PART 3 CHAPTER 1

DESIGN PRINCIPLES, DESIGN LOADS

JANUARY 2011

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CHANGES IN THE RULES

General
As of October 2010 all DNV service documents are primarily published electronically.
In order to ensure a practical transition from the “print” scheme to the “electronic” scheme, all rule chapters having incorporated amendments and corrections more recent than the date of the latest printed issue, have been given the date January 2011.
An overview of DNV service documents, their update status and historical “amendments and corrections” may be found through http://www.dnv.com/resources/rules_standards/.

Main changes
Since the previous edition (January 2005), this chapter has been amended, most recently in July 2010. All changes previously found in Pt.0 Ch.1 Sec.3 have been incorporated and a new date (January 2011) has been given as explained under “General”.
In addition, the layout has been changed to one column in order to improve electronic readability.
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SECTION 1
DESIGN PRINCIPLES

A. Documentation

A 100 Plans and particulars

101 The following plans shall normally be submitted for approval:

— midship section including main particulars (L, B, D, T, C_B, H_S (significant double amplitude))
— profile and decks
— shell expansion and framing including openings
— watertight bulkheads and transom including openings and their closing appliances
— tank structures including height of air pipes
— engine room structures including tanks and foundations for heavy machinery components
— afterpeak structures
— forepeak structures
— superstructures and deckhouses including openings with sill heights and their closing appliances
— hatchways, hatch covers, ports in craft’s sides and ends including securing and tightening appliances
— propeller shaft brackets with their attachment to the hull
— trim flaps or foils with their attachment to the hull
— rudder and rudder stock with details of bearings
— arrangement and particulars of anchoring and mooring equipment with windlass
— drawings of cathodic protection systems, showing anode types, mass, distribution, location and attachment
details (for sacrificial anodes or impressed current anodes with reference electrodes)
— selection and combination of materials for exposure to sea water and/or marine atmosphere.

Identical or similar structures in various positions should preferably be covered by the same plan.

102 When relevant an operating manual shall be submitted, see Pt.1 Ch.1 Sec.2 A400.

103 The following plans shall be submitted for information:

— general arrangement
— engine room arrangement
— tank arrangement
— capacity plan
— body plan, hydrostatic curves or tables
— specifications for corrosion protection, i.e. for coating, see Ch.3 Sec.2 C301 and for cathodic protection
including calculations, see Ch.3 Sec.2 C403.

104 Additional documentation required for approval are listed in the appropriate Parts.

A 200 Information

201 Information which may be necessary for longitudinal strength calculations shall be submitted.

202 Information which may be necessary for overall and local strength calculations shall be submitted.

A 300 Strength calculations

301 Strength calculations shall normally be submitted for reference demonstrating that stresses are within
required limits according to the rules.

302 For craft of novel design and for craft with L >50 m, global hull strength analysis demonstrating stresses
and deflections in the hull structure will normally be required.

A 400 Certificates

401 Certificates issued by Det Norske Veritas will be required for the following materials/components:

— all materials to be used in hull, superstructure and deckhouses
— trim foils or flaps
— rudder and rudder stock
— steering gear
— anchor and chain/wire ropes
— windlass.
B. Subdivision and Arrangement

B 100 General

101 The hull shall be subdivided into watertight compartments as required for the service and type notation requested.

B 200 Transverse watertight bulkheads

201 At least the following transverse watertight bulkheads shall be fitted in all craft:
   — a collision bulkhead
   — a bulkhead at each end of the machinery space(s).

202 The watertight bulkheads are in general to extend to the freeboard deck. Afterpeak bulkheads may, however, terminate at the first watertight deck above the waterline at draught T.

203 For craft with two continuous decks and a large freeboard to the uppermost deck, the following applies:
   — when the draught is less than the depth to the second deck, only the collision bulkhead need extend to the uppermost continuous deck. The remaining bulkheads may terminate at the second deck
   — when the draught is greater than the depth to the second deck, the machinery bulkheads, with the exception of afterpeak bulkhead, shall extend watertight to the uppermost continuous deck.

204 In craft with a raised quarter deck, the watertight bulkheads within the quarter deck region shall extend to this deck.

205 For craft with the additional class notation Yacht and Patrol alternative arrangements may be accepted based on special considerations.

B 300 Position of collision bulkhead

301 The distance \( x_c \) from the forward perpendicular to the collision bulkhead shall be taken between the following limits:

\[
\begin{align*}
x_c(\text{minimum}) &= 0.05 \, L \, (m) \\
x_c(\text{maximum}) &= 3.0 + 0.05 \, L \, (m) \\
L &= \text{length in m on design waterline.}
\end{align*}
\]

302 Minor steps or recesses in the collision bulkhead may be accepted, provided the requirements to minimum and maximum distances from the forward perpendicular are complied with.

303 For craft having complete or long forward superstructures, the collision bulkhead shall extend to the next deck above freeboard deck. The extension need not be fitted directly over the bulkhead below, provided the requirements to distances from the forward perpendicular are complied with, and the part of the freeboard deck forming the step is made watertight.

For craft having particular high freeboard and long bow overhang, the position of the collision bulkhead above the freeboard deck may be specially considered.

304 For craft with the additional class notation Yacht and Patrol alternative arrangements may be accepted based on special considerations.

B 400 Openings and closing appliances

401 Openings may be accepted in watertight bulkheads, except in that part of the collision bulkhead which is situated below the freeboard deck.

402 Openings situated below the freeboard deck shall have watertight doors with signboards fitted at each door stipulating that the door be kept closed while the craft is at sea. This assumption will be stated in the “Appendix to Classification Certificate”.

403 Openings in the collision bulkhead above the freeboard deck shall have weathertight doors or an equivalent arrangement. The number of openings in the bulkhead shall be reduced to the minimum compatible with the design and normal operation of the craft.

404 For Yacht and Patrol notation alternative requirements may apply.

B 500 Cofferdams

501 Cofferdams Fuel oil, lubricating oil and fresh water tanks shall be separated from each other by cofferdams.
B 600 Steering gear compartment

601 The steering gear compartment shall be readily accessible and, as far as practicable, separated from machinery spaces.

C. Scantlings

C 100 General

101 Hull scantlings are in general to be based on the two design aspects, load and strength.

102 The rules have established design loads corresponding to the loads imposed by the sea and the containment of cargo, passengers, ballast and bunkers. The design loads are applicable in strength formulae and calculation methods when satisfactory strength level is represented by allowable stress and/or usage factors.

103 The structure shall be capable of withstanding the static and dynamic loads which can act on the craft under operating conditions, without such loading resulting in inadmissible deformation and loss of watertightness or interfering with the safe operation of the craft.

104 Cyclic loads, including those from vibrations which can occur on the craft, shall not:

— impair the integrity of structure during the anticipated service life of the craft
— hinder normal functioning of machinery and equipment
— impair the ability of the crew to carry out its duties.

105 Documentation on the vibration level onboard a craft may be required.

C 200 Loading conditions

201 Static loads are derived from loading conditions submitted by the builder or standard conditions prescribed in the rules.

202 Wave-induced loads determined according to accepted theories, models tests or full scale measurements may be accepted as equivalent basis for classification. However, craft will not be classed for operation within a specific geographical area.

The determination of dynamic loads shall be based on long term distribution of responses that the craft will experience during its operating life.

C 300 Hull girder strength

301 For craft with length \( L \leq 50 \) m the minimum strength standard is normally satisfied for scantlings obtained from local strength requirements.

C 400 Resistance to slamming

401 Craft shall be strengthened to resist slamming. Requirements for minimum slamming loads and associated allowable stresses are given.

C 500 Local vibrations

501 The evaluation of structural response to vibrations caused by impulses from engine and propeller blades is not covered by the classification.

Upon request such evaluation may be undertaken by the Society.

C 600 Miscellaneous strength requirements

601 Requirements for scantlings of foundations, minimum plate thicknesses and other requirements not relating relevant load and strength parameters may reflect criteria other than those indicated by these parameters. Such requirements may have been developed from experience or represent simplifications considered appropriate by the Society.

D. Definitions

D 100 Symbols

101 \( L \) = length of the craft in m defined as the distance between perpendiculars. Amidships is defined as the middle of \( L \).
FP = forward perpendicular is the perpendicular at the intersection of the fully loaded waterline (with the craft at rest) with the foreshore of the stem

AP = after perpendicular is the perpendicular at the intersection of the fully loaded waterline (with the craft at rest) with the after side of sternpost or transom

B = greatest moulded breadth in m

D = moulded depth is the vertical distance in m from baseline to moulded deckline at the uppermost continuous deck measured amidships

T = fully loaded draught in m with the craft floating at rest in calm water

Δ = fully loaded displacement in tonnes in salt water (density 1.025 t/m³) on draught T

C_B = block coefficient, given by the formula:

\[ C_B = \frac{\Delta}{1.025L_BWL_T} \]

BWL = greatest moulded breadth of the hull(s) in m at the fully loaded waterline (with the craft at rest).

For multihull craft BWL is the net sum of the waterline breadths

BWL2 = greatest moulded breadth of the hull(s) in m at the fully loaded waterline (with the craft at rest) measured at L/2.

For multihull craft BWL2 is the net sum of the waterline breadths

V = maximum speed in knots

g_0 = standard acceleration of gravity.

= 9.81 m/s²

LCG = longitudinal centre of gravity

WL = water line.

D 200 Structural terms

201 Freeboard deck is a deck above waterline, weathertight closed or protected, from which a freeboard is measured. For details see LL3 (Load Line Convention of 1966, Regulation 3).

202 Superstructure is defined as a decked structure on 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 4% of the breadth (B). See also LL3.

203 Strength deck is normally defined as the uppermost continuous deck. A superstructure deck which within 0.4L amidships has a continuous length equal to or greater than

\[ 3\left(\frac{B}{2} + H\right) \] (m) for monohull vessels

or

\[ 3\left(\frac{L}{15} + H\right) \] (m) for twin hull vessels

shall be regarded as the strength deck instead of the covered part of the uppermost continuous deck.

H = height in m between the uppermost continuous deck and the superstructure deck in question.

Another deck may be defined as the strength deck after special consideration of its effectiveness.

An analysis may be required to estimate the effective width of the various decks in the craft, and thereby their contribution to the hull girder section modulus.

Strength deck requirements may then have to be applied to effective party of all upper decks.

204 Short superstructure deck is a superstructure deck which shall not be regarded as a strength deck.

205 Weather decks are open decks or parts of decks which may be exposed to local sea and weather loads.

206 Bulkhead deck (for passenger vessels and some special purpose vessels) is a deck above flooded waterline to which the weathertight bulkheads are carried.

207 Weathertight is used for external surfaces above freeboard (or bulkhead) deck and means that in any sea conditions water will not penetrate into the ship.

Flush with and below freeboard (or bulkhead) deck the stronger term watertight is used in the same meaning.

208 Watertight elsewhere is primarily related to the internal subdivision of the ship, and means that in a flooded condition water will not penetrate from one compartment into the other.
A certain permanent set is, however, accepted in this one-accident case, which means that a watertight bulkhead is inferior to a tank bulkhead and is not accepted as such.

209 **Girder** is a collective term for primary supporting members, usually supporting stiffeners. Other terms used are:

— bottom, side and deck transverses
— floor (a bottom transverse)
— stringer (a horizontal girder)
— web frame
— vertical web.

210 **Stiffener** is a collective term for a secondary supporting member. Other terms used are:

— beam
— frame
— reversed frame (inner bottom transverse stiffeners)
— longitudinal.

211 “Flat cross structure” is a structure having an exposed, down-facing, horizontal or near-horizontal surface above the waterline.

212 **Supporting structure.** Strengthening of the vessel structure, e.g. a deck, in order to accommodate loads and moments from a heavy or loaded object.

213 **Foundation.** A device transferring loads from a heavy or loaded object to the vessel structure.
SECTION 2
DESIGN LOADS

A. General

A 100 Introduction

101 Design loads given in this section are derived from full scale measurements and statistical analysis of high speed and light craft designs.

102 Design loads given in this section covers:

— High Speed and Light Craft (HSLC) which comply with the speed requirement in Pt.1 Ch.1 Sec.2 A104 and A105; i.e. \( V \geq 25 \) knots
— Light Craft (LC) according to \( V < 25 \) knots.

103 New design concepts may require tank tests, theoretical studies, or full scale measurements to establish seakeeping properties and design loads.

104 Design pressures caused by sea, liquid cargoes, dry cargoes, ballast and bunkers are based on extreme conditions, but are modified to equivalent values corresponding to the stress levels stipulated in the rules.

105 The effects of speed reduction in heavy weather are allowed for. Limiting sea state (significant wave height) to speed reduction may be stipulated. Such restrictions will be stated in the “Appendix to Classification Certificate”.

106 A signboard giving the relationship between allowable speed and significant wave height as restricted shall be posted in the wheelhouse.

107 Significant wave height is the average of the 1/3 highest wave heights within the wave spectrum. Visual observation of the “wave height” by an experienced person coincides well with the significant wave height.

108 Installation of an accelerometer at LCG may be required.

A 200 Definitions

201 Symbols:

\[ p = \text{design pressure in kN/m}^2 \]
\[ \rho = \text{density of liquid or stowage rate of dry cargo in t/m}^3 \]
\[ C_w = \text{wave coefficient.} \]

For unrestricted service:

\[ C_w = 0.08 \, L \] for \( L \leq 100 \)m
\[ = 6 + 0.02 \, L \] for \( L > 100 \)m.

Reduction of \( C_w \) for restricted service is given in Table A1.

<table>
<thead>
<tr>
<th>Class notation</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>R0</td>
<td>0</td>
</tr>
<tr>
<td>R1</td>
<td>0</td>
</tr>
<tr>
<td>R2</td>
<td>10%</td>
</tr>
<tr>
<td>R3</td>
<td>20%</td>
</tr>
<tr>
<td>R4</td>
<td>40%</td>
</tr>
<tr>
<td>R5-R6</td>
<td>60%</td>
</tr>
</tbody>
</table>

Restricted service class notations are defined in Pt.1 Ch.1 Sec.2.

Variation of wave coefficient \( C_w \) is shown in Fig.1.
The load point for which the design pressure shall be calculated is defined for various strength members as follows:

a) For plates: midpoint of horizontally stiffened plate.
   Half of the stiffener spacing above the lower support of vertically stiffened plate, or at lower edge of plate when the thickness is changed within the plate.

b) For stiffeners: midpoint of span.
   When the pressure varies other than linearly the design pressure shall be taken as the greater of:
   \[ p_m, \frac{p_a + p_b}{2} \]
   \( p_m \) p_a and \( p_b \) are calculated pressure at the midpoint and at each end respectively.

c) For girders: midpoint of load area.

### B. Accelerations

#### B 100 General

101 Accelerations in the craft’s vertical, transverse and longitudinal axes are in general obtained by assuming the corresponding linear acceleration and relevant components of angular accelerations as statistically independent variables. The combined acceleration in each direction may be taken as:

\[ a_c = \sqrt{\sum_{m=1}^{n} a_m^2} \]

\( n \) = number of independent variables.

Transverse or longitudinal component of the angular acceleration considered in the above expression shall include the component of gravity acting simultaneously in the same direction.

102 The combined effects given in the following may deviate from the above general expression due to practical simplifications applicable to hull structural design or based on experience regarding phasing between certain basic components.
B 200 Design vertical acceleration

201 Design vertical acceleration at craft’s centre of gravity $a_{cg}$ shall be specified by the builder, and is normally not to be less than:

$$a_{cg} = \frac{V}{\sqrt{L}} \frac{3.2}{L^{0.76}} f_g g_0 \text{ (m/s}^2).$$

Minimum $a_{cg} = 1 g_0$ for service restriction R0-R4
Minimum $a_{cg} = 0.5 g_0$ for service restriction R5

$\frac{V}{\sqrt{L}} \text{ need not be taken greater than 3.0}$

$f_g = \text{acceleration factor (fraction of } g_0\text{) dependent of type and service notation and service area restriction notation given in Table B1.}$

The design vertical acceleration is an extreme value with a 1% probability of being exceeded, in the worst intended condition of operation.

202 Unless otherwise established, the design acceleration at different positions along the craft’s length shall not be less than:

$$a_v = k_v a_{cg}$$

$k_v = \text{longitudinal distribution factor taken from Fig.2.}$

203 The allowable speed corresponding to the design vertical acceleration $a_{cg}$, may be estimated from the formulas for the relationship between instantaneous values of $a_{cg}$, $V$ and $H_s$, given in 204 and 205.

204 When $\frac{V}{\sqrt{L}} \geq 3$:

$$a_{cg} = \frac{k_h g_0}{1650} \left( \frac{H_s}{B_{WL2}} + 0.084 \right) (50 - \beta_{cg})$$

$$\left( \frac{V}{\sqrt{L}} \right)^2 \frac{L B_{WL2}^2}{\Delta} \text{ (m/s}^2)$$

$H_s = \text{significant wave height in m}$
$\beta_{cg} = \text{deadrise angle at LCG in degrees}$
$\Delta = \text{minimum 10°}$
$\Delta = \text{maximum 30°}$
$B_{WL2} = \text{water line breadth at L/2 in m.}$

For twin- and multi hull vessels the total breadth of the hulls (exclusive tunnels) shall be used

$g_0 = \text{standard acceleration of gravity} = 9.81 \text{ m/s}^2$

$k_h = \text{hull type factor given in Table B2.}$

### Table B1 Acceleration factor $f_g$

<table>
<thead>
<tr>
<th>Type and service notation</th>
<th>Service area restriction notation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R0</td>
</tr>
<tr>
<td>Passenger</td>
<td>1</td>
</tr>
<tr>
<td>Car ferry</td>
<td>1</td>
</tr>
<tr>
<td>Cargo</td>
<td>4</td>
</tr>
<tr>
<td>Patrol</td>
<td>7</td>
</tr>
<tr>
<td>Yacht</td>
<td>1</td>
</tr>
</tbody>
</table>

1) Service area restriction R0 is not available for class notations Passenger and Car Ferry.

The design vertical acceleration is an extreme value with a 1% probability of being exceeded, in the worst intended condition of operation.

202 Unless otherwise established, the design acceleration at different positions along the craft’s length shall not be less than:

$$a_v = k_v a_{cg}$$

$k_v = \text{longitudinal distribution factor taken from Fig.2.}$

203 The allowable speed corresponding to the design vertical acceleration $a_{cg}$, may be estimated from the formulas for the relationship between instantaneous values of $a_{cg}$, $V$ and $H_s$, given in 204 and 205.

204 When $\frac{V}{\sqrt{L}} \geq 3$:

$$a_{cg} = \frac{k_h g_0}{1650} \left( \frac{H_s}{B_{WL2}} + 0.084 \right) (50 - \beta_{cg})$$

$$\left( \frac{V}{\sqrt{L}} \right)^2 \frac{L B_{WL2}^2}{\Delta} \text{ (m/s}^2)$$

$H_s = \text{significant wave height in m}$
$\beta_{cg} = \text{deadrise angle at LCG in degrees}$
$\Delta = \text{minimum 10°}$
$\Delta = \text{maximum 30°}$
$B_{WL2} = \text{water line breadth at L/2 in m.}$

For twin- and multi hull vessels the total breadth of the hulls (exclusive tunnels) shall be used

$g_0 = \text{standard acceleration of gravity} = 9.81 \text{ m/s}^2$

$k_h = \text{hull type factor given in Table B2.}$

<table>
<thead>
<tr>
<th>Hull type</th>
<th>$k_h$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monohull, Catamaran</td>
<td>1.0</td>
</tr>
<tr>
<td>Wave Piercer</td>
<td>0.9</td>
</tr>
<tr>
<td>SES, ACV</td>
<td>0.8</td>
</tr>
<tr>
<td>Foil assisted hull (see 206)</td>
<td>0.7</td>
</tr>
<tr>
<td>SWATH (see 206)</td>
<td>0.7</td>
</tr>
</tbody>
</table>
The hull type factor $k_h$ is an estimate for correction of the vertical acceleration depending on the different types of hull forms.

205 When $V / \sqrt{L} < 3$:

$$a_{cg} = 6 \frac{H_S}{L} \left(0.85 + 0.35 \frac{V}{\sqrt{L}}\right) g_0 \text{ (m/s}^2\text{)}$$

206 Unless other values are justified by calculations according to accepted theories, model tests or full scale measurements, the speed reductions implied by 204 and 205 shall be applied. For SWATH and craft with foil assisted hull, accelerations shall normally be determined in accordance with the above direct methods.

207 Relationships between allowable speed and significant wave height will be stated in the “Appendix to Classification Certificate”.

Fig. 2
Longitudinal distribution factor for vertical design acceleration

B 300 Horizontal accelerations

301 The craft shall be designed for a longitudinal (surge) acceleration not less than

$$a_l = 2.5 \frac{C_W}{L} \left(0.85 + 0.25 \frac{V}{\sqrt{L}}\right)^2 g_0$$

$\frac{V}{\sqrt{L}}$ need not be taken greater than 4

Tentative formula for the relation between instantaneous values of $a_l$, $H_S$ and $V$:

$$a_l = (1.67) \frac{H_S}{L} \left(0.85 + 0.35 \frac{V}{\sqrt{L}}\right)^2 g_0$$

$a_l$ is intended for calculation of forward directed inertia forces and may have to be increased based on the overall impact possibilities in craft’s front.
a_l may be simultaneous with downward vertical inertia in forebody.

302 It may be necessary to pay attention to transverse acceleration from forced roll in bow seas.

Period of forced roll to be taken:

$$T_R = \frac{\sqrt{L}}{1.05 + 0.175 \frac{V}{\sqrt{L}}} \text{ (s)}$$
Maximum roll inclination:

\[ \theta_r = \frac{\pi h_w}{2L} \text{ (radians)} \]

Resulting transverse acceleration:

\[ a_t = \left(2 \frac{\pi}{T_R} r_r \right)^2 \theta_r \text{ (m/s}^2\text{)} \]

Static component \( g_0 \sin \theta_r \) to be added, when above axis of roll.

\( h_w \) = maximum wave height in which 70% of maximum service speed will be maintained, minimum 0.6 \( C_w \)

\( r_r \) = height above axis of roll.

Axis of roll to be taken
— at waterline for twin hull craft
— at D/2 for monohull craft.

C. Pressures and Forces

C 100 General

101 The external and internal pressures and forces considered to influence the scantlings of stiffened panels are:
— static and dynamic sea pressures
— static and dynamic pressures from liquids in a tank
— static and dynamic loads from dry cargoes, stores and equipment.

102 The design sea pressures are assumed to be acting on the craft’s outer panels at full draught.

103 The internal pressures are given for the panel in question irrespectively of possible simultaneous pressure from the opposite side.

104 The bottom structure, forebody side/bow structure and flat cross structures shall be strengthened to resist the effects of slamming and impact.

105 The gravity and acceleration forces from heavy units of cargo and equipment may influence the scantlings of primary strength members.

C 200 Slamming pressure on bottom

201 The design slamming pressure on bottom of craft with speed \( \sqrt{V/L} \geq 3 \) shall be taken as:

\[ P_{sl} = 1.3 k_l \left( \frac{A}{nA} \right)^{0.3} T_O^{0.7} \frac{50 - \beta_x}{50 - \beta_{cg}} a_{cg} \text{ (kN/m}^2\text{)} \]

\( k_l \) = longitudinal distribution factor from Fig. 3

\( n \) = number of hulls, 1 for monohulls, 2 for catamarans. Trimarans and other multihulls will be specially considered.

\( A \) = design load area for element considered in m\(^2\).

For plating \( A \) shall not be taken greater than 2.5 s\(^2\).

For stiffener and girder \( A \) is taken as the product:

\[ \text{spacing x span} \]

\( A \) need not for any structure be taken less than \( 0.002 \frac{\Delta}{T} \)

\( T_O \) = draught at L/2 in m at normal operation condition at service speed

\( \Delta \) = fully loaded displacement in tonnes in salt water on draught T

\( \beta_x \) = deadrise angle in degrees at transverse section considered (minimum 10°, maximum 30°)

\( \beta_{cg} \) = deadrise angle in degrees at LCG (minimum 10°, maximum 30°)

\( a_{cg} \) = design vertical acceleration at LCG from B200 (a\(_V\) calculated at LCG).
For transverse sections with no pronounced deadrise angle, $\beta_{cg}$ and $\beta_x$ may be estimated according to Fig.4. The bottom slamming pressure need not be applied to craft with no significant hydrodynamic or air cushion lift in normal operating condition; i.e. SWATH hull forms.

**202** Bottom slamming pressure shall be applied on elements within the area extending from the keel line to chine, upper turn of bilge or pronounced sprayrail.

---

**Fig. 3**
Longitudinal slamming pressure distribution factor for high speed mode slamming

**Fig. 4**
Deadrise angle for round bottom section

**203** All craft shall be designed for a pitching slamming pressure on bottom as given below:

$$P_{sl} = \frac{21}{\tan(\beta_x)} k_a k_b C_w \left(1 - \frac{20T_L}{L}\right) \text{ (kN/m$^2$)}$$

$\beta_x$ as in 201

$k_a = 1$ for plating

$1.1 - 20 L_A/L$; maximum 1.0, minimum 0.35 for stiffeners and girders

$L_A$ = longitudinal extent in m of load area

$k_b = 1$ for plating and longitudinal stiffeners and girders

$L/40 + 0.5$ (maximum 1.0) for transverse stiffeners and girders ($l$ = span in m of stiffener or girder)

$T_L$ = lowest service speed draft in m at FP measured vertically from waterline to keel line or extended keel line.

Above pressure shall extend within a length from FP:

$$\left(0.1 + 0.15 \frac{V}{\sqrt{L}}\right) L$$

$V/\sqrt{L}$ need not to be taken greater than 3. $P_{sl}$ may be gradually reduced to zero at 0.175 L aft of the above length.

Pitching slamming pressure shall be exposed on elements within the area extending from the keel line to chine, upper turn of bilge or pronounced sprayrail.
Pressure on bottom structure shall not be less than given in 500.

**C 300  Forebody side and bow impact pressure**

Forebody side and bow impact pressure shall be taken as, in kN/m²:

\[
P_{sl} = \frac{0.7 L C_L C_H}{A^{0.3}} \left(0.6 + 0.4 \frac{V}{\sqrt{L}} \sin \gamma \cos (90^\circ - \alpha) + \right.
\]

\[
+ \frac{2.1 a_0}{C_B} \left[ \frac{0.4 \frac{V}{\sqrt{L}}}{L} + 0.6 \sin (90^\circ - \alpha) \left(\frac{x}{L} - 0.4\right) \right]^2
\]

\[V/\sqrt{L}\] need not be taken greater than 3.

\(A\) = design load area for element considered in m²

For plating \(A\) shall not be taken greater than \(2.5 s^2\) (m²)

For stiffeners and girders \(A\) need not be taken smaller than \(e^2\) (m²)

In general \(A\) need not be taken smaller than \(L B_w/1000\) (m²)

\(e\) = vertical extent of load area, measured along shell perpendicular to the waterline

\(x\) = distance in m from AP to position considered

\(C_L\) = correction factor for length of craft

\[C_L = \frac{250L - L^2}{15000}, \quad L \text{ not be taken greater than 100m}\]

\(C_H\) = correction factor for height above waterline to load point

\[C_H = 1 - \frac{0.5}{C_W} h_0\]

\(C_W\) may be reduced according to A201

\(h_0\) = vertical distance in m from the waterline at draught \(T\) to the load point

\(\alpha\) = flare angle taken as the angle between the side plating and a horizontal line, measured at the point considered. See Fig.5

\(\gamma\) = angle between the waterline and a longitudinal line measured at the point considered. See Fig.6

\(a_0\) = acceleration parameter:

\[a_0 = 3 \frac{C_W}{L} + C_V \frac{V}{\sqrt{L}}\]

\[C_V = \frac{\sqrt{L}}{50}, \quad \text{maximum 0.2}\]
302 Forebody side and bow pressure shall not be taken less than according to 500.

303 The impact pressure according to 301 is be calculated for longitudinal positions between 0.4 L and bow.

304 In vertical direction the impact pressure shall extend from bottom chine or upper turn of bilge to main deck or vertical part of craft side.

Upper turn of bilge shall be taken at a position where deadrise angle reaches 70°, but not higher than the waterline.

If no pronounced bottom chine or upper turn of bilge is given (V-shape), the impact pressure shall extend from keel to main deck or vertical part of craft side.

C 400 Slamming pressure on flat cross structures

401 The design slamming pressure on flat cross structures (catamaran tunnel top, etc.), shall be taken as:

\[ P_{sl} = 2.6 \, k_\gamma \left( \frac{\Delta}{A} \right)^{0.3} a_{cg} \left( 1 - \frac{H_L}{H_c} \right) \text{ (kN/m}^2) \]

\[ A = \text{design load area for element considered. See 201} \]

\[ H_c = \text{minimum vertical distance in m from WL to load point in operating condition} \]

\[ k_\gamma = \text{longitudinal pressure distribution factor according to Fig.7} \]

\[ H_L = \text{necessary vertical clearance in m from WL to load point to avoid slamming} \]

\[ = 0.22 \, L \left( k_c - \frac{0.8}{1000} \, L \right) \]

\[ k_c = \text{hull type clearance factor} \]

0.3 for catamaran, wave piercer
0.3 for SES, ACV
0.3 for hydrofoil, foilcatamaran
0.5 for SWATH.
Slamming pressure shall not be less than the sea pressure according to 500 (side above WL).

C 500 Sea pressure

Pressure acting on the craft’s bottom, side (including superstructure side) and weather decks shall be taken as:

— for load point below design waterline:

\[ p = 10h_0 + \left( k_s - 1.5 \frac{h_0}{T} \right) C_W \] (kN/m²)

— for load point above design waterline:

\[ p = a k_s (C_W - 0.67 h_0) \] (kN/m²)

Minimum sea pressures are given in Table C1.

<table>
<thead>
<tr>
<th>Table C1 Minimum sea pressures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Notation</strong></td>
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<tr>
<td>R0, R1, R2, R3</td>
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<td>R4</td>
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</table>

\( h_0 \) = vertical distance in m from the waterline at draught T to the load point
\( k_s = 7.5 \) aft of amidships
\( = 5/C_B \) forward of FP.

Between specified areas \( k_s \) shall be varied linearly, see Fig. 8

\( a = 1.0 \) for craft’s sides and open freeboard deck
\( = 0.8 \) for weather decks above freeboard deck

\( C_W \) = wave coefficient according to A200.
502 The design pressure on superstructure end bulkheads and deckhouses shall not be taken less than:

\[ p = a k_s (C_W - 0.67 h_0) \ (kN/m^2) \]

\[ P_{\min} = 5 + (5 + 0.05 L) \sin \alpha (kN/m^2) \] for lowest tier of unprotected front

\[ P_{\min} = 5 \ (kN/m^2) \] for aft end bulkheads

\[ P_{\min} = 5 + 0.025 L \sin \alpha (kN/m^2) \] elsewhere

where \( \alpha \) is the angle between the bulkhead/side and deck.

\( h_0, C_W \) and \( k_s \) as given in 501.

\( a = 2.0 \) for lowest tier of unprotected fronts

\( a = 1.5 \) for deckhouse fronts

\( a = 1.0 \) for deckhouse sides

\( a = 0.8 \) elsewhere.

503 The design pressure on watertight bulkheads (compartment flooded) shall be taken as:

\[ p = 10 \ h_b \ (kN/\text{m}^2) \]

\( h_b = \) vertical distance in m from the load point to the top of bulkhead or to flooded waterline, if deeper.

504 The design pressure on deck or inner bottom forming part of watertight bulkhead shall not be less than for the bulkhead at same level.

C 600 Liquids

601 Tanks for bunkers and tank bulkheads shall normally be designed for liquids of density equal to that of sea water, taken as \( \rho = 1.025 \ \text{t/m}^3 \) (i.e. \( \rho g_0 \approx 10 \)).

602 The pressure in tanks shall be taken as the greater of:

\[ p = \rho (g_0 + 0.5 \ a_v) \ h_s \ (kN/m^2) \]

\[ p = 0.67 \rho g_0 \ h_p \ (kN/m^2) \]
\[ p = \rho g_0 h_s + 10 \text{ (kN/m}^2\text{)} \text{ for } L \leq 50\text{m} \]
\[ p = \rho g_0 h_s + 0.3 \ L - 5 \text{ (kN/m}^2\text{)} \text{ for } L > 50\text{m} \]

\[ a_v = \text{ as given in B200} \]
\[ h_s = \text{ vertical distance in m from the load point to the top of tank} \]
\[ h_p = \text{ vertical distance in m from the load point to the top of air pipe or filling station.} \]

For tanks which may be filled to top of air pipe or filling station and subsequently subjected to accelerations, the pressure shall be modified accordingly.

603 The design pressure on wash bulkheads is given by:
\[ p = 3.5 l_t \text{ (kN/m}^2\text{)} \]
\[ l_t = \text{ the greater distance in m to the next bulkhead forward or aft.} \]

For wash bulkhead plating, requirement to thicknesses may have to be based on the reaction forces imposed on the bulkhead by boundary structures.

C 700 Dry cargo, stores and equipment

701 The pressure on inner bottom, decks or hatch covers shall be taken as:
\[ p = \rho H (g_0 + 0.5 a_v) \text{ (kN/m}^2\text{)} \]
\[ a_v = \text{ as given in B200} \]
\[ H = \text{ stowage height in m.} \]

Standard values of \(\rho\) and \(H\) are given in Table C2.

If decks (excluding inner bottom) or hatch covers are designed for cargo loads heavier than the standard loads given in Table C2, the notation \(dk (+)\) or \(ha (+)\), respectively, will be entered in the Register of Ships. The design cargo load in t/m\(^2\) will be given for each individual cargo space in the “Appendix to Classification Certificate”.

702 When the weather deck or weather deck hatch covers are designed to carry deck cargo, the pressure is in general to be taken as the greater of \(p\) according to 500 and 700.

703 For transverse bulkheads in way of general cargo holds, the design loads given for watertight bulkheads apply.

<table>
<thead>
<tr>
<th>Table C2 Standard load parameters</th>
</tr>
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<tr>
<td><strong>Decks</strong></td>
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<tr>
<td>Weather deck and weather deck hatch covers intended for cargo</td>
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<tr>
<td>Sheltered deck, sheltered hatch covers and inner bottom for cargo or stores</td>
</tr>
<tr>
<td>Platform deck in machinery space</td>
</tr>
<tr>
<td>Accommodation decks</td>
</tr>
</tbody>
</table>

C 800 Heavy units

801 Heavy units The vertical force acting on supporting structures from rigid units of cargo, equipment or other structural components shall normally be taken as:
\[ P_v = (g_0 + 0.5 a_v) M \text{ (kN)} \]
\[ M = \text{ mass of unit in tonnes} \]
\[ a_v = \text{ as given in B200.} \]
SECTION 3
HULL GIRDER LOADS

A. Longitudinal Bending, Shearing and Axial Loads

A 100 General

101 For craft of ordinary hull form with L/D less than 12 and with length less than 50 m, the minimum strength standard is normally satisfied for scantlings obtained from local strength requirements.

102 For other types of craft, craft with L/D greater than 12 and for craft with length greater than 50 m, the longitudinal strength shall be calculated as described in the following.

A 200 Crest landing

201 For craft with \( V/\sqrt{L} \geq 3 \) a slamming pressure is acting on an area equal to the reference area, \( A_R \), given below. The area shall be situated with the load point at LCG of the craft. The weight distribution of the hull girder shall be increased by the acceleration at LCG. The hull girder shall be considered out of water.

\[
A_R = k \Delta \frac{b_g v}{g_0} (m^2)
\]

where:

- \( k = 0.7 \) for crest landing
- \( k = 0.6 \) for hollow landing.

202 The load combination which is illustrated in Fig.1 may be required analysed with actual weight distribution along the hull beam.

203 The longitudinal midship bending moment may be assumed to be:

\[
M_B = \frac{\Delta}{2} \left( g_0 + a_{cg} \right) \left( e_w - \frac{l_s}{4} \right) (kNm)
\]

\( \Delta \) = displacement in tonnes
\( a_{cg} \) = vertical design acceleration at LCG
\( e_w \) = one half of the distance from LCG of the fore half body to the LCG of the aft half body of the vessel, in m
\( l_s \) = longitudinal extension of slamming reference area:

\[
l_s = \frac{A_R}{b_s}
\]

where \( b_s \) is the breadth of the slamming reference area. See Fig.2.

\( e_w - l_s/4 \) shall not be taken less than 0.04 L.

204 The reduction of \( M_B \) towards ends will be determined by the weight distribution and the extent of \( A_R \).

Fig. 1
Crest landing

Fig. 2
Breadth of midship slamming reference area
A 300 Hollow landing

301 Hollow landing is similar to crest landing except that the reference area $A_R$ is situated towards AP and FP as shown in Fig.3.

302 The load combination may be required analysed with actual weight distribution along the hull beam.

303 The longitudinal midship bending moment may be assumed to be:

$$ M_B = \frac{\Delta}{2} (g_0 + a_{cg}) (e_r - e_w) $$

$e_r$ = mean distance from the centre of the $A_R/2$ end areas to the vessels LCG in m.

$(e_r - e_w)$ not to be taken less than 0.04 L

A 400 Hydrofoils

401 The calculation of longitudinal strength of hydrofoils shall be effected for the most severe condition. As a rule this will be considering the craft sustained above the water surface by the foils and supposing it to be stationary in the navigation condition, taking into account vertical acceleration as well as the vertical components of the hydrodynamic action of the water on the foils.

A 500 Hogging and sagging bending moments

501 For all craft an investigation of hogging and sagging bending moments taking into account any immersed/ emerged structures may be required.

502 The investigation is in its simplest form to be based on a predicted phasing between pitch/heave and the passage of a meeting design wave, and shall include the pitch angle and the inertia forces to be expected in the hogging and sagging conditions.

503 Tentative formulae for bending moments (still water + wave) for high speed light craft:

For monohull craft (in kNm):

$$ M_{tot\, hog} = M_{sw} + 0.19 \, C_W \, L^2 \, B \, C_B $$

$$ M_{tot\, sag} = M_{sw} + 0.14 \, C_W \, L^2 \, B \, (C_B + 0.7) $$

$M_{sw} =$ still water moment in the most unfavourable loading condition in kNm

$= 0.11 \, C_W \, L^2 \, B \, C_B$ (kNm) in hogging if not known

$= 0$ in sagging if not known.

For twin hull craft (in kNm):

$$ M_{tot\, hog} = M_{sw} + 0.19 \, C_W \, L^2 \, (B_{WL2} + k_2 \, B_{tn}) \, C_B $$

$$ M_{tot\, sag} = M_{sw} + 0.14 \, C_W \, L^2 \, (B_{WL2} + k_3 \, B_{tn}) \, (C_B + 0.7) $$

$M_{sw} =$ still water moment in the most unfavourable loading condition in kNm

$= 0.5 \, \Delta \, L$ (kNm) in hogging if not known

$= 0$ in sagging if not known.

Additional correction of 20% to be added to the wave sagging moment for craft with large flare in the foreship.

1) Documentation of the most unfavourable still water conditions shall normally be submitted for information.

2) If the still water moment is a hogging moment, 50% of this moment can be deducted where the design sagging moment $M_{tot\, sag}$ is calculated.

$B_{tn}$ = breadth in m of cross structures (tunnel breadth)

$k_2$ and $k_3 =$ empirical factors for the effect of cross structure immersion in hogging and sagging waves. If no other value available:


\[ k_2 = 1 - \frac{z - 0.5 T}{0.5 T + 2 C_W}, \text{ minimum } 0 \]

\[ k_3 = 1 - \frac{z - 0.5 T}{0.5 T + 2.5 C_W}, \text{ minimum } 0 \]

\( k_4 = 0.25 \) in general, when \( V \) is maximum speed of craft,

\( = 0.35 \) when \( V \) is taken as the slowed down speed

\( z \) = height in m from base line to wet deck (top of tunnel).

A 600 Shear forces from longitudinal bending

601 A vertical hull girder shear force may be related to the hull girder bending moments from 200, 300, and 500 as follows:

\[ Q_b = \frac{M_B}{0.25 L} \text{ (kN)} \]

\( M_B \) = bending moment in kNm.

A 700 Axial loads

701 Axial loads from

— surge = \( \Delta a/ \)

— thrust and

— sea end pressures

may have to be estimated and added together in most exposed areas (forebody buckling control).

\( a/ \) = maximum surge acceleration, not to be taken less than:

\[ 0.4 \ g_0 \text{ for } \frac{V}{\sqrt{L}} \geq 5 \]

\[ (0.2) \ g_0 \text{ for } \frac{V}{\sqrt{L}} \leq 3 \]

with linear interpolation for intermediate \( V/\sqrt{L} \).

A 800 Combination of hull girder loads

801 The hull girder loads vertical bending, vertical shear and torsion (B400) shall be considered according to the following combinations:

— 80% longitudinal bending and shear + 60% torsion

— 60% longitudinal bending and shear + 80% torsion.

802 The hull girder loads transverse vertical bending moment (B200) and pitch connecting moment (B300) shall be considered according to the following combinations:

— 70% transverse bending + 100% pitch connecting

— 100% transverse bending + 70% pitch connecting.

B. Twin Hull Loads

B 100 General

101 The transverse strength of twin hull connecting structure may be analysed for moments and forces specified below.

102 Design forces and moments given in 200, 300 and 400 shall be used unless other values are verified by model tests or full scale measurements or if similar structures have proved to be satisfactory in service.
B 200 Vertical bending moment and shear force

201 For craft with \((V/\sqrt{L} \geq 3)\) and \(L < 50\) m, the twin hull transverse bending moment may be assumed to be:

\[
M_S = \frac{\Delta a_{cg} b}{s} \text{ (kNm)}
\]

- \(b\) = transverse distance between the centrelines of the two hulls
- \(s\) = factor given in Table B1.

Fig. 4
Transverse vertical bending moment and shear force

202 For craft with \(L \geq 50\) m the twin hull transverse bending moment shall be assumed to be the greater of:

\[
M_S = M_{S0} \left(1 + \frac{a_{cg}}{\varepsilon_0}\right) \text{ (kNm)}
\]

\[
M_S = M_{S0} + F_y (z - 0.5T) \text{ (kNm)}
\]

- \(M_{S0}\) = still water transverse bending moment in kNm
- \(F_y\) = horizontal split force on immersed hull
- \(z\) = height from base line to neutral axis of cross structure (m).

\[
M_S = \frac{3.25 \left(1 + 0.0172 \frac{V}{\sqrt{L}}\right) L^{1.05} T^{1.30} (0.5 B_{WL})^{0.146}}{L}
\cdot \left[1 - \frac{L_{BMAX}}{L} + \frac{L_{BMAX}}{L} \left(\frac{B_{MAX}}{B_{WL}}\right)^{2.10}\right] H_1 \text{ (kN)}
\]

\[
H_1 = \min \left\{ 0.143B \right\}
\]

- \(B_{WL}\) = maximum width (m) in water line (sum of both hulls)
- \(B_{MAX}\) = maximum width (m) of submerged part (sum of both hulls)
- \(L_{BMAX}\) = length in metres where \(B_{MAX}/B_{WL} > 1\)
- \(H_{S,MAX}\) = maximum significant wave height in which the vessel is allowed to operate (m)
- \(B\) = beam over all (m)
- \(z\) = height from base line to neutral axis of cross structure (m).

\[
\frac{V}{\sqrt{L}} \text{ need not be taken greater than 3}
\]

See Fig.5 for explanation of symbols. The expression should not be used for Surface Effect Ships (SES) in cushion borne mode, but shall be applied to SES in a survival condition with cushion air pressure equal to zero. A reduction factor of 0.8 is then to be applied to the dynamic split moment.
The vertical shear force in centreline between twin hull may be assumed to be:

\[ S = \frac{\Delta a_{cg}}{q} \text{ (kN)} \]

\( q \) = factor given in Table B1.

<table>
<thead>
<tr>
<th>Service restriction</th>
<th>( s )</th>
<th>( q )</th>
</tr>
</thead>
<tbody>
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<td>R4-R6</td>
<td>8.0</td>
<td>6.0</td>
</tr>
<tr>
<td>R3</td>
<td>7.5</td>
<td>5.5</td>
</tr>
<tr>
<td>R2</td>
<td>6.5</td>
<td>5.0</td>
</tr>
<tr>
<td>R1</td>
<td>5.5</td>
<td>4.0</td>
</tr>
<tr>
<td>R0</td>
<td>4.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

For craft with length \( L \geq 50 \text{ m} \) the twin hull still water transverse bending moment shall be assumed to be:

\[ M_{S0} = 4.91 \Delta (\gamma_{bg} - 0.4 B^{0.88}) \text{ (kNm)} \]

\( M_{S0} \) = still water transverse bending moment
\( \Delta \) = displacement in tonnes
\( \gamma_{bg} \) = distance in m from centre line to local centre line of one hull (see Fig.6 for definition)
\( B \) = width over all in m.

Fig. 5
Definition of parameters in case of different sectional shapes

Fig. 6
Definition of local geometry for one hull on twin hull craft
The expression shall not be used for Surface Effect Ships (SES) or for twin hulls with significant weight along the centre line.

**B 300  Pitch connecting moment**

301 The twin hull pitch connection moment (see Fig. 7) may be assumed to be:

\[ M_p = \frac{\Delta a_{cg} L}{8} \text{ (kNm)} \]

![Fig. 7](image)

**B 400  Twin hull torsional moment**

401 Hull torsional moment of twin hull may be assumed to be:

\[ M_t = \frac{\Delta a_{cg} b}{4} \text{ (kNm)} \]

\( b \) = distance in m between the two hull centerlines.