



Allowable thickness diminution for hull structure

DECEMBER 2014

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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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CHANGES – CURRENT

General

This document supersedes Classification Note No. 72.1, July 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.

Det Norske Veritas AS, company registration number 945 748 931, has on 27th November 2013 changed its name to DNV GL AS. For further information, see www.dnvgl.com. Any reference in this document to “Det Norske Veritas AS” or “DNV” shall therefore also be a reference to “DNV GL AS”.

Main changes

- **General**

- Editorial changes have been made.
- References have been updated.

- **Sec.1 General**

- [1.1] Updated with respect to principles for the document.

- **Sec.4 Allowable material diminution for general corrosion, class 100A5**

- This section is new. Included minimum thickness for vessels with class notation **100A5**.

- **Sec.5 High speed craft**

- This section is new. Included minimum thickness for high speed craft.
- The following sections have been renumbered.

- **Sec.6 Pitting, groove and edge corrosion**

- Introduced limitations w.r.t extent for local corrosion.

Editorial corrections

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

Contents

CHANGES – CURRENT	3
1 General	5
1.1 Introduction.....	5
1.2 Applicability	5
1.3 Definitions.....	5
1.3.1 Definitions.....	5
1.3.2 Terminology	5
2 Categories of corrosion	7
3 Allowable material diminution for general corrosion, class 1A1.....	7
3.1 General.....	7
3.2 Assumptions	7
3.3 Vessels with length, $L < 100$ m.....	7
3.4 Vessels with length, $L \geq 100$ m.....	7
3.4.1 Structure within 0.4 L amidships	7
3.4.2 Structure outside 0.4 L amidship	12
3.5 Refined minimum thickness calculations	13
3.6 Repair.....	13
4 Allowable material diminution for general corrosion, class 100A5.....	14
4.1 Corrosion and wear tolerances.....	14
4.1.1 Longitudinal strength	14
4.1.2 General corrosion for local strength.....	14
4.1.3 Hatch covers.....	14
4.1.4 Anchor equipment.....	14
5 High speed craft.....	14
5.1 Longitudinal strength.....	14
5.2 Local strength.....	15
5.3 Anchor chain cables.....	15
6 Pitting, groove and edge corrosion	15
6.1 Pitting.....	15
6.1.1 Assumptions.....	15
6.1.2 Minimum acceptable remaining thickness without repair	15
6.1.3 Average remaining thickness for pitted areas	15
6.1.4 Repair	15
6.2 Groove and edge corrosion	16
6.2.1 General	16
6.2.2 Assumptions.....	16
6.2.3 Groove corrosion of internal structures.....	17
6.2.4 Corroded welded seams in shell plating.....	17
6.2.5 Edge corrosion	17
6.2.6 Repair	18
7 References	19
App. A Guidelines for the survey of voyage repairs	20
App. B Calculation of hull girder ultimate capacity.....	21
App. C Common structural rules vessels	22
CHANGES – HISTORIC	23

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.

The principle in this document is that general corrosion allowances will follow DNV and GL rules. This is due to differences in the existing rules where GL rules are based on a net thickness approach where the maximum general corrosion margin in service (t_k) is defined in the approval stage. DNV rules do not describe the maximum corrosion allowance in service and provided the longitudinal stress level and buckling capacity is acceptable, reductions beyond the new building corrosion allowance (t_k) may be accepted.

However local corrosion criterias such as pitting, grooving and edge corrosion applies to both DNV and GL ships.

1.2 Applicability

The Class Note applies in general to ships of normal design built of steel.

For **1A1** vessels see Sec. 1, 2, 3, 5, 6, 7 and Appendix A, B, C.

For **100A5** vessels see Sec. 1, 2, 4, 5, 6, and 7

This Class Note does not apply to vessels with class notation **CSR** for which the rules have specific requirements to ships in service. See App.C for information of **CSR** vessels.

1.3 Definitions

1.3.1 Definitions

L	rule length in m, see DNV rules Pt.3 Ch.1 Sec.1 or GL rules Pt.1 Ch.1 Sec.1 A.3.1.1
t_{orig}	original "as built" thickness in mm
t_{min}	minimum thickness in mm including a margin for further corrosion until next hull survey.
TM	thickness measurements
σ_{ult}	Panel ultimate capacity
σ_y	Yield stress
PULS	"Panel Ultimate Limit Strength" 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.

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.

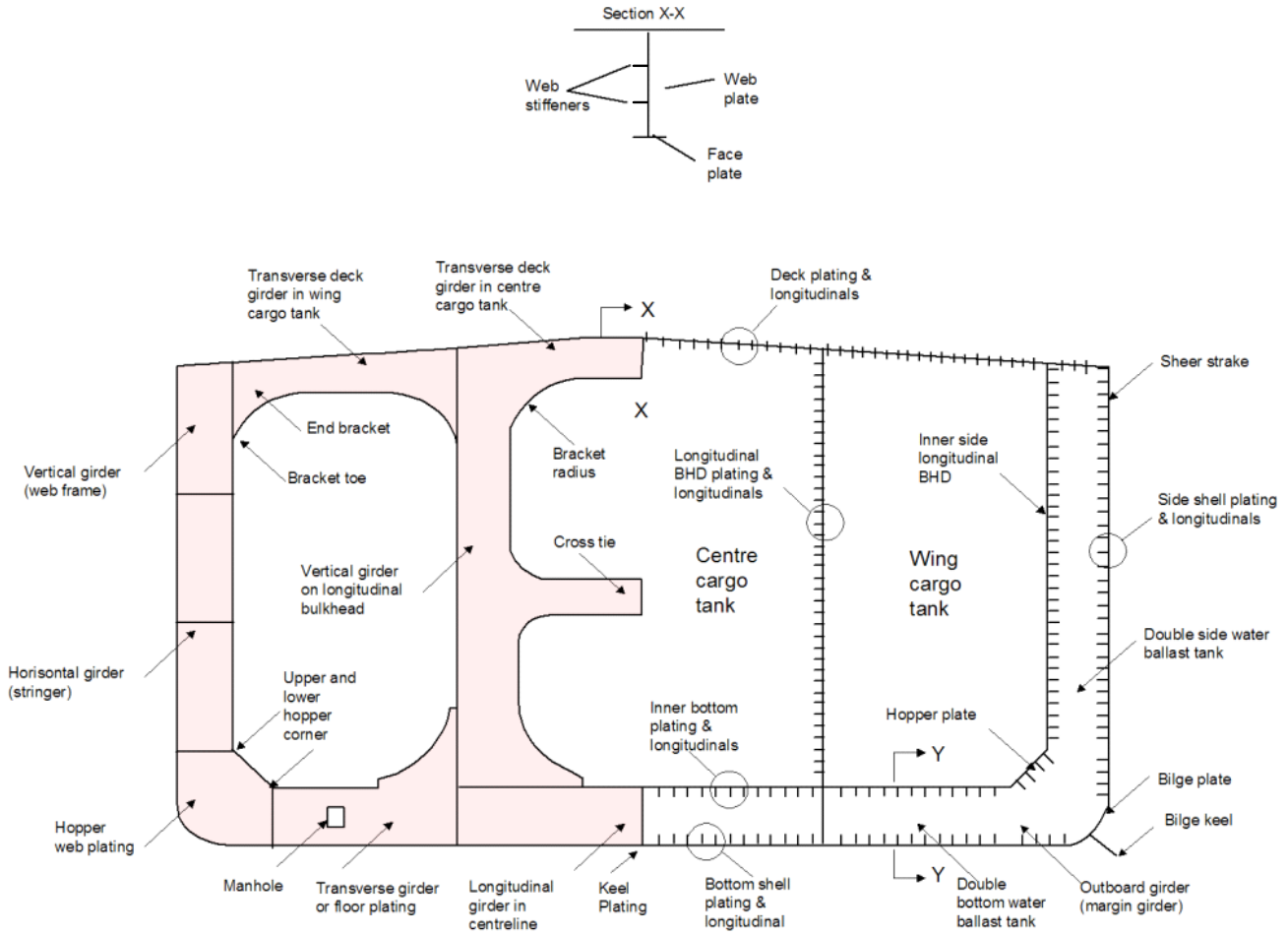


Figure 1-1
Typical double hull tanker

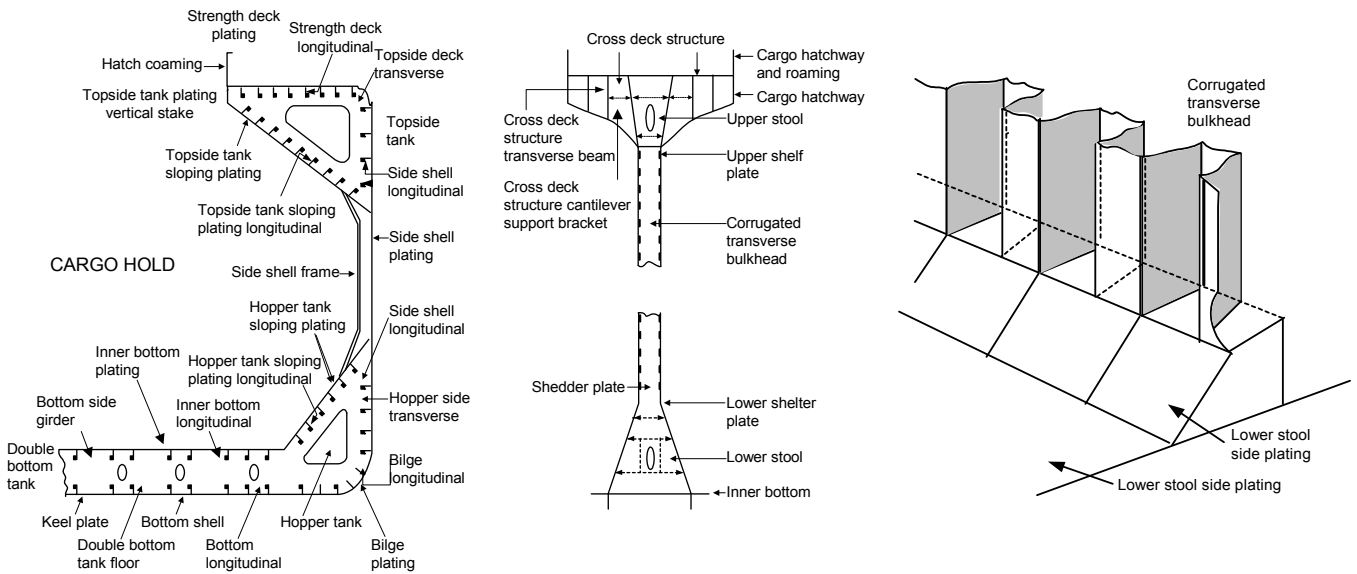


Figure 1-2
Typical bulk carrier

2 Categories of corrosion

Corrosion may be divided into the following categories:

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 Sec. [3], [4] or [5] as applicable. 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 [6.1]. 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 [6.2]. 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, class 1A1

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 GL.

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:

$$\begin{array}{ll} \text{For deck} & t_{min} > 0.9 (5.5 + 0.02 \cdot L) \\ \text{and side/bottom} & t_{min} > 0.9 (5.0 + 0.04 \cdot L). \end{array}$$

For vessels with transverse framing in the bottom, inner bottom or upper deck, more thorough calculations may be required. The methods in [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 [3.5].

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: $t_{min} = k t_{orig}$

t_{orig} = original 'as built' thickness
(Documented owner's addition will be subtracted)

k = diminution coefficient from [Table 3-2](#) or [Table 3-3](#).

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, η , of the following shall be used, depending on position of each panel and types of stiffeners used, see [Table 3-1](#).

<i>Longitudinally stiffened ships</i>	<i>Deck area panels within 0.15 D (including lower side and hopper area)</i>	<i>Bottom area panels within 0.15 D (except side and hopper area)</i>
L or T profile longitudinals	1.0	0.85
Flatbar or HP bulb longitudinals	1.1	0.94
<i>Transversely stiffened Ships</i>	<i>Deck area panels within 0.15 D (including lower side and hopper area)</i>	<i>Bottom area panels within 0.15 D (except side and hopper area)</i>
L profile, T profile, Flatbar or HP bulb stiffeners	1.0	0.85

In cases where the acceptance criteria in [\[3.4\]](#) 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 (See [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. See [Figure 3-1](#).

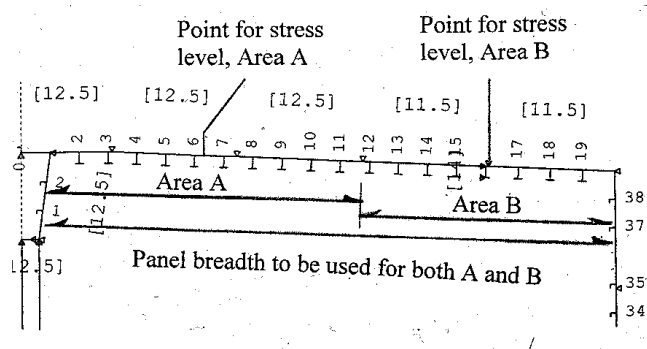
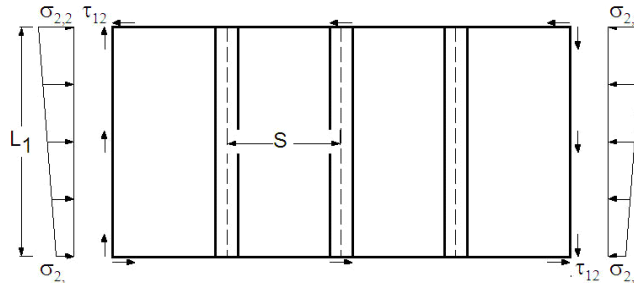


Figure 3-1
Consideration to different scantlings in calculation modelling

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:



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:

σ_{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.

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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.

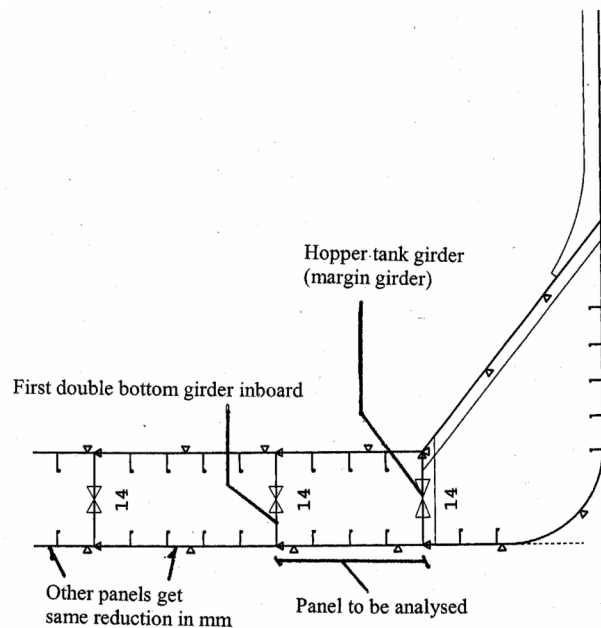


Figure 3-2
Procedure of critical ship types

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 3-3 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.

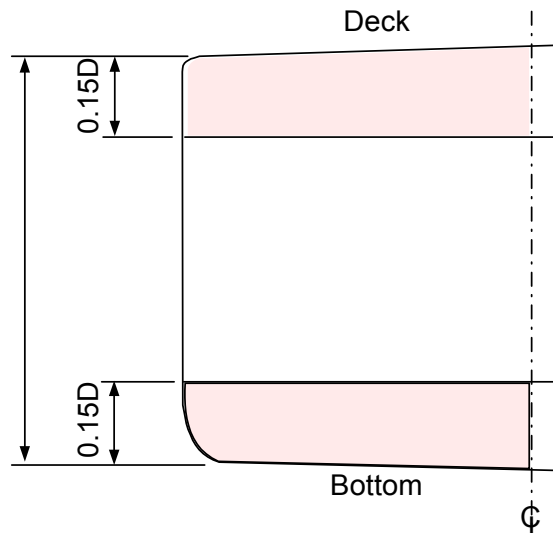


Figure 3-3
Structural elements contributing to longitudinal strength

Table 3-2 Longitudinal strength members		
<i>Structural component</i>	<i>Diminution coefficients "k"</i>	<i>Buckling control</i>
Strength members within 0.15 D from deck and bottom		
Plating	0.80	Buckling control according to 3.4.1.2
Stiffeners	0.75	Buckling control according to 3.4.1.2
Girders and stringers (1)	0.80	Buckling control according to 3.4.1.2
Side and longitudinal bulkhead between 0.15 D and 0.85 D from bottom		
Plating (2)	L < 150 m	0.80
	L > 150 m	0.80
Stiffeners	0.75	
Other longitudinal structure between 0.15 D and 0.85 D from bottom		
Plating	0.80	
Stiffeners	0.75	
Girders and stringers	0.80	
Notes:		
1) Bottom girders:		
— For single side skin bulk carriers with length $L_{pp} > 150$ m carrying cargo with density of 1.78 t/m^3 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 3-3 "Transverse bulkheads".		

Table 3-3 Transverse strength members			
Structural component		Diminution coefficients "k"	
Deck plating between hatches	Plate	0.80 ¹⁾	
	Stiffener	0.75	
Transverse bulkhead ²⁾	Plain bulkhead	0.75 ⁴⁾	
	Corrugated bulkheads	Flange	0.80
		Web	
Frames/Stiffeners	Web	0.75	
	Flange	0.75	
Web frames/ Floors ³⁾ / Girders and Stringers	Web	0.80	
	Flange	0.75	
<i>Side Frames in way of wing tank for Container Ships</i>			
Upper part - the web frame plating above first stringer from second deck	Plating	0.7	
Lower part - the web frame plating below first stringer from second deck	Plating	0.8	
Cross ties		0.85	
Hatch covers/ Coamings	Plate	0.80	
	Stiffener	0.75	
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/m ³ 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/m ³ 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 [3.4.1].

3.4.2.2 Longitudinal strength elements

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

Deck and bottom plating within 0.15 D:

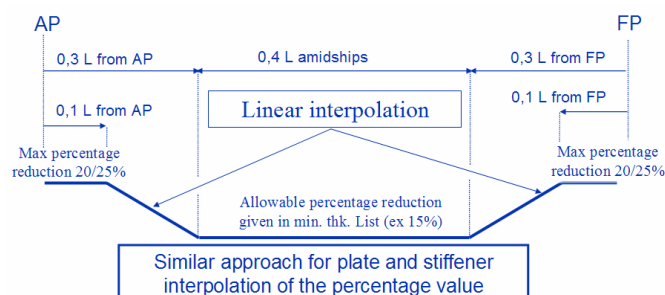
Minimum thickness 0.1 L from perpendiculars is:

$$t_{min} = k t_{orig}$$

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 [3.4.1].

Side and bulkhead longitudinals and girders:

The minimum thickness is to be based on the procedure given in [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 [3.3] and [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 3-4 Maximum allowable usage factor		
	<i>Sagging condition</i>	<i>Hogging condition</i>
General	0.90	
Double bottom within cargo area		0.85
Double bottom transition zone between cargo area and engine room (aft), when longitudinal continuity is considered		0.90

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 [App.B](#).

3.5.3

DNV GL 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 GL, 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 DNV 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 [REC no.47](#) Shipbuilding and Repair Quality Standard, Part B, and [App.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 Allowable material diminution for general corrosion, class 100A5

4.1 Corrosion and wear tolerances

Where thickness measurements according to the Rules for Ships (requirements for maintaining class) result in corrosion and wear values exceeding those stated in the following, the respective hull structural elements will have to be renewed.

DNV GL reserves the right where applicable to modify the indicated values according to [4.1.2] and [5.2] referring to the maximum permissible large-surface corrosion allowances.

Where reduced material thickness was admitted for the new building (effective system of corrosion prevention), the permissible corrosion allowances are to be based on the unreduced rule thickness.

4.1.1 Longitudinal strength

Maximum permissible reduction of midship section modulus: 10%.

4.1.2 General corrosion for local strength

t_k : maximum permissible large-surface reduction of plate thickness and web thickness of profiles:

$$t_k = 1.5 \text{ mm for } t \leq 11.5 \text{ mm}$$

$$t_k = 0.09 t + 0.45 \text{ mm, max } 3.0 \text{ mm for } t > 11.5 \text{ mm}$$

t : plate and/or web thickness in [mm], as stipulated in GL Construction Rules

In ballast tanks in way of 1.5 m below the weather deck, if the weather deck is the tank deck: $t_k = 2.5 \text{ mm}$

In cargo oil tanks in way of 1.5 m below the weather deck, if the weather deck is the tank deck, and for horizontal structural elements in cargo oil and fuel tanks: 2.0 mm

In dry cells, such as fore-to-aft passageways of container ships and comparable spaces:

$$t_k = 1.0 \text{ mm for } t \leq 11.5 \text{ mm}$$

$$t_k = 0.09 t, \text{ max } 2.5 \text{ mm for } t > 11.5 \text{ mm}$$

For hatch covers of dry cargo holds: $t_k = 1.0 \text{ mm}$

Maximum permissible surface reduction of the side shell in way of the ice belt: 2.0 mm

4.1.3 Hatch covers

For single skin hatch covers and for the plating of double skin hatch covers, steel renewal is required where the gauged thickness is less than $t_{\text{net}} + 0.5 \text{ mm}$. Where the gauged thickness is within the range $t_{\text{net}} + 0.5 \text{ mm}$ and $t_{\text{net}} + 1.0 \text{ mm}$, coating (applied in accordance with the coating manufacturer's requirements) or annual gauging may be adopted as an alternative to steel renewal. Coating is to be maintained in GOOD condition, as defined in UR Z10.2.1.2.

For the internal structure of double skin hatch covers, thickness gauging is required when hatch cover top or bottom plating renewal is to be carried out or when this is deemed necessary, at the discretion of the surveyor, on the basis of the plating corrosion or deformation condition. In these cases, steel renewal for the internal structures is required where the gauged thickness is less than t_{net} .

For corrosion addition $t_k = 1.0 \text{ mm}$ the thickness for steel renewal is t_{net} , and the thickness for coating or annual gauging is when gauged thickness is between t_{net} and $t_{\text{net}} + 0.5 \text{ mm}$.

4.1.4 Anchor equipment

Maximum permissible reduction of the mean diameter of chain links: 12%

Maximum permissible reduction in weight of anchors: 10%

5 High speed craft

For high speed crafts with class notations **HSC-PASSENGER A**, **HSC PASSENGER B**, **HSC-CARGO** or **HSDE** as defined in GL Rules for High Speed Craft (I-3-1), and HSLC vessels as defined in DNV rules vessels (**ACV**, **HYD**, **SES**, **CAT**, **MONO** and **WP**) following corrosion and wear tolerances apply for steel and aluminium alloys.

5.1 Longitudinal strength

Maximum permissible reduction of midship section modulus: 10%

5.2 Local strength

Where applicable, the maximum permissible large-surface reduction t_k of plate thickness and web thickness of profiles is:

$$t_k = 0.5 \text{ mm for } t \leq 10.5 \text{ mm}$$

$$t_k = 0.03 t + 0.2 \text{ mm, max } 1.0 \text{ mm for } t > 10.5 \text{ mm}$$

For tank bottoms: $t_k = 1.0 \text{ mm}$

Maximum permissible locally limited reduction of thickness: $0.1 t$

Corrosion reduction t_k can be assumed as 0.0 mm for steel and aluminium alloys if the measures for corrosion prevention at the construction stage are fully applied and maintained according to a document available on board and specifying all these arrangements including maintenance procedures.

5.3 Anchor chain cables

For anchor chain cable the maximum permissible reduction of the mean diameter of chain link is 10%.

6 Pitting, groove and edge corrosion

6.1 Pitting

6.1.1 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.

6.1.2 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:
 $t_{min} = 0.6 t_{orig}$
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, 4 or 5.
- c) For intermediate pitting intensities, acceptance of average remaining thickness may be decided based on linear interpolation between a) and b) above.

6.1.3 Average remaining thickness for pitted areas

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

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

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 6-1](#).

6.1.4 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.

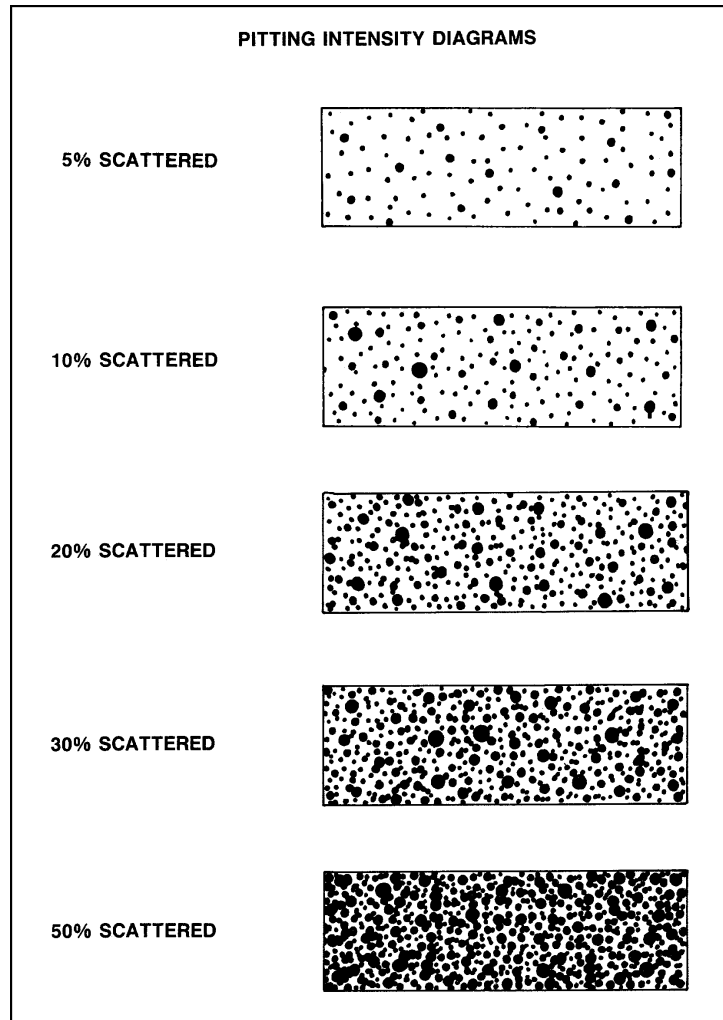


Figure 6-1
Pitting

6.2 Groove and edge corrosion

6.2.1 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.

6.2.2 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
- “accumulated transverse grooves” means the total length of all grooves at each structural member in deck, bottom, longitudinal bulkhead or side plating within the cargo area of the ship
- Limits are given in below paragraphs.

6.2.3 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:

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

$$t_{min} = 0.75 \cdot t_{orig} \text{ for L-profiles,}$$

but not less than 6.0 mm.

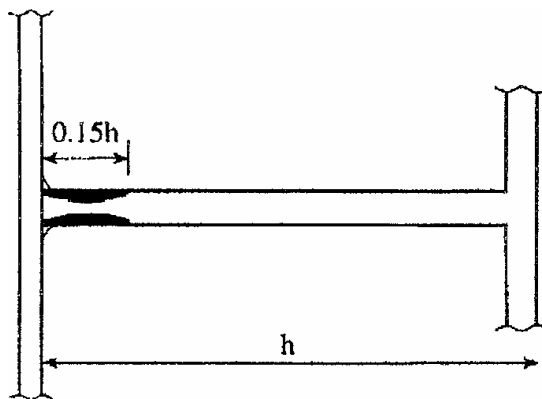


Figure 6-2
Groove corrosion

- accumulated transverse grooves in deck, bottom, longitudinal bulkhead or side plating within the cargo area is normally limited to 20% of the breadth respective height of the ship. Although for ships with large deck openings, such as container ships, the accumulated length of transverse grooves in the passageway is normally limited to 10% of the breadth.

6.2.4 Corroded welded seams in shell plating

Minimum thickness at the weld or plate:

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

- accumulated transverse grooves in bottom and side plating within the cargo area is normally limited to 20% of the breadth respective height of the ship.

6.2.5 Edge corrosion

6.2.5.1 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 $1/3 t_{orig}$ and well rounded.
- c) The thickness of the remaining part of the longitudinal is above the minimum allowable according to 3.

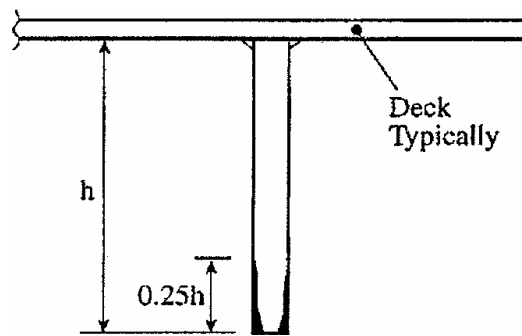


Figure 6-3
Extent of free edge corrosion

6.2.5.2 Manholes, lightening holes, etc.

Plate edges at openings for manholes, lightening holes, etc. may be reduced below the minimum thickness as described below:

- a) The maximum extent of the reduced plate thickness, below the minimum given in Sec.4, Sec.5 or Sec.6 as applicable, from the opening edge is not to be more than 20% of the smallest dimension of the opening but should not exceed 100 mm, see Figure 6-4.
- 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.

6.2.6 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 may be reinforced by:
 - i) compensation reinforcement ring 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.

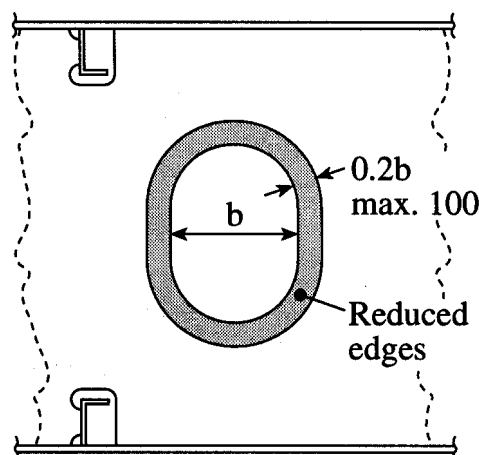


Figure 6-4
Extent of corrosion in way of manholes etc.

7 References

- a) Tanker Structure Co-operative Forum:
 - *Guidance Manual for Tanker Structures*
 - *Guidelines for the Inspection and Maintenance of Double Hull Tanker Structures.*
- b) IACS Publications:
 - *Bulk Carriers, Guidelines for Surveys, Assessment and Repair of Hull Structure*
 - *Shipbuilding and Repair Quality Standard, Part B Repair Quality Standard for Existing Ships*
 - *General Cargo ships, Guidelines for Surveys, Assessment and Repair of Hull Structure.*
- c) DNV Guidelines:
 - No. 20, *Corrosion Protection of Ships*
 - No. 10, *Guide for Ultrasonic Thickness Measurement of Ships Classed with Det Norske Veritas.*
- d) DNV Classification Notes:
 - No. 31.1 *Strength Analysis of Hull Structures in Bulk Carriers*
 - No. 31.3 *Strength Analysis of Hull Structures in Tankers.*
- e) **GL Rules and Guidelines, I - Ship Technology:**
 - **Part 0 *Classification and Surveys (I-0)***
 - **Part 3 - *Special Craft, Chapter 1 High Speed Craft (I-3-1)*.**

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 modulus.

Ultimate hull girder hogging bending moment for a section in a pure vertical bending modulus.

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:

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

- 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.)
- ε_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)
- σ = 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.

Appendix C

Common structural rules vessels

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 Sec.12 [1.4] Renewal Criteria of Local Structure for General Corrosion.* The below is for guidance.

C.2.1 Minimum thickness for renewal

t_{ren} = Renewal thickness; Minimum allowable thickness, in mm, below which renewal of structural members is to be carried out $t_{ren} = t_{as-built} - t_{corr} - t_{own}$

where:

$t_{as-built}$ = as built thickness of the member, in mm

t_{corr} = corrosion addition, in mm, defined in Sec. 6 [3.2] $t_{corr} = t_{was} + t_{corr-2.5}$

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

t_{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

$t_{corr-2.5}$ = 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_{annual} then Annual Survey (AS) is required

t_{annual} = allowable thickness at annual survey, in mm, $t_{annual} = t_{as-built} - t_{was} - t_{own}$

or simply

$t_{annual} = t_{ren} + t_{corr-2.5}$

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 have not been included. Older historic changes (if any) may be retrieved through <http://www.dnv.com>. Note that historic changes older than the editions shown below (if any), have not been included.

July 2013 edition

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 App.A.
- **App.B**
 - Appendix A has been changed to Appendix App.B.
- **App.C**
 - This is a new appendix.

January 2013 edition

Main Changes

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