Thickness diminution for mobile offshore units
FOREWORD

DNV GL class guidelines contain methods, technical requirements, principles and acceptance criteria related to classed objects as referred to from the rules.

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Any comments may be sent by e-mail to rules@dnvgl.com
CHANGES – CURRENT

General
This document supersedes DNV-RP-C101, May 2014.

Text affected by the main changes in this edition is 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.

On 12 September 2013, DNV and GL merged to form DNV GL Group. On 25 November 2013 Det Norske Veritas AS became the 100% shareholder of Germanischer Lloyd SE, the parent company of the GL Group, and on 27 November 2013 Det Norske Veritas AS, company registration number 945 748 931, changed its name to DNV GL AS. For further information, see www.dnvgl.com. Any reference in this document to “Det Norske Veritas AS”, “Det Norske Veritas”, “DNV”, “GL”, “Germanischer Lloyd SE”, “GL Group” or any other legal entity name or trading name presently owned by the DNV GL Group shall therefore also be considered a reference to “DNV GL AS”.

Main changes July 2015

• General
The revision of this document is part of the DNV GL merger, updating the previous DNV recommended practice into a DNV GL format including updated nomenclature and document reference numbering, e.g.:
— DNV replaced by DNV GL.
— DNV-RP-C101 to DNVGL-CG-0172 etc.

A complete listing with updated reference numbers can be found on DNV GL’s homepage on internet. To complete your understanding, observe that the entire DNV GL update process will be implemented sequentially. Hence, for some of the references, still the legacy DNV documents apply and are explicitly indicated as such, e.g.: Rules for Ships has become DNV Rules for Ships.

• Sec.2 General corrosion
— [2.2.2]: Clarification of scantlings shall be used for buckling control for renewal calculation.
— [2.4.2]: Removed previous item 1) related to special categorization of chords, braces and span-breakers for jack-ups.

• Sec.4 Reassessment calculation
— [4.2.3]: Clarification of scantlings shall be used for the hull girder ultimate buckling control for renewal calculation.

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

1.1 Background
An offshore unit’s original scantlings are normally based on minimum requirements according to the relevant offshore standards applicable at the time of construction, but may also include additions to the requirement due to the initial owner’s requirements or special building practices. However, there has been an extensive development in units design and optimization of scantlings during the last 20-30 years, and this development has in general contributed to reduced corrosion margins. Provision of maintaining an adequate corrosion protection system is therefore essential.

1.2 Objective
The document provides guidelines and principles for allowable thickness diminution of different structural elements for floating offshore units in operation.

1.3 Scope
This document focuses on ship shaped units, column-stabilized units, and jack-ups. Notwithstanding, the principles may be extended to all types of floating offshore units/installations based on a case by case acceptance from the Society.

The document may also be used as a guidance for evaluation of units for conversion, like tanker conversion to FPSO/FSO.

As not all designs or cases can be covered, the content herein shall then be used with due regard to specific design limitations.

1.4 Application
This class guideline applies for floating offshore units in operation as governed by the applicable DNV GL rules for classification: Offshore units (see DNVGL-RU-OU-0101, -0102, -0103 and -0104).

The principles given in this document are valid with the provision that the periodical survey requirements, given in the referred rules, are fulfilled.

Repair extent and method shall be approved by the Society.

1.5 Document structure
The main body of this document is structured as follows:

— Sec.1 gives introduction and purpose of the document
— Sec.2 describes the general corrosion thickness diminution for different Mobile offshore units
— Sec.3 describes the local corrosion diminution and the advised repair methods in general
— Sec.4 provides guidance for reassessment calculation for different Mobile offshore units.
— Sec.5 provides guidance related to expected future corrosion margin for conversions and steel renewal work
— App.A describes a method for assessing the ultimate hull girder capacity of ship shaped units.
### 1.6 Definitions

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_{\text{mod}}$</td>
<td>the total shear area accounting for the corrosion allowance</td>
</tr>
<tr>
<td>$A_{\text{orig}}$</td>
<td>the total shear area based on the original as built thickness</td>
</tr>
<tr>
<td>FPSO/FSO</td>
<td>ship shaped floating storage units</td>
</tr>
<tr>
<td>HULS</td>
<td>hull ultimate limit strength</td>
</tr>
<tr>
<td>$k$</td>
<td>diminution coefficients</td>
</tr>
<tr>
<td>$k_{\text{reass}}$</td>
<td>absolute allowable diminution coefficients when using reassessment calculations</td>
</tr>
<tr>
<td>$k_{\text{sub}}$</td>
<td>diminution coefficients for the allowable substantial corrosion margin</td>
</tr>
<tr>
<td>$M_D$</td>
<td>design bending moment, $M_D = M_S + M_W$</td>
</tr>
<tr>
<td>$M_S$</td>
<td>design still water bending moment</td>
</tr>
<tr>
<td>$M_W$</td>
<td>design wave bending moment</td>
</tr>
<tr>
<td>$M_{W\text{-rule}}$</td>
<td>design wave rule bending moment according to the DNV Rules for ships Pt.3 Ch.1</td>
</tr>
<tr>
<td>$M_{W\text{-site}}$</td>
<td>design wave 100 years site specific bending moment at the actual site specific location</td>
</tr>
<tr>
<td>PULS</td>
<td>panel ultimate limit strength</td>
</tr>
<tr>
<td>$Q_D$</td>
<td>design shear force, $Q_D = Q_S + Q_W$</td>
</tr>
<tr>
<td>$Q_S$</td>
<td>design still water shear force</td>
</tr>
<tr>
<td>$Q_W$</td>
<td>design wave shear force</td>
</tr>
<tr>
<td>$Q_{W\text{-rule}}$</td>
<td>design wave rule shear force according to the DNV Rules for ships Pt.3 Ch.1</td>
</tr>
<tr>
<td>$Q_{W\text{-site}}$</td>
<td>design wave 100 years site specific shear force at the actual site specific location</td>
</tr>
<tr>
<td>RDL</td>
<td>requested design life after renewal or conversion work (year)</td>
</tr>
<tr>
<td>$t_{\text{conv}}$</td>
<td>thickness when the unit leaving the conversion yard after renewal work</td>
</tr>
<tr>
<td>$t_{\text{corr}}$</td>
<td>corrosion addition, in mm, as defined in DNV Rules for ships Pt.8 Ch.1</td>
</tr>
<tr>
<td>$t_{\text{exist}}$</td>
<td>existing “as is” thickness</td>
</tr>
<tr>
<td>$t_{\text{gross}}$</td>
<td>rule gross thickness</td>
</tr>
<tr>
<td>$t_{\text{g}}$</td>
<td>rule corrosion addition for ship shaped units</td>
</tr>
<tr>
<td>$t_{\text{g-inc}}$</td>
<td>corrosion margin increment after conversion or renewal work (mm/year)</td>
</tr>
<tr>
<td>$t_{\text{g-ren}}$</td>
<td>corrosion margin after conversion or renewal work (mm)</td>
</tr>
<tr>
<td>$t_{\text{orig}}$</td>
<td>original “as built” thickness in mm</td>
</tr>
<tr>
<td>$t_{\text{own}}$</td>
<td>owner/builder specified thickness addition</td>
</tr>
<tr>
<td>$t_{\text{req}}$</td>
<td>net rule minimum thickness</td>
</tr>
<tr>
<td>$t_{\text{ren}}$</td>
<td>thickness limit where renewal of structural member is required</td>
</tr>
<tr>
<td>$t_{\text{ren-reass}}$</td>
<td>rule minimum allowable thickness based on reassessed calculation</td>
</tr>
<tr>
<td>$t_{\text{reass}}$</td>
<td>gross thickness based on reassessed calculation</td>
</tr>
<tr>
<td>$t_{\text{sub}}$</td>
<td>substantial corrosion thickness based on original “as built” thickness</td>
</tr>
<tr>
<td>$t_{\text{sub-reass}}$</td>
<td>substantial corrosion thickness based on reassessed thickness calculation ($t_{\text{reass}}$)</td>
</tr>
<tr>
<td>$t_{\text{w-orig}}$</td>
<td>originally “as built” weld scantlings</td>
</tr>
<tr>
<td>$t_{\text{w-ren}}$</td>
<td>renewal requirement for welds</td>
</tr>
<tr>
<td>ULS</td>
<td>ultimate limit state</td>
</tr>
<tr>
<td>$Z_{\text{act}}$</td>
<td>section modulus based on as-measured thickness</td>
</tr>
<tr>
<td>$Z_{\text{mod}}$</td>
<td>modified section modulus accounting for the corrosion allowance</td>
</tr>
<tr>
<td>$Z_{\text{orig}}$</td>
<td>section modulus based on as-build original gross scantlings</td>
</tr>
</tbody>
</table>
SECTION 2 GENERAL CORROSION

2.1 General

General corrosion is defined where uniform reductions of material are found. The criteria for substantial and minimum thickness of the hull structural elements is given for the different object types (ships, column-stabilised units, jack-ups, etc.) in [2.3] and [2.4] respectively.

The corrosion margins vary in size depending on the decisive strength criteria. The margins related to yield strength do, for example, normally allow larger diminution than the margins for buckling. It should be noted that due to varying stress levels and different stiffening arrangements simple criteria may not always be generally applied and other considerations might be required.

Requirements and principles for thickness measurements and actions related to findings are specified in the applicable DNV GL rules for offshore units.

The diminution coefficients for general corrosion presented in this section are based on simple structural approach and are generally accepted by the Society without any further extended calculations. The diminution shall be documented and informed to the Society by means of thickness measurements.

When several corrosion attacks are discovered in one structural area or in adjacent structural areas, structural analysis documenting sufficient capacity together with updated drawings shall be submitted to the Society for approval.

In general the Society reserves the right to require additional information related to structural calculations or thickness measurements as deemed necessary.

2.2 Renewal thickness calculation

2.2.1 General

In general the renewal thickness \( t_{\text{ren}} \) for the unit is based on the principle of using diminution coefficients, allowing a reduction from the required rule minimum gross thickness \( t_{\text{gross}} \) where any rule corrosion addition \( t_k \) is included.

The net scantling approach using a given rule corrosion addition \( t_k \) is basis for newbuilding of ship shaped units. For the other units (column-stabilised units, jack-ups, etc.) the minimum gross thickness \( t_{\text{gross}} \) without any rule corrosion addition is used in the newbulding design. The allowable diminution coefficients \( k \) is then depending on the design assumptions.

The rule minimum gross thickness \( t_{\text{gross}} \) is normally the original "as built" thickness \( t_{\text{orig}} \) but \( t_{\text{orig}} \) may also include an owners corrosion addition \( t_{\text{own}} \) from the new building. The renewal thickness \( t_{\text{ren}} \) is the minimum allowable thickness before steel renewal is required.

\[
t_{\text{ren}} = k \cdot t_{\text{gross}}
\]

where:

- \( t_{\text{ren}} \) = Thickness limit when renewal of structural member is required
- \( k \) = Diminution coefficients
- \( t_{\text{req}} \) = Net rule minimum thickness
- \( t_{\text{gross}} \) = Rule minimum gross thickness, \( t_{\text{gross}} = t_{\text{req}} + t_k \)
- \( t_k \) = Rule corrosion addition generally for ship shaped units. For other units \( t_k \) is normally not included.

The allowable wastage margin for a unit is then \( (1 - k) \cdot t_{\text{gross}} \) and substantial corrosion thickness is defined when more than 75% of the allowable wastage margin is used.

\[
t_{\text{sub}} = (0.25 + 0.75 \cdot k) \cdot t_{\text{gross}} => k_{\text{sub}} \cdot t_{\text{gross}}
\]
2.2.2 Buckling control
The renewal thickness ($t_{ren}$) using the diminution in [2.2.1] is accepted provided the structural element has sufficient buckling capacity, i.e. by using the renewal thickness $t_{ren}$ in the buckling control.

2.2.3 Fatigue control
No new fatigue checks are required when the actual measured thickness is greater than $t_{ren}$ calculated according to the principles in [2.2.1], provided that the unit not will move and operate in a more harsh environment than what was the basis for the original design.

2.2.4 Repair
Repairs of more extensive corrosion will typically include steel replacement back to the original scantlings. Other reinforcement as inserting additional stiffeners or brackets may be accepted upon special consideration and shall always be supported by strength calculations.

All repairs shall be cleaned and protected against further corrosion, i.e. normally by hard coating unless otherwise accepted by the Society.

Figure 2-1 Definition of corrosion allowance
2.3 Ship shaped units

2.3.1 General

The allowable diminution coefficients for ship shaped units are based on the categorization of the structural areas as specified in the DNV GL rules for offshore units for periodical survey extent, e.g. rules for drilling and support units ref. DNVGL-RU-OU-0101 Ch.3 Sec.3, and visualized in Figure 2-2 and Figure 2-3 below. The allowable diminution coefficients given below are applicable for all ship shaped units and for world wide operation, meaning relevant both for harsh and benign waters.

Figure 2-2 Typical primary and special areas for drillships
2.3.2 Definition of strength members

The structural terminology applied in the specification of minimum thickness is illustrated in Figure 2-4, showing a typical midship area of a FPSO with centre tanks and wing tanks.
2.3.3 Allowable diminution coefficients for longitudinal strength members

The following allowable diminution coefficients for the longitudinal strength members are given in Table 2-1. The longitudinal strength members shall comply with the buckling capacity as given in [2.3.7].

Table 2-1 Allowable diminution coefficients for longitudinal strength members

<table>
<thead>
<tr>
<th>Structural component</th>
<th>Diminution coefficients “k”</th>
<th>Diminution coefficients “k_sub”</th>
<th>Buckling control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plating</td>
<td>0.80</td>
<td>0.85</td>
<td>according to [2.3.7]</td>
</tr>
<tr>
<td>Stiffeners</td>
<td>0.75</td>
<td>0.81</td>
<td>according to [2.3.7]</td>
</tr>
<tr>
<td>Girders and stingers</td>
<td>0.80</td>
<td>0.85</td>
<td>according to [2.3.7]</td>
</tr>
</tbody>
</table>
2.3.4 Allowable diminution coefficients for transverse members.

The allowable diminution coefficients for the transverse strength members are given in Table 2-2.

**Table 2-2 Diminution coefficients for transverse members**

<table>
<thead>
<tr>
<th>Structural component</th>
<th>Diminution coefficients ( k )</th>
<th>Diminution coefficients ( k_{sub} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transverse Bulkheads</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plate</td>
<td>0.75</td>
<td>0.81</td>
</tr>
<tr>
<td>Stiffeners</td>
<td>0.75</td>
<td>0.81</td>
</tr>
<tr>
<td>Web-frames/Floors/</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Girders and stringers*)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plate</td>
<td>0.80</td>
<td>0.85</td>
</tr>
<tr>
<td>Stiffeners</td>
<td>0.75</td>
<td>0.81</td>
</tr>
<tr>
<td>Cross ties web and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>flange</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Web</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flange</td>
<td>0.75</td>
<td>0.81</td>
</tr>
</tbody>
</table>

*) Flanges on transverse members contributing to hull girder section modulus are to be considered according to Table 2-1.

The values in Table 2-2 may be accepted without any further new strength assessment.

2.3.5 Allowable diminution coefficients for other strength members.

The allowable diminution coefficients for other hull strength members are given in Table 2-3.

**Table 2-3 Diminution coefficients for other structural members**

<table>
<thead>
<tr>
<th>Structural component</th>
<th>Diminution coefficients ( k )</th>
<th>Diminution coefficients ( k_{sub} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Super structure and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>deckhouse</td>
<td>Plate</td>
<td>0.7</td>
</tr>
<tr>
<td>Stiffeners</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forecastle and poop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>deck</td>
<td>Plate</td>
<td>0.80</td>
</tr>
<tr>
<td>Stiffeners</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hatch covers and hatch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>coamings</td>
<td>Plate</td>
<td>0.75</td>
</tr>
<tr>
<td>Stiffeners</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The values in Table 2-3 are generally accepted without any further strength assessment. For other hull structural elements not listed in the tables above a diminution coefficient \( k = 0.8 \) shall in general be used.

2.3.6 Allowable diminution coefficients for offshore related interface members

Other members not directly related to the hull structure, as e.g. turret, topside and topside interface structures are categorized into structural components in DNVGL-OS-C102 Sec.2, and also illustrated in Figure 2-2 and Figure 2-3. Turret, topside and topside stool connections above the main deck level are normally based on the gross thickness approach without any rule corrosion addition \( t_c \) included in the newbuilding design. Hence the diminution coefficients given in Table 2-4 are then somewhat stricter than what is used for the hull structure.

**Table 2-4 Diminution coefficients for topside structure and topside interface members**

<table>
<thead>
<tr>
<th>Structural component</th>
<th>Diminution coefficients ( k )</th>
<th>Diminution coefficients ( k_{sub} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Special areas</td>
<td>0.95</td>
<td>0.96</td>
</tr>
<tr>
<td>Primary areas</td>
<td>0.90</td>
<td>0.92</td>
</tr>
<tr>
<td>Secondary areas</td>
<td>0.85</td>
<td>0.88</td>
</tr>
</tbody>
</table>
2.3.7 Hull girder longitudinal strength within 0.4 L amidships

Hull girder bending moment

In order to account for overall global corrosion, the section modulus of the vessel shall be reduced according to method a) or b) as given below.

Method a); This is the normal approach and use the original "as built" thickness. The method requires that 90% of the original section modulus \(Z_{\text{orig}}\) is used as basis to account for the expected overall global corrosion. This may be done by simply increasing the hull girder longitudinal stress used for the buckling control of the longitudinal strength elements as following:

\[
a) \quad \sigma_L = \frac{M_D}{0.9 \cdot Z_{\text{orig}}}
\]

Method b); This method uses the measured "as is" thickness. The thickness measurements shall be carried out as specified in the relevant DNV GL rules for offshore units with 95% of the actual "as is" section modulus \(Z_{\text{act}}\), i.e. 5% wastage accounts for expected future corrosion. The hull girder longitudinal stress to be used for the buckling control of the longitudinal strength members will, with this method, be as following;

\[
b) \quad \sigma_L = \frac{M_D}{0.95 \cdot Z_{\text{act}}}
\]

\(M_D = M_S + M_W\) where:

- \(M_S\) is the design still water bending moment for the seagoing transit condition, operation condition or the survival condition, given in the appendix to the classification certificate or in the approved loading manual. The relevant design still water bending moment \(M_S\) shall be combined with actual design wave bending moment \(M_W\) for transit, operational or survival condition depending which condition that is governing.

- \(M_W\) is the design wave bending moment. For transit condition the DNV Rules for ships wave moment \(M_W\)-rule or alternative using actual transit route with 10 year return period as specified in DNVGL-OS-C102 shall be used. For the survival condition the 100 years site specific wave bending moment shall be used \(M_W\)-site.
  - For units operating in benign waters the DNV rules for ships wave bending moment \(M_W\)-rule as given in the DNV Rules for ships, Pt.3 Ch.1 is governing and shall be used. Alternative the 100 years wave bending moment for the actual site specific location, \(M_W\)-site may be used if the reassessed thickness calculation method given in [4.2] is used.
  - For units operating in harsh environments the 100 years wave bending moment at the actual site specific locations \(M_W\)-site shall be used.

See also design principles given in DNVGL-OS-C102 Ch.2 Sec.2.

Hull girder shear force

The total hull girder shear force is given by:

\(Q_D = Q_S + Q_W\) where:

- \(Q_S\) is the design still water shear force for the seagoing transit condition, operational condition or the survival condition, given in the appendix to the classification certificate or in the approved loading manual. The actual relevant design still water shear force shall be combined with the actual design wave shear force \(Q_W\) for transit, operational and survival condition.

- For units operating in benign waters the DNV rules for ships wave shear force \(Q_W\)-rule as given in the DNV Rules for ships, Pt.3 Ch.1 shall be used. Alternative the 100 years wave shear force for the actual site specific location \(Q_W\)-site may be used if the reassessed thickness calculation method given in [4.2] is used.

- For units operating in harsh environments the 100 years wave shear force at the actual site specific locations, \(Q_W\)-site shall be used.

See also design principles given in DNVGL-OS-C102 Ch.2 Sec.2.
**Buckling control of longitudinal strength elements**

The midship section shall be checked using “separate panels” according to the principles given in DNVGL-OS-C102 Ch.2 Sec.4 with the allowable minimum thickness given in Table 2-1 together with the global loads defined above.

The DNV GL program Nauticus hull offshore ultimate limit state (ULS) check may be used as a tool for the buckling control where the minimum allowable thickness from Table 2-1 or actual measured thickness are used in the cross section analysis. By reducing all longitudinal strength members according to Table 2-1 the section modulus will also be reduced similarly and hence more than requested above. This may be compensated by using a modified bending moment \( M_{Dmod} \) as following:

\[
M_{Dmod} = M_D \cdot \left( \frac{Z_{mod}}{Z_{orig}} \right) 1 \ldots or \ldots M_D \cdot \left( \frac{Z_{mod}}{Z_{act}} \right) 1.05
\]

\( A_{mod} \) is the total shear area accounting for the corrosion allowance using the diminution coefficients for plates according to Table 5-1. \( A_{orig} \) is the total shear area based on the original as built thickness. The shear force distribution is assumed unchanged.

\( Z_{mod} \) is the modified section modulus accounting for the corrosion allowance using the diminution coefficients for plates according to Table 5-1. \( Z_{orig} \) is the section modulus based on the original as built thickness, and \( Z_{act} \) is the section modulus based on the actual measured thickness. The 1.1 and 1.05 factors are to account for the 90% or 95% reduction of section modulus as specified above. The global shear stress will similarly be overestimated and may be compensated by reducing the total shear force with:

\[
Q_{Dmod} = \left( \frac{A_{mod}}{A_{orig}} \right) Q_D
\]

The basic usage factor, \( \eta_0 \), as given in DNVGL-OS-C102 shall be used for the stiffened panel buckling control. However, if the requirement above is not met the hull girder ultimate strength principle as given in [4.2.3] may be considered.

### 2.3.8 Hull girder longitudinal strength outside 0.4 L amidships

Outside 0.4 L amidships the vertical bending moment is not expected to be critical for the hull girder strength. The principles and procedures given in [2.3.3] may thus be applied by using an allowable diminution coefficient, \( k = 0.8 \), for all longitudinal elements without performing any additional buckling control.

However, in the quarter length of the unit (0.25 L and 0.75 L) the hull girder shear force is high. In these areas the longitudinal strength members shall comply with the buckling capacity as given in [2.3.7].

### 2.4 Column-stabilised units and jack-ups

#### 2.4.1 General

The allowable diminution coefficients for column-stabilised units and jack-ups are based on the categorization of the structural areas as specified in the relevant DNV GL rules for offshore units for periodical survey extent, e.g. DNVGL-RU-OU-0101 Ch.3 Sec.3, and also illustrated in Figure 2-5 and Figure 2-6.
Figure 2-5 Typical primary and special areas for column-stabilised units

Figure 2-6 Typical primary and special areas for jack-Ups
2.4.2 General

The allowable diminution coefficients for column-stabilised units and jack-ups are present in Table 2-5 below.

Table 2-5 Diminution coefficients for column-stabilised units and jack-ups

<table>
<thead>
<tr>
<th>Structural component</th>
<th>Diminution coefficients “k”</th>
<th>Diminution coefficients “ksub”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Special areas</td>
<td>0.95</td>
<td>0.96</td>
</tr>
<tr>
<td>Primary areas</td>
<td>0.90</td>
<td>0.92</td>
</tr>
<tr>
<td>Secondary areas(^\text{1}))</td>
<td>0.85</td>
<td>0.88</td>
</tr>
</tbody>
</table>

\(^\text{1})\)Column-stabilized units; watertight integrity areas shall be considered as primary area with respect to the diminution

2.5 Other mobile offshore units

Other mobile offshore units are mainly related to cylindrically shaped units. The area categorization is based on the general definitions given in DNVGL-OS-C101. The allowable diminution coefficients are shown in Table 2-6.

Table 2-6 Diminution coefficients for other offshore units

<table>
<thead>
<tr>
<th>Structural component</th>
<th>Diminution coefficients “k”</th>
<th>Diminution coefficients “ksub”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Special areas</td>
<td>0.95</td>
<td>0.96</td>
</tr>
<tr>
<td>Primary areas</td>
<td>0.90</td>
<td>0.92</td>
</tr>
<tr>
<td>Secondary areas</td>
<td>0.85</td>
<td>0.88</td>
</tr>
</tbody>
</table>

Watertight integrity areas shall follow the diminution coefficients for primary structure as given in Table 2-6.
SECTION 3 LOCAL CORROSION

3.1 General
Local corrosion is corrosion attack limited to a local area within approximately $500 \times 500$ mm, and with no neighbouring corroded areas. Local corrosion is divided into three groups, namely, pitting, grooving and edge corrosion.

The diminution coefficients for local corrosion presented below are generally accepted by the Society without any further extended calculations. However, the diminution shall be documented and informed to the Society by means of thickness measurements.

The allowable local thickness reduction given below is relevant for all types of mobile offshore units.

When several local corrosion attacks are discovered in one structural area or in adjacent structural areas, the local corrosion shall be handled as general corrosion. Structural analysis documenting sufficient capacity shall be submitted to the Society for approval, together with updated drawings.

In general the Society reserves the right to require additional information related to structural calculations or thickness measurements as deemed necessary.

3.2 Pitting

3.2.1 General
Pitting is random scattered corrosion spots/areas with local material reductions. The intensity of the pitting shall be estimated in order to decide the extent of repair criteria, see Figure 3-1. For pitting corrosion the following assumptions shall be considered.

— Pitting in special areas is normally not accepted and shall be repaired, as pitting will introduce local notches that might be critical with respect to fatigue.
— Hard coatings shall normally be applied after repair unless otherwise accepted by the Society.

3.2.2 Minimum acceptable remaining thickness without repair

a) For plates in primary and secondary areas with pitting intensity less than 20%, the minimum allowable remaining thickness shall not be less than:

$$t_{ren} = 0.7 \cdot t_{orig}$$

In special areas the remaining thickness is to be minimum $t_{ren} = 0.95 \cdot t_{orig}$

The remaining plate thickness shall anyhow be minimum 6 mm

b) In cases with 50% pitting intensity or more, plates shall be regarded as exposed to general corrosion. The average remaining thickness, in the worst cross section through the pitting in a plate field should not be less than minimum thickness for general corrosion as defined in Sec.2.

c) For intermediate pitting intensities, acceptance of average remaining thickness may be decided based on linear interpolation between a) and b).

3.2.3 Average remaining thickness for pitted areas
As a rough guide for estimating the average remaining thickness for pitted areas the following may be applied:

$$t_{act} = t_{plate} (1 - Int/100) + t_{pit} Int/100$$

$\text{t}_{\text{act}}$ = corrected average remaining thickness
$\text{t}_{\text{plate}}$ = average remaining plate thickness in the pitted corroded area
$\text{t}_{\text{pit}}$ = average remaining thickness measured in the pitting groups

$\text{Int}$ = estimated pitting intensity in %
3.2.4 Repair of pittings

In special areas and where the pitting damage is moderate, repair by grinding is the preferred method in order to remove the pitting groups.

In general for all other areas not expected to be fatigue critical the following may apply:

a) For widely scattered pitting, i.e. intensity < 5%, and where the remaining plate thickness in pitting is not less than 6 mm, the following applies:
   i) The use of plastic compound filler material is only considered as a method to prevent further corrosion and does not contribute to the strength. The manufacturers instructions of the plastic compounds shall be followed and includes the following:
      — pitting to be thoroughly cleaned (sand/grit blasted) and dried prior to application
      — pitting to be completely filled
      — a top layer of coating to be applied.
   ii) Filling of pits by buttering welds may be carried out in accordance with the following:
      — pitting is to be thoroughly cleaned, ground and dried prior to welding and tested free of cracks
      — low hydrogen electrodes approved for the material in question are to be used. Weld to start outside pitting and direction reversed for each layer.
      — welding procedure to be prepared and approved
      — welds to be ground and tested free of cracks and notches.

b) For high intensity pitting and/or where the remaining thickness is below the acceptable limits plates/stiffeners are to be renewed by inserts.

Hard coating or other approved corrosion protection systems shall be provided after any repair.
3.3 Groove and edge corrosion

3.3.1 General
Grooving is loss of local line material normally adjacent to welding joints along abutting stiffeners and at stiffener, plate butts or seams. Due to the complexity and effects of groove corrosion, diminution criteria are limited and special repair considerations are required.

Grooving corrosion normally takes place adjacent to welds in areas like:

— web frame connections to deck/stiffeners (ballast tanks)
— webs of side/deck longitudinals (ballast tanks)
— external shell plates.

Edge corrosion is mainly found around cutouts in web structures and at the free edges of flat bars.

For groove and edge corrosion the following is assumed:

— grooves and edges are smooth and without sharp edges or notches
— welding is intact and with acceptable remaining throat thickness
— continuous and major grooves in global load-bearing elements shall to be specially considered.

3.3.2 Groove corrosion
The maximum extent of grooving and the acceptable minimum thickness of stiffeners and plates may be taken as follows:

In primary and secondary areas and where the groove breadth is a maximum of 15% of the web height, but not more than 100 mm, the remaining allowable minimum thickness in the groove is to be:

\[ t_{\text{ren}} = 0.7 \cdot t_{\text{orig}} \]

In Special areas the remaining thickness is to be minimum \( t_{\text{ren}} = 0.95 \cdot t_{\text{orig}} \)

If the grooves introduces notches that may be fatigue critical, the notches shall be ground smooth and re-coated.

The remaining plate thickness shall anyhow be minimum 6 mm

Grooving corrosion of stiffeners with angle profile is considered to be serious, and should be carefully considered when revealed. Lack of fixation to the plate will cause the stiffener to tilt, and over time the grooving may increase due to stress corrosion. When the stiffener is tilting the efficiency of the stiffener is reduced, and will then again reduce the plate panel capacity.

A calculation with respect to the shear strength and tripping is to be carried out if the above criteria are exceeded, but the minimum thickness in continuous grooving should not be less than 6 mm.

Figure 3-2 Typical grooving corrosion in stiffener connection
3.3.3 Edge corrosion

3.3.3.1 General
Edge corrosion is local material wastage at the free edges of plates and stiffeners.

3.3.3.2 Flat bar longitudinals part of global strength
For acceptable extent of corrosion of the free edge of the longitudinals the following may be applied:

a) The overall height of the corroded part of the edge is less than 25% of the stiffener web height.
b) The edge thickness is not less than $1/3 \ t_{\text{orig}}$ and well rounded.
c) The thickness of the remaining part of the longitudinal is above the minimum allowable according to Sec.2.

![Figure 3-3 Extent of free edge corrosion](image)

3.3.3.3 Manholes, penetrations, lightening holes, etc.
Plate edges at openings for manholes, lightening holes, etc. may be reduced below the minimum thickness provided criteria for shear area are checked and the following apply:

a) The maximum extent of the reduced plate thickness that may be below the minimum requirements given in Sec.2 from the opening edge, is not to be more than 20% of the smallest dimension of the opening but should not exceed 100 mm.

![Figure 3-4 Extent of corrosion in way of manholes etc.](image)

b) Rough or uneven edges may be cropped-back provided the maximum dimension of the opening is not increased by more than 10%. Special care is to be taken in areas with high shear stresses, including areas with adjacent cut-outs.

3.3.4 Repair of groove and edge corrosion
Where excessive edge corrosion is found, renewal by inserts will normally be required. However, alternative repairs may be considered as follows:

a) Edges of openings maybe reinforced by:
   i) compensation doubler rings with lap joint
ii) additional flanges

iii) possible closing of openings by collar plates around stiffener and at corner cutouts adjacent to the affected areas to be considered.

b) Re-welding of grooves and corroded butts or seams:

i) the surfaces are to be cleaned, ground and dried before welding

ii) low hydrogen electrodes to be used.

iii) approved welding procedure shall be applied.

In primary and secondary areas repairs may be carried out by means of edge stiffeners/doublers, but is general not accepted as a repair method in special areas.

Hard coating or other corrosion protection shall be provided after any repair unless otherwise accepted by the Society

3.4 Local corrosion of welds

3.4.1 Fillet welds

In special areas the renewal requirement for the fillet welds is: \( t_{w-ren} = 0.95 \cdot t_{w-orig} \)

In all other areas (primary and secondary) not found to be fatigue critical, the renewal requirement for the fillet welds is: \( t_{w-ren} = 0.7 \cdot t_{w-orig} \)

3.4.2 Full penetration welds

In special areas the renewal requirement for the full penetration welds is: \( t_{w-ren} = 0.95 \cdot t_{w-orig} \)

In all other areas (primary and secondary) not found to be fatigue critical, the renewal requirement for the full penetration welds is: \( t_{w-ren} = 0.7 \cdot t_{w-orig} \)

3.4.3 Repair of welds

In special areas and where the corrosion is within the limits given above, grinding is the preferred method for removing any notches or cavities.

In all other areas not expected to be fatigue critical and where the corrosion is within the limits given above, the welds may only be cleaned (sand/grid blast) and re-coated.
SECTION 4 REASSESSMENT CALCULATION

4.1 General
Offshore units are designed for site specific operations or for world wide use. A minimum thickness list based on the diminution coefficients given in Sec.2 is based on units that operate world wide.

When site specific environment condition for the operation of the unit is available more extensive calculations for the allowable wastage margin may be performed. Reassessment of the existing thickness may then optionally be performed when:

— The unit moves to a new location with less severe environment conditions than what was basis for the original design.
— Refined direct calculation method is used with actual site specific loads, e.g. life time extension.

Prior to starting such analysis the Society shall be contacted in order to evaluate the basis for the method and the procedures used.

The Society reserve the right to carry out independent global and local analysis as deemed necessary which will be charged additionally.

When reassessing the global and local strength of the unit, the operational limitations in the Appendix to Class shall be updated accordingly and a 'Restricted' service notation will normally be applied.

All new areas that are to be reassessed shall be documented by means of thickness measurements and calculations shall be submitted to the Society for approval, together with updated drawings.

For any hull structural member, the minimum thickness may be found by direct calculation using actual site specific environmental loads based on the latest rule edition of the relevant object standard.

Reassessed thickness calculation means in principal that new gross thickness \( t_{\text{reass}} \) are calculated for a given site specific location. The Society should evaluate the reassessment principles in advance of the task and the reassessed thickness will in general be reviewed on a “case by case” basis, see also Figure 4-1.

When site specific environmental loads are used as basis for a new updated minimum thickness list for a unit, the new list is then only valid for the actual geographical area or other geographical areas were the environments loads are equal or more benign than the new design basis.

In principle the minimum allowable thickness can be found by documenting global and local strength capacity using actual measured thickness \( t_{\text{exist}} \). However, there will be uncertainly related to the thickness data and how the data is incorporated in a FE model. It is therefore essential that the data is of sufficient quality and that conservative assumptions are made during the modelling. The Society reserve the right to require additional thickness measurements.

For reassessment calculations absolute allowable diminution coefficients \( k_{\text{reass}} \) are given for different structural elements. This means that the specified \( k_{\text{reass}} \) are the absolute limits when steel renewal is required, irrespectively of any further margin found from the calculations. The reason for specifying an absolute allowable diminution limit, is to take into account for uncertainties related to the weld properties and possible local hot spots from corrosion that are essential for the limit state strength assessment.

The absolute diminution coefficients for reassessment calculations \( k_{\text{reass}} \) varies from ship shaped type units to other unit types. This is due to the fact that ship shaped units are based on the net scantling approach with a rule corrosion margin included in the original scantlings, while the other units are normally based on a gross scantlings approach, without any corrosion margin included from the new building.

The renewal thickness \( t_{\text{ren}} \) using reassessment calculation, when steel renewal is required is then:

\[
t_{\text{ren}} = k_{\text{reass}} \cdot t_{\text{orig}}
\]

where the \( k_{\text{reass}} \) depends on the offshore unit type and the structural elements considered, see [4.2] to [4.4] below.
4.2 Reassessment of ship shaped units

4.2.1 Site specific loads
Actual site specific 100 year loads shall be used to check both hull girder strength and transverse strength for the survival condition according to the principles given in DNVGL-OS-C102.

4.2.2 Operation conditions
Changed operation criteria such as e.g. new mass distribution and restricted tank filling configuration shall be considered.

4.2.3 Hull girder ultimate strength
An alternative calculation approach is based on the (total) hull girder ultimate strength, evaluated for both sagging and hogging conditions.

Relevant reductions of the section modulus is to be applied and will typically be 10% or 5% as specified in [2.3.7]. The hull girder capacity \( M_{\text{cap}} \) considering global buckling and allowing for local redistribution of forces.

The usage factor for the hull girder ultimate strength, \( \eta_{0-\text{cap}} = \frac{M_w + M_s}{M_{\text{cap}}} \) where \( \eta_{0-\text{cap}} < 0.8 \).

The stillwater bending moment \( M_s \) shall be based on the limit curves from the loading manual. The wave bending moment \( M_w \) shall be based on the site specific location(s), but \( M_w \) shall not be taken less than 50% of the rule wave bending moment.

The \( M_{\text{cap}} \) shall be calculated based on \( Z_{n50-\text{reass}} \), i.e. 50% of the wastage from reassessment calculation.

When a total hull girder ultimate capacity is found within the requirement as given above, the usage factor for the individual panel buckling ref. [2.3.7], \( \eta_0 < 1.0 \), may be used.

For the individual panel buckling check the nominal hull stress shall be based on \( Z_{n50-\text{reass}} \), and each individual plate panel field shall be based on the reassessed net scantings,

An iteration process is then required in order to find the reassessed scantlings.

However, it is anticipated that this calculation method will require extensive use of non-linear calculation software and good engineering judgement. For more information regarding suitable calculation programs see App.A.

4.2.4 Transverse members
Transverse primary members (frames, girders, stringers, etc.) may be checked for yield and buckling using actual 100 year site specific sea pressure and inertia loads by means of a FE-model. A general overall corrosion reduction of 10% or using actual measured thickness shall be used. All relevant load combinations and drafts shall be considered together with the acceptance criteria given in DNVGL-OS-C102.
4.2.5 Fatigue assessment

Fatigue shall be evaluated according to the principles given in DNVGL-OS-C102. When the actual area of concern is corroded, the SN-curve for corrosion environment (no cathodic protection) shall be used from the time of last renewal survey where no corrosion was observed.

4.2.6 Total assessment

Provided all relevant structural checks as given in this section are carried out and found acceptable by the Society, the following absolute allowable diminution coefficients $k_{reass}$ may be accepted.

<table>
<thead>
<tr>
<th>Structural component</th>
<th>Diminution coefficients “$k_{reass}$”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plating</td>
<td>0.70</td>
</tr>
<tr>
<td>Stiffeners</td>
<td>0.70</td>
</tr>
<tr>
<td>Girders and stingers</td>
<td>0.70</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Structural component</th>
<th>Diminution coefficients “$k_{reass}$”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transverse Bulkheads</td>
<td></td>
</tr>
<tr>
<td>Plate</td>
<td>0.70</td>
</tr>
<tr>
<td>Stiffeners</td>
<td>0.70</td>
</tr>
<tr>
<td>Web-frames/Floors/</td>
<td></td>
</tr>
<tr>
<td>Girders and stringers</td>
<td>0.70</td>
</tr>
<tr>
<td>Plate</td>
<td>0.70</td>
</tr>
<tr>
<td>Stiffeners</td>
<td>0.70</td>
</tr>
<tr>
<td>Cross ties web and</td>
<td></td>
</tr>
<tr>
<td>flange</td>
<td>Web</td>
</tr>
<tr>
<td></td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td>Flange</td>
</tr>
</tbody>
</table>

*) Flanges on transverse members contributing to hull girder section modulus are to be considered according to Table 4-1

<table>
<thead>
<tr>
<th>Structural component</th>
<th>Diminution coefficients “$k_{reass}$”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Super structure and</td>
<td></td>
</tr>
<tr>
<td>deckhouse</td>
<td>Plate</td>
</tr>
<tr>
<td></td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>Stiffeners</td>
</tr>
<tr>
<td>Forecastle and poop</td>
<td></td>
</tr>
<tr>
<td>deck</td>
<td>Plate</td>
</tr>
<tr>
<td></td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>Stiffeners</td>
</tr>
<tr>
<td>Hatch covers and</td>
<td></td>
</tr>
<tr>
<td>hatch coamings</td>
<td>Plate</td>
</tr>
<tr>
<td></td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>Stiffeners</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Structural component</th>
<th>Diminution coefficients “$k_{reass}$”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Special areas</td>
<td>0.85</td>
</tr>
<tr>
<td>Primary areas</td>
<td>0.80</td>
</tr>
<tr>
<td>Secondary areas</td>
<td>0.75</td>
</tr>
</tbody>
</table>

For the area categorization, see DNV GL rules for offshore units for periodical survey extent, e.g. Rules for drilling and support units ref. DNVGL-RU-OU-0101 Ch.3 Sec.3.
4.3 Reassessment of column-stabilised units and jack-ups

4.3.1 Site specific loads
Actual site specific environmental loads may be used to check the global and local strength for all relevant limit states given in DNVGL-OS-C103/-C104/-C201.

4.3.2 Operation conditions
Changed operation criteria such as e.g. new mass distribution and restricted tank filling configuration shall be considered.

4.3.3 Fatigue assessment
Fatigue shall be evaluated according to the principles given in DNVGL-OS-C103/C104/C201. When the actual area of concern is corroded, the SN-curve for corrosion environment (no cathodic protection) shall be used from the time of last renewal survey where no corrosion was observed.

4.3.4 Total assessment
Provided all relevant structural checks as given in this section are carried out and found acceptable by the Society, the following absolute allowable diminution coefficients $k_{\text{reass}}$ may be accepted.

Table 4-5 Absolute allowable diminution coefficients for column-stabilized units and jack-ups

<table>
<thead>
<tr>
<th>Structural component</th>
<th>Diminution coefficients $k_{\text{reass}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Special areas</td>
<td>0.85</td>
</tr>
<tr>
<td>Primary areas</td>
<td>0.80</td>
</tr>
<tr>
<td>Secondary areas</td>
<td>0.75</td>
</tr>
</tbody>
</table>

For the area categorization, see DNV GL rules for offshore units for periodical survey extent, e.g. DNVGL-RU-OU-0101 Ch.3 Sec.3.

4.4 Reassessment of other mobile offshore units

4.4.1 General
Reassessment of other mobile offshore units except follows the same principles as for ship shaped units, column-stabilized units and jack-ups. Provided all relevant structural checks are carried out and found acceptable by the Society, the following absolute allowable diminution coefficients $k_{\text{reass}}$ may be accepted.

Table 4-6 Absolute allowable diminution coefficients for other mobile offshore units

<table>
<thead>
<tr>
<th>Structural component</th>
<th>Diminution coefficients $k_{\text{reass}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Special areas</td>
<td>0.85</td>
</tr>
<tr>
<td>Primary areas</td>
<td>0.80</td>
</tr>
<tr>
<td>Secondary areas</td>
<td>0.75</td>
</tr>
</tbody>
</table>

For the area categorization, see DNV GL rules for offshore units for periodical survey extent, e.g. DNVGL-RU-OU-0101 Ch.3 Sec.3.
SECTION 5  CONVERSIONS AND RENEWAL WORK

5.1 General principles
During conversion or renewal work a corrosion margin $t_{k-ren}$ that take into account corrosion margin for the future operation should be added on top of the allowable substantial corrosion $t_{sub}$, see Figure 5-1. The corrosion margin $t_{k-ren}$ will then act a margin in order to postpone the need for additional repairs due to progressive corrosion in the future.

$$t_{k-ren} = t_{k-inc} \cdot RDL,$$

where;
- $RDL$ is requested design life after conversion or renewal work (year)
- $t_{k-inc}$ is the corrosion margin increment after conversion or renewal work (mm/year). The values for the future corrosion rate will vary depending on the actual air temperature, water temperature, cargo oil type, actual location, etc. In general the higher temperature the more corrosion can be expected. Information of the corrosion rate from past operation, or the corrosion rate from similar units operating in the same area may be used if available.

![Figure 5-1  Definition of corrosion allowance during conversion or renewal work](image)

When a unit is leaving the conversion yard after the renewal work the actual plate thickness should then minimum be:

$$t_{conv} = t_{sub} + t_{k-ren} \quad \text{or} \quad t_{conv} = t_{sub-reass} + t_{k-ren} \quad \text{if a reassessment thickness calculation is carried out}$$

5.2 Conversion of tankers to ship shaped floating storage units
For ship shaped floating storage units (FSO/FPSO) indicative general experience numbers for $t_{k-inc}$ are listed in Table 5-1 below for relevant structural elements. However, the numbers should only be used as guidance values as future corrosion depends on many factor as described in [5.1], and may thus deviate from the tabulated values. However, designers should use their own independent values of $t_{k-inc}$ for the intended use when submitting design calculations for appraisal by the Society.

For general structural requirements related to conversion of tankers for FSO/FPSO, see DNVGL-OS-C102 App.A.
### Table 5-1  Typical minimum corrosion rate (mm/year) for FSO/FPSO’s, $t_{k-inc}$

<table>
<thead>
<tr>
<th>Structure element</th>
<th>Within 1.5 m below weather deck tank or hold top</th>
<th>Elsewhere</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transverse structural elements</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transverse web frames and BHD’s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plating</td>
<td>0.05</td>
<td>0.075</td>
</tr>
<tr>
<td>Horizontal girder/stiffener</td>
<td>0.05</td>
<td>0.075</td>
</tr>
<tr>
<td>Vertical girder/stiffener</td>
<td>0.025</td>
<td>0.05</td>
</tr>
<tr>
<td>Brackets</td>
<td>0.025</td>
<td>0.05</td>
</tr>
<tr>
<td><strong>Longitudinal structural elements</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deck structure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deck plating (one side of element)</td>
<td>0.1</td>
<td>0.15</td>
</tr>
<tr>
<td>Deck Girders/Longitudinals (Web)</td>
<td>0.05</td>
<td>0.075</td>
</tr>
<tr>
<td>Deck Girders/Longitudinals (Flange)</td>
<td>0.05</td>
<td>0.075</td>
</tr>
<tr>
<td>Brackets</td>
<td>0.05</td>
<td>0.075</td>
</tr>
<tr>
<td>Bottom structure</td>
<td></td>
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<tr>
<td>Bottom Girders/Longitudinals (Web)</td>
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<tr>
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<tr>
<td>Inner Bottom plating</td>
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<td>Bottom Girders/Longitudinals (Web)</td>
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<td>Bottom Girders/Longitudinals (Flange)</td>
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<tr>
<td>Side shell Longitudinals (Flange)</td>
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<tr>
<td>Brackets</td>
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<tr>
<td><strong>Long BHD</strong></td>
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<tr>
<td>Long BHD plating</td>
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<tr>
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<tr>
<td>Long BHD Longitudinals (Flange)</td>
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<tr>
<td>Brackets</td>
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5.3 Conversion of common structural rules tankers to ship shaped floating storage units

When a vessel is built according to the common structural rules (CSR) the “net scantling” approach is used as basis for the new-building, with the rule defined corrosion additions for the in-service phase incorporated. The minimum thickness together with possible “owners extra voluntary addition”, is normally given on the approved drawings from designer or new building yard.

The “net scantling” approach used for CSR-tanker from the new-building will then give the allowable corrosion margin for the in-service phase as a FSOFPSO.

The renewal thickness of plates $t_{\text{ren}}$ is then:

\[
t_{\text{ren}} = \text{Renewal thickness; Minimum allowable thickness, in mm, at which renewal of structural members is to be carried out, } t_{\text{ren}} = t_{\text{orig}} - t_{\text{corr}} - t_{\text{own}}
\]

where:

\[
t_{\text{orig}} = \text{original as built thickness of the member, in mm}
\]

\[
t_{\text{corr}} = \text{corrosion addition, in mm as defined in the CRS-tanker rules}
\]

\[
t_{\text{own}} = \text{owner/builder specified additional wastage allowance, if applicable, in mm}
\]

However, conversion of a CSR-tanker to FSOFPSO also requires that the hull girder ultimate strength and fatigue requirements given in DNVGL-OS-C102 App.A are satisfied.
APPENDIX A  CALCULATION OF HULL GIRDER ULTIMATE CAPACITY

$M_U$ = Ultimate hull girder hogging bending moment for a section in a pure vertical bending modus.

The $M_U$ is calculated as summing up the longitudinal loads carried by each element in section at hull girder collapse. An acceptable method for assessing the $M_U$ value is to apply the DNV GL hull girder ultimate limit state (HULS) model:

$$M_U = \int_{\text{hull-section}} \sigma z \, dA = \sum_{i=1}^{K} P_i \, z_i = \sum_{i=1}^{K} (EA)_{\text{eff-i}} \, \varepsilon_i \, z_i$$

$P_i$ = Axial load in element no. $i$ at hull girder collapse ($P_i = (EA)_{\text{eff-i}} \, \varepsilon_i \, g\text{-collapse}$)

$z_i$ = Distance from hull-section neutral axis to centre of area of element no. $i$ at hull girder collapse. The neutral axis position is to be shifted due to local buckling and collapse of individual elements in the hull-section.

$(EA)_{\text{eff-i}}$ = Axial stiffness of element no. $i$ accounting for buckling of plating and stiffeners (pre-collapse stiffness)

$K$ = Total number of assumed elements in hull section (typical stiffened panels, girders etc.)

$\varepsilon_i$ = Axial strain of centre of area of element no. $i$ at hull girder collapse ($\varepsilon_i = \varepsilon_i \, g\text{-collapse}$; the collapse strain for each element follows the displacement hypothesis assumed for the hull section)

$\sigma$ = Axial stress in hull-section

$z$ = Vertical co-ordinate in hull-section measured from neutral axis

Panel ultimate limit strength (PULS) is used for individual element ultimate capacity and stiffness assessments. PULS is a DNV GL computer program using non-linear plate theory to calculate a stiffened plate field’s ultimate buckling strength. It treats the entire, stiffened plate field as an integrated unit, allowing for internal redistribution of the stresses.

An explicit capacity check $M_{\text{tension\_yield}}$ of the tension part of the hull girder is also to be carried out. E.g., for hogging loading conditions the total capacity is limited by yield at the strength deck.

$M_{\text{cap}} = \min \{M_U, M_{\text{tension\_yield}}\}$

Alternative advanced methods, i.e. such as non-linear FE model analyses or equivalent for assessing the ultimate hull girder capacities $M_U$ will be considered by the Society on a case by case basis.
Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter and greener.