Allowable Thickness Diminution for Hull Structure

JULY 2013
FOREWORD

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Classification Notes

Classification Notes are publications that give practical information on classification of ships and other objects. Examples of design solutions, calculation methods, specifications of test procedures, as well as acceptable repair methods for some components are given as interpretations of the more general rule requirements.

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General
This document supersedes Classification Note No. 72.1, January 2013.

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.

Main changes
• Sec.1 General
  — [1.2]: References to CSR-Tank and CSR-Bulk has been added.
• App.A
  — 6 Annex has been changed to Appendix A.
• App.B
  — Appendix A has been changed to Appendix B.
• App.C
  — This is a new appendix.

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

1.1 Introduction
The purpose of the present Classification Notes is to provide the user with general information and a tool for assessing the acceptance level of deterioration in hull structures.

A ship's original scantlings are normally based on minimum requirements according to the Rules for Classification of Ships applicable at the time of construction but may also include additions due to the initial owner's requirements or special building practices. However, there has been an extensive development in ship design and optimization of scantlings during the last 20-30 years, and this development has in general contributed to reduced corrosion margins. Provision of a good corrosion protection system is, therefore, now more important than ever. As not all designs or circumstances can be covered, the instructions herein should be used with particular caution. Acceptance of repair extent and method must be given by the Society.

1.2 Applicability
The Class Note applies in general to ships of normal design built of steel. Further it does not apply to vessels with class notation CSR for which the Rules have specific requirements to ships in service. See Appendix C for information of CSR vessels.

1.3 Definitions

1.3.1 Definitions

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>rule length in m, see Pt.3 Ch.1 Sec.1</td>
</tr>
<tr>
<td>( t_{\text{orig}} )</td>
<td>original “as built” thickness in mm</td>
</tr>
<tr>
<td>( t_{\text{min}} )</td>
<td>minimum thickness in mm including a margin for further corrosion until next hull survey.</td>
</tr>
<tr>
<td>TM</td>
<td>thickness measurements</td>
</tr>
<tr>
<td>( \sigma_{\text{ult}} )</td>
<td>Panel ultimate capacity</td>
</tr>
<tr>
<td>( \sigma_y )</td>
<td>Yield stress</td>
</tr>
<tr>
<td>PULS</td>
<td>“Panel Ultimate Limit Strength” is a DNV 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.</td>
</tr>
</tbody>
</table>

1.3.2 Terminology
The structural terminology applied in the specification of minimum thickness is illustrated in Figure 1-1 “Typical double hull tanker” and Figure 1-2 “Typical bulk carrier”, showing a typical midship area of a double hull tanker and a bulk carrier.
Figure 1-1
Typical double hull tanker

Figure 1-2
Typical bulk carrier
2 Categories of Corrosion

Corrosion may be divided into the following categories:

![Diagram of deck plating with fillet weld and longitudinal structure]

**General:** Where uniform reductions of material are found. Criteria for minimum thickness of hull structural elements may be applied in order to determine average diminution values, see 3. Typically, repairs will include steel replacement to original scantlings and/or reinforcement upon special consideration.

**Pitting:** Random scattered corrosion spots/areas with local material reductions. The intensity of the pitting must first be estimated before applying criteria, see Sec.4.1. Typically, repairs will include renewal of plates, building up pits by welding or application of plastic filler compounds.

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

**Edges:** Local material wastage at the free edges of plates and stiffeners, see Sec.4.2. Typically, if not renewed, repairs may be carried out by means of edge stiffeners/doublers.

For each of the corrosion categories separate assumptions, criteria and typical repairs should be applied as given in relevant chapters, and to the surveyor’s satisfaction.

3 Allowable Material Diminution for General Corrosion

3.1 General

Criteria for allowable diminution on original scantling is based on the rule philosophy developed for newbuilding approval, and the difference is mainly related to adjustment of probability level since new vessels are considered for a 20 year period.

The corrosion margins may however 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. For the main structures of vessels with $L \geq 100$ m a list giving acceptable diminution and original thickness is normally supplied by DNV.

3.2 Assumptions

The following assumptions apply for criteria given in this Classification Note:

— The criteria may be applied to normal and high tensile steel i.e. not aluminium or stainless steel unless especially stated.
— Special considerations are carried out if the vessel has undergone major conversions e.g. has been lengthened.
— For vessels built with reduced corrosion margins, i.e. register notation corr (see Rules for Ships January 1990), the minimum values given below cannot be generally applied.
3.3 Vessels with length, L < 100 m

In general, allowable diminution of plate thickness up to 20% and for profiles up to 25% on original values will be accepted. However, the thickness of plating is not to be less than:

For deck: \( t_{\text{min}} > 0.9 (5.5 + 0.02 \cdot L) \)

and side/bottom: \( t_{\text{min}} > 0.9 (5.0 + 0.04 \cdot L) \)

For vessels with transverse framing in the bottom, inner bottom or upper deck, more thorough calculations may be required. The methods in Sec.3.4 may be applied as necessary.

3.4 Vessels with length, L \( \geq \) 100 m

3.4.1 Structure within 0.4 L amidships

The allowable material diminution is based on requirements for net scantlings at Renewal Survey Hull. The method includes criteria to local strength, buckling strength and requirement to hull girder section modulus. The maximum allowable diminution will be determined by the requirement that gives the least reduction.

It may be relevant to carry out more detailed calculations in order to get more exact and differentiated results. Some provisions for such calculations are given in Sec.3.4.2.

3.4.1.1 Local strength control

The minimum thickness of plates, stiffener/girder webs or flanges at renewal survey may be determined from the following:

General corrosion criteria: \( t_{\text{min}} = k t_{\text{orig}} \)

\( t_{\text{orig}} \) = original ‘as built’ thickness

\( k \) = diminution coefficient from Table 3-1 or Table 3-2

3.4.1.2 Buckling control in bottom and deck area

The buckling control for plates and stiffeners is to be carried out according to the PULS code.

A buckling utilisation factor, \( \eta \), of the following shall be used, depending on position of each panel and types of stiffeners used:

<table>
<thead>
<tr>
<th>Longitudinally stiffened Ships</th>
<th>Deck area panels within 0.15 D (including lower side and hopper area)</th>
<th>Bottom area panels within 0.15 D (except side and hopper area)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L or T profile longitudinals</td>
<td>1.0</td>
<td>0.85</td>
</tr>
<tr>
<td>Flatbar or HP bulb longitudinals</td>
<td>1.1</td>
<td>0.94</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Transversely stiffened Ships</th>
<th>Deck area panels within 0.15 D (including lower side and hopper area)</th>
<th>Bottom area panels within 0.15 D (except side and hopper area)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L profile, T profile, Flatbar or HP bulb stiffeners</td>
<td>1.0</td>
<td>0.85</td>
</tr>
</tbody>
</table>

In cases where the acceptance criteria in sec.3.4 gives unreasonably low allowable diminution of original scantlings, e.g. less than 5 – 10%, the Society may reconsider the acceptance criteria based on a case by case evaluation.

Allowable Still Water Bending Moments

The maximum, allowable still water bending moment for seagoing condition, given in the appendix to the classification certificate or an approved loading manual, is to be applied in combination with the wave bending moment according to the Rules Pt.3 Ch.1 Sec.5 (probability of exceedance of \( 10^{-8} \)).

When two Still Water Bending Moment Limits are given (homogenous and alternate), the homogenous limit is to be used in the calculations.

If no maximum allowable still water bending moment is given, a maximum rule still water bending moment should be calculated according to the same rules provided that no approved loading conditions exceed this value.

The longitudinal stresses applied in the buckling control are calculated by dividing the still water bending moment and wave bending moment with the section modulus of the hull girder. The section modulus is \( (\sigma_{0.9} = M/0.9Z) \), i.e. to be based on the reduced section modulus of the hull girder, normally not to be taken more than 90% of the as built section modulus in deck and bottom.
However in case of low buckling capacity in deck or bottom, 95% of the as built section modulus may be used ($\sigma_{0.95} = M/0.95Z$).

**Separate Panels**

All separate panels within 0.15 D from the top or bottom (Ref. Figure 3-3) should be checked, with a “separate panel” defined as a plate field with similar scantlings and spacing for all the plates and stiffeners included. E.g. the main deck between two main structural elements, such as the ship’s side and the longitudinal bulkhead, could be defined as a separate panel.

If there are areas with different scantlings and/or spacing between two main structural elements, one should model each of the different areas as separate panels, but use an artificial panel breadth equal to the breadth of the whole plate field. E.g. if the main deck between the ship’s side and the longitudinal bulkhead may be divided into two areas, A and B, with different thickness of the main deck plating, one should check one panel with the scantlings of area A and one with the scantlings of area B, where both panels checked should be given an artificial breadth equal to the total breadth of area A + B, i.e. the entire distance between the ship’s side and the longitudinal bulkhead.

![Figure 3-1](image)

**Consideration to different scantlings in calculation modelling**

**Buckling control of transversally stiffened side**

Vessels where the side is transversally stiffened within 0.15 D from deck or bottom should be modelled in PULS as follows:

![Diagram](image)

- $L_1$ height from bottom/deck to the neutral axis or to the first deck or stringer level.
- $S$ transverse stiffener spacing.

The stress should be varied linearly from bottom/deck to neutral axis or to the first deck or stringer level.

**Reduced Efficiency**

Local panels e.g. part of the structure such as longitudinal girder, part of ship side /longitudinal bulkhead, top wing tank plating etc. with buckling capacity below requirement may be specially considered providing surrounding panels have sufficient strength to carry the additional load. This is not applicable for main strength deck panels or bottom shell panels.

The procedure is to reduce the efficiency of the panel to a factor equal to:

$$\frac{\sigma_{ult}}{\sigma_y}$$

**Note:**

$\sigma_{ult}$ is the maximum capacity of the panel, found in “Detailed Results” in PULS.
The reduced efficiency should then be added to the Section Scantling model and the new stress level is to be used in the PULS calculations.

---e-n-d---of---N-o-t-e---

The average, longitudinal stress acting on the panel is to be used. It is not necessary to include transverse in-plane stresses, shear stress or lateral loads.

3.4.1.3 Vessels with high double bottom stresses

Bulk Carriers with class notations BC-B, BC-A or BC-B* (the old HC, HC/E or HC-EA), double hull tankers without a longitudinal bulkhead and gas carriers which in design are similar to ordinary single hull bulk carriers are ship types where double bottom stresses may be critical.

For such vessels where the bottom plating is built with increased thickness in middle of the empty holds in alternate loading conditions, the following procedure should be applied:

The buckling analysis is to be carried out for the bottom panel between the hopper tank girder (margin girder) and the first double bottom girder inboard. The allowable reduction (in mm) found by this analysis is to be applied for the other bottom plates as well.

![Figure 3-2](image)

**Figure 3-2**

**Procedure of critical ship types**

If stiffener dimension or spacing between longitudinals varies, this will be subject to special consideration. For vessels where the bottom plating is not built with increased thickness in the middle of the empty holds in alternate loading conditions, the allowable reduction for the bottom plating and stiffeners is maximum 10%.

If applying transverse stresses directly to the bottom panels, the local loads and load cases are to be based on the rules for newbuilding for the actual ship type.

3.4.1.4 Hull girder section modulus

In order to comply with global longitudinal strength requirements, the reduced section modulus of the vessel is normally not to be less than 90% of the required section modulus based on design bending moments.

In any case the reduced section modulus is not to be less than 90% of the minimum rule section modulus given in the rules Pt.3 Ch.1 Sec.5.

As a consequence of buckling criteria the allowable reduction of section modulus may be less than given above. **Table 3-2** Section modulus reduction control provides a tool for assessment of hull girder section modulus reduction, conservatively assuming a reduction factor for an area equivalent to the reduction factor for section modulus. In the subject cross section of deck or bottom all structural elements contributing to longitudinal strength below 0.15 D or above 0.85 D should be included.
### Figure 3-3
Structural elements contributing to longitudinal strength

<table>
<thead>
<tr>
<th>Structural component</th>
<th>Diminution coefficients &quot;k&quot;</th>
<th>Buckling control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strength members within 0.15 D from deck and bottom</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plating</td>
<td>0.80</td>
<td>Buckling control according to 3.4.1.2</td>
</tr>
<tr>
<td>Stiffeners</td>
<td>0.75</td>
<td>Buckling control according to 3.4.1.2</td>
</tr>
<tr>
<td>Girders and stringers (1)</td>
<td>0.80</td>
<td>Buckling control according to 3.4.1.2</td>
</tr>
<tr>
<td><strong>Side and longitudinal bulkhead between 0.15 D and 0.85 D from bottom</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plating (2)</td>
<td>L &lt; 150 m</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>L &gt; 150 m</td>
<td>0.80</td>
</tr>
<tr>
<td>Stiffeners</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td><strong>Other longitudinal structure between 0.15 D and 0.85 D from bottom</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plating</td>
<td>0.80</td>
<td></td>
</tr>
<tr>
<td>Stiffeners</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td>Girders and stringers</td>
<td>0.80</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

1) **Bottom girders:**
   - For single side skin bulk carriers with length L<sub>pp</sub> > 150 m carrying cargo with density of 1.78 t/m<sup>3</sup> or more, the shear strength of the girders in hold no.1 are additionally to be checked according to IACS UR S22, as applicable.

2) **Side and longitudinal bulkhead:**
   - For corrugated bulkheads see Table 3-2 “Transverse bulkheads”.

---

![Diagram of structural elements contributing to longitudinal strength](image_url)
### Table 3-2 Transverse strength members

<table>
<thead>
<tr>
<th>Structural component</th>
<th>Diminution coefficients &quot;k&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deck plating between hatches</td>
<td></td>
</tr>
<tr>
<td>Plate</td>
<td>0.80 1)</td>
</tr>
<tr>
<td>Stiffener</td>
<td>0.75</td>
</tr>
<tr>
<td>Transverse bulkhead 2)</td>
<td></td>
</tr>
<tr>
<td>Plain bulkhead</td>
<td>0.75 4)</td>
</tr>
<tr>
<td>Corrugated bulkheads</td>
<td></td>
</tr>
<tr>
<td>Flange</td>
<td>0.80</td>
</tr>
<tr>
<td>Web</td>
<td></td>
</tr>
<tr>
<td>Frames/Stiffeners</td>
<td></td>
</tr>
<tr>
<td>Web</td>
<td>0.75</td>
</tr>
<tr>
<td>Stiffener</td>
<td>0.75</td>
</tr>
<tr>
<td>Web frames/Floors 3)</td>
<td>Web</td>
</tr>
<tr>
<td>Web</td>
<td>0.80</td>
</tr>
<tr>
<td>Girders and Stringers</td>
<td>Flange</td>
</tr>
<tr>
<td>Web</td>
<td>0.75</td>
</tr>
<tr>
<td>Side Frames in way of wing tank for Container Ships</td>
<td></td>
</tr>
<tr>
<td>Upper part - the web frame plating above first stringer from second deck</td>
<td>Plating</td>
</tr>
<tr>
<td>Lower part - the web frame plating below first stringer from second deck</td>
<td>Plating</td>
</tr>
<tr>
<td>Cross ties</td>
<td>0.85</td>
</tr>
<tr>
<td>Hatch covers/Coamings</td>
<td>Plate</td>
</tr>
<tr>
<td>Web</td>
<td>0.80</td>
</tr>
<tr>
<td>Stiffener</td>
<td>0.75</td>
</tr>
</tbody>
</table>

**Notes:**

1) To be especially considered if cross deck stiffened in longitudinal direction in way of vertically corrugated, transverse bulkhead.

2) For single side skin bulk carriers with length L_{pp} > 150 m carrying cargo with density of 1.78 t/m³ or more, vertically corrugated transverse bulkhead between forward holds no.1 and 2 is to satisfy flooding requirements according to IACS UR S19, as applicable.

3) For single skin bulk carriers with length L_{pp} >150 m carrying cargo with density of 1.78 t/m³ or more, the shear strength of the floors in hold no.1 is additionally to be checked according to IACS UR S22, as applicable.

4) Bulkheads designed with two plate flanges connected with vertical webs ("double skin bulkheads") should have a diminution coefficient, \( k = 0.80 \).

#### 3.4.2 Structure outside 0.4 L amidship

**3.4.2.1 Transverse strength elements**

Minimum thickness calculations of transverse strength members are in general to follow the procedures of Sec.3.4.1.

**3.4.2.2 Longitudinal strength elements**

The direct strength criteria given in Sec.3.4.1 apply. Optionally the simplified method given below may be used:

- **Deck and bottom plating within 0.15 D:**

  Minimum thickness 0.1 L from perpendiculars is:

  \[ t_{\text{min}} = k \cdot t_{\text{orig}} \]

  with

  \[ k = 0.80 \]

  Linear interpolation should be applied between 0.4 L midship area and 0.1 L from perpendiculars.
Deck and bottom longitudinals within 0.15D:
The minimum thickness 0.1 L, from the perpendicular, is decided as for deck and bottom plates, but with $k = 0.75$

Where plates are given less than 20% and longitudinals are given less than 25% thickness reduction in the midship area due to buckling, a linear interpolation should be used for the margins between 0.4 L from midship and 0.1L from the perpendiculars.

Side and longitudinal bulkhead plating:
The minimum thickness is to be based on the procedure given in Sec.3.4.1.

Side and bulkhead longitudinals and girders:
The minimum thickness is to be based on the procedure given in Sec.3.4.1.

3.5 Refined minimum thickness calculations
If it is found necessary to obtain more accurate and differentiated values for the minimum thickness than offered by Sec.3.3 and Sec.3.4, then the method described in this chapter may be used.

3.5.1 For any hull structure member, the minimum thickness may be found from direct calculation according to the latest rule edition. The Society may specially consider the application of other relevant criteria on a case by case basis, for example, based on relevant operational conditions etc.

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

Relevant reductions on the hull girder is to be applied. This will typical either be 10% (maximum) or actual measured reductions on the hull girder. The hull girder capacity $M_{cap}$ is then calculated, considering global buckling and allowing for local redistribution of forces and bending moments.

This capacity is compared to standard wave bending moments and maximum still water bending moments. Maximum allowable usage factor depend on loading condition, see table below.

<table>
<thead>
<tr>
<th>Maximum allowable usage factor</th>
<th>Sagging condition</th>
<th>Hogging condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>Double bottom within cargo area</td>
<td></td>
<td>0.85</td>
</tr>
<tr>
<td>Double bottom transition zone between cargo area and engine room (aft), when longitudinal continuity is considered</td>
<td></td>
<td>0.90</td>
</tr>
</tbody>
</table>

Usage factor = $(M_w+M_s) / M_{cap}$
If the hull girder ultimate strength is found acceptable, i.e. usage factor < allowable usage factor, then local diminution coefficients of 0.80 for plating and 0.75 for longitudinals will normally be acceptable.
However, it is anticipated that this calculation method will require extensive use of nonlinear calculation software and good engineering judgement.

For more information regarding suitable calculation programs refer to Appendix B.

3.5.3 DNV may offer a special service concerning detailed assessment and re-calculation of certain structural elements in order to find the absolute minimum thickness based on the actual condition. Such calculations will normally require detailed and advanced calculation models, and fees for this service may be agreed separately with DNV, based on the scope of work. Detailed thickness measurements will normally be required in order to verify the actual thickness of the corroded structure.
Reference is made to Classification Notes No. 31.1, 31.2 and 31.3 for further information on calculation procedures.
3.6 Repair
Reference is made to the IACS publication Shipbuilding and Repair Quality Standard, Part B, and Appendix A concerning voyage repairs.

Details of hull repairs including procedures are to be agreed with the Society prior to commencement of the repair.

Areas found with diminution in excess of acceptable limits are normally to be repaired with inserted material of same grade and scantlings as original. Alternative dimensions materials and repair methods may, however, be accepted provided they are specially considered and approved, typically in connection with refined minimum thickness calculations.

Where inserts are arranged the remaining thickness of existing areas, adjacent to replacement material, should normally be at least 1 mm in excess of the minimum thickness.

4 Pitting, Groove and Edge Corrosion

4.1 Pitting

4.1.1 Assumptions

The following assumptions apply:

— Pitting repaired by plastic compound filler material is only considered as a method to prevent further corrosion and does not contribute to the strength.
— Hard coatings are normally to be applied after repair.

4.1.2 Minimum acceptable remaining thickness without repair

a) For plates with pitting intensity less than 20%, the minimum remaining thickness in pitting is to be at least:

\[ t_{min} = 0.6 \times t_{orig} \]

but, not less than 6 mm.

b) For plates with “100% pitting intensity” (i.e. 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 given in 3.

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

4.1.3 Average remaining thickness for pitted areas

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

\[ t_{act} = t_{plate} \times (1 - Int/100) + t_{pit} \times Int/100 \]

\[ t_{act} \] = corrected average remaining thickness

\[ t_{plate} \] = average remaining thickness outside pitting

\[ t_{pit} \] = average remaining thickness in pitting

\[ Int\] = estimated pitting intensity in %

Further, in order to assist in the assessment of estimated pitting intensity, see Figure 4-1.

4.1.4 Repair

a) For widely scattered pitting, i.e. intensity < 5%, and where the remaining thickness in pitting is not less than 6 mm, then the following may apply:

i) The use of filler material/plastic compound of a suitable elastic type according to the manufacturers instructions and including 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) Welding, may be carried out afloat, in accordance with the following:

— pitting is to be thoroughly cleaned, ground and dried prior to welding
— low hydrogen electrodes approved for the material in question are to be used. Weld to start outside pitting and direction reversed for each layer.

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

4.2.1 General
Grooving corrosion normally takes place adjacent to welds and is of particular concern for the connection of side frames to shell plate in single skin bulk carriers. However, grooving may be a problem for various ship types. Other commonly affected areas are:

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

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

4.2.2 Assumptions
The following assumptions apply:

— grooves and edges are smooth and without sharp edges or notches
— welding is intact and with acceptable remaining throat thickness
— continuous transverse grooves in deck, bottom, longitudinal bulkhead and side plating within the cargo area to be specially considered.

4.2.3 Groove corrosion of internal structures
The maximum extent of grooving and the acceptable minimum thickness of stiffeners and plates may be taken as follows:
Where the groove breadth is a maximum of 15% of the web height, but not more than 100 mm, the remaining allowable thickness in the grooved area may be taken as:

\[ t_{\text{min}} = 0.7 \cdot t_{\text{orig}} \text{ but, not less than 6.0 mm.} \]

![Figure 4-2](image)

**Groove corrosion**

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 will increase due to stress corrosion. When the stiffener is tilting the efficiency of the stiffener is reduced, and this may cause secondary problems to the plate panel.

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.

### 4.2.4 Corroded welded seams in shell plating

Minimum thickness at the weld or plate:

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

### 4.2.5 Edge corrosion

#### 4.2.5.1 Flat bar deck longitudinals

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 \( 1/3 \, \text{t}_{\text{orig}} \) and well rounded.

c) The thickness of the remaining part of the longitudinal is above the minimum allowable according to 3.

![Figure 4-3](image)

**Extent of free edge corrosion**

#### 4.2.5.2 Manholes, 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, below the minimum given in Sec.4, from the opening edge is not to be more than 20% of the smallest dimension of the opening but should not exceed 100 mm.
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.

4.2.6 Repair
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.

Figure 4-4
Extent of corrosion in way of manholes etc.

5 References
a) Tanker Structure Co-operative Forum:

b) IACS Publications:
   — Bulk Carriers, Guidelines for Surveys, Assessment and Repair of Hull Structure (1994)

c) DNV Guidelines:
   — No. 8, Corrosion Protection of Ships (1996)

d) DNV Classification Notes:
   — No. 31.1 Strength Analysis of Hull Structures in Bulk Carriers
   — No. 31.3 Strength Analysis of Hull Structure in Tankers.
Appendix A

Guidelines for the survey of voyage repairs

A.1 General
The purpose of these notes is to provide guidance to the field surveyors and owners dealing with voyage hull repairs and is to be considered in addition to the rules.

A.1.1 Initial meeting
A meeting is to be held with the class surveyor and owner prior to commencement of hull repairs during a vessel’s voyage to discuss and confirm the following:

a) It is the owner’s responsibility to ensure continued effectiveness of the structure, including the longitudinal strength and the watertight/weathertight integrity of the vessel.
b) Extent of intended repairs. All repairs are to be based on the classification society’s recommendations and/or concurrence.
c) Availability of pertinent drawings.
d) Verification of new materials regarding certification, grade and scantlings. Verified mill sheets to remain on board and to be provided to attending surveyor examining completed repairs.
e) Verification of welding consumables regarding certification and suitability for materials involved. Check on availability of drying ovens, holding containers, etc.
f) Verification of the qualification of welders and supervisory personnel, qualification records to remain on board and to be provided to attending surveyor examining completed repairs.
g) Review of intended repair.
h) Review of the intended provisions to facilitate sound weldments, i.e. cleaning, preheating (if applicable) adherence to welding sequence principles. Further, it might be necessary to restrict welding to certain positions and prohibit welding in more difficult positions when the ship’s motions might influence the quality of the welding.
i) Review of intended working conditions, i.e. staging, lighting, ventilation, etc.
j) Review of intended supervision and quality control.
k) Completed repairs are to be examined and tested as required to the satisfaction of the attending surveyor.

Note:
All details and results of subject meeting to be covered by a memorandum. A copy of this memorandum is to be placed on board and to be provided to the attending surveyor examining the repairs. In addition, a copy is to be sent or faxed to the arrival port where completed repairs will be examined.

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A.1.2 Contemplated repairs
Descriptions of any contemplated repairs to primary hull structures, i.e. main longitudinal and transverse members and their attachments, are to be submitted to the classification society for review prior to commencing voyage repairs. Any repairs to primary hull structures shall require attendance by a surveyor riding-ship survey or at regular intervals to confirm fit-up, alignment, general workmanship and compliance with recommendations. NDT of completed repairs to primary structure to be carried out to attending surveyor’s satisfaction. Repairs to other hull structural parts may be accepted based on examination upon completion of repairs.

A.1.3 Prerequisites for repairs
No hull repairs carried out by a riding crew should be accepted unless:

a) The initial meeting had been carried out and conditions found satisfactory.
b) A final satisfactory examination upon completion was carried out.
Appendix B
Calculation of hull girder ultimate capacity

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

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 HULS model:

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

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

\( z_i \) = 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.

\( (EA)_{eff-i} \) = 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 \( (\varepsilon_i = \varepsilon_i^{g-collapse}) \), 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 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 \( (M_{tension\_yield}) \) 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.

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

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.
Appendix C
Common Structural Rules Vessels - CSR

C.1 General
There are two different types of Common Structural Rules (CSR) vessels. Each type has their separate Rules.

— CSR-Tank: Rules for Ships Pt.8 Ch.1 Common Structural Rules for Double Hull Oil Tanker with Length 150 metres and above.
— CSR-Bulk: Rules for Ships Pt.8 Ch.2 Common Structural Rules for Bulk Carriers with Length 90 metres and above.

CSR vessels are built with the Common Structural Rules “net scantling” approach. The newbuilding requirements within the Rules incorporate defined corrosion additions. The minimum thickness together with possible “owners extra”, “voluntary addition”, or similar is stated on the approved drawings from designer or new building yard.

In case documents/drawings with information of minimum thickness is not available then the below references may be used. For CSR vessels the “substantial corrosion” limit is equivalent to “annual inspection limit”. In case there is any discrepancy between the respective rules and this Classification Note, then the Rules prevail.

Note that the CSR-Tank rules and CSR-Bulk rules also have different criteria for local corrosion.

C.2 CSR-Tank
In general see Rules for Ships Pt.8 Ch.1 Common Structural Rules for Double Hull Oil Tanker with Length 150 metres and above.

For minimum thickness in connection with thickness measurements, see Sec.12. Ship in Operation Renewal Criteria and sub item 12.1.4 Renewal Criteria of Local Structure for General Corrosion. The below is for guidance.

C.2.1 Minimum thickness for renewal

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

\[ t_{\text{as-built}} - t_{\text{corr}} - t_{\text{own}} \]

where:

- \( t_{\text{as-built}} \) = as built thickness of the member, in mm
- \( t_{\text{corr}} \) = corrosion addition, in mm, defined in Sec. 6.3.2 \( t_{\text{corr}} = t_{\text{was}} + t_{\text{corr-2.5}} \)
- \( t_{\text{own}} \) = owner/builder specified additional wastage allowance, if applicable, in mm
- \( t_{\text{was}} \) = corrosion addition, in mm, defined in Sec.12. Ship in Operation Renewal Criteria, and also Sec.12.1.4 Renewal Criteria of Local Structure for General Corrosion
- \( t_{\text{corr-2.5}} \) = 0.5 mm, wastage allowance in reserve for corrosion occurring in the two and a half years between Intermediate and Special surveys

See also the table and examples for most common corrosion additions in Sec.6.3.2.1, Table 6.3.1 and Figure 6.3.1

C.2.2 Minimum thickness for annual inspection
When the measured thickness at Intermediate Survey (IS) or Renewal Class Hull (RCH) is less than \( t_{\text{annual}} \) then Annual Survey (AS) is required

\[ t_{\text{annual}} = \text{allowable thickness at annual survey, in mm,} \]

\[ t_{\text{as-built}} - t_{\text{was}} - t_{\text{own}} \]

or simply

\[ t_{\text{annual}} = t_{\text{ren}} + t_{\text{corr-2.5}} \]

Assessment of overall hull girder wastage is to be checked according to Sec.12.1.2.3

C.3 CSR-Bulk
In general see Rules for Ships Pt.8 Ch.2 Common Structural Rules for Bulk Carriers with Length 90 metres and above. For minimum thickness in connection with thickness measurements see Chapter 13 Ship in Operation, Renewal Criteria.
CHANGES – HISTORIC

Note that historic changes older than the editions shown below (if any), have not been included.

January 2013 edition

Main Changes

— [3.4.1.4]: Min thickness requirements for side frames on Container vessels added in Table 3-2.