RULES FOR CLASSIFICATION

Ships

Edition January 2017

Part 3 Hull

Chapter 6 Hull local scantling
FOREWORD

DNV GL rules for classification contain procedural and technical requirements related to obtaining and retaining a class certificate. The rules represent all requirements adopted by the Society as basis for classification.

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CHANGES – CURRENT

This document supersedes the July 2016 edition. Changes in this document are highlighted in red colour. However, if the changes involve a whole chapter, section or sub-section, normally only the title will be in red colour.

Main changes January 2017, entering into force as from date of publication

- Sec.3 Minimum thicknesses
  — Sec.3 Table 1: The minimum thickness of superstructure side is adjusted.

- Sec.4 Plating
  — Sec.4 Table 1: The acceptance criteria for flooding pressure is adjusted for plate and stiffeners.

- Sec.5 Stiffeners
  — Sec.5 Table 4: The acceptance criteria for flooding pressure is adjusted for plate and stiffeners.

Editorial corrections

In addition to the above stated changes, editorial corrections may have been made.
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SECTION 1 GENERAL

1 Application

1.1 Application

1.1.1 This chapter applies to hull structure over the full length of the ship.

1.1.2 This chapter provides requirements for evaluation of plating, stiffeners and primary supporting members (PSM) subject to lateral pressure, local loads and hull girder loads, as applicable. Requirements are specified for:
   — load application in Sec.2
   — minimum thickness of plates, stiffeners and PSM in Sec.3
   — plating in Sec.4
   — stiffeners in Sec.5
   — PSM and pillars in Sec.6
   — intersection of stiffeners and PSM in Sec.7
   — superstructure and deckhouse in Sec.8.

   In addition, other requirements not related to defined design load sets, are provided.

1.1.3 Required scantlings

   The offered net scantling shall be greater than or equal to the required scantlings based on requirements provided in this chapter.

1.1.4 Additional local strength requirements

   Additional local strength requirements are provided in Ch.10 considering sloshing, impact loads (bow impact, bottom slamming and liquid impact in tanks), special cargo loads (steel coil and wheel loading) and additional local strength requirement for various structural members.

1.2 Acceptance criteria

1.2.1 Acceptance criteria shall be selected as defined in Sec.2 Table 1 and Sec.2 Table 2.
SECTION 2 LOAD APPLICATION

Symbols
For symbols not defined in this section, see Ch.1 Sec.4.

1 Load combination

1.1 Hull girder stress

1.1.1 Hull girder longitudinal stress applicable for load components S
The hull girder longitudinal stress $\sigma_{hg}$, in N/mm$^2$, for load component $S$ shall be taken as:

$$\sigma_{hg} = \sigma_{hg-sw}$$

where:

$\sigma_{hg-sw}$ = hull girder longitudinal stress, in N/mm$^2$, due to vertical still water bending moment as defined in Ch.5 Sec.3 [2] for ships without large deck openings and in Ch.5 Sec.3 [3] for ships with large deck openings.

1.1.2 Hull girder longitudinal stress applicable for load components S+D
The hull girder longitudinal stress $\sigma_{hg}$, in N/mm$^2$, for load components $S+D$ shall be taken as defined in Ch.5 Sec.3 [2] for ships without large deck openings and in Ch.5 Sec.3 [3] for ships with large deck openings.

1.2 Lateral pressures

1.2.1 Static and dynamic pressures in intact conditions
The static and dynamic lateral pressures, as defined in Ch.4, in intact condition induced by the sea and the various types of cargoes, ballast and other liquids shall be considered. Applied loads will depend on the location of the elements under consideration, and the adjacent type of compartments.

1.2.2 Lateral pressure in flooded conditions
Watertight boundaries of compartments not intended to carry liquids, excluding hull envelope, shall be subjected to lateral pressure in flooded conditions. Compartments intended to carry liquids which have overflow height below freeboard deck shall also be checked for lateral pressure in flooded conditions.

1.3 Pressure combination

1.3.1 Elements of the outer shell
If the compartment adjacent to the outer shell is intended to carry liquids, the static and dynamic lateral pressures to be considered are the differences between the internal pressures and the external sea pressures at the corresponding draught.

If the compartment adjacent to the outer shell is not intended to carry liquids, the internal pressures and external sea pressures shall be considered independently.

1.3.2 Elements other than those of the outer shell
Except as specified in [1.3.1], the static and dynamic lateral pressures on an element separating two adjacent compartments are those obtained considering the two compartments individually loaded.
2 Design load sets

2.1 Application of load components

2.1.1 Application
These requirements apply to:
— plating and stiffeners along the full length of the ship
— primary supporting members, if scantlings are not determined by global FE analysis or partial ship structural FE analysis
— plating, stiffeners and primary supporting members in superstructures and deckhouses contributing to hull girder longitudinal strength.

2.1.2 Load components
The static and dynamic load components shall be determined in accordance with Ch.4 Sec.7 Table 1. Radius of gyration, \( k_r \), and metacentric height, \( GM \), shall be in accordance with Ch.4 Sec.3 for the considered loading conditions specified in the design load sets given in Table 1.

2.1.3 Design load sets for plating and stiffeners
Static and dynamic design load sets for plating and stiffeners are given in Table 1. Impact and sloshing load sets are considered in Ch.10.
In addition, design load sets for specific ship types are given in Pt.5.
## Table 1 Design load sets

<table>
<thead>
<tr>
<th>Structural member</th>
<th>Design load set</th>
<th>Design load scenario</th>
<th>Load component</th>
<th>Drafth</th>
<th>Acceptance criteria</th>
<th>Loading condition for definition of GM and k_r</th>
</tr>
</thead>
<tbody>
<tr>
<td>External shell and exposed deck</td>
<td>SEA-1</td>
<td>2</td>
<td>$P_S + P_W + P_D$</td>
<td>$T_{SC}$</td>
<td>AC-II</td>
<td>Full load condition</td>
</tr>
<tr>
<td>Superstructure side</td>
<td></td>
<td></td>
<td>$\max(P_W, P_S)$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>External shell</td>
<td>SEA-2</td>
<td>1</td>
<td>$P_S$</td>
<td>$T_{SC}$</td>
<td>AC-I</td>
<td>-</td>
</tr>
</tbody>
</table>

### Boundaries of water ballast tanks and ballast holds

<table>
<thead>
<tr>
<th>Structural member</th>
<th>Design load set</th>
<th>Design load scenario</th>
<th>Load component</th>
<th>Drafth</th>
<th>Acceptance criteria</th>
<th>Loading condition for definition of GM and k_r</th>
</tr>
</thead>
<tbody>
<tr>
<td>WB-1</td>
<td>2</td>
<td>$P_{ls-1} + P_{ld} - (P_S + P_W)^{1)}$</td>
<td>$T_{BAL}$</td>
<td>AC-II</td>
<td>Normal ballast condition</td>
<td></td>
</tr>
<tr>
<td>WB-2</td>
<td>3</td>
<td>$P_{ls-2} + P_{ld} - (P_S + P_W)^{1)}$</td>
<td>$T_{BAL}$</td>
<td>AC-II</td>
<td>Normal ballast condition</td>
<td></td>
</tr>
<tr>
<td>WB-3</td>
<td>4</td>
<td>$\max(P_{ls-4}, P_{ls-ST}) - P_S^{1)}$</td>
<td>$\max(T_{BAL}; 0.25T_{SC})$</td>
<td>AC-III</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>WB-4</td>
<td>1</td>
<td>$P_{ls-3} - P_S^{1)}$</td>
<td>$\max(T_{BAL}; 0.25T_{SC})$</td>
<td>AC-I</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

### Boundaries of tanks other than ballast water tanks

<table>
<thead>
<tr>
<th>Structural member</th>
<th>Design load set</th>
<th>Design load scenario</th>
<th>Load component</th>
<th>Drafth</th>
<th>Acceptance criteria</th>
<th>Loading condition for definition of GM and k_r</th>
</tr>
</thead>
<tbody>
<tr>
<td>TK-1</td>
<td>2</td>
<td>$P_{ls-1} + P_{ld} - (P_S + P_W)^{1)}$</td>
<td>$T_{BAL}$</td>
<td>AC-II</td>
<td>Normal ballast condition</td>
<td></td>
</tr>
<tr>
<td>TK-2</td>
<td>4</td>
<td>$P_{ls-ST} - P_S^{1)}$</td>
<td>$\max(T_{BAL}; 0.25T_{SC})$</td>
<td>AC-III</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>TK-3</td>
<td>1</td>
<td>$P_{ls-3} - P_S^{1)}$</td>
<td>$\max(T_{BAL}; 0.25T_{SC})$</td>
<td>AC-I</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

### Internal structures in tanks

<table>
<thead>
<tr>
<th>Structural member</th>
<th>Design load set</th>
<th>Design load scenario</th>
<th>Load component</th>
<th>Drafth</th>
<th>Acceptance criteria</th>
<th>Loading condition for definition of GM and k_r</th>
</tr>
</thead>
<tbody>
<tr>
<td>INT-1</td>
<td>1</td>
<td>$P_{int}$</td>
<td>$T_{SC}$</td>
<td>AC-I</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

### Collision bulkhead

<table>
<thead>
<tr>
<th>Structural member</th>
<th>Design load set</th>
<th>Design load scenario</th>
<th>Load component</th>
<th>Drafth</th>
<th>Acceptance criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>FD-1</td>
<td>5</td>
<td>$P_{fs}$</td>
<td>$T_{DAM}$</td>
<td>AC-I</td>
<td>-</td>
</tr>
</tbody>
</table>

### Watertight boundaries other than collision bulkhead

<table>
<thead>
<tr>
<th>Structural member</th>
<th>Design load set</th>
<th>Design load scenario</th>
<th>Load component</th>
<th>Drafth</th>
<th>Acceptance criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>UDL-1</td>
<td>2</td>
<td>$P_{dl-s} + P_{dl-d}$</td>
<td>$T_{BAL}$</td>
<td>AC-II</td>
<td>Normal ballast condition</td>
</tr>
<tr>
<td>UDL-2</td>
<td>1</td>
<td>$P_{dl-s}$</td>
<td>$F_{U-s}$</td>
<td>AC-I</td>
<td>-</td>
</tr>
</tbody>
</table>

### Exposed decks and non-exposed decks and platforms with distributed load

<table>
<thead>
<tr>
<th>Structural member</th>
<th>Design load set</th>
<th>Design load scenario</th>
<th>Load component</th>
<th>Drafth</th>
<th>Acceptance criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>UDL-1</td>
<td>2</td>
<td>$P_{dl-s} + P_{dl-d}$</td>
<td>$F_{U-s}$</td>
<td>$F_{U-d}$</td>
<td>$T_{BAL}$</td>
</tr>
</tbody>
</table>

### Decks and hatch covers/ RO/RO equipments with wheel loading

<table>
<thead>
<tr>
<th>Structural member</th>
<th>Design load set</th>
<th>Design load scenario</th>
<th>Load component</th>
<th>Drafth</th>
<th>Acceptance criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>WL-1</td>
<td>2</td>
<td>$P_{wl-2}$</td>
<td>$T_{BAL}$</td>
<td>AC-II</td>
<td>Normal ballast condition</td>
</tr>
<tr>
<td>WL-2</td>
<td>1</td>
<td>$P_{wl-1}$</td>
<td>-</td>
<td>AC-I</td>
<td>-</td>
</tr>
</tbody>
</table>
Hull local scantling

2.1.4 Design load sets for primary supporting members
Design load sets to be applied for primary supporting members are described in Table 2. The load sets shall in general be based on the net load acting on the PSM of double- and single skin type.

In addition, design load sets for specific ship types are given in Pt. 5.

Design loading conditions in FE analysis are described in Ch. 7 Sec. 1 in general and for specific ship types are given in Pt. 5.
### Table 2 Design load sets for primary supporting members

<table>
<thead>
<tr>
<th>Description</th>
<th>Primary supporting members</th>
<th>Design load set</th>
<th>Load component</th>
<th>Draft</th>
<th>Acceptance criteria</th>
<th>Loading condition for definition of GM and $k_r$</th>
<th>Load pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical side web frames/floors</td>
<td>SEA-1</td>
<td>$P_{ex} - (P_{dls} + P_{dl-d})$ or $(F_{U-s} + F_{U-d})$</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottom and side girders/grillage</td>
<td>SEA-1h</td>
<td>$P_{ex} - (P_{dls} + P_{dl-d})$ or $(F_{U-s} + F_{U-d})$</td>
<td>$M_{wv-h} + M_{sw-h}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SEA-1h</td>
<td>$P_{ex} - (P_{dls} + P_{dl-d})$ or $(F_{U-s} + F_{U-d})$</td>
<td>$M_{wv-h} + M_{sw-h}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SEA-1s</td>
<td>$P_{ex} - (P_{dls} + P_{dl-d})$ or $(F_{U-s} + F_{U-d})$</td>
<td>$M_{wv-s} + M_{sw-s}$</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>SEA-1s</td>
<td>$P_{ex} - (P_{dls} + P_{dl-d})$ or $(F_{U-s} + F_{U-d})$</td>
<td>$M_{wv-s} + M_{sw-s}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>External shell (empty tanks), excluding decks</td>
<td>Vertical side web frames/floors</td>
<td>TK-1, WB-1</td>
<td>$P_{in} - P_{ex}$</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottom and side girders/grillage</td>
<td>TK-1h, WB-1h</td>
<td>$P_{in} - P_{ex}$</td>
<td>$M_{wv-h} + M_{sw-h}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>TK-1h, WB-1h</td>
<td>$P_{in} - P_{ex}$</td>
<td>$M_{wv-h} + M_{sw-h}$</td>
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<tr>
<td></td>
<td>TK-1s, WB-1s</td>
<td>$P_{in} - P_{ex}$</td>
<td>$M_{wv-s} + M_{sw-s}$</td>
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<td></td>
<td></td>
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<tr>
<td>Description</td>
<td>Primary supporting members</td>
<td>Design load set</td>
<td>Load component</td>
<td>Draught</td>
<td>Acceptance criteria</td>
<td>Loading condition for definition of GM and k</td>
<td>Load pattern</td>
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<tr>
<td>Local load</td>
<td>Hull girder load</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical side web frames/ floors</td>
<td>TK-1s, WB-1s</td>
<td>$P_{in} - P_{ex}$</td>
<td>$M_{sw-s} + M_{sw-s}$</td>
<td>$M_{sw-s} + M_{sw-s}$</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottom and side girders/ grillage</td>
<td>TK-3, WB-4</td>
<td>$P_{in} - P_{ex}$</td>
<td>$M_{sw-h}$</td>
<td>$T_{BAL}$</td>
<td>AC-I</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TK-3h, WB-4h</td>
<td>$P_{in} - P_{ex}$</td>
<td>$M_{sw-h}$</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>TK-3s, WB-4s</td>
<td>$P_{in} - P_{ex}$</td>
<td>$M_{sw-s}$</td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>TK-3h, WB-4h</td>
<td>$P_{in} - P_{ex}$</td>
<td>$M_{sw-s}$</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical side web frames/ floors</td>
<td>TK-2, WB-3</td>
<td>$P_{in} - P_{ex}$</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottom and side girders/ grillage</td>
<td>TK-2h, WB-3h</td>
<td>$P_{in} - P_{ex}$</td>
<td>$M_{sw-h}$</td>
<td>$T_{BAL}$</td>
<td>AC-III</td>
<td>-</td>
<td></td>
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<tr>
<td></td>
<td>TK-2h, WB-3h</td>
<td>$P_{in} - P_{ex}$</td>
<td>$M_{sw-h}$</td>
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<td></td>
<td>TK-2s, WB-3s</td>
<td>$P_{in} - P_{ex}$</td>
<td>$M_{sw-s}$</td>
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<tr>
<td></td>
<td>TK-2s, WB-3s</td>
<td>$P_{in} - P_{ex}$</td>
<td>$M_{sw-s}$</td>
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<td>Description</td>
<td>Primary supporting members</td>
<td>Design load set</td>
<td>Load component</td>
<td>Draught</td>
<td>Acceptance criteria</td>
<td>Loading condition for definition of GM and k_r</td>
<td>Load pattern</td>
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<tr>
<td>Vertical side web frames</td>
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<tr>
<td>Longitudinal stringers/grillage</td>
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<tr>
<td>Transverse girders</td>
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<td></td>
</tr>
<tr>
<td>External decks and platforms, including superstructure (green sea pressure only)</td>
<td>Longitudinal deck girders/grillage</td>
<td></td>
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<tr>
<td>Description</td>
<td>Primary supporting members</td>
<td>Design load set</td>
<td>Load component</td>
<td>Draught</td>
<td>Acceptance criteria</td>
<td>Loading condition for definition of GM and ( k_r )</td>
<td>Load pattern</td>
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<tr>
<td>-------------</td>
<td>---------------------------</td>
<td>----------------</td>
<td>----------------</td>
<td>---------</td>
<td>---------------------</td>
<td>-------------------------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Transverse deck girders and pillars</td>
<td>UDL-1</td>
<td>( P_{\text{dt-s}} + P_{\text{dt-d}} ) ( F_{U-s} + F_{U-d} ) (^1) (^8)</td>
<td>N/A</td>
<td>( T_{\text{BAL}} )</td>
<td>AC-II</td>
<td>Normal ballast condition</td>
<td></td>
</tr>
<tr>
<td>Longitudinal deck girders/grillage including pillars</td>
<td>UDL-1h</td>
<td>( P_{\text{dt-s}} + P_{\text{dt-d}} ) ( F_{U-s} + F_{U-d} ) (^2) (^8)</td>
<td>( M_{\text{wv-h}} + M_{\text{sw-h}} ) (^2)</td>
<td>( T_{\text{BAL}} )</td>
<td>AC-I</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UDL-1h</td>
<td>( P_{\text{dt-s}} + P_{\text{dt-d}} ) ( F_{U-s} + F_{U-d} ) (^3) (^8)</td>
<td>( M_{\text{wv-s}} + M_{\text{sw-s}} ) (^2)</td>
<td>( T_{\text{BAL}} )</td>
<td>AC-I</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UDL-1s</td>
<td>( P_{\text{dt-s}} + P_{\text{dt-d}} ) ( F_{U-s} + F_{U-d} ) (^2) (^8)</td>
<td>( M_{\text{wv-s}} + M_{\text{sw-s}} ) (^3)</td>
<td>( T_{\text{BAL}} )</td>
<td>AC-I</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UDL-1s</td>
<td>( P_{\text{dt-s}} + P_{\text{dt-d}} ) ( F_{U-s} + F_{U-d} ) (^3) (^8)</td>
<td>( M_{\text{wv-s}} + M_{\text{sw-s}} ) (^3)</td>
<td>( T_{\text{BAL}} )</td>
<td>AC-I</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Distributed deck load on internal or external decks (adjacent tanks empty)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longitudinal deck girders/grillage including pillars</td>
<td>UDL-2h</td>
<td>( P_{\text{dt-s}} , F_{U-s} ) (^1) (^8)</td>
<td>N/A</td>
<td>( T_{\text{BAL}} )</td>
<td>AC-I</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UDL-2s</td>
<td>( P_{\text{dt-s}} , F_{U-s} ) (^3) (^8)</td>
<td>( M_{\text{sw-s}} ) (^3)</td>
<td>( T_{\text{BAL}} )</td>
<td>AC-II</td>
<td>Normal ballast condition</td>
<td></td>
</tr>
<tr>
<td>Decks and transverse bulkheads: stringers/vertical web frames/grillage and transverse deck girders</td>
<td>TK-1, WB-1</td>
<td>( P_{\text{in}} ) (^1) (^4) (^6)</td>
<td>N/A</td>
<td>( T_{\text{BAL}} )</td>
<td>AC-II</td>
<td>Normal ballast condition</td>
<td></td>
</tr>
<tr>
<td>Longitudinal bulkheads: vertical web frames</td>
<td>TK-1, WB-1</td>
<td>( P_{\text{in}} ) (^1) (^4) (^6)</td>
<td>N/A</td>
<td>( T_{\text{BAL}} )</td>
<td>AC-II</td>
<td>Normal ballast condition</td>
<td></td>
</tr>
<tr>
<td>Tank boundaries and/or watertight boundaries (excluding external decks)</td>
<td>TK-1h, WB-1h</td>
<td>( P_{\text{in}} ) (^2) (^4) (^6)</td>
<td>( M_{\text{wv-h}} + M_{\text{sw-h}} ) (^2)</td>
<td>( T_{\text{BAL}} )</td>
<td>AC-II</td>
<td>Normal ballast condition</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TK-1h, WB-1h</td>
<td>( P_{\text{in}} ) (^3) (^4) (^6)</td>
<td>( M_{\text{wv-h}} + M_{\text{sw-h}} ) (^3)</td>
<td>( T_{\text{BAL}} )</td>
<td>AC-II</td>
<td>Normal ballast condition</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TK-1s, WB-1s</td>
<td>( P_{\text{in}} ) (^2) (^4) (^6)</td>
<td>( M_{\text{wv-s}} + M_{\text{sw-s}} ) (^2)</td>
<td>( T_{\text{BAL}} )</td>
<td>AC-II</td>
<td>Normal ballast condition</td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td>Primary supporting members</td>
<td>Design load set</td>
<td>Local load</td>
<td>Hull girder load</td>
<td>Draught</td>
<td>Acceptance criteria</td>
<td>Loading condition for definition of GM and $k_r$</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------------------------</td>
<td>-----------------</td>
<td>------------</td>
<td>------------------</td>
<td>---------</td>
<td>---------------------</td>
<td>-------------------------------------------------</td>
</tr>
<tr>
<td>Decks and transverse bulkheads: stringers/vertical web frames/grillage and transverse deck girders</td>
<td>TK-1s, WB-1s</td>
<td>$P_{in}$ 3) 4) 6)</td>
<td>$M_{sw-v} + M_{sw-s}$ 3)</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longitudinal bulkheads: vertical web frames</td>
<td>TK-3, WB-4</td>
<td>$P_{in}$ 1) 4) 6)</td>
<td>N/A</td>
<td></td>
<td>$T_{BAL}$</td>
<td>AC-I</td>
<td>-</td>
</tr>
<tr>
<td>Decks and longitudinal bulkheads: girders/grillage</td>
<td>TK-3h, WB-4h</td>
<td>$P_{in}$ 4) 6)</td>
<td>$M_{sw-h}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TK-3s, WB-4s</td>
<td>$P_{in}$ 4) 6)</td>
<td>$M_{sw-s}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical side web frames/floors</td>
<td>TK-2, WB-3</td>
<td>$P_{in} - P_{ex}$ 1) 4) 5)</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottom and side girders/grillage</td>
<td>TK-2h, WB-3h</td>
<td>$P_{in} - P_{ex}$ 2) 4) 5)</td>
<td>$M_{sw-h}$</td>
<td></td>
<td>$T_{BAL}$</td>
<td>AC-III</td>
<td>-</td>
</tr>
<tr>
<td>TK-2h, WB-3h</td>
<td>$P_{in} - P_{ex}$ 3) 4) 5)</td>
<td>$M_{sw-h}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TK-2s, WB-3s</td>
<td>$P_{in} - P_{ex}$ 2) 4) 5)</td>
<td>$M_{sw-s}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TK-2s, WB-3s</td>
<td>$P_{in} - P_{ex}$ 3) 4) 5)</td>
<td>$M_{sw-s}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decks and transverse bulkheads: stringers/vertical web frames/grillage and transverse deck girders</td>
<td>FD-1</td>
<td>$P_{in}$ 1) 7)</td>
<td>N/A</td>
<td></td>
<td>$T_{DAM}$</td>
<td>AC-III</td>
<td>-</td>
</tr>
<tr>
<td>Longitudinal bulkheads: vertical web frames</td>
<td>FD-1</td>
<td>$P_{in}$ 1) 7)</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decks and longitudinal bulkheads: girders/grillage and transverse deck girders</td>
<td>FD-1h</td>
<td>$P_{in}$ 7)</td>
<td>$M_{sw-h}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FD-1s</td>
<td>$P_{in}$ 7)</td>
<td>$M_{sw-s}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Hull Local Scantling

<table>
<thead>
<tr>
<th>Description</th>
<th>Design load set</th>
<th>Acceptance criteria for definition of $GM$ and $k_r$</th>
<th>Load pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local load 10)</td>
<td>Hull girder load</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) The EDW giving the highest pressure to be applied.
2) The EDW giving the highest pressure with corresponding bending moment to be applied. When envelope accelerations are applied for $P_{dl-d}$, the maximum hull girder bending moment shall be applied.
3) The EDW giving the highest bending moment with corresponding pressure to be applied. When envelope accelerations are applied for $P_{dl-d}$, the maximum hull girder bending moment shall be applied.
4) $P_{in}$ shall also cover water ballast and bulk cargo hold loads.
5) $P_{ex}$ shall be considered for external shell only.
6) Pressure from one side only. Full tank with adjacent tank empty.
7) Flooded pressure is not applicable to external shell. Pressure from one side only. Full tank with adjacent tank empty. The boundaries of void and dry spaces not forming part of hull external shell shall be evaluated using design load sets FD-1, FD-1h and FD-1s.
8) Distributed or concentrated loads only. Need not to be combined with simultaneously occurring green sea pressure.
9) $P_{si}$ is design pressure for external sides of superstructure and deckhouse.
10) Local loads are described in Ch.4 Sec.2 Table 1.
SECTION 3 MINIMUM THICKNESSES

Symbols
For symbols not defined in this section, see Ch.1 Sec.4.

1 Plating

1.1 Minimum thickness requirements

1.1.1 The net thickness of plating, in mm, shall comply with the minimum thickness requirement given by:

\[ t = a + bL_2 \sqrt{k} \]

where:

\( a \) = coefficient as defined in Table 1
\( b \) = coefficient as defined in Table 1.

Table 1 Minimum net thickness for plating

<table>
<thead>
<tr>
<th>Element</th>
<th>Location</th>
<th>Location</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell</td>
<td>Keel</td>
<td></td>
<td>5.0</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>Bottom and bilge</td>
<td></td>
<td>4.5</td>
<td>0.035</td>
</tr>
<tr>
<td></td>
<td>Side shell and superstructure side</td>
<td>From upper end of bilge plating to ( T_{SC} + 4.6 ) m</td>
<td>4.0</td>
<td>0.035</td>
</tr>
<tr>
<td></td>
<td></td>
<td>From ( T_{SC} + 4.6 ) m to ( T_{SC} + 6.9 ) m</td>
<td></td>
<td>0.025</td>
</tr>
<tr>
<td></td>
<td></td>
<td>From ( T_{SC} + 6.9 ) m to ( T_{SC} + 9.2 ) m</td>
<td></td>
<td>0.015</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Elsewhere( ^6 )</td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>Sea chest boundaries</td>
<td></td>
<td>4.5</td>
<td>0.05</td>
</tr>
<tr>
<td>Deck</td>
<td>Weather deck( ^1,2,3,4 ) , strength deck( ^2,3 ) and platform deck in machinery space</td>
<td></td>
<td>4.5</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Boundary for cargo tanks, water ballast tanks and hold intended for cargo in bulk</td>
<td></td>
<td>4.5</td>
<td>0.015</td>
</tr>
<tr>
<td></td>
<td>Other decks( ^3,4,5 )</td>
<td></td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td>Inner bottom</td>
<td>Cargo spaces loaded through cargo hatches except container holds</td>
<td></td>
<td>5.5</td>
<td>0.025</td>
</tr>
<tr>
<td></td>
<td>Other spaces</td>
<td></td>
<td>4.5</td>
<td>0.02</td>
</tr>
<tr>
<td>Bulkheads</td>
<td>Bulkheads for cargo tanks, water ballast tanks and hold intended for cargo in bulk</td>
<td></td>
<td>4.5</td>
<td>0.015</td>
</tr>
<tr>
<td></td>
<td>Peak bulkheads and machinery space end bulkheads</td>
<td></td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>Watertight bulkheads and other tanks bulkheads</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-tight bulkheads in tanks</td>
<td></td>
<td>5.0</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>Other non-tight bulkheads</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Walls in accommodation</td>
<td></td>
<td>4.5</td>
<td>0</td>
</tr>
</tbody>
</table>

Rules for classification: Ships — DNVGL-RU-SHIP Pt.3 Ch.6. Edition January 2017
Hull local scantling

DNV GL AS
<table>
<thead>
<tr>
<th>Element</th>
<th>Location</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) For weather deck forward of 0.2 ( L ) from F.E, ( b ) shall not be taken less than 0.01.</td>
<td>4.5 + 0.01 ( L_1 )</td>
<td>( a )</td>
<td>( b )</td>
</tr>
<tr>
<td>2) For two continuous decks arranged above 0.7 ( D ) from baseline, ( b ) may be reduced by 0.01.</td>
<td>4.0</td>
<td>( a )</td>
<td>( b )</td>
</tr>
<tr>
<td>3) For more than two continuous decks arranged above 0.7 ( D ) from baseline, ( b ) may be taken equal to 0.</td>
<td>( a )</td>
<td>( b )</td>
<td></td>
</tr>
<tr>
<td>4) For the decks not contributing to hull girder longitudinal strength, ( b ) may be taken equal to 0.</td>
<td>( a )</td>
<td>( b )</td>
<td></td>
</tr>
<tr>
<td>5) For cargo decks sheltered with wood or an approved composition, ( a ) may be taken equal to 4.0.</td>
<td>( a )</td>
<td>( b )</td>
<td></td>
</tr>
<tr>
<td>6) For superstructure side in ships with two or more continuous decks arranged above 0.7 ( D ) from baseline, ( b ) may be taken equal to 0 from 1.7 ( C_w ) m above WL at scantling draft.</td>
<td>( a )</td>
<td>( b )</td>
<td></td>
</tr>
</tbody>
</table>

For minimum thicknesses for deckhouses and superstructures see also Sec.8 [3.1].

### 2 Stiffeners and tripping brackets

#### 2.1 Minimum thickness requirements

**2.1.1** The net thickness of the web and face plate, if any, of stiffeners and tripping brackets in mm, shall comply with the minimum net thickness given in Table 2.

In addition, the net thickness of the web of stiffeners and tripping brackets, in mm, shall be:

— not less than 40% of the net required thickness of the attached plating, to be determined according to Sec.4.

**Table 2 Minimum net thickness for stiffeners and tripping brackets**

<table>
<thead>
<tr>
<th>Element</th>
<th>Location</th>
<th>Net thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stiffeners and attached end brackets</td>
<td>Tank boundary</td>
<td>4.5 + 0.01 ( L_1 )</td>
</tr>
<tr>
<td></td>
<td>Structures in deckhouse and superstructure and decks for vessels with more than 2 continuous decks above 0.7 ( D ) from baseline</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Other structure</td>
<td>4.5 + 0.005 ( L_1 )</td>
</tr>
<tr>
<td>Tripping brackets</td>
<td></td>
<td>4.5 + 0.01 ( L_1 )</td>
</tr>
</tbody>
</table>

### 3 Primary supporting members

#### 3.1 Minimum thickness requirements

**3.1.1** The net thickness of web plating and flange of primary supporting members in mm, shall comply with the appropriate minimum thickness requirements given by:

\[
t = a + bL_{2\sqrt{k}}
\]

where:

\( a \) = coefficient as defined in Table 3

\( b \) = coefficient as defined in Table 3.
### Table 3 Minimum net thickness for primary supporting members

<table>
<thead>
<tr>
<th>Element</th>
<th>$a$</th>
<th>$b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottom centreline girder and lower strake of centreline wash bulkhead</td>
<td>5.0</td>
<td>0.03</td>
</tr>
<tr>
<td>Other bottom girders</td>
<td>5.0</td>
<td>0.017</td>
</tr>
<tr>
<td>Floors</td>
<td>5.0</td>
<td>0.015</td>
</tr>
<tr>
<td>PSM supporting side shell, ballast tank, cargo tank and hold intended for cargo in bulk</td>
<td>4.5</td>
<td>0.015</td>
</tr>
<tr>
<td>Other PSM</td>
<td>4.5</td>
<td>0.015</td>
</tr>
<tr>
<td>PSM in peak tanks</td>
<td>5.0</td>
<td>0.025</td>
</tr>
</tbody>
</table>

1) The value of $bL_2$ does not need to be greater than 5.0.
2) For stringers in double side next to dry space not intended for cargo in bulk, the value of $bL_2$ does not need to be taken greater than 2.5.
3) Other specific requirements related to ship types are given in Pt.5.
SECTION 4 PLATING

Symbols

For symbols not defined in this section, see Ch.1 Sec.4.

\( \alpha_p = \) correction factor for the panel aspect ratio to be taken as follows but not to be taken greater than 1.0:

\[ \alpha_p = 1.2 - \frac{b}{2.1a} \]

\( a = \) length of plate panel, in mm, as defined in Ch.3 Sec.7 [2.1.1]

\( b = \) breadth of plate panel, in mm, as defined in Ch.3 Sec.7 [2.1.1]

\( P = \) design pressure for the considered design load set, see Sec.2 [2], calculated at the load calculation point as defined in Ch.3 Sec.7 [2.2], in kN/m²

\( \sigma_{hg} = \) hull girder longitudinal stress, in N/mm², as defined in Sec.2 [1], calculated at the load calculation point as defined in Ch.3 Sec.7 [2.2].

1 Plating subjected to lateral pressure

1.1 General

1.1.1 Plating

The net thickness, in mm, shall not be taken less than the greatest value for all applicable design load sets, as defined in Sec.2 [2.1.3], given by:

\[ t = 0.0158\alpha_p b \sqrt{\frac{P}{C_a R_{ch}}} \]

where:

\( C_a = \) permissible bending stress coefficient for plate taken equal to:

\[ C_a = \beta_a - \alpha_a \left| \frac{\sigma_{hg}}{R_{ch}} \right| \]

not to be taken greater than \( C_{a-max} \)

\( \beta_a = \) coefficient as defined in Table 1

\( \alpha_a = \) coefficient as defined in Table 1

\( C_{a-max} = \) maximum permissible bending stress coefficient as defined in Table 1.
### Table 1 Plating, definition of $\beta_a$, $\alpha_a$ and $C_{a\text{-max}}$

<table>
<thead>
<tr>
<th>Acceptance criteria</th>
<th>Structural member</th>
<th>$\beta_a$</th>
<th>$\alpha_a$</th>
<th>$C_{a\text{-max}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC-I</td>
<td>Longitudinal members</td>
<td>0.90</td>
<td>0.50</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>Longitudinal stiffened plating</td>
<td>0.90</td>
<td>1.00</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>Transverse stiffened plating</td>
<td>0.80</td>
<td>0.00</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>Other members</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Longitudinal members</td>
<td>1.05</td>
<td>0.50</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>Longitudinal stiffened plating</td>
<td>1.05</td>
<td>1.00</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>Transverse stiffened plating</td>
<td>0.95</td>
<td>0.00</td>
<td>0.95</td>
</tr>
<tr>
<td>AC-II</td>
<td>Longitudinal members</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Longitudinal stiffened plating</td>
<td>1.25</td>
<td>0.5</td>
<td>1.15</td>
</tr>
<tr>
<td></td>
<td>Transverse stiffened plating</td>
<td>1.15</td>
<td>1.0</td>
<td>1.15</td>
</tr>
<tr>
<td></td>
<td>Other longitudinal members</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Longitudinal stiffened plating</td>
<td>1.10</td>
<td>0.50</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Transverse stiffened plating</td>
<td>1.10</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Transverse boundaries of ballast water tanks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Transverse boundaries between tanks and dry spaces or dry cargo holds not intended to carry liquid or bulk cargo</td>
<td>1.15</td>
<td>0.00</td>
<td>1.15</td>
</tr>
<tr>
<td></td>
<td>Other members</td>
<td>1.10</td>
<td>0.00</td>
<td>1.15</td>
</tr>
<tr>
<td>AC-III</td>
<td>Longitudinal watertight boundaries 1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Longitudinal stiffened plating</td>
<td>1.25</td>
<td>0.50</td>
<td>1.15</td>
</tr>
<tr>
<td></td>
<td>Transverse stiffened plating</td>
<td>1.15</td>
<td>1.00</td>
<td>1.15</td>
</tr>
<tr>
<td></td>
<td>Other watertight boundaries 1)</td>
<td>1.15</td>
<td>0.00</td>
<td>1.15</td>
</tr>
</tbody>
</table>

1) Only applicable for flooding pressure

### 1.2 Plating of corrugated bulkheads

#### 1.2.1 Cold and hot formed corrugations

The net thicknesses, in mm, of the web and flange plates of corrugated bulkheads shall not be taken less than the greatest value calculated for all applicable design load sets, as defined in Sec.2 [2.1.3], given by:

$$t = 0.0158b_p \sqrt{\frac{|P|}{C_{CB^{2}}}eH}$$

where:

- $b_p$ = breadth of plane corrugation plating:
  - $b_p = a$ for flange plating, in mm, as defined in Ch.3 Sec.6 Figure 10
  - $b_p = c$ for web plating, in mm, as defined in Ch.3 Sec.6 Figure 10
Hull local scantling

\[ C_{CB} = \beta_{CB} - \alpha_{CB} \frac{\sigma_{kg}}{R_{eH}} \]

not to be greater than \( C_{CB\text{-max}} \)

\[ \beta_{CB} = \text{coefficient as defined in Table 2} \]
\[ \alpha_{CB} = \text{coefficient as defined in Table 2} \]
\[ C_{CB\text{-max}} = \text{maximum permissible bending stress coefficient as defined in Table 2}. \]

**Table 2 Corrugations, definition of \( \beta_{CB}, \alpha_{CB} \) and \( C_{CB\text{-max}} \)**

<table>
<thead>
<tr>
<th>Acceptance criteria</th>
<th>Structural member</th>
<th>( \beta_{CB} )</th>
<th>( \alpha_{CB} )</th>
<th>( C_{CB\text{-max}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC-I</td>
<td>Horizontally corrugated longitudinal bulkheads</td>
<td>0.90</td>
<td>0.50</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>Other corrugated bulkheads</td>
<td>0.75</td>
<td>0.00</td>
<td>0.75</td>
</tr>
<tr>
<td>AC-II</td>
<td>Horizontally corrugated longitudinal bulkheads</td>
<td>1.05</td>
<td>0.50</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td>Other corrugated bulkheads</td>
<td>0.90</td>
<td>0.00</td>
<td>0.90</td>
</tr>
<tr>
<td>AC-III</td>
<td>Horizontally corrugated longitudinal bulkheads</td>
<td>1.10</td>
<td>0.50</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>Other corrugated bulkheads</td>
<td>0.95</td>
<td>0.00</td>
<td>0.95</td>
</tr>
</tbody>
</table>

1.2.2 Built-up corrugations

For built-up corrugations, with flange and web plate of different thickness, the net thickness, in mm, shall be taken as the greatest value calculated for all applicable design load sets, as defined in Sec.2 [2.1.3], given by:

\[ t_1 = \sqrt{\frac{0.0005b_p^2P}{C_{CB}R_{eH}} - t_2^2} \]

where:

\( t_1 \) = net thickness of the thicker plating, either flange or web, in mm
\( t_2 \) = net required thickness of the thinner plating, either flange or web, not to be less than required by [1.2.1], in mm
\( b_p \) = breadth of thicker plate, either flange or web, in mm
\( C_{CB} \) = permissible bending stress coefficient as defined in [1.2.1].

1.2.3 Section modulus of corrugations

The requirements given in the following apply to corrugations of bulkheads.

As an alternative the strength of the corrugations may be verified by direct strength assessment in accordance with Sec.6 [2].

The net section modulus, in cm³, of corrugated bulkheads subjected to lateral pressure shall not be less than the value obtained from the following formula:

\[ Z = \frac{P_s C_{bdg}^2}{f_{bdg} s_c c'} \]
where:

\[ P \] = design pressure for the design load set as defined in Sec.2 Table 1 and calculated at the load calculation point defined in Ch.3 Sec.7 [3.2] in kN/m²

\[ s_c \] = half pitch length, in mm, of the corrugation, as defined in Ch.3 Sec.6 Figure 10

\[ \ell_{bdg} \] = effective bending span, in m, as defined in Ch.3 Sec.6 [5.1.4]

\[ f_{bdg} \] = bending moment factor given in Sec.6 Table 1. More exact value may be based on direct calculations

\[ C_s \] = permissible bending stress coefficient as defined in Table 3 for the design load set being considered, to be taken as:

\[ C_s = \beta_s - \alpha_s \sqrt{\frac{\sigma_{hgl}}{R_{eH}}} \] not to be greater than \( C_{s-max} \)

For corrugation angle between 45° and 55° the reduction in \( C_s \) as given in Ch.3 Sec.6 [5.1.1] applies.

\[ C_{s-max} \] = coefficient, as defined in Table 3
\[ \alpha_s \] = coefficient, as defined in Table 3
\[ \beta_s \] = coefficient, as defined in Table 3
\[ \sigma_{cx'} \] = ultimate buckling stress, in N/mm², of corrugation flange as defined in DNVGL-CG-0128 Sec.3 [2.2.3] applying buckling coefficients given in DNVGL-CG-0128 Sec.3 [3].

**Table 3 Corrugations, definition of \( \beta_s, \alpha_s \) and \( C_{s-max} \)**

<table>
<thead>
<tr>
<th>Acceptance criteria</th>
<th>Structural member</th>
<th>( \beta_s )</th>
<th>( \alpha_s )</th>
<th>( C_{s-max} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC-I</td>
<td>Longitudinal horizontal corrugations</td>
<td>0.85</td>
<td>1.00</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>Other corrugations</td>
<td>0.75</td>
<td>0.00</td>
<td>0.75</td>
</tr>
<tr>
<td>AC-II</td>
<td>Longitudinal, horizontal corrugations</td>
<td>1.00</td>
<td>1.00</td>
<td>0.85</td>
</tr>
<tr>
<td></td>
<td>Other corrugations</td>
<td>0.85</td>
<td>0.00</td>
<td>0.85</td>
</tr>
<tr>
<td>AC-III</td>
<td>Longitudinal horizontal corrugations</td>
<td>1.00</td>
<td>1.00</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td>Other corrugations</td>
<td>0.90</td>
<td>0.00</td>
<td>0.90</td>
</tr>
</tbody>
</table>

**2 Special requirements**

**2.1 Bilge plating**

**2.1.1 Thickness of bilge plating**
The thickness of plating in bilge area as defined in Ch.1 Sec.4 [3.8] shall be equal or greater than the lesser of [1.1.1] and [2.1.3], and shall also satisfy [2.1.2].

**2.1.2** The net thickness of the bilge plate shall not be less than that of the required adjacent bottom and side plates according to [1.1.1] based on \( R_{eH} \) for the bilge plate, whichever is the greater.
2.1.3 Thickness of curved bilge plating
The net thickness of curved bilge plating, in mm, shall not be taken less than:

\[ t = 6.45 \cdot 10^{-4} \cdot (P_{ex}^{2} R_b)^{0.4} \cdot R^{0.6} \]

where:

- \( P_{ex} \) = design sea pressure for the design load set SEA-1 as defined in Sec.2 [2.1.3] calculated at the lower turn of the bilge, in kN/m
- \( R \) = effective bilge radius, in mm, taken as:
  \[ R = R_0 + 0.5(\Delta s_1 + \Delta s_2) \]
- \( R_0 \) = radius of curvature, in mm. See Figure 1
- \( \Delta s_1 \) = distance between the lower turn of bilge and the outermost bottom longitudinal, in mm, see Figure 1. Where the outermost bottom longitudinal is within the curvature, this distance shall be taken as zero
- \( \Delta s_2 \) = distance between the upper turn of bilge and the lowest side longitudinal, in mm, see Figure 1. Where the lowest side longitudinal is within the curvature, this distance shall be taken as zero
- \( s_b \) = distance between transverse stiffeners, webs or bilge brackets, in mm.

A bilge keel is not considered as an effective "longitudinal stiffening" member.

2.1.4 Transverse extension of bilge minimum plate thickness
Where a plate seam is located in the straight plate just below the lowest stiffener on the side shell, any increased thickness required for the bilge plating does not have to be extended to the adjacent plate above the bilge provided the plate seam is not more than \( s_2/4 \) below the lowest side longitudinal. Similarly, for the flat part of adjacent bottom plating, any increased thickness for the bilge plating does not have to be extended to the adjacent plate provided that the plate seam is not more than \( s_1/4 \) beyond the outboard bottom longitudinal. For definition of \( s_1 \) and \( s_2 \), see Figure 1.

\[ \begin{align*}
\text{Figure 1 Bilge plating without longitudinal stiffening}
\end{align*} \]
2.2 Side shell plating in aft- and forebody

2.2.1 Strengthening for anchor and chain cable contact
The shell plating shall 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 shall be the same as that required for plated stems given in Ch.10 Sec.6 [1.1.1].

2.2.2 Shell plating connected with stern frame
The net thickness of shell plating connected with the stern frame shall not be less than that obtained, in mm, from the following formula:

\[ t = 0.094(L_2 - 43) + 0.009b \]

In way of the boss and heel plate, the net thickness of shell plating, in mm, shall not be less than:

\[ t = 0.105(L_2 - 47) + 0.011b \]

2.2.3 Heavy shell plates in way of rudder horn
Heavy shell plates shall be fitted locally in way of the heavy plate floors in way of the rudder horn. Outboard of the heavy floors, the heavy shell plates may be reduced in thickness.
SECTION 5 STIFFENERS

Symbols

For symbols not defined in this section, see Ch.1 Sec.4.

\[ d_{shr} = \text{effective shear depth, in mm, as defined in Ch.3 Sec.7 [1.4.3]} \]
\[ \ell_{bdg} = \text{effective bending span, in m, as defined in Ch.3 Sec.7 [1.1.2]} \]
\[ \ell_{shr} = \text{effective shear span, in m, as defined in Ch.3 Sec.7 [1.1.3]} \]
\[ P = \text{design pressure for the design load set being defined in Sec.2 and calculated at the load calculation point defined in Ch.3 Sec.7 [3.2], in kN/m}^2 \]
\[ \sigma_{hg} = \text{hull girder longitudinal stress, in N/mm}^2, \text{as defined in Sec.2 [1], calculated at the load calculation point as defined in Ch.3 Sec.7 [3.2].} \]

1 Stiffeners subject to lateral pressure

1.1 General

1.1.1 Web plating

The minimum net web thickness, in mm, shall not be taken less than the greatest value calculated for all applicable design load sets as defined in Sec.2 [2], given by:

\[ t_w = \frac{f_{shr}P \ell_{shr}}{d_{shr}C_t \sigma_{hg}} \]

where:

\[ f_{shr} = \text{shear force distribution factor as defined in Table 1. For stiffeners with end fixity deviating from the ones included in Table 1, with complex load pattern, or being part of a grillage, the requirements given in [1.2] apply.} \]

Table 1 Definition of \( f_{shr} \)

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>For continuous stiffeners with fixed end</th>
<th>For non-continuous stiffeners with simply supported ends</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Horizontal stiffeners</td>
<td>Upper end of vertical stiffeners</td>
</tr>
<tr>
<td>( f_{shr} )</td>
<td>0.5</td>
<td>0.4</td>
</tr>
</tbody>
</table>

\( C_t = \text{permissible shear stress coefficient for the acceptance criteria being considered, as defined in Table 2.} \)

Table 2 Stiffeners, definition of \( C_t \)

<table>
<thead>
<tr>
<th>Acceptance criteria</th>
<th>Structural member</th>
<th>( C_t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC-I</td>
<td>All stiffeners</td>
<td>0.75</td>
</tr>
<tr>
<td>AC-II</td>
<td>All stiffeners</td>
<td>0.90</td>
</tr>
<tr>
<td>AC-III</td>
<td>All stiffeners</td>
<td>0.95</td>
</tr>
</tbody>
</table>
1.1.2 Section modulus
The minimum net section modulus, in cm$^3$, shall not be taken less than the greatest value calculated for all applicable design load sets as defined in Sec.2 [2.1.3], given by:

$$Z = \frac{f_u |P| s^2}{f_{bdg} C_s R_{eH}}$$

where:

- $f_{bdg}$ = bending moment factor as defined in Table 5. For stiffeners with end fixity deviating from the ones included in Table 5, with complex load pattern, or being part of a grillage, the requirement given in [1.2] applies
- $f_m$ = bending moment ratio between end support and midspan as defined in Table 5
- $f_u$ = factor for unsymmetrical profiles, to be taken as:
  - 1.00 for flat bars and symmetrical profiles (T-profiles)
  - 1.03 for bulb profiles
  - 1.15 for unsymmetrical profiles (L-profiles)
- $C_s$ = permissible bending stress coefficient as defined in Table 3 for the acceptance criteria given in Table 4
- $C_{s\text{-max}}$ = coefficient, as defined in Table 4
- $a_s$ = coefficient, as defined in Table 4
- $\beta_s$ = coefficient, as defined in Table 4.

### Table 3 Stiffeners, definition of $C_s$

<table>
<thead>
<tr>
<th>Structural member</th>
<th>Sign of hull girder stress, $\sigma_{hg}$</th>
<th>Lateral pressure acting on</th>
<th>Coefficient $C_s$</th>
</tr>
</thead>
<tbody>
<tr>
<td>For continuous stiffeners</td>
<td>Tension (positive)</td>
<td>Stiffener side</td>
<td>$C_s = \beta_s - \alpha_s \frac{</td>
</tr>
<tr>
<td></td>
<td>Compression (negative)</td>
<td>Plate side</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tension (positive)</td>
<td>Plate side</td>
<td>$C_s = f_m \left( \beta_s - \alpha_s \frac{</td>
</tr>
<tr>
<td></td>
<td>Compression (negative)</td>
<td>Stiffener side</td>
<td></td>
</tr>
<tr>
<td>For non-continuous stiffeners</td>
<td>Tension (positive)</td>
<td>Plate side</td>
<td>$C_s = \beta_s - \alpha_s \frac{</td>
</tr>
<tr>
<td></td>
<td>Compression (negative)</td>
<td>Stiffener side</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tension (positive)</td>
<td>Stiffener side</td>
<td>$C_s = C_{s\text{-max}}$</td>
</tr>
<tr>
<td></td>
<td>Compression (negative)</td>
<td>Plate side</td>
<td></td>
</tr>
</tbody>
</table>
### Table 4 Stiffeners, definition of $\beta_s$, $\alpha_s$ and $C_{s\text{-max}}$

<table>
<thead>
<tr>
<th>Acceptance criteria</th>
<th>Structural member</th>
<th>$\beta_s$</th>
<th>$\alpha_s$</th>
<th>$C_{s\text{-max}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC-I</td>
<td>Longitudinal members</td>
<td>0.95</td>
<td>1.00</td>
<td>0.85</td>
</tr>
<tr>
<td></td>
<td>Other members</td>
<td>0.85</td>
<td>0.00</td>
<td>0.85</td>
</tr>
<tr>
<td>AC-II</td>
<td>Longitudinal members</td>
<td>1.10</td>
<td>1.00</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>Other members</td>
<td>0.95</td>
<td>0.00</td>
<td>0.95</td>
</tr>
<tr>
<td>AC-III</td>
<td>Longitudinal members</td>
<td>In general</td>
<td>1.20</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>On watertight boundaries (^1)</td>
<td></td>
<td>1.20</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Other members</td>
<td>In general</td>
<td>1.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>On watertight boundaries (^1)</td>
<td></td>
<td>1.15</td>
<td>0.00</td>
</tr>
</tbody>
</table>

\(^1\) Only applicable for flooding pressure

### Table 5 Stiffeners, definition of $f_{bgd}$ and $f_m$

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Acceptance criteria</th>
<th>For continuous stiffeners with fixed ends</th>
<th>For continuous stiffeners with one fixed end and one simply supported end</th>
<th>For non-continuous stiffeners with simply supported ends</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Horizontal stiffeners and upper end of vertical stiffeners</td>
<td>Lower end of vertical stiffeners</td>
<td>Horizontal and vertical stiffeners</td>
</tr>
<tr>
<td>$f_{bgd}$</td>
<td>AC-I, AC-II, AC-III</td>
<td>12.00</td>
<td>10.00</td>
<td>8.00</td>
</tr>
<tr>
<td>$f_m$</td>
<td>AC-I</td>
<td>2.00</td>
<td>2.33</td>
<td>1.77</td>
</tr>
<tr>
<td></td>
<td>AC-II, AC-III</td>
<td>1.60</td>
<td>1.86</td>
<td>1.42</td>
</tr>
</tbody>
</table>

#### 1.1.3 Grouping of stiffeners
Scantlings of stiffeners based on requirements given in [1.1.1] and [1.1.2] may be decided based on the concept of grouping designated sequentially placed stiffeners of equal scantlings on a single stiffened panel. The scantling of the group shall be taken as the greater of the following:

- the average of the required scantling of all stiffeners within a group
- 90% of the maximum scantling required for any one stiffener within the group.

#### 1.1.4 Plate and stiffener of different materials
When the minimum specified yield stress of a stiffener exceeds the minimum specified yield stress of the attached plate by more than 35%, the following criterion shall be satisfied:

$$R_{eH - S} \leq \left( R_{eH - P} - \frac{\alpha_S \sigma_{bgd}}{\beta_S} \right) \frac{2}{P} + \frac{\alpha_S \sigma_{bgd}}{\beta_S}$$
where:

- $R_{eH-S}$ = minimum specified yield stress of the material of the stiffener, in N/mm²
- $R_{eH-P}$ = minimum specified yield stress of the material of the attached plate, in N/mm²
- $\sigma_{hg}$ = hull girder longitudinal stress, in N/mm², as defined in Sec.2 [1.1] with $|\sigma_{hg}|$ not to be taken less than 0.4 $R_{eH-P}$
- $Z$ = net section modulus, in way of face plate/free edge of the stiffener, in cm³
- $Z_P$ = net section modulus, in way of the attached plate of stiffener, in cm³
- $\alpha_s$, $\beta_s$ = coefficients defined in Table 4.

### 1.1.5 Struts connecting stiffeners

Struts fitted between stiffeners in a double skin structure shall in general not be considered as effective supports for the stiffeners.

The requirements given in [1.1.1] and [1.1.2], however, may be based on reduced bending and shear span as given in Ch.3 Sec.7 [1.1.4].

The net sectional area, in cm², and the net moment of inertia about the weaker axis, in cm⁴, of struts connecting stiffeners shall not be less than the values obtained from the following formulae:

$$A_{SR} = \frac{P_{SR} \ell_{SR}}{20000}$$

$$I_{SR} = \frac{0.75s \ell (P_{SR1} + P_{SR2}) A_{ASR} \ell_{SR}^2}{47200 A_{ASR} - s \ell (P_{SR1} + P_{SR2})}$$

where:

- $P_{SR}$ = pressure to be taken as the greater of the following values, in kN/m²:
  - $P_{SR} = 0.5 (P_{SR1} + P_{SR2})$
  - $P_{SR} = P_{SR3}$
  - $P_{SR1}$ = pressure in way of the strut, in kN/m², acting on one side, outside the compartment in which the strut is located
  - $P_{SR2}$ = pressure in way of the strut, in kN/m², acting on the opposite side, outside the compartment in which the strut is located
  - $P_{SR3}$ = internal pressure at mid-span of the strut, in kN/m², in the compartment in which the strut is located
- $\ell_{SR}$ = length of the strut, in m
- $A_{ASR}$ = actual net sectional area of the strut, in cm².

### 1.2 Beam analysis

#### 1.2.1 Application

The maximum bending stress, $\sigma_b$, and shear stress, $\tau$, in a stiffener using net properties with reduced end fixity, variable load or being part of grillage shall be determined by direct calculations taking into account:

- the distribution of static and dynamic pressures and forces, if any
- the number and position of intermediate supports, e.g. decks, girders, 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
— the effective breadth, $b_{\text{eff}}$, for yield check as given in Ch.3 Sec.7 [1.3].

1.2.2 Stress criteria
The calculated stress, in N/mm$^2$, shall comply with the following criteria:

$- \quad \tau \leq C_t \tau_{eH}$
$- \quad \sigma_b \leq C_s R_{eH}$

where:

$C_t = \text{permissible shear stress coefficient for the design load set being considered, as defined in Table 2}$

$C_s = \text{permissible bending stress coefficient as defined in Table 3 for the design load set being considered}$

$\tau = \text{average shear stress in member, in N/mm}^2, \text{at the considered position, taken as:}$

$\tau = \frac{10 Q}{A_{\text{shr}}}$

$Q = \text{shear force, in kN, at the considered position}$

$A_{\text{shr}} = \text{net shear area, in cm}^2, \text{at the considered position}$

$\sigma_b = \text{bending stress, in N/mm}^2, \text{at the considered position, taken as:}$

$\sigma_b = \frac{1000 f_u M}{Z}$

$f_u = \text{factor for unsymmetrical profiles to be taken as given in [1.1.2]}$

$M = \text{bending moment, in kNm, at the considered position}$

$Z = \text{net section modulus, in cm}^3, \text{based on effective breadth according to Ch.3 Sec.7 [1.3] at the considered position.}$
SECTION 6 PRIMARY SUPPORTING MEMBERS AND PILLARS

Symbols

For symbols not defined in this section, see Ch.1 Sec.4.

\[ P \] = design pressure for the design load set being considered as defined in Sec.2 and calculated at the load calculation point as defined in Ch.3 Sec.7 [4.1], in kN/m²

\[ b'_{eff} \] = effective breadth of attached plating based on plate slenderness, as defined in Ch.3 Sec.7 [1.3.3], in m

\[ b_{eff} \] = effective breadth of attached plating, as defined in Ch.3 Sec.7 [1.3.2], in m

\[ \sigma_{hg} \] = hull girder longitudinal stress, in N/mm², as defined in Sec.2 [1], calculated at the load calculation point as defined in Ch.3 Sec.6 [4.1]

\[ \ell_{bdg} \] = effective bending span, as defined in Ch.3 Sec.7 [1.1.6], in m

\[ \ell_{shr} \] = effective shear span, as defined in Ch.3 Sec.7 [1.1.7], in m.

1 General

1.1 Application

1.1.1 The requirements for this section apply to PSM (primary supporting members) subjected to lateral pressure and concentrated loads and pillars subjected to axial loads. The yielding and where relevant buckling check shall be carried out for such members subjected to specific loads.

1.1.2 The requirements for this article apply unless verification by means of FE analysis has been carried out. The section modulus requirement given in [2.1.1] is not applicable for double skin primary supporting members and to longitudinal primary supporting members with hull girder longitudinal stresses exceeding 0.15 \( R_{eh} \). Such members shall be assessed in accordance with [2.2] or by FE analysis.

2 Primary supporting members

2.1 Scantling requirements

2.1.1 Net section modulus

The net section modulus, in cm³, of primary supporting members subjected to lateral pressure shall not be taken less than the greatest value for all applicable design load sets defined in Sec.2 [2], given by:

\[
Z_{n50} = 1000 \frac{P}{f_{bdg}} \frac{2}{C_s} \ell_{bdg}^2 \ell_{shr}^2 R_{eh}
\]

where:

\[ f_{bdg} \] = bending moment distribution factor, as given in Table 1

\[ C_s \] = permissible stress coefficient to be taken as:

\[ C_s = 0.70 \text{ for AC-I} \]

\[ C_s = 0.85 \text{ for AC-II and AC-III.} \]
The net section modulus shall be based on the effective breadth of attached plating, $b_{eff}$, as defined in Ch.3 Sec.7 \[1.3.2\].

2.1.2 Net shear area
The net shear area, in $cm^2$, of primary supporting members subjected to lateral pressure shall not be taken less than the greatest value for all applicable design load sets defined in Sec.2 \[2\], given by:

$$A_{shr-n50} = 10\frac{f_{shr}|p|s_{shr}}{C_t l t}$$

where:

$f_{shr}$ = shear force distribution factor, as given in Table 1
$C_t$ = permissible shear stress coefficient to be taken as:

- $C_t = 0.70$ for AC-I
- $C_t = 0.85$ for AC-II and AC-III.

Table 1 Definition of bending moment and shear force factors, $f_{bdg}$ and $f_{shr}$

<table>
<thead>
<tr>
<th>Load and boundary condition</th>
<th>Bending moment and shear force distribution factors (based on load at mid span, where load varies)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position</td>
<td>1</td>
</tr>
<tr>
<td>Load model</td>
<td>1</td>
</tr>
<tr>
<td>Support</td>
<td>Field</td>
</tr>
<tr>
<td>A</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
</tr>
</tbody>
</table>
### Load and boundary condition

<table>
<thead>
<tr>
<th>Position</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load model</td>
<td>1 Support</td>
<td>2 Field</td>
<td>3 Support</td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td>E</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note 1:** The bending moment distribution factor, $f_{bdg}$ for the support positions is applicable for a distance of $0.2t_{bdg}$ from the end of the effective bending span of the primary supporting member.

**Note 2:** The shear force distribution factor, $f_{shr}$ for the support positions is applicable for a distance of $0.2t_{shr}$ from the end of the effective shear span of the primary supporting member.

**Note 3:** Application of $f_{bdg}$ and $f_{shr}$:

- The section modulus requirement within $0.2t_{bdg}$ from the end of the effective span shall be determined using the applicable $f_{bdg1}$ and $f_{bdg3}$, however the $f_{bdg}$ shall not be taken greater than 12.
- The section modulus of mid-span area shall be determined using $f_{bdg} = 24$, or $f_{bdg2}$ from the table if lesser.
- The shear area requirement for end connections within $0.2t_{shr}$ from the end of the effective span shall be determined using $f_{shr} = 0.5$ or the applicable $f_{shr1}$ or $f_{shr3}$, whichever is greater.
- For models A through F, the value of $f_{shr}$ may be gradually reduced outside of $0.2t_{shr}$ towards 0.5 $f_{shr}$ at mid-span, where $f_{shr}$ is the greater value of $f_{shr1}$ and $f_{shr3}$.

#### 2.1.3 Maximum flange area of primary supporting member

The effective flange area of primary supporting member shall satisfy the following:

$$b_f t_f \leq b_{eff} t_p R_{eH,p}$$

where:

- $R_{eH,p}$ = minimum specified yield stress of the material of the plate, in N/mm²
$R_{efH}$ = minimum specified yield stress of the material of the flange, in N/mm$^2$.

### 2.2 Direct strength - beam analysis

#### 2.2.1 Application
Where complex grillage structures are employed or cross ties are fitted in side shell primary supporting members, the scantlings shall be determined by direct calculation taking into account:

- the distribution of still water and wave pressure and forces, if any
- the number and position of intermediate supports, e.g. decks, girders, etc.
- the condition of fixity at the ends of the primary supporting members and at intermediate supports
- the geometrical characteristics of the primary supporting members on the intermediate spans
- the effective breadth, $b_{eff}$, for yield check as given in Ch.3 Sec.7 [1.3.2]
- for members where large in-plane stresses are included in the attached plating the effective breadth, $b'_{eff}$, shall be applied for a yield and an implicit uni-axial buckling check, see Ch.3 Sec.7 [1.3.3].

Modelling methods and techniques for beam analysis are given in DNVGL-CG-0127 Sec.5.

#### 2.2.2 Acceptance criteria for beam analysis
The calculated stresses, in N/mm$^2$, shall comply with the following criteria:

- $\sigma \leq C_s1 R_{efH}$
- $\sigma_b \leq C_s2 R_{efH}$
- $\tau \leq C_t \tau_{efH}$

where:

- $\tau$ = average shear stress in member, in N/mm$^2$, at the considered position, taken as:
  
  $$\tau = \frac{10Q}{A_{shr-n50}}$$

- $Q$ = shear force, in kN, at the considered position
- $A_{shr-n50}$ = net shear area, in cm$^2$, at the considered position
- $\sigma$ = combined stress of normal stress including hull girder longitudinal stress, $\sigma_{hg}$, and bending stress in member, in N/mm$^2$, at the considered position
- $\sigma_b$ = bending stress, in N/mm$^2$, at the considered position, taken as:
  
  $$\sigma_b = \frac{1000M}{Z_{n50}}$$

- $M$ = bending moment, in kNm, at the considered position
- $Z_{n50}$ = net section modulus for flange and attached plating, in cm$^3$, based on effective breadth according to Ch.3 Sec.7 [1.3.2] and Ch.3 Sec.7 [1.3.3] at the considered position.

<table>
<thead>
<tr>
<th>Acceptance criteria</th>
<th>Structural member</th>
<th>$C_s1$</th>
<th>$C_s2$</th>
<th>$C_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC-I</td>
<td>All primary supporting members</td>
<td>0.85</td>
<td>0.70</td>
<td>0.70</td>
</tr>
<tr>
<td>AC-II, AC-III</td>
<td></td>
<td>0.95</td>
<td>0.85</td>
<td>0.85</td>
</tr>
</tbody>
</table>
2.2.3 Buckling criteria for beam analysis
The requirements given in [2.2.2] based on effective breadth, $b'_{eff}$, according to Ch.3 Sec.7 [1.3.3] are covering yield and uni-axial buckling of the attached plate. Additional buckling assessment may be required for panels with high bi-axial compression stresses e.g. bottom/deck in midship area, with acceptance criteria given in Ch.8 Sec.4. For the bi-axial buckling assessment full effective plate flange may be used.

The normal stresses including hull girder longitudinal stress, $\sigma_{hg}$, and the shear stresses taken from the strength assessment to be applied for buckling capacity calculation of plate panels, as given in Ch.8 Sec.4, shall be corrected as given in DNVGL-CG-0128 Sec.3 [2.2.7].

2.2.4 Yield and buckling criteria for finite element analysis
When finite element analysis is used for analysis of PSM then all significant stress components shall be considered, to a similar extent as for partial ship finite element models described in Ch.7 Sec.3. The strength shall satisfy the yield criteria given in Ch.7 Sec.3 and buckling criteria given in Ch.8 Sec.4.

3 Pillars

3.1 Pillars subjected to compressive axial load

3.1.1 Criteria
The maximum applied compressive axial load on a pillar, $F_{pill}$, in kN, shall be taken as the greatest value calculated for all applicable design load sets defined in Sec.2 [2], and is given by the following formula:

$$F_{pill} = P b_{a-sup}\ell_{a-sup} + F_{pill-upr}$$

The buckling check of the pillar shall be performed according to Ch.8 Sec.4 [4.1], with $\sigma_{av}$ in N/mm$^2$ given by:

$$\sigma_{av} = 10 \frac{F_{pill}}{A_{pill-n50}}$$

where:

$b_{a-sup}$ = mean breadth of area supported, in m

$\ell_{a-sup}$ = mean length of area supported, in m

$F_{pill-upr}$ = axial load from pillar including axial load from pillars above, in kN, if any

$A_{pill-n50}$ = net cross section area of the pillar, in cm$^2$.

3.2 Pillars subject to tensile axial load
The calculated stresses in pillars inclusive end connections subjected to tensile axial load, shall satisfy the following criteria:

$$\sigma \leq C_s R_{ehl}$$

$$\tau \leq C_t \tau_{ehl}$$

where:

$\sigma$ = normal stress in N/mm$^2$, for the minimum cross section inclusive end connections

$\tau$ = shear stress in N/mm$^2$ the bracket/gusset end connections
\( C_s \) = permissible normal stress coefficient as given in [2.1.1]
\( C_t \) = permissible shear stress coefficient as given in [2.1.2].
SECTION 7 INTERSECTION OF STIFFENERS AND PSM

Symbols
For symbols not defined in this section, see Ch.1 Sec.4.

1 Stiffener connections

1.1 Arrangement of cut-outs

1.1.1 Cut-outs for the passage of stiffeners through the web of primary supporting members, and the related collaring arrangements, shall be designed to minimise stress concentrations around the perimeter of the opening and on the attached web stiffeners.

1.1.2 The total depth of cut-outs without lug or collar plate shall be not greater than 40% of the depth of the primary supporting member. A larger depth of cut-outs may be accepted given that shear strength and buckling capacity are sufficient.

1.1.3 Cut-outs in way of cross tie ends and floors under bulkhead stools or in high stress areas shall be fitted with lug plates welded to the attached plating, see Figure 1.

1.1.4 Lug plates shall be fitted in cut-outs where required for compliance with the requirements given in [1.2], and in areas of high stress concentrations, e.g. in way of primary supporting member toes. See Figure 2 for typical lug arrangements.

1.1.5 At connection to shell envelope longitudinals below the scantling draught, \( T_{sc} \) and at connection to inner bottom longitudinals, a soft heel shall be provided in way of the heel of the primary supporting member web stiffeners when the calculated direct stress, \( \sigma_w \), in the primary supporting member web stiffener according to [1.2] exceeds 80% of the permissible values. The soft heel shall have a keyhole, similar to that shown in item (c) in Figure 3.

A soft heel is not required at the intersection with watertight bulkheads and primary supporting members, where a back bracket is fitted or where the primary supporting member web is welded to the stiffener face plate.

1.1.6 In general, cut-outs shall have rounded corners and the corner radii, \( R \), shall be as large as practicable, with a minimum of 20% of the breadth, \( b \), of the cut-out or 25 mm, whichever is greater. The corner radii, \( R \), do not need to be greater than 50 mm, see Figure 1. Consideration shall be given to other cut-out shapes on the basis of maintaining equivalent strength and minimising stress concentration.
Figure 2 Symmetric and asymmetric cut-outs
The details shown in this figure are only used to illustrate symbols and definitions and are not intended to represent design guidance.

**Figure 3 Primary supporting member web stiffener details**

Symbols shown in Figure 3 shall be taken as:

\[ t_{ws1}, t_{ws2} \] = net thickness of the primary supporting member web stiffener/backing bracket, in mm
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\[d_w, d_{w1}, d_{w2} = \text{minimum depth of the primary supporting member web stiffener/backing bracket, in mm}\]

\[d_{wc}, d_{wc1}, d_{wc2} = \text{length of connection between the primary supporting member web stiffener/backing bracket and the stiffener, in mm.}\]

**Note:**
Except where specific dimensions are noted for the details of the keyhole in way of the soft heel, the details shown in this figure are only used to illustrate symbols and definitions and are not intended to represent design guidance or recommendations.

---e-n-d---o-f---n-o-t-e---

## 1.2 Connection of stiffeners to PSM

### 1.2.1 Application

In lieu of simplified method as given in [1.3], calculations may be performed according to [1.2] irrespective of ship’s length.

### 1.2.2 General

For connection of stiffeners to PSM in case of lateral pressure other than bottom slamming and bow impact pressure, [1.2.3] and [1.2.4] shall be applied. In case of bottom slamming or bow impact pressure, Ch.10 Sec.2 [3.2.2] and Ch.10 Sec.1 [3.2.3] shall be applied respectively.

The cross sectional areas of the connections shall be determined from the proportion of load transmitted through each component in association with its appropriate permissible stress.

### 1.2.3 The load, in kN, transmitted through the shear connection shall be taken as follows.

— If the web stiffener is connected to the intersecting stiffener:

\[W_1 = W \left( \alpha_a + \frac{A_1}{4f_c A_w + A_1} \right)\]

— If the web stiffener is not connected to the intersecting stiffener:

\[W_1 = W\]

where:

\[W = \text{total load, in kN, transmitted through the stiffener connection to the PSM taken equal to:}\]

\[W = \frac{P_1 s_1 (s_1 - \frac{s_1}{2000}) + P_2 s_2 (s_2 - \frac{s_2}{2000})}{2} \times 10^{-3}\]

\[P_1, P_2 = \text{design pressure applied on the stiffener for the design load set being considered, in kN/m}^2, \text{on each side of the considered connection}\]

\[S_1, S_2 = \text{spacing between the considered and the adjacent PSM on each side of the considered connection, in m}\]

\[s_1, s_2 = \text{spacing of the stiffener, in mm, on each side of the considered connection}\]

\[\alpha_a = \text{panel aspect ratio, not to be taken greater than 0.25}\]

\[\alpha_a = \frac{s}{1000 S}\]

\[S = \frac{s_1 + s_2}{2}\]

\[s = \frac{s_1 + s_2}{2}\]
\( A_1 \) = effective net shear area, in \( \text{cm}^2 \), of the connection, to be taken equal to:
\[
A_1 = A_{1d} + A_{1c}
\]
In case of a slit type slot connections area, \( A_1 \), is given by:
\[
A_1 = 2 \ A_{1d}
\]
In case of a typical double lug or collar plate connection area, \( A_1 \), is given by:
\[
A_1 = 2 \ A_{1c}
\]
\( A_{1d} \) = net shear connection area, in \( \text{cm}^2 \), excluding lug or collar plate, as given by:
\[
A_{1d} = \frac{A_{1d}}{d} \times 10^{-2}
\]
\( \ell_d \) = length of direct connection between stiffener and PSM web, in mm
\( t_w \) = net web thickness of the primary supporting member, in mm
\( A_{1c} \) = net shear connection area, in \( \text{cm}^2 \), with lug or collar plate, given by:
\[
A_{1c} = f_1 \ell_c \ t_c \times 10^{-2}
\]
\( \ell_c \) = length of connection between lug or collar plate and PSM, in mm
\( t_c \) = net thickness of lug or collar plate shall not be less than 75% of the web plate thickness and need not to be taken greater than the net thickness of the adjacent PSM web, in mm
\( f_1 \) = shear stiffness coefficient, taken as:
\[
f_1 = 1.0, \text{ for stiffeners of symmetrical cross section}
\]
\[
f_1 = \frac{140}{w}, \text{ not to be taken greater than 1.0, for stiffeners of asymmetrical cross section}
\]
\( w \) = width of the cut-out for an asymmetrical stiffener, measured from the cut-out side of the stiffener web, in mm, as indicated in Figure 2
\( A_w \) = effective net cross sectional area, in \( \text{cm}^2 \), of the PSM web stiffener in way of the connection including backing bracket where fitted, as shown in Figure 3. If the PSM web stiffener incorporates a soft heel ending or soft heel and soft toe ending, \( A_w \) shall be measured at the throat of the connection, as shown in Figure 3
\( f_c \) = collar load factor taken equal to:
For intersecting stiffeners of symmetrical cross section:
\[
f_c = 1.85 \quad \text{for} \ A_w \leq 14
\]
\[
f_c = 1.85 - 0.0441(A_w - 14) \quad \text{for} \ 14 < A_w \leq 31
\]
\[
f_c = 1.1 - 0.013(A_w - 31) \quad \text{for} \ 31 < A_w \leq 58
\]
\[
f_c = 0.75 \quad \text{for} \ A_w > 58
\]
For intersecting stiffeners of asymmetrical cross section:
\[
f_c = 0.68 + 0.0172 \frac{\ell_s}{A_w}
\]
\( \ell_s \) = connection length equal to:
For a single lug or collar plate connection to the PSM:
\[
\ell_s = \ell_c
\]
For a single sided direct connection to the PSM:
\[
\ell_s = \ell_d
\]
In the case of a lug or collar plus a direct connection:
\[
\ell_s = 0.5 \ (\ell_c + \ell_d)
\]
1.2.4 The load, in kN, transmitted through the PSM web stiffener shall be taken as:
- if the web stiffener is connected to the intersecting stiffener:
  \[ W_2 = W \left( 1 - \alpha_a - \frac{A_1}{4f_c A_w + A_1} \right) \]
- if the web stiffener is not connected to the intersecting stiffener:
  \[ W_2 = 0 \]

The values of \( A_w, A_{wc} \) and \( A_1 \) shall be such that the calculated stresses satisfy the following criteria:
- for the connection to the PSM web stiffener not in way of the weld: \( \sigma_w \leq \sigma_{perm} \)
- for the connection to the PSM web stiffener in way of the weld: \( \sigma_{wc} \leq \sigma_{perm} \)
- for the shear connection to the PSM web: \( \tau_w \leq \tau_{perm} \)

where:
- \( W \) = load, in kN, as defined in [1.2.3]
- \( f_c \) = collar load factor as defined in [1.2.3]
- \( \alpha_a \) = panel aspect ratio, as defined in [1.2.3]
- \( A_1 \) = effective net shear area, in \( \text{cm}^2 \), as defined in [1.2.3]
- \( A_w \) = effective net cross sectional area, in \( \text{cm}^2 \), as defined in [1.2.3]
- \( \sigma_w \) = direct stress, in \( \text{N/mm}^2 \), in the PSM web stiffener at the minimum bracket area away from the weld connection:
  \[ \sigma_w = \frac{10W_2}{A_w} \]
- \( \sigma_{wc} \) = direct stress, in \( \text{N/mm}^2 \), in the PSM web stiffener in way of the weld connection:
  \[ \sigma_{wc} = \frac{10W_2}{A_{wc}} \]
- \( \tau_w \) = shear stress, in \( \text{N/mm}^2 \), in the shear connection to the PSM web:
  \[ \tau_w = \frac{10W_1}{A_1} \]
- \( A_{wc} \) = effective net area, in \( \text{cm}^2 \), of the PSM web stiffener in way of the weld as shown in Figure 3
- \( \sigma_{perm} \) = permissible direct stress, in \( \text{N/mm}^2 \), as given in Table 1
- \( \tau_{perm} \) = permissible shear stress, in \( \text{N/mm}^2 \), as given in Table 1.
Table 1 Permissible stresses for connection between stiffeners and PSMs

<table>
<thead>
<tr>
<th>Item</th>
<th>Acceptance criteria</th>
<th>Direct stress, $\sigma_{perm}$ in N/mm$^2$ (1)</th>
<th>Shear stress, $\tau_{perm}$ in N/mm$^2$ (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSM web stiffener</td>
<td>AC-I  AC-II  AC-III</td>
<td>$0.83 \ R_{eh}^{(2)}$  $R_{eh}$  $R_{eh}$</td>
<td>-  -  -</td>
</tr>
<tr>
<td>PSM web stiffener to intersecting stiffener in way of weld connection:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>— Double continuous fillet</td>
<td>AC-I  AC-II  AC-III</td>
<td>$0.58 \ R_{eh}^{(3)}$  $0.7 \ R_{eh}^{(3)}$  $0.75 \ R_{eh}^{(3)}$</td>
<td>-  -  -</td>
</tr>
<tr>
<td>— Partial penetration weld</td>
<td>AC-I  AC-II  AC-III</td>
<td>$0.83 \ R_{eh}^{(2)}$  $R_{eh}^{(2)}$  $R_{eh}^{(2)}$</td>
<td>-  -  -</td>
</tr>
<tr>
<td>PSM stiffener to intersecting stiffener in way of lapped welding</td>
<td>AC-I  AC-II  AC-III</td>
<td>$0.5 \ R_{eh}$  $0.6 \ R_{eh}$  $0.65 \ R_{eh}$</td>
<td>-  -  -</td>
</tr>
<tr>
<td>Shear connection including lugs or collar plates:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>— Single sided connection</td>
<td>AC-I  AC-II  AC-III</td>
<td>-  -  -</td>
<td>$0.71 \ \tau_{eh}$  $0.85 \ \tau_{eh}$  $0.90 \ \tau_{eh}$</td>
</tr>
<tr>
<td>— Double sided connection</td>
<td>AC-I  AC-II  AC-III</td>
<td>-  -  -</td>
<td>$0.83 \ \tau_{eh}$  $\tau_{eh}$  $\tau_{eh}$</td>
</tr>
</tbody>
</table>

1) Acceptance criteria for the design load sets are given in Sec.2 Table 1.
2) The root face shall not be greater than one third of the gross thickness of the PSM stiffener.
3) Permissible stresses may be increased by 5 percent where a soft heel is provided in way of the heel of the PSM web stiffener.

1.2.5 Where a backing bracket is fitted in addition to the PSM web stiffener, it shall be aligned with the web stiffener. The arm length of the backing bracket shall not be less than the depth of the web stiffener. The net cross sectional area through the throat of the bracket shall be included in the calculation of $A_w$ as shown in Figure 3.

1.2.6 Lapped connections of PSM web stiffeners or tripping brackets to stiffeners are not permitted within 0.4 $L$ for vessels with single deck and with length $L$ of 150 m or above.

1.2.7 Where built-up stiffeners have their flange welded to the side of the web, a double sided arrangement of web stiffener connection to the PSM shall be fitted. This may be achieved by fitting backing brackets.

1.2.8 Where the web stiffener of the PSM is parallel to the web of the intersecting stiffener, but not connected to it, the offset PSM web stiffener shall be located in close proximity to the stiffener as shown in Figure 4. The ends of the offset web stiffeners shall be suitably tapered and softened.

Locations where the web stiffener of the PSM are not connected to the intersecting stiffeners as well as the detail arrangements shall be specially considered on the basis of their ability to transmit load with equivalent effectiveness to that of [1.2.3] through [1.2.7]. Details of calculations made and/or testing procedures and results shall be submitted.
1.2.9 Size of welds
The size of the fillet welds for connections between stiffeners and PSM shall be calculated according to Ch.13 Sec.1 [2.5.6].

1.3 Simplified calculation of connection of stiffeners to PSM

1.3.1 Application
The simplified calculation method given in this sub-section is applicable for ships of length less than 90 meters.

1.3.2 General
For connection of stiffeners to PSM in case of lateral pressure other than bottom slamming and bow impact loads, [1.3.3] shall be applied. In case of bottom slamming or bow impact loads, [1.3.4] shall be applied. The cross sectional areas of the connections shall be determined from the proportion of load transmitted through each component in association with its appropriate permissible stress.

1.3.3 The total load, in kN, transmitted through the connection to the PSM shall be taken equal to:

\[
W = Ps(S - \frac{x}{2000}) 10^{-3}
\]

where:

- \( W \) = total load transmitted through the connection to the PSM, in kN
- \( P \) = design pressure applied on the stiffener for the design load set being considered, in kN/m². For stiffeners having different spans on each side of the PSM (i.e. different PSM spacing, \( S_1 \) and \( S_2 \)), and/or subject to different pressure, \( P_1 \) and \( P_2 \), at each side of the PSM, the average load for the two sides shall be applied to estimate the reaction force, e.g. vertical stiffeners at transverse bulkhead, taken as:

\[
P = \frac{P_1 + P_2}{2}
\]
\[ S = \text{average spacing of the considered PSM crossed by the stiffener, in m. For stiffeners having different spans on each side of PSM (i.e. different PSM spacing, } S_1 \text{ and } S_2), \text{ the average span is taken as:} \]
\[ S = \frac{S_1 + S_2}{2} \]

\[ A_1 = \text{effective net shear area, in cm}^2, \text{ of the connection to the PSM web, to be taken equal to the sum of the single or double sided connection:} \]
\[ A_1 \geq \frac{10W_1}{\tau_{\text{perm}}} \]

\[ A_w = \text{effective net cross sectional area, in cm}^2, \text{ of the PSM web stiffener in way of the connection including backing bracket where fitted, as shown in Figure 3} \]
\[ A_w \geq \frac{10W_2}{\sigma_{\text{perm}}} \]

\[ W_1 = \text{the load transmitted through the shear connection, in kN, see Table 2} \]
\[ W_2 = \text{the load transmitted through the PSM web stiffener, in kN, see Table 2} \]
\[ \sigma_{\text{perm}} = \text{permissible direct stress , in N/mm}^2, \text{ as given in Table 2} \]
\[ \tau_{\text{perm}} = \text{permissible shear stress , in N/mm}^2, \text{ as given in Table 2.} \]

**Table 2 Load distribution and permissible stresses**

<table>
<thead>
<tr>
<th>Load</th>
<th>Permissible stresses (^{(1)})</th>
<th>Load distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(AC-I)</td>
<td>(AC-II, AC-III)</td>
</tr>
<tr>
<td>(W_1)</td>
<td>(\tau_{\text{perm}} = 0.64 \tau_{eh})</td>
<td>(\tau_{\text{perm}} = 0.76 \tau_{ReH})</td>
</tr>
<tr>
<td>(W_2)</td>
<td>(\sigma_{\text{perm}} = 0.52 R_{eh})</td>
<td>(\sigma_{\text{perm}} = 0.63 R_{eh})</td>
</tr>
</tbody>
</table>

\(^{(1)}\) Acceptance criteria for the design load sets are given in Sec.2 Table 2

**1.3.4 Size of welds**
The size of the fillet welds for connections between stiffeners and PSM shall be calculated according to Ch.13 Sec.1 [2.5.5].
SECTION 8 SUPERSTRUCTURE, DECKHOUSE AND COMPANIONWAYS

Symbols

For symbols not defined in this section, see Ch.1 Sec.4.

\( \alpha_p \) = correction factor for the panel aspect ratio to be taken as follows but not to be taken greater than 1.0:
\[
\alpha_p = 1.2 \times \frac{b}{2.1a}
\]

\( P \) = design pressure for the design load set being defined below, and calculated at the load calculation point defined in Ch.3 Sec.7 [3.2], in kN/m\(^2\)

\( P_D \) = lateral pressure for exposed decks, in kN/m\(^2\), as defined in Ch.4 Sec.5 [3.2]

\( P_{dl} \) = lateral pressure due to distributed load, in kN/m\(^2\), as defined in Ch.4 Sec.6 and Ch.4 Sec.5 [2.3]

\( P_{SI} \) = lateral pressure for superstructure side, in kN/m\(^2\), as defined in Ch.4 Sec.5 [3.3]

\( P_A \) = external pressure for end bulkheads of superstructure and deckhouse walls, in kN/m\(^2\) according to Ch.4 Sec.5 [3.4.1]

\( \ell_{bdg} \) = effective bending span, in m, as defined in Ch.3 Sec.7 [1.1]

\( \ell_{shr} \) = effective shear span, in m, as defined in Ch.3 Sec.7 [1.1]

\( d_{shr} \) = effective shear depth, in mm, as defined in Ch.3 Sec.7 [1.4.3].

1 General

1.1 Application

1.1.1 The requirements for this section are applicable to superstructures, deckhouses and companionways. Applicable rule requirements and design pressures and forces for plate, stiffener and primary supporting members are given in Table 1 for the different design load sets.
Table 1 Design load sets

<table>
<thead>
<tr>
<th>Structural member</th>
<th>Design load set</th>
<th>Design load scenario</th>
<th>Load component</th>
<th>Applicable rule requirements</th>
<th>Acceptance criteria</th>
<th>Loading condition for definition of GM and (k_r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superstructure side</td>
<td>SEA-1</td>
<td>2</td>
<td>(\max(P_w; P_{SI}))</td>
<td>Sec.4, Sec.5 and Sec.6</td>
<td></td>
<td>Full load condition</td>
</tr>
<tr>
<td>Deckhouse side</td>
<td>SEA-1</td>
<td>2</td>
<td>(P_A)</td>
<td>Sec.8</td>
<td>AC-II</td>
<td></td>
</tr>
<tr>
<td>Front and aft bulkhead</td>
<td>SEA-1</td>
<td>2</td>
<td>(P_A)</td>
<td></td>
<td></td>
<td>Full load condition</td>
</tr>
<tr>
<td>Exposed decks</td>
<td>SEA-1</td>
<td>2</td>
<td>(P_D)</td>
<td></td>
<td></td>
<td>Full load condition</td>
</tr>
<tr>
<td>Exposed decks and non-exposed decks with distributed load</td>
<td>UDL-1(^1)</td>
<td>2</td>
<td>(P_{dl-s} + P_{dl-d} F_U-s + F_U-d)</td>
<td>Sec.4, Sec.5 and Sec.6</td>
<td></td>
<td>Normal ballast condition(^2)</td>
</tr>
<tr>
<td></td>
<td>UDL-2(^1)</td>
<td>1</td>
<td>(P_{dl-s} F_U-s)</td>
<td></td>
<td></td>
<td>AC-I</td>
</tr>
<tr>
<td>Exposed decks and non-exposed decks with wheel loading</td>
<td>WL-1(^1)</td>
<td>2</td>
<td>(P_{wl-1})</td>
<td>Ch.10 Sec.5</td>
<td>AC-II</td>
<td>Normal ballast condition(^2)</td>
</tr>
<tr>
<td></td>
<td>WL-2(^1)</td>
<td>1</td>
<td>(P_{wl-2})</td>
<td></td>
<td></td>
<td>AC-1</td>
</tr>
</tbody>
</table>

1) Distributed or concentrated loads only. Need not to be combined with simultaneously occurring green sea pressure.
2) For cargo loads, draught, GM and \(k_r\) values may be based on actual cargo conditions in the loading manual.
3) Local loads:

\[
\begin{align*}
P_w &= \text{wave pressure as given in Ch.4 Sec.5 [1.3]} \\
P_D &= \text{external design pressure for exposed decks and wheelhouse top due to green sea loading as given in Ch.4 Sec.5 [2.2] and Ch.4 Sec.5 [3.2], respectively} \\
P_A &= \text{design pressure for aft- and forward external bulkheads of superstructure and deckhouse walls as given in Ch.4 Sec.5 [3.4]} \\
P_{SI} &= \text{external design pressure for external side of superstructure as given in Ch.4 Sec.5 [3.3]} \\
P_{dl} &= \text{pressure due to distributed deck load given in Ch.4 Sec.5 [2.3.1] or Ch.4 Sec.6 [2.2]} \\
F_U &= \text{force on exposed and non-exposed decks and platforms due to unit loads as given in Ch.4 Sec.5 [2.3.2]} \\
P_{wl-1} &= \text{design pressure for wheel loading during normal operation at harbour as given in Ch.10 Sec.5 [2]} \\
P_{wl-2} &= \text{design pressure for wheel loading during normal operation at sea as given in Ch.10 Sec.5 [2].}
\end{align*}
\]
2 Structural arrangement

2.1 Structural continuity

2.1.1 Bulkheads and sides
The aft, front and side bulkheads shall be effectively supported by under deck structures such as bulkheads, girders and pillars.

Sides and main longitudinal and transverse bulkheads shall be in line in the various tiers of deckhouses. Where such arrangement in line is not possible, other effective support shall be provided.

Sufficient transverse strength shall be provided by means of transverse bulkheads or girder structures.

2.1.2 Ends of superstructure
At the end of superstructures, which are in line with the ship sides, the side plating of poop and bridge shall extend beyond the ends of the superstructure, and shall be gradually reduced in height down to the sheer strake. The transition shall be smooth and without local discontinuities. A substantial stiffener shall be fitted at the upper edge of plating, which extends beyond the superstructure. The plating shall also be additionally stiffened.

2.1.3 Openings
Arrangements shall be made to minimise the effect of structural discontinuities. All openings cut in the sides shall be framed and have well-rounded corners. Horizontal stiffeners shall be fitted at the upper and lower edge of large openings for windows. Continuous coamings or girders shall be fitted below and above doors and similar openings, and shall extend well beyond the openings.

2.1.4 Deckhouse side and corners
Deck girders shall be fitted below long deckhouses in line with deckhouse sides. The girders shall extend three frame spaces forward and aft of the deckhouse ends. Girders shall be stiffened at the lower edge.

Guidance note:
Expansions joints should be provided for long deckhouse sides, not intended to take part in the global hull girder strength.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

At the corners where the deckhouse is attached to the strength deck, attention shall be given to the arrangements to transmit load into the under deck supporting structure. The connection area between deckhouse corners and deck plating shall be increased locally.

2.1.5 Scallops
Deck beams under front and aft ends of deckhouses shall not be scalloped for a distance of 0.5 m from each side of the deckhouse corners.

2.2 End connections

2.2.1 Deck stiffeners
Transverse beams shall be connected to side frames by brackets according to Ch.3 Sec.6 [2.2]. Beams crossing longitudinal walls and girders may be attached to the stiffeners of longitudinal walls and the webs of girders respectively by welding without brackets.

2.2.2 Longitudinal and transverse deck girders
Face plates shall be stiffened by tripping brackets according to Ch.3 Sec.6 [3.3].

2.2.3 End connections of superstructure frames
Vertical frames shall be welded to the main frames below, or to the deck under provision of a sufficient supporting structure.
2.3 Local reinforcement on bulkheads

2.3.1 Local reinforcement shall be provided in way of large openings and areas supporting life saving appliances or high loads from other equipment, fittings, etc.

2.4 Exposed sides of superstructure sides

Exposed sides of superstructures, when flush with ship side, inclusive their supporting structure shall comply with the bow impact requirements given in Ch.10 Sec.1 [4.1], if applicable.

3 Scantlings

3.1 Minimum thicknesses and minimum section modulus

3.1.1 Application
For minimum thicknesses in general, see Sec.3. For members not covered by Sec.3, see [3.1.2] to [3.1.4].

3.1.2 Minimum thickness of decks
The minimum net thickness of deck plating, in mm, shall not be less than 4.5 mm in general.
For the first tier of weather deck in superstructure or deckhouse in vessels with single continuous deck when more than 50% of 0.4 \( L \) amidships is covered, the minimum net thickness of deck plating, in mm, shall not be less than \( 4.5 + 0.01 L_2 \).

3.1.3 Minimum thickness of end bulkheads
The minimum net thickness of plate for end bulkheads, i.e. front, aft and side, in mm, shall not be less than;
\[
t = 4.0 + 0.01 L_2 \text{ for first tier above freeboard deck}
\]
\[
t = 3.0 + 0.01 L_2 \text{ for upper tiers, but not to be less than 4.0 mm.}
\]

3.1.4 Minimum thickness of protected casings and internal walls
The minimum net thickness of plate for the protected casing and internal wall, in mm, shall not be less than;
\[
t = 5.0 \text{ mm for structure in the cargo area}
\]
\[
t = 4.5 \text{ mm for structure in way of accommodation.}
\]

3.1.5 Minimum section modulus of stiffeners
The minimum net section modulus, in cm\(^3\), of stiffeners used for deckhouse and superstructure shall not be less than:
\[
Z = \frac{0.6 s e^2}{R_{eh}}
\]

3.2 Plating
The net thickness, in mm, shall not be less than:
\[
t = 0.85 \alpha \frac{b}{P^{1/6}} \sqrt{P/\gamma}
\]
3.3 Stiffeners

The net section modulus, in \( \text{cm}^3 \), of stiffener shall not be taken less than:

\[
Z = 0.33 \cdot k \cdot P \cdot \frac{s}{1000} \cdot \ell_{bdg}^2
\]

This requirement assumes the webs of lowest tier stiffeners to be effectively welded to the decks. Scantlings for other types of end connections may be specially considered.

The section of house side stiffeners needs not to be greater than that of side frames on the deck situated directly below; if their spacing and unsupported span are equal.

3.4 Primary supporting members

3.4.1 Net section modulus

The minimum net section modulus, in \( \text{cm}^3 \), of primary supporting members shall not be taken less than:

\[
Z_{n50} = 1000 \cdot \frac{P \cdot S \cdot \ell_{bdg}^2}{f_{bdg} \cdot 0.9 \cdot R_{eH}}
\]

\( f_{bdg} \) = bending moment factor as given in Sec.6 Table 1.

3.4.2 Net shear area

The net shear area, in \( \text{cm}^2 \), of primary supporting members subjected to lateral pressure shall not be taken less than:

\[
A_{shr - n50} = 10 \cdot \frac{f_{shr} \cdot P \cdot S \cdot \ell_{shr}}{0.9 \cdot R_{eH}}
\]

\( f_{shr} \) = shear force distribution factor as given in Sec.6 Table 1.

3.4.3 Alternative grillage analysis for primary supporting members

Where arrangements of deck girders and transverses are such that these members act as a grillage structure, additional analysis may be carried out with a structural model based on net scantlings. The resulting stresses shall not exceed the following permissible bending, shear and equivalent stresses, in N/mm², taken as:

\[
\sigma_b = 0.9 \cdot R_{eH} \\
\tau = 0.9 \cdot \tau_{eH} \\
\sigma_{vm} = R_{eH}
\]

3.5 Aluminium deckhouse or superstructure

3.5.1 Scantlings

Scantlings of plates, stiffeners and primary supporting members shall be in accordance with [3.1] to [3.4]. Minimum thickness and slenderness will be considered on a case-by-case basis.
CHANGES – HISTORIC

July 2016 edition

Main changes July 2016, entering into force as from date of publication

- Sec.2 Load application
  - Sec.2 Table 2: PSM design load set has been updated.

- Sec.4 Plating
  - Sec.4 [1.2.3]: Reduced permissible stress for corrugation angles between 45° and 55° is added.
  - Sec.4 [2.1.3]: The criteria for rounded bilge with transverse stiffening have been clarified.
  - Sec.4 Table 1: The permissible stresses for AC-III have been changed for selected structural members.

October 2015 edition

This is a new document.
The rules enter into force 1 January 2016.

Amendments January 2016

- Sec.3 Minimum thickness requirements
  - Table 1: Modified for side shell 6.9 m above wl and above.
  - Table 2: Modified.
  - Table 3: Modified for PSM in peak tanks.

- Sec.4 Bilge plating
  - [2.1.2]: Modified.

- Sec.6 Primary supporting members and pillars
  - Clarified the application of new effective flange expression and requirements to buckling strength.

- Sec.8 Superstructure, deckhouse and companionways
  - Table 1: Error correction
  - [3.3]: A paragraph missing from legacy rules inserted.
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