depending on the compression stress level in the attached plating induced by the bending of primary stiffener under the local loading cases, it may be necessary to check the buckling of the attached plating along the primary stiffener span.

The buckling of the attached plating is to be checked according to the criteria defined in Ch 2, Sec 3.

b) Recommended proportions of primary stiffeners:

As a rule, the proportions of stiffeners are to be as defined in [2.1.3].

2.1.3 Recommended proportions of primary stiffeners

a) General:

As a rule, the proportions of primary stiffeners are to be as defined in:

- For steel stiffener: b) of the present requirement
- For aluminium alloy stiffener: NR561 Aluminium Ships, [3.3].

Other proportions may be considered if the buckling assessment under local loads and axial loads is carried out according to App 1 for steel stiffeners or NR561, App 2 for aluminium stiffeners.

b) Proportions of primary stiffeners:

As a rule, the thicknesses (web and flange) of stiffeners are to satisfy the following criteria:

$$t_w \geq \frac{h_w}{100}\sqrt{\frac{R_{eH}}{235}}$$

$$t_f \geq \frac{b_{f\text{-}out}}{C_f}\sqrt{\frac{R_{eH}}{235}}$$

where:

$b_{f\text{-}out}$: Dimension of the flange, in mm, as defined in Sec 4, Fig 6.

t_w, t_f : Thickness, in mm, of the web and the flange respectively

C_f : Slenderness coefficients to be taken equal to 12.

Note 1: For stiffened web, h_w may be replaced by the spacing between web stiffeners, in mm, if smaller.

2.1.4 Scantling for primary stiffeners under wheeled loads

The present requirements are applicable for standard structural typology where sufficient transverse bulkheads are provided to prevent racking effect. When it is not the case, a scantling approach based on the hypothesis defined in NR467 Steel Ships, Pt B, Ch 7, App 1 is to be considered.

For primary supporting members subjected to wheeled loads, the section modulus and shear area may be calculated as defined for secondary stiffener in Sec 4, [2.2.2], considering the distribution of the wheeled loads as an uniform pressures p.

This uniform pressure is to be equivalent to the distribution of vertical wheeled concentrated forces when such forces are closely located and is to be determined in the most unfavourable case, i.e. where the maximum number of axles are located on the same primary supporting member, according to Fig 1 and to Fig 2.

The uniform pressure p, in kN/m², is to be calculated as follows:

$$p = p_{eq}\left(1 + \alpha\frac{a_z\eta}{g}\right)$$

where:

p_{eq} : pressure equivalent to the vertical wheel distribution, in kN/m² to be taken equal to:

$$p_{eq} = 10\frac{n_V Q_A}{\ell s}\left(3 - \frac{X_1 + X_2}{s}\right)$$

n_V : Maximum number of vehicles possible located on the primary supporting member

Q_A : Maximum axle load, in t, as defined in Ch 3, Sec 4, [4.4.1]

X_1 : Minimum distance, in m, between two consecutive axles (see Fig 2)

X_2 : Minimum distance, in m, between axles of two consecutive vehicles (see Fig 2)

a_z : Vertical acceleration, in m/s², as defined in Ch 3, Sec 4, [2.2]

g : Gravity acceleration taken equal to 9,81 m/s²

α : Coefficient taken equal to:

- 0,5 in general
- 1,0 for landing gears of trailers

η : Acceleration coefficient to be taken equal to:

- 1,0 for ship in displacement mode
- 0,4 for ship in planing mode.

For arrangements different from those shown in Fig 1 and Fig 2, the scantling check of primary supporting members is to be carried out by direct calculation, taking into account the distribution of concentrated loads induced by the vehicle wheels as defined in Ch 3, Sec 4, [4.4.1].

Figure 1 : Distribution of vehicles on a primary supporting member

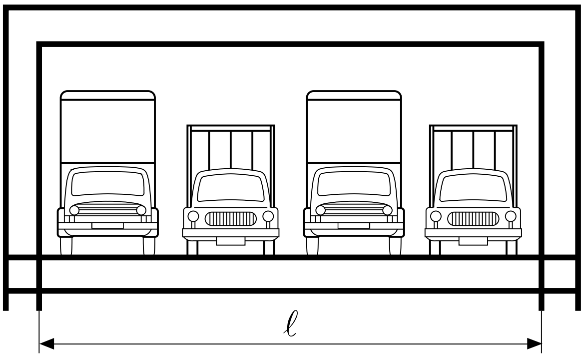
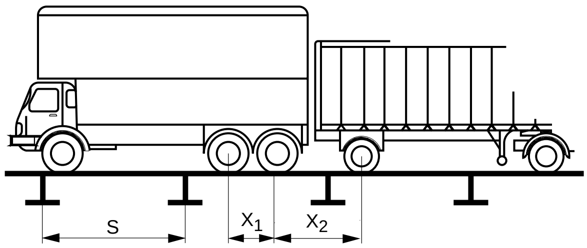


Figure 2 : Distance between axles of two consecutive vehicles



2.2 Primary stiffeners in composite, plywood and HDPE materials

2.2.1 The scantling of composite and plywood stiffeners are to be checked according to:

- the local loads defined in [1.2.1], b) or [1.2.2], b)
- the calculation methodology defined in NR546 Composite Ships
- the safety factor criteria defined in Ch 2, Sec 3, [3] for composite, Ch 2, Sec 3, [4] for plywood and Ch 2, Sec 3, [5] for HDPE structure.

2.2.2 Two- or three-dimensional structural model

When a two- or three-dimensional structural model is provided, the primary structure check is to be carried out as defined in [1.2.2] and in NR546 Composite Ships.

2.3 Scantling of primary stiffeners in way of launching appliances used for survival craft or rescue boat

2.3.1 The scantling of deck primary supporting structure are to be determined by direct calculations, taking into account loads exerted by launching appliances corresponding to the SWL of launching appliances.

For steel and aluminium structure, the combined stress σ_{vm}, in N/mm², is not to exceed the smaller of R_y / 2,2 and R_m / 4,5 where R_y is the minimum yield stress of the material (in welded conditions for aluminium) and R_m the ultimate minimum tensile strength (in welded conditions for aluminium).

For composite structure, the combined safety factor SF_{CS} defined in Ch 2, Sec 3 [3.2.3] is to be multiplied by a factor taken equal to 2,25.

3 Specific requirements

3.1 General

3.1.1 Material

The specific requirements defined in the present article are applicable to primary stiffeners made in steel.

Primary stiffeners made in aluminium are to be in accordance with the NR561 Aluminium Ships.

Primary stiffeners made in composite are to be in accordance with the NR546 Composite Ships.

3.2 Cut-outs and large openings

3.2.1 Cut-outs in web

Cut-outs for the passage of secondary stiffeners are to be as small as possible and well rounded with smooth edges.

In general, the height of cut-outs is to be not greater than 50% of the height of the primary supporting member.

3.2.2 Location of cut-out in web

As a general rules, where openings such as lightening holes or duct routing for pipes, electrical cable,..., are cut in primary supporting members, they are to be equidistant from the face plate and the attached plate. As a rule, their height is not to be more than 20% of the primary supporting member web height.

The length of the openings is to be not greater than:

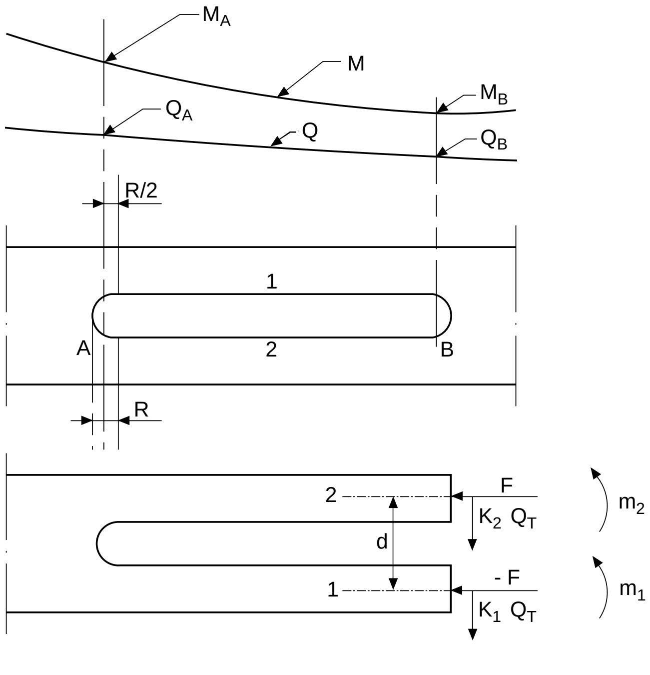
- at the end of primary member span: 25% of the distance between adjacent openings
- elsewhere: the distance between adjacent openings.

Openings may not be fitted in way of toes of end brackets.

3.2.3 Large openings

In case of large openings as shown in Fig 3, the secondary stresses in primary supporting members are to be considered for the reinforcement of the openings, where deemed necessary.

Figure 3 : Large openings in primary supporting members - Secondary stresses



The secondary stresses may be calculated in accordance with the following procedure:

- Members (1) and (2) are subjected to the following forces, moments and stresses:

$$F = \frac{M_A + M_B}{2d}$$

$$m_1 = \left|\frac{M_A - M_B}{2}\right| K_1$$

$$m_2 = \left|\frac{M_A - M_B}{2}\right| K_2$$

$$\sigma_{F1} = 10\frac{F}{S_1}$$

$$\sigma_{F2} = 10\frac{F}{S_2}$$

$$\sigma_{m1} = \frac{m_1}{w_1}10^3$$

$$\sigma_{m2} = \frac{m_2}{w_2}10^3$$

$$\tau_1 = 10\frac{K_1 Q_T}{S_{w1}}$$

$$\tau_2 = 10\frac{K_2 Q_T}{S_{w2}}$$

where:

d : Distance, in m, between the neutral axes of (1) and (2)

m_1, m_2 : Bending moments, in kN.m, in (1) and (2)

M_A, M_B : Bending moments, in kN.m, in sections A and B of the primary supporting member

I_1, I_2 : Moments of inertia, in cm^4, of (1) and (2) with attached plating

Q_T : Shear force, in kN, equal to Q_A or Q_B, whichever is greater

σ_{F1}, σ_{F2} : Axial stresses, in N/mm^2, in (1) and (2)

σ_{m1}, σ_{m2} : Bending stresses, in N/mm^2, in (1) and (2)

S_1, S_2 : Sectional areas, in cm^2, of (1) and (2)

S_{w1}, S_{w2} : Sectional areas, in cm^2, of webs in (1) and (2)

τ_1, τ_2 : Shear stresses, in N/mm^2, in (1) and (2)

w_1, w_2 : Section moduli, in cm^3, of (1) and (2)

$$K_1 = \frac{I_1}{I_1 + I_2}$$

$$K_2 = \frac{I_2}{I_1 + I_2}$$

- The combined stress σ_C calculated at the ends of members (1) and (2) is to be obtained from the following formula:

$$\sigma_c = \sqrt{(\sigma_F + \sigma_m)^2 + 3\tau^2}$$

- The combined stress σ_C is to comply with the checking criteria in Ch 2, Sec 3. Where these checking criteria are not complied with, the cut-out is to be reinforced according to one of the solutions shown from Fig 4 to Fig 6:
  - continuous face plate (solution 1): see Fig 4
  - straight face plate (solution 2): see Fig 5
  - compensation of the opening (solution 3) by increase of the web thickness t_1: see Fig 6.

  Other arrangements may be accepted provided they are supported by direct calculations submitted to the Society for review.

Figure 4 : Stiffening of large openings in primary supporting members - Solution 1

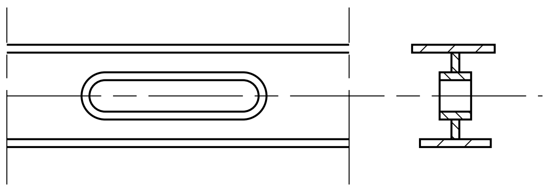


Figure 5 : Stiffening of large openings in primary supporting members - Solution 2

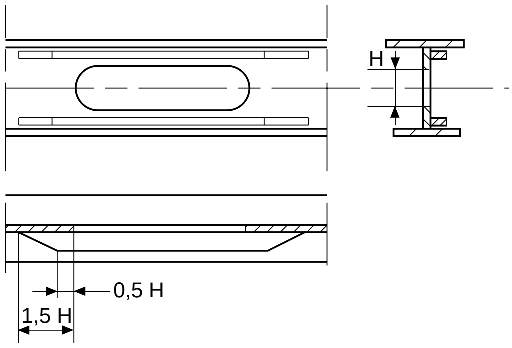
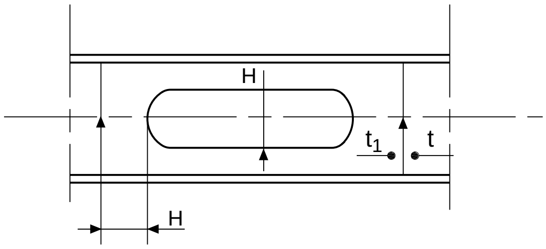


Figure 6 : Stiffening of large openings in primary supporting members - Solution 3



3.3 Web stiffening arrangement for primary supporting members

3.3.1 Minimum thicknesses

As a rule, the thicknesses of web and flange are not to be less than:

- web:

$$\frac{h_w}{t_w} \le 100\sqrt{k}$$

- face plate:

  for symmetrical flange:

$$\frac{b_f}{t_f} \le 33\sqrt{k}$$

  or, for dissymmetric flange:

$$\frac{b_f}{t_f} \le 16,5\sqrt{k}$$

Webs of primary supporting members are generally to be stiffened where their height, in mm, is greater than 100 t, where t is the web thickness, in mm, of the primary supporting member.

In general, the web stiffeners of primary supporting members are to be spaced, in mm, not more than 110 t.

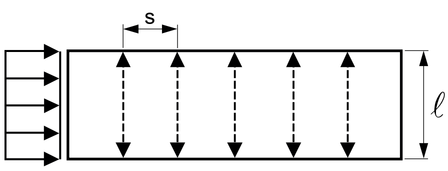
3.3.2 The moment of inertia I, in cm^4,of stiffeners of web of primary supporting members is to be not less than the value obtained from the following formula:

$$I = 11,4\, s t_w (2,5\,\ell^2 - 2s^2)\frac{R_{eH}}{235}$$

where:

ℓ	:	Length, in m, of the web stiffener (see Fig 7)
s	:	Spacing, in m, of web stiffeners (see Fig 7)
t_w	:	Web thickness, in mm, of the primary supporting member
R_{eH}	:	Minimum yield stress, in N/mm^2, as defined in Ch 1, Sec 2, of the material of the web of primary supporting member.

Figure 7 : Web stiffeners for primary supporting members



3.3.3 As a general rule, tripping brackets (see Fig 8) welded to the face plate are generally to be fitted:

- every fourth spacing of secondary stiffeners
- at the toe of end brackets
- at rounded face plates
- in way of cross ties
- in way of concentrated loads.

Where the width of the symmetrical face plate is greater than 400 mm, backing brackets are to be fitted in way of the tripping brackets.

3.3.4 The arm length d of tripping brackets is to be not less than the greater of the following values, in m:

$$d = 0,38b$$

$$d = 0,85b\sqrt{\frac{s_t}{t}}$$

where:

b : Height, in m, of tripping brackets, shown in Fig 8

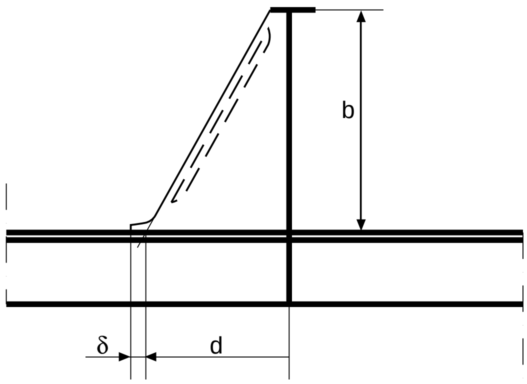
s_t : Spacing, in m, of tripping brackets

t : Thickness, in mm, of tripping brackets.

3.3.5 Steel tripping brackets with a thickness, in mm, less than 16,5 times the length, in m, of the free edge of the bracket are to be flanged or stiffened by a welded face plate.

The sectional area, in cm², of the flanged edge or the face plate is to be not less than 10 times the length, in m, of the free edge of the bracket.

Figure 8 : Primary supporting member: Web stiffener in way of secondary stiffener



Section 6 Stiffener Brackets Scantling and Stiffener End Connections

1 General arrangement of brackets

1.1 Materials

1.1.1 The requirements of the present Section are applicable to hull made totally or partly in steel.

For ship hulls built in aluminium alloys, the requirements to apply are defined in NR561 Aluminium Ships, Section 6.

For ship hulls built in composite materials, the requirements to apply are defined in NR546 Composite Ships.

1.2 General requirements

1.2.1 As a general rules, brackets are to be provided at the stiffener ends when the continuity of the web and the flange of the stiffeners is not ensured in way of their supports.

1.2.2 Arm of end brackets are to be of the same length, as far as practicable and the alignment of the brackets on each side of the supporting member is to be ensured.

1.2.3 The section of the end bracket web is generally to be not less than that of the supported stiffener.

1.2.4 The section modulus of the end bracket is to be at least equal to the section modulus of the stiffener supported by the bracket.

When the bracket is flanged, the section modulus is to be examined in way of flange as well as in way of the end of the flange.

1.2.5 Bracket flanges

Steel brackets having a thickness, in mm, less than 16,5 L_b are to be flanged or stiffened by a welded face plate, such that:

- the sectional area, in cm^2, of the flanged edge or the face plate is at least equal to 10 L_b
- the thickness of the bracket flange is not less than that of the bracket web,

where:

L_b : Length, in m, of the free edge of the bracket.

1.2.6 When a face plate is welded on end brackets to be strengthened, this face plate is to be symmetrical.

In such a case, the following arrangements are to be complied with, as a rule:

- the face plates are to be snipped at the ends, with total angle not greater than 30°
- the width of the face plates at ends is not to exceed 25 mm
- the face plates being 20 mm thick or above are to be tapered at ends over half the thickness
- the radius of the curved face plate is to be as large as possible
- a collar plate is to be fitted in way of bracket toes
- the fillet weld throat thickness is to be not less than t/2, where t is the thickness at the bracket toe.

2 Bracket for connection of perpendicular stiffeners

2.1 General arrangement

2.1.1 Typical bracket for connection of perpendicular stiffeners are shown from Fig 1 to Fig 6.

As a general rules, brackets are to be in accordance with the requirements defined in [1.2].

Where no direct calculation is carried out, the minimum length d, in mm, as defined from Fig 1 to Fig 6 may be taken equal to:

$$d = \varphi \sqrt{\frac{w + 30}{t}}$$

where:

φ : Coefficient equal to:
- for unflanged brackets: $\varphi = 48{,}0$
- for flanged brackets: $\varphi = 43{,}5$

w : Required section modulus of the supported stiffener, in cm^3

t : Bracket thickness, in mm.

Figure 1 : Bracket at upper end of secondary stiffener on plane bulkhead

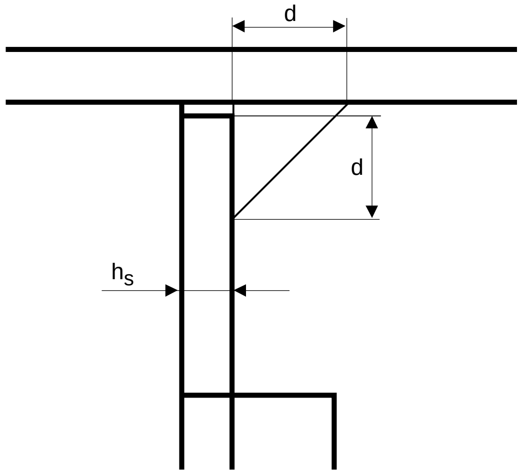


Figure 2 : Bracket at lower end of secondary stiffener on plane bulkhead

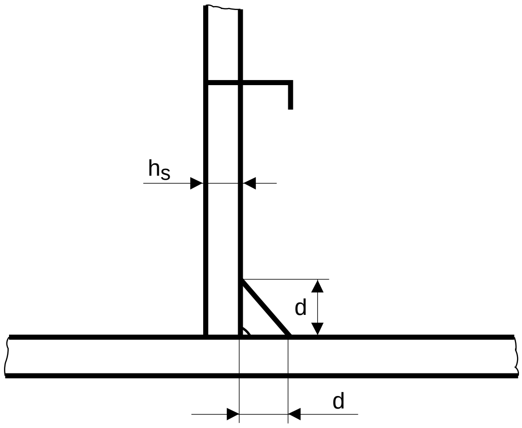


Figure 3 : Other bracket arrangement at lower end of secondary stiffeners on plane bulkhead

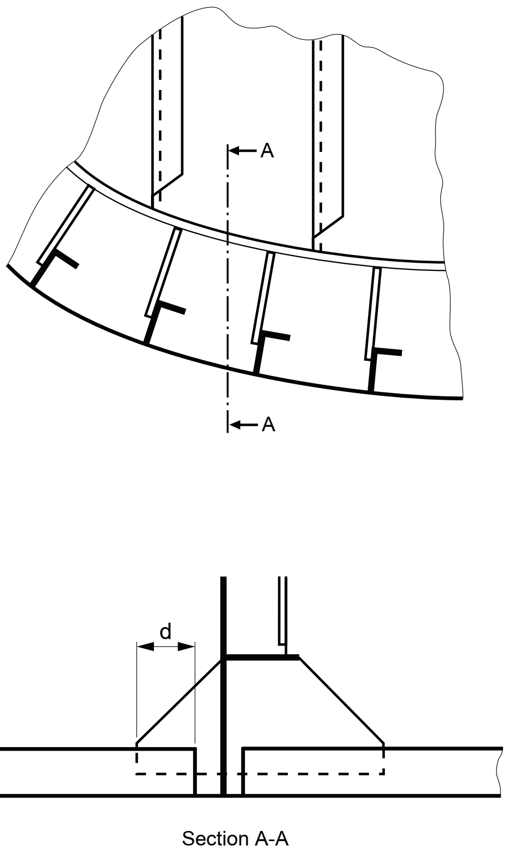


Figure 4 : Connections of perpendicular stiffeners in the same plane

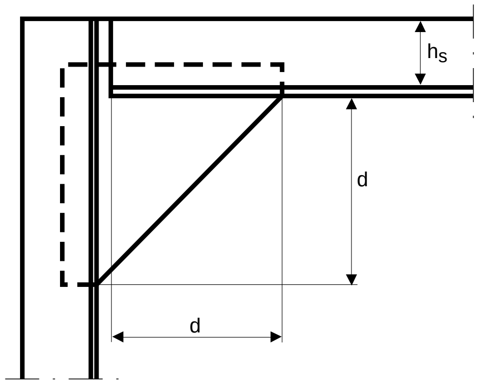


Figure 5 : Connections of stiffeners located in perpendicular planes

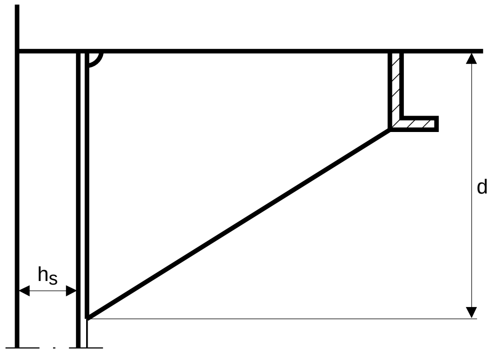
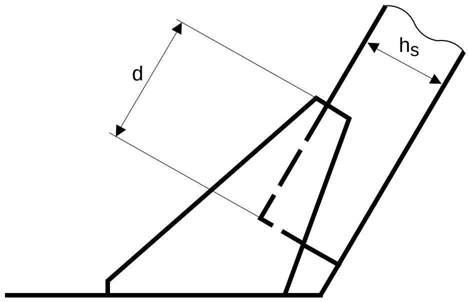


Figure 6 : Lower brackets of main frames



2.1.2 When a bracket is provided to ensure the simultaneous continuity of two (or three) stiffeners of equivalent stiffness, the bracket scantling is to be determined by direct calculation, taking into account the balanced bending moment in the connection of the two (or three) stiffeners.

3 Bracketless end stiffeners connections

3.1 Bracketless end connections

3.1.1 General

The design of bracketless connections is to be such as to provide adequate resistance to rotation and displacement of the connection.

3.1.2 Case of two stiffeners

In the case of bracketless crossing between two primary supporting members (see Fig 7), the thickness t_b of the common part of the webs, in mm, is to be not less than the greater value obtained from the following formulae:

$$t_b = \frac{Sf_1\sigma_1}{0,4h_2R_{eH}}$$

$$t_b = \frac{Sf_2\sigma_2}{0,4h_1R_{eH}}$$

t_b = Max (t_1 ; t_2)

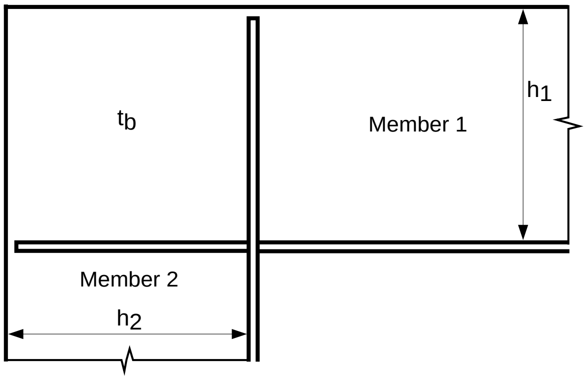
where:

Sf_1 , Sf_2 : Flange sections, in mm^2,of member 1 and member 2, respectively

σ_1 , σ_2 : Actual normal stresses, in N/mm^2, in member 1 and member 2, respectively

R_{eH} : Minimum yield stress, in N/mm^2, as defined in Ch 1, Sec 2, of the material of the web of primary supporting member.

Figure 7 : Bracketless end connections between two primary supporting members



3.1.3 Case of three stiffeners

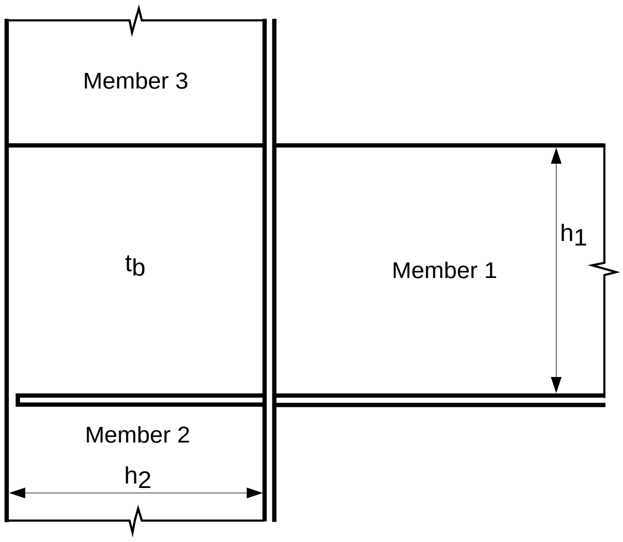
In the case of bracketless crossing between three primary supporting members (see Fig 8), and when the flange continuity is ensured between member 2 and member 3, the thickness t_b of the common part of the webs, in mm, is to be not less than:

$$t_b = \frac{S f_1 \sigma_1}{0,4 h_2 R_{eH}}$$

R_{eH} : As defined in [4.1.1].

When the flanges of member 2 and member 3 are not continuous, the thickness of the common part of the webs is to be defined as [3.1.2].

Figure 8 : Bracketless end connections between three primary supporting members



3.1.4 Stiffening of common part of webs

When the minimum value of heights h_1 and h_2 of the member 1 and member 2 is greater than 100 t_b , the common part of the webs is generally to be stiffened.

3.1.5 Lamellar tearing in way of flanges

When lamellar tearing of flanges is likely to occur, a 100% ultrasonic testing of the flanges in way of the weld may be required after welding.

3.2 Other type of end connection

3.2.1 Where end connections are made according to Fig 9, a stiffener with sniped ends is to be fitted on connection web, when:

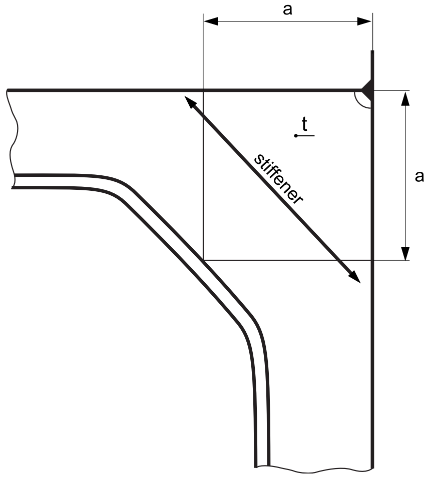
a > 100 t

where:

a : Dimension, in mm, measured as shown on Fig 9

t : Web thickness, in mm.

Figure 9 : End connection with stiffener



Section 7 Pillar Scantling

Symbols

A : Cross-sectional area, in cm², of the pillar

E : Young's modulus, in N/mm², to be taken equal to:

- for steels in general: $E = 2{,}06 \cdot 10^5$ N/mm²
- for stainless steels: $E = 1{,}95 \cdot 10^5$ N/mm²

f : Fixity coefficient, to be obtained from Tab 1

I : Minimum moments of inertia, in cm⁴, of the pillar in relation to its principal axis

ℓ : Span, in m, of the pillar

R_{eH} : Minimum guaranteed yield stress, in N/mm²

σ_{CB} : Global pillar buckling stress, in N/mm²

σ_{CL} : Local pillar buckling stress, in N/mm².

1 General

1.1 Materials

1.1.1 The requirements of the present Section are applicable to pillars built of:

- steel: as defined in Article [2]
- aluminium: as defined in Article [3]
- composite materials: as defined in Article [4].

1.2 Application

1.2.1 The requirements of this Section deals with the buckling check of independent profiles pillars or bulkheads stiffeners acting as pillar.

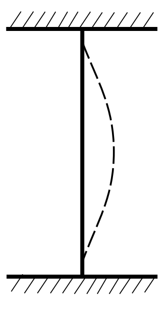
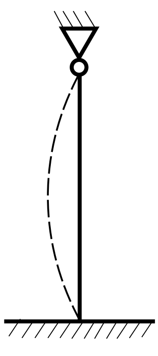
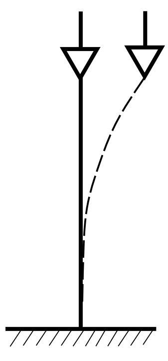
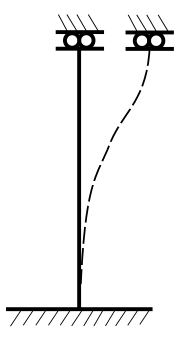
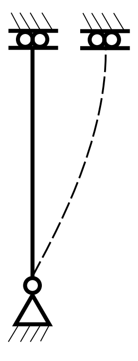
The general requirements relating to pillars arrangement are given in Ch 2, Sec 1, [6.4].

1.2.2 Calculation approach

The pillar buckling stresses σ_{CB} and σ_{CL}, in N/mm², and the maximal allowable axial load P_C, in kN, are to be successively examined according to the two following methods:

- global column buckling, and
- local buckling.

Table 1 : Coefficient f

Conditions of fixity						
f	0,5 **(1)**	0,7	1,0	2,0	1,0	2,0
(1) End clamped condition may only be considered when the structure in way of pillar ends can not rotate under the effect of loadings.						

1.2.3 Actual compression axial load

Where pillars are aligned, the compression axial load F_A, in kN, is equal to the sum of the loads supported by the pillar considered and those supported by the pillars located above, multiplied by a weighting factor r.

The load factor depends on the relative position of each pillar with respect to that considered (i.e the number of tiers separating the two pillars).

The compression axial load in the pillar is to be obtained, in kN, from the following formula:

$$F_A = A_D p + \sum_i r_i Q_i$$

where:

A_D : Area, in m², of the portion of the deck or the platform supported by the pillar considered

p : Pressure on deck, in kN/m², as defined in Ch 3, Sec 4

r_i : Load factor depending on the relative position of each pillar above the one considered, to be taken equal to:

- r_i = 0,9 for the pillar immediately above the pillar considered
- $r_i = 0{,}9^i > 0{,}478$ for the i^{th} pillar of the line above the pillar considered

Q_i : Vertical local load, in kN, supported by the i^{th} pillar of the line above the pillar considered, if any.

2 Pillar in steel material

2.1 Buckling of pillars subjected to compression axial load

2.1.1 Global critical column buckling stress

The global critical column buckling stress of pillars σ_{CB} is to be obtained, in N/mm², from the following formulae:

$$\sigma_{CB} = \sigma_E \quad \text{for} \quad \sigma_E \le \frac{R_{eH}}{2}$$

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

where:

σ_E : Euler column buckling stress of the pillar, in N/mm², to be obtain by the following formula:

$$\sigma_E = \pi^2 E \frac{I}{A(f\ell)^2} 10^{-4}$$

2.1.2 Local critical buckling stress

The local critical buckling stress of pillars σ_{CL} is to be obtained, in N/mm², from the following formulae:

$$\sigma_{CL} = \sigma_{Ei} \quad \text{for} \quad \sigma_{Ei} \le \frac{R_{eH}}{2}$$

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

where:

σ_{Ei} : Euler local buckling stress, in N/mm², to be taken equal to the values obtained from the following formulae:

- For circular tubular pillars:

$$\sigma_{Ei} = 12,5\left(\frac{E}{206000}\right)\left(\frac{t}{D}\right)10^4$$

where:

t : Pillar thickness, in mm

D : Pillar outer diameter, in mm

- For rectangular tubular pillars:

$$\sigma_{Ei} = 78\left(\frac{E}{206000}\right)\left(\frac{t}{b}\right)^2 10^4$$

where:

b : Greatest dimension of the cross-section, in mm

t : Plating thickness in relation to b, in mm

- For built up pillars, the lesser of:

$$\sigma_{Ei} = 78\left(\frac{E}{206000}\right)\left(\frac{t_W}{h_W}\right)^2 10^4$$

$$\sigma_{Ei} = 32\left(\frac{E}{206000}\right)\left(\frac{t_F}{b_F}\right)^2 10^4$$

where:

h_W : Web height of built-up section, in mm

t_W : Web thickness of built-up section, in mm

b_F : Face plate width of built-up section, in mm

t_F : Face plate thickness of built-up section, in mm.

2.1.3 Maximum allowable axial load

The maximum allowable axial load P_C, in kN, is the smaller of the two following values:

$$P_C = \frac{\sigma_{CB}}{1,35} A \cdot 10^{-1}$$

$$P_C = \frac{\sigma_{CL} A}{1,2} \cdot 10^{-1}$$

2.2 Buckling of pillars subjected to compression axial load and bending moments

2.2.1 Checking criteria

In addition to the requirements in [2.1], the scantling of the pillar loaded by the compression axial load and bending moments are to comply with the following formula:

$$10 F_A \left(\frac{1}{A} + \frac{\Phi e}{w_P} \right) + \left(10^3 \frac{M_{max}}{Z_P} \right) \le 0,85 R_{eH}$$

where:

F_A : Actual compression load, in kN, acting on the pillar

A : Cross-sectional area, in cm², of the pillar

e : Eccentricity, in cm, of the compression load with respect to the centre of gravity of the cross-section

$$\Phi = \frac{1}{1 - \frac{10 F_A}{\sigma_E A}}$$

σ_E : Euler column buckling stress, in N/mm², defined in [2.1.1]

Z_P : Minimum section modulus, in cm³, of the cross-section of the pillar

M_{max} : Max (M_1, M_2, M_0)

M_1 : Bending moment, in kN.m, at the upper end of the pillar

M_2 : Bending moment, in kN.m, at the lower end of the pillar

$$M_0 = \frac{0,5(\sqrt{1 + t^2})(M_1 + M_2)}{\cos(u)}$$

$$u = 0,5\pi \sqrt{\frac{10 F_A}{\sigma_E A}}$$

$$t = \frac{1}{\tan(u)} \left(\frac{M_2 - M_1}{M_2 + M_1} \right)$$

provided that:

$$-\tan^2 u \le \frac{M_2 - M_1}{M_2 + M_1} \le \tan^2 u$$

2.3 Pillars in tanks

2.3.1 Where pillars are submitted to tensile stress due to internal pressure in tanks, brackets or equivalent arrangements are to be provided in way of the connection elements between the pillar and the supported structure of the tank.

Doubling plate are not to be used at pillar ends.

Pillars in tanks are not to be of hollow profile type.

2.4 Vertical bulkhead stiffener acting as pillar

2.4.1 When a vertical stiffening member is fitted on the bulkhead in line with the deck primary supporting member transferring the loads from the deck to the bulkhead (as a pillar), this vertical stiffener is to be calculated as a built up pillar as defined in [2.1] or [2.2], taking into account an associated plating of a width equal to 35 times the plating thickness.

3 Pillar in aluminium material

3.1 General

3.1.1 The global critical column buckling stress σ_{CB} and the local critical buckling stress σ_{CL} , in N/mm^2, of a pillar built in aluminium material are to be as defined in NR561 Aluminium Ships, Section 8.

3.1.2 Maximum allowable axial load

The maximum allowable axial load P_C , in kN, is to be as defined in NR561 Aluminium Ships, Section 8, taking into account the following values of SF_{CB} and SF_{CL}:

$$SF_{CB} = 0,34\frac{f\ell}{r} + 1,15$$

$SF_{CL} = 1,2$

where:

r : Minimum radius of giration, in cm, equal to:

$$r = \sqrt{\frac{I}{A}}$$

4 Pillar in composite material

4.1 Scantling criteria

4.1.1 The compression and buckling check of pillars made of composite materials are to be carried out according to NR546 Composite Ships, Section 8, taking into account the following Rules safety factors in relation to the scantling criteria:

- Maximum stress in each layer: $SF = 1,2\ C_F\ C_R$
- Combined stress in each layer: $SF_{CS} = 1,2\ C_{CS}\ C_F$
- Local buckling: $SF_{lBuck} = 1,55\ C_F$
- Global buckling: $SF_{gBuck} = 1,75\ C_F$

where

C_F, C_R : Partial safety factors defined in Ch 2, Sec 3, [3.2.2]

C_{CS} : For unidirectional tape, bi-bias, three unidirectional fabric: $C_{CS} = 1,7$, or

For other type of layer: $C_{CS} = 2,1$

Appendix 1 Calculation of the Critical Buckling Stresses

Symbols

a : Length of the longer side of the plate panel, in mm

α : Aspect ratio of the plate panel, to be taken as:

$$\alpha = \frac{a}{b}$$

b : Length of the shorter side of the plate panel, in mm

b_f : Total breath, in mm, of the flange.

E : Young's modulus, in N/mm², to be taken equal to:

- for steels in general: $E = 2{,}06.10^5$ N/mm²
- for stainless steels: $E = 1{,}95.10^5$ N/mm²

h_w, t_w, $b_{f\text{-}out}$:Dimensions of the stiffener, in mm, as defined in Fig 4

ν : Poisson's ratio of the material

R_{eH} : Minimum guaranteed yield stress, in N/mm², of the stiffener material

R_{eH_P} : Minimum guaranteed yield stress of the plate, in N/mm²

σ_x : Stress applied on the shorter side b of the plate panel

σ_y : Stress applied on the longer side a of the plate panel

σ_E : Elastic buckling reference stress, in N/mm², to be taken as:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{b}\right)^2$$

s : Spacing, in m, between stiffeners

τ : Applied shear stress, in N/mm²

t_p, t_w, t_f : Thickness, in mm, of the attached plating, web and flange.

1 General

1.1 Material

1.1.1 The requirements of this Section apply for the buckling check of steel structure elements subjected to compression stresses induced by overall bending moment and shear forces due to global hull girder loads and local loads.

The buckling check of aluminium alloys structure elements is to be carried out as defined in NR561 Aluminium Ships, taking into account the buckling check criteria defined in the present Appendix.

The buckling check of composite material or HDPE structure elements is to be carried out as defined in NR546 Composite Ships, taking into account the buckling rule safety factors defined in Ch 2, Sec 3.

1.2 Sign convention for normal stresses

1.2.1 General

In the present Section, compression and shear stresses are to be taken as positive.

Tensile stresses are to be taken as negative.

2 Buckling analysis of plating

2.1 Application

2.1.1 Buckling under global hull girder loads

The hull areas to be checked under buckling induced by overall bending moment and shear forces due to global hull girder loads are mainly:

a) Under compression:
   - bottom and/or decks plating
   - bottom and deck plating of platform of catamarans, in way of platform transverse primary structure
   - side shell plating in the upper and lower areas below deck and above bottom
   - superstructure contributing to the longitudinal or transverse global strength

b) Under shear:
- side shell plating
- platform primary transverse structure of catamarans.

Other hull areas may be checked under buckling on a case by case basis when deemed necessary by the Society.

2.1.2 Buckling under local loads

Buckling analysis of plating under local loads is to be carried out:

a) According to [3.3.7] when the plate is examined as an attached plating of stiffener

b) According to the present Sub Article when the plate is submitted to local compression loads taking into account the compression stress applied to the plate induced by local load.

2.2 Calculation hypothesis

2.2.1 The buckling approach defined in the present Appendix is based on the NR615 Buckling Assessment of Plated Structures, taking into account the following simplifying hypothesis:

- the applied compression stress is considered as uniform along the edges of the plate (the edge ratio Ψ according to NR615 is taken equal to 1)

Note 1:

When the applied compression stress along the edges of the plate is not uniform (ratio Ψ different from 1), the applied stress to consider in the present Section is to be taken equal to the maximum applied compression stress along the edge

- when the buckling check is carried out with bi-axial compression hypothesis, the stresses σ_x and σ_y are as a general rule determined by finite element calculation or direct calculation.

Note 2:

When the compression stress applied on the edge not directly loaded by the global loads is not determined by FEM or direct calculation, this compression stress may be considered as null.

- plate panels are considered as being simply supported on their edges

2.2.2 The buckling approach defined in NR615 Buckling Assessment of Plated Structures may be taken into account instead of the present simplify method when deemed necessary.

2.3 Critical buckling stresses

2.3.1 Critical buckling stress by compression of the shorter edge of the panel

The ultimate buckling stress of plate panels, in N/mm², induced by compression of the shorter edge of panel, according to Fig 1, is to be taken as:

$\sigma_{cx}' = C_x R_{eH\_P}$

where:

C_x : Coefficient equal to:

$C_x = 1{,}00$ for $\lambda \leq 0{,}84$

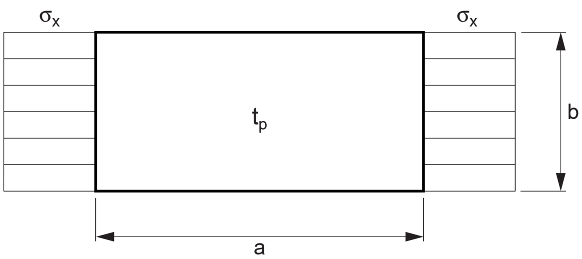
$$C_x = 1,13\left(\frac{1}{\lambda} - \frac{0,22}{\lambda^2}\right) \text{ for } \lambda > 0,84$$

λ : Reference degree of slenderness, to be taken as:

$$\lambda = \sqrt{\frac{R_{eH\_P}}{K_x \sigma_E}}$$

K_x : Buckling factor equal to 4

Figure 1 : Compression of the shorter edge of the panel



2.3.2 Critical buckling stress by compression of the longer edge of the panel

The ultimate buckling stress of plate panel, in N/mm², induced by compression of the longer edge of panel, according to Fig 2, is to be taken as:

$\sigma_{cy}' = C_y R_{eH\_P}$

where:

$$C_y = 1,13\left[\frac{1}{\lambda} - \frac{R + F^2 (H - R)}{\lambda^2}\right]$$

λ : Reference degree of slenderness, to be taken as:

$$\lambda = \sqrt{\frac{R_{eH\_P}}{K_y \sigma_E}}$$

$$K_y = \left(1 + \frac{1}{\alpha^2}\right)^2$$

R : Coefficient equal to:

$R = 0,22$ for $\lambda \geq 0,84$

$$R = \lambda\left(1 - \frac{\lambda}{1,13}\right) \text{ for } \lambda < 0,84$$

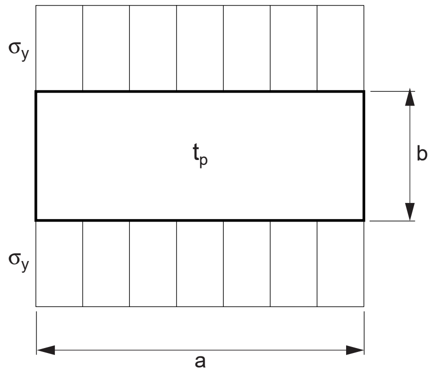
$$F = 1 - \frac{\left(\frac{K_y}{0,91} - 1\right)}{\lambda_p^2} \geq 0$$

$$\lambda_p^2 = \lambda^2 - 0,5 \text{ with } 1 \leq \lambda_p^2 \leq 3$$

$$H = \lambda - \frac{2\lambda}{1,13\ (T + \sqrt{T^2 - 4})} \geq R$$

$$T = \lambda + \frac{14}{15\lambda} + \frac{1}{3}$$

Figure 2 : Compression of the longer edge of the panel



2.3.3 Critical shear buckling stress

The ultimate shear buckling stress of plate panels, in N/mm², according to Fig 3, is to be taken as:

$$\tau_c' = C_\tau \frac{R_{eH\_P}}{\sqrt{3}}$$

where:

C_t : Coefficient equals to:

$$C_\tau = 1,00 \text{ for } \lambda \leq 0,84$$

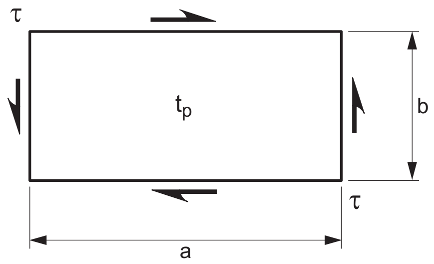
$$C_\tau = \frac{0,84}{\lambda} \text{ for } \lambda > 0,84$$

λ : Reference degree of slenderness, to be taken as:

$$\lambda = \sqrt{\frac{R_{eH\_P}}{K_t \sigma_E}}$$

$$K_\tau = \sqrt{3}\left(5,34 + \frac{4}{\alpha^2}\right)$$

Figure 3 : Shear stress



2.4 Buckling check criteria

2.4.1 General

The buckling strength or capacity defined in the present Sub Article takes into account the internal redistribution of loads depending on the load situation, slenderness and type of structure.

2.4.2 Scantling criteria

The plate scantling is to fulfill the following conditions:

- $$\left(\left(\frac{\sigma_x\, SF}{\sigma'_{cx}}\right)^{e_0} + \left(\frac{\sigma_y\, SF}{\sigma'_{cy}}\right)^{e_0} + \left(\frac{|\tau|\, SF}{\tau'_c}\right)^{e_0} - \Omega\right) \le 1$$

  with:

  $$\Omega = B\left(\frac{\sigma_x\, SF}{\sigma'_{cx}}\right)^{e_0/2}\left(\frac{\sigma_y\, SF}{\sigma'_{cy}}\right)^{e_0/2}$$

- when $\sigma_x \ge 0$ (compressive)

  $$\left(\left(\frac{\sigma_x\, SF}{\sigma'_{cx}}\right)^{2/\beta_p^{0,25}} + \left(\frac{|\tau|\, SF}{\tau'_c}\right)^{2/\beta_p^{0,25}}\right) \le 1$$

- when $\sigma_y \ge 0$ (compressive)

  $$\left(\left(\frac{\sigma_y\, SF}{\sigma'_{cy}}\right)^{2/\beta_p^{0,25}} + \left(\frac{|\tau|\, SF}{\tau'_c}\right)^{2/\beta_p^{0,25}}\right) \le 1$$

- $$\left(\frac{|\tau|\, SF}{\tau'_c}\right) \le 1$$

where:

σ_x , σ_y : Actual normal stresses applied on the plate panel, in N/mm², respectively in the shorter edge and the longer edge of the panel, taking into account the sign convention for normal stresses defined in [1.2]

τ : Actual shear stress applied on the plate panel, in N/mm², taking into account the sign convention for normal stresses defined in [1.2]

σ_{cx}' : Ultimate buckling stress, in N/mm², in the shorter edge of the panel, as defined in [2.3.1]

σ_{cy}' : Ultimate buckling stress, in N/mm², in the longer edge of the buckling panel, as defined in [2.3.2]

τ_c' : Ultimate buckling shear stresses, in N/mm², as defined in [2.3.3]

SF : Safety buckling factor SF_{buck} defined in Ch 2, Sec 3, Tab 1

B, e_0 : As defined in Tab 1

Table 1 : Coefficients B and e_0

Applied stresses	B	e_0
$\sigma_x \ge 0$ and $\sigma_y \ge 0$	$0,7 - 0,3\ \beta_p / \alpha^2$	$2 / \beta_p^{0,25}$
$\sigma_x < 0$ or $\sigma_y < 0$	1,0	2,0

Note 1:

β_p : Plate slenderness parameter taken as:

$$\beta_p = \frac{b}{t_p}\sqrt{\frac{R_{eH\_P}}{E}}$$

2.4.3 Plate capacity

For information, the plate limit state is based on the following interaction formula:

- $\left(\left(\frac{\gamma_{c1}\ \sigma_x\ SF}{\sigma'_{cx}}\right)^{e_0} + \left(\frac{\gamma_{c1}\ \sigma_y\ SF}{\sigma'_{cy}}\right)^{e_0} + \left(\frac{\gamma_{c1}\ |\tau|\ SF}{\tau'_c}\right)^{e_0} - \Omega\right) = 1$
- when $\sigma_x \geq 0$ (compressive)

$$\left(\left(\frac{\gamma_{c2}\ \sigma_x\ SF}{\sigma'_{cx}}\right)^{2/\beta_p^{0,25}} + \left(\frac{\gamma_{c2}\ |\tau|\ SF}{\tau'_c}\right)^{2/\beta_p^{0,25}}\right) = 1$$

- when $\sigma_y \geq 0$ (compressive)

$$\left(\left(\frac{\gamma_{c3}\ \sigma_y\ SF}{\sigma'_{cy}}\right)^{2/\beta_p^{0,25}} + \left(\frac{\gamma_{c3}\ |\tau|\ SF}{\tau'_c}\right)^{2/\beta_p^{0,25}}\right) = 1$$

$$\left(\frac{\gamma_{c4}\ |\tau|\ SF}{\tau'_c}\right) = 1$$

where:

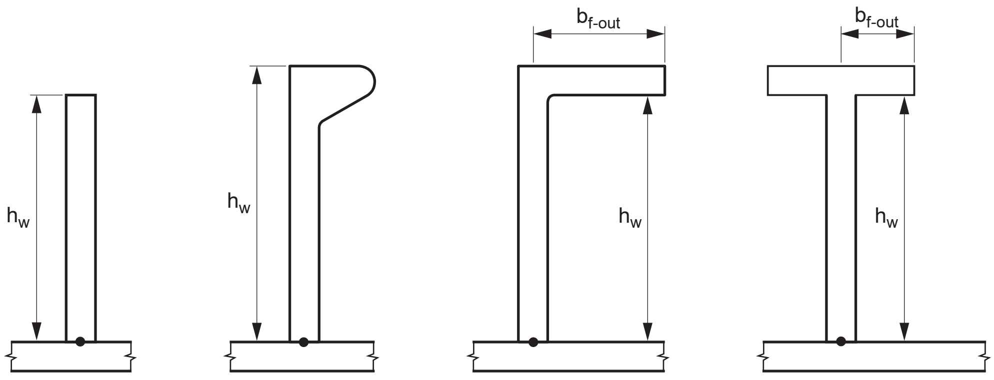
γ_c : Applied stress multiplier factor involving the plate buckling failure of the above different limit state

SF : Safety buckling factor SF_{buck} to be taken equal to 1 in the present requirement

The stress multiplier factor as failure, γ_c, is taken as:

$\gamma_c = \text{Min}\ (\gamma_{c1};\ \gamma_{c2};\ \gamma_{c3};\ \gamma_{c4})$

Figure 4 : Stiffener scantling parameters



3 Buckling analysis of stiffener

3.1 Application

3.1.1 The requirements defined in the present Article are applicable to secondary and primary stiffeners for the buckling check induced by:

- overall bending moment and shear force due to global hull girder loads, and
- bending moment and shear force induced by local loads.

3.1.2 The hull areas to be checked under buckling induced by overall bending moment and shear forces due to global hull girder loads are defined in [2.1.1] a).

3.1.3 Pillars and vertical bulkhead stiffeners acting as pillar are to be examined according to Sec 7.

3.2 Buckling check induced by global axial loads

3.2.1 General

The critical buckling stress for secondary or primary supporting member is to be obtained, in N/mm², from the following formula:

$$\sigma_c = \sigma_E \qquad \text{for } \sigma_E \leq \frac{R_{eH}}{2}$$

$$\sigma_c = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_E}\right) \qquad \text{for } \sigma_E > \frac{R_{eH}}{2}$$

where:

$\sigma_E = \min\ (\sigma_{E1},\ \sigma_{E2},\ \sigma_{E3})$

σ_{E1} : Euler column buckling stress, in N/mm², given in [3.2.2]

σ_{E2} : Euler torsional buckling stress, in N/mm², given in [3.2.3]

σ_{E3} : Euler web buckling stress, in N/mm², given in [3.2.4].

3.2.2 Column buckling stress

The Euler column buckling stress is obtained, in N/mm², from the following formula:

$$\sigma_{E1} = \pi^2 E \frac{I}{A\ell^2} 10^{-4}$$

I : Moment of inertia, in cm⁴, of the stiffener with attached shell plating, about its neutral axis parallel to the attached plating

A : Sectional area, in cm², of the stiffener with attached plating.

ℓ : Span, in m, of the stiffener

3.2.3 Torsional buckling stress

The Euler torsional buckling stresses is obtained, in N/mm², from the following formula:

$$\sigma_{E2} = \frac{\pi^2 E I_w}{10^4 I_p \ell^2}\left(\frac{K_C}{m^2} + m^2\right) + 0{,}385 E \frac{I_t}{I_p}$$

where:

ℓ : Span, in m, of the stiffener

I_w : Sectoral moment of inertia, in cm⁶, of the stiffener about its connection to the attached plating:

- for flat bars:

$$I_w = \frac{h_w^3 t_w^3}{36} 10^{-6}$$

- for T-sections:

$$I_w = \frac{t_f b_f^3 h_w^2}{12} 10^{-6}$$

- for angles and bulb sections:

$$I_w = \frac{b_f^3 h_w^2}{12(b_f + h_w)^2}[t_f(b_f^2 + 2b_f h_w + 4h_w^2) + 3t_w b_f h_w]\ 10^{-6}$$

I_p : Polar moment of inertia, in cm⁴, of the stiffener about its connection to the attached plating:

- for flat bars:

$$I_p = \frac{h_w^3 t_w}{3} 10^{-4}$$

- for stiffeners with face plate:

$$I_p = \left(\frac{h_w^3 t_w}{3} + h_w^2 b_f t_f\right) 10^{-4}$$

I_t : St. Venant's moment of inertia, in cm⁴, of the stiffener without attached plating:

- for flat bars:

$$I_t = \frac{h_w t_w^3}{3} 10^{-4}$$

- for stiffeners with face plate:

$$I_t = \frac{1}{3}\left[h_w t_w^3 + b_f t_f^3\left(1 - 0{,}63\frac{t_f}{b_f}\right)\right] 10^{-4}$$

m : Number of half waves, to be taken equal to the integer number such that (see also Tab 2):

$$m^2(m-1)^2 \le K_C < m^2(m+1)^2$$

$$K_C = \frac{C_0 \ell^4}{\pi^4 E I_w} 10^6$$

$$C_0 = \frac{E t_p^3}{2{,}73 s} 10^{-3}$$

Table 2 : Number m of half waves

K_C	$0 \le K_C < 4$	$4 \le K_C < 36$	$36 \le K_C < 144$
m	1	2	3

3.2.4 Web buckling stress

The Euler buckling stress of the stiffener web is obtained, in N/mm², from the following formula:

- for flat bars:

$$\sigma_{E3} = 16\left(\frac{t_W}{h_W}\right)^2 10^4$$

- for stiffeners with face plate:

$$\sigma_{E3} = 78\left(\frac{t_W}{h_W}\right)^2 10^4$$

In these formula, h_w is to be taken equal to the height of the web or the spacing of web stiffeners parallel to the flange when the web is stiffened, in m.

3.2.5 Buckling check criteria

The critical buckling stress of the secondary or primary supporting member is to comply with the following formula:

$\sigma_c \geq \sigma \cdot SF$

where:

σ_c : Critical buckling stress, in N/mm², as calculated in [3.2.1]

σ : Actual compression stress in the stiffener, in N/mm², induced by the overall hull girder loads defined in Ch 3, Sec 2

SF : Safety factor SF_{buck} as defined in Ch 2, Sec 3, Tab 1

3.3 Buckling induced by local bending and shear loads

3.3.1 General

As a rule, the present Sub Article is to be applied for primary structure elements.

This Sub Article may be also considered for secondary stiffeners when deemed necessary as specify in Ch 1, Sec 3, [3.1.2] a).

3.3.2 Calculation hypothesis

The buckling approach defined in the present section is based on the NR615 Buckling Assessment of Plated Structures, taking into account the following simplifying hypothesis:

a) Web:

- the web panels are considered as being simply supported on their edge, except for flat bar where the top of the web is considered free
- the bending stress in the web in way of the attached plating is considered equal to 0

b) Flange:

the flange panel is considered as being simply supported on three edges

The buckling approach defined in NR615 Buckling Assessment of Plated Structures may be taken into account instead of the present simplify method when deemed necessary.

3.3.3 Buckling check area of the stiffeners

The buckling areas and the values of local bending moments and shear forces to consider when a buckling check is carried out are defined in Tab 3 for the different stiffener elements.

3.3.4 Buckling reference stress

The elastic buckling reference stress, in N/mm², is to be taken as:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t}{b}\right)^2$$

where:

t : Thickness, in mm, of the considered element of the stiffener (t_w, t_{fl} or t_p)

b : Height of web h_w (or spacing of web stiffeners parallel to the flange when web is stiffened), or breadth of flange $b_{f\text{-}out}$, or shorter edge of the attached plating, in mm.

Table 3 : Buckling check areas

Stiffener element	Type of load	End stiffener conditions	Buckling under bending		Buckling under shear for web	
			Area to be checked	Value of bending moment M', in kNm	Area to be checked	Value of shear force T', in kN
Attached plating (according to [3.3.7])	Sea pressure or deck loads	Fixed	Mid span	M/2	NA	NA
		Simply supported or intermediate conditions	Mid span	M	NA	NA
	Internal pressure	Fixed	End	M	NA	NA
		Simply supported or intermediate conditions	NA	NA	NA	NA
Web and flange (according to [3.3.5] or [3.3.6]	Sea pressure or deck loads	Fixed	End	M	End	T
		simply supported or intermediate conditions	NA	NA	End	T
	Internal pressure	Fixed	Mid span	M/2	End	T **(1)**
		simply supported or intermediate conditions	Mid span	M	End	T **(1)**

(1) Bending stress and shear stress buckling are to be examined independently

Note 1: M and T are the bending moments, in kNm, and shear forces, in kN, induced by local loads according to Sec 5 and Sec 4 to be taken equal to:

$M = Z.\sigma_{loacam}.10^{-3}$

$T = A_{sh}.\tau_{locam}.10^{-1}$

where:

$Z, A_{sh}, \sigma_{locam}, \tau_{locam}$:As defined in Sec 5 and Sec 4

Note 2: NA: Not applicable

3.3.5 Flat bar

a) The ultimate buckling stress of the web of flat bar, in N/mm², induced by local bending stress is to be taken as:

$\sigma_{cx}' = C_x R_{eH}$

where:

C_x : Coefficient equal to:

$$C_x = 1,00 \quad \text{for } \lambda \leq 0,7$$

$$C_x = \frac{1}{\lambda^2 + 0,51} \quad \text{for } \lambda > 0,7$$

$$\lambda = \sqrt{\frac{R_{eH}}{K_x \sigma_E}}$$

$$K_x = \left(0,425 + \frac{1}{\alpha^2}\right)\frac{3}{2}$$

$\alpha = \ell_w / h_w$

ℓ_w : Length of the web, in mm, between vertical web stiffener

b) The ultimate buckling stress of the web of flat bar induced by local shear stress, in N/mm², is to be taken as:

$$\tau_c' = C_\tau \frac{R_{eH}}{\sqrt{3}}$$

where:

C_t : Coefficient equal to:

$$C_\tau = 1,00 \text{ for } \lambda \leq 0,84$$

$$C_\tau = \frac{0,84}{\lambda} \text{ for } \lambda > 0,84$$

$$\lambda = \sqrt{\frac{R_{eH}}{K_t \sigma_E}}$$

$$K_\tau = \sqrt{3}\left(0,6 + \frac{4}{\alpha^2}\right)$$

$\alpha = \ell_w / h_w$

ℓ_w : Length of the web, in mm, between vertical web stiffener

c) Buckling check criteria:

The web scantling is to fulfill the following condition:

$$\left(\left(\frac{\sigma_x\ SF}{\sigma'_{cx}}\right)^{e_0} + \left(\frac{|\tau|\ SF}{\tau'_c}\right)^{e_0}\right) \le 1$$

where:

σ_x : Actual bending stress applied to the top of the web, in N/mm², equal to:

$$\sigma_x = (M' 10^3)/Z_{acttop}$$

τ : Actual web shear stress, in N/mm², to be taken equal to:

$$\tau = (T' 10)/A_{act}$$

M', T' : As defined in Tab 3

Z_{acttop} : Actual flat bar modulus, in cm³, calculated at the top of the flat bar

A_{act} : Actual flat bar shear section, in cm², of the flat bar

σ_{cx}' : Ultimate buckling stress, in N/mm², defined in a)

τ_c' : Ultimate buckling shear stresses, in N/mm², defined in b)

SF : Safety buckling factor SF_{buck} defined in Ch 2, Sec 3, Tab 4

$$e_0 = 2/\beta_p^{0,25}$$

$$\beta_p = \frac{h_w}{t_w}\sqrt{\frac{R_{eH}}{E}}$$

3.3.6 T-bar and angle

a) The ultimate buckling stress of the web of T-bar and angle bar, in N/mm², induced by local bending stress is to be taken as:

$\sigma_{cx}' = C_x R_{eH}$

where:

C_x : Coefficient equals to:

$C_x = 1,0$ for $\lambda \le \lambda_c$

$$C_x = 1,25\left(\frac{1}{\lambda} - \frac{0,22}{\lambda^2}\right) \text{ for } \lambda > \lambda_c$$

$$\lambda = \sqrt{\frac{R_{eH}}{K_x \sigma_E}}$$

$K_x = 7,63$

$\lambda_c = 0,965$

b) The ultimate buckling stress of the web of T-bar and angle induced by local shear stress, in N/mm², is to be taken as:

$$\tau_c' = C_\tau \frac{R_{eH}}{\sqrt{3}}$$

where:

C_t : Coefficient equals to:

$$C_\tau = 1,00 \text{ for } \lambda \le 0,84$$

$$C_\tau = \frac{0,84}{\lambda} \text{ for } \lambda > 0,84$$

$$\lambda = \sqrt{\frac{R_{eH}}{K_t \sigma_E}}$$

$$K_\tau = \sqrt{3}\left(5,34 + \frac{4}{\alpha^2}\right)$$

$\alpha = \ell_w / h_w$

ℓ_w : Length of the web, in mm, between vertical web stiffener

h_w : In this formula, h_w is to be taken equal to the height of the web or the spacing of web stiffeners parallel to the flange when the web is stiffened, in m

c) The ultimate buckling stress of the flange of T-bar and angle bar, in N/mm², induced by local bending stress is to be taken as:

$\sigma_{cx}' = C_x R_{eH}$

where:

C_x : Coefficient equals to:

$$C_x = 1,00 \quad \text{for } \lambda \le 0,7$$

$$C_x = \frac{1}{\lambda^2 + 0,51} \quad \text{for } \lambda > 0,7$$

$$\lambda = \sqrt{\frac{R_{eH}}{K_x \sigma_E}}$$

$$K_x = \left(0,425 + \frac{1}{\alpha^2}\right)$$

$\alpha = \ell_w / b_{f\text{-}out}$

ℓ_w : Length of the flange, in mm, between flange tripping bracket

d) Buckling check criteria:

- The web scantling is to fulfill the following condition:

$$\left(\left(\frac{\sigma_x SF}{\sigma_{cx}'}\right)^{e_0} + \left(\frac{|\tau| SF}{\tau_c'}\right)^{e_0}\right) \le 1$$

where:

σ_x : Actual bending stress applied to the top of the web, in N/mm²,equal to:

$$\sigma_x = (0,9M' 10^3)/Z_{actfl}$$

τ : Actual web shear stress, in N/mm², to be taken equal to:

$$\tau = (T' 10)/A_{act}$$

M', T' : As defined in Tab 3

Z_{actfl} : Actual stiffener modulus, in cm³, calculated at the top of the flange

A_{act} : Actual web shear section, in cm², of the stiffener

σ_{cx}' : Ultimate buckling stress, in N/mm², defined in a)

τ_c' : Ultimate buckling shear stress, in N/mm² defined in b)

SF : Safety buckling factor SF_{buck} defined in Ch 2, Sec 3, Tab 4

$$e_0 = 2/\beta_p^{0,25}$$

$$\beta_p = \frac{h_w}{t_w}\sqrt{\frac{R_{eH}}{E}}$$

- The flange scantling is to fulfill the following condition:

$$\left(\frac{\sigma_1 SF}{\sigma_{cx}'}\right)^{e_0} \le 1$$

where:

σ_1 : Actual bending stress applied to the flange, in N/mm²,equal to:

$$\sigma_1 = (M' 10^3)/Z_{actfl}$$

Z_{actfl} : Actual stiffener modulus, in cm³, calculated at the top of the flange

σ_{cx}' : Ultimate buckling stress, in N/mm² defined in c)

SF : Safety buckling factor SF_{buck} defined in Ch 2, Sec 3, Tab 4

$$e_0 = 2/\beta_p^{0,25}$$

$$\beta_p = \frac{b_{f-out}}{t_f}\sqrt{\frac{R_{eH}}{E}}$$

3.3.7 Attached plating

a) General:

The buckling check of the attached plating of stiffener is to be checked in the area where the attached plating is submitted to compressive stresses.

The dimensions of the attached plating to be considered are:

- loaded edge: spacing between stiffeners parallel to the considered stiffener
- unloaded edge: spacing between stiffeners perpendicular to the considered stiffener

b) Case where the loaded edge is the shorter edge of the plate:

The ultimate buckling stress of the attached plating, in N/mm², induced by local bending stress is to be taken as:

$\sigma_{cx}' = C_x R_{eH\_P}$

where:

C_x : Coefficient equals to:

$C_x = 1,0$ for $\lambda \leq 0,84$

$$C_x = 1,13\left(\frac{1}{\lambda} - \frac{0,22}{\lambda^2}\right) \text{ for } \lambda > 0,84$$

$$\lambda = \sqrt{\frac{R_{eH\_P}}{K_x \sigma_E}}$$

$K_x = 4$

c) Case where the loaded edge is the longer edge of the plate:

The ultimate buckling stress of the attached plating, in N/mm², induced by local bending stress is to be taken as:

$\sigma_{cy}' = C_y R_{eH\_P}$

where:

$$C_y = 1,13\left[\frac{1}{\lambda} - \frac{R + F^2 (H - R)}{\lambda^2}\right]$$

$$\lambda = \sqrt{\frac{R_{eH\_P}}{K_y \sigma_E}}$$

$$K_y = \left(1 + \frac{1}{\alpha^2}\right)^2$$

α : Ratio between the longer edge and the shorter edge of the attached plating

R : $R = 0,22$ for $\lambda \geq 0,84$

$$R = \lambda\left(1 - \frac{\lambda}{1,13}\right) \text{ for } \lambda < 0,84$$

$$F = 1 - \frac{\left(\frac{K_y}{0,91} - 1\right)}{\lambda_p^2} \geq 0$$

$$\lambda_p^2 = \lambda^2 - 0,5 \text{ with } 1 \leq \lambda_p^2 \leq 3$$

$$H = \lambda - \frac{2\lambda}{1,13\ (T + \sqrt{T^2 - 4})} \geq R$$

$$T = \lambda + \frac{14}{15\lambda} + \frac{1}{3}$$

d) Buckling check criteria:

The attached plating scantling is to fulfill the following condition:

$$\left(\frac{\sigma_i\ SF}{\sigma_c'}\right)^{e_0} \leq 1$$

where:

σ_i : Actual bending stress applied in the attached plating in the shorter or longer edge, in N/mm², equal to:

$$\sigma_i = (M' 10^3)/Z_{actap}$$

Z_{actap} : Actual stiffener modulus, in cm³, calculated at the associated plating

σ_c' : Ultimate buckling stress in the shorter edge σ_{cx}' or in the longer edge, σ_{cy}' in N/mm² defined in a) or b)

SF : Safety buckling factor SF_{buck} defined in Ch 2, Sec 3, Tab 4

$$e_0 = 2/\beta_p^{0,25}$$

$$\beta_p = \frac{b}{t_p}\sqrt{\frac{R_{eH\_P}}{E}}$$

b : Shorter edge of the attached plating, in mm

Appendix 2 Hull Scantling Check with Local and Global Stresses Combination Criteria

Symbols

R_y : Minimum yield stress of the material, in N/mm², used for the scantling criteria as defined in Ch 1, Sec 2

P : Local pressures and forces defined in:
- for external pressure: Ch 3, Sec 3, [2]
- for internal pressures: Ch 3, Sec 4, [3] and Ch 3, Sec 4, [4]

σ_A : Actual overall stress, in N/mm², calculated according to Sec 2 for hull girder loads defined in Ch 3, Sec 2, excluding the additional specific wave hull girder loads defined in Ch 3, Sec 2, [6]

In this Appendix, σ_A is to be taken greater or equal to 0,35 R_y.

μ : Aspect ratio coefficient of the elementary plate panel, equal to:

$$\mu = 1{,}21\sqrt{1 + 0{,}33\left(\frac{s}{\ell}\right)^2} - 0{,}69\frac{s}{\ell}$$

without being greater than 1.

m : End stiffener condition coefficient, defined in Sec 4, [1.4].

1 General

1.1 Application

1.1.1 The requirements of this Appendix apply for the check of hull structure element contributing to the hull girder strength, built in steel or aluminium material, where overall stresses and local stresses are combined according to Ch 1, Sec 3, [3.1.2].

The structure elements not contributing to the hull girder strength are to be checked as defined in Sec 3, Sec 4 and Sec 5.

For hull structure built in composite material, the combined hull girder stresses and local stresses are to be calculated as defined in NR546 Composite Ships.

1.2 Overall stresses

1.2.1 The actual overall stresses are to be determined according to Sec 2 for hull girder loads defined in Ch 3, Sec 2, excluding the additional specific wave hull girder loads defined in Ch 3, Sec 2, [6].

As a rule, the values of the still water bending moments to take into account for the calculation of the actual overall stresses are to be given by the designer.

1.3 Local stresses

1.3.1 The local stresses to take into account in the present Appendix are those induced by the local pressures and forces defined in:
- for external sea pressure: Ch 3, Sec 3, [2]
- for internal loads: Ch 3, Sec 4, [3]
- for deck loads: Ch 3, Sec 4, [4]

Local stresses induced by dynamic sea pressures as defined in Ch 3, Sec 3, [3] are not to be considered in the combination with global stresses.

2 Plating scantling

2.1 General

2.1.1 The plating thickness under local loads, in mm, is to be greater than the minimum value defined in Sec 3, [2.2.1] and the following value:

$$t = 22{,}4\lambda\mu s n_p\sqrt{\frac{P}{\sigma_{ad}}}$$

where:

s : Length, in m, of the shorter side of the plate panel

n_p : Coefficient to be taken equal to:

- Steel:
  - plate longitudinally framed: $n_p = 0{,}67$
  - plate transversely framed: $n_p = 0{,}77$
- Aluminium:
  - Whatever the frame system: $n_p = 1$

λ : Corrosion coefficient to be taken equal to:

- for steel plating: $\lambda = 1{,}1$
- for aluminium plating: $\lambda = 1{,}05$

σ_{ad} : Permissible stress, in N/mm², as given in Tab 1.

Table 1 : Permissible stress, in N/mm²

	Plate longitudinally framed	Plate transversely framed
Steel **(1)**	$\sigma_{ad} = 0,75\lambda_{LT}R_y$	
Aluminium	$\sigma_{ad} = \sqrt{0,55R_y^2 - (1,1\sigma_A^2)}$	$\sigma_{ad} = 0,75R_y - \sigma_A$
(1) For plate longitudinally framed: $\lambda_{LT} = \sqrt{1 - \left(\frac{\sigma_A}{R_y}\right)^2} - \left(0,25\frac{\sigma_A}{R_y}\right)$ For plate transversely framed: $\lambda_{LT} = 1 - \left(\frac{\sigma_A}{R_y}\right)$		

3 Secondary stiffener scantling

3.1 General

3.1.1 The section modulus of secondary stiffener under local loads, in cm³, is to be greater than the minimum value defined in Sec 4, [2.2.1] and the following value:

$$Z = \frac{1000\lambda C_t P s \ell^2}{m\sigma_{ad}}$$

where:

λ : Corrosion coefficient to be taken equal to:

- for steel structure:
  - 1,1 for stiffener located in a dry compartment
  - 1,2 for stiffener located in a liquid compartment
- for aluminium structure: 1,05

s : Spacing, in m, of the secondary stiffener under consideration

C_t : Reduction coefficient defined as follows:

$$C_t = 1 - \frac{s}{2\ell}$$

to be taken greater than 0,50

ℓ : Span, in m, of the secondary stiffener under consideration

σ_{ad} : Permissible local scantling stress, in N/mm², to be taken equal to: $\sigma_{ad} = 0{,}85R_y - \sigma_A$

The shear are A_{sh}, in cm² is to be not less than the values defined in Sec 4, [2.2].

4 Primary stiffener scantling

4.1 Primary stiffener checked by isolated beam calculation

4.1.1 Section modulus

The section modulus of primary stiffener under local loads, in cm³, is to be greater than the following value:

$$Z = \frac{1000\lambda P s \ell^2}{m\sigma_{ad}}$$

where:

λ : Corrosion coefficient as defined in [3.1.1]

s : Spacing, in m, of the primary stiffener under consideration

ℓ : Span, in m, of the primary stiffener under consideration

σ_{ad} : Permissible local scantling stress, in N/mm², to be taken equal to:

- for bottom and side girder: $\sigma_{ad} = 0{,}80R_y - \sigma_A$
- for other primary stiffeners: $\sigma_{ad} = 0{,}85R_y - \sigma_A$

The shear are A_{sh}, in cm² is to be not less than the values defined in Sec 5, [2].

4.1.2 Buckling check of the associated plating

The associated plating of the primary stiffener is to be checked according to the following criterion:

$\sigma_c \geq SF\ (\sigma_A + \sigma_{loc})$

where:

σ_c : Critical buckling stress of the associated plating, in N/mm², calculated as defined in Sec 1, [2]

σ_{loc} : Actual local stress in the associated plating, in N/mm²

SF : Safety factor to be taken equal to:

- for steel structure: 1,45
- for aluminium structure: 1,30.

4.2 Primary stiffener checked by three dimensional structural model

4.2.1 Checking criteria

For primary structure analysed under local loads by three dimensional structural model, it is to be checked that the equivalent Von Mises stress σ_{VM}, in N/mm², is to comply with the following criterion:

$\sigma_{VM} \leq R_y / SF$

where:

$$\sigma_{VM} = \sqrt{(\sigma_A + \sigma_{loc})^2 + 3\tau_{loc}^2}$$

σ_{loc}, τ_{loc} : Actual local bending and shear stresses, in N/mm²

SF : Safety factor to be taken equal to 1,25.

4.2.2 Buckling check of the associated plating

The associated plating of the primary stiffener is to be checked according to [4.1.2].

CHAPTER 5
OTHER STRUCTURES

Section 1 Superstructures and Deckhouses

Symbols

B : Moulded breadth, in m

k : Material factor, defined in Ch 1, Sec 2, [2] for steel and in Ch 1, Sec 2, [3] for aluminium alloys

L_{WL} : Length at waterline at full load, in m

L_{LL} : Load line length, in m

ℓ : Length, in m, of the longer side of the plate panel

m : End stiffener condition coefficient, as defined in Ch 4, Sec 4, [1.4]

n : Coefficient navigation defined in Ch 1, Sec 1, Tab 2

σ_{locam} : Local permissible bending stress, in N/mm², as defined in Ch 2, Sec 3

s : Length, in m, of the shorter side of the plate panel

T : Draught, in m, as defined in Ch 1, Sec 1, [4.5]

τ_{locam} : Local permissible shear stress, in N/mm², as defined in Ch 2, Sec 3

μ : Aspect ratio coefficient of the elementary plate panel, equal to:

$$\mu = 1{,}21\sqrt{1 + 0{,}33\left(\frac{s}{\ell}\right)^2} - 0{,}69\frac{s}{\ell} \le 1$$

x : Distance, in m, between the section considered and the origin of the reference co-ordinate system as defined in Ch 1, Sec 1, [5]

z : Distance, in m, between the base line and the calculation point (see Ch 3, Sec 3, Fig 1).

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the scantling of plating and associated structures of front, side and aft bulkheads and decks of superstructures and deckhouses.

1.1.2 Superstructures contributing to the hull longitudinal strength are to be examined taking into account the hull analysis approach defined in Ch 1, Sec 3, [3].

1.1.3 Materials

Attention is drawn to the selection of building materials which is not only to be determined from strength consideration, but should also give consideration to structural fire protection and associated class requirements or Flag Administration requirements, where applicable.

1.1.4 Additional superstructure scantling requirements in relation to the service notation or service feature

Additional superstructure scantling requirements in relation to the service notation or feature assigned to the ship are to be taken into account as defined in Ch 6, Sec 1.

1.2 Definitions

1.2.1 Superstructure

A superstructure is a decked structure connected to the freeboard deck, extending from side to side of the ship or with the side plating not being inboard of the shell plating than 0,04 B.

1.2.2 Deckhouse

A deckhouse is a decked structure other than a superstructure, located on the freeboard deck or above.

1.2.3 Superstructures and deckhouses contributing to the longitudinal strength

A superstructures and/or deckhouses extending over 0,4 L may generally be considered as contributing to the hull longitudinal girder strength.

In this case, a global strength analysis as defined in Ch 4, Sec 2 is to be carried out for the structure elements contributing to the hull longitudinal girder strength.

1.2.4 Tiers of superstructures and deckhouses

The lowest tier is normally that which is directly situated above the freeboard deck.

The second tier is that located immediately above the lowest tier, and so on.

1.2.5 Standard height of superstructure

The standard height of superstructure is defined in Tab 1.

Table 1 : Standard height of superstructure

Load line length L_{LL} , in m	Standard height h_S, in m	
	Raised quarter deck	All other superstructures
$L_{LL} \leq 30$	0,90	1,80
$30 < L_{LL} < 75$	$0,9 + 0,00667 (L_{LL} - 30)$	1,80
$75 < L_{LL} < 90$	$1,2+0,012 (L_{LL} - 75)$	$1,8 + 0,01 (L_{LL} - 75)$

1.2.6 Position 1 and position 2

a) Position 1 includes:
- exposed freeboard and raised quarter decks
- exposed superstructure decks situated forward of 0,25 L_{LL} from the perpendicular, at the forward side of the stem, to the waterline at 85% of the least moulded depth measured from the top of the keel.

b) Position 2 includes:
- exposed superstructure decks situated aft of 0,25 L from the perpendicular, at the forward side of the stem, to the waterline at 85% of the least moulded depth measured from the top of the keel and located at least one standard height of superstructure above the freeboard deck
- exposed superstructure decks situated forward of 0,25 L_{LL} from the perpendicular, at the forward side of the stem, to the waterline at 85% of the least moulded depth measured from the top of the keel and located at least two standard heights of superstructure above the freeboard deck.

1.2.7 Side wall in the prolongation of the side shell

The requirements applicable to the side wall in the prolongation of the side shell are also to be considered where the side wall is shifted from the side shell of less than 300 mm and is not protected by a bulwark.

1.3 Superstructures and deckhouses structure arrangement

1.3.1 General

The general superstructures and deckhouses structure arrangements are to be as defined in Ch 2, Sec 1, [8].

2 Design loads

2.1 Load point

2.1.1 Lateral pressure is to be calculated at:
- the mid-height of the elementary plate panel, for plating
- mid-span, for stiffeners.

2.2 Lateral pressure on superstructure and deckhouse walls

2.2.1 General

The lateral pressure of the exposed walls of superstructure and deckhouses, in kN/m², is to be determined as follows:

a) General:

$$p = 10acn[bf - (z - T)] > p_{min}$$

where:

a : Coefficient defined in Tab 2

b : Coefficient defined in Tab 3

c : Coefficient equal to:
- for monohull:

$$c = 0,30 + 0,70\frac{b_1}{B_{ed}}$$

- for multihull:

$c = 0,50$

b_1 : Breadth of the superstructure or deckhouse, in m, at the position considered, to be taken not less than 0,25 B_{ed}

B_{ed} : Actual maximum breadth of ship on the exposed weather deck, in m, at the position considered

f : Coefficient equal to: $f = 0,076\ L_{WL} - 0,6$

p_{min} : Minimum lateral pressure, in kN/m², defined in [2.2.2].

b) Lowest tier of sidewalls of superstructures in the prolongation of the side shell:

The lateral pressure of the exposed lowest tier of sidewalls of superstructures in the prolongation of the side shell is to be taken equal to the greater value obtained from the following formula:

$$P_S = \rho g(T + h_1 - z)$$

$$P_S = \rho g\left(T + \frac{0,8B_1}{2}\sin A_R - z\right)$$

$$P_S = P_{min}$$

where ρ, g, h_1, B_1 and A_R are defined in Ch 3, Sec 3, [2.2.1].

In addition, the side shell impact is to be determined according to Ch 3, Sec 3, [3.1].

c) Front wall sloped aft:

When the front wall is sloped aft, the front wall pressures values p and p_{min} may be reduced by the value of the cosine of the angle α, where α is defined in Fig 1. The value of the angle α is not to be taken greater than 60°.

Figure 1 : Angle of superstructure

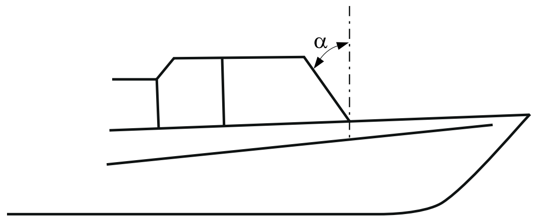


Table 2 : Coefficient a

Location		a
Unprotected front wall	First tier	$2 + \frac{L_{WL}}{120}$
	Second tier	$1 + \frac{L_{WL}}{120}$
	Upper tiers	$0,5 + \frac{L_{WL}}{120}$
Protected front wall	All tiers	$0,5 + \frac{L_{WL}}{150}$
Aft wall	All tiers	$0,5 + \frac{L_{WL}}{1000}$
Side walls		$0,5 + \frac{L_{WL}}{150}$

Table 3 : Coefficient b

x/L_{WL}	b
$x/L_{WL} \le 0,25$	1,10
$0,25 < x/L_{WL} < 0,70$	1,00
$0,70 \le x/L_{WL} < 0,85$	1,30
$0,85 \le x/L_{WL}$	1,50

2.2.2 Minimum lateral pressure

The values of the minimum lateral pressures p_{min}, in KN/m², are defined in Tab 4.

Apart from the lower tier of superstructure and deck house on the uppermost complete deck exposed to sea, p_{min} may be taken equal to 2,5 kN/m² when:

$$z > T + 0,5\,B_1\,A_R + h_1$$

where:

A_R : Roll amplitude, in rad, as defined in Ch 3, Sec 4, [2.1.7].

B_1 : Maximum moulded breadth, in m, in the considered longitudinal part of the ship as defined in Ch 3, Sec 3, [2.2.1]

h_1 : Ship relative motion, in m, in the considered longitudinal part of the ship as defined in Ch 3, Sec 3, [2.2.1]

Table 4 : Minimum lateral pressure for superstructures and deckhouses

Type of wall	Location		p_{min}
Unprotected front wall	lower tier	$x/L_{WL} \geq 0{,}70$	21 n
		$x/L_{WL} < 0{,}70$	15 n
	upper tiers		10 n
Protected front wall	lower tier		10 n
	second tier		7 n > 5
	upper tiers		5
Side walls	lower tier	$x/L_{WL} \geq 0{,}70$	19,6 n φ_2
		$x/L_{WL} < 0{,}70$	17,6 n φ_2
	second tier		7 n > 5
	upper tiers		5
Unprotected aft wall	lower tier	$x/L_{WL} \leq 0{,}25$	10 n
		$x/L_{WL} > 0{,}25$	7 n > 5
	upper tier		5
Protected aft wall	anywhere		5

Note 1:
n : Navigation coefficient defined in Ch 1, Sec 1, [3.1.1] or Ch 1, Sec 1, [3.2.1]
φ_2 : Coefficient taken equal to:

$$\varphi_2 = \frac{L_{WL}}{120} \geq 0{,}42$$

2.3 Pressures on superstructure decks

2.3.1 Exposed deck

The pressure on exposed decks, in kN/m², is defined in Ch 3, Sec 3, [2.2.2].

2.3.2 Accommodation decks

The pressure on accommodation decks, in kN/m², is defined in Ch 3, Sec 4, [4.2].

3 Plating

3.1 General

3.1.1 Application

The present Article is applicable for the scantling of plating of front, side and aft bulkheads and decks of superstructures and deckhouses.

3.2 Plating scantling

3.2.1 As a rule, the thickness of plating, in mm, is to be not less than the following value:

$$t = 22{,}4\lambda n_p \mu s \sqrt{\frac{p}{\sigma_{locam}}} \geq t_{min}$$

where:

p : Lateral pressure, in kN/m² as defined in [2.2.1]

n_p : Coefficient to be taken equal to:

- for longitudinally framed steel plating: $n_p = 0{,}67$
- for transversely framed steel plating: $n_p = 0{,}77$
- for aluminium plating, whatever the frame system: $n_p = 1{,}00$

λ : Corrosion coefficient taken, in the present Section, equal to:

- for steel plate: $\lambda = 1{,}05$
- for aluminium plate: $\lambda = 1{,}00$

t_{min} : Minimum thickness as defined in [3.2.2].

For the lowest tier of side walls of superstructure, where the side wall is in the prolongation of the side shell, the thickness of side wall plating is also to be not less than the value given in Ch 4, Sec 3, [2.2.3].

3.2.2 Minimum thickness

As a rule, the minimum thickness t_{min}, in mm, is to be taken equal to:

a) for steel structures: $t_{min} = 2,6 + 0,045\ L_{WL}\ k^{1/2}$

without being taken less than:

- 5 mm for the lower tier of unprotected front wall
- 4 mm elsewhere

b) for aluminium structures: $t_{min} = 1,35\ L_{WL}^{1/3}\ k^{1/2}$

without being taken less than:

- 4 mm for the lower tier of unprotected front wall
- 3,5 mm for rolled products and 2,5 mm for extruded products elsewhere.

3.2.3 Deck plating protected by wood sheathing

The thickness of deck plating protected by wood sheathing deemed suitable by the Society may be reduced on a case by case basis. In any case this thickness is to be not less than the minimum value defined in [3.2.2].

The sheathing is to be secured to the deck to the satisfaction of the Society.

3.2.4 Scantling for composite, plywood and HDPE panels

The scantling of composite, plywood and HDPE panels is to be checked according to:

- local loads defined in [2]
- safety factor criteria defined in:
  - Ch 2, Sec 3, [3] for composite
  - Ch 2, Sec 3, [4] for plywood
  - Ch 2, Sec 3, [5] for HDPE, and
- calculation methodology defined in NR546 Composite Ships.

4 Ordinary stiffeners

4.1 General

4.1.1 Application

The present Article is applicable for the scantling of ordinary stiffeners of front, side and aft bulkheads and decks of superstructures and deckhouses.

4.1.2 End stiffener condition for calculation

The connection of secondary stiffeners with surrounding supporting structure is taken into account in the rule section modulus, using coefficient m as defined in Ch 4, Sec 4, [1.4].

4.2 Ordinary stiffener scantling

4.2.1 Scantling for steel and aluminium ordinary stiffeners

As a rule, the section modulus Z, in cm^3, and the shear area A_{sh}, in cm^2, of the secondary stiffeners sustaining lateral local loads are to be not less than the values obtained from the following formulae:

$$Z = 1000\lambda C_t \frac{ps\ell^2}{m \cdot \sigma_{locam}} > Z_{min}$$

$$A_{sh} = 5\lambda C_t \frac{ps\ell}{\tau_{locam}}$$

where:

C_t : Reduction coefficient, equal to:

$$C_t = 1 - \frac{s}{2\ell}$$

to be taken greater than 0,50

p : Lateral pressure, in kN/m^2, as defined in [2.2.1]

λ : Corrosion coefficient taken, in the present Section, equal to:

- for steel stiffener: 1,05
- for aluminium stiffener: 1,0

Z_{min} : Minimum section modulus as defined in [4.2.2].

For the lowest tier of side walls of superstructure, where the side wall is in the prolongation of the side shell, the section modulus of side wall ordinary stiffeners is to be also not less than the value given in Ch 4, Sec 4, [2.2.3].

4.2.2 Minimum section modulus

As a rule, the minimum section modulus Z_{min} , in cm^3, of secondary stiffeners calculated according to the present Section is to be taken equal to:

- for steel stiffener:

  $Z_{min} = 3,5 + 0,15\ L_{WL}\ k$

- for aluminium stiffeners:

  $Z_{min} = 1,7\ L_{WL}^{1/3}\ k$

4.2.3 Scantling for composite, plywood and HDPE ordinary stiffeners

The scantling of composite, plywood and HDPE ordinary stiffeners are to be checked according to:

- local loads defined in Article [2]
- safety factor criteria defined in:
  - Ch 2, Sec 3, [3] for composite
  - Ch 2, Sec 3, [4] for plywood
  - Ch 2, Sec 3, [5] for HDPE
- calculation methodology defined in NR546 Composite Ships.

5 Primary stiffeners

5.1 General

5.1.1 The requirements for the scantling of primary stiffeners are to be as defined in Article [4] for ordinary stiffeners for isolated beam calculation taking into account a reduction coefficient $C_t = 1$.

The minimum section modulus for secondary stiffeners defined in [4.2.2] is not applicable to primary stiffeners.

For the lowest tier of side walls of superstructure, where the side wall is in the prolongation of the side shell, the check of primary stiffeners under side shell impact need not be carried out.

When deemed necessary to the Society, it may be requested to carry out a two or three dimensional beam analysis calculations as defined in Ch 4, Sec 5, [1.2].

6 Arrangement of superstructures and deckhouses openings

6.1 General

6.1.1 The scope of application of the present Article is defined in Tab 5.

Table 5 : Scope of application

Gross tonnage	≤ 500 **(1)**	> 500 **(2)**
Sidescuttles, windows and skylights	NR566	[7]
Door arrangements	NR566	NR467 Steel Ships
Freing ports	NR566	NR467 Steel Ships
Machinery space openings	NR566	NR467 Steel Ships
Companionway	NR566	NR467 Steel Ships
Ventilation openings	NR566	NR467 Steel Ships
Discharges	NR566	NR467 Steel Ships

(1) Except ships having the following service notations:
- **passenger ship** with **unrestricted navigation**
- **ro-ro passenger ship** with **unrestricted navigation**
- **fishing vessel**, or
- **chemical tanker**

(2) And ships having the service notations defined in **(1)**, whatever their tonnage

6.2 External openings

6.2.1 All external openings leading to compartments assumed intact in the damage analysis (which are below the final damage waterline) are required to be watertight and of sufficient strength.

6.2.2 No openings, be they permanent openings, recessed promenades or temporary openings such as shell doors, windows or ports, are allowed on the side shell between the embarkation station of the marine evacuation system and the waterline in the lightest seagoing condition.

Windows and sidescuttles of the non-opening type are allowed if they have a fire integrity at least equal to A-0 class.

6.2.3 Other closing appliances which are kept permanently closed at sea to ensure the watertight integrity of external openings are to be provided with a notice affixed to each appliance to the effect that it is to be kept closed. Manholes fitted with closely bolted covers need not be so marked.

7 Sidescuttles, windows and skylights

7.1 General

7.1.1 Application

The requirements in [7.2] to [7.4] apply to sidescuttles and rectangular windows providing light and air, located in positions which are exposed to the action of sea and/or bad weather.

7.1.2 Sidescuttle definition

Sidescuttles are round or oval openings with an area not exceeding 0,16 m^2.

7.1.3 Window definition

Windows are rectangular openings generally, having a radius at each corner relative to the window size in accordance with recognised national or international standards, and round or oval openings with an area exceeding 0,16 m^2.

7.1.4 Materials and scantlings

As a rule, sidescuttles and windows together with their glasses, deadlight and storm covers, if fitted, are to be of approval design and substantial construction in accordance with, or equivalent to, recognised national or international standards.

7.2 Opening arrangement

7.2.1 General

Sidescuttles are not to be fitted in such a position that their sills are below a line drawn parallel to the freeboard deck at side and having its lowest point 0,025 B or 0,5 m, whichever is the greater distance, above the summer load waterline (or timber summer load waterline if assigned).

7.2.2 Sidescuttles below (1,4 + 0,025 B) m above the water

Where in ‘tweendecks the sills of any of the sidescuttles are below a line drawn parallel to the bulkhead deck at side and having its lowest point (1,4 + 0,025 B) m above the water when the ship departs from any port, all the sidescuttles in that ‘tweendecks are to be closed watertight and locked before the ship leaves port, and they may not be opened before the ship arrives at the next port. In the application of this requirement, the appropriate allowance for fresh water may be made when applicable.

For any ship that has one or more sidescuttles so placed that the above requirements apply when it is floating at its deepest subdivision load line, the Society may indicate the limiting mean draught at which these sidescuttles are to have their sills above the line drawn parallel to the bulkhead deck at side, and having its lowest point (1,4 + 0,025 B) m above the waterline corresponding to the limiting mean draught, and at which it is therefore permissible to depart from port without previously closing and locking them and to open them at sea under the responsibility of the Master during the voyage to the next port. In tropical zones as defined in the International Convention on Load Lines in force, this limiting draught may be increased by 0,3 m.

7.2.3 Cargo spaces

No sidescuttles may be fitted in any spaces which are appropriated exclusively for the carriage of cargo.

Sidescuttles may, however, be fitted in spaces appropriated alternatively for the carriage of cargo or passengers, but they are to be of such construction as to prevent effectively any person opening them or their deadlights without the consent of the Master.

7.2.4 Non-opening type sidescuttles

Sidescuttles are to be of the non-opening type in the following cases:

- where they become immersed by any intermediate stage of flooding or the final equilibrium waterplane in any required damage case for ships subject to damage stability regulations
- where they are fitted outside the space considered flooded and are below the final waterline for those ships where the freeboard is reduced on account of subdivision characteristics.

7.2.5 Opening of side scuttle

All sidescuttles, the sills of which are below the bulkhead deck for passenger ships or the freeboard deck for cargo ships, are to be of such construction as to prevent effectively any person opening them without the consent of the Master of the ship.

7.2.6 Manholes and flush scuttles

Manholes and flush scuttles in positions 1 or 2, or within superstructures other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

7.2.7 Ships with several decks

In ships having several decks above the bulkhead deck, such as passenger ships, the arrangement of sidescuttles and rectangular windows is considered by the Society on a case-by-case basis.

Particular consideration is to be given to the ship side up to the upper deck and the front bulkhead of the superstructure.

7.2.8 Automatic ventilating scuttles

Automatic ventilating sidescuttles are not to be fitted in the shell plating below the bulkhead deck of passenger ships and the freeboard deck of cargo ships without the special agreement of the Society.

7.2.9 Window arrangement

Windows may not be fitted below the freeboard deck, in first tier end bulkheads or sides of enclosed superstructures and in first tier deckhouses considered as being buoyant in the stability calculations or protecting openings leading below.

7.2.10 Skylights

Fixed or opening skylights are to have glass thickness appropriate to their size and position as required for sidescuttles and windows. Skylight glasses in any position are to be protected from mechanical damage and, where fitted in position 1 or 2, to be provided with permanently attached robust deadlights or storm covers.

7.2.11 Gangway, cargo and fuelling ports

Cargo ports and other similar openings (e.g. gangway and fuelling ports) in the side of ships below the bulkhead deck of passenger ships and the freeboard deck of cargo ships are to be fitted with doors so designed as to ensure the same watertightness and structural integrity as the surrounding shell plating. Unless otherwise granted by the Society, these openings are to open outwards. The number of such openings is to be the minimum compatible with the design and proper working of the ship. In no case must these openings be so fitted as to have their lowest point below the summer load line.

7.3 Windows and sidescuttles glasses

7.3.1 General

In general, toughened glasses with frames of special type are to be used in compliance with, or equivalent to, recognised national or international standards.

The use of clear plate glasses is considered by the Society on a case-by-case basis.

7.3.2 Scantling

The windows and sidescuttles scantling assessment methodology defined in this sub-article is equivalent to Standard ISO 21005:2004.

The edge condition of window and sidescuttle are considered as simple supported in the scantling formula.

7.3.3 Material

Attention is drawn to the use of plastic materials (PMMA, PC...) from a structural fire protection point of view.

The Flag Administration may request that International Convention be applied instead of the present requirements, entailing in some cases a use limitation of these materials.

7.3.4 Thickness of monolithic window and side scuttle glasses

The thickness of windows and sidescuttles glasses are based on the guaranteed minimum flexural strength R_m, in MPa, of the glass material used. For guidance only, the guaranteed minimum flexural strength R_m for glass window may be taken equal to:

- for glass thermally or chemically toughened glass:

  $R_m = 120$ N/mm^2
- for PMMA glass:

  $R_m = 100$ N/mm^2
- for polycarbonate:

  $R_m = 90$ N/mm^2

Note 1: As a rule, the value of R_m is to be defined by the window supplier.

The thickness t, in mm, of windows and sidescuttles glasses is to be not less than the following values taking into account:

s : Shorter side, in m, of rectangular window or sidescuttle

ℓ : Longer side, in m, of rectangular window or side scuttle

d : Diameter, in m, of circular window or sidescuttle

Note 2: For windows and sidescuttles having other shapes, s and ℓ are to be determined by equivalent dimensions s_{eq} and ℓ_{eq} as defined in Tab 8.

a) Windows and side scuttles submitted to uniform pressure:

- Rectangular window or sidescuttle:

$$t = 31,6 s \alpha_{ec} \sqrt{\frac{\beta p}{R_m / S_f}}$$

where:

α_{ec} : Coefficient to be taken equal to:
- 1 for edges of glass considered as simply supported
- 0,81 for edge of rectangular window or sidescuttle considered as clamped
- 0,74 for edge of circular window or sidescuttle considered as clamped.

S_f : Safety factor equal to:
- for glass window:
  $S_f = 3,0$
- for plastic window:
  $S_f = 3,5$

β : Aspect ratio coefficient of the rectangular window or sidescuttle, obtained in Tab 6

p : To be taken:
- when located on the side shell:
  as defined in Ch 3, Sec 3, [2.2.1] with φ_2 taken equal to 1 for the calculation of p_{dmin}
- elsewhere:
  as defined in [2.2]

- Circular window or sidescuttle:

$$t = 17,4 d \alpha_{ec} \sqrt{\frac{p}{R_m / S_f}}$$

b) Windows and side scuttles submitted to side shell impact:

The thicknesses, in mm, of monolithic window and sidescuttles glasses are defined in Tab 7 where:

s, ℓ, d, R_m : As defined in item a)

S_f : Safety factor equal to:
- for glass window:
  $S_f = 2,8$
- for plastic window:
  $S_f = 3,2$

μ : Aspect ratio coefficient of the elementary window or sidescuttle glass, equal to:

$$\mu = 1,21 \sqrt{1 + 0,33\left(\frac{s}{\ell}\right)^2} - 0,69\frac{s}{\ell} \leq 1$$

Table 6 : Coefficient β

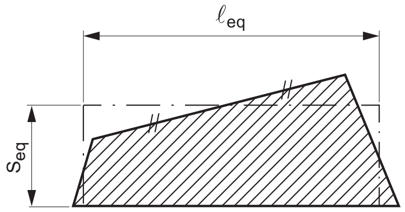
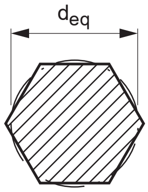
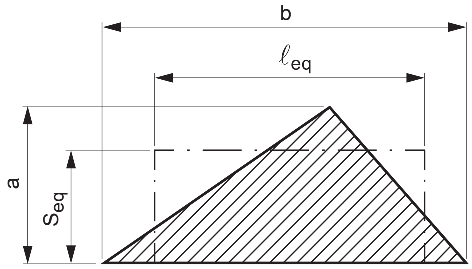
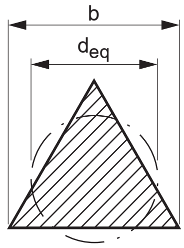
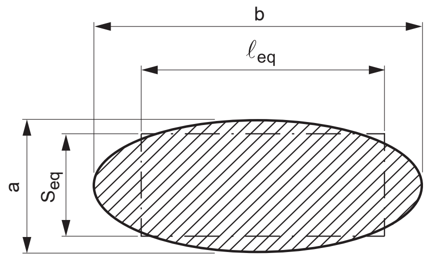
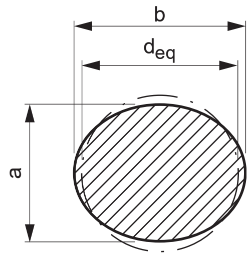
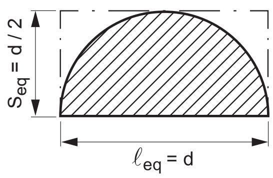
ℓ/s	1,0	1,5	2,0	2,5	3,0	3,5	≥ 4,0
β	0,284	0,475	0,608	0,684	0,716	0,734	0,750

Table 7 : Thickness of monolithic window: Side shell impact

Type of edge condition	Circular window or sidescuttle		Rectangular window or sidescuttle	
Supported condition	• if d ≤ 0,6 m **(1)**	$t = 16,7 d \sqrt{\frac{p}{R_m / S_f}}$	• if s ≤ 0,6 m **(2)**	$t = 21,2 \sqrt{\frac{1}{\ell_b}} \mu s \sqrt{\frac{p}{R_m / S_f}}$
	• if d > 0,6 m **(2)**	$t = 11,6 \sqrt{\frac{1,5 d^2 - 0,18}{\ell_b d}} \sqrt{\frac{p}{R_m / S_f}}$	• if s > 0,6 m **(2)**	$t = 16,4 \sqrt{2s - 0,6} \sqrt{\frac{1}{\ell_b}} \mu \sqrt{\frac{p}{R_m / S_f}}$

(1) $p = p_{ssmin}$ as defined in Ch 3, Sec 3, [3.1]
(2) $p = C_p P_{ssmin}$
ℓ_b : Length, in m, equal to:
$\ell_b = 0,6\ (1 + s) \leq \ell$ or d
p_{ssmin} : Impact pressure, in kN/m², as defined in and Ch 3, Sec 3, [3.1]
C_p : Pressure coefficient equal to:
$C_p = -0,98 s^2 + 0,3 s + 0,95 \geq 0,8$

Table 8 : Equivalent dimensions for windows

<table>
<tr>
<td colspan="2">a) Quadrangle:
The equivalent rectangle has the same area

</td>
<td>b) Polygon
The equivalent circle has the same area

</td>
<td colspan="2">c) Triangle
$s_{eq} = 2a/3$
$l_{eq} = 3b/4$

</td>
</tr>
<tr>
<td>d) Equilateral triangle
$d_{eq} = 3b/4$

</td>
<td colspan="2">e) Flat ellipse
$s_{eq} = 0,87a$
$l_{eq} = 0,87b$

</td>
<td>f) Round ellipse
$d_{eq} = \sqrt{ab}$

</td>
<td>g) Semi circle
$s_{eq} = d/2$
$l_{eq} = d$

</td>
</tr>
</table>

7.3.5 Thickness of laminated window with collaborating plies

Laminated windows with collaborating plies are glass windows realized with a layer of resin (polyvinyle butyral as a general rule) located between sheets of glass.

The equivalent thickness t_{eq}, in mm, of laminates made of two collaborating plies of the same material, and of thicknesses t_1 and t_2 separated by an interlayer of thickness t_I is to comply with the following formula:

$t_{eq} \geq t$

where:

t : Thickness, in mm, as defined in [7.3.4]

t_{eq} : $t_{eq} = \min[t_{1eq,s}, t_{2eq,s}]$

$t_{1eq,s}$, $t_{2eq,s}$: Equivalent thickness for strength as obtained from the following formulae:

$$t_{1eq,s} = \sqrt{\frac{t_{eq,d}^3}{t_1 + 2\Gamma t_{s2}}}$$

$$t_{2eq,s} = \sqrt{\frac{t_{eq,d}^3}{t_2 + 2\Gamma t_{s1}}}$$

$t_{eq,d}$: Equivalent thickness for deflection as obtained from the following formula:

$$t_{1eq,d} = \sqrt[3]{t_1^3 + t_2^3 + 12\Gamma I_S}$$

Γ : Shear transfer coefficient as obtained from the following formula, without being taken less than 0 (independent plies behaviour) and more than 1,0 (monolithic behaviour):

$$\Gamma = \frac{1}{1 + 9,6\dfrac{E}{G}\dfrac{I_S}{hs^2}\dfrac{t_I}{s^2}\dfrac{1}{10^6}}$$

$$t_{s1} = \frac{hs \cdot t_1}{t_1 + t_2}$$

$$t_{s2} = \frac{hs \cdot t_2}{t_1 + t_2}$$

$$I_S = t_1 t_{s2}^2 + t_2 t_{s1}^2$$

$$hs = 0,5(t_1 + t_2) + t_I$$

G : Shear modulus of the interlayer at 25 °C, in N/mm², generally taken equal to 1,6 N/mm² for polyvinyl butyral (PVB). For other interlayer materials the shear modulus value at 25 °C for short time duration load (60 s) shall be declared by the interlayer material manufacturer

E : Young's modulus of the plies, in N/mm²

s : Shorter side, in m, of rectangular window or sidescuttle.

In case of multiple (more than two plies) laminates the calculation is to be iterated. The iteration is to start from the outer ply (the one directly loaded by water pressure) and end with the inner ply.

7.3.6 Thickness of laminated window with independent plies

The equivalent thickness t_{eq}, in mm, of laminates made of n plies of different thicknesses $t_{p,1}$, $t_{p,2}$, ..., $t_{p,n}$ is to comply with the following formula:

$$t_{eq} \geq t$$

where:

t : Thickness, in mm, of a monolithic window, calculated according to [7.3.4] for the same material than the ply giving the minimum value of $t_{eq,j}$.

t_{eq} : $t_{eq} = \min[t_{eq,j}]$

$$t_{eq,j} = \sqrt{\frac{\sum_{j=1}^{n} t_{p,j}^3}{t_{p,j}}}$$

j : Ply index, ranging from 1 to n

7.3.7 Thickness of double glasses

Double glasses are glasses realized by two sheets of glass, separated by a spacebar hermetically sealed.

The thickness of the outside glass exposed to loads is to be calculated as defined in [7.3.4].

7.3.8 Thickness of glasses forming screen bulkheads or internal boundaries of deckhouses

The thickness of glasses forming screen bulkheads on the side of enclosed promenade spaces and that for rectangular windows in the internal boundaries of deckhouses which are protected by such screen bulkheads are considered by the Society on a case-by-case basis.

The Society may require both limitations on the size of rectangular windows and the use of glasses of increased thickness in way of front bulkheads which are particularly exposed to heavy sea.

7.4 Deadlight arrangement glasses

7.4.1 General

Sidescuttles to the following spaces are to be fitted with efficient hinged inside deadlights:

- spaces below the freeboard deck
- spaces within the first tier of enclosed superstructures
- first tier deckhouses on the freeboard deck protecting openings leading below or considered buoyant in stability calculations.

Deadlights are to be capable of being closed and secured watertight if fitted below the freeboard deck and weathertight if fitted above.

7.4.2 Watertight deadlights

Efficient hinged inside deadlights, so arranged that they can be easily and effectively closed and secured watertight, are to be fitted to all sidescuttles except that, abaft one eighth of the ship's length from the forward perpendicular and above a line drawn parallel to the bulkhead deck at side and having its lowest point at a height of (3,7 + 0,025 B) m above the deepest subdivision summer load line, the deadlights may be portable in passenger accommodation other than that for steerage passengers, unless the deadlights are required by the International Convention on Load Lines in force to be permanently attached in their proper positions. Such portable deadlights are to be stowed adjacent to the sidescuttles they serve.

7.4.3 Openings at the side shell in the second tier

Sidescuttles and windows at the side shell in the second tier, protecting direct access below or considered buoyant in the stability calculations, are to be provided with efficient, hinged inside deadlights capable of being effectively closed and secured weathertight.

7.4.4 Openings set inboard in the second tier

Sidescuttles and windows set inboard from the side shell in the second tier, protecting direct access below to spaces listed in [7.4.1], are to be provided with either efficient, hinged inside deadlights or, where they are accessible, permanently attached external storm covers of approved design and substantial construction capable of being effectively closed and secured weathertight.

Cabin bulkheads and doors in the second tier separating sidescuttles and windows from a direct access leading below may be accepted in place of fitted deadlights or storm covers.

Note 1: Deadlights in accordance with recognised standards are fitted to the inside of windows and sidescuttles, while storm covers of comparable specifications to deadlights are fitted to the outside of windows, where accessible, and may be hinged or portable.

7.4.5 Deckhouses on superstructures of less than standard height

Deckhouses situated on a raised quarterdeck or on a superstructure of less than standard height may be treated as being on the second tier as far as the provision of deadlights is concerned, provided the height of the raised quarterdeck or superstructure is not less than the standard quarterdeck height.

7.4.6 Openings protected by a deckhouse

Where an opening in a superstructure deck or in the top of a deckhouse on the freeboard deck which gives access to a space below the freeboard deck or to a space within an enclosed superstructure is protected by a deckhouse, then it is considered that only those sidescuttles fitted in spaces which give direct access to an open stairway need to be fitted with deadlights.

Section 2 Other Structures

Symbols

L_{WL} : Length at waterline at full load, in m

T : Draught, in m, as defined in Ch 1, Sec 1, [4.5]

k : Material factor defined in Ch 1, Sec 2, [2.1.5] for steel, and in Ch 1, Sec 2, [3.1.3] for aluminium.

1 Application

1.1 General

1.1.1 Additional requirements in relation to the service notation or service feature

Additional requirements in relation to the service notation or feature assigned to the ship are to be taken into account as defined in Ch 6, Sec 1.

2 Fore part structure

2.1 General

2.1.1 Application

The requirements of this Article apply for the scantling and the structure arrangement of structures located forward of the collision bulkhead for steel and aluminium structure.

Fore part of composite hull structure is to be examined according to NR546 Composite Ships.

2.1.2 Scantlings

The scantlings of the fore part structure and the flat bottom area are to be checked as defined in Chapter 4.

Adequate tapering is to be ensured between the structure in the fore part and the structure aft of the collision bulkhead.

Fore peak structures which form the boundary of spaces not intended to carry liquids, and which do not belong to the outer shell, are to be subjected to lateral pressure in flooding conditions. Their scantlings are to be determined as defined in Chapter 4.

2.2 Stems

2.2.1 General

Adequate continuity of strength is to be ensured at the connection of stems and surrounding structure. Abrupt changes in sections are to be avoided.

2.2.2 Bar stems

The cross-sectional area, in cm², of bar stems built of forged, rolled or casting steel or aluminium is to be not less than:

- for steel structure:

$$A_p = \left(0,40 + 10\frac{T}{L_{WL}}\right)(0,009L^2 + 20)k^{0,5} \qquad \text{with} \qquad 0,05 < \frac{T}{L_{WL}} < 0,075$$

- for aluminium structure:

$$A_p = \left(0,40 + 10\frac{T}{L_{WL}}\right)(0,0125L^2 + 28)k^{0,5} \qquad \text{with} \qquad 0,05 < \frac{T}{L_{WL}} < 0,075$$

The thickness of the bar stem, in mm, is to be not less than:

- for stem in steel:

  $t = (0,40\ L_{WL} + 13)\ k^{0,5}$

- for stem in aluminium:

  $t = (0,55\ L_{WL} + 18)\ k^{0,5}$

The cross-sectional area of the stem may be gradually tapered from the load waterline to the upper end, where it may be equal to the two thirds of the value as calculated above.

The lower part of the stem may be constructed of cast steel or aluminium alloy casting subject to the examination by the Society. Where necessary, a vertical web is to be fitted for welding of the centre keelson.

The bar stem is to be welded to the bar keel generally with butt welding.

The shell plating is also to be welded directly to the bar stem with butt welding.

2.2.3 Plate stems

Where the stem is constructed of shaped plates, the thickness of the plates below the load waterline is to be not less than the value obtained, in mm, from the following formulae:

- for steel structure:

$$t_S = 1,37(0,95 + \sqrt{L_{WL}})k^{0,5}$$

- for aluminium structure:

$$t_S = 1,90(0,95 + \sqrt{L_{WL}})k^{0,5}$$

Above the load waterline, this thickness may be gradually tapered towards the stem head, where it is to be not less than that required for side plating at ends.

As a rule, the expanded width of the stem, in m, is not to be less than:

$$b = 0,8 + 0,5\frac{L_{WL}}{100}$$

The plating forming the stems is to be supported by horizontal diaphragms spaced about 1200 mm apart and connected, as far as practicable, to the adjacent frames and side stringers.

If considered necessary, and particularly where the stem radius is large, a centreline stiffener or web of suitable scantlings is to be fitted.

2.3 Reinforcements of the flat bottom forward area

2.3.1 General

In addition to the requirements in [2.1], the structures of the flat bottom forward area are to be able to sustain the dynamic pressures due to the bottom impact where applicable as defined in Ch 3, Sec 3, [3.2.1].

2.3.2 Scantlings

The area defined in Ch 3, Sec 3, [3.2.2] is to be reinforced as defined below:

a) Plating and secondary stiffeners:

   The scantlings of plating and secondary stiffeners are to be not less than the values obtained in Ch 4, Sec 3, [2.2.2] and Ch 4, Sec 4, [2.2.2], taking into account the bottom impact pressure p_{Bi} defined in Ch 3, Sec 3, [3.2.3].

b) Primary stiffener structure:

   As a rule, primary structure is to be checked through direct calculation considering a pressure of 0,3 p_{Bi}, where p_{Bi} is the bottom impact pressure defined in Ch 3, Sec 3, [3.2.3].

c) Tapering:

   Outside the flat bottom forward area, scantlings are to be gradually tapered so as to reach the values required for the areas considered.

2.4 Bow flare

2.4.1 General

a) Bow flare structure:

   The bow flare area is the area extending forward of 0,9 L_{WL} from the aft end of L_{WL} and above the summer load waterline up to the level at which a knuckle with an angle greater than 15° is located on the side shell.

   The bow flare structure is to be checked as defined in Chapter 4 taking into account the external pressure defined in Ch 3, Sec 3.

   In addition, primary supporting members are generally to be checked through direct calculations.

   When deemed necessary by the Society, the bow flare structure for steel or aluminium structure is to be checked according to:

   - NR467 Steel Ships, Pt B, Ch 5, Sec 5 [4.3.1] for the calculation of the bow flare impact pressure, taking into account a wave parameter H equal to 0,1C_W where C_W is defined in Ch 3, Sec 3
   - NR467 Steel Ships, Pt B, Ch 7, Sec 4 [4.1] for plating scantling check
   - NR467 Steel Ships, Pt B, Ch 7, Sec 5 [1.3] for plastic section modulus check of secondary stiffeners
   - NR467 Steel Ships, Pt B, Ch 7, Sec 6 [2.3] for section modulus check of primary stiffeners

Note 1: As a rule, this bow impact pressure may be taken into account for ship greater than 40 m having a value of angle β greater than 25°, where β is the angle between a longitudinal line parallel to the centerline of the ship and the tangent to the shell plating in a horizontal plane.

b) Bow flare arrangement:

   Outside the bow flare area, scantlings are to be gradually tapered so as to reach the values required for the areas considered.

   Intercostal stiffeners are to be fitted at mid-span where the angle between the stiffener web and the attached plating is less than 70°.

2.5 Bulbous bow

2.5.1 General

Where a bulbous bow is fitted, the structural arrangements are to be such that the bulb is adequately supported and integrated into the fore peak structure.

2.5.2 Diaphragm plates

At the forward end of the bulb, the structure is generally to be supported by horizontal diaphragm plates, spaced about 1 m apart, in conjunction with a deep centreline web.

In general, vertical transverse diaphragm plates are to be arranged in way of the transition from the peak framing to the bulb framing.

2.5.3 Special bulbous bow design

In way of a wide bulb, additional strengthening in the form of a centreline wash bulkhead is generally to be fitted.

In way of a long bulb, additional strengthening in the form of transverse wash bulkheads or substantial web frames is to be fitted.

2.5.4 Strengthening for anchor and chain cable

The shell plating is to be increased in thickness at the forward end of the bulb and also in areas likely to be subjected to contact with anchors and chain cables during anchor handling. The increased plate thickness is to be the same as that required for plated stems given in [2.2.3].

2.6 Thruster tunnel

2.6.1 Scantling of the thruster tunnel and connection with the hull

The thickness of the tunnel is to be not less than that of the adjacent hull plating.

Where the outboard ends of the tunnel are provided with bars or grids, the bars or grids are to be effectively secured.

When the tunnel is not welded to the hull, the connection devices are examined by the Society on a case-by-case basis

3 Aft part structure

3.1 General

3.1.1 Application

The requirements of this Article apply for the scantling of structures located aft of the after peak bulkhead for steel and aluminium structure.

Aft part of composite hull structure are to be examined according to NR546 Composite Ships.

3.1.2 Scantling

The scantling of the aft part structure is to be checked as defined in Chapter 4.

Adequate tapering is to be ensured between the scantlings in the aft part and those fore of the after peak bulkhead. The tapering is to be such that the scantling requirements for both areas are fulfilled.

Aft peak structures which form the boundary of spaces not intended to carry liquids, and which do not belong to the outer shell, are to be subjected to lateral pressure in flooding conditions. Their scantlings are to be determined as defined in Chapter 4.

3.2 Transversely framed after peak

3.2.1 Arrangement

The arrangement of transversely framed after peak structure is to be as defined in NR467 Steel Ships, Pt B, Ch 11, Sec 3.

3.3 Other structures

3.3.1 Connection of hull structures with the rudder horn

The connection of hull structure with the rudder horn is to be as defined in NR467 Steel Ships, Pt B, Ch 11, Sec 3, [3].

3.3.2 Sternframes

Sternframes scantling, arrangement and connection to the hull are to be as defined in NR467 Steel Ships, Pt B, Ch 11, Sec 3, [4].

4 Machinery spaces

4.1 Application

4.1.1 The requirements of this Article apply for:

- the arrangement of machinery space for ships built in steel, aluminium and composite materials
- the scantling of machinery space structures as regards general strength for ships built in steel and aluminium.

It is no substitute to machinery manufacturer's requirements which have to be dealt with at Shipyard diligence.

The Designer may propose arrangements and scantlings alternative to the requirements of this Article, on the basis of direct calculations which are to be submitted to the Society for examination on a case-by-case basis.

The Society may also require such direct calculations to be carried out whenever deemed necessary.

4.2 General

4.2.1 Unless otherwise specified in this Article, the scantling of platings and stiffeners in the machinery space are to be determined according to the relevant criteria in Chapter 4, as applicable. In addition, specific requirements specified in this Section apply.

4.2.2 The structural continuity of the machinery space with hull structures located aft and forward is to be as defined in Ch 2, Sec 1.

4.2.3 Machinery space openings and access doors to casings are to be in accordance with:

- NR467 Steel Ships, for ships of 500 GT and over and for all ships having the service notation **passenger ship**, **ro-ro passenger ship**, **fishing vessel** or **chemical tanker**
- NR566 for the other ships.

4.3 Double bottom

4.3.1 General

The general double bottom arrangement is to be as defined in Ch 2, Sec 1, [4].

Access arrangement is to be as defined in Ch 2, Sec 2, [5.2]. However, the number and size of manholes in floors located in way of seatings and adjacent areas are to be kept to the minimum necessary for double bottom access and maintenance.

4.3.2 Primary structure scantling

The scantling of double bottom primary structure, for steel and aluminium alloys, is to be as defined in Ch 4, Sec 5. As a rule, in addition, the thickness t, in mm, of floor and girder webs is to be not less than:

$t = 5 + 0,045\ L_{WL}\ k^{1/2}$

4.3.3 Double bottom girders

In the machinery space the number of side bottom girders is to be adequately increased, with respect to the adjacent areas, to ensure adequate rigidity of the structure.

The side bottom girders are to be a continuation of any bottom longitudinal in the areas adjacent to the machinery space and are generally to have a spacing not greater than 3 times that of longitudinal and in no case greater than 3 m.

Additional side bottom girders are to be fitted in way of machinery seatings.

Side bottom girders arranged in way of main machinery seatings are to extend for the full length of the machinery space.

Where the machinery space is situated amidships, the bottom girders are to extend aft of the after bulkhead of such space for at least three frame spaces, and beyond to be connected to the hull structure by tapering.

Where the machinery space is situated aft, the bottom girders are to extend as far aft as practicable in relation to the shape of the bottom and to be supported by floors and side primary supporting members at the ends.

4.3.4 Double bottom floors

As a rule, floors are to be fitted in way of machinery.

4.4 Single bottom

4.4.1 General

The general single bottom arrangement is to be as defined in Ch 2, Sec 1, [4].

Furthermore, additional floors are to be fitted in way of important machinery.

As a rule, floors and girders are to be fitted with welded face plates in the engine room and especially in way of:

- engine bed plates
- thrust blocks
- auxiliary seatings.

4.4.2 Primary structure scantling

The scantling of single bottom primary structure, for steel and aluminium alloys, is to be as defined in Ch 4, Sec 5. As a rule, in addition, the thickness t, in mm, of floor and girder webs is to be not less than:

$t = 5 + 0,045\ L_{WL}\ k^{1/2}$

4.5 Side

4.5.1 Arrangement

The type of side framing in machinery spaces is generally to be the same as adopted in the adjacent areas.

When it is not the case, the structural continuity of the machinery side with surrounding structures located aft and forward is to be as defined in Ch 2, Sec 1, and abrupt structural discontinuities between longitudinally and transversely framed structure are to be avoided.

4.6 Platforms

4.6.1 The location and extension of platforms in machinery spaces are to be arranged so as to be a continuation of the structure of side longitudinals, as well as of platforms and side girders located in the adjacent hull areas.

In general, platform transverses are to be arranged in way of side or longitudinal bulkhead transverses.

4.7 Pillaring

4.7.1 Pillars are generally to be arranged in way of:

- machinery casing corners and corners of large openings on platforms; alternatively, two pillars may be fitted on the centreline (one at each end of the opening)
- the intersection of platform transverses and girders
- transverse and longitudinal bulkheads of the superstructure.

In general, pillars are to be fitted with brackets at their ends.

4.7.2 Pillar bulkhead scantlings are to be as defined in Ch 4, Sec 7.

4.8 Machinery casing

4.8.1 The scantlings of plating and stiffeners are to be not less than those obtained according to the applicable requirements in Chapter 4.

Casings are to be reinforced at the ends by deck beams and girder associated to pillars.

4.9 Seatings of main engines

4.9.1 General

The scantling of seatings of main engines and thrust bearings are to be adequate in relation to the weight and power of engines and the static and dynamic forces transmitted by the propulsive installation.

Transverse and longitudinal members supporting the seatings are to be located in line with floors and bottom girders.

They are to be so arranged as to avoid discontinuity and ensure sufficient accessibility for welding of joints and for surveys and maintenance.

Seatings are to be adequately connected to floors and girders with flanged brackets.

4.9.2 Scantling

The scantlings of the structural elements in way of the seatings of engines are to be determined by the engine manufacturer. They are to be checked on the basis of justificative calculations supplied by the engine manufacturer.

5 Side shell, superstructure walls and internal bulkhead doors

5.1 General

5.1.1 Application

The requirements of this article apply to the scantling of side shell doors, superstructure wall doors and doors in internal bulkheads that are required to be watertight or weathertight.

The opening categories depending on their means of closure are defined in NR467 Steel Ships, Pt B, Ch 3, Sec 3, [3.3.2].

5.1.2 Door scantlings

Door scantlings are to be designed to offer equivalent strength compared to the adjacent side shell or bulkhead in which they are fitted and are to be examined taking into account the same design loads.

As a rule, the door stiffeners are generally to be considered as simply supported.

5.1.3 Securing and supporting structure

Securing arrangement and supporting structure are to be as defined in NR467 Steel Ships, Pt B, Ch 11, Sec 8, [4], taking into account the permissible local stresses defined in Ch 2, Sec 3, Tab 4.

5.1.4 Inspection and testing

The requirements of NR467 Steel Ships, Pt B, Ch 11, Sec 8, [5] are applicable.

5.1.5 Type approval procedure

The requirements of NR467 Steel Ships, Pt B, Ch 11, Sec 8, [6] are applicable.

6 Hatch covers on weather deck

6.1 Hatch cover structure

6.1.1 General case

The structure of cargo hatch covers and coamings on exposed decks and hatches designed for access to spaces below the exposed decks are to be calculated according to the present Rules, taking into account the lateral pressures and forces defined in NR467 Steel Ships, Pt B, Ch 11, Sec 9, [4].

For hatches with openings greater than 2,5 m^2, the vertical deflection of primary supporting members due to the vertical weather loads is to be not more than 0,56% of the greatest span of the primary supporting members.

6.1.2 When deemed necessary by the Society, large cargo hatch covers and coamings on exposed decks are to be examined according to NR467 Steel Ships, Pt B, Ch 11, Sec 9.

6.1.3 Ships with restricted navigation or ships having a Load Line length less than 24 m

For ships with restricted navigation or for ships having a Load Line length less than 24 m, the structure of hatch covers are to be calculated according to the present Rules, taking into account the loads defined in Ch 3, Sec 3 and Ch 3, Sec 4.

When the conformity to the Convention on Load Lines is required, [6.1.1] is to be applied.

6.1.4 Ships having the service notations bulk carrier, ore carrier and combination carrier

The scantling and the arrangement of hatch covers and hatch coamings for ships having the service notations bulk carrier, ore carrier and combination carrier are to be as defined in NR467 Steel Ships, Pt B, Ch 11, Sec 9.

6.2 Arrangements

6.2.1 General

The arrangements of hatch covers and coamings are to be in accordance with NR467 Steel Ships, Pt B, Ch 11, Sec 9, [2], taking into account the height of hatch coamings as defined in NR566, Ch 1, Sec 4, [7.1.1] when applicable.

6.2.2 Weathertightness, closing arrangement, securing devices, stoppers and supports

The weathertightness, closing arrangement, securing devices, stoppers and supports are to be ensured as defined in NR467 Steel Ships, Pt B, Ch 11, Sec 9, [8] or by equivalent means.

6.2.3 Drainage and testing

Drainage and testing are to be as defined in NR467 Steel Ships, Pt B, Ch 11, Sec 9, [9] and [10].

7 Movable decks, inner ramps and external ramps

7.1 Application

7.1.1 The requirements of this Article apply to movable decks and inner ramps when the additional class notation **ALP** is not granted and when no cargo gear register is issued.

7.1.2 On special request of the owner the movable inner ramps under load may be examined by the Society in the scope of the application of NR526 Rules for the Certification of Lifting Appliances on board Ships and Offshore Units, and the assignment of additional class notation **ALP** (see NR467 Steel Ships, Pt A, Ch 1, Sec 2, [6]).

7.2 Scantling

7.2.1 Materials

The movable decks and inner ramps are to be made of steel or aluminium alloys complying with the requirements of NR216 Materials and Welding. Other materials of equivalent strength may be used, subject to a case-by-case examination by the Society.

7.2.2 Plating and secondary stiffener scantling

The thickness of plate panels and the section modulus and shear sectional area of secondary stiffeners subjected to wheeled loads are to be not less than the value obtained from Ch 4, Sec 3 and Ch 4, Sec 4, as applicable, with a value of $F_w \cdot n$ (or F_w for secondary stiffeners) to be taken not less than 5 kN, where:

F_w : Wheeled force, in kN, as defined in Ch 3, Sec 4, [4.4]

n : Number of wheels on the plate panel as defined in Ch 4, Sec 3, [2.2.4].

7.3 Primary supporting members

7.3.1 General

The supporting structure of movable decks and inner ramps is to be examined through direct calculation, considering the following cases:

- movable deck stowed in upper position, empty and locked, at sea
- movable deck in service, loaded, in lower position, resting on supports or supporting legs and locked, at sea
- movable inner ramp in sloped position, supported by hinges at one end and by a deck at the other, with possible intermediate supports, loaded, at harbour
- movable inner ramp in horizontal position, loaded and locked, at sea.

7.3.2 Loading cases

The scantlings of the structure are to be checked in both sea and harbour conditions for the following cases:

- loaded movable deck or inner ramp under loads according to the load distribution indicated by the Designer
- loaded movable deck or inner ramp under uniformly distributed loads corresponding to a pressure, in kN/m², equal to:

  $p_0 + p_1$
- empty movable deck under uniformly distributed masses corresponding to a pressure, in kN/m², equal to p_0

where:

$$p_0 = \frac{P_P}{A_P}$$

$$p_1 = n_V \frac{P_V}{A_P}$$

P_P : Mass of the movable deck, in kN

P_V : Mass of a vehicle, in kN

n_V : Maximum number of vehicles loaded on the movable deck

A_P : Effective area of the movable deck, in m².

7.3.3 Lateral pressure

The vertical and lateral pressures p, in kN/m² transmitted to the movable deck or inner ramp structures in x, y and z directions to take into account in harbour and sea conditions are to be obtained from Tab 1.

7.3.4 Checking criteria

It is to be checked that the combined stress σ_{VM} is in accordance with the criteria defined in Ch 2, Sec 3.

The scantlings of main stiffeners and the distribution of supports are to be such that the deflection of the loaded movable deck or loaded inner ramp does not exceed 5 mm/m.

7.4 Supports, suspensions and locking devices

7.4.1 Scantlings of wire suspensions are to be checked by direct calculation on the basis of the loads in [7.3.2] and [7.3.3], taking into account a safety factor at least equal to 5.

It is to be checked that the combined stress σ_{VM} in rigid supports and locking devices is in accordance with the criteria defined in Ch 2, Sec 3.

7.5 Tests and trials

7.5.1 Tests and trials defined in [7.5.2] to [7.5.4] are to be carried out in the presence of the Surveyor. Upon special request, these conditions of tests and trials may be modified to comply with any relevant national regulations in use.

7.5.2 The wire ropes are to be submitted to a tensile test on test-piece.

7.5.3 The loose gears used for the platform and ramp handling (chain, shackles, removable blocks, etc.) are to have a maximum safe working load (SWL) and are to be submitted to an individual test before fitting on board.

The test of these loose gears are to be in accordance with the applicable requirements of NR526 Rules for the Certification of Lifting Appliances on board Ships and Offshore Units.

7.5.4 A trial to verify the correct operation of lowering and lifting devices of the platform is to be carried out before going into service.

This trial is made without overload unless special requirement of National Authorities.

7.6 External ramps

7.6.1 The thicknesses of plating and the scantlings of secondary stiffeners and primary supporting members are to be determined under vehicle loads in harbour condition, at rest, as defined in Tab 1.

7.6.2 The external ramps are to be examined for their watertightness, if applicable.

7.6.3 The locking of external ramps in stowage position at sea is examined by the Society on a case-by-case basis.

7.6.4 The ship structure under the reactions due to the ramp is examined by the Society on a case-by-case basis.

Table 1 : Movable decks and inner ramps lateral pressure

Ship condition		Lateral pressure p, in kN/m²
Sea		$P_x = (p_0 + p_1)\ a_x / g$ $P_y = 0,7\ (p_0 + p_1)\ a_y / g$ $P_z = (p_0+p_1) + (p_0+p_1)\ \eta\ a_z / g + 0,7\ y\ \alpha_R / g$
Harbour **(1)**	during lifting	$p_z = 1,2\ p_0$
	at rest	$p_x = 0,035\ (p_0 + p_1)$ $p_y = 0,087\ (p_0 + p_1)$ $p_z = 1,100\ (p_0 + p_1)$

Note 1:

g : Gravity acceleration taken equal to 9,81 m/s²

a_x : Longitudinal acceleration, in m/s², taken equal to:

$$a_x = 0,65\frac{z}{T} + 0,55$$

a_y : Transversal acceleration, in m/s², taken equal to:

$$a_y = \alpha_R(z - T)$$

a_z : Vertical acceleration, in m/s², as defined in Ch 3, Sec 4, [2.2]

α_R : Roll acceleration, in rad/s², as defined in Ch 3, Sec 4, [2.1.7]

η : Acceleration coefficient to be taken equal to:

- 0,5 for ship in displacement mode
- 0,4 for ship in planing mode

y, z : Transversal and vertical co-ordinates, in m, of the centre of gravity of the ramp

T : Minimum draught of the ship, in m.

(1) For harbour conditions, a heel angle of 5° and a trim angle of 2° are taken into account.

8 Rudders

8.1 General

8.1.1 The scantling of rudders built in steel is to be in accordance with the requirements defined in NR467 Steel Ships, Pt B, Ch 12, Sec 1, [1] to [7].

For ships having the navigation notation **sea going launch** and **launch**, the navigation notation n_R considered for the calculation of the rudder force C_R is to be taken equal to 0,8 and 0,7 respectively.

For rudder built in aluminium alloys, the material factor k_1 to be taken into account in the scantling formulae is to be taken equal to:

$$k_1 = \frac{0,9 \cdot 235}{R'_{lim}}$$

where:

R'_{lim} : Minimum yield stress of the aluminium alloys considered, to be taken equal to the minimum value, in welded condition, between $R'_{p0,2}$ (proof stress) and 0,7 R'_m (tensile strength), where $R'_{p0,2}$ and R'_m are defined in Ch 1, Sec 2, [3.1.2].

In the non-welded areas, R'_{lim} may be taken equal as defined here above in non welded condition on a case by case basis.

For planing hull as defined in Ch 1, Sec 1, [2.1.5], the ahead service speed to take into account in the rudder check is to be taken equal to the minimum value between:

- V_{AV}
- $2/3\ (V_{AV} + 2\ L_{WL}^{0,5})$

where:

V_{AV} : Maximum ahead service speed, in knots.

Rudders built in composite materials are to be examined on a case-by-case basis by the Society taking into account safety factor criteria defined in Ch 2, Sec 3, [3.1] where Rules safety factors are to be increased by a coefficient to be taken at least equal to 1,3.

8.2 Rudder horn and solepiece

8.2.1 General

Arrangement of rudder horn and solepiece are to be in accordance with NR467 Steel Ships, Pt B, Ch 12, Sec 1, [8].

8.2.2 Rudder horn scantling

The scantling of rudder horn built in steel is to be as defined in NR467 Steel Ships, Pt B, Ch 12, Sec 1, [8].

For rudder horn in aluminium alloys, the allowable stresses to be taken into account are the following ones:

τ_{ALL} : Allowable shear stress, in N/mm^2, equal to:

$\tau_{ALL} = 20 / k$

$\sigma_{E,ALL}$: Allowable equivalent stress, in N/mm^2, equal to:

$\sigma_{E,ALL} = 50 / k$

$\sigma_{B,ALL}$: Allowable bending stress, in N/mm^2, equal to:

$\sigma_{B,ALL} = 30 / k$

where:

k : Material factor for aluminium, defined in Ch 1, Sec 2, [3.1.3].

For ships with notation **launch** or **seagoing launch**, the allowable stresses may be increased by 10%.

Rudder horn in composite materials are to be examined on a case-by-case basis by the Society taking into account safety factor criteria defined in Ch 2, Sec 3, [3.1] where the Rules safety factors are to be increased by a coefficient to be taken at least equal to:

- 1,9 for the main stress safety factor
- 1,3 for the combined stress safety factor.

8.2.3 Solepieces scantling

The scantling of solepieces built in steel is to be as defined in NR467 Steel Ships, Pt B, Ch 12, Sec 1, [8].

For solepieces in aluminium alloys, the allowable stresses to be taken into account are the following ones:

$\sigma_{B,ALL}$: Allowable bending stress, in N/mm^2, equal to:

$\sigma_{B,ALL} = 35 / k$

τ_{ALL} : Allowable shear stress, in N/mm^2, equal to:

$\tau_{ALL} = 20 / k$

For ships with notation **launch** or **seagoing launch**, the allowable stresses may be increased by 10%.

Solepiece in composite materials are to be examined on a case-by-case basis by the Society taking into account safety factor criteria defined in Ch 2, Sec 3, [3.1] where the Rules safety factors are to be increased by a coefficient to be taken at least equal to:

- 1,9 for main stress safety factor
- 1,3 for the combined stress safety factor.

8.3 Nozzles and azimuth propulsion system

8.3.1 General

The scantling of nozzles and azimuth propulsion system built in steel are to be as defined in NR467 Steel Ships, Pt B, Ch 12, Sec 1, [10] and [11] respectively.

9 Water jet propulsion tunnel

9.1 General

9.1.1 The drawings of water jet duct, ship supporting structure, thrust bearing, as well as shell openings and local reinforcements are to be submitted for examination.

The pressure in water jet ducts, the forces and moments induced by the water jet to the hull structure and the calculation procedure from the Designer are to be specified.

9.1.2 Waterjet supporting structure in steel or aluminium

The supporting structure of waterjets is to be able to withstand the loads induced by the waterjet in the following conditions:

- maximum ahead thrust
- maximum thrust at maximum lateral inclination
- maximum reversed thrust (going astern).

Information on the above loads is to be given by the waterjet manufacturer.

For each waterjet, the following loading cases are to be investigated:

LDC1 : Internal hydrodynamic pressure p_h in the built-in nozzle

LDC2 : Horizontal longitudinal force F_{x1} in normal service (ahead)

LDC3 : Horizontal transverse force F_y and associated moment M_z during steering operation

LDC4 : Horizontal longitudinal force F_{x2}, vertical force F_z and overturning moment M_y in crash-stop situation.

The actual location of the thrust bearing is to be adequately considered (either located aft of the stem in the stator bowl or inside the waterjet compartment).

The scantlings are to be checked by direct calculations.

Tab 2 indicates the loading cases to be considered for the various components of the waterjet system. Other loading cases could be considered for specific or new design.

The stress criteria for static analysis, in N/mm², may be taken as follows:

- bending stress: σ_{locam} = 0,65 R
- shear stress: τ_{locam} = 0,45 R
- combined stress: σ_{VMam} = 0,80 R (calculated according to Von Mises criteria).

where:

R : Minimum yield stress value defined in Ch 2, Sec 3, [2.1.1].

The stress criteria for fatigue analysis are to be specified by the Designer.

The shell thickness in way of nozzles as well as the shell thickness of the tunnel are to be individually considered. In general, such thicknesses are to be not less than 1,5 times the thickness of the adjacent bottom plating.

General principles to be followed for such structures subject to cyclic loadings are listed hereafter:

- continuous welding
- shear connections between stiffeners and transverse frames
- soft toe brackets
- no sniped ends
- no termination on plate fields
- no scallops in critical areas
- no start and stop of welding in corners or at ends of stiffeners and brackets
- possibly grinding of toes of critical welds.

As a guidance, the following criteria may be considered:

The bending natural frequency of plates and strength members of the hull in the area of waterjets should not be less than 2,3 times the blade frequency for structures below the design waterline and between transom and aft engine room bulkhead. Structural components (such as the casing of waterjet and accessory parts and the immersed shell area) which may transfer pressure fluctuations into the ship structure have to fulfil the requirements of the waterjet manufacturer. Especially with regard the grids installed in the inlet duct, the hydrodynamic design should assure an unproblematic operation with respect to cavitation phenomenon.

This checking is left to the manufacturers.

Table 2 : Loading cases

Component		LDC 1	LDC 2	LDC 3	LDC 4
Built-in nozzle:	• plating	X **(1)**	X **(2)**		
	• bending behaviour				X **(3)**
Ship stem			X **(2)**	X	X **(4)**
Bolting on stem				X **(5)**	X **(5)**

(1) To be checked under lateral pressure and against fatigue behaviour
(2) Buckling to be checked (100% of F_x transferred by built-in nozzle in case of thrust bearing aft of the stem)
(3) Ratio of M_y directly sustained by the built-in nozzle to be estimated on basis of relative stiffnesses
(4) Ratio of M_y directly sustained by the transom structure to be estimated on basis of relative stiffnesses
(5) Bolting calculation taking account of the actual pre-tension in bolts.

9.1.3 Waterjet supporting structure in composite materials

The supporting structure in composite materials are to be checked according the general principles defined in the present article and according to NR546 Composite Ships, Section 3.

10 Foils and trim tab supports

10.1 General

10.1.1 Foils and trim tab supports are not covered within the scope of classification and/or certification.

Forces and moments induced by these elements, as well as the Designer calculation, are to be submitted for the examination of the surrounding hull structure reinforcements.

As a general rule, attachment structure of foils to the hull structure are to be located within watertight compartment or equivalent.

11 Propeller shaft brackets

11.1 General

11.1.1 The scantling of propeller shaft brackets, consisting of one or two arms, are to be examined taking into account bending moment calculated in accordance with NR467 Steel Ships, Pt B, Ch 12, Sec 3.

11.1.2 Scantling

For steel and aluminium propeller shaft bracket, the scantling criteria are to in accordance with the requirement defined in NR467 Steel Ships, Pt B, Ch 12, Sec 3. For aluminium, the value of σ_{ALL} may be taken equal to 0,35R_y, where R_y is defined in Ch 1, Sec 2, [3.1.2].

For propeller shaft brackets built in composite materials, the scantling are to be checked by direct calculation, taking into account the checking criteria defined in Ch 2, Sec 3, [3.2.3] where the Rules safety factors are to be increased by a coefficient to be taken at least equal to:

- 1,8 for the main stress safety factor
- 1,5 for the combined stress safety factor.

with partial safety factor C_i = 1

12 Bulwarks and guard rails

12.1 General

12.1.1 The requirements of this Article apply to the arrangement of bulwarks and guard rails provided at boundaries of exposed decks.

Efficient bulwarks and guard rails are to be fitted around all exposed decks.

12.2 Bulwarks

12.2.1 Arrangement of bulwarks

The general arrangement of bulwarks is to be as defined in NR467 Steel Ships, Pt B, Ch 12, Sec 2.

12.2.2 Scantling of bulwarks

a) Plating and secondary stiffeners

The platings and the secondary stiffeners scantling are to be as defined in Ch 4, Sec 3, [2] and Ch 4, Sec 4, [2].

b) Stays for steel and aluminium structure:

The section modulus, in cm³, and the shear section, in cm², of stays and their connection to the deck structure in way of the lower part of the bulwark are to be not less than the greater values obtained from the following formulae:

1) for side shell sea pressure:

$$z = \frac{500 p_s s \ell^2}{\sigma_{locam}}$$

$$A_{sh} = \frac{10 p_s s \ell}{\tau_{locam}}$$

with:

σ_{locam}, τ_{locam} : Permissible stresses as defined in Ch 2, Sec 3 for local sea pressure.

2) for side shell impact:

- if $\ell \geq 0{,}6$ m and $s \geq 0{,}6$ m:

$$z = \frac{280 p_{ssmin}(\ell - 0,3)}{\sigma_{locam}}$$

$$A_{sh} = \frac{2,8 p_{ssmin}}{\tau_{locam}}$$

- if $\ell \geq 0{,}6$ m and $s < 0{,}6$ m:

$$z = \frac{600 s p_{ssmin}(\ell - 0,3)}{\sigma_{locam}}$$

$$A_{sh} = \frac{6 s p_{ssmin}}{\tau_{locam}}$$

- if $\ell < 0{,}6$ m:

$$z = \frac{500 p_{ssmin} s \ell^2}{\sigma_{locam}}$$

$$A_{sh} = \frac{10 p_{ssmin} s \ell}{\tau_{locam}}$$

with s not taken greater than 0,6 m.

where:

σ_{locam} , τ_{locam} : Permissible stresses as defined in Ch 2, Sec 3 for local dynamic sea pressure considered for secondary stiffeners.

p_s : Sea pressure on side shell as defined in Ch 3, Sec 3, [2.2.1], in kN/m², calculated at mid-height of the stay

p_{ssmin} : Impact pressure on side shell as defined in Ch 3, Sec 3, [3.1], in kN/m²

s : Spacing of stays, in m

ℓ : Length of stays, in m

c) Stays for composite structure:

The stays and their connections to the deck structure are to be examined taking into account the values of bending moments, in kN.m, and shear forces, in kN defined in NR546 Composite Ships, Sec 3, [10.2].

The scantling of the stays are to be examined as defined in NR546 Composite Ships, for stiffener analysis, taking into account the safety factors defined in Ch 2, Sec 3, [3.1].

12.3 Guard rails

12.3.1 The general arrangement and the scantling of guard rails are to be in accordance with the requirements of NR467 Steel Ships, Pt B, Ch 12, Sec 2.

13 Lifting appliances

13.1 General

13.1.1 Application

The present Article is applicable for lifting appliances operated in still water.

The lifting appliances operated at sea are to be examined on a case by case considering the ship motions and accelerations defined in the present Rules and requirements defined in NR467 Steel Ships, Pt E, Ch 8, Sec 4.

For ship built in composite materials, the lifting appliances operated at sea will be considered on a case-by-case basis.

13.1.2 The fixed parts of lifting appliances and their connections to the ship’s structure are covered by the Rules, even when the certification (especially the issuance of the Cargo Gear Register) of lifting appliances is not required.

The fixed parts of lifting appliances, considered as an integral part of the hull, are the structures permanently connected to the ship’s hull (for instance crane pedestals, masts, king posts, derrick heel seatings, etc., excluding cranes, derrick booms, ropes, rigging accessories, and, generally, any dismountable parts). The shrouds of masts embedded in the ship’s structure are considered as fixed parts.

13.1.3 Structural category and steel grades for the foundations of the lifting equipment

The steel grade of the structural elements of the foundation is to comply with NR467 Steel Ships, Pt B, Ch 4, Sec 1, Tab 9 taking into account the structural categories given in Tab 3.

When the pedestal is interrupted on deck, the continuous deck plate is to be made of Grade Z steel quality in way of the crane pedestal.

Table 3 : Structural categories

Category / Class	Structural elements
Secondary / Class I	crane resting support
Primary / Class II	crane pedestal and its foundation
Special / Class III	insert plate of deck plating in way of crane pedestal

13.1.4 Information to be submitted

The following information are to be submitted by the Designer:

- the safe working load (SWL) defined as the maximum static load which may be lifted vertically under normal use within its geometrical limits and the dynamic amplification factors of the lifting equipment self-motions based on the technical standard used for the certification of the lifting equipment
- the general arrangement of the lifting equipment specifying the weight of the main elements (crane body, crane boom…)
- the testing loads.
- the forces and moments transmitted by the crane to the ship structure.

13.1.5 Checking criteria

Local reinforcements and hull structure surrounding the crane pedestal are to be checked by direct calculations, taking into account the following permissible stresses:

a) For steel and aluminium structure:

$\sigma_{VMam} = 1,1\ \alpha\ R$

where:

σ_{VMam} : Combined stress calculated according to Von Mises criteria

R : Minimum yield stress value defined in Ch 2, Sec 3.

α : Stress factor to be taken as follow:

- $\alpha = 0,6$ for operation case
- $\alpha = 0,9$ for testing case

b) For composite structure:

- for operation case:
  - $SF_{CRANE} = \dfrac{SF}{\alpha}$
  - $SF_{CSCRANE} = \dfrac{SF_{CS}}{\alpha}$
- for testing case:
  - $SF_{CRANE} = \dfrac{0,85\ SF}{\alpha}$
  - $SF_{CSCRANE} = \dfrac{0,85\ SF_{CS}}{\alpha}$

where:

SF : Rules safety factor applicable to maximum stress defined in Ch 2, Sec 3, [3.2.3]

SF_{CS} : Rules safety factor applicable to combined stress defined in Ch 2, Sec 3, [3.2.3].

α : Stress factor to be taken as defined in a)

When the analysis of the local reinforcements of the structure is carried out by a finite element calculation submitted to the Society according to Ch 4, Sec 5, [1.3], the permissible stresses and safety factors defined in a) and b) are to be respectively increased and reduced by 10%.

13.1.6 Welding

As a rule, full penetration welding is to be provided between crane pedestal and deck plate.

14 Ships fitted with wind propulsion systems

14.1 General

14.1.1 The ship foundation structure elements and hull reinforcements in way of the safety and operating parts of the wind propulsion systems are to be examined when a ship is fitted with a wind propulsion system.

The hull structure reinforcements are to be examined according to NR206 Wind Assisted Systems, Sec 8.

15 Protection of hull structure

15.1 Protection of steel structures

15.1.1 The protection of steel structures is to be as described in NR467 Steel Ships, Pt B, Ch 4, Sec 4, and includes the following types of protection:

- coating
- galvanic corrosion in tanks
- wooden ceiling of double bottom (see Note 1)

- wood sheathing of decks
- batten in cargo side.

Note 1: Wooden ceiling on the inner bottom is not required where the thickness of the inner bottom, calculated according to Ch 4, Sec 3, [2], is increased by 2 mm.

15.2 Protection of aluminium alloys structures

15.2.1 The protection of aluminium alloys structures is to be as described in NR561 Aluminium Ships, Sec 7, [11].

16 Additional requirements in relation to the additional class notations

16.1 Strengthened bottom (STRENGTHBOTTOM)

16.1.1 Application

The additional class notation **STRENGTHBOTTOM** is assigned, in accordance with NR467 Steel Ships Pt A, Ch 1, Sec 2, [6.18.1] to ships built with specially strengthened bottom structures so as to be able to be loaded and/or unloaded when properly stranded.

For steel structure, the requirements defined in NR467 Steel Ships, Pt F, Ch 15, Sec 1 are applicable.

For aluminium structure, the requirements defined in NR561 Aluminium Ships, Sec 7, [12.3] are applicable.

16.2 Ice class notation

16.2.1 General

When requested by the Owner, one of the additional class notations for ships designed for navigation in ice-infested waters, may be assigned according to NR467 Steel Ships, Pt A, Ch 1, Sec 2, [6.10.1] to [6.10.3].

16.2.2 Strengthening for ice navigation

a) Steel and aluminium structures:

   For ships assigned one of the additional class notation described in [16.2.1], the required hull strengthening is defined in NR467 Steel Ships, Part F, Chapter 8.

   The minimum yield stress for scantling criteria of hull structure reinforcements is to be taken equal to:

   - R_{eH} for steel structure
   - R_y for aluminium structure

   where R_{eH} and R_y are defined in Ch 1, Sec 2.

b) Composite structures:

   For composite structures, the additional ice class notation **YOUNG ICE 1** or **YOUNG ICE 2** may be assigned according to NR467 Steel Ships, Pt A, Ch 1, Sec 2, [6.10.2].

   Hull strengthening required for the assignment of these additional class notations is defined in NR546 Composite Ships, Sec 3.

Section 3 Helicopter Decks and Platforms

Symbols

W_H : Maximum weight of the helicopter, in t

g : Gravity acceleration taken equal to 9,81 m/s².

1 Application

1.1 General

1.1.1 The requirements of this Section apply to areas equipped for the landing and take-off of helicopters with landing gears or landing skids, and located on a deck or on a platform permanently connected to the hull structure.

1.1.2 Helicopter deck or platform intended for the landing of helicopters having landing devices other than wheels or skids are to be examined by the Society on a case-by-case basis.

1.2 Definition

1.2.1 Landing gear

A landing gear may consist of a single wheel or a group of wheels.

2 General arrangement

2.1 Landing area and approach sector

2.1.1 The main dimensions of the landing area, its location on board, the approach sector for landing and take-off are to comply with the applicable requirements from National or other Authorities.

2.1.2 The landing area and the approach sector are to be free of obstructions above the level of the helicopter deck or platform.

Note 1: The following items may exceed the height of the landing area, but not more than 100 mm:

- guttering or slightly raised kerb
- lightning equipment
- outboard edge of the safety net
- foam monitors
- those handrails and other items associated with the landing area which are incapable of complete retraction or lowering for helicopter operations.

2.2 Sheathing of the landing area

2.2.1 Within the landing area, a non-skid deck covering is recommended.

Where the helicopter deck or platform is wood sheathed, special attention is to be paid to the fire protection.

2.3 Safety net

2.3.1 It is recommended to provide a safety net at the sides of the helicopter deck or platform.

2.4 Drainage system

2.4.1 Gutterways of adequate height and a drainage system are recommended on the periphery of the helicopter deck or platform.

2.5 Deck reinforcements

2.5.1 Local deck strengthening is to be fitted at the connection of diagonals and pillars supporting platform.

3 Design loads

3.1 Emergency landing load

3.1.1 The emergency landing force F_{EL} transmitted through one landing gear or one extremity of skid to the helicopter deck or platform is to be obtained, in kN, from the following formulae:

$F_{EL} = 1,25\ g\ W_H$

The points of application of this force are to be taken so as to produce the most severe load on the supporting structure.

3.2 Garage load

3.2.1 Where a garage zone is fitted in addition to the landing area, the local forces F_W transmitted by one wheel or a group of wheels or one skid to the helicopter deck or platform are to be obtained, in kN, as specified in Ch 3, Sec 4, [4.4], where M is to be taken equal to:

- for helicopter with landing gears:

  M is the landing gear load, in t, to be specified by the Designer.

  If the landing gear load is not known, M is to be taken equal to:

  $$M = \frac{1,25}{n} W_H$$

  where n is the total number of landing gears
- for helicopter with landing skids:

  $M = 0,5\ W_H$

3.3 Specific loads for helicopter platforms

3.3.1 The forces applied to an helicopter platform are to be determined, in kN, as follows:

- in vertical direction:

  $$F_Z = (W_H + W_P)(g + a_z + 0,7\alpha_R y) + 1,2A_{HY}$$
- in transverse direction:

  $$F_Y = 0,7(W_H + W_p)a_y + 1,2A_{HY}$$
- in longitudinal direction:

  $$F_X = (W_H + W_p)a_x + 1,2A_{HX}$$

where:

W_H : Maximum weight of the helicopter, in t

W_p : Structural weight of the helicopter platform, in t, to be evenly distributed, and to be taken not less than the value obtained from the following formula:

$W_p = 0,2\ A_H$

A_H : Area, in m^2, of the entire landing area

A_{HX}, A_{HY} : Vertical areas, in m^2, of the helicopter platform in x and y directions respectively. Unless otherwise specified, A_{HX} and A_{HY} may be taken equal to $A_H / 3$

a_x : Longitudinal acceleration, in m/s^2, equal to:

$$a_x = 0,65\frac{z}{T} + 0,55$$

a_y : Transversal acceleration, in m/s^2, equal to:

$$a_y = \alpha_R(z - T)$$

a_z : Vertical acceleration, in m/s^2, as defined in Ch 3, Sec 4, [2.2]

α_R : Roll acceleration, in m/s^2, as defined in Ch 3, Sec 4, [2.1.7]

y, z : Transversal and vertical co-ordinates, in m, of the centre of gravity of the helicopter

T : Minimum draught of the ship, in m.

3.4 Local external pressures

3.4.1 Local external pressures on exposed helicopter deck and platform, and when applicable on exposed garage zone, are to be taken into account in addition to the design loads defined in [3.1], [3.2] and [3.3] and are to be calculated as defined in Ch 3, Sec 3, [2.2.2].

4 Scantlings for steel and aluminium deck and platform structure

4.1 Plating

4.1.1 Load model

The following forces P_0 are to be considered independently:

- $P_0 = F_{EL}$

  where F_{EL} is the force corresponding to the emergency landing load, as defined in [3.1.1]

- $P_0 = 1,1\ F_W$

  where F_W is the forces corresponding to the garage load, as defined in [3.2.1], if applicable.

4.1.2 Thickness of plating

The thickness of an helicopter deck or platform subjected to forces defined in [4.1.1] is not to be less than the value obtained according to formula defined for plating subjected to wheeled loads (see Ch 4, Sec 3, [2.2.4]) with:

A_T : Tyre or skid print area, in m².

For helicopter with skids in emergency landing case, only the extremity of skid of 0,3 m x 0,01 m is to be considered.

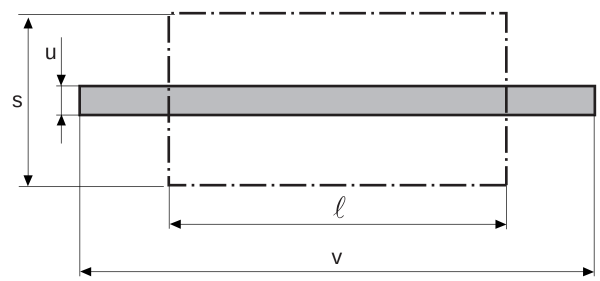
For other cases, where the print area A_T is not specified by the Designer, the following values are to be taken into account:

- for one tyre: 0,30 m x 0,30 m
- for one skid: 1,0 m x 0,01 m

4.1.3 Helicopter with skids

For helicopters with skids, in the particular case where $v > \ell$, v being equal to the skid length, the skid print outside of the plate panel is to be disregarded. In such a case, the load is to be considered as being fully distributed on the span ℓ only (see Fig 1).

Figure 1 : Skid print with v > ℓ



4.2 Ordinary stiffeners

4.2.1 Load model

The following forces P_0 are to be considered independently:

- $P_0 = F_{EL}$

  where F_{El} is the force corresponding to the emergency landing load, as defined in [3.1.1]

- $P_0 = 1,1\ F_W$

  where F_W is the forces corresponding to the garage load, as defined in [3.2.1], if applicable

- for an helicopter platform:

  $P_0 = 1,1\ F_W$

  where F_W is the forces corresponding to the garage load, as defined in [3.2.1], if applicable.

4.2.2 Normal and shear stresses

The normal stress σ and the shear stress τ induced by forces defined in [4.2.1] in an ordinary stiffener of an helicopter deck or platform are obtained, in N/mm², as follows:

$$\sigma = \frac{P_0 \ell}{mW} 10^3$$

$$\tau = \frac{10 P_0}{A_{Sh}}$$

where:

m : Coefficient to be taken equal to:
- for an helicopter with wheels: m = 6
- for an helicopter with landing skids: m = 10

4.2.3 Checking criteria

It is to be checked that the normal stress σ and the shear stress τ calculated according to [4.2.2], are in compliance with the following formulae:

$$0,95 R_y \geq \sigma$$

$$0,45 R_y \geq \tau$$

where:

R_y : Minimum yield stress, in N/mm², of the material, as defined in:
- Ch 1, Sec 2, [2.1.5] for steel structure
- Ch 1, Sec 2, [3.1.2] for aluminium structure.

4.3 Primary supporting members

4.3.1 Load model

The primary structure check is to be carried out by direct calculation, taking into account the following loads considered independently:

- emergency landing load, as defined in [3.1.1]
- garage load, as defined in [3.2.1], if applicable
- for an helicopter platform, specific loads as defined in [3.3.1].

The most unfavourable case, i.e. where the maximum number of land gears is located on the same primary supporting members, is to be considered.

4.3.2 Checking criteria

It is to be checked that the equivalent stress σ_{VM} is in compliance with the following formula:

$$\sigma_{VM} \leq 0,95 R_y$$

where:

R_y : Minimum yield stress, in N/mm², of the material, as defined in [4.2.3].

When a two- or three-dimensional beam model calculation or a finite element model calculation is carried out to check the primary structure, the permissible stresses in the primary structure are defined in Ch 2, Sec 3, [2.1.1], item b) and in Ch 2, Sec 3, [2.1.1], item c), where σ_{VMam} is to be taken equal to 0,95 R_y.

5 Scantlings for composite deck structure

5.1 Bending moments and transverse shear forces calculation for deck panel

5.1.1 Bending moments and transverse shear forces in deck panels are to be calculated taking into account the forces defined in [4.1] by direct calculation.

The panel analysis is to be carried out by a “ply by ply” analysis of the laminate taking into account the maximum stress criteria combined stress in each layer criteria as defined in NR546 Composite Ships, Sec 6, [5.1.2].

5.2 Bending moment and shear forces calculation for secondary stiffeners

5.2.1 The bending moment M, in KN.m, and the shear force T, in KN, induced by forces defined in [4.2.1] in an ordinary stiffener of an helicopter deck are obtained, in N/mm², as follows:

$$M = \frac{P_0 \ell}{m}$$

$$T = P_0$$

where:

m : Coefficient to be taken equal to:
- for an helicopter with wheels: m = 6
- for an helicopter with landing skids: m = 10

The strains and stresses induced by the bending moment and shear force in the secondary stiffener are to be calculated as defined in NR546 Composite Ships, Sec 7, [3.1].

5.3 Primary supporting members

5.3.1 The primary structure check is to be carried out by direct calculation as defined in [4.3.1].

The strains and stresses induced by the bending moment and shear force in the primary supporting members are to be calculated as defined in NR546 Composite Ships, Sec 7, [3.1].

5.4 Checking criteria

5.4.1 The structure check is to be carried out as defined in NR546 Composite Ships, for deck panels and stiffeners, taking into account the safety factors defined for local sea and internal pressures in Ch 2, Sec 3, [3.2]

Section 4 Anchoring Equipment and Shipboard Fittings for Anchoring, Mooring and Towing Equipment

1 Design assumption for anchoring equipment

1.1 General

1.1.1 The requirements of the present Section only apply to temporary anchoring of ships within a harbour or sheltered area, where the ship is awaiting for berth, tide, etc.

1.1.2 The equipment complying with these requirements is not designed to hold a ship off fully exposed coast in rough weather nor for stopping the ship which is moving or drifting. In these conditions, the loads on anchoring equipment increase to such a degree that its components can be damaged or lost.

1.1.3 For ships where frequent anchoring in open sea is expected, Owner's, shipyard's and Designer's attention is drawn to the fact that anchoring equipment should be provided in excess to the requirements of this Rules.

1.1.4 The equipment complying with the requirements in [3] is intended for holding a ship in good holding sea bottom, where the conditions are such as to avoid dragging of the anchor. In poor holding sea bottom, the holding power of the anchors is significantly reduced.

1.1.5 Anchors and chains cable components and its accessories, wire rope, etc. are to be manufactured in accordance with relevant requirements of NR216 Materials and Welding.

1.1.6 The bow anchors, connected to their own chain cables, are to be so stowed as to always be ready for use. Other arrangements of equivalent provision in security and safety may be foreseen, subjected to Society's agreement.

1.2 General case

1.2.1 The determination of the anchoring equipment, as stipulated in [2], for ships having the navigation notation **unrestricted navigation, coastal area, summer zone** or **tropical zone**, is based on the following assumptions:

- wind speed: 50 knots (25 m/s)
- current speed: 5 knots (2,5 m/s)
- minimum scope of chain cable of 6, the scope being the ratio between length of chain paid out and water depth
- the ship uses one anchor only under normal circumstances.

1.3 Specific cases

1.3.1 Ships with navigation notation sheltered area

The determination of the anchoring equipment, as stipulated in [2], for ships having the navigation notation **sheltered area** is to be based on the following assumptions:

- wind speed: 30 knots (15,5 m/s)
- current speed: 5 knots (2,5 m/s)
- minimum scope of chain cable of 6, the scope being the ratio between length of chain paid out and water depth
- the ship uses one anchor only under normal circumstances.

1.3.2 Ships with service notation seagoing launch

The determination of the anchoring equipment, as stipulated in [2], for ships having the service notation **seagoing launch** is to be based on the following assumptions:

- wind speed: 27 knots (14 m/s)
- current speed: 5 knots (2,5 m/s)
- minimum scope of chain cable of 6, the scope being the ratio between length of chain paid out and water depth
- the ship uses one anchor only under normal circumstances.

Specific arrangements are defined in Ch 6, Sec 1, [18].

1.3.3 Ships with service notation launch

The determination of the anchoring equipment, as stipulated in [2] for ships having the service notation **launch** is to be based on the following assumptions:

- wind speed: 16 knots (8,5 m/s)
- current speed: 5 knots (2,5 m/s)
- minimum scope of chain cable of 6, the scope being the ratio between length of chain paid out and water depth
- the ship uses one anchor only under normal circumstances.

Specific arrangements are defined in Ch 6, Sec 1, [18].

1.3.4 Ships with service notation ro-ro passenger ship or passenger ship

For ships having L ≤ 30 m, the service notation **ro-ro passenger ship** or **passenger ship** and a navigation notation other than **unrestricted navigation**, the determination of the anchoring equipment, as stipulated in [2], is to be based on the following assumptions:

- wind speed: 20 knots (10,5 m/s)
- current speed: 5 knots (2,5 m/s)
- minimum scope of chain cable of 6, the scope being the ratio between length of chain paid out and water depth
- the ship uses one anchor only under normal circumstances.

1.3.5 Ships with service notation tug, salvage tug or escort tug

For ships having the service notation **tug**, **salvage tug** or **escort tug** with:

L x B x T < 1000

where:

L : Rule length, in m, as defined in Ch 1, Sec 1, [4.2.1]

B : Moulded breadth, in m, as defined in Ch 1, Sec 1, [4.3.1]

T : Scantling draught, in m, as defined in Ch 1, Sec 1, [4.5.1]

the determination of the anchoring equipment, as stipulated in [2], is to be based on the following assumptions:

- wind speed: 30 knots (15,5 m/s), and
- current speed: 5 knots (2,5 m/s).

1.3.6 Fishing vessels having the navigation notation coastal area

For fishing vessels having the navigation notation **coastal area**, the determination of the anchoring equipment, based on the dynamic force F_{EN} calculated as defined in Article [2], may be reduced by 10%.

1.3.7 Ship fitted with a wind propulsion system

The force induced by wind applied on the rigging for the calculation of the equipment in chain and anchor for temporary anchoring is to be considered according to NR206, Sec 8, [5.3] taking into account the wind speed assumptions defined in the present Section.

1.3.8 Ships not covered by the present Section

For ships having the service notation **dredger**, **hopper dredger**, **hopper unit**, **split hopper dredger** or **split hopper unit**, the equipment in chain and anchor is to be as defined in Ch 6, Sec 1, [13.6].

1.3.9 Additional requirements in relation to the service notation or service feature

Additional requirements in relation to the service notation or feature assigned to the ship are to be taken into account as defined in Ch 6, Sec 1.

2 Anchoring equipment calculation

2.1 General

2.1.1 All ships are to be provided with equipment in anchors and chain cables (or cable and ropes) within the scope of classification. This equipment is determined from the dynamic forces due to wind and current acting on the ship in conditions as defined in Article [1].

2.1.2 For unmanned non-propelled units, the equipment is not required for classification purposes. The scantlings of anchors, chain cables and ropes to be fitted on board is the responsibility of the Designer.

2.2 Anchoring force calculation for monohull

2.2.1 Dynamic force F_{EN}

a) Dynamic force:

The dynamic force F_{EN} , in kN, induced by wind and current acting on monohull in anchoring condition as defined in [1.2.1] may be calculated as follows:

$F_{EN} = 2\ (F_{SLPH} + F_{SH} + F_{SS})$

where:

F_{SLPH} : Static force on wetted part of the hull due to current, as defined in [2.2.2]

F_{SH} : Static force on hull due to wind, as defined in [2.2.3]

F_{SS} : Static force on superstructures due to wind, as defined in [2.2.4].

b) Minimum value of the dynamic force:

As a rule, the dynamic force F_{EN} is to be taken greater than:

- 1,0 kN for ships having the service notation **seagoing launch** or **launch**
- 7,0 kN for ships having the service notation **tug**, **salvage tug** or **escort tug**
- 2,2 kN for ships having another service notation.

2.2.2 Static force on wetted part of hull F_{SLPH}

The theoretical static force induced by current applied on the wetted part of the hull, in kN, is defined according to the following formula:

$$F_{SLPH} = \frac{1}{2}\rho C_f S_m V_C^2 10^{-3}$$

where:

ρ : Water density, equal to 1025 kg/m^3

C_f : Coefficient equal to:

$$C_f = (1+k)\frac{0,075}{(\log R_e - 2)^2}$$

where:

R_e : Reynolds number:

$R_e = (V_C\ L_{WL})\ /\ 1,054\cdot 10^{-6}$

k : Coefficient equal to:

$$k = 0,017 + 20\frac{C_b}{L^2_{WL}\cdot T^{-0,5} B_{WL}^{-1,5}}$$

S_m : Total wetted surface of the part of the hull under draught, in m^2

The value of S_m is to be given by the Designer. When this value is not available, S_m may be taken equal to 6 $\Delta^{2/3}$

V_C : Speed of the current, in m/s, as defined in [1].

2.2.3 Static force on hull F_{SH}

The theoretical static force induced by wind applied on the upper part of the hull, in kN, is defined according to the following formula:

$$F_{SH} = \frac{1}{2}\rho(C_{hfr}S_{hfr} + 0,02 S_{hlat})V_W^2 10^{-3}$$

where:

ρ : Air density, equal to 1,22 kg/m^3

V_W : Speed of the wind, in m/s, as defined in [1]

S_{hfr} : Front surface of hull and bulwark if any, in m^2, projected on a vertical plane perpendicular to the longitudinal axis of the ship

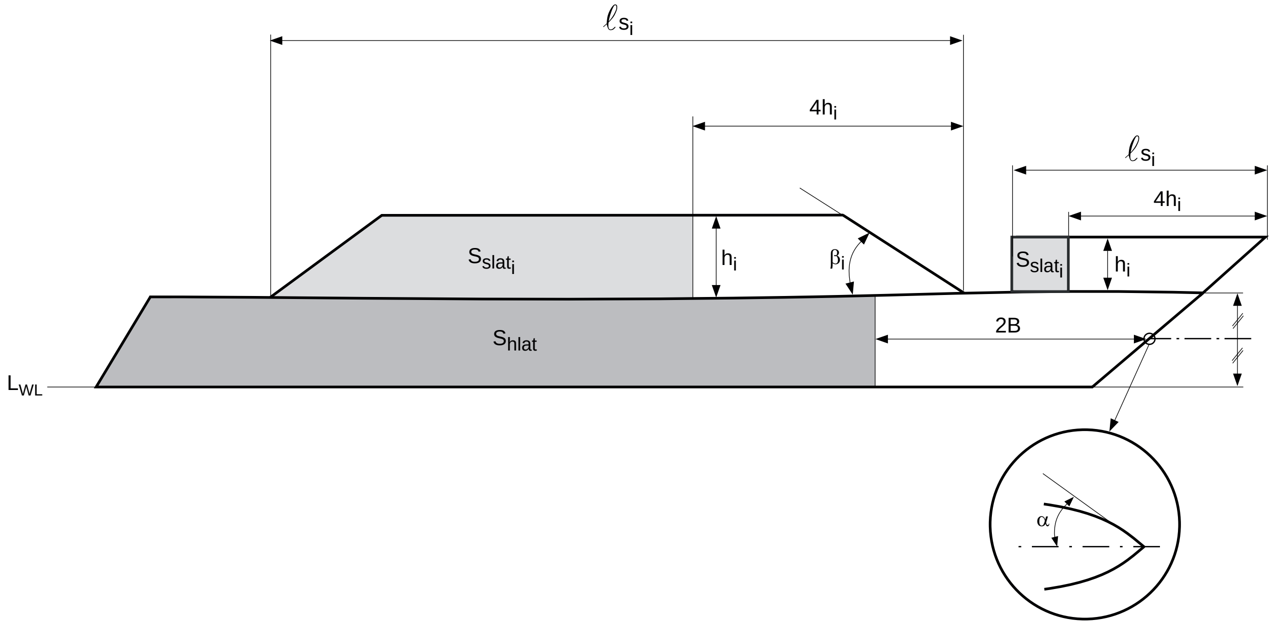
S_{hlat} : Partial lateral surface of one single side of the hull and bulwark if any, in m^2, projected on a vertical plane parallel to the longitudinal axis of the ship and delimited according to Fig 1

$C_{hfr} = 0,8 \sin\alpha$, with α defined in Fig 1.

Note 1: In Fig 1, B is the breadth of the hull, in m.

Note 2: The upper part of the hull is the part extending from side to side to the uppermost continuous deck extending over the ship length.

Figure 1 : Geometry of the upper part of the hull



2.2.4 Static forces F_{SS} on superstructures and deckhouses

a) General case:

The theoretical static force induced by wind applied on the superstructures and deckhouses, in kN, is defined as the sum of the forces applied to each superstructure and deckhouse tier according to the following formula:

$$F_{SS} = \frac{1}{2}\rho\Sigma(C_{sfr_i}S_{sfr_i} + 0,08S_{slat_i})V_W^2 10^{-3}$$

where:

ρ : Air density, equal to 1,22 kg/m³

V_W : Speed of the wind, in m/s, as defined in [1]

S_{sfri} : Front surface of tier i (superstructure or deckhouse, including bulwark if any), in m², projected on a vertical plane perpendicular to the longitudinal axis of the ship

S_{slati} : Partial lateral surface of one single side of tier i (superstructure or deckhouse, including bulwark if any), in m², projected on a vertical plane parallel to the longitudinal axis of the ship and delimited according to Fig 1.

When $4h_i \geq \ell_{si}$, S_{lati} is to be taken equal to 0

$C_{sfri} = 0,8 \sin \beta_i$, with β_i defined in Fig 1, not to be taken greater than 90°

b) Superstructures in the forward part of the ship:

Where superstructures are located in the front of the hull with front and side walls of superstructures in the continuity of the side shell, the static force induced by wind applied on these superstructures, in KN, is defined as the sum of the forces applied to each superstructure tier according to the following formula:

$$F_{SS} = \frac{1}{2}\rho\Sigma(C_{hfri}S_{hfri} + 0,08S_{slati})V_W^2 10^{-3}$$

where:

S_{hfri} : Front surface of tier i of the superstructure, in m²

C_{hfri} : $C_{hfri} = 0,8 \sin\alpha_s$, with α_s as defined for α in Fig 1 and measured at mid height of the superstructure tier located in the front of the hull

ρ, V_W, S_{slati}: As defined in [2.2.4], item a).

The static force is to be added to the static force calculated for the other superstructures and deckhouses according to [2.2.4], item a).

2.3 Anchoring force calculation for multihull

2.3.1 The dynamic force F_{EN}, in kN, induced by wind and current acting on multihull in anchoring condition as defined in [1.2.1] may be calculated as defined in [2.2] with the following particular assumptions for the calculation of the static forces on the:

- Wetted part of the hull:

F_{SLPH} : As defined in [2.2.2], taking into account the two floats for the calculation of the total wetted surface S_m

- Hull:

  F_{SH} : As defined in [2.2.3], taking into account:
  - the two floats for the calculation of S_{hfr}
  - one single side of one float for the calculation of S_{hlat} (“B” on Fig 1 is to be taken as the breadth of one float).
- Superstructure:

  F_{SS} : As defined in [2.2.4], taking also into account the frontal surface of the platform.

3 Equipment in chain and anchor

3.1 Anchors

3.1.1 Mass of individual anchor

The individual mass of anchor, in kg, is to be at least equal to:

- for ordinary anchor: $P = (F_{EN} / 7) \cdot 10^2$
- for high holding power anchor: $P = (F_{EN} / 10) \cdot 10^2$
- for very high holding power: $P = (F_{EN} / 15) \cdot 10^2$

3.1.2 Number of anchors

As a rule, the number of anchors to be provided on board is to be at least:

a) General case
- one anchor, when the dynamic force F_{EN} calculated according to [2.2] is less than 4,5 kN
- two anchors, when the dynamic force F_{EN} calculated according to [2.2] is greater than 4,5 kN

Note 1: For ships with F_{EN} between 4,5 and 9,0 kN, the second anchor may also be dispensed (except for **passenger ship** or **ro-ro passenger ship** having a navigation notation **unrestricted navigation**). In this case, the weight of the anchor and the length and size of the chain cable are to be calculated according to [3.1.1], [3.2.1] and [3.2.2], considering F_{EN} increased by one third.

b) Ships having L ≤ 30 m, the service notation **ro-ro passenger ship** or **passenger ship** and a navigation notation other than **unrestricted navigation**
- one anchor

c) Ships with service notation **seagoing launch** or **launch**

Ships with F_{EN} less than 4,7 kN are not required to carry a second anchor, except in the case of passenger launch.

For ships with F_{EN} between 4,7 kN and 9,0 kN, the second anchor may also be dispensed with, except for passenger launch. In this case, the weight of the anchor is to be increased by one third and the length and size of the chain cable are to correspond to the increased weight of the anchor according to [3.2.2].

d) Ships with service notation **tug**, **salvage tug** or **escort tug**:

A reduction of number of anchors may be accepted according to Ch 6, Sec 1, [19.4].

3.1.3 Anchor design and performance tests

Anchors are to be of an Approved Type. Therefore, Holding power - performance - assessment, Design review and Tests and examination on manufactured product are to be carried out.

Anchors are to have appropriate shape and scantlings in compliance with Society requirements. Moreover, they are to be constructed in compliance with the Society requirements.

A high or very high holding power anchor is suitable for use on board without any prior adjustment or special placement on the sea bottom.

For approval and/or acceptance as a high or very high holding power anchor, the anchor is to have a holding power equal, respectively, to at least twice or four times that of a Type Approved ordinary stockless anchor of the same mass.

Holding power is to be assessed by full-scale comparative tests.

For very high holding power anchors, the holding power test load is to be less than or equal to the proof load of the anchor, specified in NR216 Materials and Welding, Ch 10, Sec 1, [1.5.2].

Comparative tests on Type Approved Ordinary stockless anchors are to be carried out at sea and are to provide satisfactory results on various types of seabeds.

Alternatively sea trials by comparison with a previously approved HHP anchor may be accepted as a basis for approval.

Such tests are to be carried out on anchors whose masses are, as far as possible, representative of the full range of sizes proposed for the approval.

At least two anchors of different sizes are to be tested. The mass of the greatest anchor to be approved is not to be in excess of 10 times that of the maximum size tested and the mass of the smallest is to be not less than 0,1 times that of the minimum size tested.

Tests are normally to be carried out by means of a tug, but, alternatively, shore-based tests may be accepted.

The length of the chain cable connected to the tested anchor, having a diameter appropriate to its mass, is to be such that the pull acting on the shank remains practically horizontal. For this purpose a scope of chain cable equal to 10 is deemed normal; however lower values may be accepted.

Three tests are to be carried out for each anchor and type of sea bottom. Three are the types of sea bottoms in which tests are to be performed, e.g. soft mud or silt, sand or gravel and hard clay or similar compounded.

The pull is to be measured by means of a dynamometer; measurements based on the bollard pull against propeller's revolutions per minute curve may be accepted instead of dynamometer readings.

Anchor stability and its ease of dragging are to be noted down, whenever possible.

Upon satisfactory outcome of the above tests, the Society will issue a certificate declaring the compliance of high or very high holding power anchors with its relevant Rules.

3.1.4 Manufacturing, materials, test and examination

Manufacturing and materials are to comply with the relevant requirements of NR216 Materials and Welding.

Tests and examination requirements are to comply with NR216 Materials and Welding, Ch 10, Sec 1, [1.5].

3.2 Chain cables

3.2.1 Stud link chain cable scantling

Chain cable diameter, type and steel grades are to be as defined in NR216, Ch 10, Sec 2, Table 7, according to the minimum breaking load BL and proof load PL, in kN, defined according to the following formulae:

- For ships assigned the navigation notation **unrestricted navigation**:
  - for steel grade Q_1:
    $BL = 6,0\ F_{EN}$
    $PL = 0,7\ BL$
  - for steel grade Q_2:
    $BL = 6,8\ F_{EN}$
    $PL = 0,7\ BL$
  - for steel grade Q_3:
    $BL = 7,5\ F_{EN}$
    $PL = 0,7\ BL$
- For other ships:
  - for steel grade Q_1:
    $BL = 4,5\ F_{EN}$
    $PL = 0,7\ BL$
  - for steel grade Q_2:
    $BL = 5,5\ F_{EN}$
    $PL = 0,7\ BL$
  - for steel grade Q_3:
    $BL = 6,0\ F_{EN}$
    $PL = 0,7\ BL$

The chain cable scantling is to be consistent with the mass of the associated anchor. In case the anchor on board is heavier by more than 7% from the mass calculated in [3.1.1], the value of F_{EN} to take into account in the present Article for the calculation of BL and PL is to be deduced from the actual mass of the anchor according to the formulae in [3.1.1].

As a rule, the minimum diameter, in mm, corresponding to a quality Q_1 is not to be less than:

- 11 in a general case
- 7 for ships having $L \leq 30$ m, the service notation **ro-ro passenger ship** or **passenger ship** and a navigation notation other than **unrestricted navigation**.

3.2.2 Total length of chain cable

When two anchors are required to be installed on board, the total length of chain cable L_{cc}, in m, is to be determined as follows:

- If $P \geq 180$:
  L_{cc} is to be determined as required in NR467, Pt B, Ch 12, Sec 4, Tab 1 for a mass per anchor equal to P
- if $P < 180$:
  $L_{cc} = 60\ \ln(P) - 84$

where:

P : Anchor mass, in kg, defined in [3.1.1] for an ordinary anchor according to the considered case.

The minimum length of chain cable on board is to be in accordance with the water depth of anchoring as specified in [1.2.1].

When only one anchor is installed on board, L_{cc} may be reduced accordingly.

3.2.3 Chain cables arrangements

Chain cables are to be made by lengths of 27,5 m each, joined together by Dee or lugless shackles.

The total length of chain cable, required in [3.2.2], is to be divided in approximately equal parts between the two anchors ready for use.

Chain cables made of grade Q1or SL1 may not be used with high holding power and very high holding power anchors

The method of manufacture of chain cables and the characteristics of the steel used are to be approved by the Society for each manufacturer. The material from which chain cables are manufactured and the completed chain cables themselves are to be tested in accordance with the appropriate requirements.

Test and examination requirements are to comply with NR216 Materials and Welding, Ch 10, Sec 1.

3.2.4 Studless link chain cables

For ships with F_{EN} less than 18 kN, studless short link chain cables may be accepted by the Society as an alternative to stud link chain cables, provided its proof load and steel grade, as given in NR216, Ch 10, Sec 3, Tab 1, are equivalent to the stud link chain it replaces, as defined in [3.2.1].

3.3 Wire ropes and synthetic fibre ropes

3.3.1 Ships less than 40m in length

Wire ropes or synthetic fibre ropes may be used as an alternative to chain cables for both anchors on ships of less than 40m in length under the following conditions:

- The ropes are to have a length equal to 1,5 times the chain cable length as calculated in [3.2.2].
- A short length of chain cable having scantlings complying with [3.2] is to be fitted between the rope and the bow anchor. The length of this chain part is not to be less than 12,5 m or the distance from the anchor to its stowed position to the windlass, whichever is the lesser.
- Fibre ropes are to be made of polyamide or other equivalent synthetic fibres, excluding polypropylene.
- The effective breaking load P_R, in kN, of the rope is to be not less than the following value:
  - For wire rope: P_R = BL
  - For synthetic fibre rope: P_R = 1,2 BL

  where:

  BL : Required breaking load, in kN, of the replaced chain cable, as defined in [3.2.1].

3.3.2 Specific anchoring conditions

Wire ropes may be used as an alternative to chain cables on the following ships:

- ship which will need anchor for emergency purposes only. These ships, not intended to use their anchor in normal temporary anchoring operation, may typically include ships designed for the following types of operations:
  - fishing boats
  - small workboats
  - research vessels
  - dive boats
  - survey vessels
  - tugs intended for towing service only.
- ships using their anchoring equipment for positioning with a minimum of 4 points anchoring, e.g., cable or pipe laying ships.

The use of wire cable is subject to the following conditions:

- the length of the wire rope is to be 1,5 times the required chain cable total length, and its strength is to be equal to that required for a chain cable of grade Q1
- the anchor weight is to be increased by 25% compared to anchor associated with a chain cable complying with NR216, Ch 10, Sec 2, Tab 7
- a short length of chain cable is to be fitted between the wire rope and anchor having a length of 12,5 m or the distance between anchor in stowed position and winch, whichever is less
- a minimum mass per unit length of 30% of the required grade Q2 chain cable
- all surfaces being in contact with the wire are to be rounded with a radius of not less than 10 times the wire rope diameter (including stem)
- steel wire is to be selected to be fit for purpose based on the manufacturer recommendation and is to be provided with guidance for maintenance and inspection.

3.3.3 For ships with service notation **tug**, **salvage tug** or **escort tug**, see Ch 6, Sec 1, [19.4].

3.4 Attachment pieces

3.4.1 Both attachment pieces and connection fittings for chain cables are to be designed and constructed in such way as to offer the same strength as the chain cable and are to be tested in accordance with the appropriate requirements.

4 Shipboard fittings for anchoring equipment

4.1 General

4.1.1 Chain breaking load value

In the present Article, the value of the breaking load of the chain to be considered for the determination of the brake capacity of the windlass, the pull capacity of the chain stopper and the scantling of deck reinforcements is to be taken equal to the breaking load of the chain actually provided on board.

4.1.2 The design, construction and testing of windlasses and chain stopper are to comply with NR626 Anchor Windlass and Chain Stoppers.

4.2 Windlass

4.2.1 General

Windlasses used for handling anchors and suitable for the sizes of chain cables are to be fitted on board the ship.

Considering the windlass brake capacity defined in [4.2.2], the anchor windlass is to comply with the applicable requirements given in NR626 Anchor Windlass and Chain Stopper.

4.2.2 Brake capacity

Based on mooring line arrangements with brakes engaged and cable lifter disengaged, the capacity HL (Holding Load), in kN, of the windlass brake is to be sufficient to withstand the following design loads without any permanent deformation of the stressed parts and without brake slip:

- 0,8 time the breaking load of the chain if not combined with a chain stopper
- 0,45 time the breaking load of the chain if combined with a chain stopper.

4.3 Chain stopper

4.3.1 A chain stopper is generally to be fitted between the windlass and the hawse pipe in order to relieve the windlass of the pull of the chain cable when the ship is at anchor. The chain stopper is to comply with applicable requirements given in NR626. As a rule, the chain stopper is to be able to withstand a pull of 80% of the breaking load of the chain, without any permanent deformation of the stressed parts.

Chain tensioners or lashing devices supporting the weight of the anchor where housed in the anchor pocket are not to be considered as chain stoppers.

4.4 Deck reinforcements

4.4.1 Deck reinforcement under windlass and chain stopper

Local reinforcement of deck structure are to be provided in way of windlass and chain stopper, and designed in accordance with NR626, Sec 1, [6] for steel and aluminium structure.

For composite materials structure, local reinforcement structure are to be designed in accordance with NR626, taking into account the safety coefficient SF and SF_{CS} defined in Ch 2, Sec 3, [3.2.3].

4.5 Chain locker

4.5.1 The chain locker is to be of a capacity adequate to stow all chain cable equipment and provide an easy direct lead to the windlass.

Where two anchor lines are fitted, the port and starboard chain cables are to be separated by a bulkhead in the locker.

The inboard ends of chain cables are to be secured to the structure by a fastening able to withstand a force not less than 15% of the breaking load of the chain cable.

In an emergency, the attachments are to be easily released from outside the chain locker.

Where the chain locker is arranged aft of the collision bulkhead, its boundary bulkheads are to be watertight and a drainage system provided.

5 Shipboard fittings for towing and mooring

5.1 General

5.1.1 Shipboard fittings used for mooring and towing are to comply with the requirements in NR467 Steel Ships, Pt B, Ch 12, Sec 4, [4], considering design loads based on an equivalent Equipment Number EN to be taken equal to 4,7 times the value of F_{EN} as calculated in [2.2.1] with a side project area S_{hlat} including deck cargoes.

5.1.2 Ships fitted with wind propulsion system

The force induced by wind applied on the rigging for the calculation of the equipment for towing and mooring is to be considered according to NR206 Sec 8, [5.3] taking into account the wind speed assumptions defined in the present Section.

5.1.3 Documents to be submitted

Maximum safe working loads of equipment used for the mooring and the towing are to be specified.

A mooring and towing arrangement plan is to be submitted to the Society for information. This plan is to define the method of use the mooring and towing lines and to include the equipment location on the deck, the fitting type, the safe working loads and the manner of applying mooring and towing lines (including line angles).

When the mooring plan is not available, the equipment such as bitts and bollards (when the line may come and go from the same direction) are to be loaded up to twice their safe working loads.

CHAPTER 6
ADDITIONAL REQUIREMENTS IN RELATION TO THE SERVICE NOTATION OR SERVICE FEATURE ASSIGNED TO THE SHIP

Section 1 Additional Requirements in Relation to the Service Notation or Service Feature Assigned to the Ship

Symbols

L_{WL} : Ship's length at waterline, in m

L : Reference ship's length, to be taken equal to L_{WL}

k : Material factor as defined in Ch 1, Sec 2

s : Length, in m, of the shorter side of the plate panel or spacing, in m, of secondary stiffeners, or spacing, in m, of primary supporting members, as applicable.

1 General

1.1 Service notations and service features

1.1.1 Definition

The service notations define the type and/or service of the ship which is considered for its classification.

A service notation may be completed by one or more additional service features giving further precision regarding the type of service of the ship.

The service notation and the additional service features are defined in NR467 Steel Ships, Pt A, Ch 1, Sec 2, [4].

1.1.2 Application and additional requirements

The present Section defines the hull arrangement and hull structure requirements to be considered in relation to the service notation or service feature assigned to the ship and to be applied in addition to the other requirements of the present Rules.

When specified in the present Section, requirements defined in NR467 Steel Ships, Part D or Part E are to be considered for the hull arrangement and hull structure.

For information, requirements defined in NR467 Steel Ships, Part D or Part E may be also required for stability, machinery and electrical installations and fire protection.

Cross references between the present Section and NR467 Steel Ships are given in Tab 1 for information.

1.1.3 Documentation to be submitted

The plans and documents to be submitted to the Society in relation to the service notation or service feature considered are listed in the Chapters of NR467 Steel Ships, Part D or Part E as given in Tab 1.

Table 1 : List of articles in relation to the service notation or additional service feature

Ship type with service notations or service features	Reference of Article	Reference in NR467 Steel Ships	Ship type with service notation or service features	Reference of Article	Reference in NR467 Steel Ships
Ro-ro cargo ships and pure car and/or truck carriers	[2]	Part D, Chapter 1	Offshore patrol vessels	[16]	Part D, Chapter 16
Container ships	[3]	Part D, Chapter 2	Launch and seagoing launch	[18]	–
Livestock carriers	[4]	Part D, Chapter 3	Tugs	[19]	Part E, Chapter 1
Bulk carriers	[5]	Part D, Chapter 4	Anchor handling vessels	[20]	Part E, Chapter 2
Ore carriers	[6]	Part D, Chapter 5	Supply vessels	[21]	Part E, Chapter 3
Combination carriers	[7]	Part D, Chapter 6	Fire-fighting ships	[22]	Part E, Chapter 4
Oil tankers and FLS tankers	[8]	Part D, Chapter 7	Oil recovery ships	[23]	Part E, Chapter 5
Chemical tankers	[9]	Part D, Chapter 8	Cable-laying ships	[24]	Part E, Chapter 6
Tankers	[10]	Part D, Chapter 10	Diving support vessels	[25]	Part E, Chapter 7
Passenger ships	[11]	Part D, Chapter 11	Lifting units	[26]	Part E, Chapter 8
Ro-ro passenger ships	[12]	Part D, Chapter 12	Semi-submersible cargo ships	[27]	Part E, Chapter 9
Ships for dredging activity	[13]	Part D, Chapter 13	Standby rescue vessels	[28]	Part E, Chapter 10
Non-propelled units	[14]	Part D, Chapter 14	Accommodation units	[29]	Part E, Chapter 11
Fishing vessels	[15]	Part D, Chapter 15	Pipe-laying units	[30]	Part E, Chapter 12

1.1.4 Ship types not covered by the present Rules

Ship types not covered by the present Rules are defined in Ch 1, Sec 1, [1.2].

2 Ro-ro cargo ships and pure car and/or truck carriers

2.1 Application

2.1.1 The requirements of this Article apply to ships having the service notation **ro-ro cargo ship**, **PCTC** or **PCC** intended for the carriage of:

- vehicles which embark and disembark on their own wheels, and/or goods in or on pallets or containers which can be loaded and unloaded by means of wheeled vehicles
- railway cars, on fixed rails, which embark and disembark on their own wheels.

2.2 Documents to be submitted

2.2.1 In addition to the documentation requested in Ch 1, Sec 1, [7], the following documents are to be submitted:

- operating and maintenance manual of bow, side and stern doors and ramps
- plan of design loads on deck
- plan of arrangement of motor vehicles, railway cars and/or other types of vehicles which are intended to be carried, indicating securing and load bearing arrangements
- characteristics of motor vehicles, railways cars and/or other types of vehicles which are intended to be carried: (as applicable) axle load, axle spacing, number of wheels per axle, wheel spacing, size of tyre print.

2.3 General

2.3.1 Wood sheathing

Wood sheathing is recommended for caterpillar trucks and unusual vehicles.

2.3.2 Global transverse strength

When deemed necessary by the Society, the behaviour of the ship primary structural members under racking effect due to transverse forces induced by transverse accelerations is to be investigated by direct calculation on a case by case basis.

2.4 Hull scantlings for steel structure

2.4.1 Plating

As a rule, the thickness of the weather strength deck and trunk deck plating is to be not less than the values obtained, in mm, from the following formula:

$t = 3,6 + 0,013\ L_{WL} + 4,5\ s$

where:

s : Length, in m, of the shorter side of the plate panel.

2.5 Bow doors

2.5.1 Application

The requirements of this Article apply to the arrangement, strength and securing of bow doors and inner doors leading to a complete or long forward enclosed superstructure or to a long non-enclosed superstructure, where fitted to attain minimum bow height equivalence.

The requirements apply to ships assigned with the service notation **ro-ro cargo ship**, **PCTC**, **PCC** or **ro-ro passenger ship** engaged on international voyages and also to ships engaged only in domestic (non international) voyages, except where specifically indicated otherwise in this Article.

2.5.2 Type of bow doors

The type of bow door considered in the present article are:

- visor doors opened by rotating upwards and outwards about an horizontal axis through two or more hinges located near the top of the door and connected to the primary supporting members of the door by longitudinally arranged lifting arms
- side-opening doors opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the ship. It is anticipated that side-opening bow doors are arranged in pairs.

Other types of bow door are considered by the Society on a case by case basis in association with the applicable requirements of this Section.

2.5.3 Scantling and arrangement

The scantling of the plating and the secondary stiffeners of bow doors and inner doors fitted as part of the collision bulkhead are to be checked as defined in Chapter 4 for the fore part of the hull.

2.5.4 Primary supporting members, securing and supporting devices

The primary supporting members, securing and supporting devices of bow doors and inner doors fitted as part of the collision bulkhead are to be checked according to the following design loads:

- For bow door: greater value between loads defined in Ch 3, Sec 3, [2.2.1] and in NR467 Steel Ships, Pt B, Ch 11, Sec 8 [2.1]
- For inner door: loads defined in NR467 Steel Ships, Pt B, Ch 11, Sec 6 [2.2].

Scantlings of primary supporting members of bow doors and inner doors fitted as part of the collision bulkhead are generally to be checked through direct calculations taking into account:

a) Steel structure:

Scantling criteria defined in NR467 Steel Ships, Pt B, Ch 11, Sec 6 [3.3] and [4].

b) Aluminium structure:

For structures built in aluminium alloys, it is to be checked that the normal stresses σ, the shear stress τ and the equivalent stress σ_{VM} , induced in the primary supporting members and in the securing and supporting devices of bow doors are in compliance with the following conditions:

$\sigma \leq \sigma_{ALL}$

$\tau \leq \tau_{ALL}$

$\sigma_{VM} = (\sigma^2 + 3\ \tau^2)^{0,5} \leq \sigma_{VM,ALL}$

where:

σ_{ALL} : Allowable normal stress, in N/mm², equal to:

$\sigma_{ALL} = 50 / k$

τ_{ALL} : Allowable shear stress, in N/mm², equal to:

$\tau_{ALL} = 35 / k$

$\sigma_{VM,ALL}$: Allowable equivalent stress, in N/mm², equal to:

$\sigma_{VM,ALL} = 65 / k$

c) Composite structure:

For composite structure, it is to be checked that the scantling criteria defined in Ch 2, Sec 3, [3.2.1] are fulfilled, where the Rules safety factors SF and SF_{CS} are to be increased by 60%.

2.5.5 Securing and locking arrangement

The securing and locking arrangement of bow doors and inner doors fitted as part of the collision bulkhead are to be as defined in NR467 Steel Ships, Pt B, Ch 11, Sec 6, [5] to [7].

2.5.6 0perating and maintenance manual

An Operating and Maintenance Manual for the bow door and inner door is to be provided on board and is to contain the necessary information defined in NR467 Steel Ships, Pt B, Ch 11, Sec 6, [8].

2.6 Side doors and stern doors

2.6.1 Application

The requirements of this Article apply to the arrangement, strength and securing of side doors located abaft the collision bulkhead, and of stern doors leading to enclosed spaces.

The requirements apply to ships assigned with the service notation **ro-ro cargo ship**, **PCTC**, **PCC** or **ro-ro passenger ship** engaged on international voyages and also in domestic (non-international) voyages, except where specifically indicated otherwise in this article.

2.6.2 Arrangement

Side doors and stern door arrangements are to be as defined in NR467 Steel Ships, Pt B, Ch 11, Sec 7 [1.3].

2.6.3 Scantling

The scantling of the plating and the secondary stiffeners of the side doors and stern doors are to be checked as defined in Chapter 4 for side hull.

Where doors also serve as vehicle ramps, the thickness of the door plating and the scantling of the secondary stiffeners are to be as defined in Chapter 4 under wheeled loads.

The primary supporting members are to be checked according to:

- NR467 Steel Ships, Pt B, Ch 11, Sec 7, [2.1.1] for design external forces
- NR467 Steel Ships, Pt B, Ch 11, Sec 7, [5] for strength criteria.

For aluminium alloy or composite structure, the primary supporting members are to be checked according criteria defined in [2.5.4] b) and c) respectively.

2.6.4 Securing, supporting of doors and locking arrangement

Securing, supporting of doors and locking arrangement are to be as defined in NR467 Steel Ships, Pt B, Ch 11, Sec 7, [4] and [6].

2.6.5 Operating and maintenance manual

An Operating and Maintenance Manual for the side doors and stern doors is to be provided on board and is to contain the necessary information defined in NR467 Steel Ships, Pt B, Ch 11, Sec 7, [7].

3 Container ships

3.1 Application

3.1.1 Ships having the service notation **container ship** and ships assigned with the additional service feature **equipped for carriage of containers** are to comply with the requirements of the present Article.

3.1.2 The additional requirements of this Article apply to container ships intended to carry containers in holds and/or on deck.

3.2 Structure design principles

3.2.1 General strength principles

General requirements defined in NR467 Steel Ships, Pt D, Ch 2, Sec 2 [3.1] and [3.2] are to be considered.

Local reinforcements of the hull structure are to be provided under container corners and in way of fixed cargo securing devices and cell guides, if fitted.

The forces applying on the fixed cargo securing devices are to be indicated by the Designer. When one of the additional class notations **LASHING** or **LASHING-RSSA( )** is granted, these forces may be determined by the Society.

3.2.2 Structural continuity

On double hull ships, where the machinery space is located between two holds, the inner side is, in general, to be continuous within the machinery space. Where the machinery space is situated aft, the inner hull is to extend as far abaft as possible and be tapered at the ends.

3.2.3 Bottom structure

a) Floor and girder spacing:

   The floor spacing is to be such that floors are located in way of the container corners. Floors are also to be fitted in way of watertight bulkheads.

   Girders are generally to be fitted in way of container corners.

b) Reinforcement in way of cell guides:

   The structure of the bottom and inner bottom on which cell guides rest is to be adequately stiffened with doublers, brackets or other equivalent reinforcements.

3.2.4 Deck structure

a) Longitudinal girders between hatchways:

   The width of the longitudinal deck girders and hatch coaming flanges is to be such as to accommodate the hatch covers and their securing arrangements.

   The connections of the longitudinal deck girders and hatch coamings with the machinery space structure, and aft and fore part structures are to ensure proper transmission of stresses from the girders to the adjacent structures.

b) Cross decks:

   Cross decks between hatches are subject to a shear force in the longitudinal direction induced by the overall torsion of the ship. The adequate strength of these deck strips is to be checked in that respect.

   Cross decks between hatches are to be suitably overlapped at ends.

c) Deck and hatch cover reinforcements:

   Deck or hatch cover structures are to be reinforced taking into account the loads transmitted by the corners of containers and cell guides.

3.2.5 Bulkhead structure

a) Transverse box structures in way of transverse watertight bulkheads:

   Bottom and top transverse box structures are generally to be provided in way of transverse watertight bulkheads at the inner bottom and deck level, respectively.

b) Primary supporting members:

The vertical primary supporting members of transverse watertight bulkheads are to be fitted in line with the deck girders and the corresponding bottom girders.

c) Reinforcements in way of cell guide:

When cell guides are fitted on transverse or longitudinal bulkheads which form boundaries of the hold, such structures are to be adequately reinforced taking into account the loads transmitted by cell guides.

3.3 Design loads

3.3.1 Forces on containers

a) Still and inertial forces:

The vertical forces $F_{Z,i}$ and transversal forces $F_{T,i}$, in kN, applied to the containers at each level “i” of a stack are to be calculated as defined in Ch 3, Sec 4, [3.3.3] for the dry unit cargo where M, in t, is to be taken as the mass of the container.

Where empty containers are stowed at the top of a stack, the forces are to be calculated considering weight of empty containers equal to:

- 0,14 times the weight of a loaded container, in the case of steel containers
- 0,08 times the weight of a loaded container, in the case of aluminium containers.

b) Wind forces:

The forces $F_{y,wind,i,}$ in y direction applied to one container stowed above deck at the level “i” due to the effect of the wind is to be obtained, in kN, from the following formula:

$F_{y,wind,i} = 1,2\ h_C\ \ell_C$

where:

h_C : Height, in m, of a container

ℓ_C, : Dimension, in m, of the container stack in the ship longitudinal direction.

c) Reaction at the corners of stacks of containers:

The reaction at the corner of stack are to be calculated in the two following conditions of navigation:

- ship in upright condition (see Fig 1)
- ship in inclined condition (see Fig 2).

The forces to be considered as being applied at the centre of gravity of the stack, the reactions at the corners of stack are to be obtained, in kN, as specified by the following formulae:

- in upright condition:

$$R_{W,1} = R_{W,2} = \frac{F_{W,Z}}{4}$$

- in inclined condition:

$$R_{W,1} = \frac{F_{W,Z}}{4} + \frac{N h_C F_{W,Y}}{4 b_C}$$

$$R_{W,2} = \frac{F_{W,Z}}{4} - \frac{N h_C F_{W,Y}}{4 b_C}$$

where:

$F_{W,Z}$: Vertical force in a stack, in kN:

$$F_{W,Z} = \sum_{i=1}^{i=N} F_{Z,i}$$

$F_{W,Y}$: Horizontal force in a stack, in kN:

$$F_{W,Y} = \sum_{i=1}^{i=N} (F_{T,i} + F_{Y,wind,i})$$

$F_{Z,i}$, $F_{T,i}$: Vertical and transversal forces, in kN, as defined in item a)

N : Number of container per stack.

Figure 1 : Corner reactions in upright condition of navigation

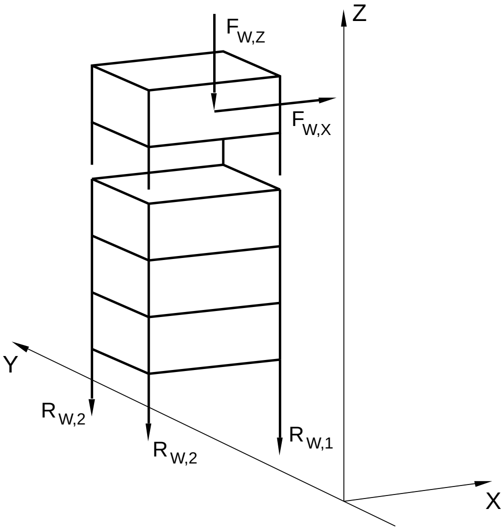
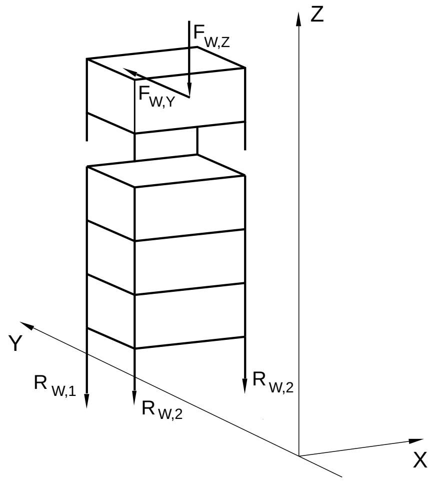


Figure 2 : Corner reactions in inclined condition of navigation



3.4 Structural strength analysis

3.4.1 Hull girder scantling

For container ships carrying containers in holds, the hull girder strength under still and wave torsional moments is to be examined on a case by case basis.

3.4.2 Specific structural elements

Specific structural elements such as fixed cell guides, lashing bridge,... are to be examined on a case by cases on the basis of the general requirements defined in NR467 Steel Ships, Pt D, Ch 2, Sec 2.

4 Livestock carriers

4.1 Application

4.1.1 Ships having the service notation **livestock carrier** are to comply with the requirements of the present Article.

4.2 General arrangement

4.2.1 General arrangement is to be as defined in NR467 Steel Ships, Pt D, Ch 3, Sec 2, [2].

4.3 Local loads

4.3.1 Cargo deck

The static pressure, in kN/m², due to livestock on decks to be considered for the assessment of plating and secondary stiffeners is to be defined by the Designer.

When no value is specified, the following may be considered:

- 15 kN/m² for cattle, horses and camels
- 8 kN/m² for sheep, goats and pigs.

For the assessment of primary supporting members, the static pressure is to be taken equal to 0,3 times the value defined above for plating and secondary stiffeners.

4.4 Hull girder strength and hull scantlings

4.4.1 Hull girder strength

In general, the decks and platform decks above the strength deck used for the carriage of livestock may not be taken into account for the calculation of the section modulus.

4.4.2 Global transverse strength

When deemed necessary by the Society, the behaviour of the ship primary structural members under racking effect due to transverse forces induced by transverse accelerations is to be investigated by direct calculation on a case by case basis.

4.4.3 Movable or collapsible structural elements above the strength deck

In general, the movable or collapsible structural elements above the strength deck used for the stocking and the distribution of livestock on decks or platform decks are not a part of ship classification.

Nevertheless, where deemed necessary by the shipyard they may be designed and constructed according to the criteria in Chapter 4.

5 Bulk carriers

5.1 Application

5.1.1 Ships having one of the service notations **bulk carrier ESP** or **bulk carrier** are to comply with the requirements of the present Article.

5.2 Ship arrangement

5.2.1 Specific ship arrangement is to comply with requirements defined in NR467 Steel Ships, Pt D, Ch 4, Sec 2.

5.3 Structure design principles

5.3.1 Structure design principles defined in NR467 Steel Ships, Pt D, Ch 4, Sec 3, [2], are applicable.

5.4 Design loads

5.4.1 Loading conditions for longitudinal strength assessment

In addition to the loading conditions specified in Ch3, the homogeneous cargo loaded conditions defined in NR467, Pt D, Ch 4, Sec 3 [3.1.2] and ballast conditions defined in NR467, Pt D, Ch 4, Sec 3 [3.1.1], item b) and item c) are to be taken into account.

5.4.2 Additional requirements on local loads for ships with the additional service feature heavycargo

For ships having the additional service feature **heavycargo [AREA1, X1 kN/m² -AREA2, X2 kN/m² -...]** as defined in NR467 Steel Ships, Part A, Ch 1, Sec 2, [4.16], the values of p_{DB} used to calculate the dry uniform cargo as defined in Ch 3, Sec 4, [3.3.2], in kN/m², are to be specified by the Designer for each AREAi, and introduced as Xi values in the above service feature.

5.4.3 Loading conditions for primary structure analysis

The following loading conditions are to be considered in the analysis of the primary structure:

- homogeneous loading and corresponding draught T
- heavy ballast (the ballast hold being full) and corresponding draught T.

5.5 Hull scantlings for steel structure

5.5.1 Plating

As a rule, the thickness of the side plating located between hopper and topside tanks, in mm, is to be not less than:

$$t_{MIN} = L_{WL}^{0,5} + 2$$

5.5.2 Secondary stiffeners

As a rule, the thicknesses of side frames and their brackets, in way of cargo holds, are to be not less than the values given in Tab 2.

Table 2 : Minimum thickness of side frames and brackets

Item	Minimum thickness, in mm
Side frame webs	$C_L (7,0 + 0,03\ L_{WL}) + 1,75$
Lower end bracket	The greater of the following: • $C_L (7,0 + 0,03\ L_{WL}) + 3,75$ • as fitted thickness of side frame web
Upper end bracket	The greater of the following: • $C_L (7,0 + 0,03\ L_{WL}) + 1,75$ • as fitted thickness of side frame web
Note 1: C_L : Coefficient equal to: • 1,15 for side frames in way of the foremost cargo hold • 1 for side frames in way of the other cargo holds.	

5.5.3 Scantlings of side frames abaft to the collision bulkhead

The scantlings of the three side frames immediately abaft the collision bulkhead are to be increased by 25% with respect to those determined according to Chapter 4, in order to prevent excessive imposed deformation on the side shell plating.

As an alternative, supporting structures, such as horizontal stringers, are to be fitted between the collision bulkhead and a side frame which is in line with transverse webs fitted in both the topside tank and hopper tank, maintaining the continuity of the forepeak stringers within the foremost hold.

5.6 Hatch covers

5.6.1 Steel large hatch covers are to be as defined in NR467 Steel Ships, Pt B, Ch 11, Sec 9.

5.7 Protection of hull metallic structure

5.7.1 Protection of cargo hold is to be as defined in NR467 Steel Ships, Pt D, Ch 4, Sec 3, [7].

5.8 Construction and testing

5.8.1 Welding and weld connections

The weld factors for some hull structural connections are specified in NR467, Pt D, Ch 4, Sec 3, Tab 2. These weld factors are to be used in lieu of the corresponding factors specified in Ch 7, Sec 2 to calculate the leg length of fillet weld T connections.

For the connections defined in NR467, Pt D, Ch 4, Sec 3 Tab 2, continuous fillet welding is to be adopted.

6 Ore carriers

6.1 Application

6.1.1 Ships having the service notation **ore carrier** are to comply with the requirements of the present Article.

6.2 Ship arrangement

6.2.1 Specific ship arrangement is to comply with the requirements defined in NR467 Steel Ships, Pt D, Ch 5, Sec 2.

6.3 Structure design principles

6.3.1 Structure design principle defined in NR467 Steel Ships, Pt D, Ch 5, Sec 3, [3] are applicable.

6.4 Design loads

6.4.1 Loading conditions for longitudinal strength assessment

In addition to the requirements of Chapter 3, the homogeneous loading conditions and ballast conditions, subdivided into departure and arrival conditions, defined in NR467 Steel Ships, Pt D, Ch 5, Sec 3, [4.1.1] are applicable for hull girder and primary structure analysis according to the present Rules.

6.5 Hull scantlings for steel structure

6.5.1 Minimum thickness of the inner bottom plating in holds

As a rule, the minimum thickness, in mm, of the inner bottom plating in holds is not to be less than:

- longitudinal framing: $t_{MIN} = 2,15\ (L_{WL}^{1/3}\ k^{1/6}) + 4,5\ s + 2$
- transverse framing: $t_{MIN} = 2,35\ (L_{WL}^{1/3}\ k^{1/6}) + 4,5\ s + 2$

where:

s : Length, in m, of the shorter side of the plate panel.

6.5.2 Strength checks of cross-ties

a) General:

Cross-ties analysis is to take into account tensile and compressive axial forces as well as bending moments around the neutral axis perpendicular to the cross-tie web.

b) Three dimensional beam analysis:

The three dimensional beam analysis is to be carried out as defined in Ch 4, Sec 5, [1.2.2] taking into account the permissible stresses defined in Ch 2, Sec 3, [2.1.2].

c) Finite element analysis:

The finite element analysis is to be carried out as defined in Ch 4, Sec 5, [1.3] taking into account the permissible stresses defined in Ch 2, Sec 3, [2.1.2] and Ch 2, Sec 3, [2.2].

6.6 Hatch covers

6.6.1 Steel large hatch covers are to be as defined in NR467 Steel Ships, Pt B, Ch 11, Sec 9.

6.7 Construction and testing

6.7.1 The weld factors for some hull structural connections are specified in NR467, Pt D, Ch 5, Sec 3, Tab 2. These weld factors are to be used in lieu of the corresponding factors specified in Ch 7, Sec 2 to calculate the leg length of fillet weld T connections.

For the connections defined in NR467, Pt D, Ch 4, Sec 3, Tab 2, continuous fillet welding is to be adopted.

7 Combination carriers

7.1 Application

7.1.1 Ships having the service notation **combination carrier** are to comply with the requirements of the present Article.

7.2 Ship arrangement

7.2.1 Specific ship arrangement is to comply with the requirements defined in NR467 Steel Ships, Pt D, Ch 6, Sec 2.

7.3 Structure design principles

7.3.1 As far as practicable, structure design principles are to be examined on the basis of the requirements defined in NR467 Steel Ships, Pt D, Ch 6, Sec 3, [3] and Pt D, Ch 6, Sec 3, [4] for ships having the service notation **combination carrier/OBO ESP** and **combination carrier/OOC ESP** respectively.

7.4 Design loads

7.4.1 Application

In addition to the requirements of Chapter 3, the loading conditions, subdivided into departure and arrival conditions, defined in NR467 Steel Ships, Pt D, Ch 6, Sec 3, [5.1.1] are applicable.

7.4.2 Oil cargo mass density

In the absence of more precise values, an oil cargo mass density of 0,9 t/m^3 is to be considered for calculating the internal pressures and forces in cargo tanks according to Ch 3, Sec 4.

7.5 Hull scantlings for steel structure

7.5.1 Plating

As a rule, the thickness of the plating of the inner bottom in holds intended to carry ore, of the strength deck and of bulkheads is to be not less than the values given in Tab 3.

Table 3 : Minimum plating thickness

Plating	Minimum thickness, in mm
Strength deck	$(5,5 + 0,02\ L_{WL})\ k^{1/2} + 1,5$
Inner bottom in holds intended to carry ore	$2,15\ (L_{WL}^{1/3}\ k^{1/6}) + 4,5\ s + 2$
Tank bulkhead	$L_{WL}^{1/3}\ k^{1/6} + 4,5\ s + 2$
Watertight bulkhead	$0,85\ L_{WL}^{1/3}\ k^{1/6} + 4,5\ s + 1$
Note 1: s : Length, in m, of the shorter side of the plate panel	

7.5.2 Secondary stiffeners

As a rule, the thickness of the web of secondary stiffeners is to be not less than the value obtained, in mm, from the following formula:

$t_{MIN} = 0,75\ L_{WL}^{1/3}\ k^{1/6} + 4,5\ s + 3$

where s is the spacing, in m, of secondary stiffeners.

7.5.3 Primary stiffeners

As a rule, the minimum thickness of plating which forms the webs of primary supporting members is to be not less than the value obtained, in mm, from the following formula:

$t_{MIN} = 1,45\ L_{WL}^{1/3}\ k^{1/6} + 3$

7.5.4 Strength checks of cross-ties

Cross-tie analysis is to be carried out as defined in [6.5.2].

7.5.5 Strength check with respect to stresses due to the temperature gradient

Direct calculations of stresses induced in the hull structures by the temperature gradient are to be performed for ships intended to carry cargoes at temperatures exceeding 90°C. In these calculations, the water temperature is to be assumed equal to 0°C according to NR467, Pt D, Ch 6, Sec 3 [6].

7.6 Other structures

7.6.1 Machinery space and opening arrangement are to be in accordance with the requirements of NR467 Steel Ships, Pt D, Ch 6, Sec 3, [7].

7.6.2 Steel large hatch covers are to be as defined in NR467 Steel Ships, Pt B, Ch 11, Sec 9.

7.7 Protection of hull metallic structures

7.7.1 Requirements of NR467 Steel Ships, Pt D, Ch 6, Sec 3, [9] are applicable.

7.8 Cathodic protection of tanks

7.8.1 Requirements of NR467 Steel Ships, Pt D, Ch 6, Sec 3, [10] are applicable.

7.9 Construction and testing

7.9.1 Requirements of NR467 Steel Ships, Pt D, Ch 6, Sec 3, [11] are applicable.

In these requirements, references to NR467, Part B are to be replaced by the equivalent requirements defined in the present Rules.

8 Oil tankers and FLS tankers

8.1 Application

8.1.1 Ships having the service notation **oil tanker** are to comply with the requirements of the present Article, taking into account the general requirements defined in NR467 Steel Ships, Pt D, Ch 7, Sec 1.

8.1.2 The liquid cargoes which are allowed to be carried by ships having the service notation **oil tanker** are specified in NR467 Steel Ships, Pt D, Ch 7, App 3.

8.2 Ship arrangement

8.2.1 Specific ship arrangement is to comply with the requirements defined in NR467 Steel Ships, Pt D, Ch 7, Sec 2.

8.3 Design loads

8.3.1 Application

In addition to the requirements of Chapter 3, the hull girder load conditions, subdivided into departure and arrival conditions, defined in NR467 Steel Ships, Pt D, Ch 7, Sec 3, [4.1.1] are applicable.

8.3.2 Cargo mass density

In the absence of more precise values, a cargo mass density of 0,9 t/m^3 is to be considered for calculating the internal pressures and forces in cargo tanks according to Ch 3, Sec 4.

8.3.3 Partial filling

The carriage of cargoes with a mass density above the one considered for the design of the cargo tanks may be allowed with partly filled tanks under the conditions stated in the NR467 Steel Ships, Pt B, Ch 5, Sec 6, [2]. The classification certificate or the annex to this certificate is to mention these conditions of carriage.

8.3.4 Overpressure due to cargo filling operations

For ships having the additional service feature **asphalt carrier**, the overpressure which may occurred under loading/ unloading operations are to be considered, if any. In such a case, the diagram of the pressures in loading/unloading conditions is to be given by the Designer.

8.4 Hull scantlings for steel structure

8.4.1 Plating

As a rule, the thickness of the strength deck and bulkhead plating is to be not less than the values given in Tab 4.

Table 4 : Minimum plating thickness

Plating	Minimum thickness in mm
Strength deck	$(5,5 + 0,02\ L_{WL})\ k^{1/2} + 1,5$
Tank bulkhead	$L_{WL}^{1/3}\ k^{1/6} + 4,5\ s + 1$
Watertight bulkhead	$0,85\ L_{WL}^{1/3}\ k^{1/6} + 4,5\ s + 1$
Note 1: s : Length, in m, of the shorter side of the plate panel	

8.4.2 Secondary stiffeners

As a rule, the thickness of the web of secondary stiffeners is to be not less than the value obtained, in mm, from the following formula:

$$t_{MIN} = 0,75\ L_{WL}^{1/3}\ k^{1/6} + 4,5\ s + 3$$

where s is the spacing, in m, of secondary stiffeners.

8.4.3 Primary stiffeners

As a rule, the minimum thickness of plating which forms the webs of primary supporting members is to be not less than the value obtained, in mm, from the following formula:

$$t_{MIN} = 1,45\ L_{WL}^{1/3}\ k^{1/6} + 3$$

8.4.4 Strength checks of cross-ties

Cross-tie analysis is to be carried out as defined in [6.5.2].

8.4.5 Strength check with respect to stresses due to the temperature gradient

Direct calculations of stresses induced in the hull structures by the temperature gradient are to be performed for ships intended to carry cargoes at temperatures exceeding 90°C. In these calculations, the water temperature is to be assumed equal to 0°C according to NR467, Pt D, Ch 7, Sec 3 [5.1].

8.4.6 Scantlings of independent tanks and supports

In general, the scantlings of independent tanks is to be not less than the values obtained in Chapter 4 where the lateral pressures are to be calculated according to Chapter 3.

Supports of independent tanks are to be as defined in NR467, Pt D, Ch 7, Sec3 [7].

8.5 Other structures

8.5.1 Machinery space and opening arrangement are to be in accordance with the requirements of NR467 Steel Ships, Pt D, Ch 7, Sec 3, [9].

8.6 Protection of hull metallic structure

8.6.1 Requirements of NR467 Steel Ships, Pt D, Ch 7, Sec 3, [11] are applicable.

8.7 Cathodic protection of tanks

8.7.1 Requirements of NR467 Steel Ships, Pt D, Ch 7, Sec 3, [12] are applicable.

8.8 Construction and testing

8.8.1 Requirements of NR467 Steel Ships, Pt D, Ch 7, Sec 3, [13] are applicable.

In these requirements, references to NR467, Part B are to be replaced by the equivalent requirements defined in the present Rules.

9 Chemical tankers

9.1 Application

9.1.1 Ships having the service notation **chemical tanker** are to comply with the requirements of the present Article, taking into account the general requirements defined in NR467 Steel Ships, Pt D, Ch 8, Sec 1.

9.2 Location of cargo tanks

9.2.1 The location of cargo tank is to be in accordance with NR467 Steel Ships, Pt D, Ch 8, Sec 2, [3].

9.3 Ship arrangement

9.3.1 Specific ship arrangement is to comply with the requirements defined in NR467 Steel Ships, Pt D, Ch 8, Sec 3.

9.4 Cargo containment

9.4.1 General

Cargo containment including structure design principles, hull girder loads, hull scantlings, independent tank structures and supports are to be in accordance with requirements defined in NR467 Steel Ships, Pt D, Ch 8, Sec 4.

In these requirements, references to NR467, Part B are to be replaced by the equivalent requirements defined in the present Rules.

9.5 Other structures

9.5.1 Machinery space is to be in accordance with the requirements of NR467 Steel Ships, Pt D, Ch 8, Sec 4, [7].

9.6 Protection of hull metallic structure

9.6.1 Requirements of NR467 Steel Ships, Pt D, Ch 8, Sec 4, [8] are applicable.

9.7 Construction and testing

9.7.1 Requirements of NR467 Steel Ships, Pt D, Ch 8, Sec 4, [9] are applicable.

In these requirements, references to NR467, Part B are to be replaced by the equivalent requirements defined in the present Rules.

10 Tankers

10.1 Application

10.1.1 Ships having the service notation **tanker** are to comply with the requirements of the present Article.

10.1.2 The liquid cargoes which are allowed to be carried by ships having the service notation **tanker** are specified in NR467 Steel Ships, Pt D, Ch 7, App 3.

10.2 Ship arrangement

10.2.1 Specific ship arrangement is to comply with the requirements defined in NR467 Steel Ships, Pt D, Ch 10, Sec 2, [2].

10.3 Design loads

10.3.1 Application

In addition to the requirements of Chapter 3, the loading conditions, subdivided into departure and arrival conditions, defined in NR467 Steel Ships, Pt D, Ch 10, Sec 2, [4] are applicable.

10.4 Hull scantlings for steel structure

10.4.1 Plating

As a rule, the thickness of the strength deck and bulkhead plating is to be not less than the values given in Tab 5.

Table 5 : Minimum plating thickness

Plating	Minimum thickness, in mm
Strength deck	$(5,5 + 0,02\ L_{WL})\ k^{1/2} + 1,5$
Tank bulkhead	$L_{WL}{}^{1/3}\ k^{1/6} + 4,5\ s + 1$
Watertight bulkhead	$0,85\ L_{WL}{}^{1/3}\ k + 4,5\ s + 1$
Note 1: s : Length, in m, of the shorter side of the plate panel	

10.4.2 Secondary stiffeners

As a rule, the thickness of the web of secondary stiffeners is to be not less than the value obtained, in mm, from the following formula:

$t_{MIN} = 0,75\ L_{WL}{}^{1/3}\ k^{1/6} + 4,5\ s + 2$

where s is the spacing, in m, of secondary stiffeners.

10.4.3 Primary stiffeners

As a rule, the thickness of plating which forms the webs of primary supporting members is to be not less than the value obtained, in mm, from the following formula:

$t_{MIN} = 1,45\ L_{WL}{}^{1/3}\ k^{1/6} + 2$

10.4.4 Scantlings of independent tanks and supports

In general, the scantlings of independent tanks is to be not less than the values obtained in Chapter 4 where the lateral pressures are to be calculated according to Chapter 3.

Supports of independent tanks are to be as defined in NR467 Steel Ships, Pt D, Ch 7, Sec 3, [7].

10.4.5 Strength check with respect to stresses due to the temperature gradient

Direct calculations of stresses induced in the hull structures by the temperature gradient are to be performed for ships intended to carry cargoes at temperatures exceeding 90°C. In these calculations, the water temperature is to be assumed equal to 0°C according to NR467, Pt D, Ch 7, Sec 3 [5.1].

10.5 Other structures

10.5.1 Machinery space is to be in accordance with the requirements of NR467 Steel Ships, Pt D, Ch 10, Sec 2, [8].

11 Passenger ships

11.1 Application

11.1.1 Ships having the service notation **passenger ship** are to comply with the requirements of the present Article, taking into account requirement defined in NR467 Steel Ships, Pt D, Ch 11, Sec 1, [1.1.3].

11.2 Ship arrangement

11.2.1 Specific ship arrangement is to comply with the requirements defined in NR467 Steel Ships, Pt D, Ch 11, Sec 2.

11.3 Hull girder strength

11.3.1 Strength deck

The contribution to the longitudinal strength of the hull structures up to the strength deck is to be assessed on a case by case basis in the following cases:

- when the size of openings in the side shell and/or longitudinal bulkheads located below the deck assumed by the Designer as the strength deck decrease significantly the capability of the plating to transmit shear forces to the strength deck.
- when the ends of superstructures which are required to contribute to longitudinal strength may be considered not effectively connected to the hull structures in way.

11.4 Hull scantlings

11.4.1 Plating

As a rule, the thickness of the inner bottom, side and weather strength deck plating for steel structure is to be not less than the values given in Tab 6.

Table 6 : Minimum plate thickness

Plating	Minimum thickness (mm)
Inner bottom outside engine room	$2,0+0,02L_{WL}k^{1/2}+4,5s$
Side • below freeboard deck • between freeboard deck and strength deck	$2,1+0,028L_{WL}k^{1/2}+4,5s$
Weather deck and trunk deck	$2,2k^{1/2}+2,1+s$
Balconies	$0,3+0,004L_{WL}k^{1/2}+4,5s$
Note 1: k, s : Material factor and length, in m, of the shorter side of the plate panel.	

11.4.2 Side shell plating

If a complete deck does exist at a distance from the freeboard deck exceeding 2 times the standard height of superstructures as defined in Ch 1, Sec 1, [4.12.4], the side shell plating located between this complete deck and the strength deck may be taken not greater than the thickness of deckhouse sides defined in Ch 5, Sec 1.

12 Ro-ro passenger ships

12.1 Application

12.1.1 Ships having the service notation **ro-ro passenger ship** are to comply with the requirements of the present Article, taking into account the requirement defined in NR467 Steel Ships, Pt D, Ch 12, Sec 1, [1.1.3].

12.2 Ship arrangement

12.2.1 Specific ship arrangement is to comply with the requirements defined in NR467 Steel Ships, Pt D, Ch 12, Sec 2.

12.3 Structure design principles

12.3.1 Specific structure design principles are to comply with the requirements defined in NR467 Steel Ships, Pt D, Ch 12, Sec 3, [3].

12.3.2 When deemed necessary by the Society, the behaviour of the ship primary structural members under racking effect due to transverse forces induced by transverse accelerations is to be investigated by direct calculation on a case by case basis.

12.4 Design loads

12.4.1 General

A plan of design static loads on deck, including fork lift areas, axle loads and any tyre print areas of wheeled loads, is to be provided for information.

All values displayed on this plan are to be at least equivalent to the values given by the present Rules for each kind of load.

12.4.2 Lowest 0,5 m of bulkheads forming vertical division along escape route in accommodation

The pressures transmitted to the structures belonging to lowest 0,5 m of bulkheads and other partitions forming vertical divisions along escape routes are to be obtained, in kN/m², as specified in Ch 3, Sec 4, [4.2], where the value p_S is to be taken not less than 1,5 kN/m² to allow them to be used as walking surfaces from the side of the escape route with the ship at large angles of heel.

12.5 Hull girder strength

12.5.1 Strength deck

The contribution to the longitudinal strength of the hull structures up to the strength deck is to be assessed on a case by case basis in the following cases:

- when the size of openings in the side shell and/or longitudinal bulkheads located below the deck assumed by the Designer as the strength deck decrease significantly the capability of the plating to transmit shear forces to the strength deck
- when the ends of superstructures which are required to contribute to longitudinal strength may be considered not effectively connected to the hull structures in way.

12.6 Hull scantlings

12.6.1 Plating

a) Minimum thickness:

As a rule, the thickness of the inner bottom, side and weather strength deck plating for steel structure is to be not less than the values given in Tab 7

b) Lowest 0,5 m of bulkheads forming vertical division along escape route:

The thickness of plating belonging to the lowest 0,5 m of bulkheads and other partitions forming vertical divisions along escape routes is to be obtained according to Ch 4, Sec 3 where the loads are defined in [12.4.2]

c) Side shell:

If a complete deck does exist at a distance from the freeboard deck exceeding 2 times the standard height of superstructures as defined in Ch 1, Sec 1, the thickness of the side shell plating located between this complete deck and the strength deck may be taken not greater than the thickness of deckhouse sides defined in Ch 5, Sec 1.

Table 7 : Minimum plate thickness

Plating	Minimum thickness (mm)
Inner bottom outside engine room	$2,0+0,02L_{WL}k^{1/2}+4,5s$
Side • below freeboard deck • between freeboard deck and strength deck	$2,1+0,028L_{WL}k^{1/2}+4,5s$
Weather deck and trunk deck	$2,2k^{1/2}+2,1+s$
Balconies	$0,3+0,004L_{WL}k^{1/2}+4,5s$
Note 1: k, s : Material factor and length, in m, of the shorter side of the plate panel	

12.6.2 Stiffeners

The scantling of secondary and primary stiffeners belonging to the lowest 0,5 m of bulkheads and other partitions forming vertical divisions along escape routes is to be obtained according to Ch 4, Sec 4 and Ch 4, Sec 5 where the loads are defined in [12.4.2].

12.6.3 Bow door, side doors and stern door

Bow door, side doors and stern door are to be examined according to [2.5] and [2.6].

12.6.4 Other structures

Requirements defined in NR467 Steel Ships, Pt D, Ch 12, Sec 3 [7] are applicable.

13 Ship for dredging activity

13.1 Application

13.1.1 General

Ships for dredging activity as defined in [13.1.2] are to comply with the requirements of the present Article, taking into account the general requirements defined in NR467 Steel Ships, Pt D, Ch 13, Sec 1.

13.1.2 Type of ship for dredging activity covered by the present Rules

a) The present Rules apply to ship for dredging activity within the following maximum length:

- up to 90 m for service notation **dredger**
- up to 65 m for service notations **hopper dredger**, **hopper unit**, **split hopper dredger** and **split hopper unit**

b) Ship group

The ship group “cargo ships” or “non-cargo ships” as defined in Ch 1, Sec 1, [2.1.3] is to be considered as a general rule as follow:

- ships with the service notation **dredger** may be considered as non-cargo ships
- ships with one of the service notations **hopper dredger**, **hopper unit**, **split hopper dredger** or **split hopper unit** may be considered as cargo ships.

13.2 Structure design principles

13.2.1 General

The general structure design principles are to comply with the requirements defined in NR467 Steel Ships, Pt D, Ch 13, Sec 2, [2.1].

13.2.2 Structure members in the area of the hopper well

a) General

Longitudinal and transverse ship structures in the area of the hopper well are to comply with the requirements defined in NR467 Steel Ships, Pt D, Ch 13, Sec 2, [2.2] and [2.3]

b) Hopper dredgers and hopper units floors

The scantling of floors of ships with open wells fitted with bottom doors is to be obtained from a direct calculation according to:

- Ch 4, Sec 5, [1.2] for two- or three-dimensional beam model, or
- Ch 4, Sec 5, [1.3] for finite element model

taking into account the assumptions defined in NR467 Steel Ships, Pt D, Ch 13, App 1, [2].

The permissible local stresses for primary structure check are defined in Ch 2, Sec 3, [2]

c) Other primary elements of hopper dredger and hopper units

Strong beams at deck level, brackets for trunks and girders supporting the hydraulic cylinder in the hopper spaces are to comply with the requirements defined in NR467 Steel Ships, Pt D, Ch 13, App 1, [3] to [5].

13.2.3 Specific arrangements

Arrangements relating to suction pipes, areas subjected to heavy wear, reinforcements for grounding and bolted structure are to comply with the requirements defined in NR467 Steel Ships, Pt D, Ch 13, Sec 2, [2.4] to [2.7].

13.3 Design loads

13.3.1 General

Design loads for ships specially intended for dredging activities are to be determined for the various load cases in the following two situations:

- navigation situation, considering the draught T and the navigation coefficient n defined in Ch 1, Sec 1, [3.1.1]
- dredging situation, considering the dredging draught T_D and the navigation coefficient n_D defined in Tab 8 in relation to the operating area notation granted to the ship.

For dredgers made of bolted structure, the Society may require the hull girder loads calculated with the maximum length of the unit when mounted to be applied to each individual element.

Table 8 : Coefficient n_D in dredging situation

Operating area notation	n_D
dredging ≤ 8 miles from shore or Hs ≤ 1,5 m (T=x m)	1/3
dredging ≤ 15 miles from shore or Hs ≤ 2,5 m (T=x m)	2/3
unrestricted dredging area (T=x m)	1
Note 1: **H_S** indicates the maximum significant wave height, in m, for operating area in dredging situation, according to the operating area notation assigned to the ship (see NR467 Steel Ships, Pt A, Ch 1, Sec 2 [5.3]). **(T= x m)** indicates the maximum allowable draught x, in m, corresponding to the design draught in dredging situation	

13.3.2 Hull girder loads

Where the hull girder strength of the ship is examined in accordance with Ch 4, Sec 2, [1.1.3], the hull girder loads are to be considered as follows:

a) General

The still water loads are to be as defined in Ch 3, Sec 2, [4].

Calculation of the still water bending moment and shear force for any loading case corresponding to a special use of the ship may be required by the Society on a case-by-case basis. In particular, in the case of stationary dredgers, the curve of the still water bending moment, where the suction pipe is horizontal, is to be submitted to the Society for approval.

b) Still water load conditions for service notations **hopper dredger**, **hopper unit**, **split hopper dredger** or **split hopper unit**

In addition to item a), still water loads are to be calculated for the following loading conditions:

- homogeneous loading at maximum dredging draught if higher than the maximum service draught
- partial loading conditions
- any specified non-homogeneous loading condition, in particular where dredgers are fitted with several hopper spaces
- navigation conditions with hopper space(s) filled with water up to the load line
- working conditions at international freeboard with the hopper space(s) filled with spoil
- ballast navigation conditions, with empty hopper space(s), if applicable.

c) Wave loads

The wave loads are to be as defined in Ch 3, Sec 2, [5].

13.3.3 Hull girder loads for dredgers of more than 65 m

The hull girder strength of the ship is to be examined taking into account the following hull girder loads:

a) Still water load conditions

As a rule, the vertical still water bending moments in dredging situation in hogging and sagging conditions are to be defined by the designer and are to be combined to the vertical wave bending moment defined in item b).

b) Vertical wave bending moments and shear forces

- In addition to the vertical wave bending moments M_{WH} and M_{WS} in navigation situation defined in Ch 3, Sec 2, the vertical wave bending moments in dredging situation at any hull transverse section are to be obtained, in kN·m, from the following formulae:
  - hogging conditions:

    $M_{WV,\,H,\,D} = 190\ n_D\ C\ L^2\ B\ C_B\ 10^{-3}$
  - sagging conditions:

    $M_{WV,\,S,\,D} = -\ 110\ n_D\ C\ L^2\ B\ (C_B + 0{,}7)\ 10^{-3}$

  where:

  n_D : Coefficient defined in Tab 8 depending on the operating area, without being taken greater than the coefficient n defined in Ch 1, Sec 1, [3.1.1].
- In addition to the vertical wave shear force Q_W in navigation situation defined in Ch 3, Sec 2, the vertical wave shear force in dredging situation at any hull transverse section is to be obtained, in kN, from the following formula:

  $Q_{W,\,D} = 30\ n_D\ C\ L\ B\ (C_B + 0{,}7)\ 10^{-2}$

The values of bending moments and shear forces are to be applied along the ship from 0,30 L to 0,75 L.

When deemed necessary by the Society, other distributions of the bending moments and shear forces may be considered on a case by case basis.

13.3.4 Internal pressure for hopper well in dredging conditions

The internal pressure to be taken into account for hopper well, in kN/m², is to be not less than the greater value of the following formulae:

$$P = \delta_1 d_D\left(g + \sqrt{a_z^2 + n_D^2}\right) \geq 22$$

$$P = \delta_1 d_D(10 + 4{,}5 n_D) \geq 22$$

where:

δ_1 : Coefficient equal to:

$\delta_1 = \delta$ for $\delta < 1{,}4$

$\delta_1 = \delta + (1{,}4 - \delta)\sin^2\alpha$ for $\delta \geq 1{,}4$

d_D : Vertical distance, in m, from the calculation point to the highest weir level with the corresponding specific gravity of the mixture of sea water and spoil

α : Angle, in degrees, between the horizontal plane and the surface of the hull structure to which the calculation point belongs

a_z : Vertical acceleration in dredging condition, in m/s², defined in Ch 3, Sec 4, [2.2.1]

n_D : Coefficient defined in Tab 8.

13.4 Hull scantlings

13.4.1 Hull girder strength for dredger, hopper dredger and hopper unit

a) General

The hull girder strength of ships is to be checked according to Ch 4, Sec 1, [2.2] and Ch 4, Sec 2, taking into account the load conditions defined in [13.3.2].

For dredger of more than 65 m in length, the hull girder strength is to be checked taking into account the still water load conditions and the vertical wave bending moments defined in [13.3.3].

b) Calculation details

As a rule, the determination of the midship section modulus according to Ch 4, Sec 2, [3] or Ch 4, Sec 2, [4], as applicable, account is to be taken of both 85% and 100% effectiveness of the sectional area of the cellular keel.

However the 85% and 100% effectiveness of the sectional area of the cellular keel may be replaced by the actual effectiveness of the cellular keel determined by a three-dimensional finite element analysis.

Where cut-outs in the side shell are needed to fit the suction pipe guides, a section modulus calculation not taking account of the side shell plating may be required by the Society on a case-by-case basis, if the structural continuity is not fully achieved.

13.4.2 Hull girder strength for split hopper dredgers and split hopper units

The hull girder strength of split hopper dredgers and split hopper units is to be checked according to Ch 4, Sec 1, [2.2] and Ch 4, Sec 2, taking into account:

- the load conditions defined in [13.3.2], item b)
- the section modulus of the transverse section as defined in Ch 4, Sec 2, [3.2], considering the both half-hulls connected.

13.4.3 Hull scantlings

a) General

Hull scantlings are to be checked according to the applicable requirements of Ch 4, Sec 3 to Ch 4, Sec 5 for the following two situations:

- navigation situation, considering the draught T and the navigation coefficient n defined in Ch 1, Sec 1, [3.1.1]
- dredging situation, considering the dredging draught T_D and the navigation coefficient n_D defined in Tab 8.

b) Minimum thicknesses

As a rule, the thickness of plating is to be not less than the greater of the following values:

- 6 mm
- thickness obtained from Tab 9.

When no protection is fitted on the deck areas where heavy items of dredging equipment may be stored for maintenance, the thickness of the deck plating is to be not less than the value obtained, in mm, from the following formula:

$t = 6{,}1 + 0{,}040\ L_{WL}\ k^{1/2} + 4{,}5\ s$

c) Bottom plating

Where the bottom is longitudinally framed and the bilge is made of a transversely framed sloped plate, the bottom is to be assumed as being transversely framed when calculating the plating thickness.

The thickness of the bottom strake, to which the longitudinal bulkheads of the hopper space are connected, is to be not less than bottom plating thickness increased by 15%.

Table 9 : Minimum thickness of plating

Plating	Minimum net thickness, in mm
Keel	$6{,}1 + 0{,}040\ L_{WL}\ k^{1/2} + 4{,}5\ s$
Bottom	
• transverse framing	$5{,}3 + 0{,}036\ L_{WL}\ k^{1/2} + 4{,}5\ s$
• longitudinal framing	$4{,}4 + 0{,}036\ L_{WL}\ k^{1/2} + 4{,}5\ s$
Inner bottom outside hopper spaces	$3{,}0 + 0{,}025\ L_{WL}\ k^{1/2} + 4{,}5\ s$
Side	
• below freeboard deck	$3{,}5 + 0{,}031\ L_{WL}\ k^{1/2} + 4{,}5\ s$
• between freeboard deck and strength deck	$3{,}5 + 0{,}013\ L_{WL}\ k^{1/2} + 4{,}5\ s$
Strength deck within 0,4L amidships	
• transverse framing	$3{,}5 + 0{,}040\ L_{WL}\ k^{1/2} + 4{,}5\ s$
• longitudinal framing	$3{,}5 + 0{,}032\ L_{WL}\ k^{1/2} + 4{,}5\ s$
Hopper well	
• transverse and longitudinal bulkheads and cellular keel plating	$3{,}7 + 0{,}034\ L_{WL}\ k^{1/2} + 4{,}5\ s$
• splash coaming	6

13.4.4 Specific hull scantlings

a) Well bulkheads and cellular keel platings

The thickness of hopper well bulkhead plating and cellular keel plating is to be not less than the thickness defined in Ch 4, Sec 3, considering the internal pressure defined in [13.3.4] and the thickness defined in Tab 9.

The thickness of the longitudinal bulkhead above the deck or within 0,1 D below the deck is to be not less than the thickness of the strength deck in way of the hatchways.

The thickness of the transverse and longitudinal bulkhead of a dredge pipe well is to be determined as for the side shell thickness.

b) Transversely framed bottoms

The scantlings of floors located inside large compartments, such as pump rooms, are to be obtained from a direct calculation, according to Ch 4, Sec 5, [1.2.2], and taking into account the following assumptions:

- floors are simply supported at ends
- local discontinuities in strength, due to the presence of wells, are to be considered.

c) Specific element scantling for split hopper unit

Superstructure hinges, deck hinges, hydraulic jack connections and chocks and hydraulic jacks and associated piping systems are to comply with the requirements defined in NR467 Steel Ships, Pt D, Ch 13, Sec 2, [8] to [11].

The vertical force F_z and transversal force F_y, in kN, applied on superstructure are to be calculated as defined in Ch 3, Sec 4, [3.3.3] for dry unit cargo where M, in t, is to be taken as the mass of the superstructure.

The longitudinal force F_x, in kN, applied on superstructure may be considered equal to 1,45M, where M, in t, is to be taken as the mass of the superstructure.

13.5 Rudders

13.5.1 General

The rudder stock diameter obtained from Ch 5, Sec 2, [8] is to be increased by 5%.

13.5.2 Rudders for split hopper dredgers and split hopper units

Each half-hull of ships with one of the service notations **split hopper unit** or **split hopper dredger** is to be fitted with a rudder complying with the requirements of Ch 5, Sec 2, [8].

An automatic system for synchronising the movement of both rudders is to be fitted.

13.6 Equipment

13.6.1 General

For ships having the service notation **dredger**, **hopper dredger**, **hopper unit**, **split hopper dredger** or **split hopper** unit with non-conventional design of the underwater part of the hull, the determination of the anchoring equipment is considered on a case-by-case basis by the Society.

14 Non-propelled units

14.1 Application

14.1.1 Non-propelled ships having the service notation **barge**, **pontoon** or **pontoon-crane** are to comply with the requirements of the present Article.

14.1.2 General requirements defined in NR467 Steel Ships, Pt D, Ch 14, Sec 2, [1] are applicable.

14.2 Structure design principles

14.2.1 Specific structure design principles defined in NR467 Steel Ships, Pt D, Ch 14, Sec 2, [3] are applicable.

14.3 Hull girder strength

14.3.1 Non-propelled units lifted by crane

For non-propelled units intended to be lifted on board ship by crane, the hull girder strength is to be checked, in the condition of fully-loaded barge lifted by crane, through criteria defined in Ch 2, Sec 3, [2.1.1], multiplied by the following coefficient:

- 0,85 for stresses
- 1,15 for buckling safety coefficient.

14.3.2 Ships with service notation pontoon carrying special cargoes

For ships with the service notation **pontoon** intended for the carriage of special cargoes, such as parts of offshore units, the hull girder strength is to be checked through criteria to be agreed with the Society on a case-by-case basis.

Moreover, where these ships are fitted with arrangements for launching the above structures, additional calculations are to be carried out in order to evaluate the stresses during the various stages of launching. The Society may accept stresses higher than those defined in [14.3.1], to be considered on a case-by-case basis, taking into account favourable sea and weather conditions during launching.

14.4 Hull scantlings

14.4.1 General for steel structure

a) Minimum thickness of ships with service notation **barge** carrying liquids

For ships with the service notation **barge** carrying liquid cargo inside tanks, the thicknesses of cargo tank platings are to be not less than the values given in Tab 10.

For other structures or transverse bulkheads not forming boundaries of cargo tanks, the above minimum thicknesses may be reduced by 1 mm.

In pump rooms, the thicknesses of plating of exposed decks, longitudinal bulkheads and associated secondary stiffeners and primary supporting members are to be not less than the values given in Tab 10.

b) Minimum thicknesses of decks forming tank top

Where the decks of non-propelled units form a tank top, the minimum thicknesses of plating are to be not less than those obtained from Tab 10.

c) Thickness of strength deck plating

Within the cargo area, the thickness of strength deck plating is to be increased by 1,5 mm with respect to that calculated according to Ch 4, Sec 3.

Table 10 : Minimum thickness of plating

Plating	Minimum thickness, in mm
Decks, sides, bottom, inner bottom, bulkheads, primary supporting members in the cargo area	• for $L_{WL} \le 45$ m: $(4,1 + 0,060\ L_{WL})\ k^{0,5} + 1$ • for $L_{WL} > 45$ m: $(5,9 + 0,023\ L_{WL})\ k^{0,5} + 1$
Weather deck, within cargo area outside 0,4 L amidships	$11,3\ s\ k^{0,5} + 1$
Web of secondary stiffeners and other structures of cargo tanks	• for $L_{WL} \le 45$ m: $(4,1 + 0,060\ L_{WL})\ k^{0,5} + 1$ • for $L_{WL} > 45$ m: $(5,9 + 0,023\ L_{WL})\ k^{0,5} + 1$
Note 1: s : Length, in m, of the shorter side of the plate panel	

14.4.2 Scantling of deck secondary stiffeners subjected to maximum allowable loads defined by the Designer

For longitudinal secondary deck stiffeners contributing to the global strength and subjected to maximum allowable deck loads defined by the Designer, the section modulus Z, in cm^3, and the shear area A_{sh}, in cm^2, may be taken not less than the values defined in Ch 4, App 2, [3], taking into account a permissible local scantling stress σ_{ad}, in N/mm^2, equal to:

$$\sigma_{ad} = 0,95 R_y - 0,72 \sigma_A$$

where:

R_y, σ_A : Defined in Ch 4, App 2.

14.4.3 Hull scantlings of non-propelled units with the service notation pontoon fitted with arrangements and systems for launching operations

a) Additional information

In addition to the documentation specified in Ch 1, Sec 1, [7], the following information is to be submitted to the Society:

- maximum draught of the ship during the different stages of the launching operations
- operating loads and their distribution
- launching cradle location.

b) Scantlings of plating, secondary and primary stiffeners

In applying the formulae in Chapter 4, T is to be taken equal to the maximum draught during the different stages of launching and taking into account, where appropriate, the differential static pressure.

c) Deck scantlings

The scantlings of decks are to be in accordance with Chapter 4, considering the maximum loads acting on the launching cradle.

The thickness of deck plating in way of launch ground ways is to be suitably increased if the cradle may be placed in different positions.

The scantlings of decks in way of pivoting and end areas of the cradle are to be obtained through direct calculations.

d) Launching cradles

The launching cradles are to be adequately connected to deck structures and arranged, as far as possible, in way of longitudinal bulkheads or at least of girders.

14.4.4 Hull scantlings of non-propelled units with service notation pontoon-crane

Requirements defined in NR467 Steel Ships, Pt D, Ch 14, Sec 2, [5.3] are applicable.

14.5 Hull outfitting

14.5.1 Equipment

a) Manned non-propelled units:

The equipment of anchors, chain cables and ropes to be fitted on board manned non-propelled units is to comply with Ch 5, Sec 4.

Chain cables for anchors may be replaced by steel ropes having the same breaking load. The ropes are to be connected to the anchors by approximately 10 m of chain cable complying with Ch 5, Sec 4.

Non-propelled units continuously assisted by a tug may have only one anchor, complying with Ch 5, Sec 4, and a chain rope having length neither less than 75% of the length obtained according to Ch 5, Sec 4, nor less than 220 m.

b) Unmanned non-propelled units:

For unmanned non-propelled units, the equipment is not required for classification purposes. The scantlings of anchors, chain cables and ropes to be fitted on board are the responsibility of the Designer.

c) Towing arrangements:

Non-propelled units are to be fitted with suitable arrangements for towing, with scantlings under the responsibility of the Designer.

The Society may, at the specific request of the Interested Party, check the above arrangements and the associated hull strengthening; to this end, the maximum pull for which the arrangements are to be checked is to be specified on the plans and documents submitted for approval.

15 Fishing vessels

15.1 Application

15.1.1 Ships having the service notation **fishing vessel** are to comply with the requirements of the present Article.

15.2 Ship arrangement

15.2.1 Specific ship arrangement is to comply with the requirements defined in NR467 Steel Ships, Pt D, Ch 15, Sec 2.

For vessels less than 45 m in length, the collision bulkhead is to be located at a distance from the forward perpendicular FP_{LL} of not less than 5% of the length L_{LL} of the ship and not more than 5% of the length L_{LL} + 1,35 m. For ships greater than 24 m in length, this distance is not to be less than 2 m.

15.3 Specific design loads

15.3.1 General

The specific design loads defined in the present Article are to be taken into account in addition to the design loads defined in Chapter 3.

15.3.2 Fish hold

The design pressure p_F, in kN/m², to be considered for the scantling of fish holds, is to be taken as defined in Ch 3, Sec 4, [3.2.1] taking into account:

- for holds intended to carry dry fish or fish stored in ice: $\rho_L = 0,7$
- for holds intended to carry live fish or frozen fish into sea water: $\rho_L = 1,025$
- for holds intended to freeze or store fish into brine: $\rho_L = 1,2$

where ρ_L is defined in Ch 3, Sec 4, [3.2.1].

Note 1: If applicable, a design vapour pressure Ppv is to be considered for live fish stored in sea water to take into account the injection of oxygen.

15.3.3 Working deck

The static pressure P_{LD} to be considered on working decks is to be taken as defined by the Designer, without being less than 8,5 kN/m².

15.4 Hull scantlings

15.4.1 Bottom, side and decks plating

The thickness of bottom, side and decks plating is to be increased by 0,5 mm with respect to that calculated according to Chapter 4.

15.4.2 Deck plating protected

The thickness of deck plating protected by wood sheathing, deck composition or other arrangements deemed suitable by the Society may be reduced by 10% with respect to that obtained from the present Rules.

15.4.3 Wells in fish holds

The thickness of fish holds wells plating, not protected by insulation, is to be increased by 1 mm with respect to that calculated according to Chapter 4, taking into account the pressure defined in [15.3.2].

This thickness increase is to be combined with the one defined in [4.2.1] if applicable.

15.4.4 Aft ramp

As a rule, the thickness of the aft ramp are defined as follow:

a) Plating of the aft ramp and the lower part of the aft ramp side:

The plating thickness of the aft ramp and of the lower part of the aft ramp side is to be increased by 1,5 mm with respect to that calculated according to the present Rules for side plating with the same plate panel dimensions.

As a rule, the plating thickness of the aft ramp and of the lower part of the aft ramp side is to be not less than 12 mm.

Note 1: The lower part of the aft ramp sides is that which can be in contact with the fish nets and ropes.

b) Plating of the upper part of the aft ramp side

The thickness of plating of the upper part of the aft ramp side is to be not less than the value calculated according to the present Rules for side plating with the same plate panel dimensions.

15.5 Machinery casings

15.5.1 Engine room skylight coamings

a) Ships greater than 65 m in length:

Engine room skylight are to be in accordance with NR467 Steel Ships, Pt B, Ch 11, [7.2].

b) Ships less than 65 m in length:

If the engine room where skylights are fitted with opening-type covers providing light and air, the height of coamings is to be not less than:

- 900 mm, for skylights located on working decks
- 300 mm, for skylights located on superstructure decks.

The thickness of engine room skylight coamings is to be not less than 6 mm.

Where the height of engine room skylight coamings is greater than 900 mm, the section modulus of vertical ordinary stiffeners with spacing not greater than 760 mm is to be increased by 10% with respect to that obtained for vertical ordinary stiffeners of deckhouses.

15.5.2 Scantlings

The scantlings of plating and ordinary stiffeners are to be not less than those of plating and ordinary stiffeners of superstructures and deckhouses. In any case, the thickness of protected or unprotected casing bulkheads is to be not less than 5 mm.

15.6 Arrangement for hull and superstructure openings

15.6.1 General

Requirements defined in the present Article are applicable to ships less than 65 m in length.

The arrangement for hull and superstructure openings of ships greater than 65 m in length are to be in accordance with NR467 Steel Ships, Pt D, Ch 15, Sec 3 [5].

15.6.2 Sidescuttles

Sidescuttles may not be fitted in such a position that their sills are below a line drawn parallel to the sheer at side and having its lowest point 0,5 m above the summer load waterline.

No sidescuttles may be fitted in any spaces which are appropriated exclusively for the carriage of cargo.

15.6.3 Freeing ports

The freeing port area in bulwarks is to be not less than the value obtained from the formulae in NR467 Steel Ships, Pt B, Ch 11, Sec 12, [6].

For ships with L < 24 m and the navigation notation **coastal area**, the freeing port area in bulwarks on each side of the ship may be not less than the value obtained from the following formula:

$$A = 0,035\ \ell_B + A_C$$

where:

ℓ_B : Length, in m, of bulwark in the well, to be taken not greater than 0,7 L

A_C : Area, in m², to be taken, with its sign, equal to:

$A_C = 0,04\ \ell_B\ (h_B - 1,2)$ for $h_B > 1,2$

$A_C = 0$ for $0,9 \le h_B \le 1,2$

$A_C = 0,04\ \ell_B\ (h_B - 0,9)$ for $h_B < 0,9$

h_B : Mean height, in m, of bulwark in the well of length ℓ_B .

15.6.4 Openings in bulkheads of enclosed superstructures and other outer structures

All access openings in bulkheads of enclosed superstructures and other outer structures (e.g. machinery casings) through which water can enter and endanger the ship are to be fitted with doors of steel or other equivalent material, permanently and strongly attached to the bulkhead, and framed, stiffened and fitted so that the whole structure is of equivalent strength to the unpierced bulkhead and weathertight when closed. The doors are to be capable of being operated from both sides and generally to open outwards to give additional protection against wave impact.

These doors are to be fitted with gaskets and clamping devices or other equivalent means permanently attached to the bulkhead or to the door themselves.

Other openings are to be fitted with equivalent covers, permanently attached in their proper position.

15.6.5 Doors sills

The height of the sill of the doors is to be not less than:

- 600 mm above the working deck
- 300 mm above the deck of the lower tier of superstructures.

For doors protected from the direct impact of waves, except for those giving direct access to machinery spaces, the height of the sill may be taken not less than:

- 380 mm above the working deck
- 150 mm above the deck of the lower tier of superstructures.

15.6.6 Ventilator coamings

The height of ventilator coamings is to be not less than the value obtained from Tab 11.

The thickness of ventilator coaming plating is to be not less than both the thickness obtained for the ship's deck and the thickness obtained for a deckhouse in the same position as the ventilator.

As a rule, ventilator coamings are to be provided with weathertight closing appliances to be used in rough weather.

Table 11 : Ventilator coamings

Ship's length, in m	Coaming height, in mm		Minimum height of ventilators, in m	
	Ventilator openings on working decks	Ventilator openings on decks of lower tier of superstructure	Ventilator openings on working decks	Ventilator openings on decks of lower tier of superstructure
L > 45	900	760	4,5	2,3
24 ≤ L ≤ 45	760	450	3,4	1,7
12 ≤ L < 24	760	450	2,5	1,0
L < 12	300	300	2,5	1,0

15.7 Lifting appliances and fishing devices

15.7.1 General

The fixed parts of lifting appliances and fishing devices, considered as an integral part of the hull, are the structures permanently connected by welding to the ship's hull (for instance crane pedestals, masts, king posts, derrick heel seatings, etc., excluding cranes, derrick booms, ropes, rigging accessories, and, generally, any dismountable parts). The shrouds of masts embedded in the ship's structure are considered as fixed parts.

15.7.2 Design loads

The design loads to be considered for the strength check of masts, fishing devices and reinforcements under decks are:

- the weights of booms and net hauling fittings
- the cargo loads, to be taken equal to the maximum traction loads of the different lifting appliances, considering the rolling-up diameters defined here after.

The rolling-up diameters to be taken for the maximum traction loads of the lifting appliances are for:

- the fishing winches: the mid rolling-up diameter
- the net winches: the maximum rolling-up diameter
- the winding-tackles: the minimum rolling-up diameter.

15.7.3 Strength check

The structure check of the reinforcements under decks supporting fishing devices, and to the strength check of fishing devices and masts if welded to the deck is to be carried out by direct calculation, taking into account the following permissible stresses:

a) for steel and aluminium structure:
   - for beam grillage analysis: $\sigma_{VM} \leq 0,5\ R$
   - for standard mesh FE analysis (s x s): $\sigma_{VM} \leq 0,6\ R$
   - for fine mesh FE analysis (50 x 50 mm):
     - for elements not adjacent to welding: $\sigma_{VM} \leq R$
     - for elements adjacent to welding: $\sigma_{VM} \leq 0,9\ R$

   where:

   σ_{VM} : Von Mises equivalent stress, in N/mm^2, to be obtained as a result of direct calculations

   R : Minimum yield stress for scantling criteria, in N/mm^2, of the material, defined in Ch 1, Sec 2.

b) for composite structure:
   - for beam grillage analysis:

     $SF_{fd} = 1,4\ SF$

     $SF_{fd} = 1,4\ SF_{CS}$
   - for standard mesh FE analysis (s x s):

     $SF_{fd} = 1,2\ SF$

     $SF_{fd} = 1,2\ SF_{CS}$
   - for fine mesh FE analysis (50 x 50 mm):

     $SF_{fd} = SF$

     $SF_{fd} = SF_{CS}$

   where:

   SF : Rules safety coefficient applicable to maximum stress defined in Ch 2, Sec 3, [3.2.3]

   SF_{CS} : Rules safety coefficient applicable to combined stress defined in Ch 2, Sec 3, [3.2.3].

The buckling strength of the structural elements of masts and fishing devices is to be checked in compliance with Chapter 4.

15.8 Hull outfitting

15.8.1 Rudder stock scantlings

The rudder stock diameter is to be increased by 5% with respect to that obtained from the formula in Ch 5, Sec 2, [8].

15.8.2 Propeller shaft brackets

Propeller shaft brackets are to be in accordance with Ch 5, Sec 2, [11].

For ships less than 30 m in length, single arm propeller shaft brackets may be fitted.

15.8.3 Equipment

The equipment in chain and anchor for ships having the service notation **fishing vessel** is defined in Ch 5, Sec 4.

Equipment in anchors and cables defined in Ch 5, Sec 4 may be reduced on a case-by-case basis. Nevertheless, it belongs to the Designer and/or shipyard to submit all the relevant information demonstrating that reduced equipment - its configuration - and all its components, fully copes with the anchoring forces most frequently encountered during service.

For ships of special design or for ships engaged in special services or on special voyage, the Society may consider anchoring equipment other than defined in the present Article and in Ch 5, Sec 4.

As an alternative to the stud link chain cables calculated in Ch 5, Sec 4, [3.2], wire ropes may be used in the following cases:

- wire ropes for both the anchors, for ship’s length less than 30 m
- wire rope for one of the two anchors, for ship’s length between 30 m and 40 m.

The wire ropes above are to have a total length equal to 1,5 times the corresponding required length of stud link chain cables, obtained from Ch 5, Sec 4, [3.2], and a minimum breaking load equal to that given for the corresponding stud link chain.

A short length of chain cable is to be fitted between the wire rope and the anchor, having a length equal to 12,5 m or the distance from the anchor in the stowed position to the winch, whichever is the lesser.

When chain cables are replaced by trawl warps, the anchor is to be positioned on the forecastle deck so that it may be readily cast after it has been shackled to the trawl warp. Chocks or rollers are to be fitted at suitable locations, along the path of the trawl warps, between the winch and the mooring chocks.

15.9 Protection of hull metallic structure

15.9.1 Protection of decks by wood sheathing

Before fitting the wood sheathing, deck plating is to be protected with suitable protective coating.

As a rule, the thickness of wood sheathing of decks is to be not less than:

- 65 mm, if made of pine
- 50 mm, if made of hardwood, such as teak.

The width of planks is not to exceed twice their thickness.

15.9.2 Protection of cargo sides by battens

In cargo spaces, where thermal insulation is fitted, battens formed by spaced planks are generally to be fitted longitudinally.

15.9.3 Deck composition

The deck composition is to be of such a material as to prevent corrosion as far as possible and is to be effectively secured to the steel structures underneath by means of suitable connections.

16 Offshore patrol vessel

16.1 General

16.1.1 Ships having the service notation **OPV** are to comply with the requirements defined in NR467 Steel Ships, Pt D, Ch 16, Sec 1.

17 Cement carriers

17.1 Application

17.1.1 Ships having the service notation **cement carrier** are to comply with the requirements of the present Article.

17.2 Ship arrangement

17.2.1 Specific ship arrangement is to comply with requirements defined in NR467 Steel Ships, Pt D, Ch 17, Sec 2.

17.3 Structure design principles

17.3.1 Structure design principles defined in NR467 Steel Ships, Pt D, Ch 17, Sec 3, [2], are applicable.

17.4 Design loads

17.4.1 Loading conditions for primary structure analysis

The following loading conditions are to be considered in the analysis of the primary structure:

- homogeneous loading and corresponding draught T
- alternate loading conditions, if allowed by the loading manual, and draught T.

17.5 Protection of hull metallic structure

17.5.1 Protection of cargo hold is to be as defined in NR467 Steel Ships, Pt D, Ch 17, Sec 3, [6].

17.6 Construction and testing

17.6.1 Welding and weld connections

The weld factors for some hull structural connections are specified in NR467, Pt D, Ch 17, Sec 3, Tab 1. These weld factors are to be used in lieu of the corresponding factors specified in Ch 7, Sec 2 to calculate the leg length of fillet weld T connections.

For the connections defined in NR467, Pt D, Ch 17, Sec 3 Tab 1, continuous fillet welding is to be adopted.

18 Launch and seagoing launch

18.1 Application

18.1.1 Ships having the service notation **launch** or **seagoing launch** are to comply with the requirements of the present Article.

18.2 Hull outfitting

18.2.1 Equipment

For small ship, the provisions for mooring and anchoring defined in the present Rules may be reduced. The attention of Shipowners is drawn to the fact that additional equipment (length of anchor lines, type of anchor...) may be necessary to ensure anchoring in the conditions of service the most frequently encountered, taking into account the depth of water and the nature of the sea-bed.

18.2.2 The equipment in anchors and chains is defined in Ch 5, Sec 4.

18.2.3 On ships carrying two anchor chains of the prescribed length, the weight of the second anchor may be reduced by one third.

18.2.4 Anchoring gear comprising only 8 to 10 m of chain attached to each anchor, supplemented by hawsers of equivalent strength to the prescribed chain, may be accepted, subject to the agreement of the Shipowner and of the National Regulations of the country whose flag the ship carries.

If such anchoring gear, with cables and reduced chains, is adopted, the weight of the second anchor is to be equal to that of the first anchor as defined in Ch 5, Sec 4.

19 Tugs

19.1 Application

19.1.1 Ships having one of the service notations **tug**, **salvage tug** or **escort tug** are to comply with the requirements of the present Article.

The general scope of application of these service notations is defined in NR467 Steel Ships, Pt E, Ch 1, Sec 1.

19.2 Hull structure general requirements

19.2.1 Specific structure design principles and arrangements are to comply with the following Sub Article of NR467 Steel Ships, Pt E, Ch 1, Sec 3:

- typical design arrangements: [2.1]
- structure design principles: [2.2]
- other structure (machinery casings, emergency exits from machinery space and height of hatchway coamings): [2.4]
- rudder and bulwarks: [2.5].

19.3 Hull scantlings

19.3.1 General

The scantlings of plating, secondary stiffeners and primary stiffeners are to be in accordance with Chapter 4, where the hull girder loads and the local loads are defined in Chapter 3, to be calculated for a moulded draught T not less than 0,85 D.

19.4 Anchoring and mooring equipment

19.4.1 Anchoring equipment

The anchoring equipment is to be determined as defined in Ch 5, Sec 4.

For ships assigned the service notation **tug**, **salvage tug** or **escort tug** with:

$L \times B \times T < 1000$

where:

L : Rule length, in m, as defined in Ch 1, Sec 1, [4.2.1]

B : Moulded breadth, in m, as defined in Ch 1, Sec 1, [4.3.1]

T : Scantling draught, in m, as defined in Ch 1, Sec 1, [4.5.1]

a chain cable length lower than required in Ch 5, Sec 4, [3.2.2] may be accepted on a case-by-case basis provided that an appropriate anchoring depth is ensured.

19.4.2 Number of anchors

A reduction of the number of anchors and chain cables defined in Ch 5, Sec 4 may be accepted, based on redundancy according to NR467 Steel Ships, Pt E, Ch 1, Sec 3, [2.6.2].

19.5 Towing arrangements

19.5.1 The towing arrangements are to be in accordance with NR467 Steel Ships, Pt E, Ch 1, Sec 3, [2.7].

19.6 Additional requirements for escort tugs

19.6.1 The requirements of NR467 Steel Ships, Pt E, Ch 1, Sec 3, [3] are applicable for ships having the service notation **escort tug**.

19.7 Additional requirements for salvage tug

19.7.1 The requirements of NR467 Steel Ships, Pt E, Ch 1, Sec 3 [4] are applicable for ships having the service notation **salvage tug**.

19.8 Integrated tug/barge combination

19.8.1 Application

The requirements of this Sub-article apply to the integrated tug/barge combinations constituted by a tug having the additional service feature **barge combined** and barge having the additional service feature **tug combined**.

The tug/barge combination is to be examined on a case by case basis with the present Rules when the length of the tug/barge combination is less than 65 m.

Where the tug/barge combination length is greater than 65 m, the requirements of NR467 Steel Ships, Pt E, Ch 1, Sec 4 are applicable.

Two types of connections between tug and barge are to be considered as defined in NR467 Steel Ships, Pt E, Ch 1, Sec 4, [1].

19.8.2 Hull scantling

Hull scantling criteria of tug and barge are to be as defined in Chapter 4 and Chapter 5 considering successively the tug and the barge as an individual ship.

Where the tug/barge combination length is less than 65 m, the hull scantling is to be examined according to the present Rules considering the integrated tug/barge combination as a ship of the size of the combination for the calculation of the local loads and the hull girder loads.

For integrated tug/barge combinations with removable flexible connection, the effect on the degree of freedom of the connection on the still water hull girder loads in the combination may be taken into account (e.g free pitch of the tug with respect to the barge implies vertical bending moment equal to zero in the connection).

The forces transmitted through the connection are to be defined by direct calculation.

19.8.3 Other structures

Fore part and aft part of integrated tug/barge structure are to be as defined in NR467 Steel Ships, Pt E, Ch 1, Sec 4, [6].

19.8.4 Connection

Local reinforcement of the tug and the barge and connection scantling are to be as defined in NR467 Steel Ships, Pt E, Ch 1, Sec 4, [5].

19.8.5 Rudder

The tug rudder and steering gear are to be in accordance with the present Rules, considering the maximum service speed in ahead and astern condition of the tug as an individual ship and the maximum service speed in ahead and astern condition of the integrated tug/barge combination.

19.8.6 Test of the disconnection procedure of removable connection

Tests are to be carried out as defined in NR467 Steel Ships, Pt E, Ch 1, Sec 4 [8].

19.8.7 Equipment

The equipment is to be in accordance with the requirements in both

- Ch 5, Sec 4 for the tug, and
- [14.5.1] for the barge, considering the barge as a ship of the size of the integrated tug/barge combination.

19.9 Testing

19.9.1 Requirements of NR467 Steel Ships, Pt E, Ch 1, Sec 5 are applicable.

20 Anchor handling vessels

20.1 Application

20.1.1 Ships having the service notations **anchor handling** are to comply with the requirements of the present Article, taking into account the general requirements defined in NR467 Steel Ships, Pt E, Ch 2, Sec 1.

20.1.2 General arrangement

Specific arrangement are to comply with the requirements defined in NR467 Steel Ships, Pt E, Ch 2, Sec 2.

20.1.3 Hull structure

Specific hull structures are to comply with the requirements defined in NR467 Steel Ships, Pt E, Ch 2, Sec 4.

20.2 Testing

20.2.1 Requirements of NR467 Steel Ships, Pt E, Ch 2, Sec 5 are applicable.

21 Supply vessels

21.1 Application

21.1.1 Ships having the service notation **supply** are to comply with the requirements of the present Article.

21.1.2 General

General requirements defined in NR467 Steel Ships, Pt E, Ch 3, Sec 1 are applicable.

21.2 Ship arrangement

21.2.1 Specific ship arrangement is to comply with the requirements defined in NR467 Steel Ships, Pt E, Ch 3, Sec 2.

21.3 Structure design principles

21.3.1 Specific structure design principles are to comply with the requirements defined in NR467 Steel Ships, Pt E, Ch 3, Sec 4, [1].

21.4 Design loads

21.4.1 Dry uniform cargoes

The still water and inertial pressures transmitted to the structure of the upper deck intended to carry loads are to be obtained, in kN/m^2, as specified in Ch 3, Sec 4, [3.3.1], where the value of p_S is to be taken not less than 24 kN/m^2.

21.5 Hull scantlings for steel structure

21.5.1 Plating

As a rule, the thickness of the side and upper deck plating is to be not less than the values given in Tab 12.

Within the cargo area, the thickness of strength deck plating is to be increased by 1,5 mm with respect to that determined according to Ch 4, Sec 3.

However, the above increase in thickness by 1.5mm may be omitted provided all the following conditions are fulfilled:

a) wooden planking provide an efficient protection of the deck at the satisfaction of the society
b) the welding of the steel fittings securing the wood protection is performed before coating application
c) full coating application is applied after item b) above.

Table 12 : Minimum plating thickness

Plating	Minimum thickness, in mm
Side below freeboard deck	The greater value obtained from: • $3,1 + 0,031\ L_{WL}\ k^{0,5} + 4,5\ s$ • $8\ k^{0,5} + 1$
Side between freeboard deck and strength deck	The greater value obtained from: • $3,1 + 0,013\ L_{WL}\ k^{0,5} + 4,5\ s$ • $8\ k^{0,5} + 1$
Upper deck	7

21.5.2 Secondary stiffeners

a) Longitudinally framed side exposed to bumping

   In the whole area where the side of the supply vessel is exposed to bumping, the section modulus of secondary stiffeners is to be increased by 15% with respect to that determined according to Ch 4, Sec 4.

b) Transversely framed side exposed to bumping

   In the whole area where the side of the supply vessel is exposed to bumping, the section modulus of secondary stiffeners, i.e. side, ‘tweendeck and superstructure frames, is to be increased by 25% with respect to that determined according to Ch 4, Sec 4.

21.5.3 Primary stiffeners

In the whole area where the side of the supply vessel is exposed to bumping, a distribution stringer is to be fitted at mid-span, consisting of an intercostal web of the same height as the secondary stiffeners, with a continuous face plate.

The section modulus of the distribution stringer is to be at least twice that calculated in [21.5.2] for secondary stiffeners.

Side frames are to be fitted with brackets at ends.

Within reinforced areas, scallop welding for all side secondary stiffeners is forbidden.

21.6 Other structure

21.6.1 Aft part

Aft part structure is to be in accordance with NR467 Steel Ships, Pt E, Ch 3, Sec 4, [4.1].

21.6.2 Superstructures and deckhouses

a) Deckhouses and forecastle

Due to their location at the forward end of the supply vessel, deckhouses are to be reduced to essentials and special care is to be taken so that their scantlings and connections are sufficient to support wave loads.

The forecastle length not exceed 0,3 to 0,4 times the length L.

b) As a rule, the thickness of forecastle aft end plating and of plating of deckhouses located on the forecastle deck for steel structure is to be not less than the values given in Tab 13.

c) Secondary stiffeners

The section modulus of secondary stiffeners of the forecastle aft end and of deckhouses located on the forecastle deck for steel structure is to be not less than the values obtained from Tab 14.

Secondary stiffeners of the front of deckhouses located on the forecastle deck are to be fitted with brackets at their ends. Those of side and aft end bulkheads of deckhouses located on the forecastle deck are to be welded to decks at their ends.

21.6.3 Structure of cargo tanks

Scantling of cargo tanks is to be in compliance with the provisions of Chapter 3 and Chapter 4.

Table 13 : Minimum thickness of forecastle and deckhouses located on the forecastle deck

Structure	Plating	Minimum thickness, in mm
Forecastle	aft end	$1,04\ (5 + 0,01\ L_{WL}) + 0,5$
Deckhouses	front	$1,44\ (4 + 0,01\ L_{WL}) + 0,5$
	sides	$1,31\ (4 + 0,01\ L_{WL}) + 0,5$
	aft end	$1,22\ (4 + 0,01\ L_{WL}) + 0,5$

Table 14 : Minimum section modulus of forecastle and deckhouse secondary stiffeners located on the forecastle deck

Structure	Secondary stiffeners on:	Section modulus, in cm^3
Forecastle	aft end plating	3 times the value calculated according to Ch 5, Sec 1, [4]
Deckhouses	front plating	
	sides plating	0,75 times the value for the forecastle 'tweendeck frames
	aft end plating	

21.7 Hull outfitting

21.7.1 Rudders

The rudder stock diameter is to be increased by 5% with respect to that determined according to Ch 5, Sec 2, [8].

21.7.2 Bulwarks

- General:

  High bulwark fitted with a face plate of large cross-sectional area which contributes to the longitudinal strength are to be examined on a case by case basis.

- Stays:

  The bulwark stays are to be designed with an attachment to the deck able to withstand an accidental shifting of deck cargo (e.g. pipes).

21.7.3 Chain locker

Chain lockers are to be arranged as gas-safe areas. Hull penetrations for chain cables and mooring lines are to be arranged outside the hazardous areas.

Note 1: Hazardous area is an area in which an explosive atmosphere is or may be expected to be present in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.

22 Fire-fighting ships

22.1 Application

22.1.1 Ships having the service notation **fire-fighting** are to comply with the requirements of the present Article.

22.1.2 Hull material

Hull and superstructure materials are to comply with the requirements defined in NR467 Steel Ships, Pt E, Ch 4, Sec 4, [2.1].

22.2 Structure design principles

22.2.1 Hull structure

The strengthening of the structure of the ships, where necessary to withstand the forces imposed by the fire-extinguishing systems when operating at their maximum capacity in all possible directions of use, are to be considered by the Society on a case-by-case basis.

22.2.2 Water and foam monitors

The seatings of the monitors are to be of adequate strength for all modes of operation.

22.2.3 Arrangement for hull and superstructure openings

On ships for which the additional service feature **water spraying** is not assigned, steel deadlights or external steel shutters are to be provided on all windows, sidescuttles and navigation lights, except for the windows of the navigation bridge.

23 Oil recovery ships

23.1 Application

23.1.1 Ships having the service notation **oil recovery** are to comply with the requirements of the present Article, taking into account general requirements defined in NR467 Steel Ships, Pt E, Ch 5, Sec 1.

23.2 Ship arrangement

23.2.1 Specific ship arrangement is to comply with the requirements defined in NR467 Steel Ships, Pt E, Ch 5, Sec 2, [1].

23.3 Hull scantlings

23.3.1 Additional loads

For the checking of structures supporting oil recovery equipment, the reactions induced by this equipment during oil recovery operations may be calculated assuming that the oil recovery operations take place in moderate sea conditions (accelerations reduced by 10%).

If lifting appliances are used during oil recovery operations, the scantling of their supporting structures is to be examined on a case by case considering the ship motions and accelerations defined in the present Rules and requirements defined in NR467 Steel Ships, Pt E, Ch 8, Sec 4 checked according to Ch 5, Sec 2, [13].

In case of oil collected in movable tanks fitted on the weather deck, the resulting reactions to be considered for deck scantling are to be calculated, as a rule, according to Ch 3, Sec 4.

23.4 Construction and testing

23.4.1 Testing

Tests are to be carried out according to a specification submitted by the Interested Party, in order to check the proper operation of the oil recovery equipment.

These tests may be performed during dock and sea trials.

24 Cable-laying ships

24.1 Application

24.1.1 Ships having the service notation **cable laying** are to comply with the requirements of the present Article.

24.2 Hull scantlings

24.2.1 Cable tanks
The scantlings of cable tanks are to be obtained through direct calculations taking into account still water and wave loads for the most severe condition of use.

24.2.2 Connection of the machinery and equipment with the hull structure
The scantling of the structures in way of the connection between the hull structure and the machinery and equipment, constituting the laying or hauling line for submarine cables, are to be obtained through direct calculation based on the service loads of such machinery and equipment, as specified by the Designer.

The service loads of machinery and equipment specified by the Designer are to take into account the inertial loads induced by ship motions in the most severe condition of use.

24.3 Other structures

24.3.1 Fore part
In general, a high freeboard is needed in the forward area, where most repair work is carried out, in order to provide adequate safety and protection against sea waves.

24.4 Equipment

24.4.1 Hawse pipe
Hawse pipes are to be integrated into the hull structure in such a way that anchors do not interfere with the cable laying.

24.4.2 Sheaves
Where there is a risk that, in rough sea conditions, sheaves are subjected to wave impact loads, special solutions such as the provision of retractable type sheaves may be adopted.

25 Diving support vessels

25.1 Application

25.1.1 Ships intended to support diving operations are to comply with the requirements of the present Article.

25.1.2 General
General requirements defined in NR467 Steel Ships, Pt E, Ch 7, Sec 1 are applicable.

25.2 General arrangement

25.2.1 General arrangements defined in NR467 Steel Ships, Pt E, Ch 7, Sec 2 are applicable.

25.2.2 Diving equipment foundations are to comply with NR467 Steel Ships, Pt E, Ch 7, Sec 3.

25.2.3 Launching system foundations are to comply with the requirements defined in Ch 5, Sec 2, [13] for lifting appliances.

25.2.4 Ships having the service notation **diving support-capable** are to comply with the requirements of NR467 Steel Ships, Pt E, Ch 7, Sec 6.

25.3 Initial inspection and testing

25.3.1 Requirements provided for initial inspection and testing of the diving equipment are defined in NR467 Steel Ships, Pt E, Ch 7, Sec 7.

26 Lifting units

26.1 Application

26.1.1 Ships having the service notation **lifting** are to comply with the requirements of the present Article.

26.1.2 General requirements defined in NR467 Steel Ships, Pt E, Ch 8, Sec 1 are applicable.

26.1.3 General arrangement
Location of lifting appliances and position of the crane during navigation are to be as defined in NR467 Steel Ships, Pt E, Ch 8, Sec 2.

26.1.4 Structural assessment
The structural assessment of the foundations of the lifting equipment, the devices for stowage during transit and the connecting bolts between the lifting equipment and the foundation is to be carried out as defined in NR467 Steel Ships, Pt E, Ch 8, Sec 4.

26.2 Initial inspection and testing

26.2.1 Lifting installations

Initial inspection and testing of the lifting installations are defined in NR467 Steel Ships, Pt E, Ch 8, Sec 6.

26.3 Self-elevating ships

26.3.1 Ships having the additional service feature **self elevating** are to be in accordance with general requirements defined in NR467 Steel Ships, Pt E, Ch 8, Sec 7.

27 Semi-submersible cargo ships

27.1 Application

27.1.1 Ships having the service notation **semi-submersible cargo ships** are to comply with the requirements of the present Article, taking into account the general requirements defined in NR467 Steel Ships, Pt E, Ch 9, Sec 1.

27.1.2 General arrangement

General arrangements defined in NR467 Steel Ships, Pt E, Ch 9, Sec 2 are applicable.

27.1.3 Hull structure

General requirements for the structural assessment of semi-submersible cargo ships are defined in NR467 Steel Ships, Pt E, Ch 9, Sec 4, [1].

In addition to the design load defined in Chapter 3, the structural assessment is to be performed against temporary submerged scenario considering the maximum submerged draft and the navigation coefficient n. the loading conditions during temporary submerged conditions are to be considered on a case by case basis.

The scantlings of the structures in way of the connection between the hull structure and the buoyancy casings are to be obtained through direct calculations taking into account permissible stresses in the elements of the buoyancy casings and in connections with the hull structure equal to the following values:

$\sigma \leq 0,8 R_{eH}$

$\tau \leq 0,4 R_{eH}$

where:

R_{eH} : Minimum guaranteed yield stress, in N/mm^2, of the material.

27.2 Initial inspection and testing

27.2.1 Initial inspection and testing of the submersion function of the ship are defined in NR467 Steel Ships, Pt E, Ch 9, Sec 8.

28 Standby rescue vessels

28.1 General

28.1.1 Ships having the service notation **standby rescue** are to comply with the requirements of NR467 Steel Ships, Pt E, Ch 10, Sec 1, Sec 2 and Sec 3.

29 Accommodation units

29.1 General

29.1.1 Ships having the service notation **accommodation** are to comply with requirements of NR467 Steel Ships, Pt E, Ch 11, Sec 1.

30 Pipe-laying units

30.1 Application

30.1.1 Ships having the service notation **pipe laying** are to comply with the requirements of the present Article, taking into account the general requirements defined in NR467 Steel Ships, Pt E, Ch 12, Sec 1.

30.2 Structural assessment

30.2.1 The structural assessment of the foundations of pipe laying equipment supported by the hull structure is to be carried out as defined in NR467 Steel Ships, Pt E, Ch 12, Sec 3.

30.3 Initial inspection and testing

30.3.1 Initial inspection and testing of the pipe laying installations are defined in NR467 Steel Ships, Pt E, Ch 12, Sec 4.

31 Hydrogen-fuelled ships

31.1 Portable tanks

31.1.1 If taken as a reference for the calculations of the lashing of H_2 portable tanks as per NR678 Ch 1, Sec 7, [1.6], the ship accelerations defined in Ch 3, Sec 4 are to be increased by 60% in order to reflect a 25-year return period.

NR600

Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non-Cargo Ships less than 90 m

CHAPTER 7
CONSTRUCTION AND TESTING

Section 1 General

1 General

1.1

1.1.1 The present Chapter contains the requirements concerning the welding, welds and assembling of structure, and the testing and construction survey.

2 Welding, welds and assembly of structure

2.1 Material

2.1.1 The scantling and joint design of welded connection for ships built in steel materials are defined in Sec 2.

2.1.2 The equivalent requirements for ships built in aluminium alloys are defined in NR561 Aluminium Ships.

The conditions for heterogeneous assembly between steel and aluminium structures are also to be as defined in NR561 Aluminium Ships.

2.1.3 The scantling of joint assembly for ships built in composite materials are to be as defined in NR546 Composite Ships.

3 Testing

3.1 General

3.1.1 The testing conditions for tanks, watertight and weathertight structures for ships built in steel, aluminium and composite materials are defined in Sec 3.

4 Construction survey

4.1 General

4.1.1 The requirements for hull construction and survey within the scope of classification and/or certification of ships hulls are defined in:

- for steel ship: in Sec 4
- for aluminium ship: in NR561 Aluminium Ships
- for composite ship: in NR546 Composite Ships.

Section 2 Weld Connections for Steel Structure

1 General

1.1 Materials

1.1.1 The requirements of the present Section apply to the scantling and joint design of welded connections of ships built in steel materials.

1.2 Application

1.2.1 The scantling and preparation for the welded connections of steel hull structure are to be as defined in the present Section.

Other equivalent standards may be accepted by the Society, on a case-by-case basis.

The general requirements relevant to the execution of welding, inspection and qualification of welding procedures are given in Chapter 12 of NR216 Materials and Welding.

1.2.2 Welding of various types of steel is to be carried out by means of welding procedures approved for the purpose.

1.2.3 Weld connections are to be executed according to:

- the approved hull construction plans, and
- the weld and welding booklets submitted to the Society.

Any details not specifically represented in the plans are, in any case, to comply with the applicable requirements of the Society.

1.2.4 The method used to prepare the parts to be welded is left to the discretion of each shipbuilder, according to its own technology and experience.

These methods are to be reviewed during the qualification of welding procedure, as defined in [1.3.2].

1.3 Weld and welding booklet

1.3.1 Weld booklet

A weld booklet, including the weld scantling such as throat thickness, pitch and design of joint, is to be submitted to the Society for examination.

The weld booklet is not required if the structure drawings submitted to the Society contain the necessary relevant data defining the weld scantling.

1.3.2 Welding booklet

A welding booklet including the welding procedures, operations, inspections and the modifications and repair during construction as defined in Sec 4, [3.4] is to be submitted to the Surveyor for examination.

2 Scantling of welds

2.1 Butt welds

2.1.1 As a rule, butt welding is to be used for plate and stiffener butts and is mandatory for heavily stressed butts such as those of the bottom, keel, side shell, sheerstrake and strength deck plating, and bulkheads (in particular bulkheads located in areas where vibrations occur).

2.1.2 As a rule, all structural butt joints are to be full penetration welds completed by a backing run weld.

2.2 Butt welds on permanent backing

2.2.1 Butt welding on permanent backing may be accepted where a backing run is not feasible.

In this case, the type of bevel and the gap between the members to be assembled are to be such as to ensure a proper penetration of the weld on its backing.

2.3 Fillet weld on a lap-joint

2.3.1 General

Fillet weld in a lap joint may be used only for members submitted to moderate stresses, taking into account the typical details shown on Tab 1.

Continuous welding is generally to be adopted.

2.3.2 The surfaces of lap-joints are to be in sufficiently close contact.

2.4 Slot welds

2.4.1 Slot welding may be used where fillet welding is not possible.

Slot welding is, in general, permitted only where stresses act in a predominant direction. Slot welds are, as far as possible, to be aligned in this direction.

2.4.2 Slot welds are to be of appropriate shape (in general oval) and dimensions, depending on the plate thickness, and may not be completely filled by the weld (see Tab 2).

The distance between two consecutive slot welds is to be not greater than a value which is defined on a case-by-case basis taking into account:

- the transverse spacing between adjacent slot weld lines
- the stresses acting in the connected plates
- the structural arrangement below the connected plates.

2.5 Plug welding

2.5.1 Plug welding may be adopted exceptionally as a substitute to slot welding.

Typical details are given in Tab 2.

Table 1 : Typical lap joint (manual welding)

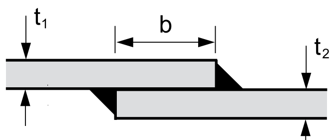
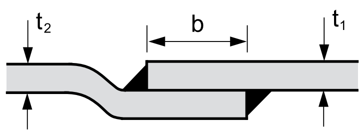
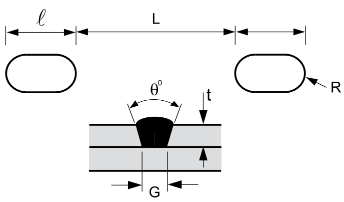
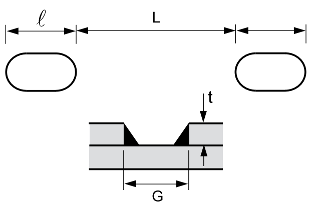
Detail	Standard	Remark
Fillet weld in lap joint  $t_1 \geq t_2$	$b = 2\ t_2 + 25$ mm	location of lap joint to be approved by the Society
Fillet weld in joggled lap joint  $t_1 \geq t_2$	$b \geq 2\ t_2 + 25$ mm	

Table 2 : Plug and slot welding (manual welding)

Detail	Standard	
Plug welding 	• $t \leq 12$ mm $\ell = 60$ mm R = 6 mm $40° \leq \theta \leq 50°$ G = 12 mm $L > 2\ \ell$	• 12 mm $< t \leq 25$ mm $\ell = 80$ mm R = 0,5 t mm $\theta = 30°$ G = t mm $L > 2\ \ell$
Slot welding 	• $t \leq 12$ mm G = 20 mm $\ell = 80$ mm $2\ \ell \leq L \leq 3\ \ell$, max 250 mm	• $t > 12$ mm G = 2 t $\ell = 100$ mm $2\ \ell \leq L \leq 3\ \ell$, max 250 mm

2.6 Fillet weld

2.6.1 Fillet welding types

Fillet welding may be of the following types:

- continuous fillet welding, where the weld is constituted by a continuous fillet on each side of the abutting plate
- intermittent fillet welding, which may be subdivided into:
  - chain welding
  - staggered welding.

2.6.2 Double continuous fillet weld location

As a general rule, double continuous fillet weld is to be required in the following locations, as appropriate:

a) Watertight and oiltight connections

b) Main engine and auxiliary machinery seatings

c) Bottom structure of planing hull in way of jet room spaces

d) Structure in way of bilge keel, stabiliser, bow thruster, cranes

e) Bottom structure in the vicinity of propeller blade

f) Primary and secondary stiffener web to attached plating or flange at ends, over a distance d at least equal to:

   - For secondary stiffeners:
     - general: the depth h of the stiffeners, with 300 mm ≥ d ≥ 75 mm. Where end brackets are fitted, the length in way of brackets and at least 50 mm beyond the bracket toes
     - floors web stiffeners: 20% of the span from span ends
     - bulkhead stiffeners: 25% of the span from span ends.
   - For primary stiffeners:
     - 20% of the span from the span ends. Where end brackets are fitted, the length in way of brackets and at least 100 mm beyond the bracket toes.

   Note 1: Where direct calculations according to [2.6.4] and [2.6.5] or equivalent are carried out, discontinuous fillet weld may be considered on a case-by-case basis.

g) Stiffeners in tanks intended for the carriage of ballast or fresh water.

h) Secondary stiffener of deck plating subjected to wheel loads.

Continuous fillet weld may also be adopted in lieu of intermittent welding wherever deemed suitable, and is recommended where the length p, defined according to [2.6.5], is low.

2.6.3 Throat thickness of double continuous fillet weld

The throat thickness t_T of a double continuous fillet weld, in mm, is to be obtained from the following formula:

$$t_T = w_F \, t \geq t_{Tmin}$$

where:

w_F : Welding factor for the various hull structural elements, defined in Tab 3

t : Actual thickness, in mm, of the thinner plate of the assembly

t_{Tmin} : Minimum throat thickness, in mm, taken equal to:

- t_{Tmin} = 3,0 mm, where the thickness of the thinner plate is less than 6 mm
- t_{Tmin} = 3,5 mm, otherwise.

Note 1: A lower value of t_{Tmin} may be accepted on a case by case basis depending on the results of structural analyses.

The throat thickness t_T may be increased for particular loading conditions.

The leg length of fillet weld is to be not less than 1,4 times the throat thickness.

When fillet welding is carried out with automatic welding procedures, the throat thickness t_T may be reduced up to 15%, depending on the properties of the electrodes and consumables. However, this reduction may not be greater than 1,5 mm.

The same reduction applies also for semi-automatic procedures where the welding is carried out in downhand position.

Table 3 : Welding factor w_F for the various hull structural connections

<table>
<tr><th rowspan="2">Hull area</th><th colspan="3">Connection</th><th rowspan="2">w_F (1)</th></tr>
<tr><th>of</th><th colspan="2">to</th></tr>
<tr><td rowspan="12">General, unless otherwise specified in the Table</td><td>watertight plates</td><td colspan="2">boundaries</td><td>0,35</td></tr>
<tr><td>non-tight plates</td><td colspan="2">boundaries</td><td>0,20</td></tr>
<tr><td>strength decks</td><td colspan="2">side shell</td><td>0,45</td></tr>
<tr><td rowspan="3">webs of secondary stiffeners</td><td colspan="2">plating</td><td>0,13</td></tr>
<tr><td colspan="2">plating at ends (2)</td><td>0,20</td></tr>
<tr><td colspan="2">web of primary stiffener</td><td>see [2.6.7]</td></tr>
<tr><td rowspan="5">web of primary stiffeners</td><td colspan="2">plating and flange</td><td>0,20</td></tr>
<tr><td colspan="2">plating and flange at ends (2)</td><td>0,30 (3)</td></tr>
<tr><td colspan="2">bottom and inner bottom (in way of transverse and/or longitudinal bulkhead supported on tank top)</td><td>0,45</td></tr>
<tr><td colspan="2">deck (for cantilever deck beam)</td><td>0,45</td></tr>
<tr><td colspan="2">web of primary stiffeners</td><td>0,35</td></tr>
<tr><td rowspan="2">Structures located forward of 0,75 L from the aft end</td><td>secondary stiffeners</td><td colspan="2">bottom and side shell plating</td><td>0,20</td></tr>
<tr><td>primary stiffeners</td><td colspan="2">bottom, inner bottom and side shell plating</td><td>0,25</td></tr>
<tr><td rowspan="2">Structures located in bottom slamming area or in the first third of the platform bottom of catamaran</td><td>secondary stiffeners</td><td colspan="2">bottom plating</td><td>0,20</td></tr>
<tr><td>primary stiffeners</td><td colspan="2">bottom plating</td><td>0,25</td></tr>
<tr><td rowspan="9">Machinery space</td><td rowspan="3">girders</td><td rowspan="3">bottom and inner bottom plating</td><td>in way of main engine foundations</td><td>0,45</td></tr>
<tr><td>in way of seating of auxiliary machinery</td><td>0,35</td></tr>
<tr><td>elsewhere</td><td>0,25</td></tr>
<tr><td rowspan="2">floors (except in way of main engine foundations)</td><td rowspan="2">bottom and inner bottom plating</td><td>in way of seating of auxiliary machinery</td><td>0,35</td></tr>
<tr><td>elsewhere</td><td>0,25</td></tr>
<tr><td rowspan="2">floors in way of main engine foundations</td><td colspan="2">bottom plating</td><td>0,35</td></tr>
<tr><td colspan="2">foundation plates</td><td>0,45</td></tr>
<tr><td rowspan="2">floors</td><td rowspan="2">centre girder</td><td>single bottom</td><td>0,45</td></tr>
<tr><td>double bottom</td><td>0,25</td></tr>
<tr><td rowspan="3">Superstructures and deckhouses</td><td>external bulkheads</td><td colspan="2">deck</td><td>0,35</td></tr>
<tr><td>internal bulkheads</td><td colspan="2">deck</td><td>0,13</td></tr>
<tr><td>secondary stiffeners</td><td colspan="2">external and internal bulkhead plating</td><td>0,13</td></tr>
<tr><td rowspan="2">Pillars</td><td rowspan="2">pillars</td><td rowspan="2">deck</td><td>pillars in compression</td><td>0,35</td></tr>
<tr><td>pillars in tension</td><td>full penetration welding</td></tr>
<tr><td rowspan="4">Rudders</td><td>primary element directly connected to solid parts or rudder stock</td><td colspan="2">solid part or rudder stock</td><td>0,45</td></tr>
<tr><td>other webs</td><td colspan="2">each other</td><td>0,20</td></tr>
<tr><td rowspan="2">webs</td><td rowspan="2">plating</td><td>in general</td><td>0,20</td></tr>
<tr><td>top and bottom plates of rudder plating</td><td>0,35</td></tr>
<tr><td colspan="5">(1) For connections where $w_F \geq 0,35$, continuous fillet welding is to be adopted.
(2) The web at the end of intermittently welded stiffeners is to be continuously welded to the plating or the flange plate (see [2.6.2], item f))
(3) Full penetration welding may be required, depending on the structural design and loads.</td></tr>
</table>

2.6.4 Direct calculation of double continuous fillet weld

Where deemed necessary, the minimum throat thickness t_T of a double continuous fillet weld between stiffener web and associated plating and/or flange, in mm, may be determined as follows:

$$t_T \geq \frac{Tm}{2I\tau} \geq t_{Tmin}$$

where:

T : Shear force, in N, in the considered section of the stiffener

I : Inertia, in mm^4, of the stiffener

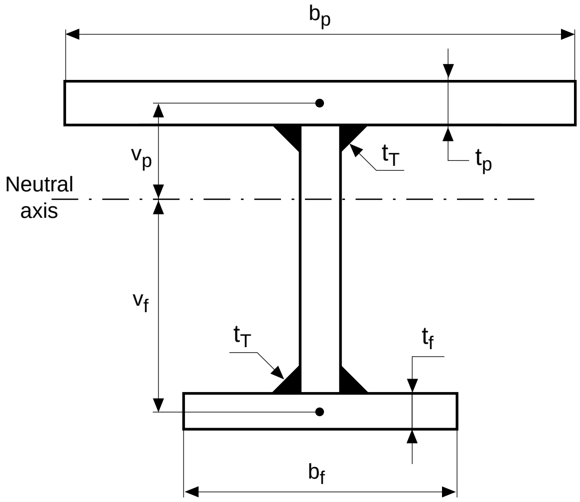
τ : Permissible shear stress, in N/mm^2, as defined in Ch 2, Sec 3

t_{Tmin} : Minimum throat thickness as defined in [2.6.3]

m : Value, in mm^3, calculated as follows (see Fig 1):

- for weld between flange and web:
  $m = t_f\, b_f\, v_f$
- for weld between associated plate and web:
  $m = t_p\, b_p\, v_p$

Figure 1 : Stiffener elements definition for m calculation



2.6.5 Throat thickness of intermittent weld

The throat thickness t_{IT}, in mm, of intermittent welds is to be not less than:

$$t_{IT} = t_T \frac{p}{d}$$

where:

t_T : Throat, in mm, of the double continuous fillet weld, equal to:
$t_T = w_F\, t$
with:
w_F, t : As defined in [2.6.3]

p, d : Defined as follows:

- chain welding (see Fig 2):
  $d \geq 75$ mm
  $p - d \leq 200$ mm
- staggered welding (see Fig 3):
  $d \geq 75$ mm
  $p - 2\,d \leq 300$ mm
  $p \leq 2\,d$ for connections subjected to high alternate stresses.

Figure 2 : Intermittent chain welding

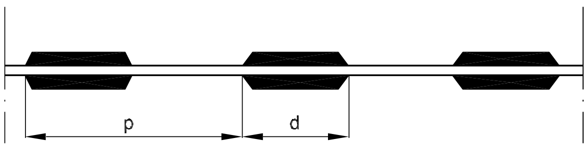
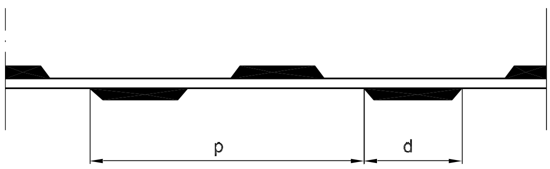


Figure 3 : Intermittent staggered welding



2.6.6 Fillet weld in way of cut-outs

The throat thickness of the welds between the cut-outs in primary supporting member webs for the passage of secondary stiffeners is to be not less than the value obtained, in mm, from the following formula:

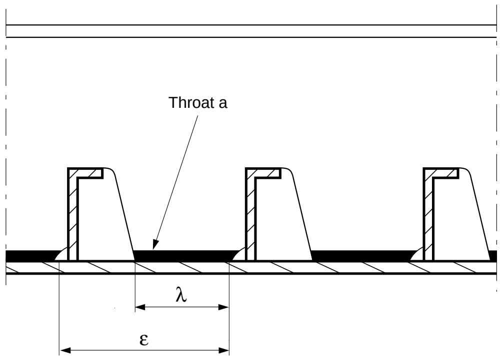
$$t_{TC} = t_T \frac{\varepsilon}{\lambda}$$

where:

t_T : Throat thickness defined in [2.6.3]

ε, λ : Dimensions, in mm, to be taken as shown in Fig 4.

Figure 4 : Continuous fillet welding between cut-outs



2.6.7 Welding between secondary and primary stiffeners

As a general rule, the resistant weld section A_W, in cm², of the fillet weld connecting the secondary stiffeners to the web of primary members is not to be less than:

a) General case:

$$A_W \geq \varphi p s \ell \left(1 - \frac{s}{2\ell}\right) k 10^{-3}$$

where:

φ : Coefficient as indicated in Tab 4

p : Design pressure, in kN/m², acting on the secondary stiffeners

s : Spacing of secondary stiffeners, in m

ℓ : Span of secondary stiffeners, in m

k : Greatest material factor of secondary stiffener and primary member, as defined in Ch 1, Sec 2

b) Case of side shell impact:

$$A_W \geq \varphi s P \left(0,6 - \frac{s}{4}\right) k 10^{-3}$$

where:

s : Spacing of secondary stiffeners, in m, without being taken greater than 0,6 m

P : Pressure, in KN/m², to be taken equal to:

$P = C_p \, P_{ssmin}$

C_p : Pressure coefficient equal to:

$C_p = -0,98s^2 + 0,3s + 0,95 \geq 0,8$

p_{ssmin} : Impact pressure, in kN/m², acting on the secondary stiffeners as defined in Ch 3, Sec 3, [3.1.2].

c) Case of wheeled loads:

$$A_W \geq \varphi p_w k 10^{-3}$$

where:

p_w : Maximum shear force reaction in way of the connection with the primary stiffener, in kN, induced by wheeled load applied on the secondary stiffener

φ, k : Coefficients defined in item a).

Table 4 : Coefficient φ

Case	Weld	φ
1	Parallel to the reaction exerted on primary member	100
2	Perpendicular to the reaction exerted on primary member	75

3 Typical joint preparation

3.1 General

3.1.1 The type of connection and the edge preparation are to be appropriate to the welding procedure adopted, the structural elements to be connected and the stresses to which they are subjected.

3.2 Butt welding

3.2.1 Permissible root gap between elements to be welded and edge preparations are to be defined during qualification tests of welding procedures and indicated in the welding booklet.

For guidance purposes, typical edge preparations and gaps are indicated in Tab 5.

3.2.2 In case of welding of two plates of different thickness equal to or greater than:

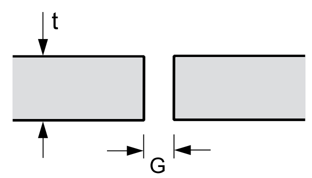
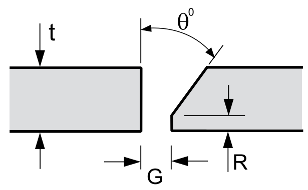
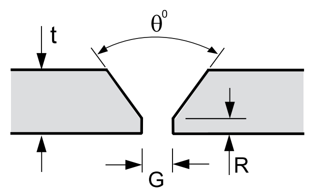
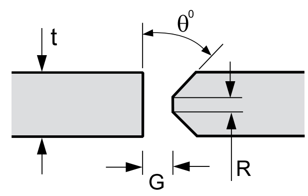
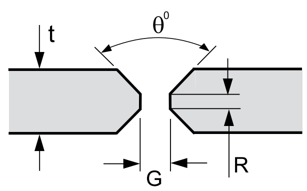
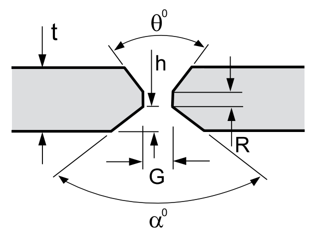
- 3 mm, if the thinner plate has a thickness equal to or less than 10 mm, or
- 4 mm, if the thinner plate has a thickness greater than 10 mm,

a taper having a length of not less than 4 times the difference in thickness is to be adopted for connections of plating perpendicular to the direction of main stresses. For connections of plating parallel to the direction of main stresses, the taper length may be reduced to 3 times the difference in thickness.

When the difference in thickness is less than the above values, it may be accommodated in the weld transition between plates.

For large thicknesses (e.g. 25 mm), other criteria may be considered on a case-by-case basis, when deemed equivalent.

Table 5 : Typical butt weld plate edge preparation (manual welding) - See Note 1

Detail	Standard	Detail	Standard
Square butt 	$t \leq 5$ mm $G = 3$ mm	**Single bevel butt** 	$t > 5$ mm $G \leq 3$ mm $R \leq 3$ mm $50° \leq \theta \leq 70°$
Single vee butt 	$G \leq 3$ mm $50° \leq \theta \leq 70°$ $R \leq 3$ mm	**Double bevel butt** 	$t > 19$ mm $G \leq 3$ mm $R \leq 3$ mm $50° \leq \theta \leq 70°$
Double vee butt, uniform bevels 	$G \leq 3$ mm $R \leq 3$ mm $50° \leq \theta \leq 70°$	**Double vee butt, non-uniform bevels** 	$G \leq 3$ mm $R \leq 3$ mm $6 \leq h \leq t/3$ mm $\theta = 50°$ $\alpha = 90°$
Note 1: Different plate edge preparation may be accepted or approved by the Society on the basis of an appropriate welding procedure specification.			

3.2.3 Butt welding on backing

For butt welding on temporary or permanent backing, the edge preparations and gaps are to be defined by the shipyard, taking into account the type of backing plate.

3.2.4 Section, bulbs and flat bars

Stiffeners contributing to the longitudinal or transversal strength, or elements in general subject to high stresses, are to be connected together by butt joints with full penetration weld. Other solutions may be adopted if deemed acceptable by the Society on a case-by-case basis.

The work is to be done in accordance with an approved procedure, in particular, for work done on board or in conditions of difficult access to the welded connection where special measures may be required by the Society.

3.3 Fillet weld

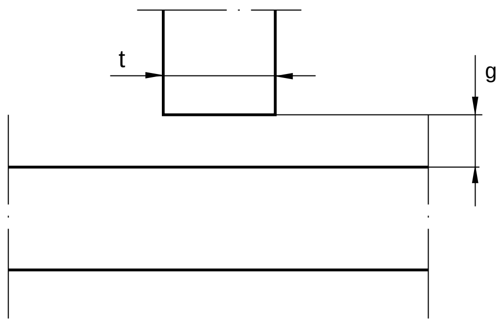
3.3.1 Clearance

In fillet weld T connections, a gap g, as shown in Fig 5, not greater than 2 mm may be accepted without increasing the throat thickness calculated according to [2.6.3] to [2.6.6] as applicable.

In the case of a gap greater than 2 mm, the above throat thickness is to be increased.

In any event, the gap g may not exceed 4 mm.

Figure 5 : Gap in fillet weld T connections

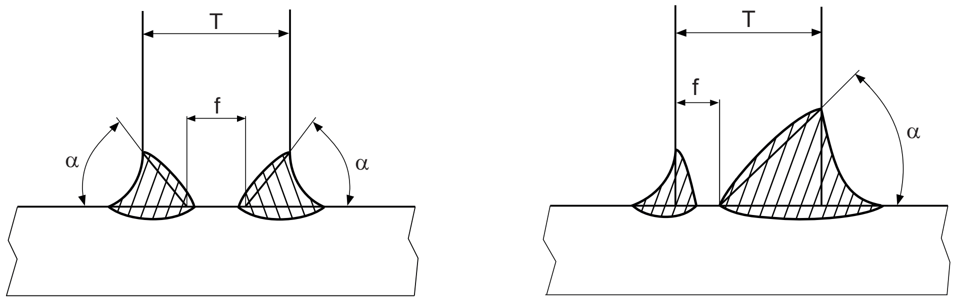


3.3.2 Preparation and penetration of fillet weld

Where partial or full T penetration welding are adopted for connections subjected to high stresses for which fillet welding is considered unacceptable by the Society, typical edge preparations are indicated in:

- for partial penetration welds: Fig 6, in which f, in mm, is to be taken between 3 mm and T/3, and α between 45° and 60°

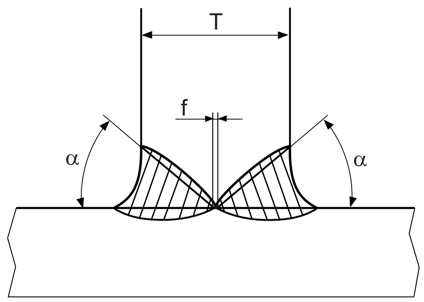
Figure 6 : Partial penetration weld



- for full penetration welds: Fig 7, in which f, in mm, is to be taken between 0 and 3 mm, and α between 45° and 60°.

  Back gouging may be required for full penetration welds.

Figure 7 : Full penetration weld



3.3.3 Lamellar tearing

Precautions are to be taken in order to avoid lamellar tears, which may be associated with:

- cold cracking when performing T connections between plates of considerable thickness or high restraint
- large fillet welding and full penetration welding on higher strength steels.

4 Plate misalignment

4.1 Misalignment in butt weld

4.1.1 Plate misalignment in butt connections

The misalignment m, measured as shown in Fig 8, between plates with the same thickness is to be less than 15% of the plate thickness without being greater than 3 mm.

4.2 Misalignment in cruciform connections

4.2.1 Misalignment in cruciform connections

The misalignment m in cruciform connections, measured on the median lines as shown in Fig 9, is to be less than t/2, where t is the thickness of the thinner abutting plate.

The Society may require lower misalignment to be adopted for cruciform connections subjected to high stresses.

Figure 8 : Plate misalignment in butt connections

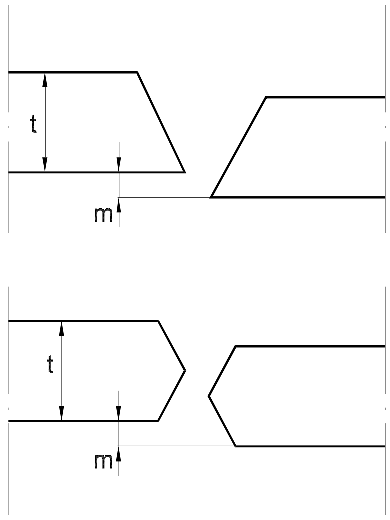
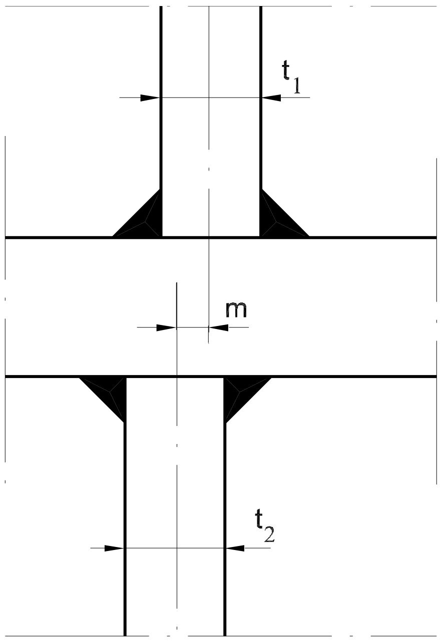


Figure 9 : Misalignment in cruciform connections



Section 3 Testing

1 Testing procedures of watertight compartments

1.1 Definitions

1.1.1 Each type of structural test (see [1.1.2]) and leak test (see [1.1.3]) is defined in Tab 1.

1.1.2 Structural test

A structural test is a test to verify the structural adequacy of tank construction. This may be a hydrostatic test or, where the situation warrants, a hydropneumatic test.

1.1.3 Leak test

A leak test is a test to verify the tightness of a boundary. Unless a specific test is indicated, this may be a hydrostatic/ hydropneumatic test or an air test. A hose test may be considered to be an acceptable form of leak test for certain boundaries, as indicated by footnote **(9)** of Tab 2.

1.1.4 Top of overflow

Top of any overflow system which is used to prevent overfilling of a tank. Such system can be an overflow pipe, air pipe, intermediate tank. For gravity tanks (i.e. sewage, grey water and similar tanks, not filled with pumps) the top of the overflow is to be taken as the highest point of the filling line.

Where a tank is fitted with multiple means of preventing overfilling, the decision on which overflow system is to be used to determine the test head is to be based on the highest point to which the liquid may rise in service.

Note 1: Gauging devices are not considered equivalent to an overflow system with the exception of fuel oil overflow tanks not intended to hold fuel which have been fitted with a level alarm.

1.2 General

1.2.1 Tests are to be carried out in the presence of a Surveyor at a stage sufficiently close to the completion of work, with all the hatches, doors, windows, etc., installed and all the penetrations including pipe connections fitted, and before any ceiling and cement work is applied over the joints. Specific test requirements are given in [1.6] and Tab 2 and Tab 3. For the timing of the application of coating and the provision of safe access to joints, see [1.7], [1.8] and Tab 4.

1.3 Application

1.3.1 As a rule, tests defined in the present Section are to be carried out for ships surveyed by the Society during construction within the scope of classification.

These test procedures are to confirm the watertightness of tanks, watertight boundaries, and the structural adequacy of tanks forming a part of the watertight subdivisions of ships. These procedures may also be applied to verify the weathertightness of structures and shipboard outfitting.

The tightness of all tanks and watertight boundaries of ships during new construction and ships relevant to major conversions or major repairs is to be confirmed by these test procedures prior to the delivery of the ships.

Note 1: Major repair means a repair affecting structural integrity.

1.3.2 All gravity tanks and other boundaries required to be watertight or weathertight are to be tested in accordance with these procedures and proven tight and structurally adequate as follows:

- gravity tanks for their tightness and structural adequacy
- watertight boundaries other than tank boundaries for their watertightness
- weathertight boundaries for their weathertightness.

Note 1: Gravity tank means a tank that is subject to vapour pressure not greater than 70 kPa.

1.3.3 Testing of structures not listed in Tab 2 or Tab 3 is to be specially considered by the Society.

1.3.4 Testing procedures of watertight compartments are defined in:

- for SOLAS ships: [1.3.5]
- for SOLAS exempt/equivalent ships: [1.3.6]
- for non-SOLAS ships: [1.3.7].

1.3.5 Testing procedures of watertight compartments for SOLAS Ships are to be carried out in accordance with the requirements of [1.4] to [1.9], unless:

a) the shipyard provides documentary evidence of the shipowner's agreement to a request to the Flag Administration for an exemption from the application of SOLAS Chapter II-1, Regulation 11, or for an equivalency agreeing that the content of [1.10] is equivalent to SOLAS Chapter II-1, Regulation 11; and

b) the above-mentioned exemption/equivalency has been granted by the responsible Flag Administration.

1.3.6 Testing procedures of watertight compartments for SOLAS exempt/equivalent Ships are to be carried out in accordance with the requirements of [1.10], for which:

a) the shipyard provides documentary evidence of the shipowner's agreement to a request to the Flag Administration for an exemption from the application of SOLAS Chapter II-1, Regulation 11, or for an equivalency agreeing that the content of [X.X] is equivalent to SOLAS Chapter II-1, Regulation 11; and

b) the above-mentioned exemption/equivalency has been granted by the responsible Flag Administration.

1.3.7 Testing procedures of watertight compartments for non-SOLAS Ships are to be carried out in accordance with the requirements of [1.11].

Table 1 : Types of test

Test types	Procedure
Hydrostatic test (leak and structural)	The space to be tested is filled with a liquid to a specified head
Hydropneumatic test (leak and structural)	Combination of a hydrostatic test and an air test, the space to be tested being partially filled with liquid and pressurized with air
Hose test (leak)	Tightness check of the joint to be tested by means of a jet of water, the joint being visible from the opposite side
Air test (leak)	Tightness check by means of an air pressure differential and a leak-indicating solution. It includes tank air tests and joint air tests, such as compressed air fillet weld tests and vacuum box tests
Compressed air fillet weld test (leak)	Air test of fillet welded tee joints, by means of a leak indicating solution applied on fillet welds
Vacuum box test (leak)	A box over a joint with a leak indicating solution applied on the welds. A vacuum is created inside the box to detect any leaks
Ultrasonic test (leak)	Tightness check of the sealing of closing devices such as hatch covers, by means of ultrasonic detection techniques
Penetration test (leak)	Check, by means of low surface tension liquids (i.e. dye penetrant test), that no visual dye penetrant indications of potential continuous leakages exist in the boundaries of a compartment

1.4 Structural test procedures

1.4.1 Type and time of test

Where a structural test is specified in Tab 1 or Tab 2, a hydrostatic test in accordance with [1.6.1] is acceptable. Where practical limitations (strength of building berth, light density of liquid, etc.) prevent the performance of a hydrostatic test, a hydropneumatic test in accordance with [1.6.2] may be accepted instead.

A hydrostatic or hydropneumatic test for the confirmation of structural adequacy may be carried out while the ship is afloat, provided the results of a leak test are confirmed to be satisfactory before the ship is set afloat.

Alternative equivalent tank testing procedures may be considered for tanks which are constructed from composite materials such as glass reinforced plastic (GRP) and fibre reinforced plastic (FRP) based on the recommendations of the composite manufacturer.

1.4.2 Testing schedule for new construction and major structural conversion or repair

a) Tanks which are intended to hold liquids, and which form part of the watertight subdivision of the ship, shall be tested for tightness and structural strength as indicated in Tab 2 and Tab 3.

b) The tank boundaries are to be tested from at least one side. The tanks for the structural test are to be selected so that all the representative structural members are tested for the expected tension and compression.

c) The watertight boundaries of spaces other than tanks may be exempted from the structural test, provided that the boundary watertightness of the exempted spaces is verified by leak tests and inspections. The tank structural test is to be carried out and the requirements from item a) to item b) are to be applied for ballast holds, chain lockers, and for a representative cargo hold in case of cargo holds intended for in-port ballasting.

d) Tanks which do not form part of the watertight subdivision of the ship, may be exempted from structural testing provided that the boundary watertightness of the exempted spaces is verified by leak tests and inspections.

1.5 Leak test procedures

1.5.1 For the leak tests specified in Tab 2, tank air tests, compressed air fillet weld tests and vacuum box tests, in accordance respectively with [1.6.3], [1.6.5] and [1.6.6], or their combinations, are acceptable. Hydrostatic or hydropneumatic tests may be also accepted as leak tests, provided [1.7], [1.8] and [1.9] are complied with. Hose tests, in accordance with [1.6.3], are also acceptable for items 14 to 17 referred to in Tab 2, taking footnote **(9)** into account.

1.5.2 Air tests of joints may be carried out at the block stage, provided that all work on the block that may affect the tightness of a joint is completed before the test. See also [1.7.1] for the application of final coatings, [1.8] for the safe access to joints, and Tab 4 for the summary.

1.6 Test methods

1.6.1 Hydrostatic test

Unless another liquid is approved, hydrostatic tests are to consist in filling the space with fresh water or sea water, whichever is appropriate for testing, to the level specified in Tab 2 or Tab 3.

In case where a tank is intended for cargoes having a density higher than the density of the liquid used for the test, the testing pressure height is to be specially considered, but the test pressure shall not exceed the maximum design internal pressure at the top of tank.

All the external surfaces of the tested space are to be examined for structural distortion, bulging and buckling, any other related damage, and leaks.

Table 2 : Test requirements for tanks and boundaries

Item	Tank or boundaries to be tested	Test type	Test head or pressure	Remarks
1	Double bottom tanks **(1)**	leak and structural **(2)**	The greater of: • top of the overflow **(3)** • 2,4 m above top of tank **(4)** • bulkhead deck	
2	Double bottom voids **(5)**	leak	See [1.6.4] to [1.6.6], as applicable	Including pump room double bottom and bunker tank protection double hull required by MARPOL Annex I
3	Double side tanks	leak and structural **(2)**	The greater of: • top of the overflow **(3)** • 2,4 m above top of tank **(4)** **(10)** • bulkhead deck	
4	Double side voids	leak	See [1.6.4] to [1.6.6], as applicable	
5	Other tanks than those listed elsewhere in this Table	leak and structural **(2)**	The greater of: • top of the overflow **(3)** • 2,4 m above top of tank **(4)** **(10)**	
6	Cargo oil tanks	leak and structural **(2)**	The greater of: • top of the overflow **(3)** • 2,4 m above top of tank **(4)** • top of tank plus the design vapour pressure **(4)**	
7	Ballast holds of bulk carriers	leak and structural **(2)**	The greater of: • top of the overflow • top of cargo hatch coaming	
8	Peak tanks	leak and structural **(2)**	The greater of: • top of the overflow **(3)** • 2,4 m above top of tank **(4)** **(10)**	After peak to be tested after installation of stern tube
9	a) Fore peak spaces with equipment	leak	See [1.6.3] to [1.6.6], as applicable	
	b) Fore peak voids	leak	See [1.6.3] to [1.6.6], as applicable	
	c) Aft peak spaces with equipment	leak	See [1.6.3] to [1.6.6], as applicable	After peak to be tested after installation of stern tube
	d) Aft peak voids	leak	See [1.6.4] to [1.6.6], as applicable	
10	Cofferdams	leak	See [1.6.4] to [1.6.6], as applicable	
11	a) Watertight bulkheads	leak **(6)**	See [1.6.3] to [1.6.6], as applicable **(7)**	
	b) Superstructure end bulkheads	leak	See [1.6.3] to [1.6.6], as applicable	
12	Watertight doors below freeboard or bulkhead deck	leak **(8)** **(7)**	See [1.6.3] to [1.6.6], as applicable	

Item	Tank or boundaries to be tested	Test type	Test head or pressure	Remarks
13	Double plate rudder blades	leak	See [1.6.4] to [1.6.6], as applicable	
14	Shaft tunnels clear of deep tanks	leak **(9)**	See [1.6.3] to [1.6.6], as applicable	
15	Shell doors	leak **(9)**	See [1.6.3] to [1.6.6], as applicable	
16	Weathertight hatch covers and closing appliances	leak **(9)** **(7)**	See [1.6.3] to [1.6.6], as applicable	Hatch covers closed by tarpaulins and battens excluded
17	Dual purpose tank/dry cargo hatch covers	leak **(9)** **(7)**	See [1.6.3] to [1.6.6], as applicable	In addition to the structural test in item 6 or item 7
18	Chain lockers	leak and structural	Head of water up to top of chain pipe	
19	L.O. sump tanks and other similar tanks/spaces under main engines	leak **(11)**	See [1.6.3] to [1.6.6], as applicable	
20	Ballast ducts	leak and structural **(2)**	The greater of: • ballast pump maximum pressure • setting of any pressure relief valve	
21	Fuel oil tanks	leak and structural **(2)**	The greater of: • top of the overflow **(3)** • 2,4 m above top of tank **(4)** **(10)** • top of tank plus the design vapour pressure **(4)** • bulkhead deck	
22	Fuel oil overflow tanks not intended to hold fuel	leak and structural **(2)**	The greater of: • top of the overflow **(3)** • 2,4 m above top of tank **(4)** **(10)** • bulkhead deck	

(1) Including the tanks arranged in accordance with the provisions of NR467 Steel Ships Pt B, Ch 2, Sec 2, [3.1.4], where applicable.
(2) See [1.4.2], item a).
(3) See [1.1.4]
(4) The top of a tank is the deck forming the top of the tank, excluding any hatchways.
(5) Including the duct keels and dry compartments arranged in accordance with the provisions of SOLAS, Regulations II-1/11.2 and II-1/9.4 respectively, and/or the oil fuel tank protection and pump room bottom protection arranged in accordance with the provisions of MARPOL Annex I, Chapter 3, Part A, Regulation 12A and Chapter 4, Part A, Regulation 22, respectively, where applicable.
(6) A structural test (see [1.4.2]) is also to be carried out for a representative cargo hold in case of cargo holds intended for in-port ballasting. The filling level required for the structural test of such cargo holds is to be the maximum loading that will occur in-port, as indicated in the loading manual.
(7) As an alternative to the hose test, other testing methods listed in [1.6.7] to [1.6.9] may be acceptable, subject to adequacy of such testing methods being verified. See SOLAS Regulation II-1/11.1. For watertight bulkheads (item 11 a)), alternatives to the hose test may be used only where the hose test is not practicable.
(8) Where watertightness of watertight doors has not been confirmed by a prototype test, a hydrostatic test (filling of the watertight spaces with water) is to be carried out. See SOLAS Regulation II-1/16.2 and MSC.1/Circ.1572/Rev.1.
(9) Hose test may be also considered as a medium of the leak test. See [1.1.3].
(10) For non-SOLAS ships, 2,4 is be replaced by 0,3D + 0,76, in m above the top of the tank, without being taken greater than 2,4 m.
(11) Where L.O. sump tanks and other similar spaces under main engines intended to hold liquid form part of the watertight subdivision of the ship, they are to be tested as per the requirements of Item 5, Deep tanks other than those listed elsewhere in this table.

Table 3 : Additional test requirements for special service ships/tanks

Item	Type of ship/tank	Structure to be tested	Type of test	Test head or pressure	Remarks
1	Edible liquid tanks	Independent tanks	leak and structural	The greater of: • top of the overflow **(2)** • 0,9 m above top of tank **(1)**	
2	Chemical carriers	Integral or independent cargo tanks	leak and structural	The greater of: • 2,4 m above top of tank **(1)** • top of tank plus the design vapour pressure **(1)**	Where a cargo tank is designed for the carriage of cargoes with specific gravities greater than 1,0 , see [1.6.1]

(1) Top of tank is deck forming the top of the tank excluding any hatchways.
(2) See [1.1.4]

1.6.2 Hydropneumatic test

Hydropneumatic tests, where approved, are to be such that the test condition, in conjunction with the approved liquid level and supplemental air pressure, simulates the actual loading as far as practicable. The requirements and recommendations in [1.6.4] for tank air tests apply also to hydropneumatic tests.

All the external surfaces of the tested space are to be examined for structural distortion, bulging and buckling, any other related damage, and leaks.

1.6.3 Hose test

Hose tests are to be carried out with the pressure in the hose nozzle maintained at least at $2 \cdot 10^5$ Pa during the test. The nozzle is to have a minimum inside diameter of 12 mm and to be at a perpendicular distance from the joint not exceeding 1,5 m. The water jet is to impinge upon the weld.

Where a hose test is not practical because of possible damage to machinery, electrical equipment insulation, or outfitting items, it may be replaced by a careful visual examination of the welded connections, supported where necessary by means such as a dye penetrant test or an ultrasonic leak test, or equivalent.

1.6.4 Tank air test

All boundary welds, erection joints and penetrations including pipe connections are to be examined in accordance with approved procedures and under a stabilized pressure differential above atmospheric pressure not less than $0,15 \cdot 10^5$ Pa, with a leak-indicating solution (such as soapy water/detergent or a proprietary solution) applied.

A U-tube having a height sufficient to hold a head of water corresponding to the required test pressure is to be arranged. The cross-sectional area of the U-tube is not to be less than that of the pipe supplying air to the tank.

Note 1: Arrangements involving the use of two calibrated pressure gauges to verify the required test pressure may be accepted taking into account the provisions in F5.1 and F7.4 of IACS Recommendation 140, “Recommendation for Safe Precautions during Survey and Testing of Pressurized Systems”

A double inspection of the tested welds is to be carried out. The first inspection is to be made immediately upon application of the leak indication solution; the second one is to be made approximately four or five minutes after, in order to detect those smaller leaks which may take time to appear.

1.6.5 Compressed air fillet weld test

In this air test, compressed air is injected from one end of a fillet welded joint, and the pressure verified at the other end of the joint by a pressure gauge. Pressure gauges are to be arranged so that an air pressure of at least $0,15 \cdot 10^5$ Pa can be verified at each end of any passage within the portion being tested.

Note 1: Where a leak test is required for fabrication involving partial penetration welds, a compressed air test is also to be carried out in the same manner as to fillet weld where the root face is large, i.e. 6-8 mm.

1.6.6 Vacuum box test

A box (vacuum testing box) with air connections, gauges and an inspection window is placed over the joint with a leak-indicating solution applied to the weld cap vicinity. The air within the box is removed by an ejector to create a vacuum of $0,20 \cdot 10^5$ to $0,26 \cdot 10^5$ Pa inside the box.

1.6.7 Ultrasonic test

An ultrasonic echo transmitter is to be arranged on the inside of a compartment, and a receiver on the outside. The watertight/ weathertight boundaries of the compartment are scanned with the receiver, in order to detect an ultrasonic leak indication. Any leakage in the sealing of the compartment is indicated at a location where sound is detectable by the receiver.

1.6.8 Penetration test

For the test of butt welds or other weld joints, a low surface tension liquid is applied on one side of a compartment boundary or a structural arrangement. If no liquid is detected on the opposite sides of the boundaries after the expiration of a defined period of time, this indicates tightness of the boundaries. In certain cases, a developer solution may be painted or sprayed on the other side of the weld to aid leak detection.

1.6.9 Other test

Other methods of testing may be considered by the Society upon submission of full particulars prior to the commencement of the tests.

1.7 Application of coating

1.7.1 Final coating

For butt joints welded by means of an automatic process, the final coating may be applied at any time before completion of a leak test of the spaces bounded by the joints, provided that the welds have been visually inspected with care, to the satisfaction of the Surveyor.

The Surveyors reserve the right to require a leak test prior to the application of a final coating over automatic erection butt welds.

For all the other joints, the final coating is to be applied after the completion of the joint leak test. See also Tab 4.

1.7.2 Temporary coating

Any temporary coating which may conceal defects or leaks is to be applied at the same time as for a final coating (see [1.7.1]). This requirement does not apply to shop primers.

1.8 Safe access to joints

1.8.1 For leak tests, a safe access to all joints under examination is to be provided. See also Tab 4.

1.9 Hydrostatic or hydropneumatic tightness test

1.9.1 In cases where the hydrostatic or hydropneumatic tests are applied instead of a specific leak test, the examined boundaries are to be dew-free, otherwise small leaks are not visible.

1.10 Testing procedures for SOLAS exempt/equivalent ships

1.10.1 With reference to [1.3.7], testing procedures are to be carried out in accordance with the requirements of [1.4.1] and [1.5] to [1.9] in association with the following alternative procedures for [1.4.2].

Table 4 : Application of leak test, coating, and provision of safe access for the different types of welded joints

Type of welded joints		Leak test	Coating (1)		Safe access (2)	
			Before leak test	After leak test but before structural test	Leak test	Structural test
Butt	Automatic	not required	allowed (3)	not applicable	not required	not required
	Manual or semi-automatic (4)	required	not allowed	allowed	required	not required
Fillet	Boundary including penetrations	required	not allowed	allowed	required	not required

(1) Coating refers to internal (tank/hold) coating, where applied, and external (shell/deck) painting. It does not refer to shop primer.
(2) Temporary means of access for verification of the leak test.
(3) The condition applies provided that the welds have been visually inspected with care, to the satisfaction of the Surveyor.
(4) Flux Core Arc Welding (FCAW) semi-automatic butt welds need not be tested, provided careful visual inspections show continuous and uniform weld profile shape, free from repairs, and the results of NDT show no significant defects.

1.10.2 The tank boundaries are to be tested from at least one side. The tanks for structural test are to be selected so that all representative structural members are tested for the expected tension and compression.

1.10.3 Structural tests are to be carried out for at least one tank of a group of tanks having structural similarity (i.e. same design conditions, alike structural configurations with only minor localised differences determined to be acceptable by the attending Surveyor) on each vessel provided all other tanks are tested for leaks by an air test. The acceptance of leak testing using an air test instead of a structural test does not apply to cargo space boundaries adjacent to other compartments in tankers and combination carriers or to the boundaries of tanks for segregated cargoes or pollutant cargoes in other types of ships.

1.10.4 Additional tanks may require structural testing if found necessary after the structural testing of the first tank.

1.10.5 For tanks which are less than 2 m^3 in volume, structural testing may be replaced by leak testing.

1.10.6 Where the structural adequacy of the tanks and spaces of a vessel were verified by the structural testing required by either [1.4] to [1.9] or [1.10.3], subsequent vessels in the series (i.e. sister ships built from the same plans at the same shipyard) may be exempted from structural testing of tanks, provided that:

a) Water-tightness of boundaries of all tanks and spaces is verified by leak tests and thorough inspections are carried out.

b) Structural testing is carried out for at least one tank or space of each type among all tanks/spaces of each sister vessel.

c) Additional tanks and spaces may require structural testing if found necessary after the structural testing of the first tank or if deemed necessary by the attending Surveyor.

For cargo space boundaries adjacent to other compartments in tankers and combination carriers or boundaries of tanks for segregated cargoes or pollutant cargoes in other types of ships, structural tests are to be carried out for at least one tank of a group of tanks having structural similarity (i.e. same design conditions, alike structural configurations with only minor localised differences determined to be acceptable by the attending Surveyor) on each vessel provided all other tanks are tested for leaks by an air test.

1.10.7 Sister ships built (i.e. keel laid) two years or more after the delivery of the last ship of the series, may be tested in accordance with [1.10.6] at the discretion of the Society, provided that:

a) general workmanship has been maintained (i.e. there has been no discontinuity of shipbuilding or significant changes in the construction methodology or technology at the yard, shipyard personnel are appropriately qualified and demonstrate an adequate level of workmanship as determined by the Society); and

b) an NDT plan is implemented and evaluated by the Society for the tanks not subject to structural tests. Shipbuilding quality standards for the hull structure during new construction are to be reviewed and agreed during the kick-off meeting. The work is to be carried out in accordance with the Rules and under survey of the Society.

1.11 Non-SOLAS ships

1.11.1 Testing procedures are to be carried out in accordance with the requirements [1.4] to [1.9] in association with the following alternative procedures for [1.4.2].

1.11.2 The tank boundaries are to be tested from at least one side. The tanks for structural test are to be selected so that all representative structural members are tested for the expected tension and compression.

1.11.3 The requirements given in Tab 2 to structurally test tanks to 2.4 metres above the top of the tank do not apply. Instead, the minimum test pressure for structural testing is to be taken as 0.3D + 0,76 metres above the top of the tank where the top of the tank is the deck forming the top of the tank, excluding any hatchways and D is the depth of the ship. The minimum test pressure need not be taken greater than 2,4 metres above the top of the tank.

1.11.4 Structural tests are to be carried out for at least one tank of a group of tanks having structural similarity (i.e. same design conditions, alike structural configurations with only minor localised differences determined to be acceptable by the attending Surveyor) on each vessel provided all other tanks are tested for leaks by an air test. The acceptance of leak testing using an air test instead of a structural test does not apply to cargo space boundaries adjacent to other compartments in tankers and combination carriers or to the boundaries of tanks for segregated cargoes or pollutant cargoes in other types of ships.

1.11.5 Additional tanks may require structural testing if found necessary after the structural testing of the first tank.

1.11.6 For tanks which are less than 2 m^3 in volume, structural testing may be replaced by leak testing.

1.11.7 Where the structural adequacy of the tanks of a vessel were verified by the structural testing required by either Tab 2 or [1.11.4], subsequent vessels in the series (i.e. sister ships built from the same plans at the same shipyard) may be exempted from structural testing of tanks, provided that:

a) water-tightness of boundaries of all tanks and spaces are verified by leak tests and thorough inspections are carried out.

b) structural testing is carried out for at least one tank or space among all tanks/spaces of each sister vessel.

c) additional tanks and spaces may require structural testing if found necessary after the structural testing of the first tank or if deemed necessary by the attending Surveyor.

For cargo space boundaries adjacent to other compartments in tankers and combination carriers or boundaries of tanks for segregated cargoes or pollutant cargoes in other types of ships, structural tests are to be carried out for at least one tank of a group of tanks having structural similarity (i.e. same design conditions, alike structural configurations with only minor localised differences determined to be acceptable by the attending Surveyor) on each vessel provided all other tanks are tested for leaks by an air test.

1.11.8 Sister ships built (i.e. keel laid) two years or more after the delivery of the last ship of the series, may be tested in accordance with [1.11.7] at the discretion of the Society, provided that:

a) general workmanship has been maintained (i.e. there has been no discontinuity of shipbuilding or significant changes in the construction methodology or technology at the yard, shipyard personnel are appropriately qualified and demonstrate an adequate level of workmanship as determined by the Society); and

b) an NDT plan is implemented and evaluated by the Classification Society for the tanks not subject to structural tests. Shipbuilding quality standards for the hull structure during new construction are to be reviewed and agreed during the kick-off meeting. The work is to be carried out in accordance with the Rules and under survey of the Society.

2 Miscellaneous

2.1 Watertight decks, trunks, etc.

2.1.1 After completion, a hose or flooding test is to be applied to watertight decks and a hose test to watertight trunks, tunnels and ventilators.

2.2 Steering nozzles

2.2.1 Upon completion of manufacture, the nozzle is to be subjected to a leak test.

Section 4 Construction Survey

1 General

1.1 Scope

1.1.1 The purpose of this Section is to define hull construction and survey requirements within the scope of the classification of ships and/or certification of ship hulls built in steel materials.

Equivalent requirements are defined in:

- NR561 Aluminium Ships, for ships built in aluminium
- NR546 Composite Ships, for ships built in composite materials.

The scope of classification is defined in NR467 Steel Ships, Part A.

2 Structure drawing examination

2.1 General

2.1.1 The structure drawings submitted within the scope of classification and/or certification are to include the details of the welded connections between the main structural elements, including throat thicknesses and joint types, as far as class is concerned.

A weld booklet, as defined in Sec 2, [1.3.1] may be requested.

Note 1: For the various structural typical details of welded construction in shipbuilding and not dealt with in this Section, the rules of good practice, recognized standards and past experience are to apply as agreed by the Society.

2.1.2 Where several steel types are used, a plan showing the location of the various steel types is to be submitted at least for outer shell, deck and bulkhead structures.

3 Hull construction and shipyard procedures

3.1 Shipyard details and procedures

3.1.1 The following details are to be submitted by the Shipyard to the Society:

- design office and production work staff
- production capacity (number of units per year, number of types, sizes)
- total number of hull units already built.

3.1.2 The following procedures are to be submitted by the Shipyard to the Society:

a) Traceability
   - procedure to ensure traceability of materials, consumable and equipment covered by the Society's Rules (from the purchase order to the installation or placing on ship)
   - data to ensure traceability of the production means (describing the different steps such as inspection or recording during production)
   - handling of non-conformities (from the reception of materials or equipment to the end of construction)
   - handling of client complaints and returns to after-sales department.

b) Construction
   - procedure to ensure that the hull is built in accordance with the approved drawings, as defined in [2]
   - procedure to precise the equipment references, the references to any equipment approval, the suppliers' technical requirements, the precautions to be taken when installing the equipment
   - builder's inspection process and handling of defects
   - procedure to ensure that the remedial measures concerning the defects and deficiencies noticed by the Surveyor of the Society during the survey are taken into account.

     Procedures are also to define:

     - the precautions to be taken to comply with the suppliers and Society requirements in order not to cause, during installation, structure damages affecting structural strength and watertightness, and
     - the preparations to be made on the hull in anticipation of installation.

3.2 Materials

3.2.1 The following details about materials used are to be submitted by the Shipyard to the Society:

- list of steel types used for plates, stiffeners, filler products etc., with their references and suppliers' identification
- references of existing material approval certificates
- material data sheets containing, in particular, the suppliers' recommendations on storage use.

3.2.2 The storage conditions of materials and welding consumable are to be in accordance with the manufacturers' recommendations, in dry places without condensation and clear of the ground.

All the materials are to be identifiable in the storage site (type of steel and welding consumable, reference of batches and type of approval certificate,...).

The builder is to provide an inspection to ensure that the incoming plates, stiffeners and consumable are in accordance with the purchase batches and that defective materials have been rejected.

3.3 Forming

3.3.1 Forming operations are to be in accordance with the material manufacturer's recommendation or recognized standard.

3.4 Welding

3.4.1 Welding booklet

A welding booklet, including the welding procedures, filler products and the design of joints (root gap and clearance), as well as the sequence of welding provided to reduce to a minimum restraint during welding operations, is to be submitted to the Surveyor for examination.

Moreover, the welding booklet is:

- to indicate, for each type of joint, the preparations and the various welding parameters
- to define, for each type of assembly, the nature and the extent of the inspections proposed, in particular those of the non-destructive testing such as dye-penetrant tests and, if needed, those of the radiographic inspection.

3.4.2 Welding consumable

The various consumable materials for welding are to be used within the limits of their approval and in accordance with the conditions of use specified in the respective approval documents.

- Welding filler product

  The choice of the welding filler metal is to be made taking into account the welding procedure, the assembly and the grade of steel corresponding to the parent metal

  Welding filler products are generally to be approved by the Society and are of type as defined in NR216 Materials and Welding, Chapter 11 or of other types accepted as equivalent by the Society.

- Welding consumable and welding procedures adopted are to be approved by the Society.

  The minimum consumable grades to be adopted are specified in Tab 1 depending on the steel grade.

  Consumable used for manual or semi-automatic welding (covered electrodes, flux-cored and flux-coated wires) of higher strength hull structural steels are to be at least of hydrogen-controlled grade H15 (H). Where the carbon equivalent Ceq is not more than 0,41% and the thickness is below 30 mm, any type of approved higher strength consumable may be used at the discretion of the Society.

  Especially, welding consumable with hydrogen-controlled grade H15 (H) and H10 (HH) shall be used for welding hull steel forgings and castings of respectively ordinary strength level and higher strength level.

Manual electrodes, wires and fluxes are to be stored in suitable locations so as to ensuring their preservation in proper condition. Especially, where consumable with hydrogen-controlled grade are to be used, proper precautions are to be taken to ensure that manufacturer's instructions are followed to obtain (drying) and maintain (storage, maximum time exposed, re-backing,...) hydrogen-controlled grade.

3.4.3 Welding procedures

Welding procedures adopted are to be approved by the Society as defined in NR216 Materials and Welding, Chapter 12.

The approval of the welding procedure is not required in the case of manual metal arc welding with approved covered electrodes, except in the case of one side welding on refractory backing (ceramic).

Table 1 : Minimum consumable grades

Steel grade	Butt welding, partial and full T penetration welding	Fillet welding
A	1	1
B - D	2	
E	3	
AH32 - AH36 DH32 - DH36	2Y	2Y
EH32 - EH36	3Y	
Note 1: Welding consumable approved for welding higher strength steels (Y) may be used in lieu of those approved for welding normal strength steels having the same or a lower grade; welding consumable approved in grade Y having the same or a lower grade. **Note 2:** In the case of welded connections between two hull structural steels of different grades, as regards strength or notch toughness, welding consumable appropriate to one or the other steel are to be adopted.		

3.4.4 Welder qualification and equipment

- Qualification of welders:

  Welders for manual welding and for semi-automatic welding processes are to be properly trained and are to be certified by the Society according to the procedures given in NR476 Approval Testing of Welders, unless otherwise agreed.

  The qualifications are to be appropriate to the specific applications

  Personnel manning automatic welding machines and equipment are to be competent and sufficiently trained.

  The internal organization of the shipyard is to be such as to provide for assistance and inspection of welding personnel, as necessary, by means of a suitable number of competent supervisors.

- Equipment:

  The welding equipment is to be appropriate to the adopted welding procedures, of adequate output power and such as to provide for stability of the arc in the different welding positions.

  In particular, the welding equipment for special welding procedures is to be provided with adequate and duly calibrated measuring instruments, enabling easy and accurate reading, and adequate devices for easy regulation and regular feed.

3.4.5 Weather protection

Adequate protection from the weather is to be provided to parts being welded; in any event, such parts are to be dry.

In welding procedures using bare, cored or coated wires with gas shielding, the welding is to be carried out in weather protected conditions, so as to ensure that the gas outflow from the nozzle is not disturbed by winds and draughts.

3.4.6 Butt connection edge preparation

The edge preparation is to be of the required geometry and correctly performed. In particular, if edge preparation is carried out by flame, it is to be free from cracks or other detrimental notches.

3.4.7 Surface condition

The surfaces to be welded are to be free from rust, moisture and other substances, such as mill scale, slag caused by oxygen cutting, grease or paint, which may produce defects in the welds.

Effective means of cleaning are to be adopted particularly in connections with special welding procedures; flame or mechanical cleaning may be required.

The presence of a shop primer may be accepted, provided it has been approved by the Society.

Shop primers are to be approved by the Society for a specific type and thickness according to NR216 Materials and Welding, Ch 13, Sec 1.

3.4.8 Assembling and gap

The plates of the shell and strength deck are generally to be arranged with their length in the fore-aft direction. Possible exceptions to the above will be considered by the Society on a case-by-case basis.

The amount of welding to be performed on board is to be limited to a minimum and restricted to easily accessible connections.

The setting appliances and system to be used for positioning are to ensure adequate tightening adjustment and an appropriate gap of the parts to be welded, while allowing maximum freedom for shrinkage to prevent cracks or other defects due to excessive restraint.

The gap between the edges is to comply with the required tolerances or, when not specified, it is to be in accordance with normal good practice.

Welds located too close to one another are to be avoided. The minimum distance between two adjacent welds is considered on a case-by-case basis, taking into account the level of stresses acting on the connected elements.

3.4.9 Crossing of structural element

In the case of T crossing of structural elements (one element continuous, the other physically interrupted at the crossing) when it is essential to achieve structural continuity through the continuous element (continuity obtained by means of the welded connections at the crossing), particular care is to be devoted to obtaining the correspondence of the interrupted elements on both sides of the continuous element. Suitable systems for checking such correspondence are to be adopted.

3.4.10 Welding sequences and interpass cleaning

Welding sequences and direction of welding are to be determined so as to minimize deformations and prevent defects in the welded connection.

All main connections are generally to be completed before the ship is afloat.

Departures from the above provision may be accepted by the Society on a case-by-case basis, taking into account any detailed information on the size and position of welds and the stresses of the zones concerned, both during ship launching and with the ship afloat.

After each run, the slag is to be removed by means of a chipping hammer and a metal brush; the same precaution is to be taken when an interrupted weld is resumed or two welds are to be connected.

3.4.11 Preheating

Suitable preheating, to be maintained during welding, and slow cooling may be required by the Society on a case-by-case basis.

3.5 Inspection and check

3.5.1 Materials, workmanship, structures and welded connections are to be subjected, at the beginning of the work, during construction and after completion, to inspections by the Shipbuilder suitable to check compliance with the applicable requirements, approved plans and standards.

3.5.2 The Shipbuilder is to make available to the Surveyor a list of the manual welders and welding operators and their respective qualifications.

The Shipbuilder's internal organisation is responsible for ensuring that welders and operators are not employed under improper conditions or beyond the limits of their respective valid qualifications and that welding procedures are adopted within the approved limits and under the appropriate operating conditions.

3.5.3 The Shipbuilder is responsible for ensuring that the operating conditions, welding procedures and work schedule are in accordance with the applicable requirements, approved plans and recognised good welding practice.

3.5.4 The Shipbuilder is responsible for ensuring that non-destructive testing are planned, carried out and reported in accordance with NR467, Pt B, Ch 13, Sec 4.

3.6 Modifications and repairs during construction

3.6.1 General

Deviations in the joint preparation and other specified requirements, in excess of the permitted tolerances and found during construction, are to be repaired as agreed with the Society on a case-by-case basis.

3.6.2 Gap and weld deformations

Welding by building up of gaps exceeding the required values and repairs of weld deformations may be accepted by the Society upon special examination.

3.6.3 Defects

Defects and imperfections on the materials and welded connections found during construction are to be evaluated for possible acceptance on the basis of the applicable requirements of the Society.

Where the limits of acceptance are exceeded, the defective material and welds are to be discarded or repaired, as deemed appropriate by the Surveyor on a case-by-case basis.

When any serious or systematic defect is detected either in the welded connections or in the base material, the manufacturer is required to promptly inform the Surveyor and submit the repair proposal.

The Surveyor may require destructive or non-destructive examinations to be carried out for initial identification of the defects found and, in the event that repairs are undertaken, for verification of their satisfactory completion.

3.6.4 Repairs on structure already welded

In the case of repairs involving the replacement of material already welded on the hull, the procedures to be adopted are to be agreed with the Society on a case-by-case basis.

4 Survey for unit production

4.1 General

4.1.1 The survey includes the following steps:

- survey at yard with regards to general requirements of [3]
- structure drawing examination (see [2])
- survey at yard during unit production with regards to approved drawings, yard's response to comments made by the Society during structure review examination and construction requirements.

These can only focus on the construction stage in progress during the survey. It is to the responsibility of the inspection department of the yard to present to the Surveyor any defects noted during the construction of the ship.

5 Alternative survey scheme for production in large series

5.1 General

5.1.1 Where the hull construction is made in large series, an alternative survey scheme may be agreed with the Society for hull to be surveyed as far as Classification is concerned or hull to be certified by the Society on voluntary basis.

5.1.2 The general requirements for the alternative survey scheme, BV Mode I, are given in NR320 Classification Scheme of Materials and Equipment, as amended.

5.2 Type approval

5.2.1 General

The type approval of a hull made of steel and built in large series comprises:

- examination, in accordance with the present Rule Note of drawings and documents defining the main structural components of the hull
- examination of certain items of equipment and their fittings if requested by the Society Rules for the classification and/or certification of ships
- inspection of the first hull (or a hull representing the large series production).

5.2.2 Examination of drawings

The structure drawing examination is to be carried out as defined in [2].

5.2.3 Examination of certain items of equipment

The equipment requiring a particular drawing examination is defined in the present Rule. As a general rule, this equipment consists mainly in portholes, deck hatches and doors.

This examination may be carried out as defined in the Society's Rules or through an homologation process, at the satisfaction of the Society.

5.2.4 Inspections

The purpose of the inspections, carried out by a Surveyor of the Society on the initial hull of the series (or a representative hull of the series), is to make surveys at yard during unit production with regards to approved drawings, yard's response to comments made by the Society during structure review examination and construction requirements as listed in [3].

5.2.5 Type Approval Certificate

A Type Approval Certificate (TAC) is issued for the initial hull covered by the type approval procedure.

5.3 Quality system documentation

5.3.1 The quality system documentation submitted to the Society is to include the information required in [3.1] and in the Rule Note NR320 as amended.

5.4 Manufacturing, testing and inspection plan (MTI plan)

5.4.1 For each type of hull, the manufacturing, testing and inspection plan is to detail specifically:

- Materials:

  Special requirements of the supplier (storage conditions, type of checks to be performed on incoming products and properties to be tested by the yard before use).

  - Storage conditions:

    Information about storage sites (ventilation conditions to avoid condensation, supplier data sheets specifying the storage conditions, listing documents to record arrival and departure dates for consignment).

- Reception:

  Information about consignment (traceability of consignment specifying date of arrival, type of inspection, check on product packaging, types of specific tests performed).

- Traceability:

  Description of the yard process to ensure traceability of the materials from the time of the reception to the end of the production operations.

• Hull construction:

  Description of the yard process to ensure that the scantlings and construction meet the rule requirements in relation to the approved drawings.

• Installation of internal structure:

  Information about the main operations of the internal structure installation.

• Equipment:

  The main equipment to be covered by the rules of the Society are portholes, windows and deck hatches, watertight doors, independent tanks and rudders, the scheduled tests and traceability on the equipment upon arrival and/or after installation.

• Testing and damage reference documents:

  For all the previously defined MTI plan processes, procedures are to be written, defining the types of tests or inspections performed, the acceptance criteria and the means of handling non-conformities.

5.5 Society's certificate

5.5.1 Certificate of recognition

After completion of the examination, by the Society, of the quality assurance manual, the MTI plan and the yard audit, a Certificate of recognition may be granted as per the provisions of NR320, as amended.

5.5.2 Certificate of conformity

Each hull may be certified individually upon request made to the Society.

5.6 Other certification scheme for production in large series

5.6.1 Other certification scheme for production in large series, based on NR320 may be considered by the Society on a case by case basis.

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