

RULES FOR THE CLASSIFICATION OF **STEEL SHIPS**

NR467 - JULY 2022

PART B
HULL AND STABILITY



STEEL SHIPS



**BUREAU
VERITAS**

BUREAU VERITAS RULES FOR THE CLASSIFICATION OF STEEL SHIPS

NR467 - JULY 2022

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These Rules are provided within the scope of the Bureau Veritas Marine & Offshore General Conditions, enclosed at the end of Part A of NR467 “Rules for the Classification of Steel Ships”. The current version of these General Conditions is available on the Bureau Veritas Marine & Offshore website.

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NR467 A DT R19 JULY 2022

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NR467

RULES FOR THE CLASSIFICATION OF STEEL SHIPS

Part B **Hull and Stability**

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Part B

Hull and Stability

CHAPTER 1

GENERAL

Section 1	Application
Section 2	Rules Principles
Section 3	Symbols and Definitions
Section 4	Documentation to be Submitted
Section 5	Loading Manual and Loading Instruments
Appendix 1	Equivalences between Current Revision and July 2021 Edition of the Rules for the Classification of Steel Ships

Section 1 Application

1 Scope of application

1.1 General

1.1.1 These Rules contain the requirements for the determination of the minimum hull scantlings, applicable to all types of seagoing monohull displacement ships of conventional shape, speed and proportions, made in welded steel construction. Other types of ships will be considered by the Society on a case by case basis.

These requirements are to be integrated with those specified in Part D and Part E, for any individual ship type, and in Part F, as applicable, depending on the additional class notations assigned to the ships.

1.1.2 Ships covered by NR600 "Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m" are not covered in these Rules.

Note 1: NR600 is applicable for:

- cargo ships with length less than 65 m, and
- non cargo ships with length less than 90 m.

The wording "cargo ships" and "non-cargo ships" used in NR600 means:

- Cargo ships: ships liable to carry cargoes and having a deadweight greater than 30% of the total displacement. As a general rule, these ships are fitted with cargo holds, tanks and lateral ballast tanks (i.e bulk or ore carriers, oil or chemical tanker, container ship, general cargo ship) and the value of the block coefficient is greater than 0,75
- Non-cargo ships: type of ships other than cargo ships defined here above or ships having a deadweight greater than 30% of the total displacement and not fitted with lateral ballast tanks used in non loaded navigation condition.

Note 2: NR600 is not applicable for liquefied gas carriers and any cargo ships with alternate light and heavy cargo loading conditions.

1.1.3 These Rules apply to welded hull structures made of steel having characteristics complying with requirements in Ch 4, Sec 1. These Rules applies also to welded steel ships in which parts of the hull, such as superstructures or small hatch covers, are built in material other than steel, complying with requirements in Ch 4, Sec 1.

Ships whose hull materials are different than those given in the first paragraph are to be individually considered by the Society, on the basis of the principles and criteria adopted in these Rules.

1.1.4 The strength of ships constructed and maintained according to the Rules is sufficient for the draught corresponding to the assigned freeboard. The scantling draught considered when applying the Rules is to be not less than that corresponding to the assigned freeboard.

1.1.5 Where scantlings are obtained from direct calculation procedures which are different from those specified in Part B, Chapter 7, adequate supporting documentation is to be submitted to the Society, as detailed in Ch 1, Sec 4.

1.2 Limits of application to lifting appliances

1.2.1 The fixed parts of lifting appliances, considered as an integral part of the hull, are the structures permanently connected by welding to the ship's hull (for instance crane pedestals, masts, king posts, derrick heel seatings, etc., excluding cranes, derrick booms, ropes, rigging accessories, and, generally, any dismantable parts). The shrouds of masts embedded in the ship's structure are considered as fixed parts.

1.2.2 The fixed parts of lifting appliances and their connections to the ship's structure are covered by the Rules, even when the certification (especially the issuance of the Cargo Gear Register) of lifting appliances is not required.

1.2.3 The foundations of lifting appliances intended to be used at sea are to comply with the requirements of Part E, Chapter 8.

2 Rule application

2.1 Ship parts

2.1.1 General

For the purpose of application of these Rules, the ship is considered as divided into the following three parts:

- fore part
- central part
- aft part.

2.1.2 Fore part

The fore part is the part of the ship located forward of the collision bulkhead, i.e.:

- the fore peak structures
- the stem.

2.1.3 Central part

The central part includes the structures located between the collision bulkhead (included) and the after peak bulkhead.

Where the flat bottom forward area or the bow flare area extend aft of the collision bulkhead, they are considered as belonging to the fore part.

2.1.4 Aft part

The aft part includes the structures located aft of the aft peak bulkhead.

2.2 Rules applicable to various ship parts

2.2.1 The various Chapters and Sections of Part B are to be applied for the scantling and arrangement of ship parts according to Tab 1.

Table 1 : Part B Chapters and Sections applicable for the scantling of ship parts

Applicable Chapters and Sections		
All ship parts	Specific ship parts	
Part B, Chapter 1 Part B, Chapter 2 Part B, Chapter 3 Part B, Chapter 4 Part B, Chapter 5 Part B, Chapter 6		
Part B, Chapter 7	Central part	Part B, Chapter 7
Part B, Chapter 8 Part B, Chapter 9 Part B, Chapter 10		
Part B, Chapter 11 (1)(2)	Fore part	Ch 11, Sec 1
	Aft part	Ch 11, Sec 3
Part B, Chapter 13		
(1) See also [2.3].		
(2) excluding Ch 11, Sec 1 and Ch 11, Sec 3		

2.3 Rules applicable to other ship items

2.3.1 The various Chapters and Sections of Part B are to be applied for the scantling and arrangement of other ship items according to Tab 2.

Table 2 : Part B Chapters and Sections applicable for the scantling of other items

Item	Applicable Chapters and Sections	Item	Applicable Chapters and Sections
Machinery space	Ch 11, Sec 2	Rudders	Ch 12, Sec 1
Tanks subject to sloshing	Ch 11, Sec 4	Other hull outfitting	Ch 12, Sec 2 Ch 12, Sec 3 Ch 12, Sec 4
Superstructures and deckhouses	Ch 11, Sec 5		
Bow doors and inner doors	Ch 11, Sec 6		
Side shell doors and stern doors	Ch 11, Sec 7		
Watertight and weathertight doors	Ch 11, Sec 8		
Large hatch covers	Ch 11, Sec 9		
Small hatches	Ch 11, Sec 10		
Movable decks and inner ramp External ramps	Ch 11, Sec 11		
Arrangement of hull and superstructures openings	Ch 11, Sec 12		
Helicopter decks	Ch 11, Sec 13		

Section 2 Rules Principles

1 Design basis

1.1 General

1.1.1 Ships are to be designed to withstand, in intact condition, the environmental conditions as defined in [1.4] anticipated during the design life, for the appropriate loading conditions. Structural strength is to be determined against buckling and yielding. Ultimate strength calculations must include ultimate hull girder capacity and ultimate strength of plates and stiffeners.

1.1.2 Ships are to be designed to have sufficient reserve strength to withstand loads in damaged conditions, e.g. flooded scenarios.

1.1.3 Finite element analysis

Scantlings of structural members within the cargo hold region of ships having a length L of 150 m or above are to be assessed according to the requirements specified in Part B, Chapter 8.

1.1.4 Fatigue life

Ships having a length L of 150 m or above are to be assessed according to the design fatigue life for structural details specified in Part B, Chapter 10.

1.2 Hull form limit

1.2.1 Loads applying to the ship hull, as described in these Rules, are based on hull forms within the following limits:

- $L < 500$ m
- $C_B > 0,6$
- $L/B > 5$
- $B/D < 2,5$

with the Rule length L , the block coefficient C_B , the moulded breadth B and the moulded depth D defined in Ch 1, Sec 3. Specific consideration will be given by the Society to ships with different hull forms.

1.3 Design life

1.3.1 Rule loads and scantling criteria are based on a target design life of 25 years. The design life is the period during which the ship is assumed to be exposed to operating conditions.

1.4 Environmental conditions

1.4.1 Wave environment

Unless otherwise specified, the rule requirements are based on north atlantic wave environment for the strength and fatigue assessments.

1.4.2 Wind and current

The effects of current are not considered with regard to the strength of the structure.

The effects of wind are only considered for defining the minimum external pressure acting on the hull, superstructures and deckhouses.

1.4.3 Design temperatures

The structural assessment of hull strength members is assumed to be valid for the following design temperatures:

- lowest mean daily average temperature in air: -10°C
- lowest mean daily average temperature in seawater: 0°C .

Ships intended to operate in areas with lower mean daily average temperature, e.g. regular service during winter seasons to Arctic or Antarctic waters, are subject to specific requirements.

In the above, the following definitions apply:

daily average : Average during one day and one night

mean : Statistical mean over an observation period (at least 20 years)

lowest : The lowest value during one year.

For seasonally restricted service, the lowest value within the period of operation applies.

1.5 Operating conditions

1.5.1 The Rules specify the minimum loading conditions that are to be assessed for compliance.

Specification of loading conditions other than those required by the Rules is the responsibility of the Owner. These other loading conditions are to be documented and assessed for compliance.

1.6 Operating draughts

1.6.1 The design operating draughts are to be specified by the builder/designer, subject to acceptance by the Owner, and are to be used to derive the appropriate structural scantlings.

All operational loading conditions in the loading manual are to comply with the specified design operating draughts. The following design operating draughts are, as a minimum, to be considered:

- scantling draught for the assessment of structure
- minimum ballast draught at midship for the assessment of structure
- minimum forward draught, T_F , for the assessment of bottom structure forward subjected to slamming loads, as defined in Ch 5, Sec 5, [4.2.1].

1.7 Maximum service speed

1.7.1 The maximum service speed is to be specified. Although the hull structure assessment accounts for the service speed, this does not relieve the responsibilities of the Owner and personnel to properly handle the ship.

1.8 Owner's extras

1.8.1 The Owner's specification above the general classification or statutory requirements may affect the structural design. Owner's extras may include requirements for:

- vibration analysis
- maximum percentage of high strength steel
- additional scantlings above those required by the Rules
- additional design margin on the loads specified by the Rules, etc
- improved fatigue resistance, in the form of a specified increase in design fatigue life or equivalent.

Owner's extras are not specified in these Rules. Owner's extras, if any, that may affect the structural design are to be clearly specified in the design documentation.

2 Design principles

2.1 Overall principles

2.1.1 These Rules are based on the following overall principles:

- the safety of the structure can be assessed by addressing the potential structural failure mode(s) when the ship is subject to operational loads and environmental loads/conditions
- the structural requirements are based on consistent design load sets which cover the appropriate operating modes of ships complying with Ch 1, Sec 1, [1].

2.1.2 The ship structure is so designed that:

- it has a degree of redundancy. The ship structure should work in a hierarchical manner and, in principle, failure of structural elements lower down in the hierarchy does not result in immediate consequential failure of elements higher up in the hierarchy
- it has sufficient reserve strength to withstand the wave and internal loads in damaged conditions that are reasonably foreseeable, e.g. flooding scenarios
- the incidence of in-service cracking is minimised, particularly in locations which affect the structural integrity or containment integrity, affect the performance of structural or other systems, or are difficult to inspect and repair
- it has adequate structural redundancy to survive in the event that the structure is accidentally damaged by a minor impact leading to flooding of any compartment.

2.2 Loads

2.2.1 Design load scenarios

The structural assessment is based on the design load scenarios encountered by the ship, as defined in Ch 5, Sec 7 and reminded below:

N : Seagoing conditions with extrem sea loads

H	: Harbour and sheltered water conditions
T	: Tank testing operations
I	: Application of impact loads such as bottom slamming and bow impact encountered during seagoing operations
SL	: Application of sloshing loads encountered during seagoing operations
F	: Fatigue design load scenario
A	: Accidental scenarios with loads not occurring during normal operations
BWE	: Ballast water exchange scenario.

2.2.2 Load categories

The design load scenarios given in [2.2.1] may be associated to one of the following load categories:

- S when the associated load components result only from static effects
- S+D when the associated load components result from both static and dynamic effects.

2.3 Structural capacity assessment

2.3.1 General

The basic principle in structural design is to apply the defined design loads, identify plausible failure modes and use appropriate capacity models to obtain the required structural scantlings.

2.3.2 Capacity models for strength assessment

The capacity models for strength assessment are able to analyse the failure mode with regard to the required degree of accuracy. The capacity models are either in a prescriptive format or require the use of more advanced calculations such as finite element analysis methods.

The formulae used to determine stress, deformations and capacity are deemed appropriate for the selected capacity assessment method and the type and magnitude of the design load set.

2.3.3 Capacity models for fatigue assessment

The capacity models for fatigue assessment:

- provide rule requirements to assess structural details against fatigue failure
- are based on a linear cumulative damage summation (Palmgren-Miner rule) in combination with a design S-N curve, a reference stress range and an assumed long-term stress distribution curve, and
- are either in a prescriptive format or require the use of more advanced calculations, such as finite element analysis methods. These methods account for the combined effects of global and local dynamic loads.

2.3.4 Net scantling approach

The objective of the net scantling approach is to:

- provide a relationship between the thickness used for strength calculations during the newbuilding stage and the minimum thickness accepted during the operational phase
- enable the status of the structure with respect to corrosion to be clearly ascertained throughout the life of the ship.

The net scantling approach distinguishes between local corrosion and global corrosion:

- local corrosion is defined as uniform corrosion of local structural elements, such as a single plate or stiffener
- global corrosion is defined as the overall average corrosion of larger areas, such as primary supporting members and the hull girder.

Both the local corrosion and the global corrosion are used as a basis for the newbuilding review and are to be assessed during operation of the ship.

No credit is given in the assessment of structural capability for the presence of coatings or similar corrosion protection systems.

The application of the net thickness approach to assess the structural capacity is specified in Ch 4, Sec 2.

3 Rule design methods

3.1 General

3.1.1 Design methods

Scantling requirements are specified to cover the relevant failure modes, as necessary, for various structural parts.

The criteria for the assessment of scantlings are based on one of the following design methods:

- Working stress design (WSD) method, also known as the permissible or allowable stress method
- Partial safety factor (PSF) method, also known as load and resistance factor design (LRFD).

For both WSD and PSF, two design assessment conditions are given, as well as the corresponding acceptance criteria. These conditions are associated with the probability level of the combined loads, A and B.

a) Composition of the WSD method

- for condition A:

$$W_{\text{stat}} \leq \eta_1 R$$

- for condition B:

$$W_{\text{stat}} + W_{\text{dyn}} \leq \eta_2 R$$

where:

W_{stat} : Simultaneously occurring static loads (or load effects in terms of stresses)

W_{dyn} : Simultaneously occurring dynamic loads. The dynamic loads are typically a combination of local and global load components

R : Characteristic structural capacity (e.g. specified minimum yield stress or buckling capacity)

η_i : Permissible utilisation factor (resistance factor). The utilisation factor includes consideration of uncertainties in loads, structural capacity and the consequence of failure.

b) Composition of the PSF method

- for condition A:

$$\gamma_{\text{stat-1}} W_{\text{stat}} + \gamma_{\text{dyn-1}} W_{\text{dyn}} \leq \frac{R}{\gamma_R}$$

- for condition B:

$$\gamma_{\text{stat-2}} W_{\text{stat}} + \gamma_{\text{dyn-2}} W_{\text{dyn}} \leq \frac{R}{\gamma_R}$$

where:

$\gamma_{\text{stat-i}}$: Partial safety factor that accounts for the uncertainties related to static loads in condition A or B

$\gamma_{\text{dyn-i}}$: Partial safety factor that accounts for the uncertainties related to dynamic loads in condition A or B

γ_R : Partial safety factor that accounts for the uncertainties related to structural capacity.

The acceptance criteria for both the WSD method and the PSF method are calibrated for the various requirements such that consistent and acceptable safety levels for all combinations of static and dynamic load effects are derived.

3.2 Minimum requirements

3.2.1 The minimum requirements specify the minimum scantling requirements which are to be applied irrespective of all other requirements, hence thickness below the minimum is not allowed.

The minimum requirements are usually in one of the following forms:

- minimum thickness, which is independent of the specified minimum yield stress
- minimum stiffness and proportion, which are based on buckling failure modes.

3.3 Load-capacity based requirements**3.3.1 General**

In general, the working stress design (WSD) method is applied in the requirements, except for the hull girder ultimate strength criteria, where the partial safety factor (PSF) method is applied for its highly critical failure mode, in order to better account for uncertainties related to static loads, dynamic loads and capacity formulations.

The identified load scenarios are addressed by the Rules in terms of design loads, design format and acceptance criteria set.

Load-capacity based prescriptive requirements provide scantling requirements for all plating, local support members, most primary supporting members and the hull girder and cover all structural elements including deckhouses and foundations for deck equipment.

In general, these requirements explicitly control one particular failure mode and hence several requirements may be applied to assess one particular structural member.

3.3.2 Design loads for strength assessment

The structural assessment of the compartment boundaries, e.g. the bulkheads, is based on the loading condition deemed relevant for the type of ship and the operation the ship is intended for.

To provide consistency of approach, standardised rule values for parameters, such as GM and C_B , are applied to calculate the rule load values.

The design load scenarios for structural verification combine the applicable and simultaneously acting local and global load components. The relevant design load scenarios are given in Ch 5, Sec 7.

The simultaneously occurring dynamic loads are obtained by applying a dynamic load combination factor to the dynamic load values given in Part B, Chapter 5. The dynamic load combination factors for each dynamic load case are given in Ch 5, Sec 2.

Design load conditions for the hull girder ultimate strength are given in Ch 6, Sec 2.

3.3.3 Design loads for fatigue assessment

For the fatigue requirements given in Part B, Chapter 10, the load assessment is based on the expected load history and an average approach is applied. The expected load history for the design life is characterised by the 10^{-2} probability level of the dynamic load value, the load history for each structural member is represented by Weibull probability distributions of the corresponding stresses.

The considered wave induced loads include:

- hull girder loads (i.e. vertical and horizontal bending moments)
- dynamic wave pressures
- dynamic pressure from cargo, if any.

The load values are based on rule parameters corresponding to the loading conditions, e.g. GM , C_B and the applicable draughts amidships.

The simultaneously occurring dynamic loads are accounted for, combining the stresses due to the various dynamic load components. The stress combination procedure is given in Part B, Chapter 10.

3.3.4 Structural response analysis

The following approaches are used for the determination of the structural response to the applied design load combinations:

- a) beam theory is used for prescriptive requirements
- b) finite element analysis is used for:
 - standard mesh for cargo hold model
 - fine mesh for local models
 - very fine mesh for fatigue assessment.

3.4 Acceptance criteria

3.4.1 General

The acceptance criteria are categorised into four sets. The specific acceptance criteria sets applied in the rule requirements depend on the probability level of the characteristic combined load.

- a) The acceptance criteria set AC-1- is typically applied for the static design load scenarios (S) and for the sloshing design loads. The allowable stress for such loads is lower than for an extreme load to take into account effects of:
 - repeated yield
 - allowance for some dynamics
 - margins for some selected limited operational mistakes.
- b) the acceptance criteria set AC-2 is typically applied for the static + dynamic design load scenarios (S+D), where the considered loads are extreme loads with a low probability of occurrence.
- c) the acceptance criteria set AC-3 is typically applied for exceptional static conditions load scenarios (A: S and T: S), such as flooding or tank testing loads.
- d) the acceptance criteria set AC-4 is typically applied for impact design load scenarios (I), such as bottom slamming and bow impact loads.

3.4.2 Criteria

A general overview of the acceptance criteria is provided in Tab 1 and Tab 2 for the different design load scenarios covered by these Rules for the yield and buckling failure modes:

- for the yield criteria, the permissible stress is proportional to the specified minimum yield stress of the material
- for the buckling failure mode, the acceptance criteria are based on the control of stiffness and proportions as well as on the buckling utilisation factor.

3.5 Design verification

3.5.1 Design verification - Hull girder ultimate strength

The requirements for the ultimate strength of the hull girder are based on a partial safety factor (PSF) method. A safety factor is assigned to each of the basic variables, the still water bending moment, the wave bending moment and the ultimate capacity. The safety factors are determined using a structural reliability assessment approach, the long-term load history distribution of the wave bending moment is derived using ship motion analysis techniques suitable for determining extreme wave bending moments.

The purpose of the hull girder ultimate strength verification is to demonstrate that one of the most critical failure modes of the ship is controlled.

3.5.2 Design verification - Finite element analysis

The finite element analysis is used to verify the scantlings given by the load-capacity based prescriptive requirements to better consider the complex interactions between the ship's structural components, complex local structural geometry, change in thicknesses and member section properties as well as the complex load regime with sufficient accuracy.

A linear elastic three dimensional finite element analysis of the cargo region, if any, or of the full length model is carried out to assess and verify the structural response of the actual hull girder and primary supporting members and to provide the scantling requirements for the primary supporting members. The purpose of the finite element analysis is to verify that the stresses and buckling capability of the primary supporting members are within acceptable limits for the applied design loads.

3.5.3 Design verification - Fatigue assessment

The fatigue assessment is required to verify that the fatigue life of critical structural details is adequate. A simplified fatigue requirement is applied to details such as end connections of longitudinal stiffeners using stress concentration factors (SCF) to account the actual detail geometry. A fatigue assessment procedure using finite element analysis for determining the actual hot spot stress of the geometric detail is applied to selected details. In both cases, the fatigue assessment method is based on the Palmgren-Miner linear damage model.

3.5.4 Relationship between prescriptive scantling requirements and finite element analysis

The scantlings defined by the prescriptive requirements are not to be reduced by any form of alternative calculations such as finite element analysis, unless explicitly stated.

Table 1 : Acceptance criteria - Prescriptive requirements

Acceptance criteria	Plate panels and local supporting members(1)		Primary supporting members(1)		Hull girder members	
	Yield	Buckling	Yield	Buckling	Yield	Buckling
AC-1 AC-2 AC-3	Permissible stress: Ch 7, Sec 4 Ch 7, Sec 5	Control of stiffness and proportions: Ch 9, Sec 1	Permissible stress: Ch 7, Sec 6	Control of stiffness and proportions: Ch 9, Sec 1	Permissible stress: Ch 6, Sec 1	Allowable buckling utilisation factor: Ch 9, Sec 1
AC-4	Plastic criteria: Ch 11, Sec 1, [3] Ch 11, Sec 3, [6] Ch 11, Sec 4, [3]	Control of stiffness and proportions: Ch 9, Sec 1	Plastic criteria: Ch 11, Sec 1, [3] Ch 11, Sec 3, [6] Ch 11, Sec 4, [3]	Control of stiffness and proportions: Ch 9, Sec 1	N/A	N/A

(1) Refer to Part B, Chapter 11 for other structures and to Ch 11, Sec 5 for superstructures, deckhouses and hull outfitting.

Table 2 : Acceptance criteria - Finite Element Analysis

Acceptance criteria	Cargo hold analysis		Fine mesh analysis
	Yield	Buckling	Yield
AC-1 AC-2 AC-3	Permissible stress: refer to Ch 8, App 1, [5]	Allowable buckling utilisation factor: refer to Ch 9, Sec 1	Permissible stress: refer to Ch 8, App 2, [4] Screening criteria: refer to Ch 8, App 2, [1.2.3]

Section 3 Symbols and Definitions

1 Symbols and units

1.1

1.1.1 Ship's dimensions and main data

Unless otherwise specified, symbols regarding ship's main data and their units used in these Rules are those defined in Tab 1.

1.1.2 Materials

Unless otherwise specified, symbols regarding materials and their units used in these Rules are those defined in Tab 2.

Table 1 : Ship's dimensions and main data

Symbol	Meaning				Unit	Reference
B	Moulded breadth of the ship				m	[2.1.4]
C_B	Block coefficient at draught T_{SC}				–	[2.1.9]
C_{B-BAL}	Block coefficient at draught T_{BAL}				–	[2.1.9]
C_W	Waterplane coefficient at draught T_{SC}				–	[2.1.10]
C_{W-BAL}	Waterplane coefficient at draught T_{BAL}				–	[2.1.10]
D	Moulded depth of the ship				m	[2.1.5]
Δ	Moulded displacement at draught T_{SC}				t	[2.1.7]
L	Rule length				m	[2.1.1]
	$L_0 = \min(L; 120)$	$L_1 = \min(L; 200)$	$L_2 = \min(L; 250)$	$L_3 = \min(L; 300)$		
L_{LL}	Load line length				m	[2.1.2]
L_S	Subdivision length				m	[2.1.3]
T	Moulded draught				m	[2.1.6]
T_{BAL}	Minimum draught amidships among ballast conditions				m	[2.1.6]
T_{BAL-H}	Minimum draught amidships among heavy ballast conditions				m	[2.1.6]
T_{LC}	Draught amidships at the considered loading condition				m	[2.1.6]
T_{SC}	Scantling draught				m	[2.1.6]
V	Maximum service speed				knots	[2.1.8]
x, y, z	Coordinates of the calculation point with respect to the reference coordinate system				m	[2.6]

Table 2 : Materials

Symbol	Meaning	Unit	Reference
E	Young's modulus	N/mm ²	Ch 4, Sec 1, [2]
G	Shear modulus: $G = \frac{E}{2(1 + \nu)}$	N/mm ²	–
k	Material factor	–	Ch 4, Sec 1, [2]
ν	Poisson's ratio	–	Ch 4, Sec 1, [2]
R_{eH}	Specified minimum yield stress	N/mm ²	Ch 4, Sec 1, [2]
R_m	Specified minimum tensile strength	N/mm ²	Ch 4, Sec 1, [2]
R_Y	Nominal yield stress, taken equal to 235/k	N/mm ²	–
τ_{eH}	Specified shear yield stress: $\tau_{eH} = \frac{R_{eH}}{\sqrt{3}}$	N/mm ²	–

1.1.3 Loads

Unless otherwise specified, symbols regarding loads and their units used in these Rules are those defined in Tab 3.

1.1.4 Scantlings

Unless otherwise specified, symbols regarding scantlings and their units used in these Rules are those defined in Tab 4.

1.1.5 Gravity acceleration

The gravity acceleration g is taken equal to $9,81 \text{ m/s}^2$.

1.1.6 Density of seawater

The density of seawater ρ is taken equal to $1,025 \text{ t/m}^3$.

Table 3 : Loads

Symbol	Meaning	Unit	Reference
T θ	Roll period	s	Ch 5, Sec 3, [2.1.1]
θ	Roll angle	deg	Ch 5, Sec 3, [2.1.1]
T φ	Pitch period	s	Ch 5, Sec 3, [2.1.2]
φ	Pitch angle	deg	Ch 5, Sec 3, [2.1.2]
a_x	Longitudinal acceleration	m/s^2	Ch 5, Sec 3, [3]
a_y	Transverse acceleration	m/s^2	Ch 5, Sec 3, [3]
a_z	Vertical acceleration	m/s^2	Ch 5, Sec 3, [3]
k_r	Roll radius of gyration	m	Ch 5, Sec 3, Tab 4
GM	Metacentric height	m	Ch 5, Sec 3, Tab 4
S	Static load scenario	–	–
S+D	Dynamic load scenario	–	–
P_{ex}	Total sea pressure	kN/m^2	Ch 5, Sec 5, [1]
P_{in}	Total internal pressure due to liquid	kN/m^2	Ch 5, Sec 6, [1]
P_s	Static sea pressure	kN/m^2	Ch 5, Sec 5, [1.2]
P_{ls}	Static tank pressure	kN/m^2	Ch 5, Sec 6, [1.2]
P_w	Dynamic wave pressure	kN/m^2	Ch 5, Sec 5, [1.3] and Ch 5, Sec 5, [1.4]
P_{ld}	Dynamic tank pressure	kN/m^2	Ch 5, Sec 6, [1.3]
P_d	Green sea deck pressure	kN/m^2	Ch 5, Sec 5, [3.2]
P_{sl}	Sloshing pressure	kN/m^2	Ch 5, Sec 6, [2.2.1]
P_{dl}	Total pressure due to uniform cargo	kN/m^2	Ch 5, Sec 6, [6.1]
P_{SLI}	Bottom and stern slamming pressure	kN/m^2	Ch 5, Sec 5, [4.2]
P_{FI}	Bow impact pressure	kN/m^2	Ch 5, Sec 5, [4.3]
P_{fs}	Static pressure in flooded conditions	kN/m^2	Ch 5, Sec 6, [1.4.1]
P_{ST}	Tank testing pressure	kN/m^2	Ch 5, Sec 6, [10.1.1]
F_{u-s}	Force due to unit cargo in static (S) design load scenario	kN	Ch 5, Sec 6, [6.2.1]
F_{u-d}	Force due to unit cargo in static plus dynamic (S+D) design load scenario	kN	Ch 5, Sec 6, [6.2.1]
M_{sw}	Vertical still water bending moment	$\text{kN}\cdot\text{m}$	Ch 5, Sec 4, [2.1.1]
Q_{sw}	Vertical still water shear force	kN	Ch 5, Sec 4, [2.3.1]
M_{wv}	Vertical wave bending moment	$\text{kN}\cdot\text{m}$	Ch 5, Sec 4, [3.1]
Q_{wv}	Vertical wave shear force	kN	Ch 5, Sec 4, [3.2]
M_{wt}	Torsional wave moment	$\text{kN}\cdot\text{m}$	Ch 5, Sec 4, [3.5]
M_{wh}	Horizontal wave bending moment	$\text{kN}\cdot\text{m}$	Ch 5, Sec 4, [3.3]
Q_{wh}	Horizontal wave shear force	kN	Ch 5, Sec 4, [3.4]

Table 4 : Scantlings

Symbol	Meaning	Unit	Reference
I_{y-n50}	Net vertical moment of inertia of hull girder, calculated with half corrosion reduction	m ⁴	–
I_{z-n50}	Net horizontal moment of inertia of hull girder, calculated with half corrosion reduction	m ⁴	–
Z_{D-n50}	Net vertical hull girder section moduli, at deck, calculated with half corrosion reduction	m ³	–
Z_{B-n50}	Net vertical hull girder section moduli, at bottom, calculated with half corrosion reduction	m ³	–
z_n	Vertical distance from BL to horizontal neutral axis	m	–
a	Length of an elementary plate panel (EPP)	mm	Ch 4, Sec 6, [2.1.1]
b	Breadth of an elementary plate panel (EPP)	mm	Ch 4, Sec 6, [2.1.1]
s	Stiffener spacing	mm	Ch 4, Sec 6, [1.2.1]
S	Primary supporting member spacing	m	Ch 4, Sec 6, [1.2.2]
ℓ	Span of stiffeners or primary supporting members	m	Ch 4, Sec 6, [1]
ℓ_b	Bracket arm length	m	–
t	Net thickness with full corrosion reduction	mm	–
t_{n50}	Net thickness with half corrosion reduction	mm	–
t_c	Corrosion addition	mm	–
t_{gr}	Gross thickness	mm	–
t_{as_built}	As-built thickness taken as the actual thickness provided at the newbuilding stage	mm	–
t_{gr_off}	Gross thickness offered	mm	–
t_{gr_req}	Gross thickness required	mm	–
t_{off}	Net thickness offered	mm	–
t_{req}	Net thickness required	mm	–
t_{vol_add}	Thickness for voluntary addition	mm	–
t_{res}	Reserve thickness, taken equal to 0,5	mm	–
t_{c1}, t_{c2}	Corrosion addition on each side of structural member	mm	–
h_w	Web height of stiffener or primary supporting member	mm	–
t_w	Web thickness of stiffener or primary supporting member	mm	–
b_f	Face plate width of stiffener or primary supporting member	mm	–
h_{stf}	Height of stiffener or primary supporting member	mm	–
t_f	Face plate/flange thickness of stiffener or primary supporting member	mm	–
t_p	Thickness of the plating attached to a stiffener or a primary supporting member	mm	–
b_{eff}	Effective breadth of attached plating, in bending, for yield and fatigue	mm	–
A_{eff}	Net sectional area of stiffener or primary supporting member, with attached plating of width s, calculated with full corrosion reduction	cm ²	–
$A_{eff-n50}$	Net sectional area of stiffener or primary supporting member, with attached plating of width s, calculated with half corrosion reduction	cm ²	–
A_{shr}	Net shear sectional area of stiffener or primary supporting member, calculated with full corrosion reduction	cm ²	–
$A_{shr-n50}$	Net shear sectional area of stiffener or primary supporting member, calculated with half corrosion reduction	cm ²	–
I_p	Net polar moment of inertia of a stiffener about its connection to plating	cm ⁴	–
I	Net moment of inertia of a stiffener, with attached plating, about its neutral axis parallel to the plating	cm ⁴	–
Z	Net section modulus of a stiffener or primary supporting member, with attached plating of breadth b_{eff} , calculated with full corrosion reduction	cm ³	–
Z_{n50}	Net section modulus of a stiffener or primary supporting member, with attached plating of breadth b_{eff} , calculated with half corrosion reduction	cm ³	–

2 Definitions

2.1 Ship's dimensions and main data

2.1.1 Rule length

The rule length L is the distance, in m, measured on the waterline at the scantling draught T_{SC} from the fore-side of the stem to the after side of the rudder post, or to the centre of the rudder stock where there is no rudder post. L is to be not less than 96% and need not exceed 97% of the extreme length on the waterline at the scantling draught T_{SC} .

In ships without rudder stock (e.g. ships fitted with azimuth thrusters), the rule length L is to be taken equal to 97% of the extreme length on the waterline at the scantling draught T_{SC} .

In ships with unusual stem or stern arrangements, the rule length is considered on a case-by-case basis.

2.1.2 Load line length

The load line length L_{LL} shall be taken as 96% of the total length on a waterline at 85% of the least moulded depth measured from the top of the keel, or as the length from the fore side of the stem to the axis of the rudder stock on that waterline, if that be greater.

For ships without a rudder stock, the length L_{LL} is to be taken as 96% of the waterline at 85% of the least moulded depth.

Where the stem contour is concave above the waterline at 85% of the least moulded depth, both the forward terminal of the total length and the fore-side of the stem is taken at the vertical projection to that waterline of the aftermost point of the stem contour (see Fig 1).

In ship design with a rake of keel, the waterline on which this length is measured is parallel to the designed waterline at 85% of the least moulded depth D_{min} found by drawing a line parallel to the keel line of the ship (including skeg) tangent to the moulded sheer line of the freeboard deck. The least moulded depth is the vertical distance measured from the top of the keel to the top of the freeboard deck beam at side at the point of tangency (see Fig 2).

Figure 1 : Concave stem contour

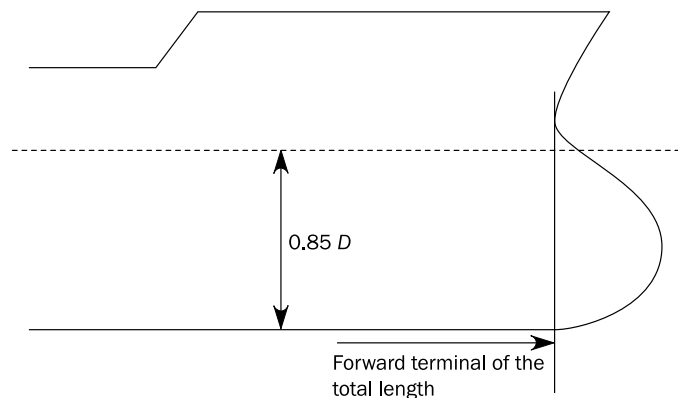
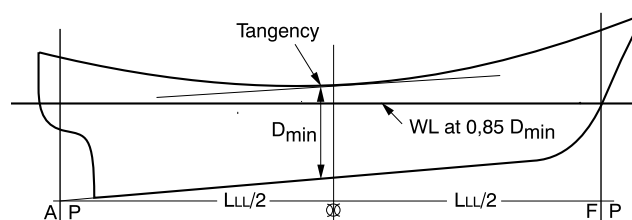


Figure 2 : Length of ships with a rake of keel



2.1.3 Subdivision length

The subdivision length L_s of the ship is the greatest projected moulded length of that part of the ship at or below deck or decks limiting the vertical extent of flooding with the ship at the deepest subdivision draught.

2.1.4 Moulded breadth

The moulded breadth B is the greatest moulded breadth, in m, measured amidships at the scantling draught T_{SC} .

2.1.5 Moulded depth

The moulded depth D is the vertical distance measured from the top of the keel to the top of the freeboard deck beam at side. Where the form at the lower part of the midship section is of a hollow character or where thick garboards are fitted, the distance is measured from the point where the line of the flat of the bottom continued inwards cuts the side of the keel.

In ships having rounded gunwales, the moulded depth is to be measured to the point of intersection of the moulded lines of deck and sides, the lines extending as though the gunwales were of angular design.

Where the freeboard deck is stepped and the raised part of the deck extends over the point at which the moulded depth is to be determined, the moulded depth is to be measured to a line of reference extending from the lower part of the deck along a line parallel with the raised part.

2.1.6 Draught

The draught T , in m, is the summer load line draught for the ship in operation, measured from the moulded baseline at midship.
Note 1: This may be less than the maximum permissible summer load waterline draught.

In the case of ships with a solid bar keel, the moulded base line is to be taken at the intersection between the upper face of the bottom plating with the solid bar keel at the middle of the length L .

T_{SC} is the scantling draught, in m, at which the strength requirements for the scantlings of the ship are met and represents the full load condition. The scantling draught T_{SC} is to be not less than that corresponding to the assigned freeboard. The draught of ships to which timber freeboards are assigned corresponds to the loading condition of timber, and the requirements of the Society are to be applied to this draught.

T_{LC} is the draught, in m, amidships for a considered load case

T_{BAL} is the minimum design normal ballast draught amidships, in m, at which the strength requirements for the scantlings of the ship are met. This normal ballast draught is the minimum draught of ballast conditions including ballast water exchange operation, if any, for any ballast conditions in the loading manual including both departure and arrival conditions.

T_{BAL-H} is the minimum design heavy ballast draught, in m, at which the strength requirements for the scantlings of the ship are met. This heavy ballast draught is to be considered for ships having heavy ballast condition.

2.1.7 Moulded displacement

The moulded displacement Δ , in t, corresponds to the underwater volume of the ship, at draught T_{SC} , in seawater with a density of 1,025 t/m³.

The moulded displacement Δ_{LC} , in t, at a considered load case, corresponds to the underwater volume of the ship, at draught T_{LC} , in seawater with a density of 1,025 t/m³.

2.1.8 Maximum service speed

The maximum ahead service speed V , in knots, means the greatest speed which the ship is designed to maintain in service at her deepest seagoing draught at the maximum propeller RPM (revolution per minute) and corresponding engine MCR (maximum continuous rating).

2.1.9 Block coefficient

The block coefficient C_B , at scantling draught T_{SC} , is defined by:

$$C_B = \frac{\Delta}{1,025 L B T_{SC}}$$

The block coefficient C_{B-LC} , at a considered load case, is defined by:

$$C_{B-LC} = \frac{\Delta_{LC}}{1,025 L B T_{LC}}$$

2.1.10 Waterplane coefficient

The waterplane coefficient C_W , at scantling draught T_{SC} , is defined by:

$$C_W = \frac{A_{WP}}{L B}$$

where:

A_{WP} : Waterplane area at scantling draught T_{SC} , in m².

The waterplane coefficient C_{W-LC} , at a considered load case, is defined by:

$$C_{W-LC} = \frac{A_{WP-LC}}{L B}$$

where:

A_{WP-LC} : Waterplane area at draught T_{LC} , in m².

2.1.11 Lightweight

The lightweight is the ship displacement, in t, complete in all respects, but without cargo, consumable, stores, passengers and crew and their effects, and without any liquids on board except the machinery and piping fluids, such as lubricants and hydraulics, which are at operating levels.

2.1.12 Deadweight

The deadweight DWT is the difference, in t, between the displacement, at the summer draught in seawater of density $\rho = 1,025 \text{ t/m}^3$, and the lightweight.

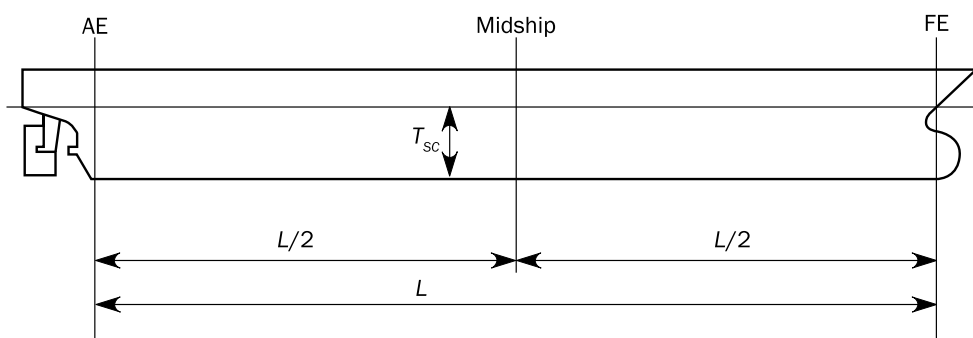
2.1.13 Fore end or forward perpendicular

The fore end (FE) of the rule length L is the perpendicular to the scantling draught waterline at the forward side of the stem. See Fig 3.

2.1.14 Aft end

The aft end (AE) of the rule length L is the perpendicular to the scantling draught waterline at a distance L aft of the fore end. See Fig 3.

Figure 3 : Fore end, Aft end and midship part



2.1.15 After perpendicular

The after perpendicular is the perpendicular to the waterline at the after side of the rudder post on the summer load waterline. For ships without rudder post, the after perpendicular is the perpendicular to the waterline at the centre of the rudder stock on the summer load waterline.

2.1.16 Midship

The midship is the perpendicular to the scantling draught waterline at a distance 0,5 L aft of the fore end.

2.1.17 Midship part

The midship part of a ship is the part extending 0,4 L amidships, unless otherwise specified.

2.2 Superstructure and deckhouse

2.2.1 Superstructure

A superstructure is a decked structure on the freeboard deck extending from side to side of the ship or with the side plating not being inboard of the shell plating more than 0,04 B.

2.2.2 Deckhouse

A deckhouse is a decked structure on the freeboard or superstructure deck which does not comply with the definition of a superstructure.

2.2.3 Bridge

A bridge is an elevated superstructure having a clear view forward and at each side, and from which a ship is steered.

2.2.4 Enclosed/open superstructure

Enclosed superstructure means a superstructure with bulkheads forward and/or aft fitted with weathertight doors and closing appliances.

An open superstructure is a superstructure which does not comply with the definition of a enclosed superstructure.

2.2.5 Forecastle

A forecastle is a short superstructure situated at the bow.

2.2.6 Poop

The poop is the superstructure located at the extreme aft end of the ship.

2.2.7 Raised quarterdeck

A raised quarterdeck is a partial superstructure of reduced height as defined in [2.2.9].

It extends forward from the after perpendicular and has an intact front bulkhead (sidescuttles of the non-opening type fitted with efficient deadlights and bolted man hole covers).

Where the forward bulkhead is not intact due to doors and access openings, the superstructure is then to be considered as a poop.

2.2.8 Trunk

A trunk is a decked structure similar to a deckhouse but not provided with a lower deck.

2.2.9 Standard height of superstructure

The standard height of superstructure is defined in Tab 5.

Table 5 : Standard height of superstructure

Load line length L_{LL} , in m	Standard height h_s , in m	
	Raised quarter deck	All other superstructures
$L_{LL} \leq 30$	0,90	1,80
$30 < L_{LL} < 75$	$0,9 + 0,00667 (L_{LL} - 30)$	1,80
$75 \leq L_{LL} < 125$	$1,2 + 0,012 (L_{LL} - 75)$	$1,8 + 0,01 (L_{LL} - 75)$
$L_{LL} \geq 125$	1,80	2,30

2.2.10 Tiers of superstructure

A tier is extending over one standard height of superstructure as defined in [2.2.9].

The lowest tier is the tier located immediately above the freeboard deck.

When the freeboard exceeds one standard superstructure height, as defined in [2.2.9] for “all other superstructures”, the lowest tier may be considered as an upper tier when calculating the scantlings of superstructures and deckhouses.

The second tier is the tier located immediately above the lowest tier, and so on.

2.3 Type A and Type B ships

2.3.1 Type A ship

A Type A ship is one which:

- is designed to carry only liquid cargoes in bulk;
- has a high integrity of the exposed deck with only small access openings to cargo compartments, closed by watertight gasketed covers of steel or equivalent material; and
- has low permeability of loaded cargo compartments.

A Type A ship is to be assigned a freeboard following the requirements reported in the International Load Line Convention 1966, as amended.

2.3.2 Type B ship

All ships which do not come within the provisions regarding Type A ships stated in [2.3.1] are to be considered as Type B ships.

A Type B ship is to be assigned a freeboard following the requirements reported in the International Load Line Convention 1966, as amended.

2.3.3 Type B-60 ship

A Type B-60 ship is any Type B ship of over 100 metres in length which, fulfilling the requirements reported in Ch 3, App 4, [4.4], is assigned with a value of tabular freeboard which can be reduced up to 60 per cent of the difference between the “B” and “A” tabular values for the appropriate ship lengths.

2.3.4 Type B-100 ships

A Type B-100 ship is any Type B ship of over 100 metres in length which, fulfilling the requirements reported in Ch 3, App 4, [4.4], is assigned with a value of tabular freeboard which can be reduced up to 100 per cent of the difference between the “B” and “A” tabular values for the appropriate ship lengths.

2.4 Positions 1 and 2

2.4.1 Position 1

Position 1 includes:

- exposed freeboard and raised quarter decks,
- exposed superstructure decks situated forward of $0,25 L_{LL}$ from the perpendicular, at the forward side of the stem, to the waterline at 85% of the least moulded depth measured from the top of the keel.

2.4.2 Position 2

Position 2 includes:

- exposed superstructure decks situated aft of $0,25 L$ from the perpendicular, at the forward side of the stem, to the waterline at 85% of the least moulded depth measured from the top of the keel and located at least one standard height of superstructure above the freeboard deck,

- *exposed superstructure decks situated forward of $0,25 L_{LL}$ from the perpendicular, at the forward side of the stem, to the waterline at 85% of the least moulded depth measured from the top of the keel and located at least two standard heights of superstructure above the freeboard deck.*

2.5 Sister ship

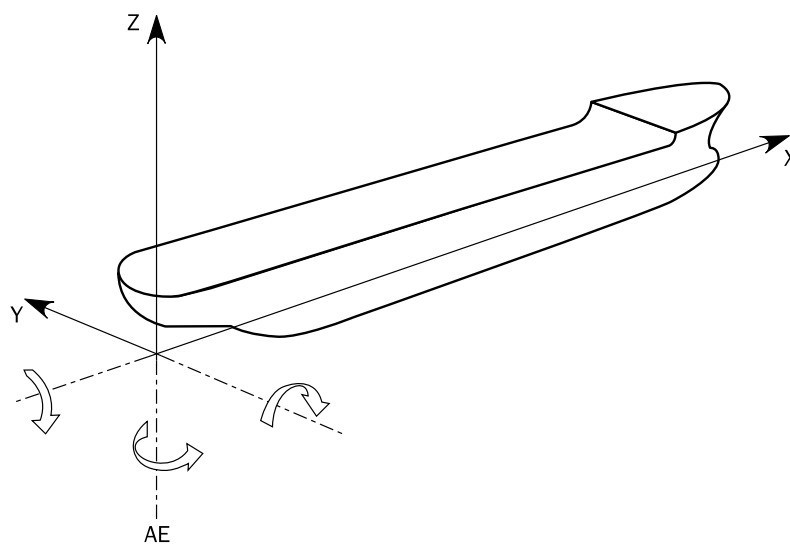
2.5.1 A sister ship is a ship built by the same yard from the same plans.

2.6 Reference coordinate system

2.6.1 The ship's geometry, motions, accelerations and loads are defined with respect to the following right-hand coordinate system (see Fig 4):

- Origin : At the intersection of the longitudinal plane of symmetry of ship, the aft end of L, and the baseline
X axis : Longitudinal axis, positive forwards
Y axis : Transverse axis, positive towards portside
Z axis : Vertical axis, positive upwards.

Figure 4 : Reference coordinate system



2.7 Arrangement

2.7.1 Aft peak

The aft peak is the area aft of the aft peak bulkhead.

The aft peak bulkhead is the first main transverse watertight bulkhead forward of the stern.

The aft peak tank is the compartment in the narrow part of the stern, aft of the aft peak bulkhead.

2.7.2 Bow

The bow is the structural arrangement and form of the forward end of the ship.

2.7.3 Bulkhead

A bulkhead is a structural partition wall subdividing the interior of the ship into compartments.

In a cargo ship the freeboard deck may be taken as the bulkhead deck.

An engine room bulkhead is a transverse bulkhead located either directly forward or aft of the engine room.

2.7.4 Compartment

A compartment is an internal space bounded by bulkheads or plating.

2.7.5 Deck

A deck is the horizontal structure element defining the upper or lower boundary of a compartment.

The freeboard deck is the deck designated as such by the designer, in accordance with International Convention on Load Lines (ICLL), generally the uppermost complete deck exposed to weather and sea, with permanent means of closing for all the exposed openings.

The strength deck is the uppermost continuous deck.

The superstructure deck is the deck forming the upper boundary of a superstructure.

2.7.6 Fore peak

The fore peak is the area of the ship forward of the collision bulkhead.

2.7.7 Stern

The stern is the after end of the vessel.

2.7.8 Tank

Tank is a generic term for space intended to carry liquid such as seawater, fresh water, oil, liquid cargoes, fuel oil, water ballast, etc.

2.7.9 Well

Well means any area on the deck exposed to the weather, where water may be entrapped. Wells are considered to be deck areas bounded on two or more sides by deck structures.

2.8 Structural components

2.8.1 Bilge plating

The bilge plating is the curved plating between the bottom shell and the side shell, to be taken as follows:

- Within the cylindrical part of the ship: from the start of the curvature at the lower turn of bilge on the bottom to the end of the curvature at the upper turn of the bilge
- Outside the cylindrical part of the ship: from the start of the curvature at the lower turn of the bilge on the bottom to the lesser of:
 - a point on the side shell located $0,2D$ above the baseline/local centreline elevation
 - the end of the curvature at the upper turn of the bilge

2.8.2 Bottom shell

The bottom shell is the shell envelope plating forming the predominantly flat bottom portion of the shell envelope, including the keel plate.

2.8.3 Bracket

A bracket is an extra structural component used to increase the strength of a joint between two structural members

2.8.4 Double skin member

A double skin member is a structural member where the idealised beam comprises the web with top and bottom flanges formed by the attached plating.

2.8.5 Elementary plate panel (EPP)

An elementary plate panel is the smallest plate element surrounded by structural members such as stiffeners, PSM, bulkheads, etc.

2.8.6 Flange

A flange is a section of a stiffening member attached to the web, or sometimes formed by bending the web over. It is usually parallel to the plated surface.

2.8.7 Girder

Girder is a collective term for primary supporting structural members.

2.8.8 Keel

The keel is the main structural member or backbone of a ship running longitudinally along the centreline of the bottom, usually a flat plate stiffened by a vertical plate on its centreline inside the shell.

2.8.9 Plating

A plating is a sheet of steel supported by stiffeners, primary supporting members or bulkheads.

2.8.10 Primary supporting member (PSM)

A primary supporting member is a member of the beam, girder or stringer type, which provide the overall structural integrity of the hull envelope and tank boundaries, e.g. double bottom floors and girders, transverse side structure, deck transverses, bulkhead stringers and vertical webs on longitudinal bulkheads.

2.8.11 Shelf plate

A shelf plate is an horizontal plate located on the top of a bulkhead stool.

2.8.12 Shell envelope plating

The shell envelope plating is the shell plating forming the effective hull girder exclusive of the strength deck plating.

2.8.13 Side shell

The side shell is the shell envelope plating forming the side portion of the shell envelope above the bilge plating.

2.8.14 Single skin member

A single skin member is a structural member where the idealised beam comprises a web, a top flange formed by an attached plating and a bottom flange formed by a face plate.

2.8.15 Stiffener

Stiffener is a collective term for secondary supporting structural members.

2.8.16 Strake

Strake means course or row of shell, deck, bulkhead, or other plating.

2.8.17 Stringer

A stringer is an horizontal girder linking vertical web frames.

A stringer plate is the outside strake of deck plating.

2.8.18 Web

A web is a section of a stiffening member attached to the plated surface, usually perpendicular.

Web frame means a transverse primary supporting member, including deck transverse

Section 4 Documentation to be Submitted

1 Documentation to be submitted for all ships

1.1 Ships surveyed by the Society during the construction

1.1.1 Plans and documents to be submitted for approval

The plans and documents to be submitted to the Society for approval are listed in Tab 1.

The above plans and documents are to be supplemented by further documentation which depends on the service notation and, possibly, the additional class notation (see Pt A, Ch 1, Sec 2) assigned to the ship, as specified in [2].

Structural plans are to show details of connections of the various parts and, in general, are to specify the materials used, including their manufacturing processes, welded procedures and heat treatments. See also Ch 13, Sec 1.

Table 1 : Plans and documents to be submitted for approval for all ships

Plan or document	Containing also information on
Midship section Transverse sections Shell expansion Decks and profiles Double bottom Pillar arrangements Framing plan Deep tank and ballast tank bulkheads, wash bulkheads	Class characteristics Main dimensions Minimum ballast draught Frame spacing Maximum ahead service speed Density of cargoes Design loads on decks and double bottom, including details of unitary loads, if any, as vehicles, steel coils, containers, etc. Steel grades Areas subjected to low temperatures Location and height of air vent outlets of various compartments Corrosion protection Welding details Openings in decks and shell and relevant compensations Boundaries of flat areas in bottom and sides Details of structural reinforcements and/or discontinuities Bilge keel with details of connections to hull structures Overpressure due to sustained liquid flow through air pipe or overflow pipe in case of overfilling or filling during flow through ballast water exchange Relief valve setting pressure Design still water bending moments and shear forces at midship
Loading manual and loading instruments	See Ch 1, Sec 5, [2]
Watertight subdivision bulkheads Watertight tunnels	Openings and their closing appliances, if any
Fore part structure	Location and height of air vent outlets of various compartments
Transverse thruster, if any, general arrangement, tunnel structure, connections of thruster with tunnel and hull structures	
Aft part structure	Location and height of air vent outlets of various compartments
Machinery space structures Foundations of propulsion machinery and boilers	Type, power and r.p.m. of propulsion machinery Mass and centre of gravity of machinery and boilers(1) Details, including SWL, of travelling gantry cranes, if any
Superstructures and deckhouses Machinery space casing	Extension and mechanical properties of the aluminium alloy used (where applicable)
Bow doors, stern doors and inner doors, if any, side doors and other openings in the side shell	Closing appliances Electrical diagrams of power control and position indication circuits for bow doors, stern doors, side doors, inner doors, television system and alarm systems for ingress of water

Plan or document	Containing also information on
Hatch covers, if any	Design loads on hatch covers Sealing and securing arrangements, type and position of locking bolts Distance of hatch covers from the summer load waterline and from the fore end
Bow or stern ramps, elevators for cargo handling and movable decks, if any	Structural arrangements of ramps, elevators and movable decks with their masses Arrangement of vehicles on ramps and movable decks and vehicles characteristics Arrangements of securing and locking devices Connection of ramps, lifting and/or hoisting appliances to the hull structures, with indication of design loads (amplitude and direction) Wire ropes and hoisting devices in working and stowed position Hydraulic jacks Loose gear (blocks, shackles, etc.) indicating the safe working loads and the testing loads Test conditions
Windows and side scuttles, arrangements and details	Type of material (glass, PMMA, PC) and its mechanical properties
Scuppers and sanitary discharges	
Bulwarks and freeing ports	Arrangement and dimensions of bulwarks and freeing ports on the freeboard deck and superstructure deck
Helicopter decks, if any	General arrangement Main structure Characteristics of helicopters: maximum mass, distance between landing gears or landing skids, print area of wheels or skids, distribution of landing gear loads
Rudder and rudder horn (1)	Maximum ahead service speed
Sternframe or sternpost, sterntube Propeller shaft boss and brackets (1)	
Derricks and cargo gear Cargo lift structures	Design loads (forces and moments) Connections to the hull structures
Sea chests, stabiliser recesses, etc.	Overpressure due to the inlet grating cleaning system
Hawse pipes	
Plan of outer doors and hatchways	
Plan of manholes	
Plan of access to and escape from spaces	
Plan of ventilation	Use of spaces
Plan of tank testing	Testing procedures for the various compartments Height of pipes for testing
Plan of watertight doors and scheme of relevant manoeuvring devices	Manoeuvring devices Electrical diagrams of power control and position indication circuits
Freeboard calculations	
Stability documentation	See Ch 3, Sec 1, [2.1]
Calculations relevant to intact stability and, where required, damage stability	
Equipment number calculation	Geometrical elements for calculation List of equipment Construction and breaking load of steel wires Material, construction, breaking load and relevant elongation of synthetic ropes
Emergency towing arrangement	See Ch 12, Sec 4
(1) Where other steering or propulsion systems are adopted (e.g. steering nozzles or azimuth propulsion systems), the plans showing the relevant arrangement and structural scantlings are to be submitted. For azimuth propulsion systems, see Ch 12, Sec 1, [11].	

1.1.2 Plans and documents to be submitted for information

In addition to those in [1.1.1], the following plans and documents are to be submitted to the Society for information:

- general arrangement
- capacity plan, indicating the volume and position of the centre of gravity of all compartments and tanks
- lines plan
- hydrostatic curves
- lightweight distribution.
- towing and mooring arrangement plan

In addition, when direct calculation analyses are carried out by the Designer according to the rule requirements, they are to be submitted to the Society.

1.2 Ships for which the Society acts on behalf of the relevant Administration

1.2.1 Plans and documents to be submitted for approval

The plans required by the National Regulations concerned are to be submitted to the Society for approval, in addition to those in [1.1].

2 Further documentation to be submitted for ships with certain service notations or additional class notations

2.1 General

2.1.1 Depending on the service notation and, possibly, the additional class notation (see Pt A, Ch 1, Sec 2) assigned to the ship, other plans or documents may be required to be submitted to the Society, in addition to those in [1.1]. They are listed in the relevant parts of the Rules applicable to these notations as defined in Pt A, Ch 1, Sec 2.

Section 5 Loading Manual and Loading Instruments

1 Loading manual and loading instrument requirement criteria

1.1 Ship categories

1.1.1 Category I ships

- ships having large openings in the strength decks where combined stresses due to vertical and horizontal hull girder bending and torsional and lateral loads need to be considered
- ships liable to carry non-homogeneous loadings, where the cargo and/or ballast may be unevenly distributed; exception is made for ships less than 120 metres in length, when their design takes into account uneven distribution of cargo or ballast: such ships belong to Category II
- ships having the service notation **chemical tanker ESP**, **liquefied gas carrier** or **LNG bunkering ship**.

1.1.2 Category II ships

- ships whose arrangement provides small possibilities for variation in the distribution of cargo and ballast
- ships on a regular and fixed trading pattern where the loading manual gives sufficient guidance
- the exception given under Category I.

1.2 Requirement criteria

1.2.1 All ships

An approved loading manual is to be supplied for all ships equal to or greater than 65 m in length, except those of Category II less than 90 m in length in which the deadweight does not exceed 30% of the displacement at the summer loadline draught.

In addition, an approved loading instrument is to be supplied for all ships of Category I of 65 m in length and above.

The loading instrument is ship specific onboard equipment and the results of the calculations are only applicable to the ship for which it has been approved.

An approved loading instrument may not replace an approved loading manual.

1.2.2 In any case, when a loading instrument is present onboard, it is to be approved by the Society.

1.2.3 Bulk carriers, ore carriers and combination carriers equal to or greater than 150 m in length

Ships with one of the service notations **bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP** or **combination carrier ESP**, and equal to or greater than 150 m in length, are to be provided with an approved loading manual and an approved computer-based loading instrument, in accordance with the applicable requirements of this Section.

1.2.4 Bulk carriers, ore carriers or combination carriers less than 150 m in length

Ships with one of the service notation **bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP** or **combination carrier ESP**, and less than 150 m in length, are to be provided with an approved computer-based loading instrument in accordance with the applicable requirements of this Section. The approved loading instrument is to be capable of providing information on the ship's stability in the intact condition.

1.2.5 Oil tankers and chemical tankers

Ships with one of the service notation **oil tanker ESP**, or **chemical tanker**, are to be provided with an approved computer-based loading instrument in accordance with the applicable requirements of this Section. The approved loading instrument is to be capable of verifying compliance with the intact and applicable damage stability requirements. Exemptions may be granted on a case by case basis.

2 Loading manual

2.1 Definitions

2.1.1 All ships

A loading manual is a document which describes:

- the loading conditions on which the design of the ship has been based, including permissible limits of still water bending moment and shear force
- the results of the calculations of still water bending moments, shear forces and, where applicable, limitations due to torsional and lateral loads
- the allowable local loading for the structure (hatch covers, decks, double bottom, etc.).

2.1.2 Bulk carriers, ore carriers and combination carriers equal to or greater than 150 m in length

In addition to [2.1.1], for ships with one of the service notations **bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP** or **combination carrier ESP**, and equal to or greater than 150 m in length, the loading manual is also to describe:

- for cargo holds of ships with the service notation **bulk carrier** or **bulk carrier ESP**: the envelope results and permissible limits of still water bending moments and shear forces in the hold flooded condition
- the cargo hold(s) or combination of cargo holds which might be empty at full draught
- hold mass curves for each single hold in the relevant loading conditions listed in Pt D, Ch 4, Sec 3, [3.1], showing the maximum allowable and the minimum required masses of cargo and double bottom contents of each hold as a function of the draught at mid-hold position (for determination of permissible mass in cargo holds, refer to Pt D, Ch 4, App 2)
- hold mass curves for any two adjacent holds in the relevant loading conditions listed in Pt D, Ch 4, Sec 3, [3.1], showing the maximum allowable and the minimum required masses of cargo and double bottom contents of any two adjacent holds as a function of the mean draught in way of these holds. This mean draught may be calculated by averaging the draught of the two mid-hold positions (for determination of permissible mass in cargo holds, refer to Pt D, Ch 4, App 2)
- maximum allowable tank top loading together with specification of the nature of the cargo for cargoes other than bulk cargoes
- maximum allowable load on deck and hatch covers. If the ship is not approved to carry load on deck or hatch covers, this is to be clearly stated in the loading manual
- the maximum rate of ballast change together with the advice that a load plan is to be agreed with the terminal on the basis of the achievable rates of change of ballast.

2.2 Conditions of approval

2.2.1 All ships

The approved loading manual is to be based on the final data of the ship. The manual is to include the design (cargo and ballast) loading conditions, subdivided into departure and arrival conditions as appropriate, upon which the approval of the hull scantlings is based, defined in Ch 5, Sec 8, [3.1.1].

In the case of modifications resulting in changes to the main data of the ship, a new approved loading manual is to be issued.

2.2.2 Bulk carriers, ore carriers and combination carriers equal to or greater than 150 m in length

In addition to [2.2.1], for ships with one of the service notations **bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP** or **combination carrier ESP**, and equal to or greater than 150 m in length, the following loading conditions, subdivided into departure and arrival conditions as appropriate, are also to be included in the loading manual:

- alternate light and heavy cargo loading conditions at maximum draught, where applicable
- homogeneous light and heavy cargo loading conditions at maximum draught
- ballast conditions

For ships with ballast holds adjacent to topside wing, hopper and double bottom tanks, it may be acceptable that the ballast holds are filled when the topside wing, hopper and double bottom tanks are empty

- short voyage conditions where the ship is to be loaded to maximum draught but with a limited amount of bunkers
- Multi-port (MP) loading/unloading conditions
- deck cargo conditions, where applicable
- typical loading sequences where the ship is loaded from commencement of cargo loading to reaching full deadweight capacity, for homogeneous conditions, relevant part load conditions and alternate conditions where applicable. Typical unloading sequences for these conditions are also to be included

The typical loading/unloading sequences are also to be developed to not exceed applicable strength limitations. The typical loading sequences are also to be developed paying due attention to the loading rate and deballasting capability

- typical sequences for change of ballast at sea, where applicable.

2.2.3 Language

The loading manual is to be prepared in a language understood by the users. If this is not English, a translation into English is to be included.

3 Loading instrument

3.1 Additional class notations LI

3.1.1 The additional class notations **LI-HG**, **LI-S1**, **LI-S2**, **LI-S3**, **LI-S4**, **LI-HG-S1**, **LI-HG-S2**, **LI-HG-S3**, **LI-HG-S4** and **LI-LASHING** may be assigned in accordance with Pt A, Ch 1, Sec 2, [6.16.1] to ships equipped with a loading instrument, as defined in [3.1.2].

3.1.2 When the ship is equipped with a loading instrument performing:

- only hull girder calculations, the additional class notation **LI-HG** is assigned
- only intact stability calculations (when the ship is not required to meet damage stability requirements), the additional class notation **LI-S1** is assigned

- intact stability calculations and damage stability on a basis of a limit curve, the additional class notation **LI-S2** is assigned
- intact stability calculations and direct damage stability calculations based on pre-programmed damage cases, the additional class notation **LI-S3** is assigned.
- damage stability calculations associated with an actual loading condition and actual flooding case, using direct application of user defined damage, for the purpose of providing operational information for safe return to port, the additional class notation **LI-S4** is assigned.
- lashing calculations, the additional class notation **LI-LASHING** is assigned.

When the loading instrument performs hull girder and stability calculations, the additional class notation **LI-HG-S1**, **LI-HG-S2**, **LI-HG-S3**, **LI-HG-S4** is assigned, as applicable.

3.2 Definitions

3.2.1 All ships

A loading instrument is an instrument which is either analog or digital and by means of which it can be easily and quickly ascertained that, at specified read-out points, the still water bending moments, shear forces and still water torsional moments and lateral loads, where applicable, in any load or ballast condition, do not exceed the specified permissible values.

An operational manual is always to be provided for the loading instrument.

Single point loading instruments are not acceptable.

The approval of a loading instrument for lashing calculation is to be performed according to the approval of lashing software as applicable in Pt F, Ch 12, Sec 5.

3.2.2 Bulk carriers, ore carriers and combination carriers equal to or greater than 150 m in length

For ships with one of the service notations **bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP** or **combination carrier ESP**, and equal to or greater than 150 m in length, the loading instrument is an approved digital system as defined in [3.2.1]. In addition to [3.2.1], it is also to ascertain as applicable that:

- the mass of cargo and double bottom contents in way of each hold as a function of the draught at mid-hold position
- the mass of cargo and double bottom contents of any two adjacent holds as a function of the mean draught in way of these holds
- the still water bending moment and shear forces in the hold flooded conditions, where required,

do not exceed the specified permissible values.

3.3 Conditions of approval

3.3.1 All ships

The loading instrument is subject to approval, which is to include:

- verification of type approval, if any
- verification that the final data of the ship have been used
- acceptance of number and position of all read-out points
- acceptance of relevant limits for read-out points
- checking of proper installation and operation of the instrument on board, under agreed test conditions, and that a copy of the operation manual is available.

3.3.2 Bulk carriers, ore carriers and combination carriers equal to or greater than 150 m in length

In addition, for ships with one of the service notations **bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP** or **combination carrier ESP**, and equal to or greater than 150 m in length, the approval is also to include, as applicable:

- acceptance of hull girder bending moment limits for all read-out points
- acceptance of hull girder shear force limits for all read-out points
- acceptance of limits for the mass of cargo and double bottom contents of each hold as a function of draught (for determination of permissible mass in cargo holds, refer to Pt D, Ch 4, App 2)
- acceptance of limits for the mass of cargo and double bottom contents in any two adjacent holds as a function of draught (for determination of permissible mass in cargo holds, refer to Pt D, Ch 4, App 2).

3.3.3 In the case of modifications implying changes in the main data of the ship, the loading instrument is to be modified accordingly and approved.

3.3.4 The operation manual and the instrument output are to be prepared in a language understood by the users. If this is not English, a translation into English is to be included.

3.3.5 The operation of the loading instrument is to be verified upon installation under the agreed test conditions. It is to be checked that the agreed test conditions and the operation manual for the instrument are available on board.

3.3.6 When the loading instrument also performs stability calculations, it is to be approved for stability purposes in accordance with the procedures indicated in [3.6], [3.7] and [3.8], as applicable.

3.4 Approval procedure

3.4.1 General

The loading instrument approval process includes the following procedures for each ship:

- data verification which results in endorsed test conditions
- approval of computer hardware, where necessary, as specified in Pt C, Ch 3, Sec 6, [2.4.1]
- installation testing which results in an Installation Test Report.

3.4.2 Data verification approval - Endorsed test conditions

The Society is to verify the results and actual ship data used by the calculation program for the particular ship on which the program will be installed.

Upon application for data verification, the Society is to advise the applicant of a minimum of four loading conditions, taken from the ship's approved loading manual, which are to be used as the test conditions. Within the range of these test conditions, each compartment is to be loaded at least once. The test conditions normally cover the range of load draughts from the deepest envisaged loaded condition to the light ballast condition. In addition, the lightship test condition is to be submitted.

When the additional class notation **LI-S4** is assigned, at least three damage cases are to be examined, each of them associated with at least three loading conditions taken from the ship's approved stability information. Output of the software is to be compared with results of corresponding load / damage case in the approved damage stability booklet or an alternative independent software source.

When the loading instrument also performs stability calculations, it is to cover all the stability requirements applicable to the ship. The test conditions are to be taken from the ship's approved trim and stability booklet.

The data indicated in [3.4.3] and contained in the loading program are to be consistent with the data specified in the approved loading manual. Particular attention is drawn to the final lightship weight and centres of gravity derived from the inclining experiment or lightweight check.

The approval of the computer application software is based on the acceptance of the results of the test conditions according to [3.5], [3.6], [3.7], and [3.8], as applicable.

When the requested information has been submitted and the results of the test conditions are considered satisfactory, the Society endorses the test conditions, a copy of which is to be available on board.

3.4.3 Data to be submitted

The following data, submitted by the applicant, are to be consistent with the as-built ship:

- identification of the calculation program including the version number
- main dimensions, hydrostatic particulars and, if applicable, ship profile
- position of the forward and after perpendiculars and, if appropriate, the calculation method to derive the forward and after draughts at the actual position of the ship's draught marks
- ship lightweight and lightweight distribution along the ship's length
- lines plans and/or offset tables
- compartment definitions, including frame spacing and centre of volumes, together with capacity tables (sounding/ullage tables), if appropriate
- deadweight definitions for each loading condition.

3.4.4 Installation testing

During the installation test, one of the ship's senior officers is to operate the loading instrument and calculate the test conditions. This operation is to be witnessed by a Surveyor of the Society. The results obtained from the loading instrument are to be identical to those stated in the endorsed test conditions. If the numerical output from the loading instrument is different from the endorsed test conditions, no approval will be confirmed.

An installation test is also to be carried out on the second nominated computer, when applicable as indicated in Pt C, Ch 3, Sec 6, [2.4.1], which would be used in the event of failure of the first computer. Where the installation test is carried out on a type approved computer, a second nominated computer and test are not required.

Subject to the satisfactory completion of installation tests, the Society's Surveyor endorses the test conditions, adding details of the place and the date of the installation test survey, as well as the Society stamp and the Surveyor's signature.

3.4.5 Operational manual

A uniquely identified ship specific operational manual is to be submitted to the Society for documentation.

The operational manual is to be written in a concise and unambiguous manner. The use of illustrations and flowcharts is recommended.

The operational manual is to contain:

- a general description of the program denoting identification of the program and its stated version number

- details of the hardware specification needed to run the loading program
- a description of error messages and warnings likely to be encountered, and unambiguous instructions for subsequent actions to be taken by the user in each case
- where applicable, the shear force correction factors
- where applicable, the local permissible limits for single and two adjacent hold loadings as a function of the appropriate draught and the maximum weight for each hold
- where applicable, the Society's restrictions (maximum allowable load on double bottom, maximum specific gravity allowed in liquid cargo tanks, maximum filling level or percentage in liquid cargo tanks)
- example of a calculation procedure supported by illustrations and sample computer output
- example computer output of each screen display, complete with explanatory text.

3.4.6 Calculation program specifications

The software is to be written so as to ensure that the user cannot alter the critical ship data files containing the following information:

- lightship weight and lightship weight distribution and associated centres of gravity
- the Society's structural limitations or restrictions
- geometric hull form data
- hydrostatic data and cross curves, where applicable
- compartment definitions, including frame spacing and centre of volumes, together with capacity tables (sounding/ullage tables), if appropriate
- when intact stability criteria are given, a listing of all calculated stability criteria with the obtained values and the conclusions (criteria fulfilled or not fulfilled), the down-flooding angle and the corresponding down-flooding opening.

Any changes in the software are to be made by the manufacturer or his appointed representative and the Society is to be informed immediately of such changes. Failure to advise of any modifications to the calculation program may invalidate the approval issued. In cases where the approval is considered invalid by the Society, the modified calculation program is to be re-assessed in accordance with the approval procedure.

3.4.7 Functional specification

The calculation program is to be user-friendly and designed such that it limits possible input errors by the user.

The forward, midship and after draughts, at the respective perpendiculars, are to be calculated and presented to the user on screen and hardcopy output in a clear and unambiguous manner.

It is recommended that the forward, midship and after draughts, at the actual position of the ship's draught marks are calculated and presented to the user on screen and hard copy output in a clear and unambiguous manner.

The displacement is to be calculated for the specified loading condition and corresponding draught readings and presented to the user on screen and hardcopy output.

The loading instrument is to be capable of producing print-outs of the results in both numerical and graphical forms. The numerical values are to be given in both forms, as absolute values and as the percentage of the permissible values. This print-out is to include a description of the corresponding loading condition.

All screen and hardcopy output data is to be presented in a clear and unambiguous manner with an identification of the calculation program (the version number is to be stated).

When the additional class notation **LI-S3** is assigned, the software is to include pre-defined relevant damage cases for both sides of the ship according to the applicable rules for automatic check of a given loading condition.

When the additional class notation **LI-S3** or **LI-S4** is assigned, the damage stability is to be based on a hull form model, that is, directly calculated from a full three-dimensional geometric model. In addition, the system shall be pre-loaded with a detailed computer model of the complete hull, including appendages, all compartments, tanks and the relevant parts of the superstructure considered in the damage stability calculation, wind profile, down-flooding and up-flooding openings, cross-flooding arrangements, internal compartment connections and escape routes, as applicable and according to the type of stability software.

When the additional class notation **LI-S1** or **LI-S2** is assigned, in case a full three dimensional model is used for stability calculations, the requirements of the computer model for the additional class notation **LI-S3** or **LI-S4** are applicable.

For ships engaged in anchor handling operations, planning tools are to be provided in compliance with operational manual requirements. Information such as ballasting and consumables sequences, permissible tension, working sectors, heeling angles and use of roll-reduction devices are to be stated.

3.4.8 Specific functional requirements for LI-S4

The software used for damage stability for SRTP need not to be totally separated from other software used for normal stability.

When the software for damage stability for SRTP is not separated:

- the function of switching between normal software and SRTP software is to be provided
- the actual intact loading condition is to be the same for both functions (normal operation and SRTP)
- the SRTP module needs only to be activated in case of an incident.

For passenger ships which are subject to SRTP and have an onboard stability computer and shore-based support, such software need not be identical.

Each internal space is to be assigned its permeability as given in Tab 1, unless a more accurate permeability has been reflected in the approved stability information.

The system is to be capable of accounting for applied moments such as wind, lifeboat launching, cargo shifts and passenger relocation.

The system is to take into account for the effect of wind by using the method in SOLAS regulation II-1/7-2.4.1.2 as the default, but allow for manual input of the wind speed/pressure if the on-scene pressure is significantly different ($P = 120 \text{ N/m}^2$ equates to Beaufort 6; approximately 13,8 m/s or 27 knots).

The system is to be capable of assessing the impact of open main watertight doors on stability (e.g. for each damage case provided for verification, additional damage stability calculation shall be done and presented, taking into account any watertight door located within the damaged compartment(s)).

The system is to utilize the latest approved lightship weight and centre of gravity information.

The output of the software is to be such that it provides the master with sufficient clear unambiguous information to enable quick and accurate assessment of the stability of the vessel for any actual damage, the impact of flooding on the means of escape and the controls of devices necessary for managing and/or controlling the stability of the ship.

When the actual loading condition is input in the software, in addition to the information required in [3.4.6] and in [3.4.7], the following output corresponding to intact stability are to be available:

- free surfaces
- GZ values relevant to an adequate range of heeling (not less than 60°) available indicatively at the following intervals: 0 5 10 15 20 25 30 40 50 60 deg
- GM/KG limiting curve according to SOLAS, Ch II-1, Regulation 5-1

When the actual loading condition is associated to the actual damage case(s) due to the casualty, in addition to the information required in [3.4.6] and in [3.4.7], the following output corresponding to the damage stability are to be available:

- progressive flooding angle and corresponding progressive flooding openings
- GM value
- GZ values relevant to an adequate range of heeling (not less than 60°) available indicatively at the following intervals: 0 5 10 15 20 25 30 40 50 60 deg
- the survivability criteria are left to the discretion of the Society
- relevant flooding points (unprotected or weathertight) with the distance from the damage waterline to each point
- list of all flooded compartments with the permeability considered
- amount of water in each flooded compartment
- escape route immersion angles
- a profile view, deck views and cross-sections of the ship indicating the flooded waterplane and the damaged compartments.

For Ro-Ro Passenger ships subject to the Stockholm Agreement (IMO Circular Letter No. 1891), the software is to include algorithms for estimating the effect of water accumulation on deck (WOD). For example, in addition to the predefined significant wave height taken from the approved stability document, the software allows the crew to input manually the significant wave height of the ship navigation area. For checking the correctness of the algorithms for estimating the effect of WOD, the calculations with two additional significant wave heights are to be submitted.

Table 1 : Permeability for internal spaces

Spaces	Default	Full	Partially filled	Empty
Container spaces	0,95	0,70	0,80	0,95
Dry cargo spaces	0,95	0,70	0,80	0,95
Ro-Ro spaces	0,95	0,90	0,90	0,95
Cargo liquids	0,95	0,70	0,80	0,95
Intended for consumable liquids	0,95	0,95	0,95	0,95
Stores	0,95	0,60	0,60	0,95
Occupied by machinery	0,85			
Void spaces	0,95			
Occupied by accommodation	0,95			

3.5 Hull girder forces and moments

3.5.1 General

The loading program is to be capable of calculating the following hull girder forces and moments in accordance with Ch 5, Sec 4, [2]:

- Still Water Shear Force (SWSF) including the shear force correction, where applicable
- Still Water Bending Moment (SWBM)
- Still Water Torsion Moment (SWTM), where applicable
- for ships with relatively large openings in the strength deck, additional considerations such as torsional loads are to be considered.

The data which are to be provided to, or accepted by, the Society are specified in Tab 3.

Read-out points are usually to be selected at the position of the transverse bulkheads or other obvious boundaries. Additional read-out points may be required between bulkheads of long holds or tanks, or between container stacks.

Where the still water torsion moments are required to be calculated, one test condition is to demonstrate such a calculation.

The calculated forces and moments are to be displayed in both graphical and tabular formats, including the percentage of permissible values. The screen and hardcopy output is to display the calculated forces or moments, and the corresponding permissible limits, at each specified read-out point. Alternative limits may be considered by the Society on a case by case basis.

3.5.2 Acceptable tolerances

The accuracy of the calculation program is to be within the acceptable tolerance band, specified in Tab 2, of the results at each read-out point obtained by the Society, using an independent program or the approved loading manual with identical input.

3.5.3 Permissible limits and restrictions

The user is to be able to view the following Society structural limitations in a clear and unambiguous manner:

- all permissible still water shear forces and still water bending moments
- where applicable, the permissible still water torsion moments
- where applicable, all local loading limits both for one hold and for adjacent hold loadings
- cargo hold weight
- ballast tank/hold capacities
- filling restrictions.

It is to be readily apparent to the user when any of the structural limits has been exceeded.

Table 2 : Tolerance band for the comparison of computational accuracy

Computation	Tolerance (percentage of the permissible values)
Still Water Shear Force	± 5%
Still Water Bending Moment	± 5%
Still Water Torsion Moment, where applicable	± 5%

Table 3 : Data to be provided to, or to be accepted by, the Society

Calculation	Data to be provided to, or accepted by, the Society
Still Water Shear Force (SWSF)	<ul style="list-style-type: none"> • The read-out points (frame locations) for the SWSF calculations. These points are normally selected at the position of the transverse bulkhead or other obvious boundaries. Additional read-out points may be specified between the bulkheads of long holds or tanks or between container stacks. • Shear force correction factors and method of application. • The permissible seagoing and harbour SWSF limits at the read-out points. Where appropriate, additional sets of permissible SWSF values may be specified.
Still Water Bending Moment (SWBM)	<ul style="list-style-type: none"> • The read-out points (frame locations) for the SWBM calculations. These points are normally selected at the position of the transverse bulkhead, mid-hold or other obvious boundaries. • The permissible seagoing and harbour SWBM limits at the read-out points. Where appropriate, additional sets of permissible SWBM values may be specified.
Still Water Torsion Moment (SWTM), where applicable	<ul style="list-style-type: none"> • The read-out points (frame locations) for the SWTM calculations, where applicable. • The permissible limits at the read-out points.

3.6 Intact stability

3.6.1 Application

The loading instrument approval for stability purposes is required when a loading instrument to be installed on board a ship performs stability calculations, as stated in [3.3.6].

3.6.2 Data verification approval - Endorsed test conditions

The requirements in [3.4.2] apply. In addition, at least one of the four loading conditions required is to show the compartments, intended for liquid loads in which the free surface effect is considerable, filled in order to have the maximum free surface moment.

The additional data necessary for the approval of the loading instrument for stability purposes are specified in [3.6.3].

In order to obtain the approval of the loading instrument, all the intact stability requirements (and relevant criteria) applicable to the ship, reported in Ch 4, Sec 2 as well as in Part D or Part E, are to be available in the computer output; the lack of any one of them is sufficient to prevent the endorsement of the test conditions.

3.6.3 Additional data to be submitted

In addition to the data required in [3.4.3], the following are to be submitted:

- cross curves of stability calculated on a free trimming basis, for the ranges of displacement and trim anticipated in normal operating conditions, with indication of the volumes which have been considered in the computation of these curves
- capacity tables indicating, for each compartment or space, the values of the co-ordinates X_G , Y_G and Z_G of the centre of gravity, as well as the inertia, corresponding to an adequate number of filling percentages
- list of all the openings (location, tightness, means of closure), pipes or other sources which may lead to progressive flooding
- deadweight definitions for each loading condition in which, for any load taken into account, the following information is to be specified:
 - weight and centre of gravity co-ordinates
 - percentage of filling (if liquid load)
 - free surface moment (if liquid load)
- information on loading restrictions (maximum filling level or percentage in liquid cargo tanks, maximum KG or minimum GM curve or table which can be used to determine compliance with the applicable intact and damage stability criteria), when applicable
- all the intact stability criteria applicable to the ship concerned.

3.7 Grain loading

3.7.1 Application

The loading instrument approval for stability purposes is required when a loading instrument to be installed on board a ship performs grain loading stability calculations, as stated in [3.3.6].

In such case, the loading instrument is also to perform intact stability calculations, and therefore the approval is to be based on the requirements specified in [3.6].

Additional requirements relevant to grain stability are provided in [3.7.2] and [3.7.3].

3.7.2 Data verification approval - Endorsed test conditions

The requirements stated in [3.6.2] apply. In addition, when the ship is allowed to carry grain in slack hold, at least one of the four loading conditions required is to include partially filled holds.

The additional data necessary for the approval of the loading instrument for grain stability purposes are specified in [3.7.3].

In order to obtain the approval of the loading instrument, all the grain stability requirements and relevant criteria specified in NR 467 Pt D, Ch 4, Sec 3, [1.2] are to be available in the computer output.

In addition, the outputs are to include:

- the reference to the type of calculation (trimmed or untrimmed ends)
- the value of the actual grain heeling moment for each hold
- the value of the maximum permissible grain heeling moment for each hold
- the total value of the actual grain heeling moment
- the total value of the maximum permissible grain heeling moment.

The lack of any of the above is sufficient to prevent the endorsement of the test conditions.

3.7.3 Additional data to be submitted

In addition to the data required in [3.6.3], the following are to be submitted:

- calculation of the total grain heeling moment
- calculation of the maximum permissible total grain heeling moment as a function of the draught (or displacement) and maximum KG

- curves or tables of volume, centre of volume and volumetric heeling moment for partially filled compartments (if applicable)
- for filled holds: volumetric heeling moment for trimmed and/or untrimmed ends, as applicable, including temporary bulkheads, if any.

3.8 Damage stability

3.8.1 Application

The loading instrument approval for stability purposes is required when a loading instrument to be installed on board a ship performs damage stability calculations, as stated in [3.3.6].

In such case, the loading instrument is also to perform intact stability calculations, and therefore the approval is to be based on the requirements specified in [3.6].

Additional requirements relevant to damage stability are given in [3.8.2] and [3.8.3].

3.8.2 Data verification approval - Endorsed test conditions

The requirements specified in [3.6.2] apply.

The additional data necessary for the approval of the loading instrument for stability purposes are specified in [3.8.3].

The approval of damage stability calculations performed by a loading instrument is limited to those relevant to deterministic damage stability rules specified in Part D applicable to ships with one of the service notations **passenger ship**, **oil tanker ESP**, **chemical tanker ESP**, **liquefied gas carrier** or **LNG bunkering ship**. In order to obtain the approval of the loading instrument, all the damage stability requirements (and relevant criteria) applicable to the ship are to be available in the computer output. The lack of any one of them is sufficient to prevent the endorsement of the test conditions.

3.8.3 Additional data to be submitted

In addition to the data required in [3.6.3], the following are to be submitted:

- List of all the damage cases which are to be considered in accordance with the relevant deterministic damage stability rules. Each damage case is to clearly indicate all the compartments or spaces taken into account, as well as the permeability associated with each compartment or space.
This information is to be taken from the approved damage stability documentation, and the source details are to be clearly indicated; in the case of unavailability of such documentation, the above-mentioned information may be requested from the Society
- All the damage stability criteria applicable to the ship concerned.

3.9 Acceptable tolerances

3.9.1 General

The acceptable tolerances for the stability particulars are to be in agreement with the requirements of IACS Unified Requirements UR L5 as amended.

Appendix 1 Equivalences between Current Revision and July 2021 Edition of the Rules for the Classification of Steel Ships

1 General

1.1 Equivalences between current revision and edition July 2021 of NR467, Part B

1.1.1 Tab 1 provides equivalences between the provisions of the current revision of the Rules and former revision (Edition July 2021 amended in January 2022).

Table 1 : Equivalences between current revision and edition July 2021 of NR467, Part B

Reference in Current revision of Part B	Reference in July 2021 edition of Part B	Reference in Current revision of Part B	Reference in July 2021 edition of Part B	Reference in Current revision of Part B	Reference in July 2021 edition of Part B
Ch 1, Sec 1	Ch 1, Sec 1	Ch 5, Sec 5	Ch 5, Sec 5	Ch 11, Sec 3	Ch 8, Sec 2
Ch 1, Sec 2	–	Ch 5, Sec 6	Ch 5, Sec 6	Ch 11, Sec 4	Ch 9, Sec 3
Ch 1, Sec 3	Ch 1, Sec 2	Ch 5, Sec 7	Ch 5, App 1		Ch 5, Sec 6, [2]
Ch 1, Sec 4	Ch 1, Sec 3		–		Ch 7, Sec 1
–	Ch 1, Sec 4	Ch 5, Sec 8	Ch 5, Sec 1, [2.5.2]	Ch 11, Sec 5	Ch 7, Sec 2
Ch 1, Sec 5	Ch 10, Sec 2	Ch 6, Sec 1	Ch 5, Sec 2, [2.1.2]		Ch 8, Sec 4
Ch 2, Sec 1	Ch 2, Sec 1		Ch 6, Sec 1	Ch 6, Sec 1	Ch 11, Sec 6
Ch 2, Sec 2	Ch 2, Sec 2	Ch 6, Sec 2	Ch 6, Sec 2	Ch 11, Sec 7	Ch 8, Sec 6
Ch 2, Sec 3	Ch 2, Sec 3		Ch 6, Sec 3	Ch 6, Sec 3	Ch 11, Sec 8
Ch 2, Sec 1	Ch 3, Sec 1	Ch 6, App 1	Ch 6, Sec 1, [2.6]	Ch 11, Sec 9	Ch 8, Sec 7
Ch 3, Sec 2	Ch 3, Sec 2		Ch 6, Sec 2, [2.3]	Ch 11, Sec 10	Ch 8, Sec 8
Ch 3, Sec 3	Ch 3, Sec 3		Ch 6, Sec 2, [2.4]	Ch 11, Sec 11	Ch 8, Sec 9
Ch 3, App 1	Ch 3, App 1	Ch 6, App 2	Ch 6, App 1	Ch 11, Sec 12	Ch 8, Sec 10
Ch 3, App 2	Ch 3, App 2	Ch 7, Sec 1	–	Ch 11, Sec 13	Ch 8, Sec 11
Ch 3, App 3	Ch 3, App 3	Ch 7, Sec 2	–	Ch 12, Sec 1	Ch 9, Sec 1
Ch 3, App 4	Ch 3, App 4	Ch 7, Sec 3	Chapter 7	Ch 12, Sec 2	Ch 9, Sec 2
Ch 4, Sec 1	Ch 4, Sec 1	Ch 7, Sec 4	Ch 7, Sec 1	Ch 12, Sec 3	Ch 9, Sec 3
Ch 4, Sec 2	Ch 4, Sec 2, [1]	Ch 7, Sec 5	Ch 7, Sec 2	Ch 12, Sec 4	Ch 9, Sec 4
	Ch 4, Sec 2, [2]	Ch 7, Sec 6	Ch 7, Sec 3	Ch 12, App 1	Ch 9, App 1
Ch 4, Sec 3	Ch 4, Sec 2, [3]	Ch 7, App 1	Ch 7, App 2	Ch 12, App 2	Ch 9, App 2
Ch 4, Sec 4	Ch 10, Sec 1	Ch 8, Sec 1	Ch 7, App 1	– (1)	Ch 10, App 1
Ch 4, Sec 5	Ch 4, Sec 3	Ch 8, App 1		Ch 13, Sec 1	Ch 13, Sec 2
Ch 4, Sec 6	Ch 4, Sec 4	Ch 8, App 2	Ch 7, App 3	Ch 13, Sec 3	
	Ch 4, Sec 5	Ch 8, App 3	Ch 7, Sec 1	Ch 13, Sec 4	Ch 11, Sec 2
	Ch 4, Sec 6	Ch 9, Sec 1		Ch 7, Sec 2	Ch 13, Sec 5
Ch 4, Sec 7	Ch 5, Sec 1	Ch 10, Sec 1		Ch 7, Sec 3	Ch 13, Sec 6
Ch 5, Sec 2			Ch 5, Sec 4	Ch 7, Sec 4	Ch 13, App 1
Ch 5, Sec 3	Ch 5, Sec 3	Ch 11, Sec 1	Ch 8, Sec 1	Ch 13, App 2	Ch 11, App 2
Ch 5, Sec 4	Ch 5, Sec 2	Ch 11, Sec 2	Ch 8, Sec 3		

(1) See Pt D, Ch 4, App 2

Part B

Hull and Stability

CHAPTER 2

GENERAL ARRANGEMENT DESIGN

- Section 1 Subdivision Arrangement
- Section 2 Compartment Arrangement
- Section 3 Access Arrangement

Section 1 Subdivision Arrangement

1 General

1.1 Application to ships having additional service feature SPxxx or SPxxx-capable

1.1.1 Ships having additional service feature **SPxxx** or **SPxxx-capable** with xxx equal to or greater than 240 are to comply, in addition to the applicable requirements of this Section, with the requirements of Pt D, Ch 11, Sec 2, considering the special personnel as passengers.

1.1.2 Ships having additional service feature **SPxxx** or **SPxxx-capable** with xxx less than 240 are to comply with the requirements of this Section, unless otherwise specified, considering the special personnel as crew.

2 Number and arrangement of transverse watertight bulkheads

2.1 Number of watertight bulkheads

2.1.1 General

All ships, in addition to complying with the requirements of [2.1.2], are to have at least the following transverse watertight bulkheads:

- one collision bulkhead
- one after peak bulkhead
- two bulkheads forming the boundaries of the machinery space in ships with machinery amidships, and a bulkhead forward of the machinery space in ships with machinery aft. In the case of ships with an electrical propulsion plant, both the generator room and the engine room are to be enclosed by watertight bulkheads.

2.1.2 Additional bulkheads

For ships not required to comply with subdivision regulations, transverse bulkheads adequately spaced and in general not less in number than indicated in Tab 1 are to be fitted.

Additional bulkheads may be required for ships having to comply with subdivision or damage stability criteria (see Part D or Part E for the different types of ships).

Table 1 : Number of bulkheads

Length (m)	Number of bulkheads for ships with aft machinery (1)	Number of bulkheads for other ships
$L < 65$	3	4
$65 \leq L < 85$	4	5
$85 \leq L < 105$	4	5
$105 \leq L < 120$	5	6
$120 \leq L < 145$	6	7
$145 \leq L < 165$	7	8
$165 \leq L < 190$	8	9
$L \geq 190$	to be defined on a case by case basis	
(1) After peak bulkhead and aft machinery bulkhead are the same.		

2.2 Water ingress detection

2.2.1 A water ingress detection system is to be fitted according to Pt C, Ch 1, Sec 10, [6.12].

3 Collision bulkhead

3.1

3.1.1 A collision bulkhead is to be fitted which is to be watertight up to the bulkhead deck of passenger ships and the freeboard deck of cargo ships. This bulkhead is to be located at a distance from the forward perpendicular FP_{LL} of not less than 5 per cent of the length L_{LL} of the ship or 10 m, whichever is the less, and, except as may be permitted by the Society, not more than 8 per cent of L_{LL} or 5 per cent of the $L_{LL} + 3$ m, whichever is the greater.

For ships not covered by the SOLAS Convention, the length L_{LL} need not be taken less than 50 m, unless required by the National Authorities.

3.1.2 Where any part of the ship below the waterline extends forward of the forward perpendicular, e.g. a bulbous bow, the distances, in metres, stipulated in [3.1.1] are to be measured from a point either:

- at the mid-length of such extension, or
- at a distance 1,5 per cent of the length L_{LL} of the ship forward of the forward perpendicular, or
- at a distance 3 metres forward of the forward perpendicular; whichever gives the smallest measurement.

3.1.3 The bulkhead may have steps or recesses provided they are within the limits prescribed in [3.1.1] or [3.1.2].

No door, manhole, ventilation duct or any other opening is to be fitted in the collision bulkhead below the bulkhead deck of passenger ships and the freeboard deck of cargo ships.

3.1.4 At Owner request and subject to the agreement of the flag Administration, the Society may, on a case by case basis, accept a distance from the collision bulkhead to the forward perpendicular FP_{LL} greater than the maximum specified in [3.1.1] and [3.1.2], provided that subdivision and stability calculations show that, when the ship is in upright condition on full load summer waterline, flooding of the space forward of the collision bulkhead will not result in any part of the freeboard deck becoming submerged, or in any unacceptable loss of stability.

In such a case, the attention of the Owner and the Shipyard is drawn to the fact that the flag Administration may impose additional requirements and that such an arrangement is, in principle, formalised by the issuance of a certificate of exemption under the SOLAS Convention provisions. Moreover, in case of change of flag, the taking Administration may not accept the exemption.

3.1.5 Where a long forward superstructure is fitted, the collision bulkhead is to be extended weathertight to the next deck above the bulkhead deck of passenger ships and the freeboard deck of cargo ships. The extension need not be fitted directly above the bulkhead below provided that all parts of the extension, including any part of the ramps attached to it, are located within the limits prescribed in [3.1.1] or [3.1.2] with the exemption permitted by [3.1.6] and the part of the deck which forms the step is made effectively weathertight. The extension is to be so arranged as to preclude the possibility of the bow door or ramp, where fitted, causing damage to it in the case of damage to, or detachment of, a bow door or any part of the ramp.

3.1.6 Where bow doors are fitted and a sloping loading ramp forms part of the extension of the collision bulkhead above the bulkhead deck of passenger ships and the freeboard deck of cargo ships, the ramp is to be weathertight over its complete length. In cargo ships, the part of the ramp which is more than 2,3 m above the freeboard deck may extend forward of the limit specified in [3.1.1] or [3.1.2]. Ramps not meeting the above requirements are to be disregarded as an extension of the collision bulkhead.

3.1.7 The number of openings in the extension of the collision bulkhead above the freeboard deck is to be restricted to the minimum compatible with the design and normal operation of the ship. All such openings are to be capable of being closed weathertight.

4 After peak, machinery space bulkheads and stern tubes

4.1

4.1.1 General

Bulkheads are to be fitted separating the machinery space from cargo and accommodation spaces forward and aft and made watertight up to the bulkhead deck of passenger ships and the freeboard deck of cargo ships. An after peak bulkhead is also to be fitted and made watertight up to the bulkhead deck or the freeboard deck. The after peak bulkhead may, however, be stepped below the bulkhead deck or the freeboard deck, provided the degree of safety of the ship as regards subdivision is not thereby diminished.

4.1.2 Sterntubes

In all cases, sterntubes are to be enclosed in watertight spaces of moderate volume. In passenger ships, the stern gland is to be situated in a watertight shaft tunnel or other watertight space separate from the sterntube compartment and of such volume that, if flooded by leakage through the stern gland, the bulkhead deck will not be immersed. In cargo ships, other measures to minimise the danger of water penetrating into the ship in case of damage to sterntube arrangements may be taken at the discretion of the Society.

For ships less than 65 m, where the after peak bulkhead in way of the sterntube stuffing box is not provided, sterntubes are to be enclosed in watertight spaces of moderate volume.

5 Height of transverse watertight bulkheads other than collision bulkhead and after peak bulkhead

5.1

5.1.1 Transverse watertight bulkheads are to extend watertight up to the bulkhead deck. In exceptional cases at the request of the Owner, the Society may allow transverse watertight bulkheads to terminate at a deck below that from which freeboard is measured, provided that this deck is at an adequate distance above the full load waterline.

5.1.2 Where it is not practicable to arrange a watertight bulkhead in one plane, a stepped bulkhead may be fitted. In this case, the part of the deck which forms the step is to be watertight and equivalent in strength to the bulkhead.

6 Openings in watertight bulkheads and decks for ships having a service notation other than passenger ship or ro-ro passenger ship

6.1 Application

6.1.1 The requirements in [6.2] and [6.3] apply to ships having a service notation other than **passenger ship** or **ro-ro passenger ship**.

Openings in watertight bulkheads below the bulkhead deck for ships with service notation **passenger ship** or **ro-ro passenger ship** are to comply with Part D, Chapter 11 or Part D, Chapter 12, respectively.

6.1.2 The requirements in [6.2] and [6.3] are not applicable to ships having additional service feature **SPxxx** or **SPxxx-capable** with xxx less than 240.

Openings in watertight bulkheads below the bulkhead deck for ships with additional service feature **SPxxx** or **SPxxx-capable** with xxx less than 240 are to comply with Part D, Chapter 11.

6.2 General

6.2.1 *The number of openings in watertight subdivisions is to be kept to a minimum compatible with the design and proper working of the ship. Where penetrations of watertight bulkheads and internal decks are necessary for access, piping, ventilation, electrical cables, etc., arrangements are to be made to maintain the watertight integrity. The Society may permit relaxation in the watertightness of openings above the freeboard deck, provided that it is demonstrated that any progressive flooding can be easily controlled and that the safety of the ship is not impaired.*

6.2.2 No door, manhole ventilation duct or any other opening is permitted in the collision bulkhead below the subdivision deck.

6.2.3 Lead or other heat sensitive materials may not be used in systems which penetrate watertight subdivision bulkheads, where deterioration of such systems in the event of fire would impair the watertight integrity of the bulkheads.

6.2.4 Valves not forming part of a piping system are not permitted in watertight subdivision bulkheads.

6.2.5 The requirements relevant to the operating systems for doors complying with the provisions in [6.3] are specified in:

- Tab 2 for doors of internal watertight bulkheads, and
- Tab 3 for doors of external watertight boundaries below equilibrium or intermediate waterplane.

6.2.6 A diagram showing the location of the door and an indication to show its position is to be provided at the central operating console located at the navigation bridge. A red light is to indicate that the door is in the open position and a green light is to indicate that the door is in the closed position. The red light is to flash when the door is in an intermediate position.

6.2.7 Signboard/instructions are to be placed in way of the door advising how to act when the door is closed.

6.2.8 For watertight doors, including sliding doors, operated by hydraulic door actuators, either a central hydraulic unit or an independent hydraulic unit for each door is to be provided with a low fluid level alarm or low gas pressure alarm, as applicable or some other means of monitoring loss of stored energy in the hydraulic accumulators. This alarm is to be both audible and visible and is to be located at the navigation bridge.

6.3 Openings in the watertight bulkheads and internal decks

6.3.1 Openings used while at sea

Doors provided to ensure the watertight integrity of internal openings which are used while at sea are to be sliding watertight doors capable of being remotely closed from the bridge and are also to be operable locally from each side of the bulkhead.

For cargo ships, the angle of list at which operation by hand is to be possible is 30 degrees.

Position indicators are to be provided at all remote operating positions for all ships and locally on both sides of the internal doors for cargo ships. An audible alarm is also to be provided at the door closure. The power, control and indicators are to be operable in the event of main power failure. Particular attention is to be paid to minimise the effect of control system failure. Each power-

operated sliding watertight door is to be provided with an individual hand-operated mechanism. The possibility of opening and closing the door by hand at the door itself from both sides is to be assured.

Failure of the normal power supply of the required alarms is to be indicated by an audible and visual alarm at the navigation bridge.

6.3.2 Openings normally closed at sea

Access doors and access hatch covers normally closed at sea, intended to ensure the watertight integrity of internal openings, are to be provided with position indicators on the bridge for all ships, and locally on both sides of the internal doors for cargo ships, showing whether these doors or hatch covers are open or closed. A notice is to be affixed to each such door or hatch cover to the effect that it is not to be left open.

6.3.3 Doors or ramps in large cargo spaces

Watertight doors or ramps of satisfactory construction may be fitted to internally subdivide large cargo spaces, provided that the Society is satisfied that such doors or ramps are essential. These doors or ramps may be hinged, rolling or sliding doors or ramps, but are not to be remotely controlled. Such doors are to be closed before the voyage commences and are to be kept closed during navigation. Should any of the doors or ramps be accessible during the voyage, they are to be fitted with a device which prevents unauthorised opening.

The word “satisfactory” means that scantlings and sealing requirements for such doors or ramps are to be sufficient to withstand the maximum head of the water at the flooded waterline.

6.3.4 Openings permanently kept closed at sea

Other closing appliances which are kept permanently closed at sea to ensure the watertight integrity of internal openings are to be provided with a notice which is to be affixed to each such closing appliance to the effect that it is to be kept closed. Manholes fitted with closely bolted covers need not be so marked.

Table 2 : Doors in internal watertight bulkheads of cargo ships

Position relative to freeboard deck	Frequency of use while at sea	Type(1)	Remote closure	Remote indication	Audible or visual alarm	Notice
Below	Used	POS	X	X	X (local)	
	Normally closed(2)	S, H		X		X
	Permanently closed(3)	S, H				X
At or above	Used(4)(5)	POS	X	X	X (local)	
	Normally closed(2)	S, H		X		X
	Permanently closed(3)	S, H				X

(1) POS : Power operated, sliding or rolling
 S : Sliding or rolling
 H : Hinged

(2) If hinged, this door is to be of single action type.

(3) Doors are to be fitted with a device which prevents unauthorized opening.

(4) According to Ch 3, App 4, [3], doors separating a main machinery space from a steering gear compartment may be hinged single action type provided the lower sill of such doors is above the summer load line and the doors remain closed at sea whilst not in use.

(5) Under MARPOL, hinged watertight doors may be acceptable in watertight bulkhead in the superstructure.

Table 3 : Doors in external watertight boundaries below equilibrium or intermediate waterplane of cargo ships

Position relative to freeboard deck	Frequency of use while at sea	Type(1)	Remote closure	Remote indication	Audible or visual alarm	Notice
Below	Permanently closed(2)	S, H		X		X
At or above	Normally closed(3)	S, H		X		X
	Permanently closed(2)	S, H		X		X

(1) POS : Power operated, sliding or rolling
 S : Sliding or rolling
 H : Hinged

(2) Doors are to be fitted with a device which prevents unauthorized opening.

(3) If hinged, this door is to be of single action type.

Section 2 Compartment Arrangement

1 General

1.1 Application to ships having additional service feature SPxxx or SPxxx-capable

1.1.1 Ships having additional service feature **SPxxx** or **SPxxx-capable** with xxx equal to or greater than 240 are to comply, in addition of the applicable requirements of this Section with the requirements of Pt D, Ch 11, Sec 2, considering the special personnel as passengers.

1.1.2 Ships having additional service feature **SPxxx** or **SPxxx-capable** with xxx less than 240 are to comply with the requirements of this Section, unless otherwise specified, considering the special personnel as crew.

1.2 Definitions

1.2.1 Cofferdam

A cofferdam means an empty space arranged so that compartments on each side have no common boundary; a cofferdam may be located vertically or horizontally. As a rule, a cofferdam is to be properly ventilated and of sufficient size to allow for inspection.

2 Cofferdams

2.1 Cofferdam arrangement

2.1.1 Cofferdams are to be provided between:

- fuel oil tanks and lubricating oil tanks
- compartments intended for liquid hydrocarbons (fuel oil, lubricating oil) and compartments intended for fresh water (drinking water, water for propelling machinery and boilers, water for fire-fighting purposes)
- compartments intended for liquid hydrocarbons (fuel oil, lubricating oil) and tanks intended for the carriage of liquid foam for fire extinguishing.

2.1.2 Cofferdams separating:

- fuel oil tanks and lubricating oil tanks
- lubricating oil tanks from compartments intended for fresh water
- lubricating oil tanks from those intended for the carriage of liquid foam for fire extinguishing
- fuel oil tanks from tanks intended for the carriage of liquid foam for fire extinguishing on ships having the service notation **fire-fighting**

need not to be required when agreed by the Society in relation to the characteristics and dimensions of the spaces containing such tanks, provided that:

- the thickness of common boundary plates of adjacent tanks is increased, with respect to the thickness obtained according to Ch 7, Sec 4, by 2 mm in the case of tanks carrying fresh water or boiler feed water, and by 1 mm in all other cases
- the sum of the throats of the weld fillets at the edges of these plates is not less than the thickness of the plates themselves
- the structural test is carried out with a head increased by 1 m with respect to Ch 13, Sec 6, [1.4].

2.1.3 Vented cofferdam may be required to separate heated oil fuel tanks from enclosed spaces located directly above (see Pt C, Ch 1, Sec 10, [11.7.2], item a)).

3 Double bottoms

3.1 Double bottom arrangement for ships other than tankers

3.1.1 A double bottom is to be fitted extending from the collision bulkhead to the after peak bulkhead, as far as this is practicable and compatible with the design and proper working of the ship.

3.1.2 Where a double bottom is required to be fitted, the inner bottom is to be continued out to the ship's sides in such a manner as to protect the bottom to the turn of the bilge. Such protection is to be deemed satisfactory if the inner bottom is not lower at any part than a plane parallel with the keel line and which is located not less than a vertical distance h measured from the keel line, as calculated by the formula:

$h = B/20$

However, in no case is the value of h to be less than 760 mm, and need not to be taken as more than 2 m.

3.1.3 Small wells constructed in the double bottom in connection with drainage arrangement are not to extend downward more than necessary. The vertical distance from the bottom of such a well to a plane coinciding with the keel line is not to be less than $h/2$ or 500 mm, whichever is greater, or compliance with requirement defined in Ch 3, Sec 3, [3.4.3] is to be shown for that part of the ship.

Other wells (e.g. for lubricating oil under main engines) may be permitted by the Society if satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with this regulation.

Proof of equivalent protection is to be shown by demonstrating that the ship is capable of withstanding bottom damages as specified in Ch 3, Sec 3, [3.4.3]. Alternatively, wells for lubricating oil below main engines may protrude into the double bottom below the boundary line defined by the distance h provided that the vertical distance between the well bottom and a plane coinciding with the keel line is not less than $h/2$ or 500 mm, whichever is the greater.

For a cargo ship of less than 80 m in length, the arrangements are to provide a level of safety to the satisfaction of the Society.

3.1.4 A double bottom need not be fitted in way of watertight tanks, including dry tanks of moderate size, provided the safety of the ship is not impaired in the event of bottom or side damage as defined in Ch 3, Sec 3, [3.4].

3.1.5 Any part of a ship that is not fitted with a double bottom in accordance with [3.1.1] or [3.1.4] is to be capable of withstanding bottom damages, as specified in Ch 3, Sec 3, [3.4.3]. For cargo ships of less than 80 m in length, the alternative arrangements are to provide a level of safety to the satisfaction of the Society.

3.1.6 In the case of unusual bottom arrangements, it is to be demonstrated that the ship is capable of withstanding bottom damages as specified in Ch 3, Sec 3, [3.4.3]. For cargo ships of less than 80 m in length, the alternative arrangements are to provide a level of safety to the satisfaction of the Society.

4 Compartments forward of the collision bulkhead

4.1 General

4.1.1 The fore peak and other compartments located forward of the collision bulkhead cannot be used for the carriage of fuel oil or other flammable products.

This requirement does not apply to ships of less than 400 tons gross tonnage, except for those where the fore peak is the forward cofferdam of tanks arranged for the carriage of flammable liquid products having a flash point not exceeding 60°C.

5 Minimum bow height

5.1 General

5.1.1 The bow height F_b defined as the vertical distance at the forward perpendicular between the waterline corresponding to the assigned summer freeboard and the designed trim and the top of the exposed deck at side, is to be not less than:

$$F_b = [6075(L_{LL}/100) - 1875(L_{LL}/100)^2 + 200(L_{LL}/100)^3] \times [2,08 + 0,609C_b - 1,603C_{wf} - 0,0129(L_{LL}/T_1)]$$

where:

F_b : Calculated minimum bow height, in mm

T_1 : Draught at 85% of the least moulded depth, in m, as defined in Ch 1, Sec 3, [2.1.6]

C_{wf} : Waterplane area coefficient forward of $L_{LL}/2$:

$$C_{wf} = \frac{A_{wf}}{\frac{L_{LL}B}{2}}$$

A_{wf} : Waterplane area forward of $L_{LL}/2$ at draught T_1 , in m².

For ships to which timber freeboards are assigned, the summer freeboard (and not the timber summer freeboard) is to be assumed when applying the formula above.

5.1.2 Where the bow height required in [5.1.1] is obtained by sheer, the sheer is to extend for at least 15% of L_{LL} of the ship measured from the forward perpendicular. Where it is obtained by fitting a superstructure, such superstructure is to extend from the stem to a point at least $0,07L_{LL}$ abaft the forward perpendicular and is to be enclosed as defined in Ch 11, Sec 5.

5.1.3 Ships which, to suit exceptional operational requirements, cannot meet the requirements in [5.1.1] and [5.1.2] will be considered by the Society on a case by case basis.

5.1.4 The sheer of the forecastle deck may be taken into account, even if the length of the forecastle is less than $0,15L_{LL}$, but greater than $0,07L_{LL}$, provided that the forecastle height is not less than one half of standard height of superstructure between $0,07L_{LL}$ and the forward perpendicular.

5.1.5 Where the forecastle height is less than one half of the standard height of superstructure, the credited bow height may be determined as follows:

- a) Where the freeboard deck has sheer extending from abaft $0,15L_{LL}$ by a parabolic curve having its origin at $0,15L_{LL}$ abaft the forward perpendicular at a height equal to the midship depth of the ship, extended through the point of intersection of forecastle bulkhead and deck, and up to a point at the forward perpendicular not higher than the level of the forecastle deck (see Fig 1). However, if the value of the height denoted h_t in Fig 1 is smaller than the value of the height denoted h_b then h_t may be replaced by h_b in the available bow height, where:

$$h_t = Z_b \left(\frac{0,15L_{LL}}{x_b} \right)^2 - Z_t$$

Z_b, Z_t : As defined in Fig 1

h_f : Half standard height of superstructure.

- b) Where the freeboard deck has sheer extending for less than $0,15L_{LL}$ or has no sheer, by a line from the forecastle deck at side at $0,07L_{LL}$ extended parallel to the base line to the forward perpendicular (see Fig 2).

Figure 1 : Credited bow height where the freeboard deck has sheer extending from abaft $0,15 L$

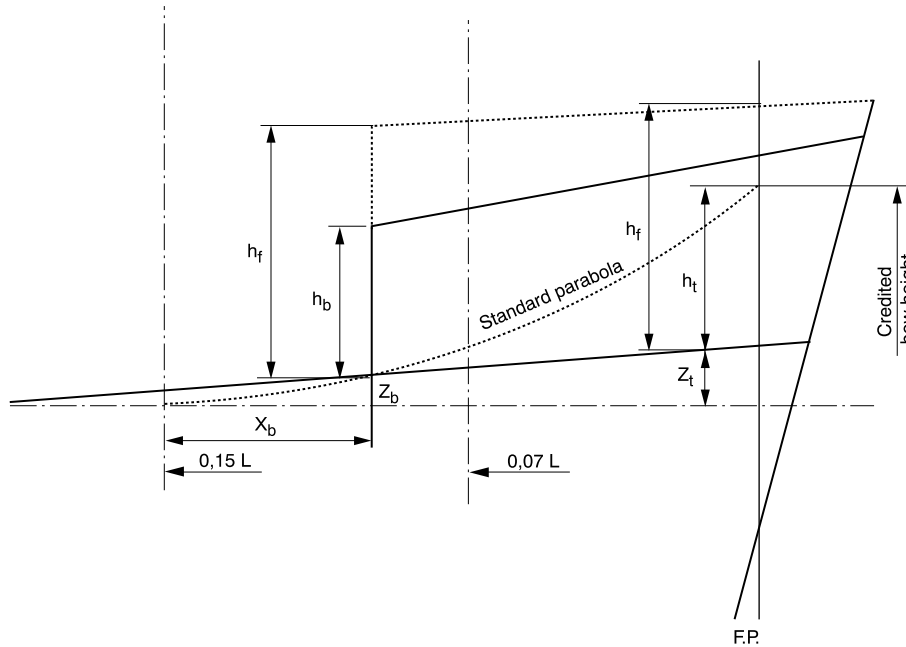
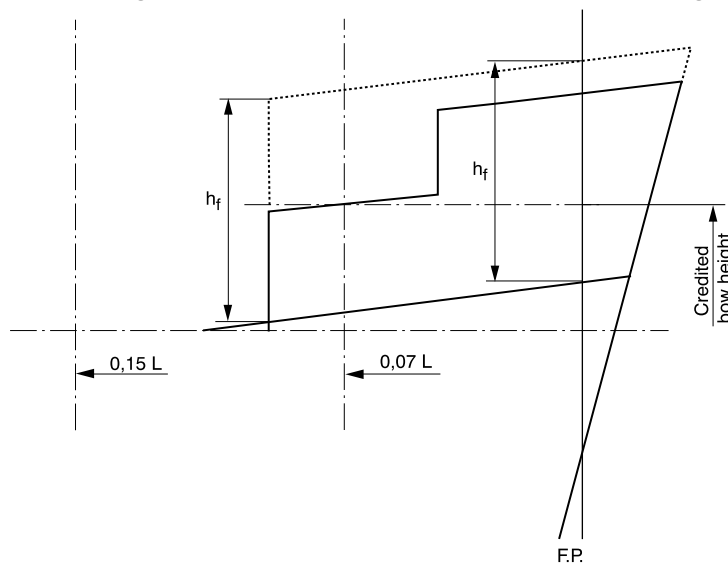


Figure 2 : Credited bow height where the freeboard deck has sheer extending for less than $0,15 L$



5.1.6 All ships assigned a type B freeboard, other than oil tankers, chemical tankers and gas carriers, are to have additional reserve buoyancy in the fore end. Within the range of $0,15L_{LL}$ abaft of the forward perpendicular, the sum of the projected area between the summer load waterline and the deck at side (A1 and A2 in Fig 3) and the projected area of an enclosed superstructure, if fitted, is, in m^2 , to be not less than:

$$A3 = (0,15 F_{min} + 4 (L_{LL}/3 + 10)) L_{LL}/1000$$

where:

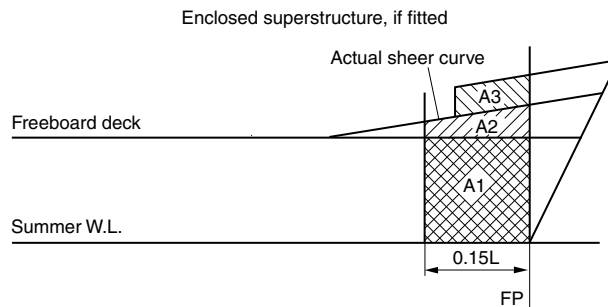
$$F_{min} : F_{min} = (F_0 \cdot f_1) + f_2$$

F_0 : Tabular freeboard, in mm, taken from the International Convention on Load Lines, as amended, Table 28.2, corrected for regulation 27(9) or 27(10), as applicable

f_1 : Correction for block coefficient given in the International Convention on Load Lines, as amended, regulation 30

f_2 : Correction for depth, in mm, given in the International Convention on Load Lines, as amended, regulation 31.

Figure 3 : Areas A1, A2 and A3



6 Shaft tunnels

6.1 General

6.1.1 Shaft tunnels are to be watertight.

7 Watertight ventilators and trunks

7.1 General

7.1.1 Watertight ventilators and trunks are to be carried at least up to the bulkhead deck in passenger ships and up to the freeboard deck in ships other than passenger ships.

8 Fuel oil tanks

8.1 General

8.1.1 The arrangements for the storage, distribution and utilisation of the fuel oil are to be such as to ensure the safety of the ship and persons on board.

8.1.2 As far as practicable, fuel oil tanks are to be part of the ship's structure and are to be located outside machinery spaces of category A.

Where fuel oil tanks, other than double bottom tanks, are necessarily located adjacent to or within machinery spaces of category A, at least one of their vertical sides is to be contiguous to the machinery space boundaries, they are preferably to have a common boundary with the double bottom tanks and the area of the tank boundary common with the machinery spaces is to be kept to a minimum.

Where such tanks are situated within the boundaries of machinery spaces of category A, they may not contain fuel oil having a flashpoint of less than 60°C.

Note 1: Machinery spaces of category A are defined in Pt C, Ch 4, Sec 1, [3.29].

8.1.3 Fuel oil tanks may not be located where spillage or leakage therefrom can constitute a hazard by falling on heated surfaces. Precautions are to be taken to prevent any oil that may escape under pressure from any pump, filter or heater from coming into contact with heated surfaces.

Fuel oil tanks in boiler spaces may not be located immediately above the boilers or in areas subjected to high temperatures, unless special arrangements are provided in agreement with the Society.

8.1.4 Where a compartment intended for goods or coal is situated in proximity of a heated liquid container, suitable thermal insulation is to be provided.

8.2 Fuel oil tank protection

8.2.1 All ships with an aggregate oil fuel capacity of 600 m³ are to comply with the requirements of the Regulation 12 A of Annex I to Marpol Convention, as amended.

9 Tanks containing fuel for auxiliary vehicles

9.1 General

9.1.1 Tanks containing fuel for auxiliary vehicles are to comply with the requirements of Pt C, Ch 4, Sec 11, [3.1].

9.2 Tank protection and segregation

9.2.1 Tanks containing fuel for auxiliary vehicles are to be located in accordance with the requirements of Pt C, Ch 4, Sec 11, [3.2].

10 Tanks containing chemical treatment fluids for exhaust gas pollution prevention system

10.1 Tank protection and segregation

10.1.1 Tanks containing chemical treatment fluids for exhaust gas pollution prevention system are to comply with requirements of:

- Pt C, Ch 1, Sec 11, [3.2] for tank containing urea
- Pt C, Ch 1, Sec 11, [4.2] for tank containing sodium hydroxide (NaOH) or calcium hydroxide (Ca(OH)₂)
- Pt C, Ch 1, Sec 11, [4.8] for tank residues
- Pt C, Ch 1, Sec 11, [5.4] for tanks containing other chemicals.

Section 3 Access Arrangement

1 General

1.1

1.1.1 The number and size of small hatchways for trimming and access openings to tanks or other enclosed spaces, are to be kept to the minimum consistent with access and maintenance of the space.

2 Double bottom

2.1 Inner bottom manholes

2.1.1 Inner bottom manholes are to be not less than 400 mm x 400 mm. Their number and location are to be so arranged as to provide convenient access to any part of the double bottom.

2.1.2 Inner bottom manholes are to be closed by watertight plate covers.

Doubling plates are to be fitted on the covers, where secured by bolts.

Where no ceiling is fitted, covers are to be adequately protected from damage by the cargo.

2.2 Floor and girder manholes

2.2.1 Manholes are to be provided in floors and girders so as to provide convenient access to all parts of the double bottom.

2.2.2 The size of manholes and lightening holes in floors and girders is, in general, to be less than 50 per cent of the local height of the double bottom.

Where manholes of greater sizes are needed, edge reinforcement by means of flat bar rings or other suitable stiffeners may be required.

2.2.3 Manholes may not be cut into the continuous centreline girder or floors and girders below pillars, except where allowed by the Society on a case by case basis.

3 Access arrangement to and within spaces in, and forward of, the cargo area

3.1 General

3.1.1 The requirements in [3.2] to [3.4] are not applicable to ships with service notations **bulk carrier**, **bulk carrier CSR ESP**, **bulk carrier CSR BC-A ESP**, **bulk carrier CSR BC-B ESP**, **bulk carrier CSR BC-C ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP**, **combination carrier ESP**, of 20,000 gross tonnage and over, and to ships with service notation **oil tanker ESP** of 500 gross tonnage and over. For such ships, refer to the applicable requirements of Part D.

3.1.2 The requirements in [3.2] to [3.4] are not applicable to spaces in double bottom and double side tanks.

3.2 Access to tanks

3.2.1 Tanks with a length equal to or greater than 35 m

Tanks and subdivisions of tanks having lengths of 35 m and above are to be fitted with at least two access hatchways and ladders, as far apart as practicable longitudinally.

3.2.2 Tanks with a length less than 35 m

Tanks less than 35 m in length are to be served by at least one access hatchway and ladder.

3.2.3 Dimensions of access hatchways

The dimensions of any access hatchway are to be sufficient to allow a person wearing a self-contained breathing apparatus to ascend or descend the ladder without obstruction and also to provide a clear opening to facilitate the hoisting of an injured person from the bottom of the tank. In no case is the clear opening to be less than 600 mm x 600 mm.

3.2.4 Tanks subdivided by wash bulkheads

When a tank is subdivided by one or more wash bulkheads, at least two hatchways are to be fitted, and these hatchways are to be so located that the associated ladders effectively serve all subdivisions of the tank.

3.3 Access within tanks

3.3.1 Wash bulkheads in tanks

Where one or more wash bulkheads are fitted in a tank, they are to be provided with openings not less than 600 x 800 mm and so arranged as to facilitate the access of persons wearing breathing apparatus or carrying a stretcher with a patient.

3.3.2 Passage on the tank bottom

To provide ease of movement on the tank bottom throughout the length and breadth of the tank, a passageway is to be fitted on the upper part of the bottom structure of each tank, or alternatively, manholes having at least the dimensions of 600 mm x 800 mm are to be arranged in the floors at a height of not more than 600 mm from the bottom shell plating.

3.3.3 Passageways in the tanks

- a) Passageways in the tanks are to have a minimum width of 600 mm considering the requirement for the possibility of carrying an unconscious person. Elevated passageways are to be provided with guard rails over their entire length. Where guard rails are provided on one side only, foot rails are to be fitted on the opposite side. Shelves and platforms forming a part of the access to the tanks are to be of non-skid construction where practicable and be fitted with guard rails. Guard rails are to be fitted to bulkhead and side stringers when such structures are being used for recognised access
- b) Access to elevated passageways from the ship's bottom is to be provided by means of easily accessible passageways, ladders or treads. Treads are to provide lateral support for the foot. Where rungs of ladders are fitted against a vertical surface, the distance from the centre of the rungs to that surface is to be at least 150 mm
- c) When the height of the bottom structure does not exceed 1,50 m, the passageways required in a) may be replaced by alternative arrangements having regard to the bottom structure and requirement for ease of access of a person wearing a self-contained breathing apparatus or carrying a stretcher with a patient.

3.3.4 Manholes

Where manholes are fitted, as indicated in [2.2.2], access is to be facilitated by means of steps and hand grips with platform landings on each side.

3.3.5 Guard rails

Guard rails are to be 900 mm in height and consist of a rail and intermediate bar. These guard rails are to be of substantial construction.

3.4 Construction of ladders

3.4.1 General

In general, the ladders are not to be inclined at an angle exceeding 70°. The flights of ladders are not to be more than 9 m in actual length. Resting platforms of adequate dimensions are to be provided.

3.4.2 Construction

Ladders and handrails are to be constructed of steel of adequate strength and stiffness and securely attached to the tank structure by stays. The method of support and length of stay are to be such that vibration is reduced to a practical minimum.

3.4.3 Corrosive effect of the cargo

Provision is to be made for maintaining the structural strength of the ladders and railings taking into account the corrosive effect of the cargo.

3.4.4 Width of ladders

The width of ladders is not to be less than:

- 350 mm for vertical ladders
- 400 mm for inclined ladders.

3.4.5 Treads

The treads are to be equally spaced at a distance apart measured vertically not exceeding 300 mm. They are to be formed of two square steel bars of not less than 22 mm by 22 mm in section fitted to form a horizontal step with the edges pointing upward, or of equivalent construction. The treads are to be carried through the side stringers and attached thereto by double continuous welding.

3.4.6 Sloping ladders

All sloping ladders are to be provided with handrails of substantial construction on both sides fitted at a convenient distance above the treads.

4 Shaft tunnels

4.1 General

4.1.1 Tunnels are to be large enough to ensure easy access to shafting.

4.1.2 Access to the tunnel is to be provided by a watertight door fitted on the aft bulkhead of the engine room in compliance with Ch 2, Sec 1, [6].

5 Access to steering gear compartment

5.1

5.1.1 The steering gear compartment is to be readily accessible and, as far as practicable, separated from machinery spaces.

5.1.2 Suitable arrangements to ensure working access to steering gear machinery and controls are to be provided. These arrangements are to include handrails and gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

Part B

Hull and Stability

CHAPTER 3

STABILITY

Section 1	General
Section 2	Intact Stability
Section 3	Damage Stability
Appendix 1	Inclining Test and Lightweight Check
Appendix 2	Trim and Stability Booklet
Appendix 3	Probabilistic Damage Stability Method for Cargo Ships
Appendix 4	Damage Stability Calculation for Ships Assigned with a Reduced Freeboard

Section 1 General

1 General

1.1 Application

1.1.1 General

All ships equal to or greater than 24 m in length may be assigned class only after it has been demonstrated that their intact stability is adequate. Adequate intact stability means compliance with standards laid down by the relevant Administration or with the requirements specified in this Chapter taking into account the ship's size and type. In any case, the level of intact stability is not to be less than that provided by the Rules.

1.1.2 Ships less than 24 m in length

The Rules also apply to ships less than 24 m in length. In this case, the requirements concerned may be partially omitted when deemed appropriate by the Society.

1.1.3 Approval of the Administration

Evidence of approval by the Administration concerned may be accepted for the purpose of classification.

1.2 Application to ships having additional service feature SPxxx or SPxxx-capable

1.2.1 Ships having additional service feature **SPxxx** or **SPxxx-capable** with xxx equal to or greater than 240 are to comply, in addition to the applicable requirements of this Chapter, with the requirements of Pt D, Ch 11, Sec 3, considering the special personnel as passengers.

1.2.2 Ships having additional service feature **SPxxx** or **SPxxx-capable** with xxx less than 240 are to comply with the requirements of this Chapter, unless otherwise specified, considering the special personnel as crew.

1.3 Application to ships having additional class notation STABLIFT

1.3.1 Ships having additional class notation **STABLIFT** are to comply, in addition to the applicable requirements of this Chapter, with the requirements of Pt E, Ch 8, Sec 3.

2 Examination procedure

2.1 Documents to be submitted

2.1.1 List of documents

For the purpose of the examination of the stability, the documentation listed in Ch 1, Sec 4, [1.1.2] is to be submitted for information.

The stability documentation to be submitted for approval, as indicated in Ch 1, Sec 4, [1.2.1], is as follows:

- inclining test report for the ship, as required in [2.2] or:
 - where the stability data is based on a sister ship, the inclining test report of that sister ship along with the lightship measurement report for the ship in question; or
 - where lightship particulars are determined by methods other than inclining of the ship or its sister, the lightship measurement report of the ship along with a summary of the method used to determine those particulars as indicated in [2.2.4].
- trim and stability booklet, as required in Ch 3, Sec 2, [1.1.1]
- and, as applicable:
 - grain loading manual, as required in Pt D, Ch 4, Sec 3, [1.2.2]
 - damage stability calculations, as required in Ch 3, Sec 3, [3.1]
 - damage control documentation, as required in Ch 3, Sec 3, [4]
 - loading computer documentation, as required in Ch 3, Sec 2, [1.1.2] and in Ch 3, Sec 3, [3.1.3].

A copy of the trim and stability booklet and, if applicable, the grain stability booklet, the damage control documentation or the loading computer documentation is to be available on board for the attention of the Master.

2.1.2 Provisional documentation

The Society reserves the right to accept or demand the submission of provisional stability documentation for examination.

Provisional stability documentation includes loading conditions based on estimated lightship values.

2.1.3 Final documentation

Final stability documentation based on the results of the inclining test or the lightweight check is to be submitted for examination.

When provisional stability documentation has already been submitted and the difference between the estimated values of the lightship and those obtained after completion of the test is less than:

- 2% for the displacement, and
- 1% of the length between perpendiculars for the longitudinal position of the centre of gravity

and the determined vertical position of the centre of gravity is not greater than the estimated vertical position of the centre of gravity, the provisional stability documentation may be accepted as the final stability documentation.

2.2 Inclining test/lightweight check

2.2.1 Definitions

a) Lightship

The lightship is a ship complete in all respects, but without consumables, stores, cargo, and crew and effects, and without any liquids on board except for machinery and piping fluids, such as lubricants and hydraulics, at operating levels, and mediums required for the fixed fire-extinguishing systems, such as fresh water, CO₂, dry chemical powder, foam concentrate, etc.

b) Inclining test

The inclining test is a procedure which involves moving a series of known weights, normally in the transverse direction, and then measuring the resulting change in the equilibrium heel angle of the ship. By using this information and applying basic naval architecture principles, the ship's vertical centre of gravity (VCG or KG) is determined.

c) Lightweight check

The lightweight check is a procedure which involves auditing all items which are to be added, deducted or relocated on the ship at the time of the inclining test so that the observed condition of the ship can be adjusted to the lightship condition. The weight and longitudinal, transverse and vertical location of each item are to be accurately determined and recorded. The lightship displacement and longitudinal centre of gravity (LCG) can be obtained using this information, as well as the static waterline of the ship at the time of the inclining test as determined by measuring the freeboard or verified draught marks of the ship, the ship's hydrostatic data and the sea water density.

2.2.2 General

Any ship for which a stability investigation is requested in order to comply with class requirements is to be initially subjected to an inclining test permitting the evaluation of the position of the lightship centre of gravity, or a lightweight check of the lightship displacement, so that the stability data can be determined. Cases for which the inclining test is required and those for which the lightweight check is accepted in its place are listed in [2.2.4] and [2.2.5].

A detailed procedure of the test is to be submitted to the Society prior to the test. This procedure is to include:

a) Identification of the ship by name and shipyard hull number, if applicable

b) Date, time and location of the test

c) Inclining weight data:

- type
- amount (number of units and weight of each)
- certification
- method of handling (i.e. sliding rail or crane)
- anticipated maximum angle of heel to each side

d) Measuring devices:

- pendulums - approximate location and length
- U-tubes - approximate location and length
- inclinometers - Location and details of approvals and calibrations

e) Approximate trim

f) Condition of tanks

g) Estimate weights to deduct, to complete, and to relocate in order to place the ship in its true lightship condition.

The inclining test or lightweight check is to be attended by a Surveyor of the Society. The Society may accept inclining tests or lightweight checks attended by a member of the flag Administration.

The inclining test is adaptable to ships less than 24 m in length, provided that precautions are taken, on a case by case basis, to ensure the accuracy of the test procedure.

The inclining test or lightweight test report is to be signed by the Surveyor to confirm the information witnessed during the test. In addition, for ships performing regular adjustments of equipment such as for example supply vessels, the report is to include the detailed list of the major equipment on the decks, if they are included in the lightship particulars.

2.2.3 Inclining test

The inclining test is required in the following cases:

- any new ship, after its completion, except for the cases specified in [2.2.4]
- any ship, if deemed necessary by the Society, where any alterations are made so as to materially affect the stability.

Note 1: Due attention is to be paid to SOLAS Ch.II.1 Reg.22 (if applicable) whereby it is stipulated that such allowance is subject to the Flag Authorities agreement (refer to Pt A, Ch 1, Sec 1, [3.1.1]).

2.2.4 Lightweight check

The Society may allow a lightweight check to be carried out in lieu of an inclining test in the case of:

- *stability data are available from the inclining test of a sister ship and it is shown to the satisfaction of the Society that reliable stability information for the exempted ship can be obtained from such basic data. A lightweight survey shall be carried out upon completion and the ship shall be inclined whenever in comparison with the data derived from the sister ship, a deviation from the lightship displacement exceeding 1% for ships of 160 m or more in length and 2% for ships of 50 m or less in length and as determined by linear interpolation for intermediate lengths or a deviation from the lightship longitudinal centre of gravity exceeding 0.5% of L_{LL} is found.*
- special types of ship, such as pontoons, provided that the vertical centre of gravity is considered at the level of the deck.
- special types of ship provided that:
 - a detailed list of weights and the positions of their centres of gravity is submitted
 - a lightweight check is carried out, showing accordance between the estimated values and those determined
 - adequate stability is demonstrated in all the loading conditions reported in the trim and stability booklet.

2.2.5 Detailed procedure

A detailed procedure for conducting an inclining test is included in Ch 3, App 1. For the lightweight check, the same procedure applies except as provided for in Ch 3, App 1, [1.1.9].

Section 2 Intact Stability

1 General

1.1 Information for the Master

1.1.1 Stability booklet

Each ship is to be provided with a stability booklet, approved by the Society, which contains sufficient information to enable the Master to operate the ship in compliance with the applicable requirements contained in this Section.

Where any alterations are made to a ship so as to materially affect the stability information supplied to the Master, amended stability information is to be provided. If necessary the ship is to be re-inclined.

Stability data and associated plans are to be drawn up in the working language of the ship and any other language the Society may require. reference is also made to the International Safety Management (ISM) Code, adopted by IMO by resolution A.741(18). All translations of the stability booklet are to be approved.

The format of the trim and stability booklet and the information included are specified in Ch 3, App 2.

1.1.2 Loading instrument

As a supplement to the approved stability booklet, a loading instrument, approved by the Society, may be used to facilitate the stability calculations mentioned in Ch 3, App 2.

A simple and straightforward instruction manual is to be provided.

In order to validate the proper functioning of the computer hardware and software, pre-defined loading conditions are to be run in the loading instrument periodically, at least at every periodical class survey, and the print-out is to be maintained on board as check conditions for future reference in addition to the approved test conditions booklet.

The procedure to be followed, as well as the list of technical details to be sent in order to obtain loading instrument approval, are given in Ch 1, Sec 5, [3].

1.1.3 Operating booklets for certain ships

Ships with innovative design are to be provided with additional information in the stability booklet such as design limitations, maximum speed, worst intended weather conditions or other information regarding the handling of the craft that the Master needs to operate the ship.

1.2 Permanent ballast

1.2.1 If used, permanent ballast is to be located in accordance with a plan approved by the Society and in a manner that prevents shifting of position. Permanent ballast is not to be removed from the ship or relocated within the ship without the approval of the Society. Permanent ballast particulars are to be noted in the ship's stability booklet.

1.2.2 Permanent solid ballast is to be installed under the supervision of the Society.

2 Design criteria

2.1 General intact stability criteria

2.1.1 General

The intact stability criteria specified in [2.1.2], [2.1.3], [2.1.4], and [2.1.5] are to be complied with for the loading conditions mentioned in Ch 3, App 2, [1.2].

However, the lightship condition not being an operational loading case, the Society may accept that part of the above-mentioned criteria are not fulfilled.

These criteria set minimum values, but no maximum values are recommended. It is advisable to avoid excessive values of metacentric height, since these might lead to acceleration forces which could be prejudicial to the ship, its equipment and to safe carriage of the cargo.

2.1.2 GZ curve area

The area under the righting lever curve (GZ curve) is to be not less than 0,055 m·rad up to $\theta = 30^\circ$ angle of heel and not less than 0,09 m·rad up to $\theta = 40^\circ$ or the angle of down flooding θ_i , if this angle is less than 40° . Additionally, the area under the righting lever curve (GZ curve) between the angles of heel of 30° and 40° or between 30° and θ_i , if this angle is less than 40° , is to be not less than 0,03 m·rad.

Note 1: θ_i is an angle of heel at which openings in the hull, superstructures or deckhouses which cannot be closed weathertight submerge.

In applying this criterion, openings which cannot be closed weathertight include ventilators that have to remain open to supply air to the engine room or emergency generator room for the effective operation of the ship, but exclude small openings through which progressive flooding cannot take place. This interpretation is not intended to be applied to existing ships.

The means of closing air pipes are to be weathertight and of an automatic type if the openings of the air pipes to which the devices are fitted would be submerged at an angle of less than 40 degrees (or any lesser angle which may be needed to suit stability requirements) when the ship is floating at its summer load line draught. Pressure/vacuum valves (P.V. valves) may be accepted on tankers. Wooden plugs and trailing canvas hoses may not be accepted in positions 1 and 2 as defined in Ch 1, Sec 3, [2.4].

2.1.3 Minimum righting lever

The righting lever GZ is to be at least 0,20 m at an angle of heel equal to or greater than 30°.

2.1.4 Angle of maximum righting lever

The maximum righting arm is to occur at an angle of heel preferably exceeding 30° but not less than 25°.

When the righting lever curve has a shape with two maximums, the first is to be located at a heel angle not less than 25°.

In cases of ships with a particular design and subject to the prior agreement of the flag Administration, the Society may accept an angle of heel θ_{max} less than 25° but in no case less than 15°, provided that the area “A” below the righting lever curve up to the angle of θ_{max} is not less than the value obtained, in m.rad, from the following formula:

$$A = 0,055 + 0,001 (30^\circ - \theta_{max})$$

where θ_{max} is the angle of heel in degrees at which the righting lever curve reaches its maximum.

2.1.5 Initial metacentric height

The initial metacentric height GM_0 is not to be less than 0,15 m.

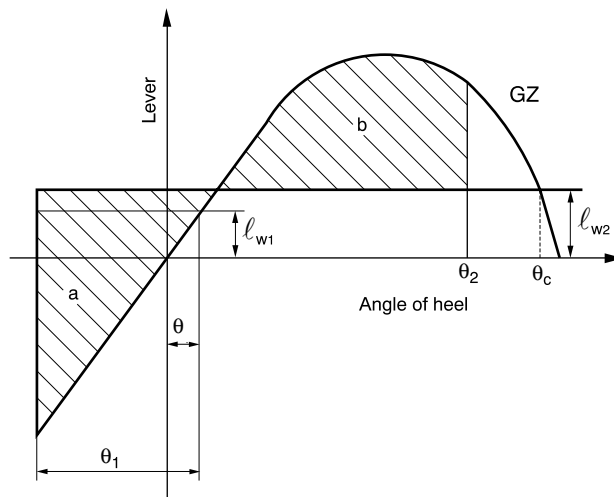
2.1.6 Elements affecting stability

A number of influences such as beam wind on ships with large windage area, icing of topsides, water trapped on deck, rolling characteristics, following seas, etc., which adversely affect stability, are to be taken into account.

2.1.7 Elements reducing stability

Provisions are to be made for a safe margin of stability at all stages of the voyage, regard being given to additions of weight, such as those due to absorption of water and icing (details regarding ice accretion are given in [6]) and to losses of weight such as those due to consumption of fuel and stores.

Figure 1 : Severe wind and rolling



3 Severe wind and rolling criterion (weather criterion)

3.1 Scope

3.1.1 This criterion supplements the stability criteria given in [2.1] for ships of 24 m in length and over. The more stringent criteria of [2.1] and the weather criterion are to govern the minimum requirements.

3.2 Weather criterion

3.2.1 Assumptions

The ability of a ship to withstand the combined effects of beam wind and rolling is to be demonstrated for each standard condition of loading, with reference to Fig 1 as follows:

- the ship is subjected to a steady wind pressure acting perpendicular to the ship's centreline which results in a steady wind heeling lever (ℓ_{w1})
- from the resultant angle of equilibrium (θ_0), the ship is assumed to roll owing to wave action to an angle of roll (θ_1) to windward
- the ship is then subjected to a gust wind pressure which results in a gust wind heeling lever (ℓ_{w2})
- free surface effects, as described in [4], are to be accounted for in the standard conditions of loading as set out in Ch 3, App 2, [1.2].

3.2.2 Criteria

Under the assumptions of [3.2.1], the following criteria are to be complied with:

- the area "b" is to be equal to or greater than area "a", where:
 - a : Area above the GZ curve and below ℓ_{w2} , between θ_R and the intersection of ℓ_{w2} with the GZ curve
 - b : Area above the heeling lever ℓ_{w2} and below the GZ curve, between the intersection of ℓ_{w2} with the GZ curve and θ_2
- the angle of heel under action of steady wind (θ_0) is to be limited to 16° or 80% of the angle of deck edge immersion, whichever is less.

3.2.3 Heeling levers

The wind heeling levers ℓ_{w1} and ℓ_{w2} , in m, referred to in [3.2.2], are constant values at all angles of inclination and are to be calculated as follows:

$$\ell_{w1} = \frac{PAZ}{1000g\Delta}$$

and

$$\ell_{w2} = 1,5 \ell_{w1}$$

where:

- P : 504 N/m² for unrestricted navigation notation. The value of P used for ships with restricted navigation notation may be reduced subject to the approval of the Society
 - A : Projected lateral area in m², of the portion of the ship and deck cargo above the waterline
 - Z : Vertical distance in m, from the centre of A to the centre of the underwater lateral area or approximately to a point at one half the draught
 - Δ : Displacement in t
- $g = 9,81 \text{ m/s}^2$.

3.2.4 Angles of heel

For the purpose of calculating the criteria of [3.2.2], the angles in Fig 1 are defined as follows:

- θ_0 : Angle of heel, in degrees, under action of steady wind
 - θ_1 : Angle of roll, in degrees, to windward due to wave action, calculated as follows:

$$\theta_1 = 109kX_1X_2\sqrt{r_s}$$
 - θ_2 : Angle of downflooding (θ_f) in degrees, or 50° or θ_c , whichever is less
 - θ_f : Angle of heel in degrees, at which openings in the hull, superstructures or deckhouses which cannot be closed weathertight immerse. In applying this criterion, openings which cannot be closed weathertight include ventilators that have to remain open to supply air to the engine room or emergency generator room for the effective operation of the ship, but exclude small openings through which progressive flooding cannot take place.
 - θ_c : Angle in degrees, of second intercept between wind heeling lever ℓ_{w2} and GZ curves
- $\theta_R = \theta_0 - \theta_1$
- X_1 : Coefficient defined in Tab 1
 - X_2 : Coefficient defined in Tab 2
 - k : Coefficient equal to:
 - $k = 1,0$ for a round-bilged ship having no bilge or bar keels
 - $k = 0,7$ for a ship having sharp bilge
 For a ship having bilge keels, a bar keel or both, k is defined in Tab 3.

$$r = 0,73 \pm 0,6 \text{ (OG)/T}_1$$

OG : Distance in m , between the centre of gravity and the waterline (positive if centre of gravity is above the waterline, negative if it is below)

T_1 : Mean moulded draught in m , of the ship

s : Factor defined in Tab 4.

Note 1: The angle of roll θ_1 for ships with anti-rolling devices is to be determined without taking into account the operations of these devices.

Note 2: The angle of roll θ_1 may be obtained, in lieu of the above formula, from model tests or full scale measurements.

The rolling period T_R , in s , is calculated as follows:

$$T_R = \frac{2CB}{\sqrt{GM}}$$

where:

$$C = 0,373 + 0,023 \frac{B}{T_1} - 0,043 \frac{L_W}{100}$$

The symbols in the tables and formula for the rolling period are defined as follows:

L_W : Length in m , of the ship at the waterline

T_1 : Mean moulded draught in m , of the ship

A_K : Total overall area in m^2 of bilge keels, or area of the lateral projection of the bar keel, or sum of these areas, or area of the lateral projection of any hull appendages generating added mass during ship roll

GM : Metacentric height in m , corrected for free surface effect.

3.2.5 Tab 1 to Tab 4 and formulae described in [3.2.4] are based on data from ships having:

- B/T_1 smaller than 3,5
- $(KG/T_1 - 1)$ between $-0,3$ and $0,5$
- T_R smaller than 20 s .

For ships with parameters outside of the above limits the angle of roll (θ_1) may be determined with model experiments of a subject ship with the procedure described in IMO MSC.1/Circ. 1200 as the alternative. In addition, the Society may accept such alternative determinations for any ship, if deemed appropriate.

Table 1 : Values of coefficient X_1

B/T_1	X_1
$\leq 2,4$	1,00
2,5	0,98
2,6	0,96
2,7	0,95
2,8	0,93
2,9	0,91
3,0	0,90
3,1	0,88
3,2	0,86
3,4	0,82
$\geq 3,5$	0,80

Note 1: Intermediate values in this table are to be obtained by linear interpolation

Table 2 : Values of coefficient X_2

C_B	X_2
$\leq 0,45$	0,75
0,50	0,82
0,55	0,89
0,60	0,95
0,65	0,97
$\geq 0,70$	1,00

Note 1: Intermediate values in this table are to be obtained by linear interpolation

Table 3 : Values of coefficient k

$\frac{A_K \times 100}{L \times B}$	k
0,0	1,00
1,0	0,98
1,5	0,95
2,0	0,88
2,5	0,79
3,0	0,74
3,5	0,72
≥ 4,0	0,70

Note 1: Intermediate values in this table are to be obtained by linear interpolation

Table 4 : Values of factor s

T_R	s
≤ 6	0,100
7	0,098
8	0,093
12	0,065
14	0,053
16	0,044
18	0,038
≥ 20	0,035

Note 1: Intermediate values in this table are to be obtained by linear interpolation

3.2.6 Alternative means for determining the wind heeling lever (ℓ_{W1}) may be accepted, to the satisfaction of the Society as an equivalent to the calculation in [3.2.3]. When such alternative tests are carried out, reference shall be made based on the Interim Guidelines for alternative assessment of the weather criterion (IMO MSC.1/Circ.1200). The wind velocity used in the tests shall be 26 m/s in full scale with uniform velocity profile. The value of wind velocity used for ships in restricted services may be reduced to the satisfaction of the Society.

4 Effects of free surfaces of liquids in tanks

4.1 General

4.1.1 For all loading conditions, the initial metacentric height and the righting lever curve are to be corrected for the effect of free surfaces of liquids in tanks.

4.2 Consideration of free surface effects

4.2.1 Free surface effects are to be considered whenever the filling level in a tank is less than 98% of full condition. Free surface effects need not be considered where a tank is nominally full, i.e. filling level is 98% or above. Free surface effects for small tanks may be ignored under the condition in [4.8.1].

4.2.2 Nominally full cargo tanks should be corrected for free surface effects at 98% filling level. In doing so, the correction to initial metacentric height should be based on the inertia moment of liquid surface at 5° of the heeling angle divided by displacement, and the correction to righting lever is suggested to be on the basis of real shifting moment of cargo liquids.

4.3 Categories of tanks

4.3.1 Tanks which are taken into consideration when determining the free surface correction may be one of two categories:

- tanks with fixed filling level (e.g. liquid cargo, water ballast). The free surface correction is to be defined for the actual filling level to be used in each tank.
- tanks with variable filling level (e.g. consumable liquids such as fuel oil, diesel oil, and fresh water, and also liquid cargo and water ballast during liquid transfer operations). Except as permitted in [4.5.1] and [4.6.1], the free surface correction is to be the maximum value attainable among the filling limits envisaged for each tank, consistent with any operating instructions.

4.4 Consumable liquids

4.4.1 *In calculating the free surfaces effect in tanks containing consumable liquids, it is to be assumed that for each type of liquid at least one transverse pair or a single centreline tank has a free surface and the tank or combination of tanks taken into account are to be those where the effect of free surface is the greatest.*

4.5 Water ballast tanks

4.5.1 *Where water ballast tanks, including anti-rolling tanks and anti-heeling tanks, are to be filled or discharged during the course of a voyage, the free surfaces effect is to be calculated to take account of the most onerous transitory stage relating to such operations.*

4.6 Liquid transfer operations

4.6.1 *For ships engaged in liquid transfer operations, the free surface corrections at any stage of the liquid transfer operations may be determined in accordance with the filling level in each tank at the stage of the transfer operation.*

4.7 GM₀ and GZ curve corrections

4.7.1 *The corrections to the initial metacentric height and to the righting lever curve are to be addressed separately as indicated in [4.7.2] and [4.7.3].*

4.7.2 *In determining the correction to the initial metacentric height, the transverse moments of inertia of the tanks are to be calculated at 0 degrees angle of heel according to the categories indicated in [4.3.1].*

4.7.3 *The righting lever curve may be corrected by any of the following methods:*

- *correction based on the actual moment of fluid transfer for each angle of heel calculated; corrections may be calculated according to the categories indicated in [4.3.1]*
- *correction based on the moment of inertia, calculated at 0 degrees angle of heel, modified at each angle of heel calculated; corrections may be calculated according to the categories indicated in [4.3.1].*

4.7.4 *Whichever method is selected for correcting the righting lever curve, only that method is to be presented in the ship's trim and stability booklet. However, where an alternative method is described for use in manually calculated loading conditions, an explanation of the differences which may be found in the results, as well as an example correction for each alternative, are to be included.*

4.8 Small tanks

4.8.1 *Small tanks which satisfy the following condition corresponding to an angle of inclination of 30° need not be included in the correction:*

$$M_{is}/\Delta_{min} < 0,01 \text{ m}$$

where:

Δ_{min} : Minimum ship displacement, in t, calculated at d_{min}

d_{min} : Minimum mean service draught, in m, of ship without cargo, with 10% stores and minimum water ballast, if required.

4.9 Remainder of liquid

4.9.1 *The usual remainder of liquids in the empty tanks need not be taken into account in calculating the corrections, providing the total of such residual liquids does not constitute a significant free surface effect.*

5 Cargo ships carrying timber deck cargoes

5.1 Application

5.1.1 *The provisions given hereunder apply to ships engaged in the carriage of timber deck cargoes. Ships that are provided with and make use of their timber load line are also to comply with the requirements of regulations 41 to 45 of the International Load Line Convention 1966, as amended.*

5.2 Definitions

5.2.1 Timber

Timber means sawn wood or lumber, cants, logs, poles, pulpwood and all other types of timber in loose or packaged forms. The term does not include wood pulp or similar cargo.

5.2.2 Timber deck cargo

Timber deck cargo means a cargo of timber carried on an uncovered part of a freeboard or superstructure deck. The term does not include wood pulp or similar cargo.

5.2.3 Timber load line

Timber load line means a special load line assigned to ships complying with certain conditions related to their construction set out in the International Convention on Load Lines 1966, as amended, and used when the cargo complies with the stowage and securing conditions of the Code of Safe Practice for Ships Carrying Timber Deck Cargoes, 1991 (Resolution A.715(17)).

5.3 Stability criteria

5.3.1 *For ships loaded with timber deck cargoes and provided that the cargo extends longitudinally between superstructures (where there is no limiting superstructure at the after end, the timber deck cargo is to extend at least to the after end of the aftermost hatchway) and transversely for the full beam of ship after due allowance for a rounded gunwale not exceeding 4% of the breadth of the ship and/or securing the supporting uprights and which remains securely fixed at large angles of heel, the Society may apply the criteria given in [5.3.2] to [5.3.5], which substitute those given in [2.1.2], [2.1.3], [2.1.4] and [2.1.5] and in [3.2].*

5.3.2 *The area under the righting lever curve (GZ curve) is to be not less than 0,08 m·rad up to $\theta = 40^\circ$ or the angle of flooding if this angle is less than 40° .*

5.3.3 *The maximum value of the righting lever (GZ) is to be at least 0,25 m.*

5.3.4 *At all times during a voyage, the metacentric height GM_0 is to be not less than 0,10 m after correction for the free surface effects of liquid in tanks and, where appropriate, the absorption of water by the deck cargo and/or ice accretion on the exposed surfaces. (Details regarding ice accretion are given in [6]).*

5.3.5 *When determining the ability of the ship to withstand the combined effect of beam wind and rolling according to [3.2], the 16° limiting angle of heel under action of steady wind is to be complied with, but the additional criterion of 80% of the angle of deck edge immersion may be ignored.*

5.4 Stability booklet

5.4.1 *The ship is to be supplied with comprehensive stability information which takes into account timber deck cargo. Such information is to enable the Master, rapidly and simply, to obtain accurate guidance as to the stability of the ship under varying conditions of service. Comprehensive rolling period tables or diagrams have proved to be very useful aids in verifying the actual stability conditions.*

5.4.2 *For ships carrying timber deck cargoes, the Society may deem it necessary that the Master be given information setting out the changes in deck cargo from that shown in the loading conditions, when the permeability of the deck cargo is significantly different from 25% (see [5.5.1]).*

5.4.3 *For ships carrying timber deck cargoes, conditions are to be shown indicating the maximum permissible amount of deck cargo having regard to the lightest stowage rate likely to be met in service.*

5.5 Calculation of the stability curve

5.5.1 *In addition to the provisions given in Ch 3, App 2, [1.3], the Society may allow account to be taken of the buoyancy of the deck cargo assuming that such cargo has a permeability of 25% of the volume occupied by the cargo. Additional curves of stability may be required if the Society considers it necessary to investigate the influence of different permeabilities and/or assumed effective height of the deck cargo.*

5.6 Loading conditions to be considered

5.6.1 *The loading conditions which are to be considered for ships carrying timber deck cargoes are specified in Ch 3, App 2, [1.2.2]. For the purpose of these loading conditions, the ship is assumed to be loaded to the summer timber load line with water ballast tanks empty.*

5.7 Assumptions for calculating loading conditions

5.7.1 *The following assumptions are to be made for calculating the loading conditions referred to in Ch 3, App 2, [1.2.2]:*

- *the amount of cargo and ballast is to correspond to the worst service condition in which all the relevant stability criteria reported in [2.1.2], [2.1.3], [2.1.4] and [2.1.5], or the optional criteria given in [5.3], are met*
- *in the arrival condition, it is to be assumed that the weight of the deck cargo has increased by 10% due to water absorption.*

5.7.2 The stability of the ship at all times, including during the process of loading and unloading timber deck cargo, is to be positive and in compliance with the stability criteria of [5.3]. It is to be calculated having regard to:

- the increased weight of the timber deck cargo due to:
 - absorption of water in dried or seasoned timber, and
 - ice accretion, if applicable (as reported in [6])
- variations in consumable
- the free surface effect of liquid in tanks, and
- the weight of water trapped in broken spaces within the timber deck cargo and especially logs.

5.7.3 Excessive initial stability is to be avoided as it will result in rapid and violent motion in heavy seas which will impose large sliding and racking forces on the cargo causing high stresses on the lashings. Unless otherwise stated in the stability booklet, the metacentric height is generally not to exceed 3% of the breadth in order to prevent excessive acceleration in rolling provided that the relevant stability criteria given in [5.3] are satisfied.

5.8 Stowage of timber deck cargoes

5.8.1 The stowage of timber deck cargoes is to comply with the provisions of chapter 3 of the Code of Safe Practice for Ships Carrying Timber Deck Cargoes, 1991 (resolution A.715(17)).

6 Icing

6.1 Application

6.1.1 For any ship having an ice class notation or operating in areas where ice accretion is likely to occur, adversely affecting a ship's stability, icing allowances are to be included in the analysis of conditions of loading.

6.2 Ships carrying timber deck cargoes

6.2.1 The Master is to establish or verify the stability of his ship for the worst service condition, having regard to the increased weight of deck cargo due to water absorption and/or ice accretion and to variations in consumable.

6.2.2 When timber deck cargoes are carried and it is anticipated that some formation of ice will take place, an allowance is to be made in the arrival condition for the additional weight.

6.2.3 Allowance for ice accretion

The ice accretion weight, w , in kg/m^2 , is to be taken as follows:

$$w = 30 \cdot \frac{2,3 (15,2 L - 351,8)}{I_{FB}} \cdot f_{TL} \cdot \frac{l_{bow}}{0,16 L}$$

where:

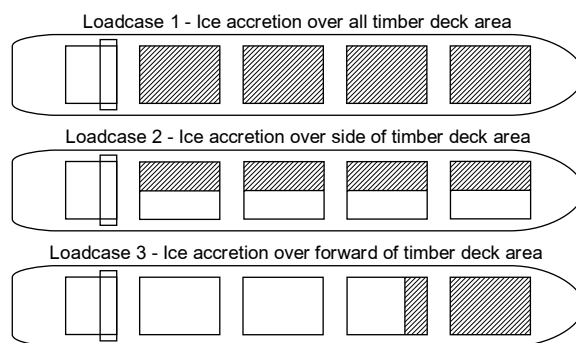
f_{TL} : Timber and lashing factor:
 $f_{TL} = 1,2$

I_{FB} : Freeboard height, in mm

l_{bow} : Length of bow flare region, in m, to be taken as the distance from the longitudinal position at which the maximum breadth occurs on a water line located 0,5 m below the freeboard deck at side to the foremost point of the bow at that waterline.

The ice accretion weight w over the timber deck region is to be applied to each of the load cases as illustrated in Fig 2.

Figure 2 : Ice accretion load case for timber deck cargoes



Load cases are to be applied in stability calculations.

6.3 Calculation assumptions

6.3.1 For ships operating in areas where ice accretion is likely to occur, the following icing allowance is to be made in the stability calculations:

- 30 kg per square metre on exposed weather decks and gangways
- 7,5 kg per square metre for the projected lateral area of each side of the ship above the water plane
- the projected lateral area of discontinuous surfaces of rail, sundry booms, spars (except masts) and rigging of ships having no sails and the projected lateral area of other small objects are to be computed by increasing the total projected area of continuous surfaces by 5% and the static moments of this area by 10%.

6.3.2 Ships intended for operation in areas where ice is known to occur are to be:

- designed to minimise the accretion of ice, and
- equipped with such means for removing ice as, for example, electrical and pneumatic devices, and/or special tools such as axes or wooden clubs for removing ice from bulwarks, rails and erections.

6.4 Guidance relating to ice accretion

6.4.1 The following icing areas are to be considered:

- a) The area north of latitude 65°30'N, between longitude 28°W and the west coast of Iceland; north of the north coast of Iceland; north of the rhumb line running from latitude 66°N, longitude 15°W to latitude 73°30'N, longitude 15°E, north of latitude 73°30'N between longitude 15°E and 35°E, and east of longitude 35°E, as well as north of latitude 56°N in the Baltic Sea
- b) The area north of latitude 43°N bounded in the west by the North American coast and the east by the rhumb line running from latitude 43°N, longitude 48°W to latitude 63°N, longitude 28°W and thence along longitude 28°W
- c) All sea areas north of the North American Continent, west of the areas defined in a) and b)
- d) The Bering and Okhotsk Seas and the Tartary Strait during the icing season, and
- e) South of latitude 60°S.

6.4.2 For ships operating where ice accretion may be expected:

- within the areas defined in a), c), d) and e) of [6.4.1] known to having icing conditions significantly different from those described in [6.3], ice accretion requirements of one half to twice the required allowance may be applied
- within the area defined in b), where ice accretion in excess of twice the allowance required by [6.3] may be expected, more severe requirements than those given in [6.3] may be applied.

Section 3 Damage Stability

1 Application

1.1 Ships for which damage stability is required

1.1.1 Damage stability calculation is required for ships which are assigned with the additional class notation **SDS**.

1.1.2 The damage stability criteria to be applied depend on the ship type as described by its service notation and corresponding rules defined in Pt A, Ch 1, Sec 2.

1.1.3 For tankers assigned with a tropical freeboard and granted with **SDS** additional class notation, the corresponding loading conditions and damage stability calculations are to be submitted into the damage stability booklet.

1.2 Ships having additional class notation **SDS** and additional service feature **SPxxx** or **SPxxx-capable**

1.2.1 Ships having the additional class notation **SDS** and the additional service feature **SPxxx** or **SPxxx-capable** are to comply, in addition to the applicable requirements of this Section, with the requirements of Pt D, Ch 11, Sec 3, [2.3], considering the special personnel as passengers, where the attained subdivision index A (defined in Pt D, Ch 11, Sec 3, [2.3.3]) is not to be less than:

- R, where the ship is carrying 240 persons or more
- 0,8 R, where the ship is carrying not more than 60 persons
- R value to be calculated by linear interpolation between 0,8 R and R, where the ship is carrying more than 60 (but not more than 240) persons.

where:

$$R = 1 - \frac{5000}{L_s + 2,5N + 15225}$$

$$N = N_1 + 2 N_2$$

N_1 : Number of persons for whom lifeboats are provided

N_2 : Number of persons (including officers and crew) the ship is permitted to carry in excess of N_1

L_s : Subdivision length of the ship, as defined in Pt D, Ch 11, Sec 3, [2.1.4]

Where the conditions of service are such that compliance with Pt D, Ch 11, Sec 3, [2.3] on the basis of $N = N_1 + 2 N_2$ is impracticable and where the Society considers that a suitably reduced degree of hazard exists, a lesser value of N may be taken but in no case less than $N = N_1 + N_2$.

1.2.2 However, for ships having additional class notation **SDS** and additional service feature **SPxxx** or **SPxxx-capable** with xxx less than 240 persons, Pt D, Ch 11, Sec 3, [2.3.12] is not applicable.

2 General

2.1 Approaches to be followed for damage stability investigation

2.1.1 General

The purpose of damage stability calculations is to assess the equilibrium position and reserve stability of the ship after flooding. In order to assess the behaviour of the ship after damage, two approaches have been developed: the deterministic and the probabilistic, which are to be applied depending on the ship type.

The metacentric heights (GM), stability levers (GZ) and centre of gravity positions for judging the final conditions are to be calculated by the constant displacement (lost buoyancy) method.

2.1.2 Deterministic approach

The deterministic approach is based on standard dimensions of damage extending anywhere along the ship's length or between transverse bulkheads depending on the relevant requirements.

The consequence of such standard of damage is the creation of a group of damage cases, the number of which, as well as the number of compartments involved in each case, depend on the ship's dimensions and internal subdivision.

For each loading condition, each damage case is to be considered, and the applicable criteria are to be complied with.

Different deterministic methods in damage stability have been developed depending on ship type, on freeboard reduction, and on the kind of cargo carried.

The deterministic methods to be applied in the case of freeboard reduction are specified in Ch 3, App 4.

2.1.3 Probabilistic approach

The probabilistic concept takes the probability of survival after collision as a measure of ship safety in the damaged condition, referred to as the attained subdivision index A .

The damage stability calculations are performed for a limited number of draughts and relevant GM values in order to draw a minimum GM curve where the attained subdivision index A achieves the minimum required level of safety R . For cargo ships, each case of damage is not required to comply with the applicable criteria, but the attained index A , which is the sum of the contribution of all damage cases, is to be equal to or greater than R .

The probabilistic method developed on the basis of the above-mentioned concepts is detailed in Ch 3, App 3.

As a general rule, the probabilistic method applies to cargo ships of a length not less than 80 m, and for which no deterministic methods apply.

3 Documents to be submitted

3.1 Damage stability calculations

3.1.1 Damage stability documentation

For all ships to which damage stability requirements apply, documents including damage stability calculations are to be submitted.

The damage stability calculations are to include:

- list of the characteristics (volume, centre of gravity, permeability) of each compartment which can be damaged
- a table of openings in bulkheads, decks and side shell reporting all the information about:
 - identification of the opening
 - vertical, transverse and horizontal location
 - type of closure: sliding, hinged or rolling for doors
 - type of tightness: watertight, weathertight, semi-watertight or unprotected
 - operating system: remote control, local operation, indicators on the bridge, television surveillance, water leakage detection, audible alarm, as applicable
 - foreseen utilization: open at sea, normally closed at sea, kept closed at sea
- list of all damage cases corresponding to the applicable requirements
- detailed results of damage stability calculations for all the loading conditions foreseen in the applicable requirements
- the limiting GM/KG curve, if foreseen in the applicable requirements
- capacity plan
- cross and down flooding devices and the calculations thereof according to Pt D, Ch 11, App 1 with informations about diameter, valves, pipe lengths and coordinates of inlet/outlet
- watertight and weathertight door plan with pressure calculation
- side contour and wind profile
- pipes and damaged area when the destruction of these pipes results in progressive flooding.

3.1.2 Additional information for the probabilistic approach

In addition to the information listed in [3.1.1], the following is to be provided:

- *subdivision length L_s*
- *initial draughts and the corresponding GM-values*
- *required subdivision index R*
- *attained subdivision index A with a summary table for all contributions for all damaged zones.*
- *draught, trim, GM in damaged condition*
- *damage extension and definition of damage cases with probabilistic values p , v and r*
- *righting lever curve (including GZ_{max} and range) with factor of survivability s*
- *critical weathertight and unprotected openings with their angle of immersion*
- *details of sub-compartments with amount of in-flooded water/lost buoyancy with their centres of gravity.*

3.1.3 Loading instrument

As a supplement to the approved damage stability documentation, a loading instrument, approved by the Society, may be used to facilitate the damage stability calculations mentioned in [3.1.1].

The procedure to be followed, as well as the list of technical details to be sent in order to obtain loading instrument approval, are given in Ch 1, Sec 5, [3.7].

3.2 Permeabilities

3.2.1 Definition

The permeability of a space means the ratio of the volume within that space which is assumed to be occupied by water to the total volume of that space.

3.2.2 General

The permeabilities relevant to the type of spaces which can be flooded depend on the applicable requirements. Such permeabilities are indicated in Part D or Part E for each type of ship.

3.3 Progressive flooding

3.3.1 Definition

Progressive flooding is the additional flooding of spaces which were not previously assumed to be damaged. Such additional flooding may occur through openings or pipes as indicated in [3.3.2] and [3.3.3].

3.3.2 Openings

The openings may be listed in the following categories, depending on their means of closure:

- **Unprotected**
Unprotected openings may lead to progressive flooding if they are situated within the range of the positive righting lever curve or if they are located below the waterline after damage (at any stage of flooding). Unprotected openings are openings which are not fitted with at least weathertight means of closure, or ventilators that have to remain open to supply air to the engine room or emergency generator room for the effective operation of the ship.
- **Weathertight**
Openings fitted with weathertight means of closure are not able to sustain a constant head of water, but they can be intermittently immersed within the positive range of stability.
Weathertight openings may lead to progressive flooding if they are located below the waterline after damage (at any stage of flooding).
- **Semi-watertight**
Internal openings fitted with semi-watertight means of closure are able to sustain a constant head of water corresponding to the immersion relevant to the highest waterline after damage at the equilibrium of the intermediate stages of flooding.
Semi-watertight openings may lead to progressive flooding if they are located below the final equilibrium waterline after damage.
- **Watertight**
Internal openings fitted with watertight means of closure are able to sustain a constant head of water corresponding to the distance between the lowest edge of this opening and the bulkhead/freeboard deck.
Air pipe closing devices complying with Pt C, Ch 1, Sec 10, [9.1.6] may not be considered watertight, unless additional arrangements are fitted in order to demonstrate that such closing devices are effectively watertight.
The pressure/vacuum valves (PV valves) currently installed on tankers do not theoretically provide complete watertightness.
Manhole covers may be considered watertight provided the cover is fitted with bolts located such that the distance between their axes is less than five times the bolt's diameter.
Access hatch covers leading to tanks may be considered watertight.
Watertight openings do not lead to progressive flooding.

3.3.3 Pipes

Progressive flooding through pipes may occur when:

- the pipes and connected valves are located within the assumed damage, and no valves are fitted outside the damage
- the pipes, even if located outside the damage, satisfy all of the following conditions:
 - the pipe connects a damaged space to one or more spaces located outside the damage
 - the highest vertical position of the pipe is below the waterline, and
 - no valves are fitted.

The possibility of progressive flooding through ballast piping passing through the assumed extent of damage, where positive action valves are not fitted to the ballast system at the open ends of the pipes in the tanks served, is to be considered. Where remote control systems are fitted to ballast valves and these controls pass through the assumed extent of damage, then the effect of damage to the system is to be considered to ensure that the valves would remain closed in that event.

If pipes, ducts or tunnels are situated within assumed flooded compartments, arrangements are to be made to ensure that progressive flooding cannot thereby extend to compartments other than those assumed flooded. However, the Society may permit minor progressive flooding if it is demonstrated that the additional flooding of those compartments cannot lead to the capsizing or the sinking of the ship.

Requirements relative to the prevention of progressive flooding are specified in Pt C, Ch 1, Sec 10, [5.5].

3.4 Bottom damages

3.4.1 General

Ships which are not fitted with a double bottom as required by Ch 2, Sec 2, [3.1.2] or which are fitted with unusual bottom arrangements as defined in Ch 2, Sec 2, [3.1.6], are to comply with [3.4.2] and [3.4.3].

3.4.2 Bottom damage description

The assumed extent of damage is described in Tab 1.

If any damage of a lesser extent than the maximum damage specified in Tab 1 would result in a more severe condition, such damage should be considered.

3.4.3 Stability criteria

Compliance with the requirements of Ch 2, Sec 2, [3.1.5] or Ch 2, Sec 2, [3.1.6] is to be achieved by demonstrating that s_i , when calculated in accordance with Ch 3, App 3, [1.6], is not less than 1 for all service conditions when subject to a bottom damage with an extent specified in [3.4.2] for any position in the affected part of the ship.

Flooding of such spaces shall not render emergency power and lighting, internal communication, signals or other emergency devices inoperable in other parts of the ship.

Table 1 : Assumed extent of damage

	For 0,3 L from the forward perpendicular of the ship	Any other part of the ship
Longitudinal extent	1/3 $L^{2/3}$ or 14,5 m, whichever is less	1/3 $L^{2/3}$ or 14,5 m, whichever is less
Transverse extent	B/6 or 10 m, whichever is less	B/6 or 5 m, whichever is less
Vertical extent, measured from the keel line	B/20, to be taken not less than 0,76 m and not more than 2 m	B/20, to be taken not less than 0,76 m and not more than 2 m

4 Damage control documentation

4.1 General

4.1.1 Application

The damage control documentation is to include a damage control plan which is intended to provide ship's officers with clear information on the ship's watertight compartmentation and equipment related to maintaining the boundaries and effectiveness of the compartmentation so that, in the event of damage causing flooding, proper precautions can be taken to prevent progressive flooding through openings therein and effective action can be taken quickly to mitigate and, where possible, recover the ship's loss of stability.

The damage control documentation is to be clear and easy to understand. It is not to include information which is not directly relevant to damage control, and is to be provided in the language or languages of the ship's officers. If the languages used in the preparation of the documentation are not English or French, a translation into one of these languages is to be included.

The use of a loading instrument performing damage stability calculations may be accepted as a supplement to the damage control documentation. This instrument is to be approved by the Society according to the requirements of Ch 1, Sec 5, [3.8].

The damage control plan is required for the following ships:

- ships carrying passengers
- cargo ships of 500 GT and over.

4.1.2 Application to ships having additional service feature SPxxx or SPxxx-capable

The damage control documentation of ships having additional service feature **SPxxx** or **SPxxx-capable** is to comply with Pt D, Ch 11, Sec 3, [2.3.14].

5 Specific interpretations

5.1 Assumed damage penetration in way of sponsons

5.1.1 *If sponsons are fitted, it is necessary to establish the maximum assumed damage penetration (B/5) to be used when deciding on the various damage cases. For this purpose, the breadth B in the way of such sponsons is to be measured to the outside of the sponsons.*

Clear of any suck sponsons, the breadth B is to be the midship breadth measured to the outside of the original shell. In other words, the assumed penetration of B/5 is the same as that which applied before the fitting of sponsons.

Appendix 1 Inclining Test and Lightweight Check

1 Inclining test and lightweight check

1.1 General

1.1.1 General conditions of the ship

The following conditions are to be met, as far as practicable:

- the weather conditions are to be favourable
- the ship should be moored in a quiet, sheltered area free from extraneous forces such as propeller wash from passing vessels, or sudden discharges from shore side pumps. The tide conditions and the trim of the ship during the test should be considered. Prior to the test, the depth of water should be measured and recorded in as many locations as are necessary to ensure that the ship will not contact the bottom. The specific gravity of water should be accurately recorded. The ship should be moored in a manner to allow unrestricted heeling. The access ramps should be removed. Power lines, hoses, etc., connected to shore should be at a minimum, and kept slack at all times
- the ship should be as upright as possible; with inclining weights in the initial position, up to one-half degree of list is acceptable. The actual trim and deflection of keel, if practical, should be considered in the hydrostatic data. In order to avoid excessive errors caused by significant changes in the water plane area during heeling, hydrostatic data for the actual trim and the maximum anticipated heeling angles should be checked beforehand
- cranes, derrick, lifeboats and liferafts capable of inducing oscillations are to be secured
- main and auxiliary boilers, pipes and any other system containing liquids are to be filled
- the bilge and the decks are to be thoroughly dried
- the anticipated liquid loading for the test should be included in the planning for the test. Preferably, all tanks should be empty and clean, or completely full. The number of slack tanks should be kept to an absolute minimum. The viscosity of the fluid, the depth of the fluid and the shape of the tank should be such that the free surface effect can be accurately determined
- the weights necessary for the inclination are to be already on board, located in the correct place. Their certificates are to be presented to the Surveyor witnessing the inclining test and are also to be included into the inclining test report.
- all work on board is to be suspended and crew or personnel not directly involved in the incline test are to leave the ship
- the ship is to be as complete as possible at the time of the test. The number of weights to be removed, added or shifted is to be limited to a minimum. Temporary material, tool boxes, staging, sand, debris, etc., on board is to be reduced to an absolute minimum
- decks should be free of water. Water trapped on deck may shift and pocket in a fashion similar to liquids in a tank. Any rain, snow or ice accumulated on the ship should be removed prior to the test.

1.1.2 Inclining weights

The total weight used is preferably to be sufficient to provide a minimum inclination of one degree and a maximum of four degrees of heel to each side. The Society may, however, accept a smaller inclination angle for large ships provided that the requirement on pendulum deflection or U-tube difference in height specified in [1.1.4] is complied with. Test weights are to be compact and of such a configuration that the VCG (vertical centre of gravity) of the weights can be accurately determined. Each weight is to be marked with an identification number and its weight. Re-certification of the test weights is to be carried out prior to the incline. A crane of sufficient capacity and reach, or some other means, is to be available during the inclining test to shift weights on the deck in an expeditious and safe manner. Water ballast transfer may be carried out, when it is impractical to incline using solid weights and subject to requirement of [1.1.3].

Weights, such as porous concrete, that can absorb significant amounts of moisture should only be used if they are weighed just prior to the inclining test or if recent weight certificates are presented. Each weight should be marked with an identification number and its weight. For small ships, drums completely filled with water may be used. Drums should normally be full and capped to allow accurate weight control. In such cases, the weight of the drums should be verified in the presence of a surveyor of the Society using a recently calibrated scale.

Precautions should be taken to ensure that the decks are not overloaded during weight movements. If deck strength is questionable then a structural analysis should be performed to determine if existing framing can support the weight.

Generally, the test weights should be positioned as far outboard as possible on the upper deck. The test weights should be on board and in place prior to the scheduled time of the inclining test.

1.1.3 Water ballast as inclining weight

Where the use of solid weights to produce the inclining moment is deemed to be impracticable, the movement of ballast water may be permitted as an alternative method. This acceptance would be granted for a specific test only, and approval of the test procedure by the Society is required. As a minimal prerequisite for acceptability, the following conditions are to be required:

- inclining tanks are to be wall-sided and free of large stringers or other internal members that create air pockets

- tanks are to be directly opposite to maintain ship's trim
- specific gravity of ballast water is to be measured and recorded
- pipelines to inclining tanks are to be full. If the ship's piping layout is unsuitable for internal transfer, portable pumps and pipes/hoses may be used
- blanks must be inserted in transverse manifolds to prevent the possibility of liquids being "leaked" during transfer. Continuous valve control must be maintained during the test
- all inclining tanks must be manually sounded before and after each shift
- vertical, longitudinal and transverse centres are to be calculated for each movement
- accurate sounding/ullage tables are to be provided. The ship's initial heel angle is to be established prior to the incline in order to produce accurate values for volumes and transverse and vertical centres of gravity for the inclining tanks at every angle of heel. The draught marks amidships (port and starboard) are to be used when establishing the initial heel angle
- verification of the quantity shifted may be achieved by a flowmeter or similar device
- the time to conduct the inclining is to be evaluated. If time requirements for transfer of liquids are considered too long, water may be unacceptable because of the possibility of wind shifts over long periods of time.

1.1.4 Pendulums

The use of three pendulums is recommended but a minimum of two are to be used to allow identification of bad readings at any one pendulum station. However, for ships of a length equal to or less than 30 m, only one pendulum can be accepted. They are each to be located in an area protected from the wind. The pendulums are to be long enough to give a measured deflection, to each side of upright, of at least 15 cm. To ensure recordings from individual instruments are kept separate, it is suggested that the pendulums be physically located as far apart as practical.

The use of an inclinometer or U-tube is to be considered in each separate case. It is recommended that inclinometers or other measuring devices only be used in conjunction with at least one pendulum.

1.1.5 Free surface and slack tanks

The number of slack tanks should normally be limited to one port/starboard pair or one centreline tank of the following:

- fresh water reserve feed tanks
- fuel/diesel oil storage tanks
- fuel/diesel oil day tanks
- lube oil tanks
- sanitary tanks
- potable water tanks.

To avoid pocketing, slack tanks are normally to be of regular (i.e. rectangular, trapezoidal, etc.) cross section and be 20% to 80% full if they are deep tanks and 40% to 60% full if they are double-bottom tanks. These levels ensure that the rate of shifting of liquid remains constant throughout the heel angles of the inclining test. If the trim changes as the ship is inclined, then consideration are also to be given to longitudinal pocketing. Slack tanks containing liquids of sufficient viscosity to prevent free movement of the liquids, as the ship is inclined (such as bunker at low temperature), are to be avoided since the free surface cannot be calculated accurately. A free surface correction for such tanks is not to be used unless the tanks are heated to reduce viscosity. Communication between tanks are never to be allowed. Cross-connections, including those via manifolds, are to be closed. Equal liquid levels in slack tank pairs can be a warning sign of open cross connections. A bilge, ballast, and fuel oil piping plan can be referred to, when checking for cross connection closures.

1.1.6 Means of communications

Efficient two-way communications are to be provided between central control and the weight handlers and between central control and each pendulum station. One person at a central control station is to have complete control over all personnel involved in the test.

1.1.7 Documentation

The person in charge of the inclining test is to have available a copy of the following plans at the time of the test:

- lines plan
- hydrostatic curves or hydrostatic data
- general arrangement plan of decks, holds, inner bottoms, etc.
- capacity plan showing capacities and vertical and longitudinal centres of gravity of cargo spaces, tanks, etc. When water ballast is used as inclining weights, the transverse and vertical centres of gravity for the applicable tanks, for each angle of inclination, must be available
- tank sounding tables
- draught mark locations, and
- docking drawing with keel profile and draught mark corrections (if available).

1.1.8 Determination of the displacement

The operations necessary for the accurate evaluation of the displacement of the ship at the time of the inclining test, as listed below, are to be carried out:

- draught mark readings are to be taken at aft, midship and forward, at starboard and port sides
- the mean draught (average of port and starboard reading) is to be calculated for each of the locations where draught readings are taken and plotted on the ship's lines drawing or outboard profile to ensure that all readings are consistent and together define the correct waterline. The resulting plot is to yield either a straight line or a waterline which is either hogged or sagged. If inconsistent readings are obtained, the freeboards/ draughts are to be retaken
- the specific gravity of the sea water is to be determined. Samples are to be taken from a sufficient depth of the water to ensure a true representation of the sea water and not merely surface water, which could contain fresh water from run off of rain. A hydrometer is to be placed in a water sample and the specific gravity read and recorded. For large ships, it is recommended that samples of the sea water be taken forward, midship and aft, and the readings averaged. For small ships, one sample taken from midship is sufficient. The temperature of the water is to be taken and the measured specific gravity corrected for deviation from the standard, if necessary.

A correction to water specific gravity is not necessary if the specific gravity is determined at the inclining experiment site. Correction is necessary if specific gravity is measured when the sample temperature differs from the temperature at the time of the inclining (e.g., if the check of specific gravity is performed at the office). Where the value of the average calculated specific gravity is different from that reported in the hydrostatic curves, adequate corrections are to be made to the displacement curve

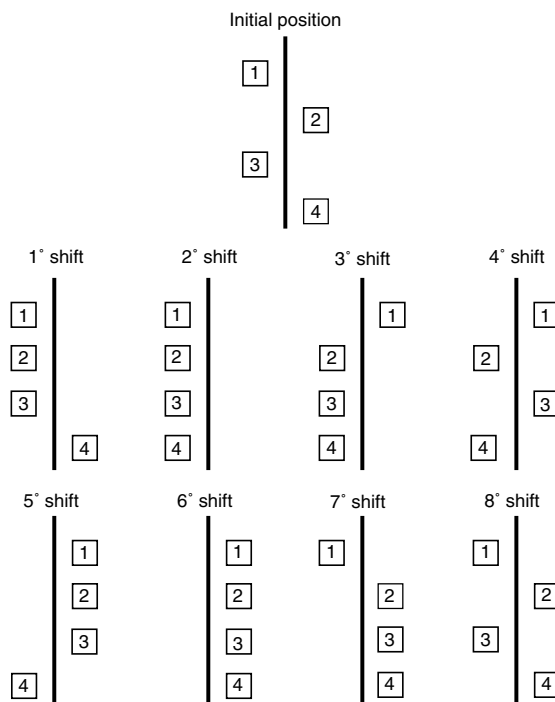
- all double bottoms, as well as all tanks and compartments which can contain liquids, are to be checked, paying particular attention to air pockets which may accumulate due to the ship's trim and the position of air pipes, and also taking into account the provisions of [1.1.1]
- it is to be checked that the bilge is dry, and an evaluation of the liquids which cannot be pumped, remaining in the pipes, boilers, condenser, etc., is to be carried out
- the entire ship is to be surveyed in order to identify all items which need to be added, removed or relocated to bring the ship to the lightship condition. Each item is to be clearly identified by weight and location of the centre of gravity
- the possible solid permanent ballast is to be clearly identified and listed in the report.
- normally, the total value of missing weights is not to exceed 2% and surplus weights, excluding liquid ballast, not exceed 4% of the lightship displacement. For smaller vessels, higher percentages may be allowed.

1.1.9 The incline

The standard test generally employs eight distinct weight movements as shown in Fig 1.

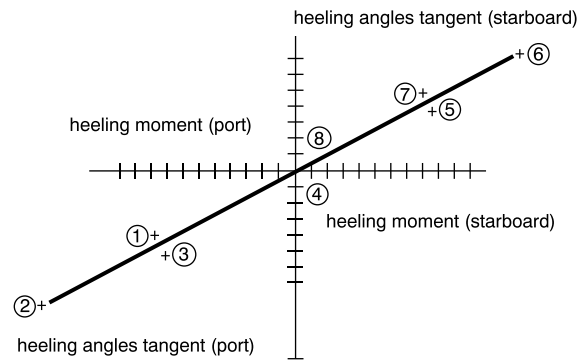
Movement No.8, a recheck of the zero point, may be omitted if a straight line plot is achieved after movement No.7. If a straight line plot is achieved after the initial zero and six weight movements, the inclining test is complete and the second check at zero may be omitted. If a straight line plot is not achieved, those weight movements that did not yield acceptable plotted points should be repeated or explained.

Figure 1 : Weight shift procedure



The weights are to be transversely shifted, so as not to modify the ship's trim and vertical position of the centre of gravity. After each weight shifting, the new position of the transverse centre of gravity of the weights is to be accurately determined. After each weight movement, the distance the weight was moved (centre to centre) is to be measured and the heeling moment calculated by multiplying the distance by the amount of weight moved. The tangent is calculated for each pendulum by dividing the deflection by the length of the pendulum. The resultant tangents are plotted on the graph as shown in Fig 2. The plot is to be run during the test to ensure that acceptable data are being obtained. The pendulum deflection is to be read when the ship has reached a final position after each weight shifting. During the reading, no movements of personnel are allowed. For ships with a length equal to or less than 30 m, six distinct weight movements may be accepted.

Figure 2 : Graph of resultant tangents



Appendix 2 Trim and Stability Booklet

1 Trim and stability booklet

1.1 Information to be included in the trim and stability booklet

1.1.1 General

A trim and stability booklet is a stability manual, to be approved by the Society, which is to contain information to enable the Master to operate the ship in compliance with the applicable requirements contained in the Rules.

The format of the stability booklet and the information included vary depending on the ship type and operation.

Additional information may be required depending on the type of the ship as specified in Part D and Part E.

1.1.2 List of information

The following information is to be included in the trim and stability booklet:

- a general description of the ship, including:
 - the ship's name and the Society classification number
 - the ship type and service notation
 - the class notations
 - the yard, the hull number and the year of delivery
 - the Flag, the port of registry, the international call sign and the IMO number
 - the moulded dimensions
 - the draught corresponding to the assigned summer load line, the draught corresponding to the assigned summer timber load line and the draught corresponding to the tropical load line, if applicable
 - the displacement corresponding to the above-mentioned draughts
- instructions on the use of the booklet
- general arrangement and capacity plans indicating the assigned use of compartments and spaces (cargo, passenger, stores, accommodation, etc.)
- a sketch indicating the position of the draught marks referred to the ship's perpendiculars
- hydrostatic curves or tables corresponding to the design trim, and, if significant trim angles are foreseen during the normal operation of the ship, curves or tables corresponding to such range of trim are to be introduced. A reference relevant to the sea density, in t/m^3 , is to be included as well as the draught measure (from keel or underkeel)
- cross curves (or tables) of stability calculated on a free trimming basis, for the ranges of displacement and trim anticipated in normal operating conditions, with indication of the volumes which have been considered in the computation of these curves
- tank sounding tables or curves showing capacities, centres of gravity, and free surface data for each tank
- lightship data from the inclining test, as indicated in Ch 3, Sec 1, [2.2], including lightship displacement, centre of gravity co-ordinates, place and date of the inclining test, as well as the Society approval details specified in the inclining test report. It is suggested that a copy of the approved test report be included

Where the above-mentioned information is derived from a sister ship, the reference to this sister ship is to be indicated, and a copy of the approved inclining test report relevant to this sister ship is to be included
- standard loading conditions as indicated in [1.2] and examples for developing other acceptable loading conditions using the information contained in the booklet
- intact stability results (total displacement and its centre of gravity co-ordinates, draughts at perpendiculars, GM, GM corrected for free surfaces effect, GZ values and curve, criteria as indicated in Ch 3, Sec 2, [2] and Ch 3, Sec 2, [3] as well as possible additional criteria specified in Part D or Part E when applicable, reporting a comparison between the actual and the required values) are to be available for each of the above-mentioned operating conditions. The method and assumptions to be followed in the stability curve calculation are specified in [1.3]
- information on loading restrictions (maximum allowable load on double bottom, maximum specific gravity allowed in liquid cargo tanks, maximum filling level or percentage in liquid cargo tanks, maximum KG or minimum GM curve or table which can be used to determine compliance with the applicable intact and damage stability criteria) when applicable
- information about openings (location, tightness, means of closure), pipes or other progressive flooding sources
- information concerning the use of any special cross-flooding fittings with descriptions of damage conditions which may require cross-flooding, when applicable
- any other guidance deemed appropriate for the operation of the ship
- a table of contents and index for each booklet.

1.2 Loading conditions

1.2.1 General

The standard loading conditions to be included in the trim and stability booklet are:

- lightship condition
- ship in ballast in the departure condition, without cargo but with full stores and fuel
- ship in ballast in the arrival condition, without cargo and with 10% stores and fuel remaining.

Further loading cases may be included when deemed necessary or useful.

The heel at the equilibrium of any sailing condition is not to be greater than 1°.

1.2.2 Ships carrying cargo on deck

In addition to the loading conditions indicated in [1.2.1] to [1.2.14], in the case of cargo carried on deck the following cases are to be considered:

- ship in the fully loaded departure condition having cargo homogeneously distributed in the holds and a cargo specified in extension and weight on deck, with full stores and fuel
- ship in the fully loaded arrival condition having cargo homogeneously distributed in holds and a cargo specified in extension and weight on deck, with 10% stores and fuel.

1.2.3 General cargo ships

In addition to the standard loading conditions reported in [1.2.1], the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition, with cargo homogeneously distributed throughout all cargo spaces and with full stores and fuel
- ship in the fully loaded arrival condition with cargo homogeneously distributed throughout all cargo spaces and with 10% stores and fuel remaining.

For ships with service notation **general cargo ship** completed by the additional feature **nonhomload**, the following loading cases are also to be included in the trim and stability booklet:

- ship in the departure condition, with cargo in alternate holds, for at least three stowage factors, one of which is relevant to the summer load waterline and with full stores and consumables
Where the condition with cargo in alternate holds relevant to the summer load waterline leads to local loads on the double bottom greater than those allowed by the Society, it is to be replaced by the one in which each hold is filled in order to reach the maximum load allowed on the double bottom; in no loading case is such value to be exceeded
- same conditions as above, but with 10% stores and consumables.

1.2.4 Container ships

In addition to the standard loading conditions specified in [1.2.1], for ships with the service notation **container ship** the following loading cases are to be included in the trim and stability booklet:

- ship with a number of containers having a weight corresponding to the maximum permissible weight for each container at the summer load waterline when loaded with full stores and consumables
- same loading condition as above, but with 10% stores and consumables

The vertical location of the centre of gravity for each container is generally to be taken at one half of the container height. Different locations of the vertical centre of gravity may be accepted in specific cases, if documented.

1.2.5 Bulk carriers, ore carriers and combination carriers

Dry cargo is intended to mean grain, as well as any other type of solid bulk cargo.

The term grain covers wheat, maize (corn), oats, rye, barley, rice, pulses, seeds and processed forms thereof, whose behaviour is similar to that of grain in its natural state.

The term solid bulk cargo covers any material, other than liquid or gas, consisting of a combination of particles, granules or any larger pieces of material, generally uniform in composition, which is loaded directly into the cargo spaces of a ship without any intermediate form of containment.

In addition to the standard loading conditions defined in [1.2.1], for ships with the service notation **bulk carrier, bulk carrier ESP, self-unloading bulk carrier ESP, ore carrier ESP and combination carrier ESP** the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure conditions at the summer load waterline, with cargo homogeneously distributed throughout all cargo holds and with full stores and consumables, for at least three specific gravities, one of which is relevant to the complete filling of all cargo holds
- same conditions as above, but with 10% stores and consumables
- ship in the departure condition, with cargo holds not entirely filled, for at least three stowage factors, one of which is relevant to the summer load waterline and with full stores and consumables
- same conditions as above, but with 10% stores and consumables.

For ships with one of the service notations **self-unloading bulk carrier ESP**, **ore carrier ESP** and **combination carrier ESP** and for ships with the service notation **bulk carrier** or **bulk carrier ESP** completed by the additional feature **nonhomload**, the following loading cases are also to be included in the trim and stability booklet:

- ship in the departure conditions, with cargo in alternate holds, for at least three stowage factors, one of which is relevant to the summer load waterline, and with full stores and consumables.

Where the condition with cargo in alternate holds relevant to the summer load waterline leads to local loads on the double bottom greater than those allowed by the Society, it is to be replaced by the one in which each hold is filled in order to reach the maximum load allowed on the double bottom; in no loading case is such value to be exceeded.

- same conditions as above, but with 10% stores and consumables.

1.2.6 Oil tankers and FLS tankers

All the intended cargo loading conditions are to be included in the trim and stability booklet for examination within the scope of Pt D, Ch 7, Sec 3, [2].

Further cases are subject to prior examination by the Society before the loading; alternatively, an approved loading instrument capable of performing damage stability calculations in accordance with the requirements in Pt D, Ch 7, Sec 3, [2] may be used.

In addition to the standard loading conditions specified in [1.2.1], for ships with the service notation **oil tanker ESP** or **FLS tanker** the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition at the summer load waterline, with cargo homogeneously distributed throughout all cargo tanks and with full stores and consumables
- same condition as above, but with 10% stores and consumables
- ship in the departure condition loaded with a cargo having a density in order to fill all cargo tanks, with full stores and consumables, but immersed at a draught less than the summer load waterline
- same condition as above, but with 10% stores and consumables
- ship in the fully loaded departure condition at the summer load waterline, with cargo tanks not entirely filled and with full stores and consumables
- same condition as above, but with 10% stores and consumables
- two loading conditions corresponding to different cargo segregations in order to have slack tanks with full stores and consumables

When it is impossible to have segregations, these conditions are to be replaced by loading conditions with the same specific gravity and with slack cargo tanks

- same loading condition as above, but with 10% stores and consumables
- for oil tankers having segregated ballast tanks as defined in Pt D, Ch 7, Sec 2, [2], the lightship condition with segregated ballast only is also to be included in the trim and stability booklet for examination.

1.2.7 Chemical tankers

All the intended cargo loading conditions are to be included in the trim and stability booklet for examination within the scope of Pt D, Ch 8, Sec 2, [6].

Further cases are subject to prior examination by the Society before the loading; alternatively, an approved loading instrument capable of performing damage stability calculations in accordance with Pt D, Ch 8, Sec 2, [6] may be used.

In addition to the standard loading conditions defined in [1.2.1], for ships with the service notation **chemical tanker ESP** the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition, with cargo homogeneously distributed throughout all cargo tanks and with full stores and consumables
- same loading condition as above, but with 10% stores and consumables
- three loading conditions corresponding to different specific gravities with cargo homogeneously distributed throughout all cargo tanks and with full stores and consumables
- same loading conditions as above, but with 10% stores and consumables
- four loading conditions corresponding to different cargo segregations in order to have slack tanks with full stores and consumables. Cargo segregation is intended to mean loading conditions with liquids of different specific gravities

When it is impossible to have segregations, these conditions are to be replaced by loading conditions corresponding to different specific gravities with slack cargo tanks

- same loading conditions as above, but with 10% stores and consumables.

When it is impossible to have segregations, these conditions may be replaced by cases corresponding to different specific gravities with slack cargo tanks.

1.2.8 Liquefied gas carriers

All the intended cargo loading conditions are to be included in the trim and stability booklet for examination within the scope of Pt D, Ch 9, Sec 2, [7.1.2].

Further cases are subject to prior examination by the Society before the loading; alternatively, an approved loading instrument capable of performing damage stability calculations in accordance with Pt D, Ch 9, Sec 2, [7.1.2] may be used.

In addition to the standard loading conditions defined in [1.2.1], for ships with the service notation **liquefied gas carrier** or **LNG bunkering ship** the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition, with cargo homogeneously distributed throughout all cargo spaces and with full stores and fuel
- ship in the fully loaded arrival condition with cargo homogeneously distributed throughout all cargo spaces and with 10% stores and fuel remaining.

1.2.9 Passenger ships

In addition to the standard loading conditions specified in [1.2.1], for ships with the service notation **passenger ship** the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition with full stores and fuel and with the full number of passengers with their luggage
- ship in the fully loaded arrival condition, with the full number of passengers and their luggage but with only 10% stores and fuel remaining
- ship without cargo, but with full stores and fuel and the full number of passengers and their luggage
- ship in the same condition as above, but with only 10% stores and fuel remaining.

1.2.10 Dredgers

For ships with one of the service notations **dredger**, **hopper dredger**, **hopper unit**, **split hopper dredger** and **split hopper unit**, the loading conditions described in a) and b) are to replace the standard loading conditions defined in [1.2.1].

a) State of cargo: liquid

- ship loaded to the dredging draught with cargo considered as a liquid
- hopper(s) fully loaded with a homogeneous cargo having density ρ_m , up to the spill out edge of the hopper coaming:

$$\rho_m = M_1 / V_1$$

M_1 : Mass of cargo, in t, in the hopper when loaded at the dredging draught

V_1 : Volume, in m³, of the hopper at the spill out edge of the hopper coaming.

The conditions of stores and fuel are to be equal to 100% and 10%, and an intermediate condition is to be considered if it is more critical than both 100% and 10%.

- hopper(s) filled or partly filled with a homogeneous cargo having densities equal to 1000, 1200, 1400, 1600, 1800 and 2000 kg/m³

When the dredging draught cannot be reached due to the density of the cargo, the hopper is to be considered filled up to the spill out edge of the hopper coaming.

The conditions of stores and fuel are to be the most conservative obtained from the stability calculations with the density ρ_m .

b) State of the cargo: solid

- ship loaded to the dredging draught with cargo considered as a solid
- hopper(s) fully loaded with a homogeneous cargo having density ρ_m up to the spill out edge of the hopper coaming, as calculated in a)

The conditions of stores and fuel are to be equal to 100% and 10%, and an intermediate condition is to be considered if it is more conservative than both 100% and 10%.

- hopper(s) filled or partly filled with a homogeneous cargo having densities equal to 1400, 1600, 1800, 2000 and 2200 kg/m³ if greater than ρ_m .

1.2.11 Tugs and fire-fighting ships

In addition to the standard loading conditions defined in [1.2.1], for ships with one of the service notations **tug** and **fire-fighting**, the following loading cases are to be included in the trim and stability booklet:

- ship in the departure condition at the waterline corresponding to the maximum assigned immersion, with full stores, provisions and consumables
- same conditions as above, but with 10% stores and consumables
- same conditions as above, but with 50% stores and consumables.

1.2.12 Anchor handling vessels

In addition to the standard loading conditions defined in [1.2.1], for ships with the service notation **anchor handling**, the following loading cases are to be included in the trim and stability booklet:

- service loading condition at the maximum draught at which anchor handling operations may occur with the heeling levers as defined in Pt E, Ch 2, Sec 3, [1.3] for the line tension the ship is capable of with a minimum of 67% stores and fuel, in which all the relevant stability criteria defined in Pt E, Ch 2, Sec 3 are met.
- service loading condition at the minimum draught at which anchor handling operations may occur with the heeling levers as defined in Pt E, Ch 2, Sec 3, [1.3] for the line tension the ship is capable of with 10% stores and fuel, in which all the relevant stability criteria as defined in Pt E, Ch 2, Sec 3 are met.

1.2.13 Supply vessels

In addition to the standard loading conditions specified in [1.2.1], for ships with the service notation **supply** the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition having under deck cargo, if any, and cargo specified by position and weight on deck, with full stores and fuel, corresponding to the worst service condition in which all the relevant stability criteria are met
- ship in the fully loaded arrival condition with cargo as specified above, but with 10 per cent stores and fuel
- ship in the worst anticipated operating condition.

1.2.14 Fishing vessels

In addition to the standard loading conditions defined in [1.2.1], for ships with the service notation **fishing vessel** the following loading cases are to be included in the trim and stability booklet:

- departure conditions for the fishing grounds with full fuel stores, ice, fishing gear, etc.
- departure from the fishing grounds with full catch
- arrival at home port with 10% stores, fuel, etc. remaining and full catch
- arrival at home port with 10% stores, fuel, etc. and a minimum catch, which is normally to be 20% of the full catch but may be up to 40% if documented.

1.2.15 Ships having the additional service feature SPxxx or SPxxx-capable

In addition to the standard loading conditions specified in [1.2.1], for ships with the additional service feature **SPxxx** or **SPxxx-capable** the following loading cases are to be included in the trim and stability booklet:

- ship in the fully loaded departure condition, having cargo specified by position and weight, with full stores and fuel, and with the total number of persons on board, including crew, special personnel and passengers
- ship in the fully loaded arrival condition, with cargo and total number of persons as specified above, but with 10 per cent stores and fuel
- ship in the worst anticipated operating condition.

1.2.16 Oil recovery ships

For oil recovery ships, additional information to be included in stability booklet are specified in Pt E, Ch 5, Sec 2.

1.2.17 Lifting units

For lifting units, additional information to be included in stability booklet are specified in Pt E, Ch 8, Sec 3.

1.2.18 Semi-submersible cargo ships

For semi-submersible cargo ships, additional information to be included in stability booklet are specified in Pt E, Ch 9, Sec 3.

1.3 Stability curve calculation

1.3.1 General

Hydrostatic and stability curves are normally prepared on a designed trim basis. However, where the operating trim or the form and arrangement of the ship are such that change in trim has an appreciable effect on righting arms, such change in trim is to be taken into account.

The calculations are to take into account the volume to the upper surface of the deck sheathing.

1.3.2 Superstructures, deckhouses, etc. which may be taken into account

Enclosed superstructures complying with Ch 1, Sec 3, [2.2] may be taken into account.

The second tier of similarly enclosed superstructures may also be taken into account.

Deckhouses on the freeboard deck may be taken into account, provided that they comply with the conditions for enclosed superstructures laid down in Ch 1, Sec 3, [2.2.2].

Where deckhouses comply with the above conditions, except that no additional exit is provided to a deck above, such deckhouses are not to be taken into account; however, any deck openings inside such deckhouses are to be considered as closed even where no means of closure are provided.

Deckhouses, the doors of which do not comply with the requirements of Ch 11, Sec 5, [1.5.4], are not to be taken into account; however, any deck openings inside the deckhouse are regarded as closed where their means of closure comply with the requirements of Ch 11, Sec 9, [8.3] or Ch 11, Sec 10, as relevant.

Deckhouses on decks above the freeboard deck are not to be taken into account, but openings within them may be regarded as closed.

Superstructures and deckhouses not regarded as enclosed may, however, be taken into account in stability calculations up to the angle at which their openings are flooded (at this angle, the static stability curve is to show one or more steps, and in subsequent computations the flooded space are to be considered non-existent).

Trunks may be taken into account. Hatchways may also be taken into account having regard to the effectiveness of their closures.

1.3.3 Angle of flooding

In cases where the ship would sink due to flooding through any openings, the stability curve is to be cut short at the corresponding angle of flooding and the ship is to be considered to have entirely lost its stability.

Small openings such as those for passing wires or chains, tackle and anchors, and also holes of scuppers, discharge and sanitary pipes are not to be considered as open if they submerge at an angle of inclination more than 30°. If they submerge at an angle of 30° or less, these openings are to be assumed open if the Society considers this to be a source of significant progressive flooding; therefore such openings are to be considered on a case by case basis.

Appendix 3 Probabilistic Damage Stability Method for Cargo Ships

1 Probabilistic damage stability method for cargo ships

1.1 Application

1.1.1 The requirements included in this Appendix are to be applied to cargo ships over 80 m in length L_{LL} as defined in Ch 1, Sec 3, [2.1.2], but are not to be applied to those ships which are shown to comply with subdivision and damage stability regulations already required in Part D or Part E.

Any reference hereinafter to regulations refers to the set of regulations contained in this Appendix.

The Society may, for a particular ship or group of ships, accept alternative arrangements, if it is satisfied that at least the same degree of safety as represented by these regulations is achieved.

This includes, for example, the following:

- ships constructed in accordance with a standard of damage stability with a set of damage criteria agreed by the Society
- ships of a multi-hull design, where the subdivision arrangements need to be evaluated against the basic principles of the probabilistic method since the regulations have been written specifically for mono-hulls.

1.1.2 The requirements of this Appendix are to be applied in conjunction with the explanatory notes as set out by the IMO resolution MSC 281 (85).

1.2 Definitions

1.2.1 Deepest subdivision draught

The deepest subdivision draught (d_s) is the waterline which corresponds to the summer load line draught of the ship.

1.2.2 Light service draught

Light service draught (d_l) is the service draught corresponding to the lightest anticipated loading and associated tankage, including, however, such ballast as may be necessary for stability and/or immersion.

1.2.3 Partial subdivision draught

The partial subdivision draught (d_p) is the light service draught plus 60% of the difference between the light service draught and the deepest subdivision draught.

1.2.4 Subdivision length L_s

The subdivision length L_s is the greatest projected moulded length of that part of the ship at or below deck or decks limiting the vertical extent of flooding with the ship at the deepest subdivision draught.

1.2.5 Machinery space

Machinery spaces are spaces between the watertight boundaries of a space containing the main and auxiliary propulsion machinery, including boilers, generators and electric motors primarily intended for propulsion. In the case of unusual arrangements, the Society may define the limits of the machinery spaces.

1.2.6 Other definitions

Mid-length is the mid point of the subdivision length of the ship.

Aft terminal is the aft limit of the subdivision length.

Forward terminal is the forward limit of the subdivision length.

Breadth B is the greatest moulded breadth, in m, of the ship at or below the deepest subdivision draught.

Draught d is the vertical distance, in m, from the moulded baseline at mid-length to the waterline in question.

Permeability μ of a space is the proportion of the immersed volume of that space which can be occupied by water.

Note 1: In determining the permeability of a space, the volume of a space is to be taken as the moulded volume, i.e. the immersed volume of a space shall be the underwater moulded volume of that space multiplied by the permeability.

1.3 Required subdivision index R

1.3.1 These regulations are intended to provide ships with a minimum standard of subdivision.

The degree of subdivision to be provided is to be determined by the required subdivision index R , as follows:

- for ships greater than 100 m in length L_s :

$$R = 1 - \frac{128}{L_s + 152}$$

- for ships of 80 m in length L_s and upwards, but not greater than 100 m in length L_s :

$$R = 1 - \frac{1}{\left(1 + \frac{L_s - R_0}{100(1 - R_0)}\right)}$$

where R_0 is the value of R as calculated in accordance with the formula given for ships greater than 100 m in length L_s .

1.4 Attained subdivision index A

1.4.1 The attained subdivision index A is obtained by the summation of the partial indices A_s , A_p and A_l (weighed as shown), calculated for the draughts d_s , d_p and d_l defined in [1.2.1], [1.2.2] and [1.2.3], in accordance with the following formula:

$$A = 0,4 A_s + 0,4 A_p + 0,2 A_l$$

The attained subdivision index A is not to be less than the required subdivision index R . In addition, the partial indices A_s , A_p and A_l are not to be less than 0,5 R .

1.4.2 Each partial index is a summation of contributions from all damage cases taken in consideration, using the following formula:

$$A = \sum p_i s_i$$

where:

- i : Represents each compartment or group of compartments under consideration
- p_i : Accounts for the probability that only the compartment or group of compartments under consideration may be flooded, disregarding any horizontal subdivision, as defined in [1.5]
- s_i : Accounts for the probability of survival after flooding the compartment or group of compartments under consideration, and includes the effects of any horizontal subdivision, as defined in [1.6].

1.4.3 As a minimum, the calculation of A is to be carried out at the level trim for the deepest subdivision draught d_s and the partial subdivision draught d_p . The estimated service trim may be used for the light service draught d_l . If, in any anticipated service condition within the draught range from d_s to d_l , the trim variation in comparison with the calculated trim is greater than 0,005 L , one or more additional calculations of A are to be performed for the same draughts but including sufficient trims to ensure that, for all intended service conditions, the difference in trim in comparison with the reference trim used for one calculation will be not more than 0,005 L . Each additional calculation of A is to comply with [1.3].

When determining the positive righting lever (GZ) of the residual stability curve in the intermediate and final equilibrium stages of flooding, the displacement used should be that of the intact loading condition. All calculations should be done with the ship freely trimming.

The summation indicated by the formula in [1.4.2] is to be taken over the ship's subdivision length (L_s) for all cases of flooding in which a single compartment or two or more adjacent compartments are involved. In the case of unsymmetrical arrangements, the calculated A value is to be the mean value obtained from calculations involving both sides. Alternatively, it is to be taken as that corresponding to the side which evidently gives the least favourable result.

1.4.4 Wherever wing compartments are fitted, contribution to the summation indicated by the formula is to be taken for all cases of flooding in which wing compartments are involved. Additionally, cases of simultaneous flooding of a wing compartment or group of compartments and the adjacent inboard compartment or group of compartments, but excluding damage of transverse extent greater than one half of the ship breadth B , may be added. For the purpose of this regulation, transverse extent is measured inboard from ship's side, at right angle to the centreline at the level of the deepest subdivision draught.

1.4.5 In the flooding calculations carried out according to the regulations, only one breach of the hull and only one free surface need to be assumed. The assumed vertical extent of damage is to extend from the baseline upwards to any watertight horizontal subdivision above the waterline or higher. However, if a lesser extent of damage gives a more severe result, such extent is to be assumed.

1.4.6 If pipes, ducts or tunnels are situated within the assumed extent of damage, arrangements are to be made to ensure that progressive flooding cannot thereby extend to compartments other than those assumed flooded. However, the Society may permit minor progressive flooding if it is demonstrated that its effects can be easily controlled and the safety of the ship is not impaired.

1.5 Calculation of factor p_i

1.5.1 The factor p_i for a compartment or group of compartments is to be calculated in accordance with [1.5.2] to [1.5.6] using the following notations:

- j : The aftmost damage zone number involved in the damage starting with no.1 at the stern
 n : The number of adjacent damage zones involved in the damage
 k : The number of a particular longitudinal bulkhead as barrier for transverse penetration in a damage zone, counted from shell towards the centreline. The shell has $k = 0$
 x_1 : The distance from the aft terminal of L_s to the aft end of the zone in question
 x_2 : The distance from the aft terminal of L_s to the forward end of the zone in question
 b : The mean transverse distance in metres measured at right angles to the centreline at the deepest subdivision draught between the shell and an assumed vertical plane extended between the longitudinal limits used in calculating the factor p_i and which is a tangent to, or common with, all or part of the outermost portion of the longitudinal bulkhead under consideration. This vertical plane shall be so orientated that the mean transverse distance to the shell is a maximum, but not more than twice the least distance between the plane and the shell. If the upper part of a longitudinal bulkhead is below the deepest subdivision draught, the vertical plane used for the determination of b is assumed to extend upwards to the deepest subdivision waterline. In any case, b is not to be taken greater than $B/2$.

If the damage involves a single zone only:

$$p_i = p(x_{1(j)}, x_{2(j)}) \cdot [r(x_{1(j)}, x_{2(j)}, b_k) - r(x_{1(j)}, x_{2(j)}, b_{(k-1)})]$$

If the damage involves two adjacent zones:

$$p_i = p(x_{1(j)}, x_{2(j+1)}) \cdot [r(x_{1(j)}, x_{2(j+1)}, b_k) - r(x_{1(j)}, x_{2(j+1)}, b_{(k-1)})] \\ - p(x_{1(j)}, x_{2(j)}) \cdot [r(x_{1(j)}, x_{2(j)}, b_k) - r(x_{1(j)}, x_{2(j)}, b_{(k-1)})] \\ - p(x_{1(j+1)}, x_{2(j+1)}) \cdot [r(x_{1(j+1)}, x_{2(j+1)}, b_k) - r(x_{1(j+1)}, x_{2(j+1)}, b_{(k-1)})]$$

If the damage involves three or more adjacent zones:

$$p_i = p(x_{1(j)}, x_{2(j+n-1)}) \cdot [r(x_{1(j)}, x_{2(j+n-1)}, b_k) - r(x_{1(j)}, x_{2(j+n-1)}, b_{(k-1)})] \\ - p(x_{1(j)}, x_{2(j+n-2)}) \cdot [r(x_{1(j)}, x_{2(j+n-2)}, b_k) - r(x_{1(j)}, x_{2(j+n-2)}, b_{(k-1)})] \\ - p(x_{1(j+1)}, x_{2(j+n-1)}) \cdot [r(x_{1(j+1)}, x_{2(j+n-1)}, b_k) - r(x_{1(j+1)}, x_{2(j+n-1)}, b_{(k-1)})] \\ + p(x_{1(j+1)}, x_{2(j+n-2)}) \cdot [r(x_{1(j+1)}, x_{2(j+n-2)}, b_k) - r(x_{1(j+1)}, x_{2(j+n-2)}, b_{(k-1)})]$$

and where $r(x_1, x_2, b_0) = 0$

1.5.2 The factor $p(x_1, x_2)$ is to be calculated according to the formulae given in [1.5.3] to [1.5.5], with:

J_{max} : Overall normalized max damage length

$$J_{max} = 10 / 33$$

J_{kn} : Knuckle point in the distribution

$$J_{kn} = 5 / 33$$

p_k : Cumulative probability at J_{kn}

$$p_k = 11 / 12$$

ℓ_{max} : Maximum absolute damage length

$$\ell_{max} = 60 \text{ m}$$

L^* : Length where normalized distribution ends

$$L^* = 260 \text{ m}$$

b_0 : Probability density at $J = 0$

$$b_0 = 2 \left(\frac{p_k}{J_{kn}} - \frac{1 - p_k}{J_{max} - J_{kn}} \right)$$

- when $L_s \leq L^*$:

$$J_m = \min \left\{ J_{max}, \frac{\ell_{max}}{L_s} \right\}$$

$$J_k = \frac{J_m}{2} + \frac{1 - \sqrt{1 + (1 - 2p_k)b_0 \cdot J_m + \frac{1}{4}b_0^2 \cdot J_m^2}}{b_0}$$

$$b_{12} = b_0$$

- when $L_s > L^*$:

$$J_m^* = \min \left\{ J_{max}, \frac{\ell_{max}}{L^*} \right\}$$

$$J_k^* = \frac{J_m^*}{2} + \frac{1 - \sqrt{1 + (1 - 2p_k)b_0 \cdot J_m^* + \frac{1}{4}b_0^2 \cdot J_m^{*2}}}{b_0}$$

$$J_m = \frac{J_m^* \cdot L^*}{L_s}$$

$$J_k = \frac{J_k^* \cdot L^*}{L_s}$$

$$b_{12} = 2 \left(\frac{p_k}{J_k} - \frac{1-p_k}{J_m - J_k} \right)$$

$$b_{11} = 4 \frac{1-p_k}{(J_m - J_k)J_k} - 2 \frac{p_k}{J_k^2}$$

$$b_{21} = -2 \frac{1-p_k}{(J_m - J_k)^2}$$

$$b_{22} = -b_{21} \cdot J_m$$

J : Non-dimensional damage length:

$$J = \frac{x_2 - x_1}{L_s}$$

J_n : Normalized length of a compartment or group of compartments, to be taken as the lesser of J and J_m .

1.5.3 Where neither limit of the compartment or group of compartments under consideration coincides with the aft or forward terminals:

- $J \leq J_k$:

$$p(x_1, x_2) = p_1 = \frac{1}{6} J^2 (b_{11} \cdot J + 3b_{12})$$

- $J > J_k$:

$$p(x_1, x_2) = p_2 = -\frac{b_{11} \cdot J_k^3}{3} + \frac{(b_{11} \cdot J - b_{12})J_k^2}{2} + b_{12} \cdot J \cdot J_k - \frac{b_{21}(J_n^3 - J_k^3)}{3} + \frac{(b_{21} \cdot J - b_{22})(J_n^2 - J_k^2)}{2} + b_{22} \cdot J(J_n - J_k)$$

1.5.4 Where the aft limit of the compartment or group of compartments under consideration coincides with the aft terminal or the forward limit of the compartment or group of compartments under consideration coincides with the forward terminal:

- $J \leq J_k$:

$$p(x_1, x_2) = \frac{1}{2}(p_1 + J)$$

- $J > J_k$:

$$p(x_1, x_2) = \frac{1}{2}(p_2 + J)$$

1.5.5 Where the compartment or group of compartments considered extends over the entire subdivision length (L_s):

$$p(x_1, x_2) = 1$$

1.5.6 The factor $r(x_1, x_2, b)$ is to be determined by the following formula:

$$r(x_1, x_2, b) = 1 - (1 - C) \cdot \left[1 - \frac{G}{p(x_1, x_2)} \right]$$

where:

$$C = 12J_b(-45J_b + 4)$$

with $J_b = b / (15 B)$

- where the compartment or group of compartments considered extends over the entire subdivision length (L_s):

$$G = G_1 = \frac{1}{2} b_{11} \cdot J_b^2 + b_{12} \cdot J_b$$

- where neither limit of the compartment or group of compartments under consideration coincides with the aft or forward terminals:

$$G = G_2 = -\frac{1}{3} b_{11} \cdot J_0^3 + \frac{1}{2} (b_{11} \cdot J - b_{12}) J_0^2 + b_{12} \cdot J \cdot J_0$$

with $J_0 = \min(J, J_b)$

- where the aft limit of the compartment or group of compartments under consideration coincides with the aft terminal or the forward limit of the compartment or group of compartments under consideration coincides with the forward terminal:

$$G = \frac{1}{2}(G_2 + G_1 \cdot J)$$

1.6 Calculation of factor s_i

1.6.1 The factor s_i is to be determined for each case of assumed flooding involving a compartment or group of compartments according to the requirement indicated in [1.6.2] to [1.6.12] and the following notations:

θ_e : Equilibrium heel angle in any stage of flooding, in degrees

θ_v : Angle, in any stage of flooding, where the righting lever becomes negative, or the angle at which an opening incapable of being closed weathertight becomes submerged

GZ_{max} : Maximum positive righting lever, in metres, up to the angle θ_v

Range : Range of positive righting levers, in degrees, measured from the angle θ_e . The positive range is to be taken up to the angle θ_v

Flooding stage is any discrete step during the flooding process, including the stage before equalization (if any) until final equilibrium has been reached.

1.6.2 The factor s_i , for any damage case at any initial loading condition, d_i , shall be obtained from the formula:

$$s_i = \min[s_{intermediate,i}, s_{final,i}]$$

where:

$s_{intermediate,i}$: The probability to survive all intermediate flooding stages until the final equilibrium stage, calculated in accordance with [1.6.3]

$s_{final,i}$: The probability to survive in the final equilibrium stage of flooding, calculated in accordance with [1.6.4].

1.6.3 Calculation of $s_{intermediate}$

- For cargo ships fitted with cross-flooding devices, the factor $s_{intermediate,i}$ is to be taken as the least of the s-factors obtained from all flooding stages including the stage before equalization, if any, and is to be calculated as follows:

$$s_{intermediate,i} = \left(\frac{GZ_{max}}{0,05} \cdot \frac{Range}{7} \right)^{\frac{1}{4}}$$

where GZ_{max} is not to be taken as more than 0,05 m and Range as not more than 7°.

$s_{intermediate} = 0$, if the intermediate heel angle exceeds 30°.

- For cargo ships not fitted with cross-flooding devices the factor $s_{intermediate,i}$ is taken as unity, except if the Society considers that the stability in intermediate stages of flooding may be insufficient. It should require further investigation thereof.

Where cross-flooding fittings are required, the time for equalization is not to exceed 10 min. The time for equalization is to be calculated in accordance with Pt D, Ch 11, App 1.

1.6.4 Calculation of s_{final}

The factor $s_{final,i}$ is to be obtained from the formula:

$$s_{final,i} = K \left(\frac{GZ_{max}}{TGZ_{max}} \cdot \frac{Range}{TRange} \right)^{\frac{1}{4}}$$

where:

GZ_{max} is not to be taken as more than TGZ_{max}

Range is not to be taken as more than TRange.

$TGZ_{max} = 0,12$ m

$TRange = 16^\circ$

K is to be taken equal to:

- $K = 1$ if $\theta_e \leq \theta_{min}$
- $K = 0$ if $\theta_e \geq \theta_{max}$

$$K = \sqrt{\frac{\theta_{max} - \theta_e}{\theta_{max} - \theta_{min}}} \quad \text{otherwise}$$

θ_{min} is equal to 25°

θ_{max} is equal to 30°.

1.6.5 Cases where s_i is taken as zero

- a) The factor s_i is to be taken as zero in those cases where the final waterline, taking into account sinkage, heel and trim, immerses:
- the lower edge of openings through which progressive flooding may take place and such flooding is not accounted for in the calculation of factor s_i . Such openings are to include air-pipes, ventilators and openings which are closed by means of weathertight doors or hatch covers, but the openings closed by means of watertight manhole covers and flush scuttles, small watertight hatch covers, remotely operated sliding watertight doors, side scuttles of the non-opening type as well as watertight access doors and hatch covers required to be kept closed at sea need not be considered.
 - any part of the bulkhead deck considered a horizontal evacuation route.
- b) The factor s_i is to be taken as zero if, taking into account sinkage, heel and trim, any of the following occur in any intermediate stage or in the final stage of flooding:
- immersion of any vertical escape hatch in the freeboard deck of cargo ships intended for compliance with the applicable requirements of Pt C, Ch 4, Sec 8
 - any controls intended for the operation of watertight doors, equalization devices, valves on piping or on ventilation ducts intended to maintain the integrity of watertight bulkheads from above the freeboard deck of cargo ships become inaccessible or inoperable
 - immersion of any part of piping or ventilation ducts located within the assumed extent of damage and carried through a watertight boundary if this can lead to the progressive flooding of compartment not assumed as flooded.

1.6.6 The ship is to be so designed that s_i calculated in accordance with [1.6.1] will not be less than 1 at the deepest subdivision draught loading condition, level trim or any forward trim loading conditions, if any part of the ship forward of the collision bulkhead is flooded without vertical limits.

1.6.7 Unsymmetrical flooding is to be kept to a minimum consistent with the efficient arrangements. Where it is necessary to correct large angles of heel, the means adopted are, where practicable, to be self-acting, but in any case where controls to equalization devices are provided they are to be operable from above the freeboard deck of cargo ships. These fittings, together with their controls, are to be acceptable to the Society. Suitable information concerning the use of equalization devices are to be supplied to the master of the ship.

1.6.8 Tanks and compartments taking part in such equalization are to be fitted with air pipes or equivalent means of sufficient cross-section to ensure that the flow of water into the equalization compartments is not delayed.

1.6.9 Where horizontal watertight boundaries are fitted above the waterline under consideration, the s -value calculated for the lower compartment or group of compartments is to be obtained by multiplying the value as determined in [1.6.2] by the reduction factor v_m according to [1.6.10], which represents the probability that the spaces above the horizontal subdivision will not be flooded.

1.6.10 The factor v_m is to be obtained from the following formula:

$$v_m = v(H_{j,n,m}, d) - v(H_{j,n,m-1}, d)$$

where:

$H_{j,n,m}$: Least height above the baseline, in metres, within the longitudinal range of $x_1(j) \dots x_2(j+n-1)$ of the m^{th} horizontal boundary which is assumed to limit the vertical extent of flooding for the damaged compartments under consideration

$H_{j,n,m-1}$: Least height above the baseline, in metres, within the longitudinal range of $x_1(j) \dots x_2(j+n-1)$ of the $(m-1)^{\text{th}}$ horizontal boundary which is assumed to limit the vertical extent of flooding for the damaged compartments under consideration

j : The aft terminal of the damaged compartments under consideration

m : Each horizontal boundary counted upwards from the waterline under consideration

d : Draught in question, as defined in [1.2]

x_1, x_2 : Terminals of the compartment or group of compartments considered in [1.5.1].

1.6.11 The factors $v(H_{j,n,m}, d)$ and $v(H_{j,n,m-1}, d)$ are to be obtained from the following formulae:

- if $(H_m - d) \leq 7,8 m$:

$$v(H, d) = 0,8 \frac{(H-d)}{7,8}$$

- in all other cases:

$$v(H, d) = 0,8 + 0,2 \left[\frac{(H-d) - 7,8}{4,7} \right]$$

where:

- $v(H_{j,n,m}, d)$ is to be taken as 1, if H_m coincides with the uppermost watertight boundary of the ship within the range $(x_{1(j)} \dots x_{2(j+n-1)})$
 - $v(H_{j,n,0}, d)$ is to be taken as 0.
- In no case is v_m to be taken as less than zero or more than 1.

1.6.12 In general, each contribution dA to the index A in the case of horizontal subdivisions is obtained from the following formula:

$$dA = p_i \cdot [v_1 \cdot s_{\min 1} + (v_2 - v_1) \cdot s_{\min 2} + \dots + (1 - v_{m-1}) \cdot s_{\min m}]$$

where:

- v_m : The v-value calculated in accordance with [1.6.10] and [1.6.11]
- s_{\min} : The least s-factor for all combinations of damages obtained when the assumed damage extends from the assumed damage height H_m downwards.

1.7 Permeability

1.7.1 For the purpose of the subdivision and damage stability calculations reported in this Appendix, the permeability of each space or part of a space is to be as per Tab 1.

Table 1 : Permeability

Spaces	Permeability
Appropriated to stores	0,60
Occupied by accommodations	0,95
Occupied by machinery	0,85
Void spaces	0,95
Intended for liquids	0 or 0,95 (1)
(1) whichever results in the more severe requirements	

1.7.2 For the purpose of the subdivision and damage stability calculations reported in this Appendix, the permeability of each cargo compartment is to be as per Tab 2.
Other figures for permeability may be used if substantiated by calculations.

Table 2 : Permeability of cargo compartments

Spaces	Permeability at draught		
	d_s	d_p	d_t
Dry cargo spaces	0,70	0,80	0,95
Container spaces	0,70	0,80	0,95
Ro-ro spaces	0,90	0,90	0,95
Cargo liquids	0,70	0,80	0,95

1.8 Stability information

1.8.1 The master is to be supplied with such information satisfactory to the Society as is necessary to enable him by rapid and simple processes to obtain accurate guidance as to the stability of the ship under varying conditions of service. A copy of the stability information is to be furnished to the Society.

1.8.2 Information to be submitted

The information is to include:

- curves or tables of minimum operational metacentric height (GM) versus draught which assures compliance with the relevant intact and damage stability requirements, alternatively corresponding curves or tables of the maximum allowable vertical centre of gravity (KG) versus draught, or with the equivalents of either of these curves
- instructions concerning the operation of cross-flooding arrangements, and
- all other data and aids which might be necessary to maintain the required intact stability and stability after damage.

1.8.3 The stability information is to show the influence of various trims in cases where the operational trim range exceeds $\pm 0,5\%$ of L_s .

1.8.4 For ships which have to fulfil the stability requirements of this Annex, information referred to in [1.8.2] is determined from considerations related to the subdivision index, in the following manner: Minimum required GM (or maximum permissible vertical position of centre of gravity KG) for the three draughts d_s , d_p and d_l are equal to the GM (or KG values) of corresponding loading cases used for the calculation of survival factor s_i . For intermediate draughts, values to be used are to be obtained by linear interpolation applied to the GM value only between the deepest subdivision draught and the partial subdivision draught and between the partial load line and the light service draught respectively. Intact stability criteria are also to be taken into account by retaining for each draught the maximum among minimum required GM values or the minimum of maximum permissible KG values for both criteria. If the subdivision index is calculated for different trims, several required GM curves are to be established in the same way.

1.8.5 When curves or tables of minimum operational metacentric height (GM) versus draught are not appropriate, the master is to ensure that the operating condition does not deviate from a studied loading condition, or verify by calculation that the stability criteria are satisfied for this loading condition.

Appendix 4 Damage Stability Calculation for Ships Assigned with a Reduced Freeboard

1 Application

1.1 General

1.1.1 The requirements of this Appendix apply to:

- Type A ships having a length greater than 150 m, and
- Type B-60 ships and Type B-100 ships having a length greater than 100 m.

Any reference hereafter to regulations refers to the set of regulations contained in this Appendix.

2 Initial loading condition

2.1 Initial condition of loading

2.1.1 *The initial condition of loading before flooding is to be determined according to [2.1.2] and [2.1.3].*

2.1.2 *The ship is loaded to its summer load waterline on an imaginary even keel.*

2.1.3 *When calculating the vertical centre of gravity, the following principles apply:*

- Homogeneous cargo is carried.*
- All cargo compartments, except those referred to under c), but including compartments intended to be partially filled, are to be considered fully loaded except that in the case of fluid cargoes each compartment is to be treated as 98 per cent full.*
- If the ship is intended to operate at its summer load waterline with empty compartments, such compartments are to be considered empty provided the height of the centre of gravity so calculated is not less than as calculated under b).*
- Fifty per cent of the individual total capacity of all tanks and spaces fitted to contain consumable liquids and stores is allowed for. It is to be assumed that for each type of liquid, at least one transverse pair or a single centre line tank has maximum free surface, and the tank or combination of tanks to be taken into account are to be those where the effect of free surfaces is the greatest; in each tank the centre of gravity of the contents is to be taken at the centre of volume of the tank. The remaining tanks are to be assumed either completely empty or completely filled, and the distribution of consumable liquids between these tanks is to be effected so as to obtain the greatest possible height above the keel for the centre of gravity.*
- At an angle of heel of not more than 5 degrees in each compartment containing liquids, as prescribed in b) except that in the case of compartments containing consumable fluids, as prescribed in d), the maximum free surface effect is to be taken into account.*

Alternatively, the actual free surface effects may be used, provided the methods of calculation are acceptable to the Society.

f) *Weights are to be calculated on the basis of Tab 1.*

Table 1 : Specific gravities

Weight item	Specific gravity, in t/m ³
Salt water	1,025
Fresh water	1,000
Fuel oil	0,950
Diesel oil	0,900
Lubricating oil	0,900

3 Damage assumptions

3.1 Damage dimension

3.1.1 *The principles indicated in [3.1.2] to [3.1.5] regarding the character of the assumed damage apply.*

3.1.2 *The vertical extent of damage in all cases is assumed to be from the base line upwards without limit.*

3.1.3 The transverse extent of damage is equal to $B/5$ or 11,5 metres, whichever is the lesser, measured inboard from the side of the ship perpendicularly to the centre line at the level of the summer load waterline.

3.1.4 If damage of a lesser extent than specified in [3.1.2] and [3.1.3] results in a more severe condition, such lesser extent is to be assumed.

3.1.5 Except where otherwise required in [3.4.3], the flooding is to be confined to a single compartment between adjacent transverse bulkheads provided the inner longitudinal boundary of the compartment is not in a position within the transverse extent of assumed damage. Transverse boundary bulkheads of wing tanks, which do not extend over the full breadth of the ship are to be assumed not to be damaged, provided they extend beyond the transverse extent of assumed damage prescribed in [3.1.3].

3.2 Steps and recesses

3.2.1 If in a transverse bulkhead there are steps or recesses of not more than 3,05 metres in length located within the transverse extent of assumed damage as defined in [3.1.3], such transverse bulkhead may be considered intact and the adjacent compartment may be floodable singly. If, however, within the transverse extent of assumed damage there is a step or recess of more than 3,05 metres in length in a transverse bulkhead, the two compartments adjacent to this bulkhead are to be considered as flooded. The step formed by the after peak bulkhead and the after peak tank top is not to be regarded as a step for the purpose of this regulation.

3.2.2 Where a main transverse bulkhead is located within the transverse extent of assumed damage and is stepped in way of a double bottom or side tank by more than 3,05 metres, the double bottom or side tanks adjacent to the stepped portion of the main transverse bulkhead are to be considered as flooded simultaneously. If this side tank has openings into one or several holds, such as grain feeding holes, such hold or holds are to be considered as flooded simultaneously. Similarly, in a ship designed for the carriage of fluid cargoes, if a side tank has openings into adjacent compartments, such adjacent compartments are to be considered as empty and flooded simultaneously. This provision is applicable even where such openings are fitted with closing appliances, except in the case of sluice valves fitted in bulkheads between tanks and where the valves are controlled from the deck. Manhole covers with closely spaced bolts are considered equivalent to the unpierced bulkhead except in the case of openings in topside tanks making the topside tanks common to the holds.

3.2.3 Where a transverse bulkhead forming the forward or aft limit of a wing tank or double bottom tank is not in line with the main transverse bulkhead of the adjacent inboard compartment, it is considered to form a step or recess in the main transverse bulkhead.

Such a step or recess may be assumed not to be damaged provided that, either:

- the longitudinal extent of the step or recess, measured from the plan of the main transverse bulkhead, is not more than 3,05 metres, or
- any longitudinal surface forming the step or recess is located inboard of the assumed damage.

3.2.4 Where, otherwise, the transverse and longitudinal bulkheads bounding a main inboard compartment are entirely inboard of the assumed damage position, damage is assumed to occur between the transverse bulkheads and the adjacent wing compartment. Any step or recess in such wing tank is to be treated as indicated above.

Examples are shown in Fig 1 to Fig 4:

- Fig 1 and Fig 2 refer to [3.2.2]
- Fig 3 and Fig 4 refer to [3.2.1] and [3.2.2].

Figure 1 : Step and recesses - Example 1

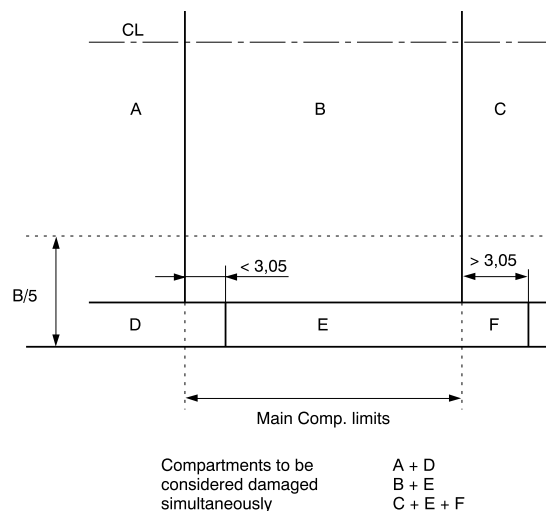


Figure 2 : Step and recesses - Example 2

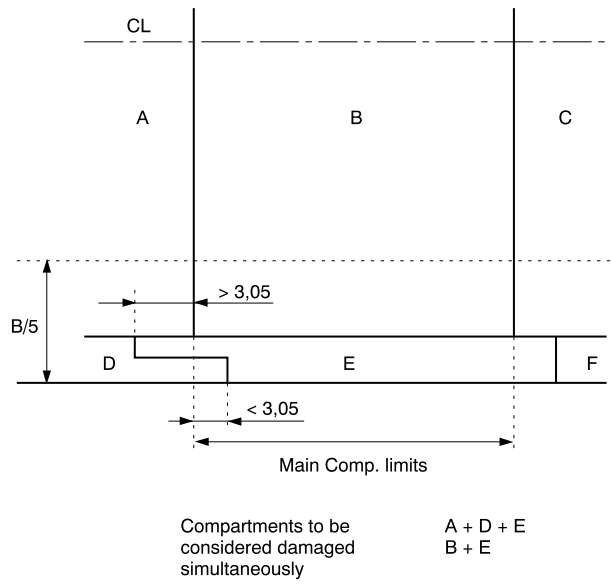


Figure 3 : Step and recesses - Example 3

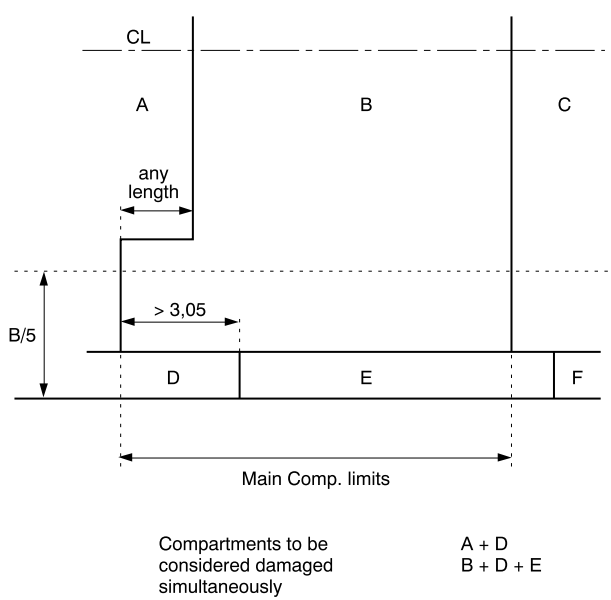
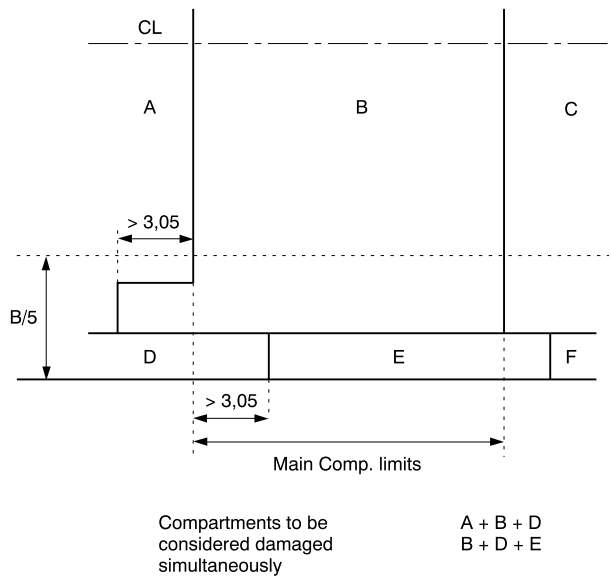


Figure 4 : Step and recesses - Example 4



3.3 Transverse bulkhead spacing

3.3.1 Where the flooding of any two adjacent fore and aft compartments is envisaged, main transverse watertight bulkheads are to be spaced at least $1/3(L)^{2/3}$ or 14,5 metres, whichever is the lesser, in order to be considered effective. Where transverse bulkheads are spaced at a lesser distance, one or more of these bulkheads are to be assumed as non-existent in order to achieve the minimum spacing between bulkheads.

3.4 Damage assumption

3.4.1 A Type A ship, if over 150 metres in length to which a freeboard less than Type B has been assigned, when loaded as considered in [2.1], is to be able to withstand the flooding of any compartment or compartments, with an assumed permeability of 0,95, consequent upon the damage assumptions specified in [3.1], and is to remain afloat in a satisfactory condition of equilibrium as specified in [3.5] and [3.6]. In such a ship, the machinery space is to be treated as a floodable compartment, but with a permeability of 0,85. See Tab 2.

3.4.2 A Type B-60 ship, when loaded as considered in [2.1], is to be able to withstand the flooding of any compartment or compartments, with an assumed permeability of 0,95, consequent upon the damage assumptions specified in [3.1], and is to remain afloat in a satisfactory condition of equilibrium as specified in [3.5] and [3.6]. In such a ship, if over 150 metres in length, the machinery space is to be treated as a floodable compartment, but with a permeability of 0,85. See Tab 2.

3.4.3 A Type B-100 ship, when loaded as considered in [2.1], is to be able to withstand the flooding of any compartment or compartments, with an assumed permeability of 0,95, consequent upon the damage assumptions specified in [3.1], and is to remain afloat in a satisfactory condition of equilibrium as specified in [3.5] and [3.6]. Furthermore all the requirements stated in [4.1] are to be complied with, provided that throughout the length of the ship any one transverse bulkhead will be assumed to be damaged, such that two adjacent fore and aft compartments are to be flooded simultaneously, except that such damage will not apply to the boundary bulkheads of a machinery space. In such a ship, if over 150 metres in length, the machinery space is to be treated as a floodable compartment, but with a permeability of 0,85. See Tab 2.

Table 2 : Damage assumption

Type	L, in m	Standard of flooding (1)
A	≥ 150	one compartment
B - 60	≥ 100	one compartment
B - 100	≥ 100	two adjacent compartments (exemption for machinery space which is to be flooded alone)
(1) except where otherwise required by [4.2].		

3.5 Condition of equilibrium

3.5.1 The condition of equilibrium after flooding is to be regarded as satisfactory according to [3.5.2] and [3.5.3].

3.5.2 The final waterline after flooding, taking into account sinkage, heel and trim, is below the lower edge of any opening through which progressive downflooding may take place. Such openings are to include air pipes, ventilators and openings which are closed by means of weathertight doors or hatch covers, unless closed by watertight gasketed covers of steel or equivalent material, and may exclude those openings closed by means of manhole covers and flush scuttles, cargo hatch covers, remotely operated sliding watertight doors, and side scuttles of the non-opening type. However, in the case of doors separating a main machinery space from a steering gear compartment, watertight doors may be of a hinged, quick acting type kept closed at sea, whilst not in use, provided also that the lower sill of such doors is above the summer load waterline.

3.5.3 If pipes, ducts or tunnels are situated within the assumed extent of damage penetration as defined in [3.1.3], arrangements are to be made so that progressive flooding cannot thereby extend to compartments other than those assumed to be floodable in the calculation for each case of damage.

3.6 Damage stability criteria

3.6.1 The angle of heel due to unsymmetrical flooding does not exceed 15 degrees. If no part of the deck is immersed, an angle of heel of up to 17 degrees may be accepted.

3.6.2 The metacentric height in the flooded condition is positive.

3.6.3 When any part of the deck outside the compartment assumed flooded in a particular case of damage is immersed, or in any case where the margin of stability in the flooded condition may be considered doubtful, the residual stability is to be investigated. It may be regarded as sufficient if the righting lever curve has a minimum range of 20 degrees beyond the position of equilibrium with a maximum righting lever of at least 0,1 metre within this range. The area under the righting lever curve within this range is to be not less than 0,0175 metre-radians. The Society is to give consideration to the potential hazard presented by protected or unprotected openings which may become temporarily immersed within the range of residual stability.

3.6.4 *The Society is satisfied that the stability is sufficient during intermediate stages of flooding. In this regard, the Society will apply the same criteria relevant to the final stage, also during the intermediate stages of flooding.*

4 Requirements for Type B-60 and B-100 ships

4.1 Requirements for Type B-60 ships

4.1.1 *Any Type B ships of over 100 metres, having hatchways closed by weathertight covers as specified in [4.3], may be assigned freeboards less than those required for Type B, provided that, in relation to the amount of reduction granted, the requirements in [4.1.2] to [4.1.4] are considered satisfactory by the Society.*

In addition, the requirements stated in [3.4.2] are to be complied with.

4.1.2 *The measures provided for the protection of the crew are to be adequate.*

4.1.3 *The freeing arrangements are to comply with the provisions of Ch 11, Sec 12.*

4.1.4 *The covers in positions 1 and 2 comply with the provisions of [4.3] and have strength complying with Ch 11, Sec 9, special care being given to their sealing and securing arrangements.*

4.2 Requirements for Type B-100 ships

4.2.1 In addition to the requirements specified in [4.1], not taking into account the prescription stated in [3.4.2], the requirements in [4.2.2] to [4.2.4] are to be complied with.

In addition, the provisions of [3.4.3] are to be complied with.

4.2.2 Machinery casings

Machinery casings on Type A ships are to be protected by an enclosed poop or bridge of at least standard height, or by a deckhouse of equal height and equivalent strength, provided that machinery casings may be exposed if there are no openings giving direct access from the freeboard deck to the machinery space. A door complying with the requirements of [4.4] may, however, be permitted in the machinery casing, provided that it leads to a space or passageway which is as strongly constructed as the casing and is separated from the stairway to the engine room by a second weathertight door of steel or other equivalent material.

4.2.3 Gangway and access

An efficiently constructed fore and aft permanent gangway of sufficient strength is to be fitted on Type A ships at the level of the superstructure deck between the poop and the midship bridge or deckhouse where fitted, or equivalent means of access is to be provided to carry out the purpose of the gangway, such as passages below deck. Elsewhere, and on Type A ships without a midship bridge, arrangements to the satisfaction of the Society are to be provided to safeguard the crew in reaching all parts used in the necessary work of the ship.

Safe and satisfactory access from the gangway level is to be available between separate crew accommodation spaces and also between crew accommodation spaces and the machinery space.

4.2.4 Freeing arrangements

Type A ships with bulwarks are to be provided with open rails fitted for at least half the length of the exposed parts of the weather deck or other effective freeing arrangements. The upper edge of the sheer strake is to be kept as low as practicable.

Where superstructures are connected by trunks, open rails are to be fitted for the whole length of the exposed parts of the freeboard deck.

4.3 Hatchways closed by weathertight covers of steel or other equivalent material fitted with gaskets and clamping devices

4.3.1 At positions 1 and 2 the height above the deck of hatchway coamings fitted with weathertight hatch covers of steel or other equivalent material fitted with gaskets and clamping devices is to be:

- 600 millimetres if in position 1
- 450 millimetres if in position 2.

The height of these coamings may be reduced, or the coamings omitted entirely, upon proper justification. Where coamings are provided they are to be of substantial construction.

4.3.2 *Where weathertight covers are of mild steel the strength is to be calculated with assumed loads not less than those specified in Ch 11, Sec 9.*

4.3.3 *The strength and stiffness of covers made of materials other than mild steel are to be equivalent to those of mild steel to the satisfaction of the Society.*

4.3.4 *The means for securing and maintaining weathertightness are to be to the satisfaction of the Society. The arrangements are to ensure that the tightness can be maintained in any sea conditions, and for this purpose tests for tightness are required at the initial survey, and may be required at periodical surveys and at annual inspections or at more frequent intervals.*

4.4 Doors

4.4.1 *All access openings in bulkheads at ends of enclosed superstructures are to be fitted with doors of steel or other equivalent material, permanently and strongly attached to the bulkhead, and framed, stiffened and fitted so that the whole structure is of equivalent strength to the unpierced bulkhead and weathertight when closed. The means for securing these doors weathertight are to consist of gaskets and clamping devices or other equivalent means and are to be permanently attached to the bulkhead or to the doors themselves, and the doors are to be so arranged that they can be operated from both sides of the bulkhead.*

4.4.2 *Except as otherwise provided, the height of the sills of access openings in bulkheads at ends of enclosed superstructures is to be at least 380 millimetres above the deck.*

Part B

Hull and Stability

CHAPTER 4

STRUCTURE DESIGN PRINCIPLES

Section 1	Materials
Section 2	Net Scantling Approach
Section 3	Corrosion Additions
Section 4	Protection of Hull Metallic Structures
Section 5	Structural Detail Principles
Section 6	Structural Idealisation

Section 1 Materials

1 General

1.1 Standard of material

1.1.1 Materials used during construction are to comply with the applicable requirements of NR216 Materials and Welding.

1.1.2 Materials other than those covered in [1.1.1] may be accepted, provided their specification (e.g. manufacture, chemical composition, mechanical properties, welding) is submitted to the Society for approval.

1.2 Testing of materials

1.2.1 Materials are to be tested in compliance with the applicable requirements of NR216 Materials and Welding.

1.3 Manufacturing process

1.3.1 The requirements of this Section presume that welding and other cold or hot manufacturing processes are carried out in compliance with current sound working practice and with the applicable requirements of NR216 Materials and Welding.

In particular:

- parent material and welding processes are to be within the limits stated for the specified type of material for which they are intended
- specific preheating may be required before welding
- welding or other cold or hot manufacturing processes may need to be followed by an adequate heat treatment.

2 Hull structural steel

2.1 General

2.1.1 Young's modulus and Poisson's ratio

For carbon steel materials, Young's modulus is equal to 206000 N/mm² and Poisson's ratio is equal to 0,3.

In case of steel used at a temperature θ between 90°C and 300°C, and when no other information is available, the minimum specified yield stress R_{eH} and the Young's modulus E of the steel at the temperature θ may be taken respectively equal to:

$$R_{eH} = R_{eH0} \left(1,04 - \frac{0,75}{1000} \theta \right)$$

$$E = E_0 \left(1,03 - \frac{0,5}{1000} \theta \right)$$

where:

- R_{eH0} : Value of the minimum specified yield stress at ambient temperature, in N/mm²
- E_0 : Value of the Young's modulus at ambient temperature, in N/mm²
- θ : Temperature of use of the steel, in °C.

2.1.2 Steel material grades and mechanical properties

Steel having a specified minimum yield stress equal to 235 N/mm² is regarded as normal strength steel and is denoted 'NSS'. Steel having a higher specified minimum yield stress is regarded as higher strength steel and is denoted 'HSS'.

Steel grades are referred to as follows:

- A, B, D and E denote normal strength steel grades
- AH, DH and EH denote higher strength steel grades.

Tab 1 gives the mechanical characteristics of steels generally used in the construction of ships.

Higher strength steels other than those indicated in Tab 1 are considered by the Society on a case-by-case basis.

2.1.3 Steels with through thickness properties

Characteristics of steels with specified through thickness properties are given in NR216 Materials and Welding, Ch 3, Sec 1, [1].

2.1.4 Onboard documents

It is advised to keep onboard a plan indicating the steel types and grades adopted for the hull structures. Where steels other than those indicated in Tab 1 are used, their mechanical and chemical properties, as well as any workmanship requirements or recommendations, are to be available onboard together with the above plan.

Table 1 : Mechanical properties of hull steels

Steel grades for plates with $t_{as_built} \leq 100$ mm	Specified minimum yield stress R_{eH} in N/mm ²	Specified minimum tensile strength R_m in N/mm ²
A-B-D-E	235	400 - 520
AH32-DH32 EH32-FH32	315	440 - 570
AH36-DH36 EH36-FH36 EH36CAS1-EH36CAS2 FH36CAS1-FH36CAS2	355	490 - 630
AH40-DH40 EH40-FH40 EH40CAS1-EH40CAS2 FH40CAS1-FH40CAS2	390	510 - 660
EH47 EH47CAS1-FH47CAS2	460	570 - 720
Note 1: Refer to NR216 Materials and Welding, Ch 3, Sec 2		

2.2 Material factor k

2.2.1 Unless otherwise specified, the material factor k of normal and higher strength steels for hull girder strength and scantling purposes is to be taken as given in Tab 2, as a function of the specified minimum yield stress R_{eH} .

For intermediate values of R_{eH} , k is obtained by linear interpolation.

Steels with a yield stress lower than 235 N/mm² or greater than 460 N/mm² are considered on a case by case basis by the Society.

Table 2 : Material factor k

R_{eH} , in N/mm ²	k
235	1,00
315	0,78
355	0,72
390	0,68 (1)
460	0,62
(1) k may be taken equal to 0,66 for steels with a minimum yield stress R_{eH} equal to 390 N/mm ² , provided the hull structure is additionally verified for compliance with finite element analysis and spectral fatigue assessment according to NI611.	

2.3 Steel grades

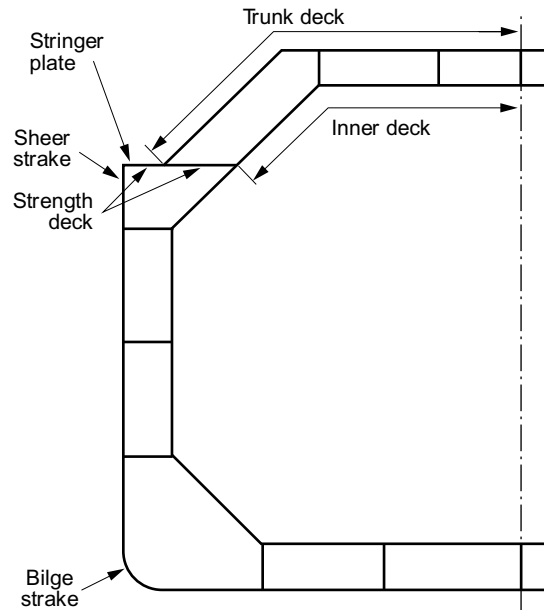
2.3.1 Materials in the various strength members are not to be of lower grade than those corresponding to the material classes and grades specified in Tab 3 to Tab 9.

General requirements are given in Tab 3. Additional minimum requirements are given in:

- Tab 4 for ships, excluding membrane-type liquefied gas carriers, greater than 150 m in length and having a single strength deck
- Tab 5 for membrane type liquefied gas carriers greater than 150 m in length and having a deck arrangement as shown in Fig 1. Tab 5 may apply to similar ships with a double deck arrangement above the strength deck.
- Tab 6 for ships greater than 250 m in length
- Tab 7 for single-side **bulk carriers, bulk carriers ESP, self-unloading bulk carriers ESP, ore carrier ESP and combination carrier / OBO ESP**
- Tab 8 for ships with ice strengthening.

2.3.2 Materials are to be of a grade not lower than that indicated in Tab 9 depending on the material class and structural member gross thickness (see [2.3.5]).

Figure 1 : Typical deck arrangement for membrane-type liquefied natural gas carriers



2.3.3 For strength members not mentioned in Tab 3, Tab 4, Tab 5, Tab 6, Tab 7 and Tab 8, grade A/AH may generally be used.

2.3.4 Plating materials for stern frames supporting the rudder and propeller boss, rudders, rudder horns and shaft brackets are generally to be of grades not lower than those corresponding to Class II.

For rudder and rudder body plates subjected to stress concentrations (e.g. in way of lower support of semi-spade rudders or at upper part of spade rudders), Class III is to be applied.

2.3.5 The steel grade is to correspond to the as fitted gross thickness when this is greater than the gross thickness obtained from the net thickness required by the Rules, according to Ch 4, Sec 2, [1].

2.3.6 Steel grades of plates or sections of gross thickness greater than the limiting thicknesses in Tab 9 are considered by the Society on a case by case basis.

2.3.7 In specific cases, such as [2.3.8], with regard to stress distribution along the hull girder, the classes required within 0,4L amidships may be extended beyond that zone, on a case by case basis.

2.3.8 The material classes required for the strength deck plating, the sheer strake and the upper strake of longitudinal bulkheads within 0,4L amidships are to be maintained for an adequate length across the poop front and at the ends of the bridge, where fitted.

2.3.9 Rolled products used for welded attachments on hull plating, such as gutter bars are to be of the same grade as that used for the hull plating in way.

Where it is necessary to weld attachments to the sheer strake or stringer plate, attention is to be given to the appropriate choice of material and design, the workmanship and welding and the absence of prejudicial undercuts and notches, with particular regard to any free edges of the material.

2.3.10 In the case of full penetration welded joints located in positions where high local stresses may occur perpendicular to the continuous plating, the Society may, on a case by case basis, require the use of rolled products having adequate ductility properties in the through thickness direction, such as to minimize the risk of lamellar tearing (Z type steel, see NR216 Materials and Welding).

2.3.11 In highly stressed areas, the Society may require that plates of gross thickness greater than 20 mm are of grade D/DH or E/EH.

2.4 Grades of steel for structures exposed to low air temperatures

2.4.1 For ships intended to operate in areas with low air temperatures (-10°C or below), e.g. regular service during winter seasons to Arctic or Antarctic waters (known as the Polar Regions), the materials in exposed structures are to be selected based on the design temperature t_D , to be taken as defined in [2.4.2].

Table 3 : Material classes and grades for ships in general

Structural member category		Material class or grade	
		Within 0,4L amidships	Outside 0,4L amidships
SECONDARY	<ul style="list-style-type: none"> Longitudinal bulkhead strakes, other than that belonging to the primary category Deck plating exposed to weather, other than that belonging to the primary or special category Side plating 	I	A / AH
	<ul style="list-style-type: none"> Bottom plating, including keel plate Strength deck plating, excluding that belonging to the special category Continuous longitudinal plating of strength members above strength deck, excluding hatch coamings, for ships equal to or greater than 90 m in length Uppermost strake in longitudinal bulkhead Vertical strake (hatch side girder) and uppermost sloped strake in top wing tank 	II	A / AH
SPECIAL	<ul style="list-style-type: none"> Sheer strake at strength deck (1) Stringer plate in strength deck (1) Deck strake at longitudinal bulkhead excluding deck plating in way of inner-skin bulkhead of double hull ships (1) 	III	II I outside 0,6L amidships
	<ul style="list-style-type: none"> Strength deck plating at outboard corners of cargo hatch openings in container carriers and other ships with similar hatch openings configurations 	III	II I outside 0,6L amidships Min. class III within cargo region
	<ul style="list-style-type: none"> Strength deck plating at corners of cargo hatch openings in bulk carriers, ore carriers, combination carriers and other ships with similar hatch openings configurations Trunk deck and inner deck plating at corners of openings for liquid and gas domes in membrane type liquefied gas carriers 	III	III within 0,6L amidships II within the rest of cargo region
	<ul style="list-style-type: none"> Bilge strake in ships with double bottom over the full breadth and length less than 150 m 	II	II within 0,6L amidships I outside 0,6L amidships
	<ul style="list-style-type: none"> Bilge strake in other ships (1) 	III	II I outside 0,6L amidships
	<ul style="list-style-type: none"> Longitudinal hatch coamings of length greater than 0,15 L, including top plate and flange, for ships equal to or greater than 90 m in length End brackets and deck house transition of longitudinal cargo hatch coamings 	III Not to be less than grade D/DH	II I outside 0,6L amidships Not to be less than grade D/DH
(1) Single strakes required to be of class III within 0.4L amidships are to have breadths not less than (800 + 5 L) mm, need not to be greater than 1800 mm, unless limited by the geometry of the ship's design.			

Table 4 : Minimum material grades for ships greater than 150 m in length

Structural member category	Material grade
<ul style="list-style-type: none"> Longitudinal plating of strength deck where contributing to the longitudinal strength Continuous longitudinal plating of strength members above strength deck 	B/AH within 0,4 L amidships
<ul style="list-style-type: none"> Single side strakes for ships without inner continuous longitudinal bulkhead(s) between the bottom and the strength deck 	B/AH within cargo region

Table 5 : Material classes and grades for membrane-type liquefied gas carriers, greater than 150 m in length

Structural member category	Material class or grade	
Longitudinal plating of strength deck where contributing to the longitudinal strength	B/AH within 0,4 L amidships	
Continuous longitudinal plating of strength members above the strength deck	Trunk deck plating	II within 0,4L amidships
	<ul style="list-style-type: none"> Inner deck plating Longitudinal strength member plating between the trunk deck and the inner deck 	B/AH within 0,4 L amidships

Table 6 : Minimum material grades for ships greater than 250 m in length

Structural member category(1)	Material grade within 0,4 L amidships
<ul style="list-style-type: none"> • Sheer strake at strength deck • Stringer plate in strength deck 	E/EH
<ul style="list-style-type: none"> • Bilge strake 	D/DH
(1) Single strakes required to be of grade D/DH or grade E/EH and within 0,4 L amidships are to have breadths not less than (800 + 5 L) mm, but need not be greater than 1800 mm, unless limited by the geometry of the ship's design.	

Table 7 : Material classes and grades for single-side bulk carrier, bulk carrier ESP, self-unloading bulk carrier, ore carrier ESP and combination carrier / OBO ESP

Structural member category	Material grade
Lower bracket of ordinary side frame (1) (2)	D/DH
Side shell strakes included totally or partially between the two points located to 0,125 ℓ above and below the intersection of side shell and bilge hopper sloping plate or inner bottom plate (2)	D/DH
(1) the term "lower bracket" means web of lower bracket and web of the lower part of side frames up the point of 0,125 ℓ above the intersection of side shell and bilge hopper sloping plate or inner bottom plate.	
(2) the span of the side frame, ℓ, is defined as the distance between the supporting structures.	

Table 8 : Material classes and grades for ships with ice strengthening

Structural member category	Material grade
Shell strakes in way of ice strengthening area for plates	B/AH

Table 9 : Material grade requirements for classes I, II and III

As-built thickness, in mm	Class I		Class II		Class III	
	NSS	HSS	NSS	HSS	NSS	HSS
t ≤ 15	A	AH	A	AH	A	AH
15 < t ≤ 20	A	AH	A	AH	B	AH
20 < t ≤ 25	A	AH	B	AH	D	DH
25 < t ≤ 30	A	AH	D	DH	D	DH
30 < t ≤ 35	B	AH	D	DH	E	EH
35 < t ≤ 40	B	AH	D	DH	E	EH
40 < t ≤ 50	D	DH	E	EH	E	EH

2.4.2 The design temperature t_D is to be taken as the lowest mean daily average air temperature in the area of operation, where:

Mean : Statistical mean over observation period

Average : Average during one day and night

Lowest : Lowest during one year.

Fig 2 illustrates the temperature definition for Arctic waters.

For seasonally restricted service, the lowest value within the period of operation applies.

For the purpose of issuing a Polar Ship Certificate in accordance with the Polar Code, the design temperature t_D shall be no more than 13°C above the Polar Service Temperature (PST) of the ship.

In the Polar Regions, the statistical mean over observation period is to be determined for a period of, at least, 10 years.

2.4.3 For the purpose of the selection of steel grades to be used for the structural members above the lowest ballast waterline and exposed to air, the latter are divided into categories (SECONDARY, PRIMARY and SPECIAL), as indicated in Tab 10.

Tab 10 also specifies the classes (I, II and III) of the materials to be used for the various categories of structural members. Class I is to be considered for superstructures and deckhouses structural members exposed to air.

For non-exposed structures (except bulkhead strakes as mentioned in footnote (6) of Tab 10) and structures below the lowest ballast waterline, see [2.3].

Figure 2 : Commonly used definitions of temperatures

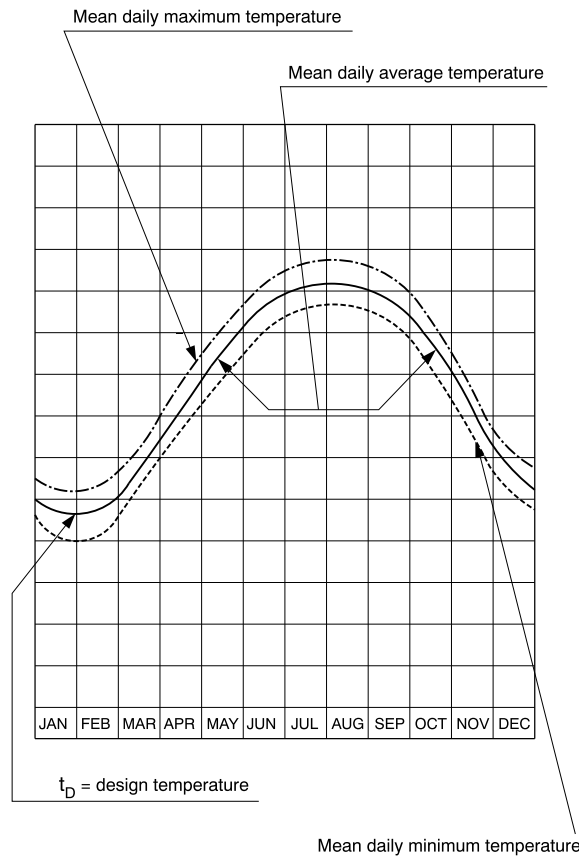


Table 10 : Material classes and grades - Structures exposed to low air temperatures

Structural member category		Material class	
		Within 0,4L amidships	Outside 0,4L amidships
SECONDARY	Deck plating exposed to weather (in general) Side plating above T_{BAL} Transverse bulkheads above T_{BAL} (5)	I	I
PRIMARY	Strength deck plating (1) Continuous longitudinal members above strength deck (excluding longitudinal hatch coamings of ships equal to or greater than 90 m in length) Longitudinal bulkhead above T_{BAL} (5) Topside tank bulkhead above T_{BAL} (5)	II	I
SPECIAL	Sheer strake at strength deck (2) Stringer plate in strength deck (2) Deck strake at longitudinal bulkhead (3) Continuous longitudinal hatch coamings of ships equal to or greater than 90 m in length(4)	III	II

(1) Plating at corners of large hatch openings to be considered on a case by case basis. Class III or grade E/EH to be applied in positions where high local stresses may occur.
 (2) To be not less than grade E/EH within 0,4 L amidships in ships with length exceeding 250 m.
 (3) In ships with breadth exceeding 70 metres at least three deck strakes to be class III.
 (4) To be not less than grade D/DH.
 (5) Applicable to plating attached to hull envelope plating exposed to low air temperature. At least one strake is to be considered as exposed plating over a width of not less than 600 mm.

Note 1: Plating materials for sternframes, rudder horns, rudders and shaft brackets are to be of grades not lower than those corresponding to the material classes in [2.3].

2.4.4 Materials may not be of a lower grade than that indicated in Tab 11 to Tab 13 depending on the material class, structural member gross thickness and design temperature t_D .

For design temperatures $t_D < -55^\circ\text{C}$, materials will be specially considered by the Society on a case by case basis.

2.4.5 Single strakes required to be of class III or of grade E/EH or FH are to have breadths not less than $(800+5L)$ mm, but not necessarily greater than 1800 mm.

2.5 Grades of steel within refrigerated spaces

2.5.1 For structural members within or adjacent to refrigerated spaces, when the design temperatures is below 0°C , the materials are to be of grade not lower than those indicated in Tab 14, depending on the design temperature, the structural member gross thickness and its category (as defined in Tab 3).

Table 11 : Material grade requirements for class I at low temperatures

Gross thickness, in mm	$-20^\circ\text{C} / -25^\circ\text{C}$		$-26^\circ\text{C} / -35^\circ\text{C}$		$-36^\circ\text{C} / -45^\circ\text{C}$		$-46^\circ\text{C} / -55^\circ\text{C}$	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
$t \leq 10$	A	AH	B	AH	D	DH	D	DH
$10 < t \leq 15$	B	AH	D	DH	D	DH	D	DH
$15 < t \leq 20$	B	AH	D	DH	D	DH	E	EH
$20 < t \leq 25$	D	DH	D	DH	D	DH	E	EH
$25 < t \leq 30$	D	DH	D	DH	E	EH	E	EH
$30 < t \leq 35$	D	DH	D	DH	E	EH	E	EH
$35 < t \leq 45$	D	DH	E	EH	E	EH	N.A.	FH
$45 < t \leq 50$	E	EH	E	EH	N.A.	FH	N.A.	FH

Note 1: "NSS" and "HSS" mean, respectively, "Normal Strength Steel" and "Higher Strength Steel".
Note 2: N.A. = not applicable.

Table 12 : Material grade requirements for class II at low temperatures

Gross thickness, in mm	$-20^\circ\text{C} / -25^\circ\text{C}$		$-26^\circ\text{C} / -35^\circ\text{C}$		$-36^\circ\text{C} / -45^\circ\text{C}$		$-46^\circ\text{C} / -55^\circ\text{C}$	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
$t \leq 10$	B	AH	D	DH	D	DH	E	EH
$10 < t \leq 20$	D	DH	D	DH	E	EH	E	EH
$20 < t \leq 30$	D	DH	E	EH	E	EH	N.A.	FH
$30 < t \leq 40$	E	EH	E	EH	N.A.	FH	N.A.	FH
$40 < t \leq 45$	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.
$45 < t \leq 50$	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.

Note 1: "NSS" and "HSS" mean, respectively, "Normal Strength Steel" and "Higher Strength Steel".
Note 2: N.A. = not applicable.

Table 13 : Material grade requirements for class III at low temperatures

Gross thickness, in mm	$-20^\circ\text{C} / -25^\circ\text{C}$		$-26^\circ\text{C} / -35^\circ\text{C}$		$-36^\circ\text{C} / -45^\circ\text{C}$		$-46^\circ\text{C} / -55^\circ\text{C}$	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
$t \leq 10$	D	DH	D	DH	E	EH	E	EH
$10 < t \leq 20$	D	DH	E	EH	E	EH	N.A.	FH
$20 < t \leq 25$	E	EH	E	EH	E	FH	N.A.	FH
$25 < t \leq 30$	E	EH	E	EH	N.A.	FH	N.A.	FH
$30 < t \leq 35$	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.
$35 < t \leq 40$	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.
$40 < t \leq 50$	N.A.	FH	N.A.	FH	N.A.	N.A.	N.A.	N.A.

Note 1: "NSS" and "HSS" mean, respectively, "Normal Strength Steel" and "Higher Strength Steel".
Note 2: N.A. = not applicable.

Table 14 : Material grade requirements for members within or adjacent to refrigerated spaces

Design temperature, in °C	Gross thickness, in mm	Structural member category	
		Secondary	Primary or Special
$-10 \leq t_D < 0$	$t \leq 20$	B / AH	B / AH
	$20 < t \leq 25$	B / AH	D / DH
	$t > 25$	D / DH	E / EH
$-25 \leq t_D < -10$	$t \leq 15$	B / AH	D / DH
	$15 < t \leq 25$	D / DH	E / EH
	$t > 25$	E / EH	E / EH
$-40 \leq t_D < -25$	$t \leq 25$	D / DH	E / EH
	$t > 25$	E / EH	E / EH

2.5.2 Unless a temperature gradient calculation is carried out to assess the design temperature and the steel grade in the structural members of the refrigerated spaces, the design temperatures to be considered are specified below:

- a) For members within refrigerated spaces:
 - temperature of the space on the uninsulated side, for plating insulated on one side only, either with uninsulated stiffening members (i.e. fitted on the uninsulated side of plating) or with insulated stiffening members (i.e. fitted on the insulated side of plating)
 - mean value of temperatures in the adjacent spaces, for plating insulated on both sides, with insulated stiffening members, when the temperature difference between the adjacent spaces is generally not greater than 10 °C (when the temperature difference between the adjacent spaces is greater than 10°C, the temperature value is established by the Society on a case by case basis)
- b) For members adjacent to refrigerated spaces:
 - temperature of the non-refrigerated space, conventionally taken equal to 0°C (in such case, the steel grades are to be considered as per [2.3]).

2.5.3 Situations other than those mentioned in [2.5.1] and [2.5.2] or special arrangements will be considered by the Society on a case by case basis.

2.5.4 Irrespective of the provisions of [2.5.1], [2.5.2] and Tab 14, steel having grades lower than those required in [2.3], Tab 3 and Tab 9, in relation to the class and gross thickness of the structural member considered, may not be used.

2.6 Through thickness properties

2.6.1 Where normal tensile loads induce out-of-plane stress greater than 0,5 R_y in steel plates:

- for plates with $t < 15$ mm, ultrasonic testing is to be performed
- for plates with $t \geq 15$ mm, Z-quality steel is to be used or ultrasonic testing is to be performed,

in order to prevent laminar tearing.

The above mentioned ultrasonic testing is to be performed, before and after welding, on the area of the plate located within 50 mm or t , whichever is the greater, around the weld, in accordance with NR216 Materials and Welding, Ch 3, Sec 11.

2.7 Stainless steel

2.7.1 The reduction of strength of stainless steel with increasing temperature is to be taken into account in the calculation of the material factor k and in the material Young's modulus E .

Stainless steels are considered by the Society on a case-by-case basis.

3 Steels for forging and casting

3.1 General

3.1.1 Mechanical and chemical properties of steels for forging and casting to be used for structural members are to comply with the applicable requirements of NR216 Materials and Welding.

3.1.2 Steels of structural members intended to be welded are to have mechanical and chemical properties deemed appropriate for this purpose by the Society on a case-by-case basis.

3.1.3 The steels used are to be tested in accordance with the applicable requirements of NR216 Materials and Welding.

3.2 Steels for forging

3.2.1 For the purpose of testing, which is to be carried out in accordance with the applicable requirements of NR216 Materials and Welding, steels for forging to be used for structural members are assigned to class 1 (see NR216 Materials and Welding, Ch 5, Sec 1, [2]).

3.2.2 Rolled bars may be accepted in lieu of forged products, after consideration by the Society on a case-by-case basis. In such case, compliance with the applicable requirements of NR216 Materials and Welding, relevant to the quality and testing of rolled parts accepted in lieu of forged parts, may be required.

3.3 Steels for casting

3.3.1 Cast parts intended for stems and stern frames in general may be made of C and C-Mn weldable steels, having a specified minimum tensile strength R_m equal to 400 N/mm², in accordance with the applicable requirements of NR216 Materials and Welding.

Items which may be subjected to high stresses may be required to be of quality 2 steels of the above types.

3.3.2 For the purpose of testing, which is to be carried out in accordance with NR216 Materials and Welding, Chapter 6, steels for casting to be used for structural members are assigned to class 1 irrespective of their quality.

3.3.3 The welding of cast parts to main plating contributing to hull strength members is considered by the Society on a case-by-case basis.

The Society may require additional properties and tests for such casting, in particular impact properties which are appropriate to those of the steel plating on which the cast parts are to be welded and non-destructive examinations.

3.3.4 Heavily stressed cast parts of steering gear, particularly those intended to form a welded assembly and tillers or rotors mounted without key, are to be subjected to surface and volumetric non-destructive examination to check their internal structure.

4 Aluminium alloys

4.1 General

4.1.1 The use of aluminium alloys in superstructures, deckhouses, hatch covers, helicopter platforms, or other local components is to be specially considered. A specification of the proposed alloys and their proposed method of fabrication is to be submitted for approval.

Material requirements and scantlings are to comply with the applicable requirements of NR216 Materials and Welding, Chapter 9. Series 5000 aluminium-magnesium alloys or series 6000 aluminium-magnesium-silicon alloys are to be used (see NR216 Materials and Welding, Ch 9, Sec 2).

4.1.2 In the case of structures subjected to low service temperatures or intended for other specific applications, the alloys to be employed are to be agreed by the Society.

4.1.3 Unless otherwise agreed, the Young's modulus for aluminium alloys is equal to 70000 N/mm² and the Poisson's ratio equal to 0,33.

4.1.4 Details of the proposed method of joining any aluminium and steel structures are to be submitted for approval.

4.2 Extruded plating

4.2.1 Extrusions with built-in plating and stiffeners, referred to as extruded plating, may be used.

4.2.2 In general, the application of extruded plating is limited to decks, bulkheads, superstructures and deckhouses. Other uses may be permitted by the Society on a case-by-case basis.

4.2.3 Extruded plating is to be oriented so that the stiffeners are parallel to the direction of main stresses.

4.2.4 Connections between extruded plating and primary members are to be given special attention.

4.3 Mechanical properties of weld joints

4.3.1 Welding heat input lowers locally the mechanical strength of aluminium alloys hardened by work hardening (series 5000 other than condition O or H111) or by heat treatment (series 6000).

4.3.2 The as-welded properties of aluminium alloys of series 5000 are in general those of condition O or H111. Higher mechanical characteristics may be considered, provided they are duly justified.

4.3.3 The as-welded properties of aluminium alloys of series 6000 are to be agreed by the Society.

4.4 Material factor k

4.4.1 The material factor k for aluminium alloys is to be obtained from the following formula:

$$k = \frac{235}{R'_{lim}}$$

where:

- R'_{lim} : Minimum guaranteed yield stress of the parent metal in welded condition $R'_{p0,2}$, in N/mm², but not to be taken greater than 70% of the minimum guaranteed tensile strength of the parent metal in welded condition R'_m , in N/mm²
- $R'_{p0,2}$: Minimum guaranteed yield stress, in N/mm², of material in welded condition:
 $R'_{p0,2} = \eta_1 R_{p0,2}$
- R'_m : Minimum guaranteed tensile strength, in N/mm², of material in welded condition:
 $R'_m = \eta_2 R_m$
- $R_{p0,2}$: Minimum guaranteed yield stress, in N/mm², of the parent metal in delivery condition
- R_m : Minimum guaranteed tensile strength, in N/mm², of the parent metal in delivery condition
- η_1, η_2 : Coefficients specified in Tab 15.

Table 15 : Aluminium alloys - Coefficients for welded construction

Aluminium alloy	η_1	η_2
Alloys without work-hardening treatment (series 5000 in annealed condition 0 or annealed flattened condition H111)	1	1
Alloys hardened by work hardening (series 5000 other than condition 0 or H111)	$R'_{p0,2} / R_{p0,2}$	R'_m / R_m
Alloys hardened by heat treatment (series 6000) (1)	$R'_{p0,2} / R_{p0,2}$	0,6
(1) When no information is available, coefficient η_1 is to be taken equal to the metallurgical efficiency coefficient β as defined in Tab 16.		

Table 16 : Aluminium alloys - Metallurgical efficiency coefficient β

Aluminium alloy	Temper condition	As-built thickness, in mm	β
6005A (Open sections)	T5 or T6	$t \leq 6$	0,45
		$t > 6$	0,40
6005A (Closed sections)	T5 or T6	all	0,50
6061 (Sections)	T6	all	0,53
6082 (Sections)	T6	all	0,45

4.4.2 In the case of welding of two different aluminium alloys, the material factor k to be considered for the scantlings is the greater material factor of the aluminium alloys of the assembly.

4.4.3 For welded constructions in hardened aluminium alloys (series 5000 other than condition 0 or H111 and series 6000), greater characteristics than those in welded condition may be considered, provided that welded connections are located in areas where stress levels are acceptable for the alloy considered in annealed or welded condition.

4.5 Others

4.5.1 Aluminium fittings in tanks used for the carriage of oil, and in cofferdams and pump rooms are to be avoided.

4.5.2 The underside of heavy portable aluminium structures such as gangways, is to be protected by means of a hard plastic or wood cover, or other approved means, in order to avoid the creation of smears. Such protection is to be permanently and securely attached to the structures.

5 Other materials and products

5.1 General

5.1.1 Other materials and products such as parts made of iron castings, where allowed, products made of copper and copper alloys, rivets, anchors, chain cables, cranes, masts, derrick posts, derricks, accessories and wire ropes are to comply with the applicable requirements of NR216 Materials and Welding.

5.1.2 The use of plastics or other special materials not covered by these Rules is to be considered by the Society on a case-by-case basis. In such cases, the requirements for the acceptance of the materials concerned are to be agreed by the Society.

5.1.3 Materials used in welding processes are to comply with the applicable requirements of NR216 Materials and Welding.

5.2 Iron cast parts

5.2.1 As a rule, the use of grey iron, malleable iron or spheroidal graphite iron cast parts with combined ferritic/perlitic structure is allowed only to manufacture low stressed elements of secondary importance.

5.2.2 Ordinary iron cast parts may not be used for windows or sidescuttles; the use of high grade iron cast parts of a suitable type is to be considered by the Society on a case-by-case basis.

Section 2 Net Scantling Approach

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

- d_f : Distance in mm, for the extension of flange for L1 profiles, see Fig 3.
 t_{dm} : Design production margin, in mm, taken as the thickness difference between offered gross thickness and required gross thickness (equal also to the difference between offered net and required net thickness) as a result of scantlings applied by the designer or builder to suit design or production situation. This difference in thickness is not to be considered as an additional corrosion margin.

1 General

1.1 Application

1.1.1 Net thickness approach

The scantling of a structural element determined for its strength in compliance with the design basis is expressed in terms of net thickness t , i.e. it does not include the corrosion addition.

The corrosion addition, t_c , for a structural element is derived independently from the net scantling requirements as shown in Fig 1.

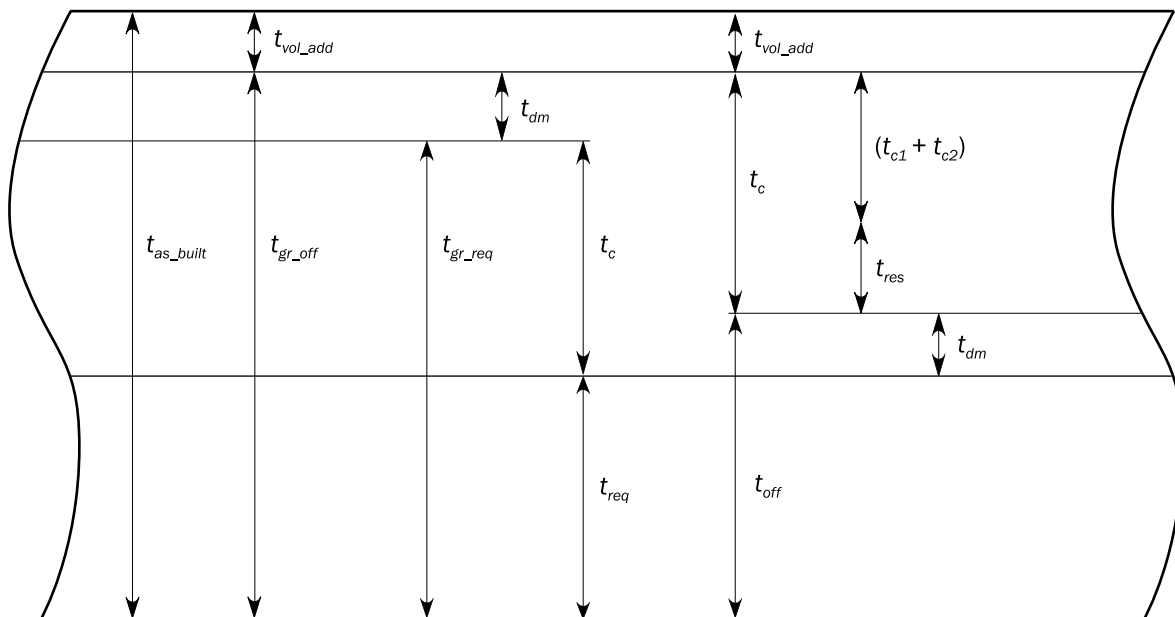
This approach clearly separates the net thickness from the thickness added to address the corrosion that is likely to occur during the ship-in-operation phase.

1.1.2 Exceptions in gross scantling

Items that are directly determined in terms of gross scantlings do not follow the net scantling approach, i.e. they already include additions for corrosion but without any Owner's extra margin. Gross scantling requirements are identified with the suffix "gr" and examples are:

- scantlings of superstructures and deckhouses as given in Ch 11, Sec 5
- scantlings of bow doors and inner doors as given in Ch 11, Sec 6
- scantlings of side doors and stern doors as given in Ch 11, Sec 7
- scantlings of rudder structures and hull appendages in Part B, Chapter 12
- scantlings of massive pieces made of steel forgings and steel castings.

Figure 1 : Net scantling approach scheme



1.2 Gross and net scantling definitions

1.2.1 Gross required thickness

The gross required thickness, t_{gr_req} is the thickness obtained by adding the corrosion addition as defined in Ch 4, Sec 3 to the net required thickness, as follows:

$$t_{gr_req} = t_{req} + t_c$$

1.2.2 Gross offered thickness

The gross offered thickness, t_{gr_off} , is the gross thickness provided at the newbuilding stage, which is obtained by deducting any thickness for voluntary addition from the as-built thickness, as follows:

$$t_{gr_off} = t_{as_built} - t_{vol_add}$$

1.2.3 Net offered thickness

The net offered thickness, t_{off} , is obtained by subtracting the corrosion addition from the gross offered thickness, as follows:

$$t_{off} = t_{gr_off} - t_c = t_{as_built} - t_{vol_add} - t_c$$

1.3 Rounding off of scantlings

1.3.1 Thicknesses

The rounding off of thicknesses is to be performed as follows:

- the gross required thickness t_{gr_req} as defined in [1.2.1] is rounded off to the nearest half-millimetre.
- the rounded net thickness is taken equal to the rounded gross thickness, obtained in a), minus the corrosion addition t_c .

Note 1: Examples of thickness values rounded off to the nearest half-millimetre are given below for reference:

- for $10,75 \leq t_{gr_req} < 11,25$ mm:
The rounded value of t is 11 mm
- for $11,25 \leq t_{gr_req} < 11,75$ mm:
The rounded value of t is 11,5 mm

1.3.2 Stiffener section moduli

Stiffener section moduli as calculated in accordance with the Rule requirements are to be rounded off to the nearest standard value; however, no reduction may exceed 3%.

1.4 Scantling compliance

1.4.1 Scantling compliance in relation to the Rules is as follows:

- The net offered thickness of plating is to be equal to or greater than the net required thickness of plating.
- The net offered section modulus, moment of inertia and shear area of local supporting members are to be equal to or greater than the net required properties calculated using the net thickness of the attached plate, web and flange. The net sectional dimensions of local supporting members are defined in Fig 2 and Fig 3. The required section modulus and web net thickness apply to areas clear of the end brackets.
- the offered net sectional properties of primary supporting members and the hull girder are to be equal to or greater than the required net sectional properties which are to be based on the gross offered scantling with a reduction of the applicable corrosion addition, as specified in Tab 1, applied to all component structural members
- the strength assessment methods prescribed are to be assessed by applying the corrosion reduction specified in Tab 1 to the offered gross scantlings. Half of the applied corrosion addition specified in Tab 1 is to be deducted from both sides of the structural members being considered
- corrosion additions are not to be taken less than those given in Ch 4, Sec 3, [1.2].

Any additional thickness specified by the Owner or the builder is not to be included when considering the compliance with the Rules.

The net cross-sectional area, the moment of inertia about the y-axis and the associated neutral axis position are to be determined applying a corrosion magnitude of $0,5 t_c$ deducted from the surface of the profile cross-section.

Figure 2 : Net sectional properties of local supporting members

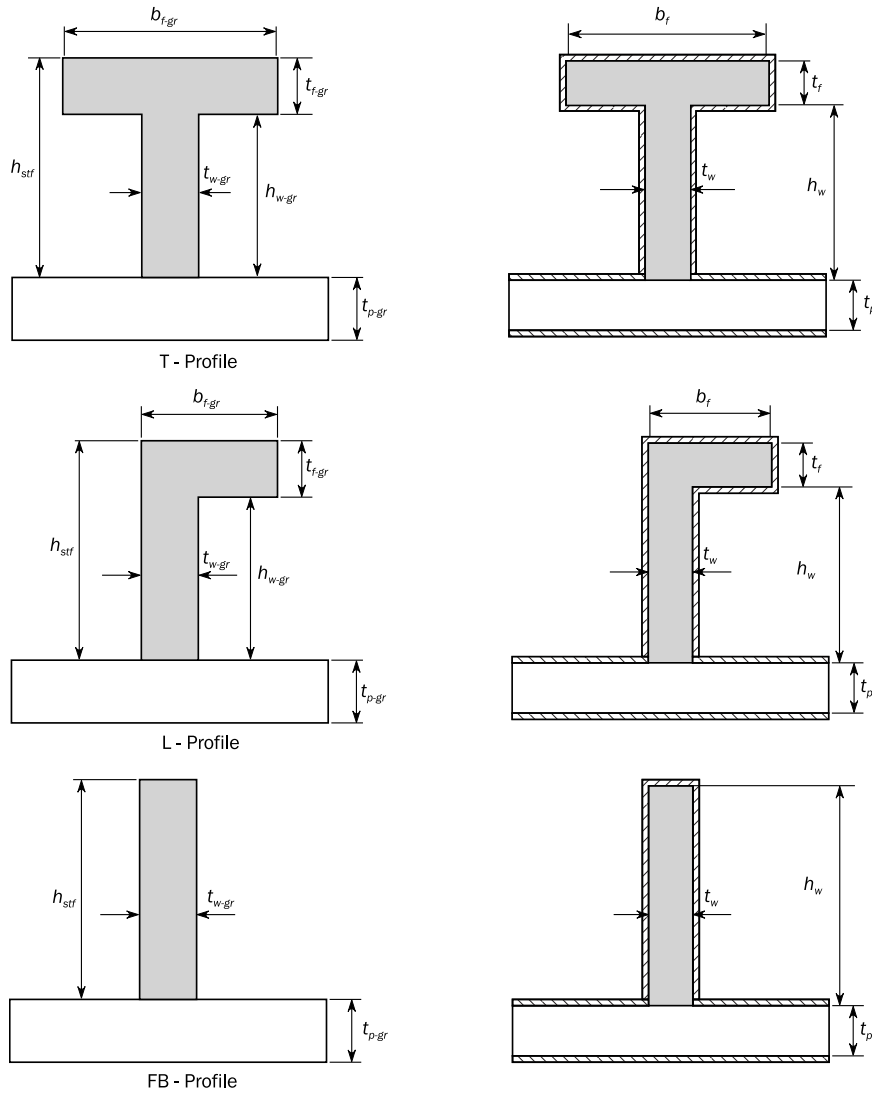


Figure 3 : Net sectional properties of local supporting members (continued)

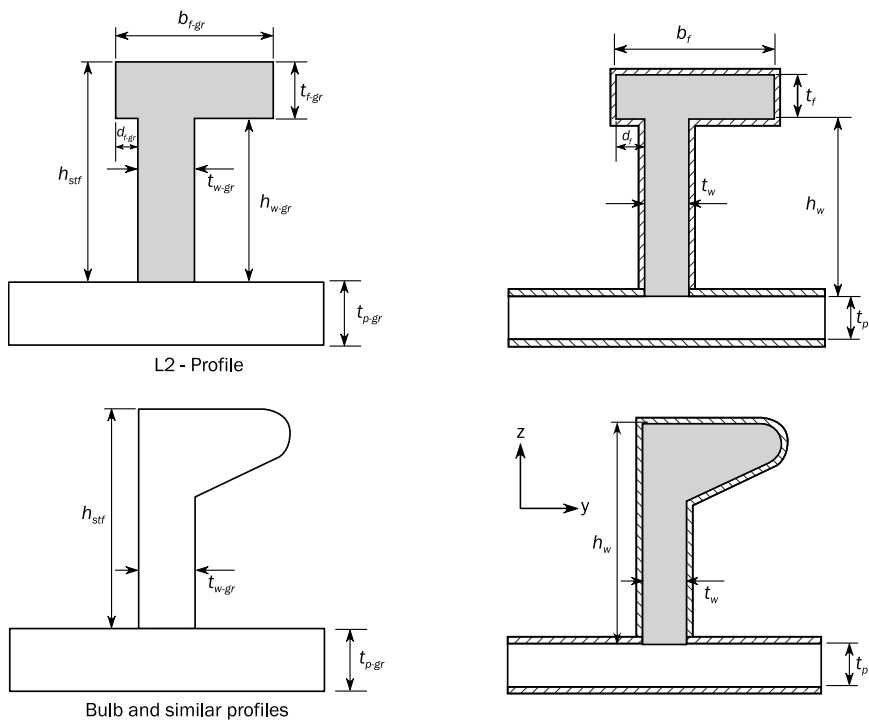


Table 1 : Assessment for corrosion applied to the gross scantlings

Structural requirement	Property/analysis type	Applied corrosion addition
Minimum thickness (all members including PSM)	Thickness	t_c
Local strength (plates, stiffeners)	Thickness/sectional properties	t_c
	Stiffness / Proportions / Buckling capacity	t_c
Primary supporting members (prescriptive)	Sectional properties (1)	$0,5 t_c$
	Stiffness/proportions of web and flange Buckling capacity	t_c
Strength assessment by direct strength analysis	Cargo hold / Complete ship model	$0,5 t_c$
	Buckling capacity	t_c
	Local fine mesh	$0,5 t_c$
Hull girder strength	Sectional properties	$0,5 t_c$
	Buckling capacity	t_c
Hull girder ultimate strength	Sectional properties	$0,5 t_c$
	Buckling/collapse capacity	$0,5 t_c$
Fatigue assessment (simplified stress analysis)	Hull girder section properties Local support member	$0,5 t_c$
Fatigue assessment (FE stress analysis)	Standard mesh FE model Very fine mesh portion	$0,5 t_c$
<p>Note 1: Different values may be defined for ships granted a specific service notation, in compliance with the applicable chapters of Part D or Part E.</p> <p>(1) t_c is to be applied to sectional properties of bulkheads corrugations.</p>		

Section 3 Corrosion Additions

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

t_{res} : Reserve thickness, taken equal to 0,5 mm.

1 General

1.1 Applicability

1.1.1 The corrosion additions are applicable to carbon-manganese steels, stainless steels, stainless clad steels and aluminium alloys.

1.2 Corrosion addition determination

1.2.1 Corrosion addition for steel other than stainless steel

The total corrosion addition, t_c , in mm, for both sides of the structural member is obtained as follows:

- for structural members with a gross thickness greater than 10 mm:

$$t_c = t_{c1} + t_{c2} + t_{res}$$

- for structural members with a gross thickness less than or equal to 10 mm, t_c is the smallest of the following values:

$$t_{c1} + t_{c2} + t_{res}$$

$$0,2 t_{gr_off}$$

The corrosion addition for each of the two sides of a structural member, t_{c1} or t_{c2} , is specified in Tab 1.

However, when $t_{c1} = t_{c2} = 0$, the total corrosion addition is to be taken as $t_c = 0$.

Note 1: For an internal member within a given compartment, the formula $t_{c1} + t_{c2} + t_{res}$ becomes $2 t_{c1} + t_{res}$, where t_{c1} is the value specified in Tab 1 for one side exposure to that compartment.

1.2.2 Corrosion addition for steel clad with stainless steel

In case of stainless clad steel, the total corrosion addition is to be obtained as described in [1.2.1] with the following adjustments:

- the corrosion addition for the carbon steel side t_{c1} is the value specified in Tab 1 for the corresponding compartment
- the corrosion addition for the stainless steel side is:

$$t_{c2} = 0$$

1.2.3 Corrosion addition for aluminium alloys and stainless steel

The total corrosion addition, t_c , in mm, for compartment boundaries and internal members made of stainless steel or aluminium alloy is to be taken as:

$$t_c = 0$$

1.2.4 Stiffener

The corrosion addition of a stiffener is determined according to the location of its connection to the attached plating.

The total corrosion addition determined as per [1.2.1] based on the thinner thickness part of the stiffener is to be applied to both web and flange.

1.2.5 When a local structural member/plate is affected by more than one value of corrosion addition, the most onerous value is to be applied to the entire strake.

Table 1 : Corrosion addition for one side of a structural member

Compartment type		t_{c1} or t_{c2}
Ballast water tank (1), bilge tank, drain storage tank, chain locker (2)		1,00
Exposed to atmosphere		1,00
Exposed to seawater		1,00
Cargo oil tank, fuel and lube oil tank (3) Independent or integral methanol fuel tank of ships with additional service feature methanolfuel (10)		0,50
Liquefied gas tank (5) (11)		0,00
Dry bulk cargo hold (4)	General	1,00
	Inner bottom plating	1,75
	Side plating for single hull ship	
	Inner side plating for double hull ship	
	Transverse bulkhead plating	
Sloping stool plate of hopper tanks and lower stool		1,00
Frames, ordinary stiffeners and primary supporting members(6)		
Fresh water tank		0,50
Moonpool		1,75
Tanks dedicated to water-based or oil-based process muds or brines		1,25
Hopper well of dredging ships		2,00
Compartment located between independent tank and inner side of ships with the additional service feature asphalt carrier		1,00
Cofferdam or void space (7)(8)		0,50
Dry spaces (inside of machinery spaces, pump room, store rooms, steering gear space, passageways, etc.)		0,50 (9)
Container holds	Transverse bulkheads	0,50
	Elsewhere	1,00
Accommodation spaces		0,00
Compartments other than those mentioned above		0,50
<p>(1) Ballast water tank: does not include cargo oil tanks which may carry ballast according to Regulation 18 of MARPOL 73/78.</p> <p>(2) 1,0 mm is to be added to the plate surface within 3 m above the upper surface of the chain locker bottom.</p> <p>(3) For ships with the service notation chemical tanker ESP, the corrosion addition t_c may be taken equal to 0 for cargo tanks covered with a protective lining or coating (see IBC, 6).</p> <p>(4) Dry bulk cargo hold: includes holds, intended for the carriage of dry bulk cargoes, which may carry oil or water ballast.</p> <p>(5) The corrosion addition t_c specified for liquefied gas tanks is to be applied when required in:</p> <ul style="list-style-type: none"> • Pt D, Ch 9, Sec 4, [2.1.5], or • NR529, [6.4.1], or • NR686, Sec 1, [3.1.5]. <p>(6) 0,50 mm is to be added within 3 m above the bottom of the hold.</p> <p>(7) Cofferdam includes cofferdam in cargo area of ships with the service notation liquefied gas carrier or LNG bunkering ship or cofferdams adjacent to the gasfuel tank on ships with additional service feature LNGfuel, CNGfuel, LPGfuel or ammoniafuel.</p> <p>(8) For the determination of the corrosion addition of the outer shell plating, the pipe tunnel is considered as a ballast water tank.</p> <p>(9) For the direct strength assessment according to Ch 8, Sec 1, t_{c1} or t_{c2} is to be taken equal to 0,0 mm.</p> <p>(10) The corrosion addition t_c may be taken equal to 0 for tanks covered with a protective lining or coating.</p> <p>(11) Including tanks of ships with service notation liquefied gas carrier or LNG bunkering ship and gas fuel tanks of ships with the additional service feature LNGfuel, CNGfuel, LPGfuel or ammoniafuel.</p>		

Section 4 Protection of Hull Metallic Structures

1 Protection by coating

1.1 General

1.1.1 It is the responsibility of the shipbuilder and the Owner to choose the coating and have it applied in accordance with the manufacturer's requirements.

1.2 Structures to be protected

1.2.1 All salt water ballast spaces with boundaries formed by the hull envelope are to have a corrosion protective coating, epoxy or equivalent, applied in accordance with the manufacturer's requirements.

For ships assigned with the additional service feature or the additional class notation **CPS (WBT)** according to Pt A, Ch 1, Sec 2, [4.16.10] or Pt A, Ch 1, Sec 2, [6.24.4], reference is to be made to NR530 Coating Performance Standard.

1.2.2 Corrosion protective coating is not required for internal surfaces of spaces intended for the carriage of cargo oil or fuel oil.

1.2.3 Narrow spaces are generally to be filled by an efficient protective product, particularly at the ends of the ship where inspections and maintenance are not easily practicable due to their inaccessibility.

2 Protection against galvanic corrosion in tanks

2.1 General

2.1.1 Non-stainless steel is to be electrically insulated from stainless steel or from aluminium alloys.

2.1.2 Where stainless steel or aluminium alloys are fitted in the same tank as non-stainless steel, a protective coating is to cover both materials.

3 Protection of bottom by ceiling

3.1 General

3.1.1 In double bottom ships, ceiling is to be laid over the inner bottom and lateral bilges, if any.

Ceiling on the inner bottom is not required where the thickness of the inner bottom is increased in accordance with Ch 7, Sec 4, [6.3.1].

3.2 Arrangement

3.2.1 Planks forming ceiling over the bilges and on the inner bottom are to be easily removable to permit access for maintenance.

3.2.2 Where the double bottom is intended to carry fuel oil, ceiling on the inner bottom is to be separated from the plating by means of battens 30 mm high, in order to facilitate the drainage of oil leakages to the bilges.

3.2.3 Where the double bottom is intended to carry water, ceiling on the inner bottom may lie next to the plating, provided a suitable protective composition is applied beforehand.

3.2.4 The Shipyard is to take care that the attachment of ceiling does not affect the tightness of the inner bottom.

3.2.5 In single bottom ships, ceiling is to be fastened to the reversed frames by galvanised steel bolts or any other equivalent detachable connection.

A similar connection is to be adopted for ceiling over the lateral bilges in double bottom ships.

3.3 Scantlings

3.3.1 The thickness of ceiling boards, when made of pine, is to be not less than 60 mm. Under cargo hatchways, the thickness of ceiling is to be increased by 15 mm.

Where the floor spacing is large, the thicknesses may be considered by the Society on a case by case basis.

4 Protection of decks by wood sheathing

4.1 General

4.1.1 Where decks are intended to carry specific loads, such as caterpillar trucks and unusual vehicles, the Society may require such decks wood sheathed.

4.2 Arrangement

4.2.1 Wood sheathing is to be fixed to the plating by welded studs or bolts of at least 12 mm in diameter, every second frame.

4.2.2 Before fitting the wood sheathing, deck plates are to be provided with protective coating declared to be suitable by the Shipyard.

Caulking is Shipyard's responsibility.

4.3 Scantlings

4.3.1 The thickness of wood sheathing of decks is to be not less than:

- 65 mm if made of pine
- 50 mm if made of hardwood, such as teak.

The width of planks is not to exceed twice their thickness.

5 Protection of cargo sides by battens

5.1 General

5.1.1 The requirements in [5.2] apply to sides in cargo spaces of ships with the service notation **general cargo ship** or **livestock carrier**.

5.2 Arrangement

5.2.1 In the case of transversally framed sides, longitudinal battens formed by spaced planks are to be fitted to the frames by means of clips.

5.2.2 Where sides are longitudinally framed, battens are to be fitted vertically.

5.2.3 Battens are to extend from the bottom of the cargo space to at least the underside of the beam knees.

5.2.4 Cargo battens are to be not less than 50 mm in thickness and 150 mm in width. The space between battens is not to exceed 300 mm.

Section 5 Structural Detail Principles

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

Z : Net required section modulus, of the stiffener, in cm³. In the case of two stiffeners connected, Z is the smallest net required section modulus of the two connected stiffeners.

1 Application

1.1 General

1.1.1 The requirements of this Section apply to the hull structure.

2 General principles

2.1 Structural continuity

2.1.1 General

Attention is to be paid to the structural continuity, in particular in the following areas:

- in way of changes in the framing system
- at end connections of primary supporting members or ordinary stiffeners
- in way of the transition zones between central part and fore part, aft part and machinery space (See Ch 11, Sec 1, Ch 11, Sec 2 and Ch 11, Sec 3)
- in way of front, side and aft bulkheads of superstructures
- stepped or knuckled decks contributing to longitudinal strength.

At the termination of a structural member, structural continuity is to be maintained by the fitting of suitable supporting structure. Abrupt changes in transverse section properties of longitudinal members are to be avoided. Smooth transitions are to be provided.

2.1.2 Longitudinal members

Longitudinal members are to be arranged in such a way that continuity of strength is maintained.

Longitudinal members contributing to the hull girder longitudinal strength are to extend continuously as far as practicable towards the ends of the ship.

Longitudinals of the bottom, bilge, sheerstrake, deck, upper and lower longitudinal bulkhead and inner side strakes, as well as the latter strakes themselves, the lower strake of the centreline bottom girder and the upper strake of the centreline deck girder, where fitted, are to be continuous through the transverse bulkheads of the cargo area and cofferdams. Alternative solutions may be examined by the Society on a case by case basis, provided they are equally effective.

2.1.3 Primary supporting members

Primary supporting members are to be arranged in such a way that continuity of strength is maintained.

Abrupt changes of web height or cross-section are to be avoided.

2.1.4 Stiffeners

Stiffeners are to be arranged in such a way that continuity of strength is maintained.

Stiffeners contributing to the hull girder longitudinal strength are generally to be continuous when crossing primary supporting members within 0,4 L amidships and as far as practicable outside 0,4 L amidships.

For ships with L less than 90m, alternative arrangements to ensure structural continuity such as brackets may be considered on a case-by-case basis.

Where stiffeners are terminated in way of large openings, foundations and partial girders, compensation is to be arranged to provide structural continuity in way of the end connection.

2.1.5 Plating

Where plates with different thicknesses are joined, the change in the as-built plate thickness is not to exceed 50% of the larger plate thickness in the load carrying direction. This does not apply in the case of insert plates thicker than the plate they are welded to. If the difference in thickness is greater than 50% of the larger plate thickness, an intermediate plate is to be inserted. Welding of the plates is to be as per Ch 13, Sec 3, [2.1.2].

2.1.6 Weld joints

Weld joints are to be avoided in areas with high stress concentration.

2.2 Local reinforcements

2.2.1 General

Where stress concentration may occur in way of structural discontinuities, adequate compensation and reinforcement are to be provided.

2.2.2 Reinforcements at knuckles

- a) Knuckles are in general to be stiffened to achieve out-of-plane stiffness by fitting ordinary stiffeners or equivalent means in line with the knuckle. Arrangements without stiffener may be accepted on a case-by-case basis depending on the knuckle angle and stress level.
- b) Whenever a knuckle in a main member (shell, longitudinal bulkhead, etc) is arranged, stiffening in the form of webs, brackets or profiles is to be connected to the members to which they are to transfer the load (in shear).
- c) For longitudinal shallow knuckles, closely spaced carlings are to be fitted across the knuckle, between longitudinal members above and below the knuckle. Carlings or other types of reinforcement need not be fitted in way of shallow knuckles that are not subject to high lateral loads and/or high in-plane loads across the knuckle, such as deck camber knuckles.
- d) Generally, the distance between the knuckle and the support stiffening in line with the knuckle is not to be greater than 50 mm. Otherwise, fatigue analysis according to Part B, Chapter 10 is to be submitted by the designer.

2.2.3 Reinforcement in way of attachments for permanent means of access

Local reinforcement, considering location and strength, is to be provided in way of attachments to the hull structure for permanent means of access to and within spaces in the cargo area on ships with service notation **oil tanker** or **bulk carriers**, **bulk carriers ESP**, **self-unloading bulk carriers ESP**, **ore carrier ESP** and **combination carrier ESP**.

2.2.4 Reinforcement of deck structure in way of concentrated loads

The deck structure is to be reinforced in way of concentrated loads, such as anchor windlass, deck machinery, cranes, masts and derrick posts.

Special arrangements, such as girders supported by cantilevers, are considered by the Society on a case-by-case basis.

Stiffeners are also to be fitted in way of the ends and corners of deck houses and partial superstructures.

2.2.5 Reinforcement by insert plates

A local increase in plating thickness is generally to be achieved through insert plates. Local doublers, which are normally only allowed for temporary repair, may however be accepted by the Society on a case by case basis.

In any case, doublers and insert plates are to be made of materials with, at least, the same specified minimum yield stress and the same grade as the plates to which they are welded. See also [2.1.5].

2.2.6 Doublers

In general, doublers having width, in mm, greater than:

- 20 times their thickness, for thicknesses equal to or less than 15 mm
- 25 times their thickness, for thicknesses greater than 15 mm

are to be fitted with slot welds, to be effected according to Ch 13, Sec 3, [4.2].

When doublers fitted on the outer shell and strength deck within 0,6L amidships are accepted by the Society, their width and thickness are to be such that slot welds are not necessary according to the above requirements. Outside this area, the possibility of fitting doublers requiring slot welds will be considered by the Society on a case by case basis.

2.3 Connection between steel and aluminium

2.3.1 Any direct contact between steel and aluminium alloy is to be avoided (e.g. by means of zinc or cadmium plating of the steel parts and application of a suitable coating on the corresponding light alloy parts).

Any heterogeneous jointing system is considered by the Society on a case-by-case basis.

The use of transition joints made of aluminium/steel-clad plates or profiles is considered by the Society on a case-by-case basis (see NR216 Materials and Welding, Ch 9, Sec 4).

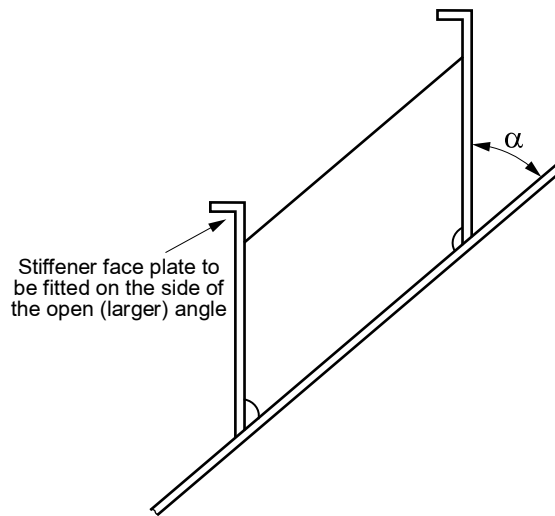
3 Stiffeners

3.1 General

3.1.1 All types of stiffeners (excluding web stiffeners) are to be connected at their ends. However, in special cases such as isolated areas of the ship where end connections cannot be applied, sniped ends may be permitted. Requirements for the various types of connections (bracketed, bracketless or sniped ends) are given in [3.2] to [3.4].

3.1.2 Where the angle α between the web plate of the stiffener and the attached plating is less than 50 deg, as shown on Fig 1, a tripping bracket is to be fitted. If the angle between the web plate of an unsymmetrical stiffener and the attached plating is less than 50 deg, the face plate of the stiffener is to be fitted on the side of the open angle.

Figure 1 : Stiffener on attached plating with an angle less than 50 deg



3.2 Bracketed end connections of non-continuous stiffeners

3.2.1 Where continuity of strength of longitudinal members is provided by brackets, the alignment of the brackets on each side of the primary supporting member is to be ensured, and the scantlings of the brackets are to be such that the combined stiffener/bracket section modulus and effective cross-sectional area are not less than those of the member.

3.2.2 At bracketed end connections, continuity of strength is to be maintained at the stiffener connection to the bracket and at the connection of the bracket to the supporting member.

3.2.3 The arrangement of the connection between the stiffener and the bracket is to be such that, at no point in the connection, the section modulus is less than that required for the stiffener.

3.2.4 Net web thickness

The net bracket web thickness t_b , in mm, is to comply with the following condition:

$$t_b \geq (2 + f_{bkt} \sqrt{Z}) \sqrt{\frac{R_{eH-stf}}{R_{eH-bkt}}}$$

and need not be greater than 13,5 mm,

with:

- f_{bkt} : Coefficient taken equal to:
 - 0,2 for brackets with flange or edge stiffener
 - 0,3 for brackets without flange or edge stiffener
- R_{eH-stf} : Specified minimum yield stress of the stiffener material, in N/mm²
- R_{eH-bkt} : Specified minimum yield stress of the bracket material, in N/mm².

3.2.5 Brackets at the ends of non-continuous stiffeners

Brackets are to be fitted, at the ends of non-continuous stiffeners, with arm lengths ℓ_1 and ℓ_2 (see Fig 2), in mm, at least equal to ℓ_{bkt} , as defined below:

$$\ell_{bkt} = c_{bkt} \sqrt{\frac{Z}{t_b}}$$

with:

- c_{bkt} : Coefficient taken equal to:
 - 65 for brackets with flange or edge stiffener
 - 70 for brackets without flange or edge stiffener
- t_b : Minimum net bracket web thickness, in mm, as defined in [3.2.4]

l_{bkt} is not to be taken less than:

- $1,8 h_{stf}$ for connections where the end of the stiffener web is supported and the bracket is welded in line with the stiffener web or with offset necessary to enable welding, see case (c) in Fig 2
- $2,0 h_{stf}$ for other cases, see (a), (b) and (d) in Fig 2
- $2,0 h_{stf}$ for connections similar to item (b) in Fig 2 but not lapped
- $2,0 h_{stf}$ for connections similar to cases (c) and (d) in Fig 2 where the smaller stiffener is connected to a primary supporting member or bulkhead.

3.2.6 Brackets with different arm lengths

The arms lengths l_1 and l_2 as shown on Fig 2, measured from the plating to the toe of the bracket, are to be such that:

$$l_1 + l_2 > 2 l_{bkt} \quad \text{and} \quad l_1 \geq 0,8 l_{bkt} \quad \text{and} \quad l_2 \geq 0,8 l_{bkt}$$

where l_{bkt} is as defined in [3.2.5].

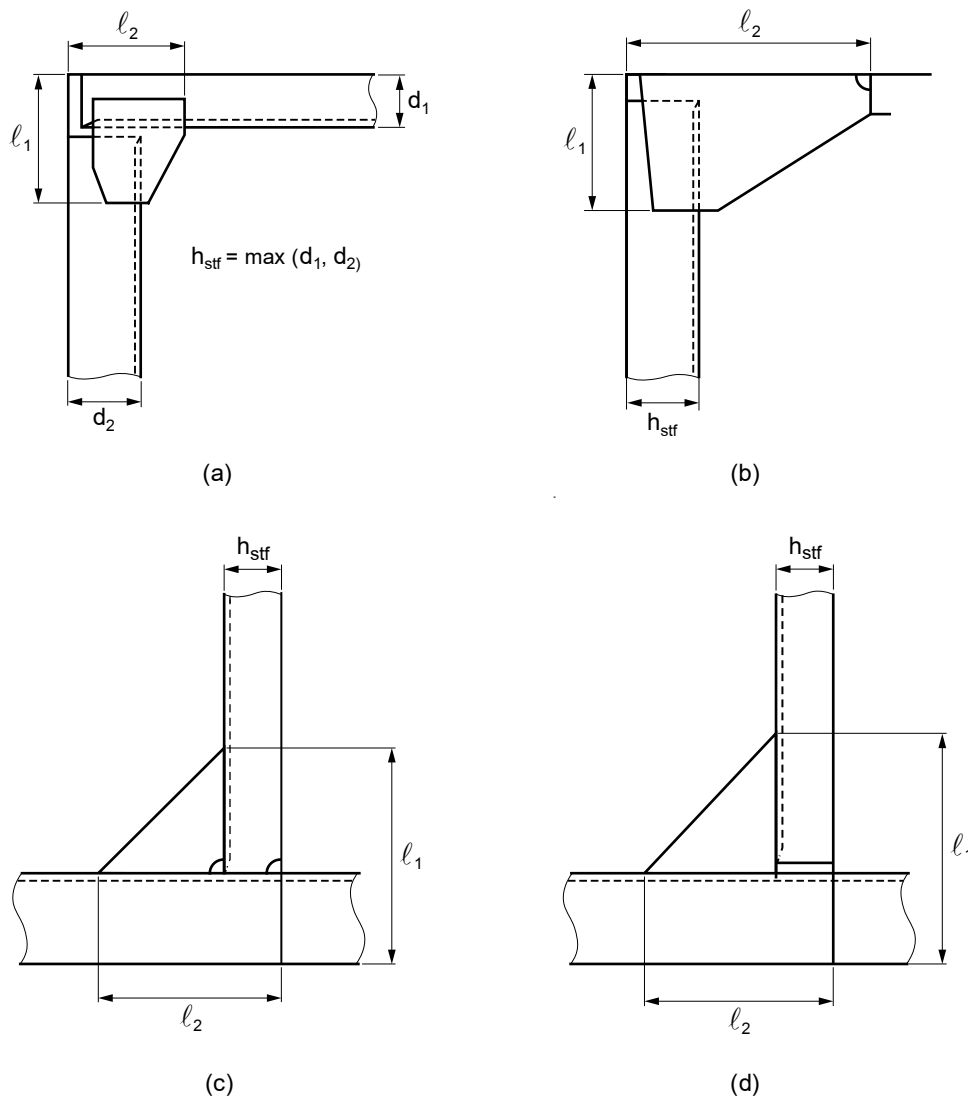
3.2.7 Edge stiffening of bracket

An edge stiffener is required when the net bracket thickness t_b , in mm, is less than $15 L_b$, where L_b is the length, in m, of the free edge of the bracket. The web height of the edge stiffener h_w , in mm, is not to be less than:

$$h_w = 45 \left(1 + \frac{Z}{2000} \right)$$

without being less than 50 mm.

Figure 2 : Bracket arm lengths of non-continuous stiffeners



3.3 Bracketless connections

3.3.1 The design of bracketless connections is to be such as to provide adequate resistance to rotation and displacement of the connection.

3.4 Sniped ends

3.4.1 Sniped ends may be used where dynamic loads are small, provided the net thickness t_p of plating supported by the stiffener, in mm, is not less than:

$$t_p = c_1 \sqrt{\left(1000\ell - \frac{s}{2}\right) \frac{sPk}{10^6}}$$

where:

P : Design pressure for the stiffener for the design load set being considered, in kN/m²

c_1 : Coefficient for the design load set being considered, to be taken as:

- $c_1 = 1,2$ for acceptance criteria set AC-1
- $c_1 = 1,1$ for acceptance criteria set AC-2
- $c_1 = 1,0$ for acceptance criteria set AC-3

k : Material factor, as defined in Ch 4, Sec 1, for the plating.

Sniped stiffeners are not to be used on structures in the vicinity of engines or generators or propeller impulse zone nor on the shell envelope.

3.4.2 Bracket toes and sniped stiffeners ends are to be terminated close to the adjacent member. The distance is not to exceed 40 mm unless the bracket or member is supported by another member on the opposite side of the plating. Tapering of the sniped end is not to be more than 30 deg. The depth of toe or sniped end is not to exceed the thickness of the bracket toe or sniped end member, but need not be less than 15 mm.

4 Primary supporting members (PSM)

4.1 General

4.1.1 Primary supporting members web stiffeners, tripping brackets and end brackets and connections are to comply with [4.2] to [4.5]. Where the structural arrangement is such that these requirements cannot be complied with, adequate alternative arrangement has to be demonstrated to the Society by the designer.

4.2 Web stiffening arrangement

4.2.1 Webs of primary supporting members are generally to be stiffened where the height, in mm, is greater than 100t, where t is the web net thickness, in mm, of the primary supporting member. Alternatively, this requirement may be waived based on a satisfactory buckling analysis as per Ch 9, Sec 1.

In general, the web stiffeners of primary supporting members are to be spaced not more than 110t.

4.3 Tripping bracket arrangement

4.3.1 Tripping brackets are to be fitted:

- at positions along the member span such that they satisfy the criteria for tripping bracket spacing and flange slenderness given in Ch 9, Sec 1
- in way of end brackets toes (see Fig 3, (b))
- at ends of continuous curved face plates (see Fig 3, (c))
- in way of concentrated loads
- near primary supporting members changes of sections.

4.3.2 Where the face plate of the primary supporting members exceeds 180 mm on either side of the web, a tripping bracket is to support the face plate.

4.3.3 Where the face plate of the primary supporting members is symmetrical and greater than 400 mm in width, backing brackets are to be fitted in way of the tripping brackets (see Fig 3, (a)).

4.3.4 Arm length

The arm length of tripping brackets is not to be less than the greater of the following values, in m:

- $d = 0,38 b$
- $d = 0,85b \sqrt{\frac{s_1}{t}}$

where:

- b : Height, in m, of tripping brackets, see Fig 3, (a)
- s_t : Spacing, in m, of tripping brackets
- t : Net thickness, in mm, of tripping brackets.

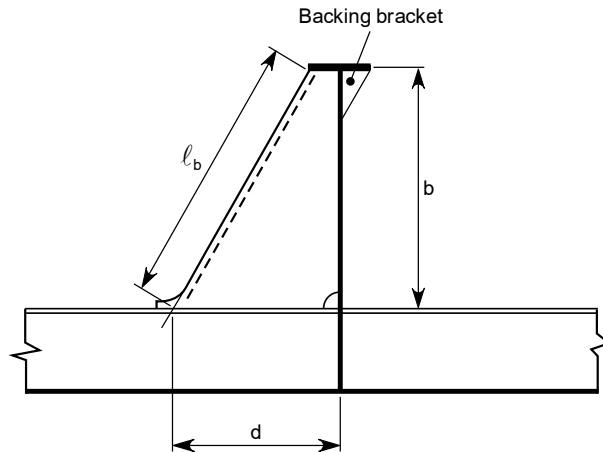
4.3.5 Tripping brackets with a net thickness t less than $15 \ell_b$ are to be flanged or stiffened by a welded face plate; the net sectional area, in cm^2 , of the flanged edge or the face plate is to be not less than $10 \ell_b$, where:

ℓ_b : Length, in m, of the free edge of the bracket (see Fig 3, (a)).

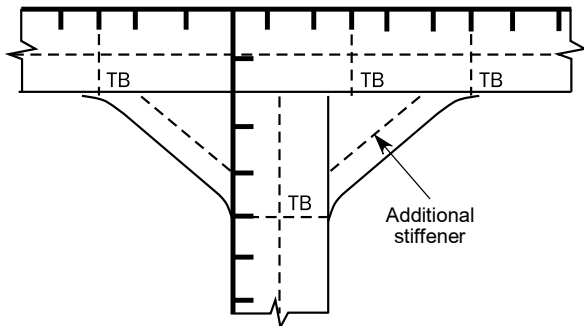
Where the depth of tripping brackets is greater than 3m, an additional stiffener is to be fitted parallel to the bracket free edge (see Fig 3, (b)).

Figure 3 : Primary supporting member - Tripping bracket arrangement

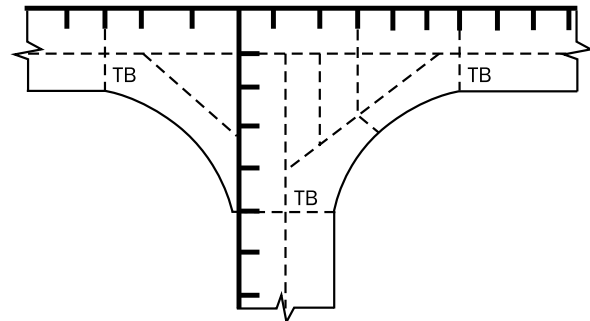
a) Tripping bracket in way of stiffener



b) Tripping brackets at the toe of end brackets



c) Tripping brackets at the ends of continuous curved face plates



4.4 Bracketed end connections

4.4.1 General

Brackets or equivalent structure are to be provided at ends of primary supporting members.

Bracketless connections may be applied according to [4.5], provided there is adequate support of adjoining face plates.

4.4.2 Scantling of end brackets

The scantling of the end brackets is to be such that the section modulus of the primary supporting member with end bracket, excluding face plate where it is sniped, is not less than that of the primary supporting member at mid-span.

The net cross-sectional area A_f , in cm^2 , of the bracket face plates is to be such that:

$$A_f \geq \ell_b t_b$$

where:

ℓ_b : Length of the bracket edge, in m (see Fig 4). For curved brackets, ℓ_b may be taken as the length of the tangent at midpoint of the edge

t_b : Minimum net bracket web thickness, in mm, as defined in [3.2.4].

Moreover, the net thickness of the face plate is to be not less than that of the bracket web.

Figure 4 : Dimension of brackets

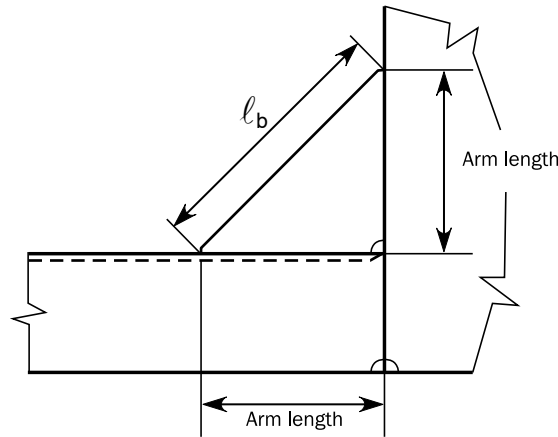
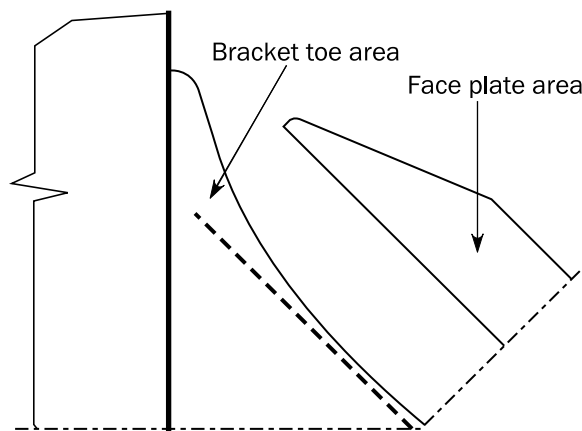


Figure 5 : Bracket face plate adjacent to the edge



4.4.3 Arrangement of end brackets

Where the length l_b of the bracket free edge is greater than 1,5 m, the web of the bracket is to be stiffened as follows:

- the net sectional area, in cm^2 , of web stiffeners is to be not less than $16,5 \ell$, where ℓ is the span, in m, of the stiffener
- tripping flat bars are to be fitted, and, where the width of the symmetrical face plate is greater than 400 mm, additional backing brackets are to be provided.

For a ring system, where the end bracket is integral with the web of the two connected members and the face plate runs continuously on the bracket from the web of one member to the other, the full cross section of the larger face plate of the two members is to be maintained close to the mid-point of the bracket and gradually tapered to the smaller face plate. Butts in face plates are to be kept well clear of the bracket toes.

Where a wide face plate abuts a narrower one, the taper is not to be greater than 1 to 4.

The bracket toes are not to land on unstiffened plating. The toe height is not to be greater than the thickness of the bracket toe, but need not be less than 15 mm. Where primary supporting members are constructed of steel having a strength higher than the strength of the bracket steel, particular attention is to be paid to the design of the end bracket toes in order to minimise stress concentrations.

Where a face plate is welded onto, or welded adjacent to, the edge of the end bracket (see Fig 5), the face plate is to be sniped and tapered at an angle not greater than 30° .

4.5 Bracketless end connections

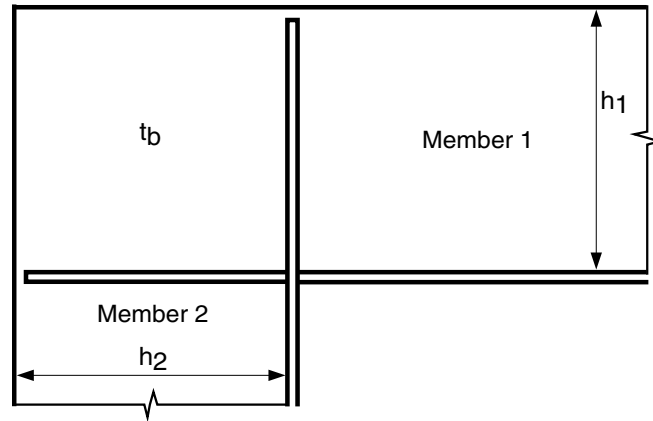
4.5.1 In the case of bracketless crossing between two primary supporting members (see Fig 6), the net thickness of the common part of the webs t_b , in mm, is to be not less than the greatest value obtained from the following formulae:

- $t_b = \frac{Sf_1 \sigma_1 k}{0,5 h_2 R_{eH}}$
- $t_b = \frac{Sf_2 \sigma_2 k}{0,5 h_1 R_{eH}}$
- $t_b = \max(t_1 ; t_2)$

where:

- k : Material factor as defined in Ch 4, Sec 1
- h_1, h_2 : Width, in mm, of member 1 and member 2, respectively, see Fig 6
- Sf_1, Sf_2 : Net flange sectional area, in mm², of member 1 and member 2, respectively
- σ_1, σ_2 : Normal stresses, in N/mm² in member 1 and member 2, respectively
- t_1, t_2 : Net web thicknesses, in mm, of member 1 and member 2, respectively.

Figure 6 : Bracketless end connections between two primary supporting members



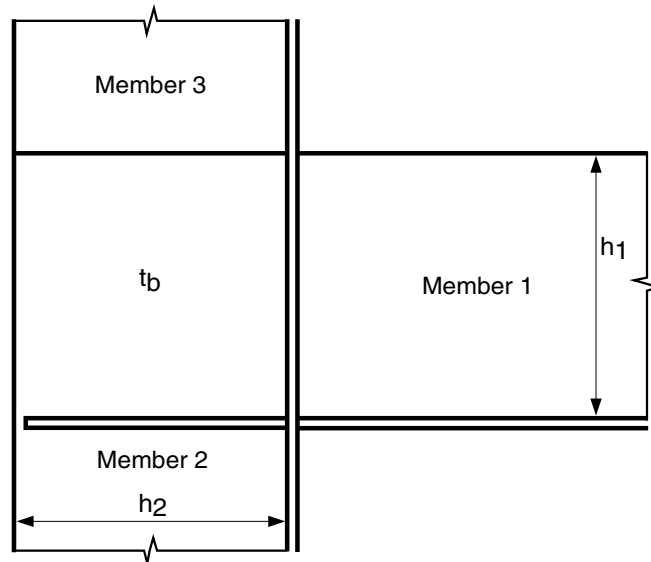
4.5.2 In the case of bracketless crossing between three primary supporting members (see Fig 7), when the flange of member 2 and member 3 is continuous, the net thickness, in mm, of the common part of the webs is not to be less than the greater of:

- $t_b = \frac{Sf_1 \sigma_1 k}{0,5 h_2 R_{eH}}$
- $t_b = \max (t_1 ; t_2)$

Where $Sf_1, \sigma_1, k, h_2, t_1$ and t_2 are as defined in [4.5.1] and Fig 7.

When the flanges of member 2 and member 3 are not continuous, the net thickness of the common part of the webs is to be defined as per [4.5.1].

Figure 7 : Bracketless end connections between three primary supporting members



4.5.3 The common part of the webs is to be generally stiffened where the minimum height of the member 1 and member 2 is greater than $100 t_b$. Alternatively, this requirement may be waived based on a satisfactory buckling analysis as per Ch 9, Sec 1.

4.5.4 When lamellar tearing of flanges may occur, the flange in way of the connection may be requested to be of Z quality or a 100% ultrasonic testing of the flange in way of the weld may be required prior to and after welding.

5 Intersection of stiffeners and primary supporting members

5.1 Cut-outs

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

5.1.2 The total depth of cut-outs without collar plate is to be not greater than 50% of the depth of the primary supporting member.

5.1.3 Cut-outs in high stress areas are to be fitted with full collar plates, see Fig 8.

5.1.4 Lug type collar plates are to be fitted in cut-outs where required for compliance with the requirements of [5.2], and in areas of high stress concentrations, e.g. in way of primary supporting member toes. See Fig 10 for typical lug arrangements.

5.1.5 On cargo ships with length greater than 150m, a soft heel is to be provided in way of the heel of the primary supporting member web stiffeners at connection to shell envelope longitudinals below the scantling draught T_{sc} and at connection to inner bottom longitudinals, when the calculated direct stress σ_w in the primary supporting member web stiffener according to [5.2] exceeds 80% of the allowable values. The soft heel is to have a keyhole similar to that shown in Fig 9.

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

When calculating the direct stress, σ_w , the bottom slamming, stern slamming or bow impact loads using the design pressures defined in Ch 5, Sec 5, [4.2] and Ch 5, Sec 5, [4.3] need not be applied.

5.1.6 Cut-outs are to have rounded corners and the corner radii R are to be as large as practicable, with a minimum of 20% of the breadth b of the cut-out or 25 mm, whichever is greater. See Fig 8. The corner radii R do not need be greater than 50 mm. Consideration is to be given to other shapes, on the basis of maintaining equivalent strength and minimising stress concentration.

5.2 Connection of stiffeners to PSM

5.2.1 General

For connection of stiffeners to PSM subjected to lateral pressure, [5.2.2] and [5.2.3] are to be applied.

The cross-sectional areas of the connections are to be determined from the proportion of load transmitted through each component in association with its appropriate allowable stress.

Figure 8 : Full collar plates

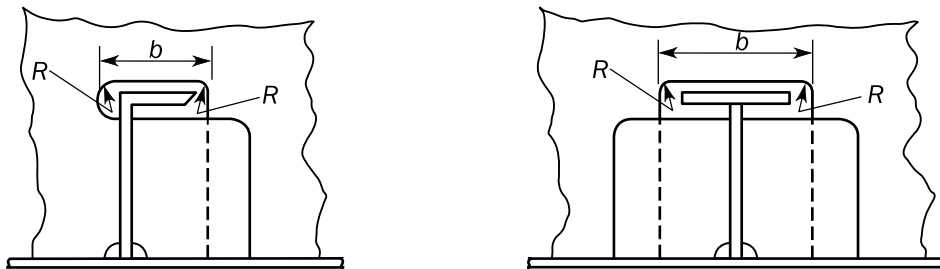


Figure 9 : Typical keyhole for soft heel at the heel of primary supporting member web stiffeners

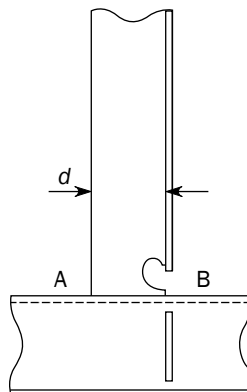
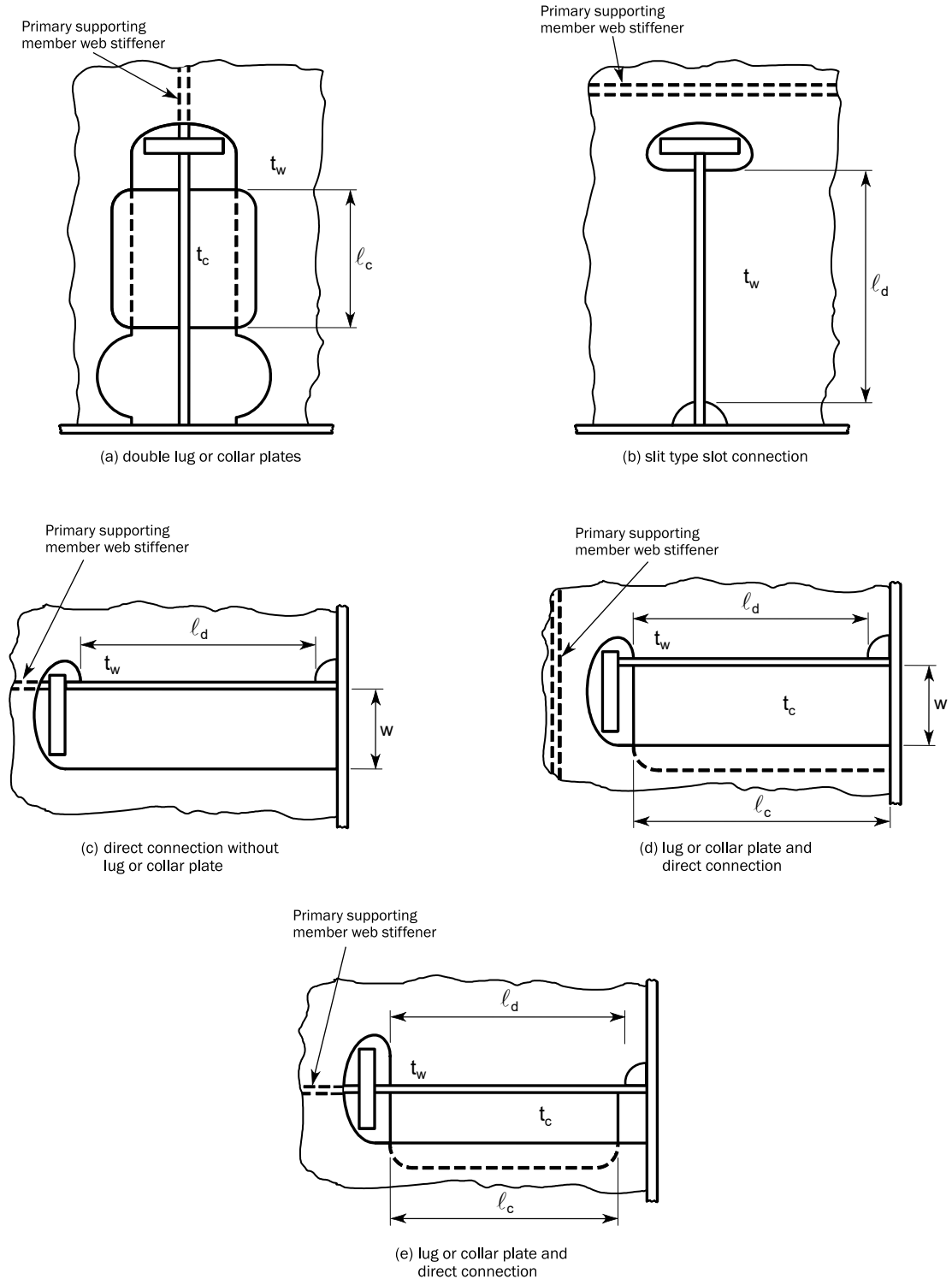


Figure 10 : Symmetric and asymmetric cut-outs



5.2.2 The load W_1 , in kN, transmitted through the shear connection is to be taken as follows:

- for web stiffener connected to the intersecting stiffener:

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

- for web stiffener not connected to the intersecting stiffener:

$$W_1 = W$$

where:

W : Total load, in kN, transmitted through the stiffener connection to the PSM, taken equal to:

$$W = \frac{P_1 s_1 \left(S_1 - \frac{s_1}{2000} \right) + P_2 s_2 \left(S_2 - \frac{s_2}{2000} \right)}{2 \sin \varphi_{W1} \sin \varphi_{W2}} 10^{-3}$$

P_1, P_2 : Design pressures applied on the stiffener for the design load set being considered, in kN/m², on each side of the considered connection. For bottom slamming, stern slamming or bow impact loads, P_1 and P_2 are the design pressure as defined in Ch 5, Sec 5, [4.2] and Ch 5, Sec 5, [4.3] respectively.

S_1, S_2 : Spacings, in m, between the considered and the adjacent PSM, on each side of the considered connection

s_1, s_2 : Spacings of the stiffener, in mm, on each side of the considered connection

α_a : Panel aspect ratio, equal to:

$$\alpha_a = \frac{s}{1000 S}$$

without being taken greater than 0,25, with:

$$s = \frac{s_1 + s_2}{2}$$

$$S = \frac{S_1 + S_2}{2}$$

φ_{W1} : Angle between primary supporting member and attached plating, in deg, as defined in Ch 4, Sec 6.

φ_{W2} : Angle between stiffener and attached plating, in deg, as defined in Ch 4, Sec 6.

A_1 : Effective net shear area, in cm², of the connection, to be taken equal to:

- in general: $A_1 = A_{1d} + A_{1c}$
- in case of a slit type slot connections area: $A_1 = 2 A_{1d}$
- in case of a typical double lug or collar plate connection area: $A_1 = 2 A_{1c}$

A_{1d} : Net shear connection area, in cm², excluding lug or collar plate, given by: $A_{1d} = \ell_d t_w 10^{-2}$

ℓ_d : Length of direct connection between stiffener and PSM web, in mm

t_w : Net web thickness of the primary supporting member, in mm

A_{1c} : Net shear connection area, in cm², with lug or collar plate, given by: $A_{1c} = f_1 \ell_c t_c 10^{-2}$

ℓ_c : Length of connection between lug or collar plate and PSM, in mm

t_c : Net thickness of lug or collar plate, in mm, not to be taken greater than the net thickness of the adjacent PSM web

f_1 : Shear stiffness coefficient, taken equal to:

- for stiffeners of symmetrical cross-section: $f_1 = 1,0$
- for stiffeners of asymmetrical cross-section: $f_1 = 140/w$ without being taken greater than 1,0

w : Width of the cut-out for an asymmetrical stiffener, measured from the cut-out side of the stiffener web, in mm, as indicated in Fig 10

A_w : Effective net cross-sectional area, in cm², of the PSM web stiffener in way of the connection, including backing bracket where fitted, as shown in Fig 11. If the PSM web stiffener incorporates a soft heel ending or soft heel and soft toe ending, A_w is to be measured at the throat of the connection, as shown in Fig 11

f_c : Collar load factor taken equal to:

- for intersecting stiffeners of symmetrical cross-section:
 - for $A_w \leq 14$: $f_c = 1,85$
 - for $14 < A_w \leq 31$: $f_c = 1,85 - 0,0441 (A_w - 14)$
 - for $31 < A_w \leq 58$: $f_c = 1,10 - 0,0130 (A_w - 31)$
 - for $A_w > 58$: $f_c = 0,75$
- for intersecting stiffeners of asymmetrical cross-section:

$$f_c = 0,68 + 0,0172 \frac{\ell_s}{A_w}$$

ℓ_s : Connection length, in mm, equal to:

- for a single lug or collar plate connection to the PSM: $\ell_s = \ell_c$
- for a single sided direct connection to the PSM: $\ell_s = \ell_d$
- in case of a lug or collar plus a direct connection: $\ell_s = 0,5 (\ell_c + \ell_d)$.

5.2.3 The load W_2 , in kN, transmitted through the PSM web stiffener is to be taken as:

- for web stiffener connected to the intersecting stiffener:

$$W_2 = W \left(1 - \alpha_a - \frac{A_1}{4 f_c A_w + A_1} \right)$$

- for web stiffener not connected to the intersecting stiffener:

$$W_2 = 0$$

where:

$W, \alpha_a, A_1, f_c, A_w$: As defined in [5.2.2].

The values of A_w, A_{wc} and A_1 are to be such that the calculated stresses satisfy the following criteria:

- for a connection to the PSM web stiffener not in way of the weld: $\sigma_w \leq \sigma_{perm}$
- for a connection to the PSM web stiffener in way of the weld: $\sigma_{wc} \leq \sigma_{perm}$
- for a shear connection to the PSM web: $\tau_w \leq \tau_{perm}$

where:

σ_w : Direct stress, in N/mm², in the PSM web stiffener at the minimum bracket area away from the weld connection:

$$\sigma_w = \frac{10W_2}{A_w}$$

σ_{wc} : Direct stress, in N/mm², in the PSM web stiffener in way of the weld connection:

$$\sigma_{wc} = \frac{10 W_2}{A_{wc}}$$

with:

A_{wc} : Effective net area, in cm², of the PSM web stiffener in way of the weld, as shown in Fig 11

τ_w : Shear stress, in N/mm², in the shear connection to the PSM web:

$$\tau_w = \frac{10 W_1}{A_1}$$

σ_{perm} : Permissible direct stress, in N/mm², given in Tab 1 for AC-1, AC-2, AC-3 and AC-4

τ_{perm} : Permissible shear stress, in N/mm², given in Tab 1 for AC-1, AC-2, AC-3 and AC-4.

5.2.4 Where a backing bracket is fitted in addition to the PSM web stiffener, it is to be aligned with the web stiffener. The arm length of the backing bracket is not to be less than the depth of the web stiffener. The net cross-sectional area through the throat of the bracket is to be included in the calculation of A_w as shown in Fig 11.

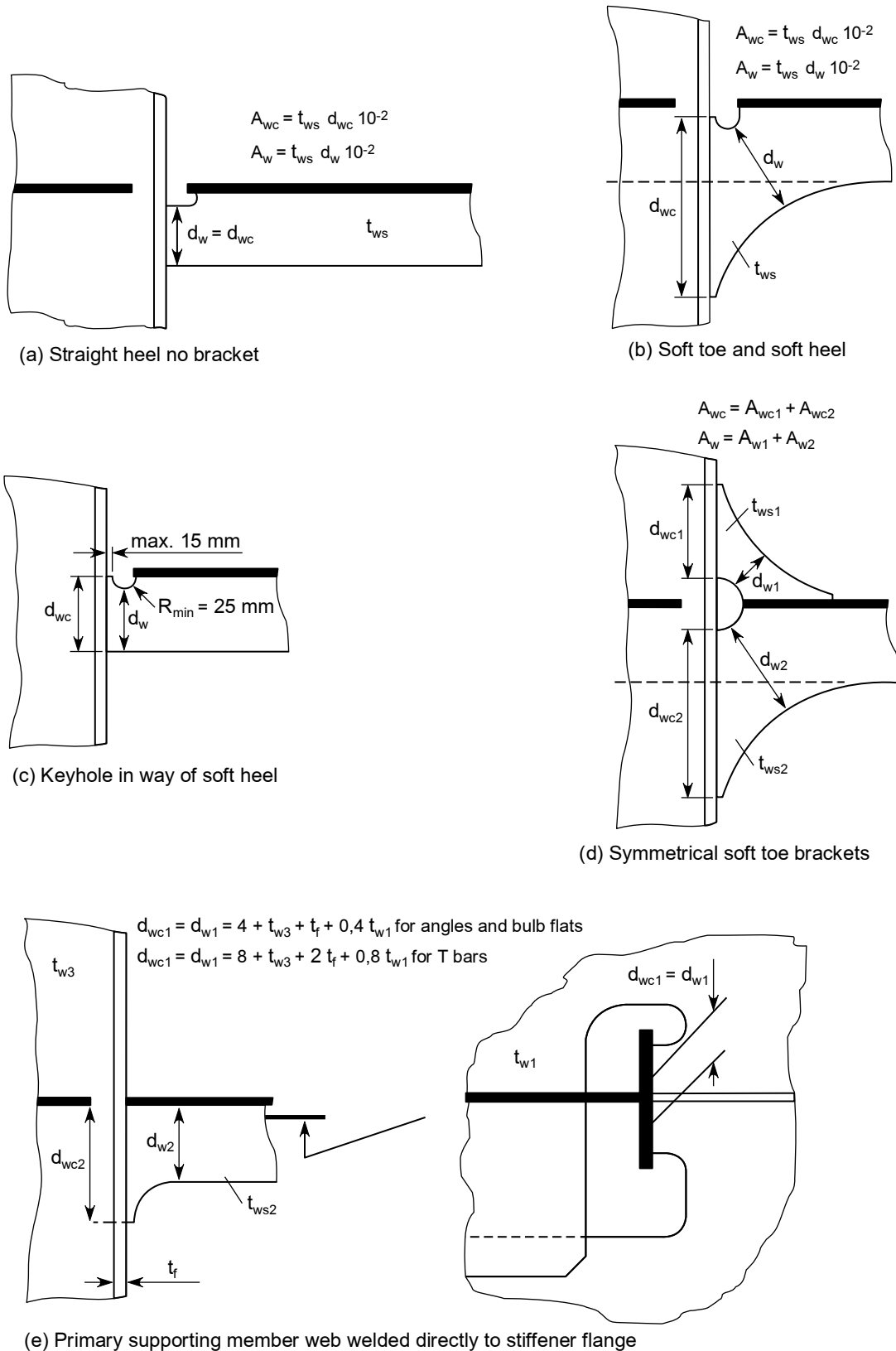
5.2.5 Lapped connections of PSM web stiffeners or tripping brackets to stiffeners are to be avoided as far as possible in the central part.

5.2.6 Where built-up stiffeners have their face plate welded to the side of the web, a symmetrical arrangement of connection to the PSM is to be fitted. This may be achieved by fitting backing brackets on the opposite side of the PSM or bulkhead. The PSM web stiffener and backing brackets are to be butt welded to the intersecting stiffener web.

Table 1 : Permissible stresses for connection between stiffeners and PSMs

Item	Direct stress σ_{perm} in N/mm ²			Shear stress τ_{perm} in N/mm ²		
	Acceptance criteria set			Acceptance criteria set		
	AC-1	AC-2	AC-3 AC-4	AC-1	AC-2	AC-3 AC-4
PSM web stiffener	0,83 R_{eH} (2)	R_{eH}	R_{eH}	–	–	–
PSM web stiffener to intersecting stiffener in way of weld connection:						
	• double continuous fillet	0,58 R_{eH} (2)	0,70 R_{eH} (2)	R_{eH}	–	–
• partial penetration weld	0,83 R_{eH} (1)(2)	R_{eH} (1)	R_{eH}	–	–	–
PSM web stiffener to intersecting stiffener in way of lapped welding	0,50 R_{eH}	0,60 R_{eH}	R_{eH}	–	–	–
Shear connection including lugs or collar plates:						
	• single-sided connection	–	–	–	0,71 τ_{eH}	0,85 τ_{eH}
• double-sided connection	–	–	–	0,83 τ_{eH}	τ_{eH}	τ_{eH}
(1) The root face is not to be greater than one third of the gross thickness of the PSM web stiffener.						
(2) The permissible stresses may be increased by 5% where a soft heel is provided in way of the heel of the PSM web stiffener.						

Figure 11 : Primary supporting member web stiffener details



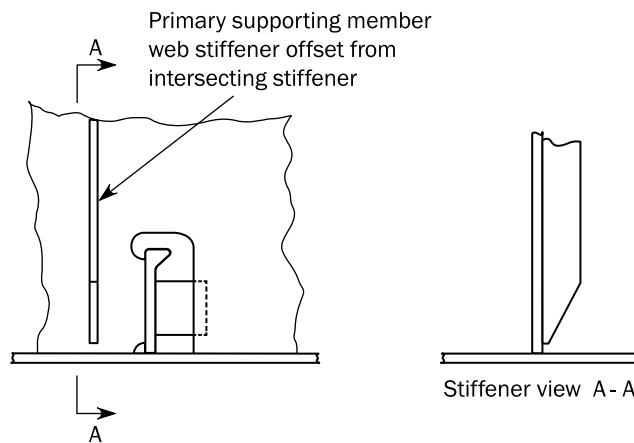
t_{ws} , t_{ws1} , t_{ws2} : Net thickness of the primary supporting member web stiffener/backing bracket, in mm
 d_w , d_{w1} , d_{w2} : Minimum depth of the primary supporting member web stiffener/backing bracket, in mm
 d_{wc} , d_{wc1} , d_{wc2} : Length of connection between the primary supporting member web stiffener/backing bracket and the stiffener, in mm
 t_f : Net thickness of the flange, in mm. For bulb profile, t_f is to be taken as defined in Ch 4, Sec 6, [1.4.1].

Table 2 : Weld factor w_f for connection between stiffeners and PSMs

Item	Acceptance criteria	Weld factor w_f
PSM web stiffener to intersecting stiffener	AC-1 AC-2 AC-3	$0,6 \sigma_{wc} / \sigma_{perm}$ not to be less than 0,38
Shear connection inclusive of lug or collar plate		0,38
Shear connection inclusive of lug or collar plate, where the web stiffener of the PSM is not connected to the intersecting stiffener	AC-4	$0,6 \tau_w / \tau_{perm}$ not to be less than 0,44

Note 1:
 σ_{wc} : Stress, in N/mm², as defined in [5.2.3]
 σ_{perm} : Permissible direct stress, in N/mm², see Tab 1
 τ_w : Shear stress, in N/mm², as defined in [5.2.3]
 τ_{perm} : Permissible shear stress, in N/mm², see Tab 1

Figure 12 : Offset PSM web stiffeners



5.2.7 Where the web stiffener of the PSM is parallel to the web of the intersecting stiffener but not connected to it, the offset PSM web stiffener is to be located in close proximity to the slot edge as shown in Fig 12. The ends of the offset web stiffeners are to be suitably tapered and softened.

5.2.8 The size of the fillet welds is to be calculated according to Ch 13, Sec 3, [3.2.6] based on the weld factor w_f given in Tab 2. For the welding in way of the shear connection, the size is not to be less than that required for the PSM web plate for the location under consideration.

6 Openings

6.1 Openings and scallops in stiffeners

6.1.1 Fig 13 shows examples of air holes, drain holes and scallops. In general, the ratio a/b , as defined in Fig 13, is to be between 0,5 and 1,0. In fatigue sensitive areas, further consideration may be required with respect to the details and arrangements of openings and scallops.

In general, scallops & drain holes are to be kept as small as practicable.

6.1.2 Openings and scallops are to be kept (see Fig 14):

- at least 200 mm clear of the toes of end brackets, end connections and other areas of high stress concentration, measured along the length of the stiffener toward the mid-span, and
- at least 50 mm measured along the length in the opposite direction.

In areas where the shear stress is less than 60% of the permissible stress, alternative arrangements may be accepted.

Figure 13 : Examples of air holes, drain holes and scallops

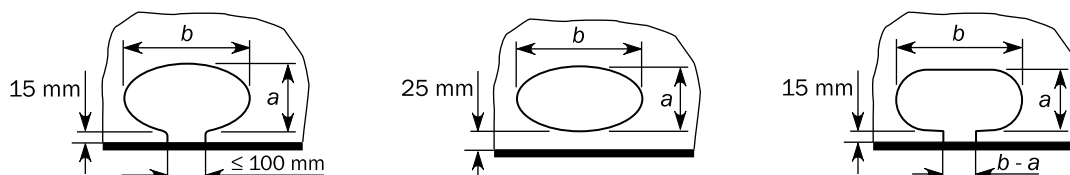
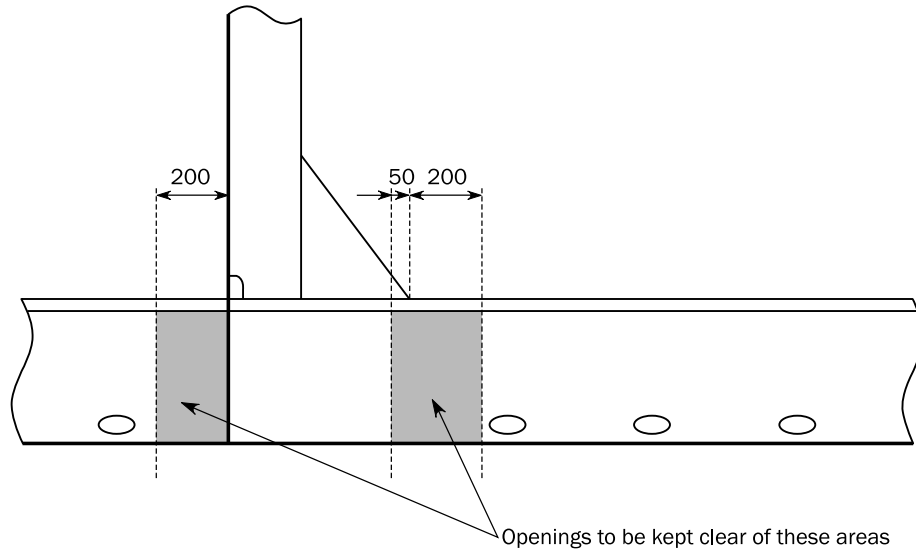


Figure 14 : Location of air and drain holes



6.1.3 Closely spaced scallops or drain holes, i.e. where the distance between scallops/drain holes is less than twice the width b as shown in Fig 13, are not permitted in stiffeners contributing to the longitudinal strength.

For the other stiffeners, closely spaced scallops/drain holes are not permitted within 20% of the stiffener span measured from the end of the stiffener. Widely spaced air or drain holes may be permitted, provided they are of elliptical shape or equivalent to minimise stress concentration and they are cut clear of the welds.

6.2 Openings in primary supporting members

6.2.1 General

Manholes, lightening holes and other similar openings are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are to be avoided in high stress areas, unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory.

Examples of high stress areas include:

- floors or double bottom girders close to their span ends or in way of cargo hold bulkheads
- primary supporting member webs in way of end bracket toes
- above the heads and below the heels of pillars.

Where openings are arranged, their shape is to be such that the stress concentration remains within the acceptable limits.

Openings are to be well rounded, with smooth edges.

6.2.2 Manholes and lightening holes

The web openings do not require reinforcement:

- in single skin sections: when the openings have depth not exceeding 25% of the web depth and are so located that the edges are not at less than 40% of the web depth from the face plate
- in double skin sections: when the openings have depth not exceeding 50% of the web depth and are so located that the edges are well clear of cut-outs for the passage of stiffeners.

The opening length is not to be greater than:

- at mid-span of primary supporting members: the distance between the adjacent openings
- at ends of the span: 25% of the distance between the adjacent openings
- for openings cut in single skin sections: the web depth or 60% of the stiffener spacing, whichever is greater.

The ends of the openings are to be equidistant from the cut-outs for the passage of stiffeners.

Where lightening holes are cut in the brackets, the distance from the hole circumference to the bracket free flange is not to be less than the diameter of the lightening hole.

Openings not complying with the above requirement are to be reinforced according to [6.2.3].

6.2.3 Reinforcements around openings

Manholes and lightening holes are to be stiffened according to this requirement, except where alternative arrangements are demonstrated as satisfactory, in accordance with the analysis methods described in Part B, Chapter 8.

On members contributing to longitudinal strength, stiffeners are to be fitted alongside the opening free edges and parallel to the vertical and horizontal axes of the opening. See Fig 15. Edge reinforcement may be used as an alternative to the stiffeners.

Stiffeners may be omitted:

- in one direction if the shortest dimension of the opening is less than 400 mm, and
- in both directions if the sum of the dimensions (length plus width) of the opening is less than 300 mm.

In the case of large openings in the web of PSMs (e.g. where a pipe tunnel is fitted in the double bottom), the secondary stresses in PSMs are to be considered for the reinforcement of these openings.

Where no FE analysis is performed, this may be carried out by assigning an equivalent net shear sectional area to the PSM obtained, in cm², according to the following formula:

$$A_{s-n50} = \frac{A_{1-n50}}{1 + \frac{32 \ell_{shr}^2 A_{1-n50}}{I_{1-n50}}} + \frac{A_{2-n50}}{1 + \frac{32 \ell_{shr}^2 A_{2-n50}}{I_{2-n50}}}$$

where:

I_{1-n50}, I_{2-n50} : Net moments of inertia, in cm⁴, of deep webs (1) and (2), respectively, with attached plating around their neutral axes parallel to the plating

A_{1-n50}, A_{2-n50} : Net shear sectional areas, in cm², of deep webs (1) and (2), respectively, taking account of the web height reduction by the depth of the cut-outs for the passage of the ordinary stiffeners, if any

ℓ_{shr} : Shear span, in m, of deep webs (1) and (2) as defined in Ch 4, Sec 6, [1.1.7].

Deep web (1) and (2) are defined in Fig 16.

Figure 15 : Web plate with openings

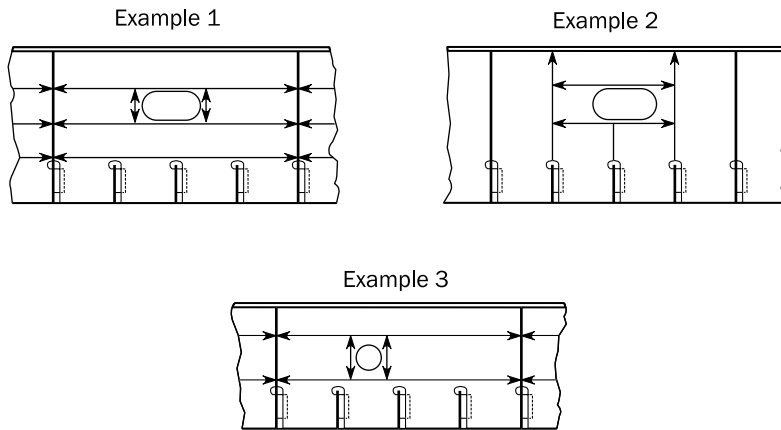


Figure 16 : Large openings in the web of primary supporting members

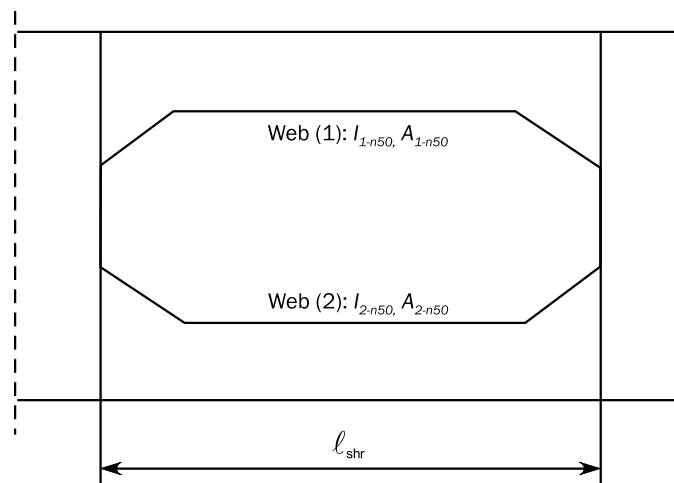
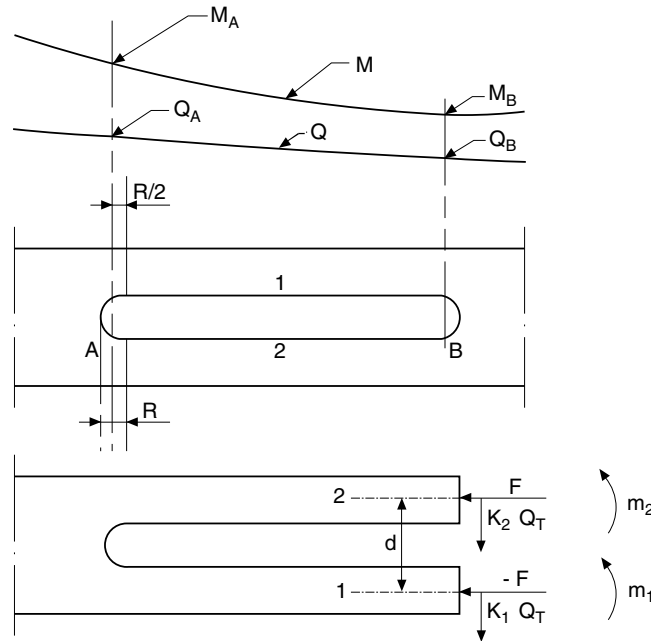


Figure 17 : Large openings in primary supporting members - Secondary stresses



6.2.4 In the case of large openings as shown in Fig 17, the secondary stresses in primary supporting members are to be considered for the reinforcement of the openings.

The secondary stresses may be calculated in accordance with the following procedure.

Members (1) and (2) are subjected to the following forces, moments and stresses:

$$F = \frac{M_A + M_B}{2d}$$

$$m_1 = \left| \frac{M_A - M_B}{2} \right| K_1$$

$$m_2 = \left| \frac{M_A - M_B}{2} \right| K_2$$

$$\sigma_{F1} = 10 \frac{F}{S_1}$$

$$\sigma_{F2} = 10 \frac{F}{S_2}$$

$$\sigma_{m1} = \frac{m_1}{w_1} 10^3$$

$$\sigma_{m2} = \frac{m_2}{w_2} 10^3$$

$$\tau_1 = 10 \frac{K_1 Q_T}{S_{w1}}$$

$$\tau_2 = 10 \frac{K_2 Q_T}{S_{w2}}$$

where:

- M_A, M_B : Bending moments, in kN.m, in sections A and B of the primary supporting member
- m_1, m_2 : Bending moments, in kN.m, in (1) and (2)
- d : Distance, in m, between the neutral axes of (1) and (2)
- σ_{F1}, σ_{F2} : Axial stresses, in N/mm², in (1) and (2)
- σ_{m1}, σ_{m2} : Bending stresses, in N/mm², in (1) and (2)
- Q_T : Shear force, in kN, equal to Q_A or Q_B , whichever is greater
- τ_1, τ_2 : Shear stresses, in N/mm², in (1) and (2)
- w_1, w_2 : Net section moduli, in cm³, of (1) and (2)
- S_1, S_2 : Net sectional areas, in cm², of (1) and (2)
- S_{w1}, S_{w2} : Net sectional areas, in cm², of webs in (1) and (2)
- I_1, I_2 : Net moments of inertia, in cm⁴, of (1) and (2) with attached plating

$$K_1 = \frac{I_1}{I_1 + I_2}$$

$$K_2 = \frac{I_2}{I_1 + I_2}$$

The combined stress σ_c calculated at the ends of members (1) and (2) is to be obtained from the following formula:

$$\sigma_c = \sqrt{(\sigma_F + \sigma_m)^2 + 3\tau^2}$$

The combined stress σ_c is to comply with the checking criteria in Ch 7, Sec 6 or Ch 8, App 1, [5.2.3], as applicable. Where these checking criteria are not complied with, the cut-out is to be reinforced according to one of the solutions shown in Fig 18 to Fig 20:

- continuous face plate (solution 1): see Fig 18
- straight face plate (solution 2): see Fig 19
- compensation of the opening (solution 3): see Fig 20
- combination of the above solutions.

Other arrangements may be accepted provided they are supported by direct calculations submitted to the Society for review.

Figure 18 : Stiffening of large openings in primary supporting members - Solution 1

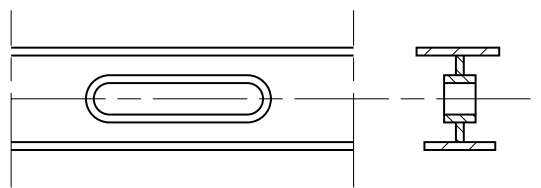


Figure 19 : Stiffening of large openings in primary supporting members - Solution 2

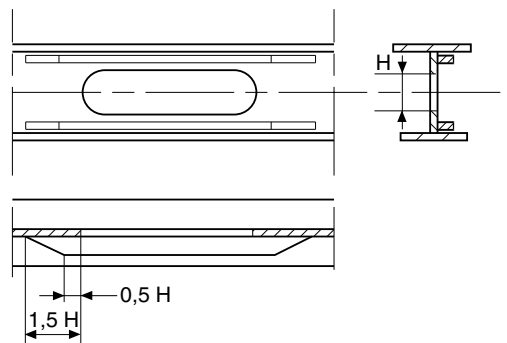
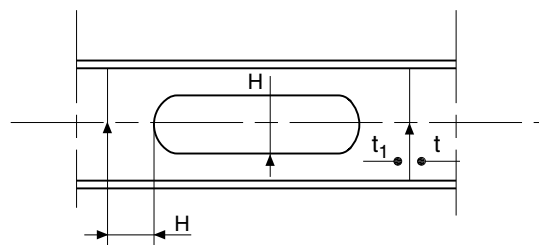


Figure 20 : Stiffening of large openings in primary supporting members - Solution 3

Inserted plate



6.3 Openings in strength deck

6.3.1 General

Openings in the strength deck are to be kept to a minimum and spaced as far as practicable from one another and from the ends of superstructures. Openings are to be located as far as practicable from high stress regions such as side shell platings, hatchway corners, or hatch side coamings.

6.3.2 Small opening location

Small openings are generally to be located outside the shaded areas shown in Fig 21 and defined by:

- the bent area of a rounded sheer strake, if any, or the side shell
- the transverse distance e , from the longitudinal edge of the hatchway, equal to:
 $e = 0,25 (B - b)$
- the longitudinal distance c , from the transverse edge of the hatchway, equal to:
 $c = 0,07 \ell + 0,1 b$ or $0,25 b$, whichever is greater
- the transverse distance g_i , measured from the limit of the shaded areas at the connection between deck and side, equal to:
 - for a circular opening: $g_i = 2 a_i$
 - for an elliptical opening: $g_i = a_i$

where (see Fig 21):

- a_i : Transverse dimension, in m, of the small opening i considered
- b : Width, in m, of the hatchway considered, measured in the transverse direction
- ℓ : Width, in m, in way of the corner considered, of the cross deck strip between two consecutive hatchways, measured in the longitudinal direction.

Distances between small openings are not to be less than:

- a) in longitudinal direction (see openings 1 and 3 in Fig 22):
 - $(a_1 + a_3)$ for circular openings
 - $0,75 (a_1 + a_3)$ for elliptical openings and for an elliptical opening in line with a circular one
- b) in transverse direction (see openings 1 and 2 in Fig 22):
 - $2,0 (a_1 + a_2)$ for circular openings
 - $1,5 (a_1 + a_2)$ for elliptical openings and for an elliptical opening in line with a circular one

If the opening arrangements do not comply with these requirements, the hull girder longitudinal strength assessment is to be carried out by subtracting such opening areas, see Ch 6, Sec 1, [1.2].

Figure 21 : Position of small openings with respect to sides and hatchways in the strength deck

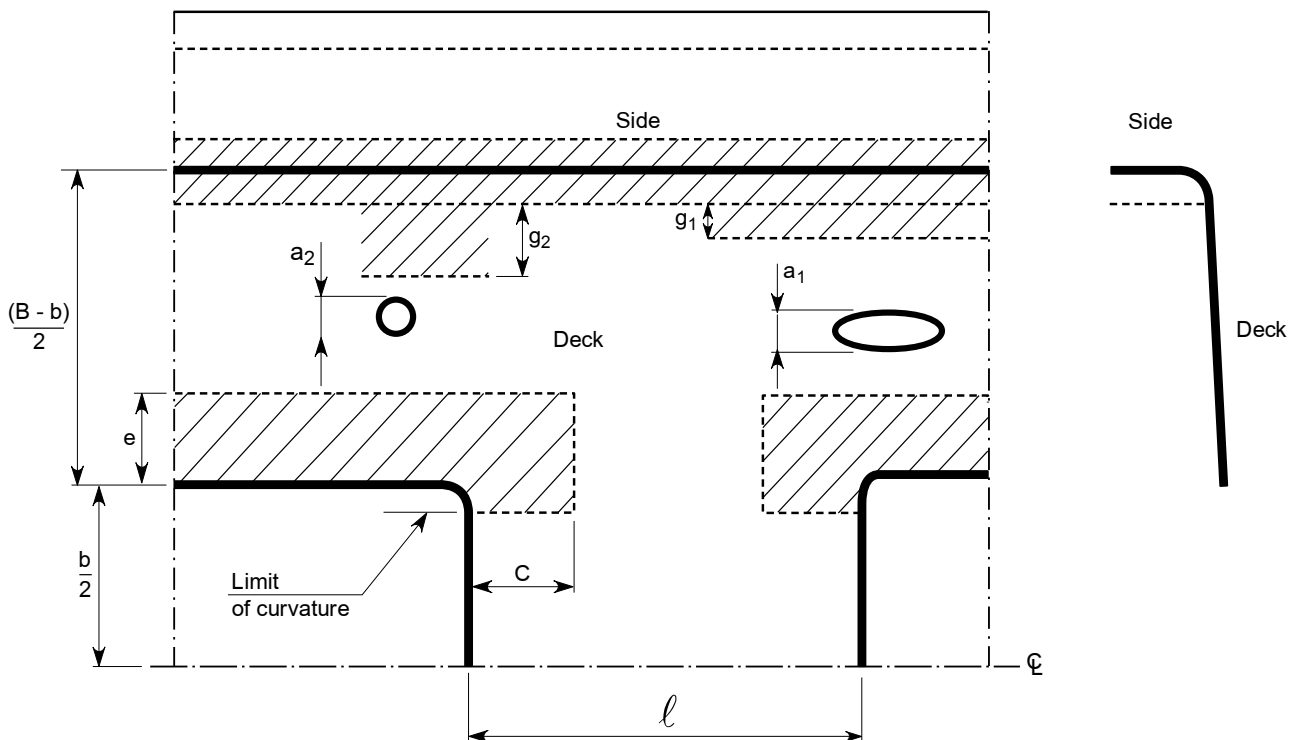
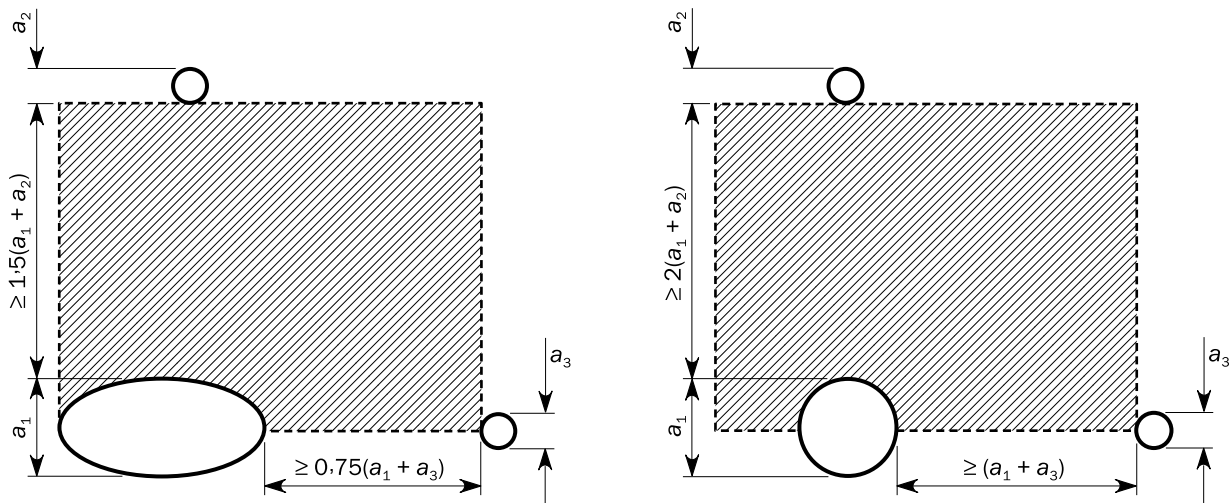


Figure 22 : Distances between small openings in the strength deck



6.4 Corners of hatchways

6.4.1 For hatchways located within the cargo area, insert plates, whose thickness is to be determined according to [6.4.3], are generally to be fitted in way of corners where the plating cut-out has a circular profile.

The radius of circular corners is to be not less than:

- 5% of the hatch width, where a continuous longitudinal deck girder is fitted below the hatch coaming
- 8% of the hatch width, where no continuous longitudinal deck girder is fitted below the hatch coaming.

Corner radiusing, in the case of the arrangement of two or more hatchways athwartship, is considered by the Society on a case by case basis.

6.4.2 For hatchways located in the positions specified in [6.4.1], insert plates are, in general, not required in way of corners where the plating cut-out has an elliptical or parabolic profile and the half axes of elliptical openings, or the half lengths of the parabolic arch, are not less than:

- 1/20 of the hatchway width or 600 mm, whichever is the lesser, in the transverse direction
- twice the transverse dimension, in the fore and aft direction.

6.4.3 Where insert plates are required, their thickness is obtained, in mm, from the following formula:

$$t_{\text{INS}} = \left(0,8 + 0,4 \frac{\ell}{b} \right) t$$

without being taken less than t or greater than $1,6t$

where:

- ℓ : as defined in [6.3.2].
- b : as defined in [6.3.2].
- t : Actual thickness, in mm, of the deck at the side of the hatchways.

For the extreme corners of end hatchways, the thickness of insert plates is to be 60% greater than the actual thickness of the adjacent deck plating. A lower thickness may be accepted by the Society on the basis of calculations showing that stresses at hatch corners are lower than permissible values.

6.4.4 Where insert plates are required, the arrangement shown in Ch 13, App 2, Tab 66 is to be complied with.

6.4.5 For hatchways located in positions other than those in [6.4.1], a reduction in the thickness of the insert plates in way of corners may be considered by the Society on a case by case basis.

6.5 Openings in shell plating

6.5.1 Position of openings

Openings in the shell plating are to be located at a vertical distance from the deck at side, taken under the bent area of the rounded sheer strake if any, not less than:

- two times the opening diameter, in case of circular openings
- the transverse dimension of the opening (along the minor axis), in case of elliptical openings.

See also Fig 21.

6.5.2 Local strengthening

Openings in the ship sides, e.g. for pilot doors, are to be well rounded at the corners and located well clear of superstructure ends or of any openings in the deck areas at sides of hatchways.

Openings for sea intakes are to be well rounded at the corners and, within 0,6 L amidships, located outside the bilge strakes. Where arrangements are such that sea intakes are unavoidably located in the curved zone of the bilge strakes, such openings are to be elliptical with the major axis in the longitudinal direction. Openings for stabiliser fins are considered by the Society on a case-by-case basis. The thickness of the sea chests is to be generally that of the local shell plating, but in no case less than 12 mm. Above mentioned openings, when deemed necessary by the Society, other openings may be adequately compensated by means of insert plates of increased thickness or doublers sufficiently extended in length. Such compensation is to be partial or total, depending on the stresses occurring in the area of the openings.

Circular openings on the sheer strake need not be compensated where their diameter does not exceed 20% of the sheer strake minimum width as defined in [8.1.4], or 380 mm, whichever is the lesser, and where they are located away from openings on deck at side of hatchways and away from superstructure ends.

7 Bottom structure

7.1 General

7.1.1 Framing system

For ships greater than 120 m in length, the bottom shell and the inner bottom are to be longitudinally stiffened within the central part. Where it is not practicable to apply a longitudinal framing system to fore and aft parts of the central part due to the hull form, transverse framing may be accepted on a case-by-case basis, subject to appropriate brackets and other arrangements being incorporated to provide structural continuity in way of the changes to the framing system.

7.1.2 Variation in height of double bottom

Any variation in the double bottom height is to be made gradually and over an acceptable length; the knuckles of inner bottom plating are to be located in way of double bottom floors. Where such arrangement is not possible, longitudinal structures, such as partial girders, longitudinal brackets, fitted across the knuckle, are to be arranged.

7.1.3 Drainage of tank top

Effective arrangements are to be provided for draining water from the tank top. Where wells are provided for the drainage, such wells are not to extend over more than one-half height of double bottom.

7.1.4 Striking plate

Striking plates of adequate thickness or other equivalent arrangements are to be provided under sounding pipes to prevent the sounding rod from damaging the plating.

7.1.5 Duct keel

Where a duct keel is arranged, the centre girder may be replaced by two girders spaced not more than 3 m apart. Otherwise, for a spacing wider than 3 m, the two girders are to be provided with support of the adjacent structure and subject to the Society's approval.

The structures in way of the floors are to provide sufficient continuity of the latter.

7.2 Keel plate

7.2.1 Keel plating is to extend over the flat part of the bottom for the full length of the ship.

The width of the keel, in m, is not to be less than:

$0,8 + L/200$, without being taken greater than 2,3 m.

7.3 Girders

7.3.1 Centre girder

When fitted, the centre girder is to extend within the central part and is to extend forward and aft as far as practicable. Structural continuity of the centre girder is to be maintained within the full length of the ship.

7.3.2 Side girders

The side girders are to extend within the parallel part of the central part and are to extend forward and aft of the central part as far as practicable.

7.4 Floors

7.4.1 Web stiffeners

Where the web stiffeners are not welded to the longitudinal stiffeners, fatigue strength assessment for the cut-out and connection of longitudinal stiffeners may be required.

7.4.2 Floor spacing

Floors are also to be fitted in way of the watertight bulkheads.
For transversally framed bottom, floors are to be fitted at every frame.

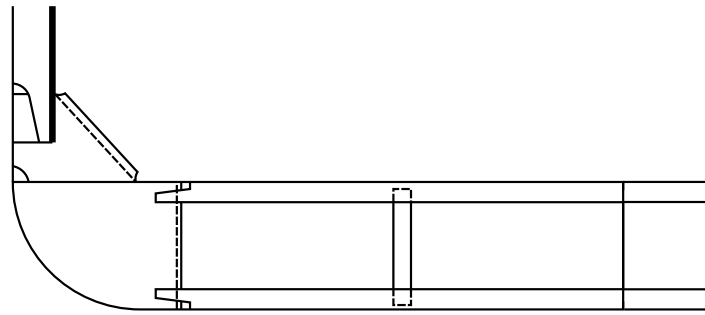
7.5 Open floors

7.5.1 Open floors may be fitted in way of intermediate frames, consisting of a frame connected to the bottom plating and a reverse frame connected to the inner bottom plating (See Fig 23).

7.5.2 Open floors are to be attached to the centreline girder and to the margin plate by means of flanged brackets having a width of flange not less than 1/10 of the local double bottom height.

7.5.3 Where frames and reverse frames are interrupted in way of girders, double brackets are to be fitted.

Figure 23 : Open floor



7.6 Bilge keel

7.6.1 Material

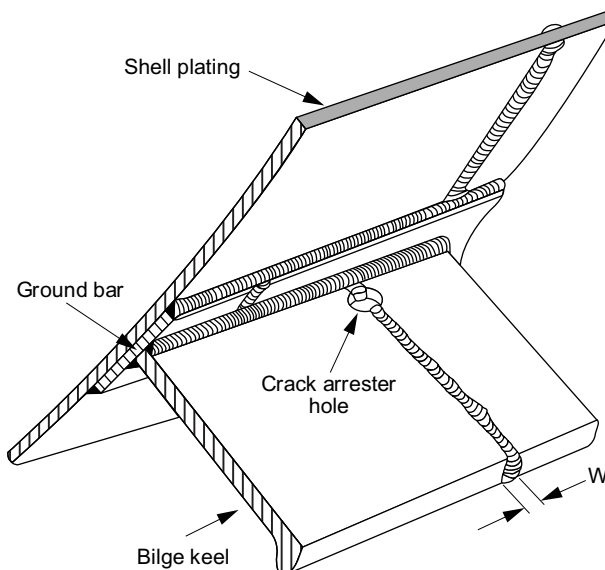
The material of the bilge keel and ground bar is to be of the same yield stress as the material to which they are attached.
In addition, when the bilge keel extends over a length more than 0,15 L, the material of the ground bars are to be of the same grade as the material to which they are attached and the material of the bilge keels are to be of the same material class to which they are attached.

7.6.2 Design

The design of single web bilge keels is to be such that failure to the web occurs before failure of the ground bar. This may be achieved by ensuring that the web thickness of the bilge keel does not exceed that of the ground bar.
In general, scallops and cut-outs are not to be used. Crack arresting holes are to be drilled in the bilge keel butt welds as close as practicable to the ground bar. The diameter of the hole is to be greater than the width W of the butt weld and is to be a minimum of 25 mm (see Fig 24). Where the butt weld has been subject to non-destructive examination, the crack arresting hole may be omitted.

Bilge keels of a design different from that shown in Fig 24 are to be specially considered by the Society.

Figure 24 : Bilge keel construction



7.6.3 Ground bars

Bilge keels are not to be welded directly to the shell plating. A ground bar, or doubler, is to be fitted on the shell plating as shown in Fig 24 to Fig 26. In general, the ground bar is to be continuous.

The gross thickness of the ground bar is not to be less than the gross thickness of the bilge plating or 14 mm, whichever is the lesser.

Figure 25 : Bilge keel and design

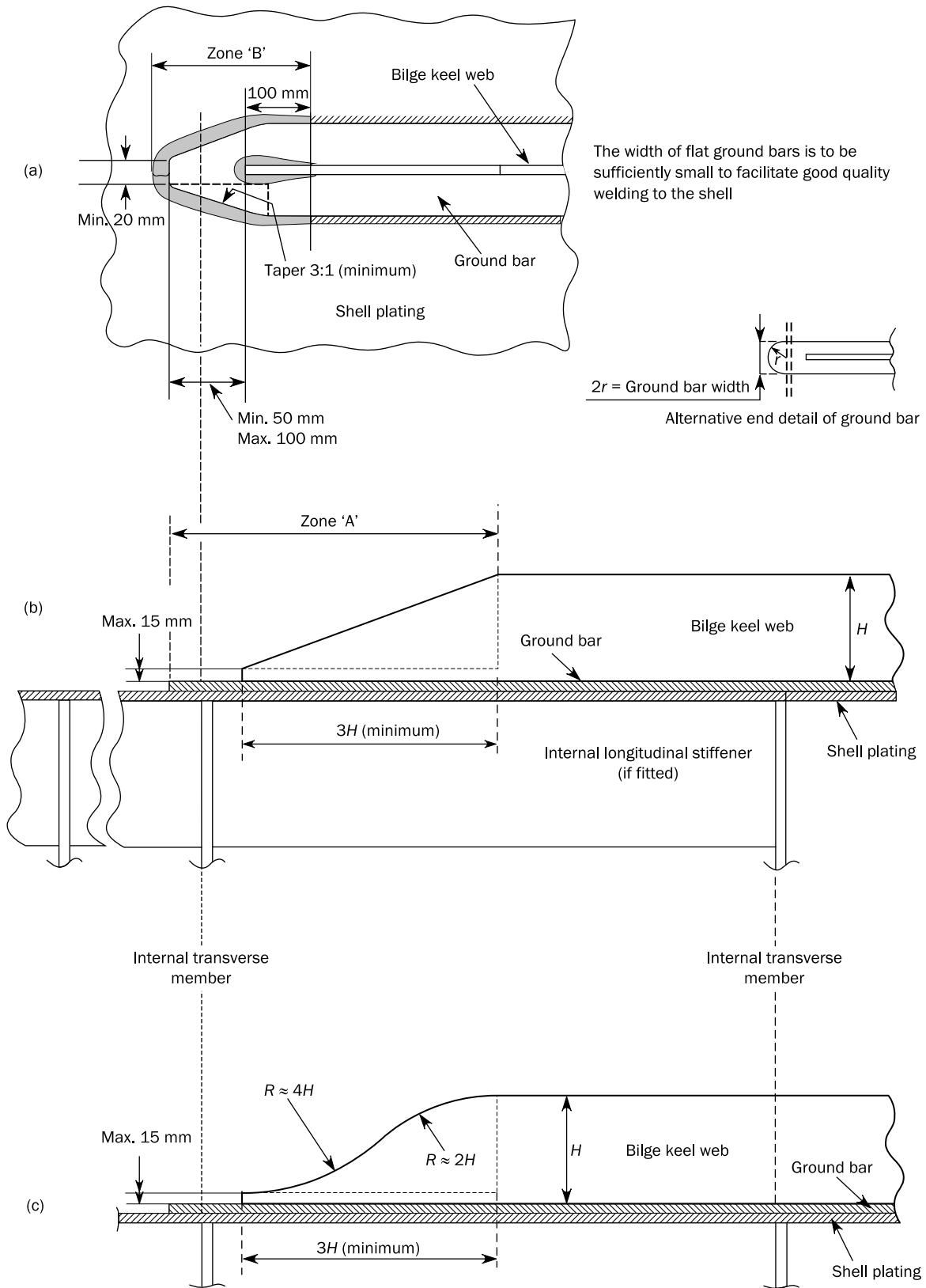
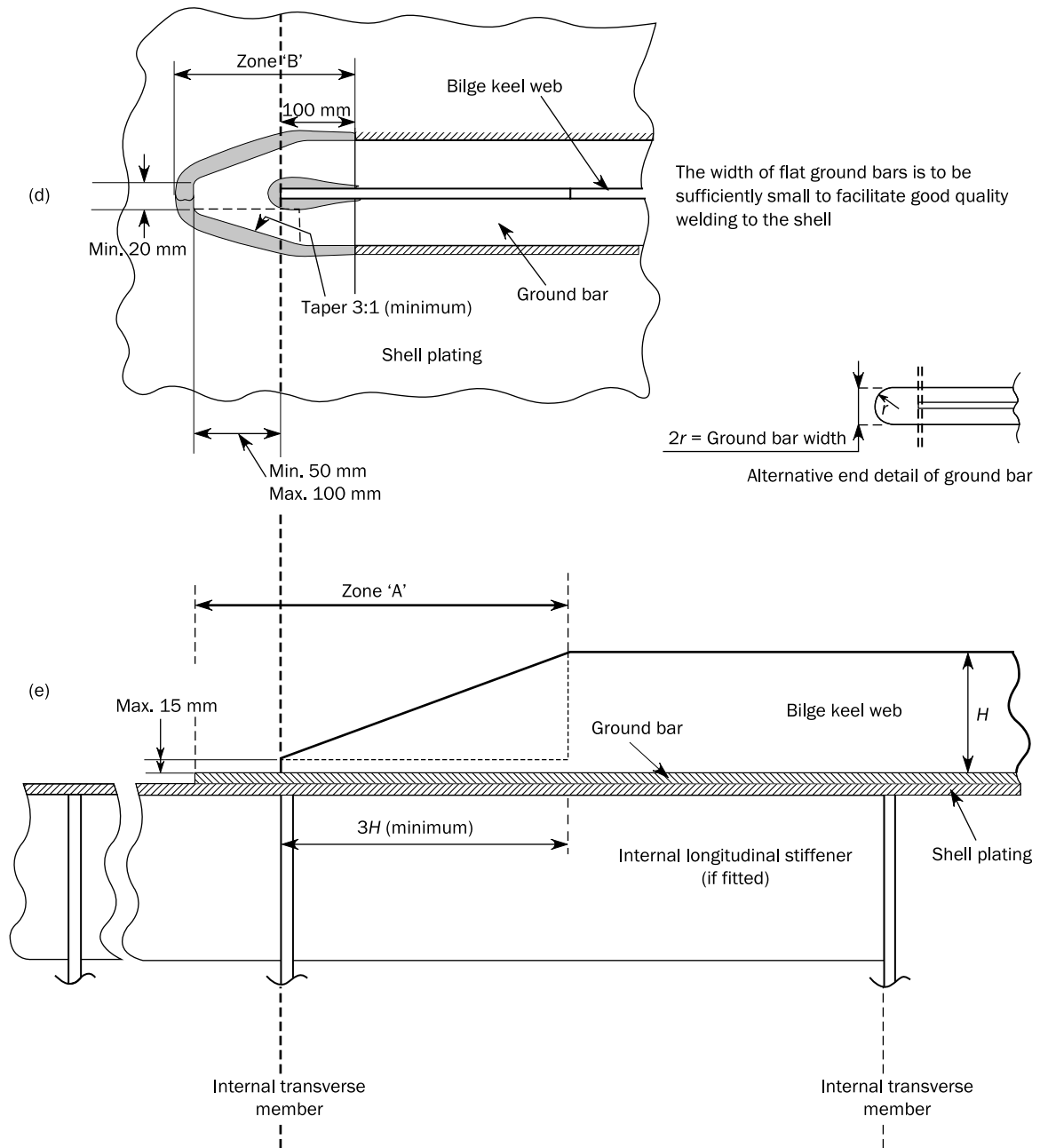


Figure 26 : Bilge keel and design



7.6.4 End details

The ground bar and bilge keel ends are to be tapered or rounded. Tapering is to be gradual with a minimum ratio of 3:1, see Fig 25 items (a) and (b), and Fig 26 items (d) and (e). Rounded ends are to be as shown in Fig 25, item (c). Cut-outs on the bilge keel web within zone A (see Fig 25 item (b) and Fig 26 item (e)) are not permitted.

The end of the bilge keel web is to be not less than 50 mm and not greater than 100 mm from the end of the ground bar, see Fig 25 item (a) and Fig 26 item (d).

Ends of the bilge keel and ground bar are to be supported by either transverse or longitudinal members inside the hull, as indicated as follows:

- transverse support member is to be fitted at mid-length between the end of the bilge keel web and the end of the ground bar, see Fig 25 items (a), (b) and (c)
- longitudinal stiffener is to be fitted in line with the bilge keel web, it is to extend to at least the nearest transverse member forward and aft of zone A (see Fig 25 item (b) and Fig 26 item (e)).

Alternative end arrangements may be considered by the Society on a case by case basis.

7.7 Docking

7.7.1 General

The dry docking arrangement itself is not covered by these Rules.

8 Side structure

8.1 Structural arrangement

8.1.1 Primary supporting members

Side or double side web frames are to be fitted in line with the bottom web frames. Alternative framing arrangements may be considered by the Society on a case by case basis.

For double side arrangement, a vertical framing is to be fitted in way of the structure of the transverse bulkheads.

8.1.2 Longitudinal stiffeners

The longitudinal stiffeners on side shell and inner hull, where fitted, are to be continuous within the length of the parallel part of the central part. They are to be effectively connected to the transverse web frames and bulkheads of the double side structure. Longitudinal framing of the side shell is to extend outside the central part, as far forward as practicable.

8.1.3 Transverse stiffeners

The transverse stiffeners on side shell and inner hull, where fitted, are to be continuous or fitted with bracket end connections. At their upper and lower ends, the shell and inner hull transverse stiffeners are to be connected by brackets to the supporting stringer plates.

8.1.4 Sheer strake

Sheer strakes are to have breadths, in m, not less than $0,8 + L/200$, measured vertically, but need not be greater than 1,8 m.

The sheer strake may be either welded to the stringer plate or rounded.

If the sheer strake is rounded, its radius, in mm, is to be not less than $17 t_s$, where:

t_s : Net thickness, in mm, of the sheer strake.

The upper edge of the welded sheer strake is to be rounded, smooth and free of notches. Fixtures, such as bulwarks and eye plates, are not to be directly welded on the upper edge of the sheer strake, except in fore and aft parts. Drainage openings with a smooth transition in the longitudinal direction may be permitted.

Longitudinal seam welds of rounded sheer strake are to be located outside the bent area at a distance not less than 5 times the maximum net thickness of the sheer strake.

The welding of deck fittings to rounded sheer strakes is to be avoided within $0,6 L$ amidships.

The transition from a rounded sheer strake to an angled sheer strake associated with the arrangement of superstructures is to be designed to avoid any discontinuities.

9 Deck structure

9.1 Structural arrangement

9.1.1 Framing system

For ships greater than 120 m in length, deck areas contributing to the longitudinal strength are to be longitudinally framed.

Transverse framing may be accepted on a case-by-case basis subject to appropriate brackets and other arrangements being incorporated to provide structural continuity in way of changes to the framing system.

9.1.2 Stringer plate

Stringer plates are to have breadths, in m, not less than $0,8 + L/200$, measured horizontally, but need not be greater than 1,8 m.

Rounded stringer plates, where adopted, are to comply with the requirements in [8.1.4].

9.1.3 Connection of deckhouses and superstructures

Connection of the deckhouses and superstructures to the strength deck is to be so designed that loads are transmitted to the supporting structure under deck.

10 Bulkhead structure

10.1 Application

10.1.1 The requirements of this Article apply to longitudinal and transverse bulkheads, which may be plane or corrugated.

10.2 Plane bulkheads

10.2.1 General

The bulkheads are to be stiffened in way of the deck girders.

The horizontally framed bulkheads are made of horizontal stiffeners supported by vertical primary supporting members.

The vertically framed bulkheads are made of vertical stiffeners supported by horizontal stringers, if needed.

The crossing of stiffeners through a watertight bulkhead is to be watertight.

Bulkheads that support girders or pillars and longitudinal bulkheads which are fitted in lieu of girders are to be stiffened to provide supports not less effective than required for stanchions or pillars that would be located at the same position.

Where bulkheads are penetrated by cargo or ballast piping, the structural arrangements in way of the connection are to be adequate for the loads imparted to the bulkheads by the hydraulic forces in the pipes.

10.2.2 End connection of stiffeners

End connections of stiffeners are to be bracketed or welded to the supporting member.

For isolated areas where bracketed or welded end connections cannot be applied due to hull lines, other arrangements including sniped ends are acceptable.

Sniped ends may be used for stiffeners on bulkheads subject to hydrostatic pressure, provided they comply with [3.4].

10.3 Corrugated bulkheads

10.3.1 General

Transverse vertically corrugated watertight bulkheads are to be fitted with a lower stool, and generally with an upper stool below deck in the following cases:

- bulkheads normally submitted to liquid pressure, e.g. tank bulkheads and ballast hold bulkheads on ships of 16 m moulded depth and above; and
- any bulkhead on ships of 18 m moulded depth and above.

Otherwise corrugations may extend from inner bottom to deck.

10.3.2 Construction

The main dimensions b_{f-cg} , R , b_{w-cg} , d_{cg} , t_f , t_w , s_{cg} of corrugated bulkheads are defined in Fig 27.

The corrugation angle ϕ is not to be less than 55°.

When welds in a direction parallel to the bend axis are provided in the zone of the bend, the welding procedures are to be submitted to the Society for approval.

10.3.3 Corrugated bulkhead depth

The depth of the corrugation, d_{cg} , in mm, is not to be less than:

$$d_{cg} = \frac{1000 \ell_c}{C}$$

where:

ℓ_c : Mean span of considered corrugation, in m, as defined in [10.3.5].

C : Coefficient to be taken as:

- C = 15 for tank and water ballast cargo hold bulkheads.
- C = 18 for dry cargo hold bulkheads.

10.3.4 Actual section modulus of corrugations

The net section modulus of a corrugation may be obtained, in cm³, from the following formula:

$$Z = \left[\frac{d_{cg}(3b_{f-cg}t_f + b_{w-cg}t_w)}{6} \right] 10^{-3}$$

where:

t_f , t_w : Net thickness of the plating of the corrugation, in mm, shown in Fig 27.

d_{cg} , b_{f-cg} , b_{w-cg} : Dimensions of the corrugation, in mm, shown in Fig 27.

Where the web continuity is not ensured at ends of the bulkhead, the net section modulus of a corrugation is to be obtained, in cm³, from the following formula:

$$Z = 0.5b_{f-cg}t_f d_{cg} 10^{-3}$$

10.3.5 Span of corrugations

The span l_c of the corrugations is to be taken as the distance shown in Fig 28.

For the definition of l_c , the bottom of the upper stool is not to be taken more than a distance from the deck at the centre line equal to:

- 3 times the depth of corrugation, for non rectangular stool.
- 2 times the depth of corrugation, for rectangular stool.

10.3.6 Structural arrangements

Where corrugated bulkheads are cut in way of primary supporting members, corrugations on each side of the primary member are to be aligned with each other.

Figure 27 : Dimensions of a corrugated bulkhead

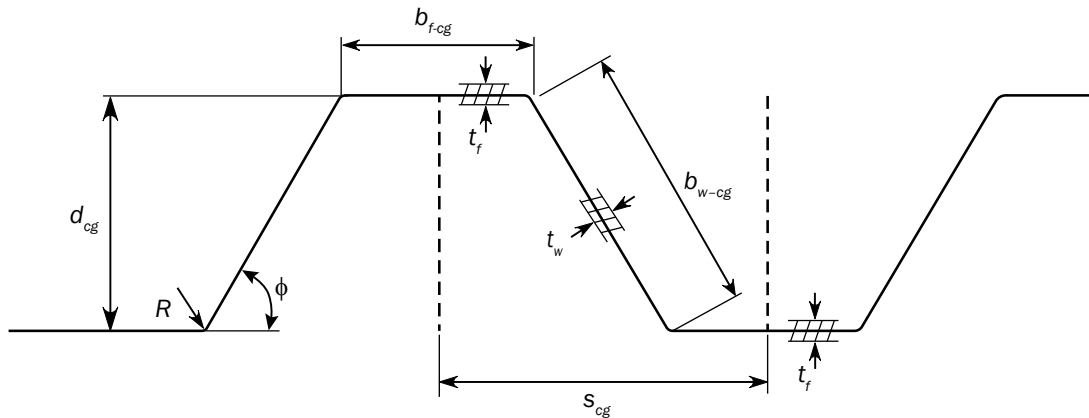
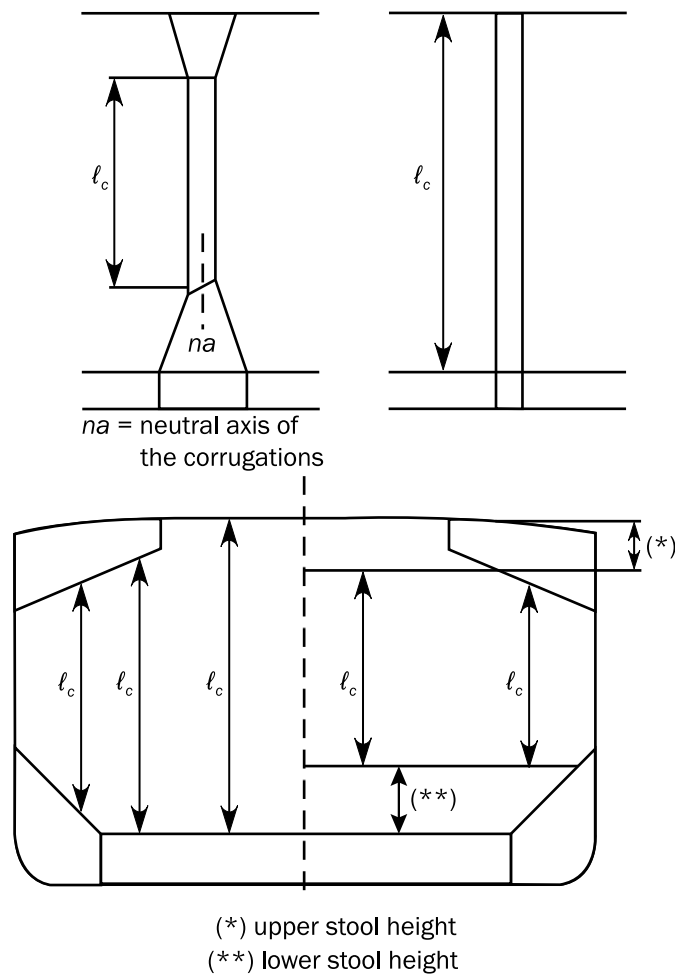


Figure 28 : Span of the corrugations



10.3.7 Bulkhead end supports

The strength continuity of corrugated bulkheads is to be maintained at the ends of corrugations.

Where a bulkhead is provided with a lower stool, floors or girders are to be fitted in line with both sides of the lower stool. Where a bulkhead is not provided with a lower stool, floors or girders are to be fitted in line with both flanges of the vertically corrugated transverse bulkhead.

The supporting floors or girders are to be connected to each other by suitably designed shear plates.

At deck, if no upper stool is fitted, transverse or longitudinal stiffeners are to be fitted in line with the corrugation flanges.

When the corrugation flange connected to the adjoining boundary structures (i.e. inner hull, side shell, longitudinal bulkhead, trunk, etc) is smaller than 50% of the width of the typical corrugation flange, an advanced analysis of the connection is required.

10.3.8 Bulkhead stools

Stool side plating is to be aligned with the corrugation flanges.

10.3.9 Lower stool

The lower stool, when fitted, is to have a height not less than:

- 3 corrugation depths for dry cargo hold bulkheads.
- one corrugation depth for tank and water ballast cargo hold bulkheads.

The ends of stool side ordinary stiffeners, when fitted in a vertical plane, are to be attached to brackets at the upper and lower ends of the stool. Lower stool side vertical stiffeners and their brackets in the stool are to be aligned with the inner bottom structures such as longitudinals or similar. Lower stool side plating is not to be knuckled anywhere between the inner bottom plating and the stool top plate.

The distance d from the edge of the stool top plate to the surface of the corrugation flange is to be in accordance with the distance shown on Fig 29.

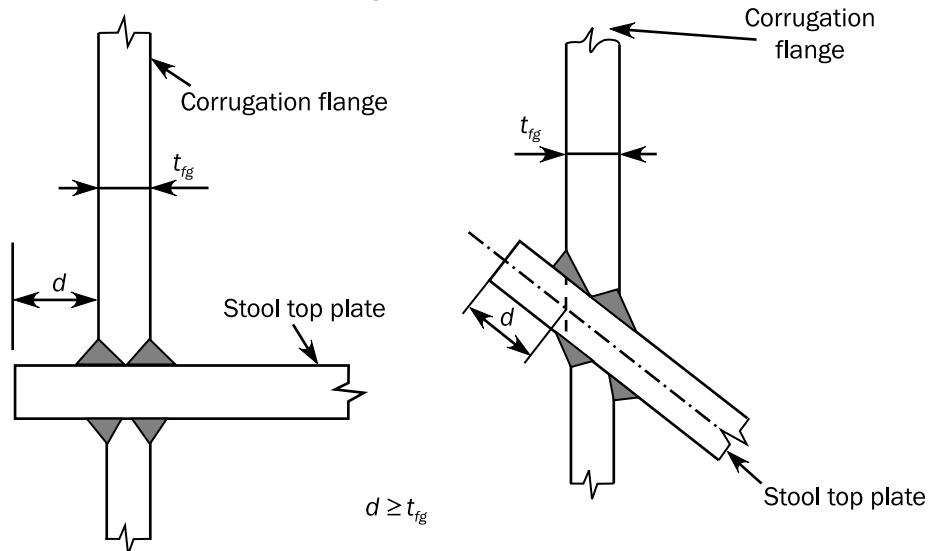
The lower part of the stool side plates is to be in line with double bottom floors or girders as the case may be, and the stool bottom is to have a width not less than:

- 2.5 corrugation depths for dry cargo hold bulkheads.
- one corrugation depth for tank and water ballast cargo hold bulkheads.

The stool is to be fitted with diaphragms in line with the longitudinal double bottom girders or floors. Scallops in the brackets and diaphragms in way of the connections to the stool top plate are to be avoided.

The stool side plating is to be connected to the stool top plate and the inner bottom plating by either full penetration or partial penetration welds. The supporting floors are to be connected to the inner bottom by either full penetration or partial penetration welds.

Figure 29 : Permitted distance, d , from the edge of the stool top plate to the surface of the corrugation flange



10.3.10 Upper stool

The upper stool, when fitted, is to have a height:

- Not less than two times the corrugation depth for dry cargo hold bulkheads.
- At least one corrugation depth for tank and water ballast cargo hold bulkheads.

Rectangular stools are to have a height in general equal to twice the depth of corrugations, measured from the deck level and at the hatch side girder or at the inner hull as applicable. Brackets or deep webs are to be fitted to connect the upper stool to the deck transverse or hatch end beams.

The upper stool of a transverse bulkhead is to be properly supported by deck girders or deep brackets between the adjacent hatch end beams. The width of the upper stool bottom plate is generally to be the same as that of the lower stool top plate. The stool top of non-rectangular stools of bulk carriers is to have a width not less than twice the depth of corrugations. The ends of stool side ordinary stiffeners when fitted in a vertical plane, are to be attached to brackets at the upper and lower end of the stool.

The stool is to be fitted with diaphragms in line with and effectively attached to longitudinal deck girders extending to the hatch end coaming girders or transverse deck primary supporting members. Scallops in the brackets and diaphragms in way of the connection to the stool bottom plate are to be avoided.

10.4 Wash bulkheads

10.4.1 General

In general, openings in wash bulkheads are to have their aggregate area between 10% and 30% of the bulkhead area.

10.5 Watertight bulkheads of trunks and tunnels

10.5.1 Watertight bulkheads of trunks, tunnels, duct keels and ventilators are to be of the same strength as watertight bulkheads at corresponding levels. The means used for making them watertight, and the arrangements adopted for closing their openings, are to be to the satisfaction of the Society.

10.6 Bulkheads acting as pillars

10.6.1 Each vertical stiffener, in association with a width of plating equal to:

- 35 times the plating net thickness
- 1/12 of stiffener length, or
- the stiffener spacing, whichever is the smaller,

is to comply with the applicable requirements in Part B, Chapter 7, for the load being supported.

10.6.2 Non-tight corrugated bulkheads

Where non-tight bulkheads are corrugated, each corrugation is to comply with the applicable requirements in Part B, Chapter 7, for the load being supported.

10.7 Watertight doors

10.7.1 Where vertical stiffeners are cut in way of watertight doors, reinforced stiffeners are to be fitted on each side of the door and suitably overlapped; cross-bars are to be provided to support the interrupted stiffeners.

11 Pillars

11.1 General

11.1.1 Wherever possible, pillars are to be fitted in the same vertical line. If not possible, effective means are to be provided for transmitting the pillar loads to the supports below. Effective arrangements are to be made to distribute the loads at the heads and the heels of all the pillars. Where pillars support eccentric loads, they are to be strengthened to withstand the additional bending moment applied on them.

11.1.2 Pillars connected to the inner bottom are to be fitted at the intersection of girders and floors, or as close thereto as practicable, and the structure above and below the pillars is to be of sufficient strength to provide effective distribution of the load.

Where pillars connected to the inner bottom are not located in way of the intersection of floors and girders, partial floors or girders, or equivalent structures, are to be fitted as necessary to support the pillars.

11.1.3 In tanks, solid or open section pillars are generally to be fitted. Pillars located in spaces intended for products which may produce explosive gases are to be of open section type.

11.2 Connections

11.2.1 Heads and heels of the pillars are to be secured by thick doubling plates and brackets, as necessary. Alternative arrangements for doubling plates may be accepted, provided they are considered equivalent, as deemed appropriate by the Society.

Where the pillars are likely to be subjected to tensile loads, heads and heels of the pillars are to be efficiently secured to withstand the tensile loads and the doubling plates are to be replaced by insert plates complying with the through thickness properties requirements in Ch 4, Sec 1, [2.6].

In general, the net thickness of the doubling plates, when fitted, is to be not less than 1,5 times the net thickness of the pillar. Pillars are to be attached at their heads and heels by continuous welding.

11.2.2 Contact pressure

At connexions between pillars and decks, it is to be checked that the contact pressure σ_C , in N/mm², is in compliance with the following formula:

$$\sigma_C \leq R_{eH}$$

where:

$$\sigma_C = 10 \frac{F_A}{A_C}$$

with:

- F_A : Compression axial load in the pillar, in kN
- A_C : Contact area between the pillar and the deck structural members, in cm²
- R_{eH} : Smallest of the assembled elements yield stress, in N/mm².

Section 6 Structural Idealisation

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

- φ_w : Angle, in deg, between the stiffener or the primary supporting member web and the attached plating, see Fig 14. φ_w is to be taken equal to 90° if the angle is greater or equal than 75° and smaller or equal than 105° .
- ℓ_{bdg} : Effective bending span, in m, as defined in:
- [1.1.2] for stiffeners, and
 - [1.1.6] for primary supporting members.
- ℓ_{shr} : Effective shear span, in m, as defined in:
- [1.1.3] for stiffeners, and
 - [1.1.7] for primary supporting members.
- LCP : Load Calculation Point.

1 Structural idealisation of stiffeners and primary supporting members

1.1 Effective spans

1.1.1 General

Where arrangements differ from those defined in this Article, the span definition may be specially considered, depending on the actual arrangement at the ends of the stiffeners or primary supporting members.

1.1.2 Effective bending span of stiffeners

The effective bending span ℓ_{bdg} of stiffeners is to be obtained as shown in Fig 1 for single skin structures and in Fig 3 for double skin structures.

If the stiffener on the PSM web is sniped at the end or not attached to the stiffener under consideration, the effective bending span is to be taken as the full length between PSMs unless a backing bracket is fitted, see Fig 1, items a) and b).

The effective bending span may be reduced where brackets are fitted to the flange or free edge of the stiffener. Brackets fitted on the side opposite to that of the stiffener with respect to attached plating are not to be considered as effective in reducing the effective bending span.

In single skin structures, the effective bending span of a stiffener supported by a bracket or by a web stiffener on one side only of the primary supporting member is to be taken as the total span between primary supporting members, as shown in item a) of Fig 1. If brackets are fitted on both sides of the primary supporting member, the effective bending span is to be taken as shown in items b), c) and d) of Fig 1.

Where the face plate of the stiffener is continuous along the edge of the bracket, the effective bending span is to be taken to the position where the depth of the bracket is equal to one quarter of the depth of the stiffener, see Fig 2.

1.1.3 Effective shear span of stiffeners

The effective shear span ℓ_{shr} of stiffeners is to be obtained as shown in Fig 4 for single skin structures and in Fig 6 for double skin structures.

The effective shear span may be reduced for brackets fitted on either the flange or the free edge of the stiffener, or for brackets fitted to the attached plating on the side opposite to that of the stiffener.

If brackets are fitted both on the flange or the free edge of the stiffener and to the attached plating on the side opposite to that of the stiffener, the effective shear span may be reduced using the longer effective bracket arm.

Regardless of the support detail, the full length of the stiffener may be reduced by a length, in m, at least equal to $s/4000$ at each end of the member, hence the effective shear span ℓ_{shr} is not to be taken greater than:

$$\ell_{shr} \leq \ell - \frac{s}{2000}$$

For curved and/or long brackets (high length/height ratio), the effective bracket length is to be taken as the maximum inscribed 1:1,5 right angled triangle as shown in items c) of Fig 4 and Fig 6.

Where the face plate of the stiffener is continuous along the curved edge of the bracket, the bracket length to be considered for determination of the span point location is not to be taken greater than 1,5 times the length of the bracket arm as shown in Fig 5.

Figure 1 : Single skin construction - Effective bending span ℓ_{bdg} of stiffeners supported by web stiffeners

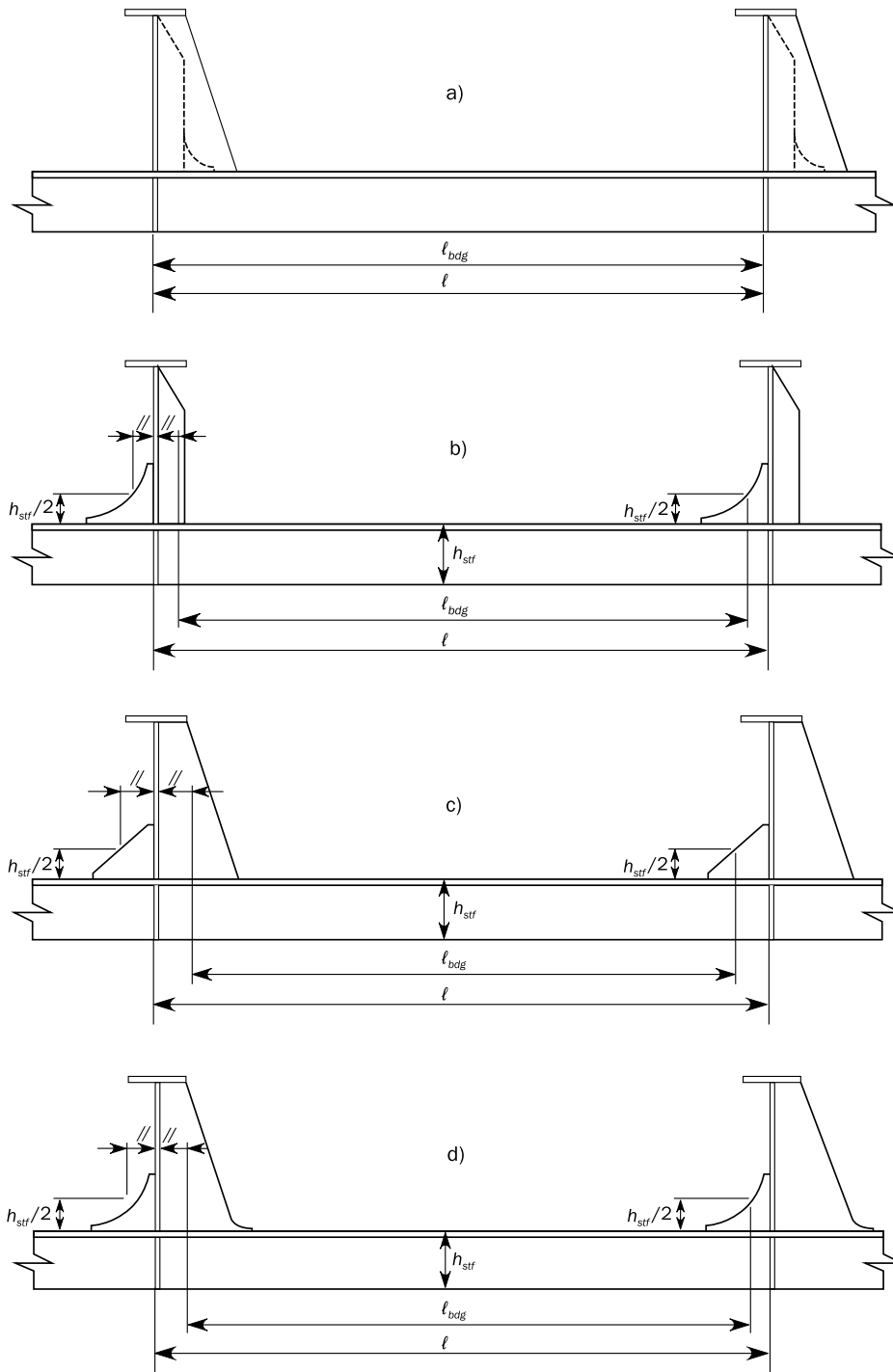


Figure 2 : Effective bending span ℓ_{bdg} for local support members with continuous face plate along bracket edge

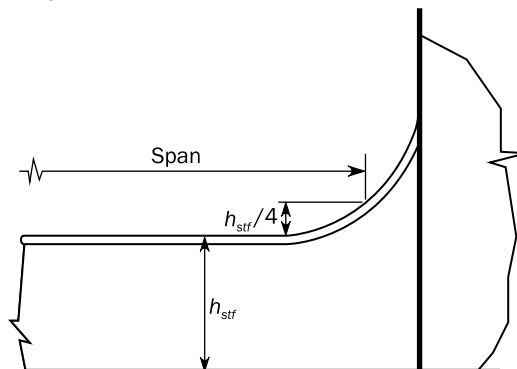


Figure 3 : Double skin construction - Effective bending span ℓ_{bdg} of stiffeners supported by web stiffeners

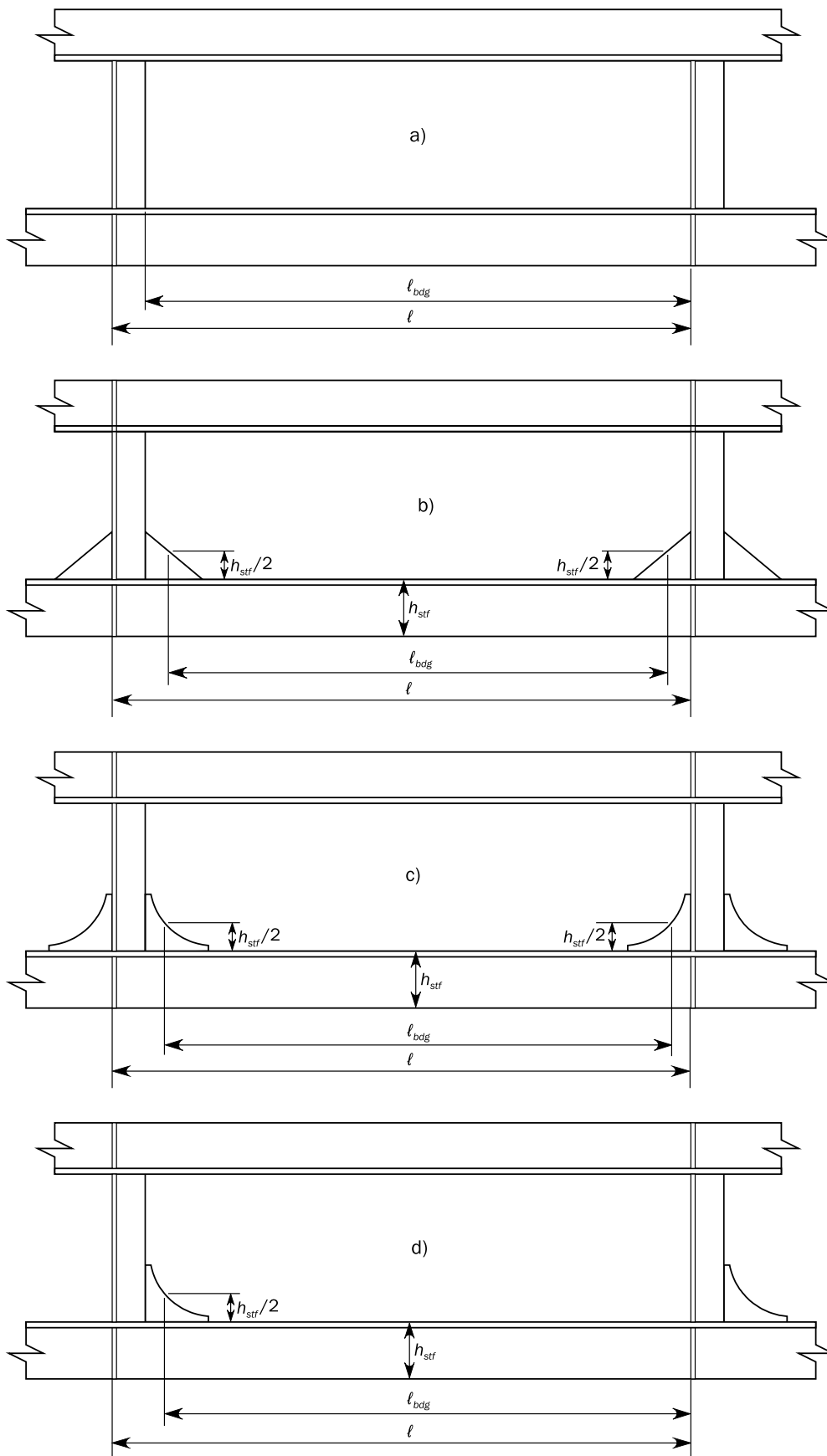


Figure 4 : Single skin construction - Effective shear span l_{shr} of stiffeners supported by web stiffeners

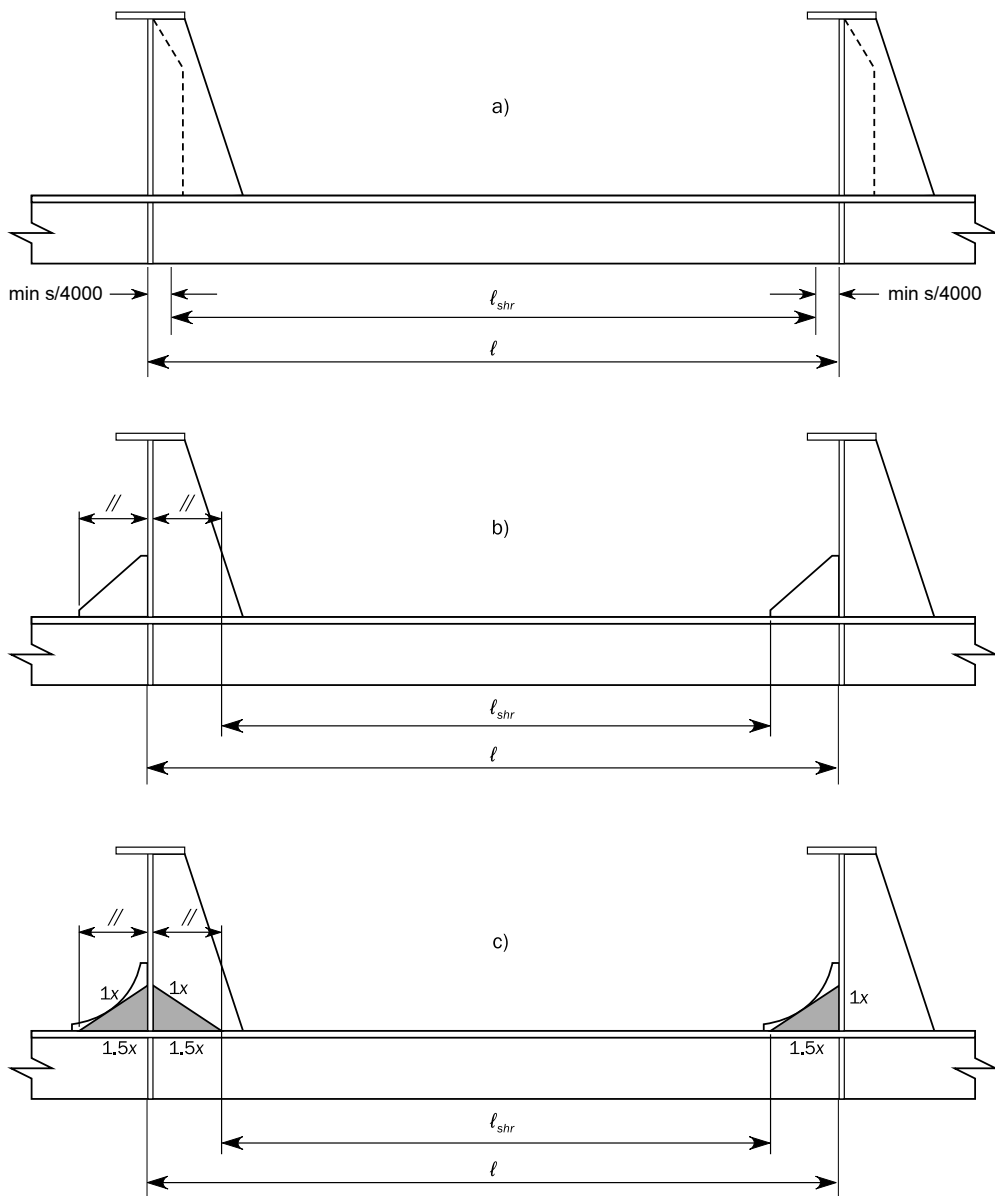


Figure 5 : Effective shear span l_{shr} for local support members with continuous face plate along the bracket edge

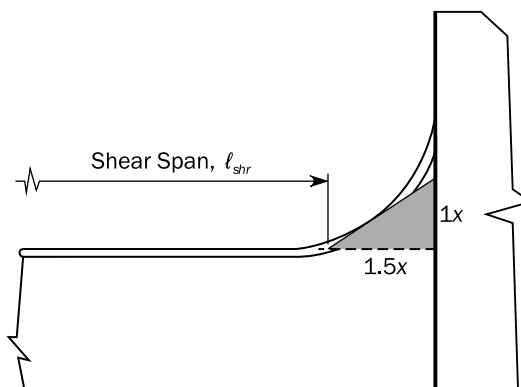
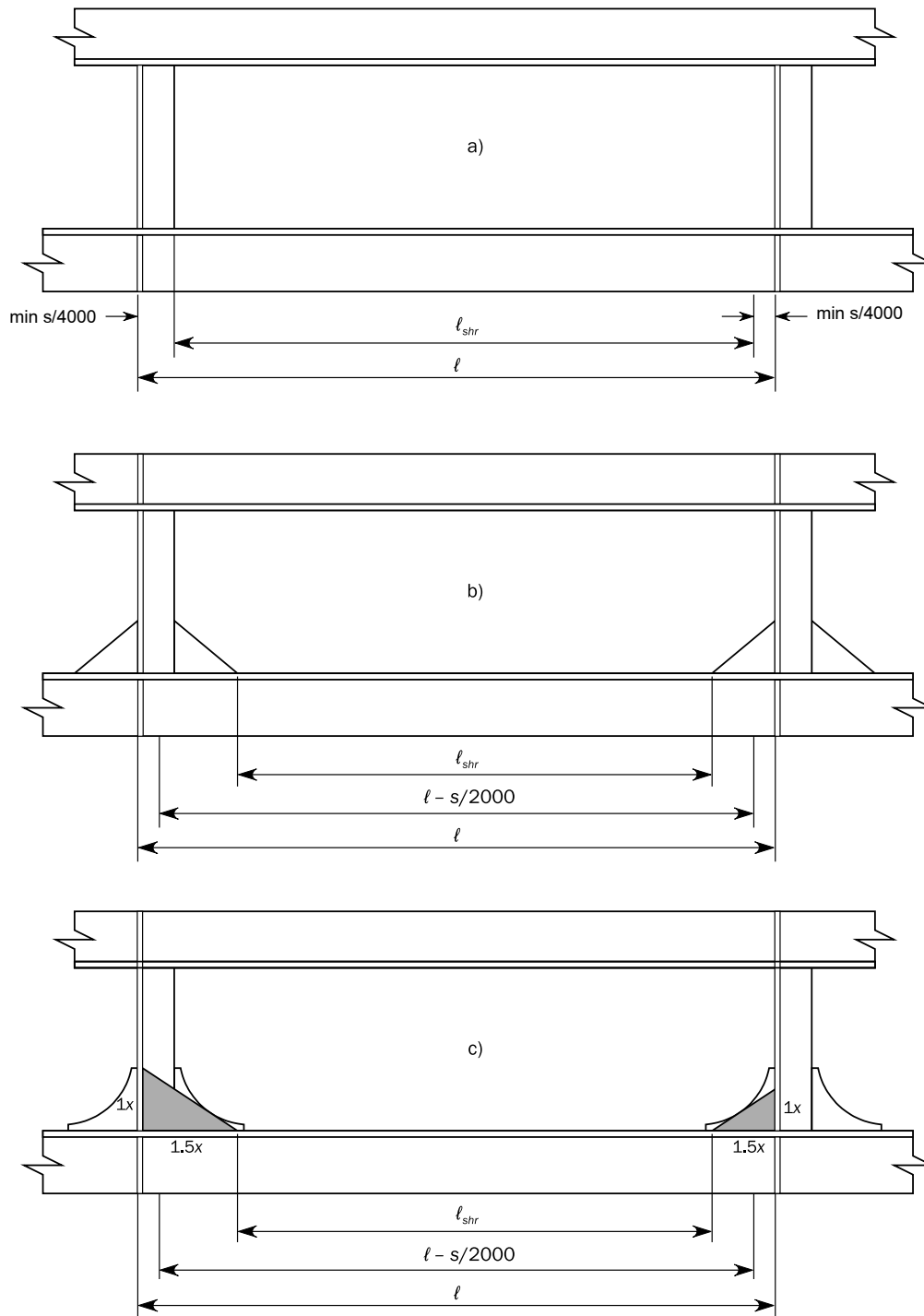


Figure 6 : Double skin construction - Effective shear span l_{shr} of stiffeners supported by web stiffeners



1.1.4 Effect of hull form shape on span of stiffeners

For curved stiffeners, the span is defined as the chord length between span points to be measured at the flange for stiffeners with a flange, and at the free edge for flat bar stiffeners. The calculation of the effective span is to be in accordance with requirements given in [1.1.2] and [1.1.3].

1.1.5 Effective span of stiffeners supported by struts

The arrangement of stiffeners supported by struts is not allowed for ships greater than 120 m in length.

The span l of the stiffeners supported by one strut fitted at mid-distance of the primary supporting members is to be taken as $0,7 l_2$.

In case where two struts are fitted at $1/3$ and $2/3$ of the distance between primary supporting members, the span l of the stiffeners is to be taken as $0,7 l_2$.

The spans l_1 and l_2 are defined in Fig 7 and Fig 8.

Figure 7 : Span of stiffeners with one strut

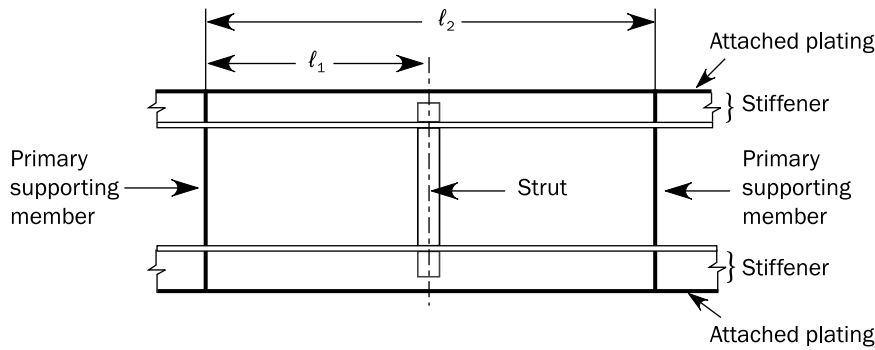
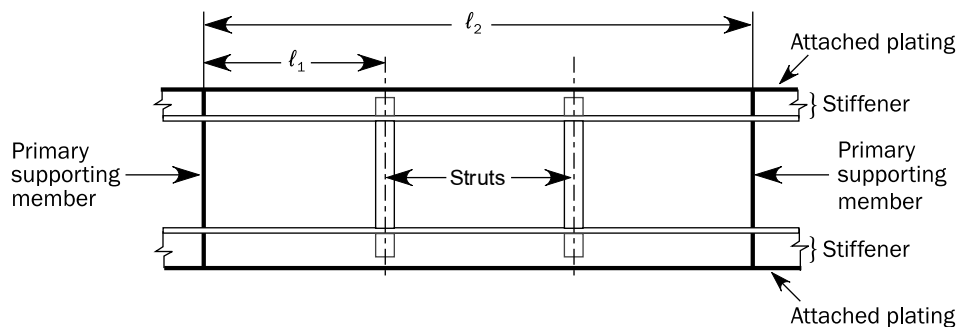


Figure 8 : Span of stiffeners with two struts



1.1.6 Effective bending span of primary supporting members

The effective bending span l_{bdg} of a primary supporting member without end bracket is to be taken as the length of the primary supporting member between supports.

The effective bending span l_{bdg} of a primary supporting member may be taken as less than the full length of the primary supporting member between supports, provided that suitable end brackets are fitted, i.e.:

- in case of separate welded end brackets, l_{bdg} is taken as the length between the points where the depth of the brackets is equal to one-half the web height h_w of the primary supporting member (see item b) of Fig 9)
- in case of end brackets where the face plate of the primary supporting member is continuous along the face of the brackets (see items a), c) and d) of Fig 9), l_{bdg} is taken as the length between the points where the depth of the brackets is equal to one-quarter the web height h_w of the primary supporting member.

The end brackets used to determine the span points are to be either the effective brackets as defined in [1.1.8] or the fitted brackets:

- for straight brackets with a length to height ratio greater than 1,5, the span point is to be taken to the effective bracket: see item c) of Fig 9; otherwise the span point is to be taken to the fitted bracket: see item d) of Fig 9
- for curved brackets, for span positions above the tangent point between fitted bracket and effective bracket, the span point is to be taken to the fitted bracket; otherwise, the span point is to be taken to the effective bracket.

For arrangements where the primary supporting member face plate is carried on to the bracket and backing brackets are fitted, the span point need not be taken greater than to the position where the total depth reaches twice the depth of the primary supporting member. Arrangements with small and large backing brackets are shown in items e) and f) of Fig 9.

For arrangements where the height of the primary supporting member is maintained and the face plate width is increased towards the support, the effective bending span l_{bdg} may be taken to a position where the face plate breadth reaches twice the nominal breadth.

1.1.7 Effective shear span of primary supporting members

The effective shear span l_{shr} of a primary supporting member may be reduced and taken between the toes of the effective brackets at ends of the primary supporting member, where these toes are as shown in Fig 10. The effective brackets used to define the toe points are defined in [1.1.8].

For arrangements where the effective backing bracket is larger than the effective bracket in way of the PSM face plate, the shear span is to be taken as the mean distance between toes of the effective brackets as shown in item f) of Fig 10.

1.1.8 Effective bracket

The effective bracket is defined as the maximum size of the right-angled triangular bracket with a length to height ratio of 1,5 that fits inside the fitted bracket. See Fig 9 and Fig 10 for examples.

Figure 9 : Effective bending span l_{bdg} of primary supporting members

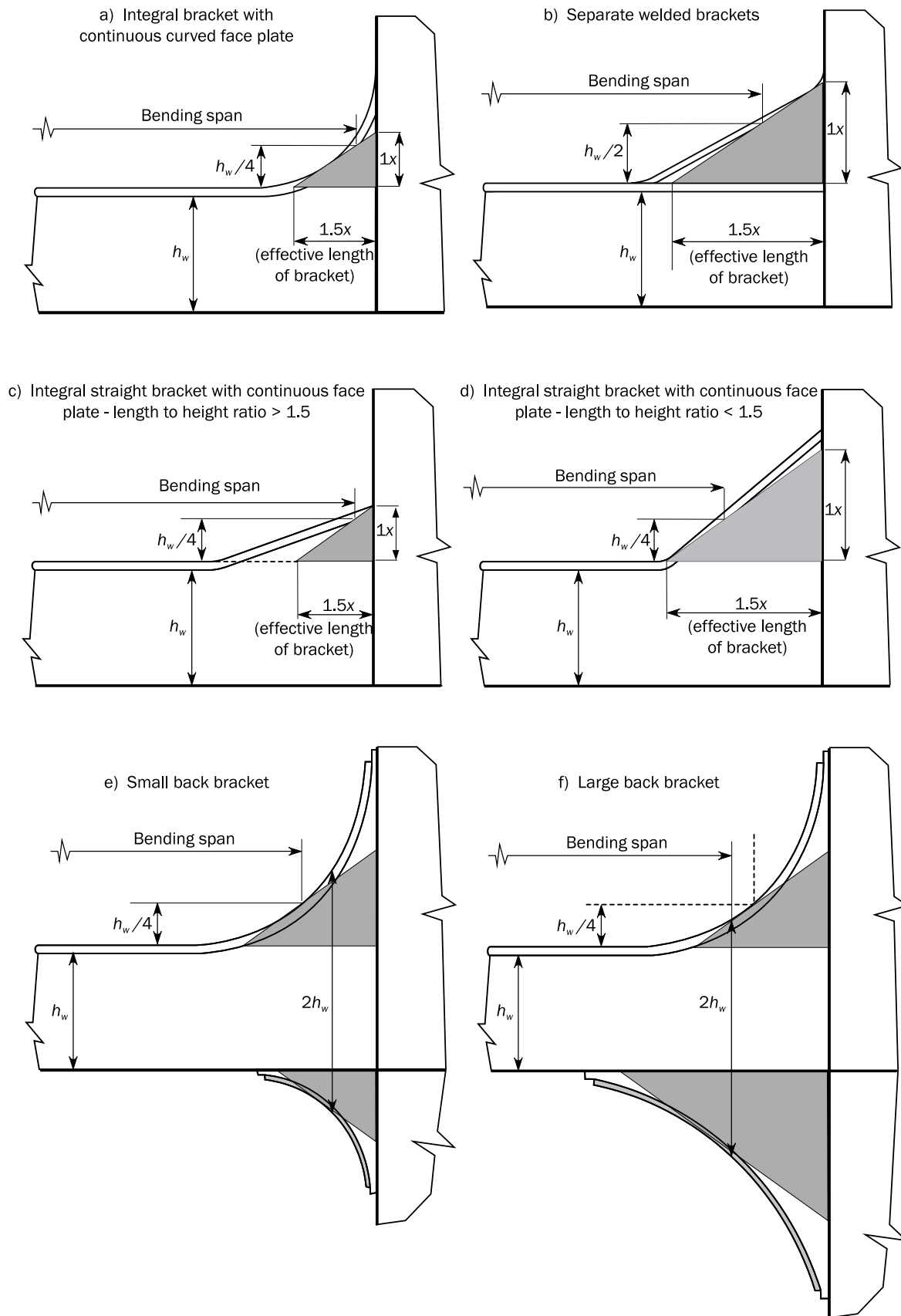
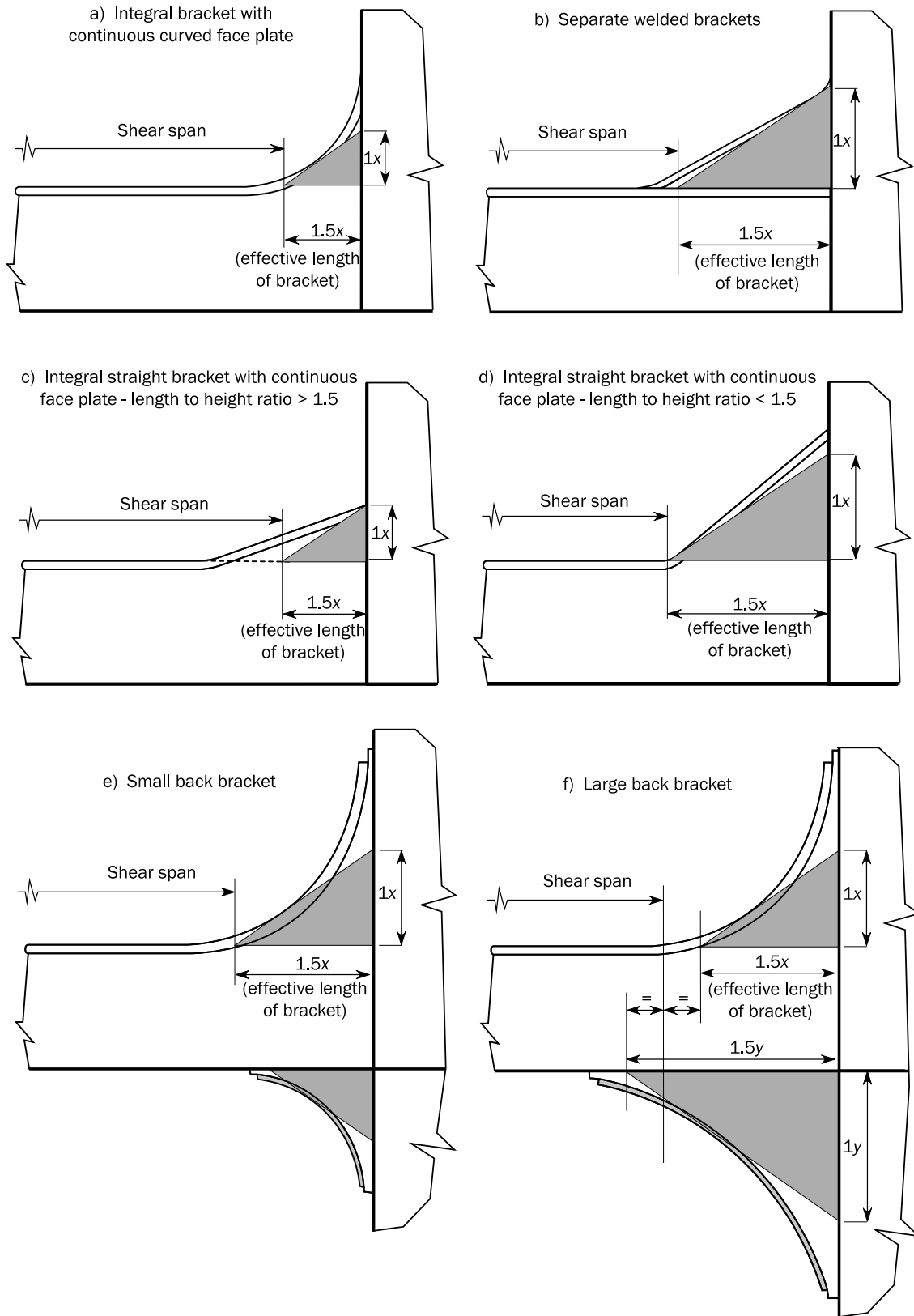


Figure 10 : Effective shear span l_{shr} of primary supporting members



1.2 Spacing and load supporting breadth

1.2.1 Stiffeners

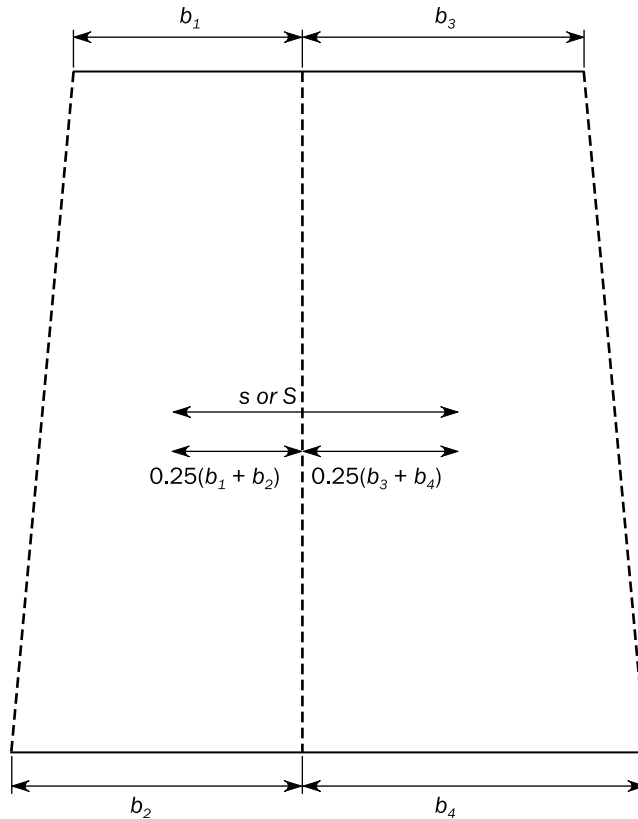
Stiffener spacing s , in mm, for calculation of the effective breadth of the attached plating for stiffeners, is to be taken as the mean spacing between stiffeners at ends (see Fig 11):

$$s = \frac{b_1 + b_2 + b_3 + b_4}{4}$$

where:

b_1, b_2, b_3, b_4 : Spacings between stiffeners at ends, in mm.

Figure 11 : Spacing of plating



1.2.2 Primary supporting member

Primary supporting member spacing S , in m, for calculation of the effective breadth of the attached plating for primary supporting members, is to be taken as the mean spacing between adjacent primary supporting members at ends (see Fig 11):

$$S = \frac{b_1 + b_2 + b_3 + b_4}{4}$$

where:

b_1, b_2, b_3, b_4 : Spacings between primary supporting members at ends, in m.

1.2.3 Spacing of curved plating

For curved plating, the stiffener spacing s or the primary supporting member spacing S is to be measured on the mean chord between stiffeners or between primary supporting members, respectively.

1.3 Effective breadth

1.3.1 Stiffeners

a) Yielding check

The effective breadth b_{eff} , in mm, of the attached plating to be considered in the actual net section modulus for the yielding check of a stiffener is to be obtained from the following formulae:

- where the plating extends on both sides of the stiffener:
 $b_{eff} = \min (200 \ell ; s)$
- where the plating extends on one side of the stiffener (i.e. stiffener bounding an opening):
 $b_{eff} = \min (100 \ell ; 0,5 s)$

However, where the attached plate net thickness is less than 8 mm, the effective breadth is not to be taken greater than 600 mm.

b) Buckling check

The effective breadth b_{eff} of the attached plating to be considered for the buckling check of stiffeners is given in Ch 9, Sec 1.

1.3.2 Primary supporting members

The effective breadth b_{eff} , in m, of the attached plating for calculation of the section modulus and/or moment of inertia of a primary supporting member is to be taken as:

- for $\frac{\ell_{bdg}}{S\sqrt{3}} \geq 1$: $b_{eff} = S \cdot \min \left[\frac{1,12}{1 + \frac{1,75}{\frac{\ell_{bdg}}{S\sqrt{3}}^{1,6}}}; 1,0 \right]$
- for $\frac{\ell_{bdg}}{S\sqrt{3}} < 1$: $b_{eff} = 0,407 \frac{\ell_{bdg}}{\sqrt{3}}$

1.3.3 Effective area of curved face plate and curved attached plating of primary supporting members

The effective net area is applicable to primary supporting members for the following calculations:

- actual net section modulus used for comparison with the scantling requirements in Ch 7, Sec 6
- actual effective net area of curved face plates, modeled by beam elements, used in Part B, Chapter 8.

The following effective net area $A_{eff-n50}$, in mm², is only applicable to curved face plates and curved attached plating of primary supporting members and is not applicable for the area of web stiffeners parallel to the face plate.

a) for curved face plates supported by radial brackets or attached plating supported by cylindrical stiffeners:

$$A_{eff-n50} = \left(\frac{3r_f t_{f-n50} + C_f s_r^2}{3r_f t_{f-n50} + s_r^2} \right) t_{f-n50} b_f$$

b) for other curved face plates and curved attached platings: $A_{eff-n50} = C_f t_{f-n50} b_f$

where:

C_f : Flange efficiency coefficient to be obtained from the following formula but not to be greater than 1,0:

- for symmetrical face plate

$$C_f = C_{f1} \frac{1,285}{\beta k_1}$$

- for unsymmetrical face plate

$$C_f = 0,18 + \frac{0,08}{\beta^2}$$

- for attached plating of box girders

$$C_f = C_{f1} \frac{1,285}{\beta}$$

C_{f1} : Coefficient taken equal to:

- for symmetrical face plates:

$$C_{f1} = \frac{(\sinh k_1 \beta \cosh k_1 \beta + \sin k_1 \beta \cos k_1 \beta)}{(\cosh k_1 \beta)^2 + (\cos k_1 \beta)^2}$$

- for attached plating of box girders with two webs:

$$C_{f1} = \frac{0,78 (\sinh \beta + \sin \beta) (\cosh \beta - \cos \beta)}{(\sinh \beta)^2 + \sin^2 \beta}$$

- for attached plating of box girders with multiple webs:

$$C_{f1} = \frac{1,56 (\cosh \beta - \cos \beta)}{\sinh \beta + \sin \beta}$$

k_1 : Coefficient calculated as:

$$k_1 = 1,4 + 1,25 (1,4 - \beta)^3 \quad \text{for} \quad \beta < 1,4$$

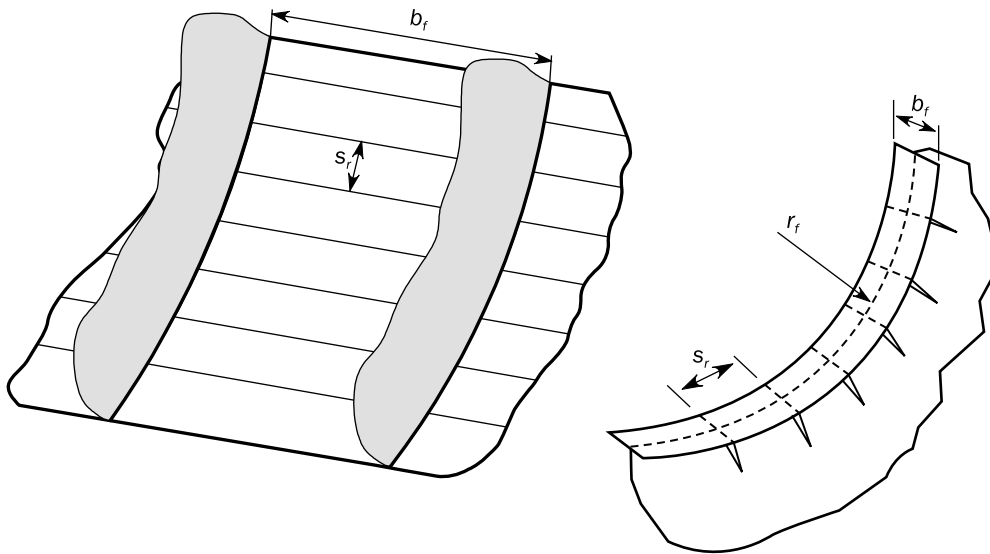
$$k_1 = 1,4 \quad \text{for} \quad \beta \geq 1,4$$

β : Coefficient, in rad, taken equal to:

$$\beta = \frac{1,285 b_1}{\sqrt{r_f t_{f-n50}}}$$

- b_1 : Breadth, in mm, to be taken equal to:
- for symmetrical face plates: $b_1 = 0,5 (b_f - t_{w-n50})$
 - for unsymmetrical face plates: $b_1 = b_f$
 - for attached plating of box girders: $b_1 = s_w - t_{w-n50}$
- s_w : Spacing of supporting webs for box girders, in mm
- t_{f-n50} : Net flange thickness, in mm. For calculation of C_i and β of unsymmetrical face plates, t_{f-n50} is not to be taken greater than t_{w-n50}
- t_{w-n50} : Net web plate thickness, in mm
- r_f : Radius, in mm, of face plate or attached plating at mid thickness, see Fig 12
- b_f : Breadth, in mm, of face plate or attached plating, see Fig 12
- s_r : Spacing, in mm, of tripping brackets or web stiffeners or stiffeners normal to the web plating, see Fig 12.

Figure 12 : Curved shell panel and face plate



1.4 Geometrical properties of stiffeners and primary supporting members

1.4.1 Steel stiffener profile with a bulb section

The properties of bulb sections are to be determined considering the actual stiffener profile.

Where such calculation of properties is not possible, a bulb section equivalent to a built-up section is to be taken for steel stiffeners with a bulb section. The net dimensions of the equivalent built-up section are to be obtained, in mm, from the following formulae (see Fig 13):

$$h_w = h'_w - \frac{h'_w}{9,2} + 2$$

$$b_i = \alpha \left(t'_w + \frac{h'_w}{6,7} - 2 \right)$$

$$t_i = \frac{h'_w}{9,2} - 2$$

$$t_w = t'_w$$

where:

h'_w, t'_w : Net height and thickness of a bulb section, in mm, as shown in Fig 13

α : Coefficient equal to:

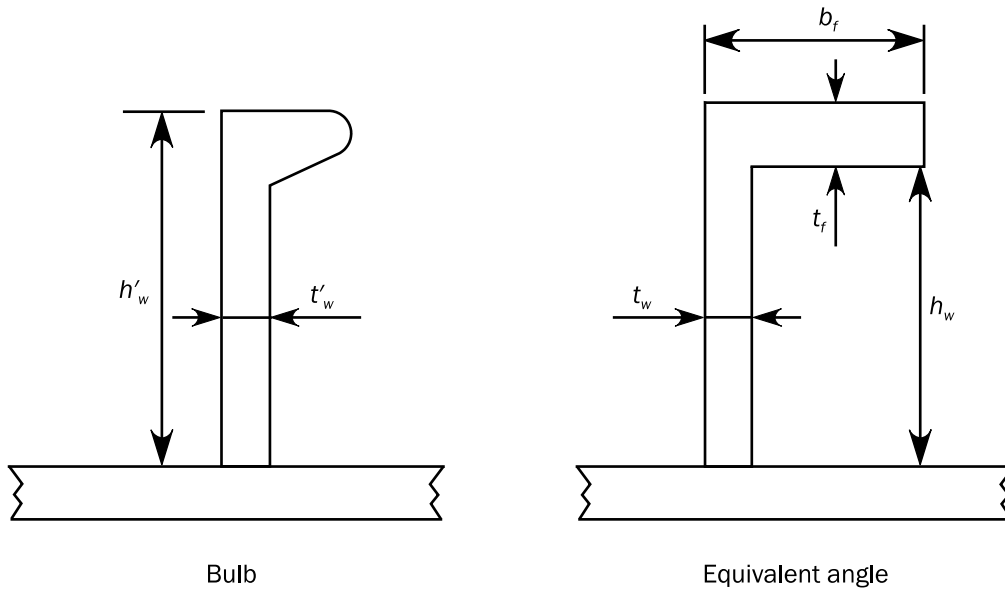
- for $h'_w \leq 120$:

$$\alpha = 1,1 + \frac{(120 - h'_w)^2}{3000}$$

- for $h'_w > 120$:

$$\alpha = 1,0$$

Figure 13 : Bulb section and its equivalent built-up section



1.4.2 Aluminium stiffener profile with a bulb section

For aluminium stiffeners, the equivalent built-up section as defined in [1.4.1] is not applicable and the properties of bulb sections are to be determined considering the actual stiffener profile.

1.4.3 Net elastic shear area of stiffeners

The net elastic shear area A_{shr} , in cm^2 , of stiffeners is to be taken as:

$$A_{shr} = d_{shr} t_w 10^{-2}$$

where:

d_{shr} : Effective shear depth of stiffener, in mm, as defined in [1.4.4]

t_w : Net web thickness of the stiffener, in mm, as defined in Ch 4, Sec 2, Fig 2.

1.4.4 Effective shear depth of stiffeners

The effective shear depth of stiffeners d_{shr} , in mm, is to be taken as:

$$d_{shr} = (h_{stf} - 0,5 t_{c-stf} + t_p + 0,5 t_{c-pl}) \sin \varphi_w$$

where:

h_{stf} : Height of stiffener, in mm, as defined in Ch 4, Sec 2, Fig 2

t_p : Net thickness of the stiffener attached plating, in mm, as defined in Ch 4, Sec 2, Fig 2

t_{c-stf} : Corrosion addition, in mm, of the considered stiffener as given in Ch 4, Sec 3

t_{c-pl} : Corrosion addition, in mm, of the attached plate to the considered stiffener as given in Ch 4, Sec 3.

1.4.5 Elastic net section modulus of stiffeners

The elastic net section modulus Z of stiffeners, in cm^3 , is to be taken as:

$$Z = Z_{stf} \sin \varphi_w$$

where:

Z_{stf} : Net section modulus of the stiffener, in cm^3 , considered perpendicular to its attached plate, i.e. with $\varphi_w = 90^\circ$

1.4.6 Net moment of inertia of stiffeners

The net moment of inertia I of stiffeners, in cm^4 , is to be taken as:

$$I = I_{stf} \sin^2 \varphi_w$$

where:

I_{stf} : Net moment of inertia of the stiffener, in cm^4 , considered perpendicular to its attached plate, i.e. with $\varphi_w = 90^\circ$

1.4.7 Effective net plastic shear area of stiffeners

The net plastic shear area A_{shr-pl} of stiffeners, in cm^2 , which is used for assessment against impact loads is to be taken as:

$$A_{shr-pl} = A_{shr}$$

where:

A_{shr} : Net elastic shear area, in cm^2 , as defined in [1.4.3].

1.4.8 Effective net plastic section modulus of stiffeners

The effective net plastic section modulus Z_{pl} of stiffeners, in cm^3 , is given by the formula in item a) or item b), depending on:

- the cross-sectional area of the attached plate A_p
- the net cross-sectional area of the ordinary stiffener: $A_w' + A_f$

where:

A_p : Net cross-sectional area of the attached plate, in cm^2 , taken equal to:

$$A_p = \frac{s t_p}{100}$$

A_f : Net cross-sectional area of the stiffener flange, in cm^2 , taken equal to:

$$A_f = \frac{b_f t_f}{100}$$

A_w' : Net cross-sectional area of the stiffener web, in cm^2 , taken equal to:

$$A_w' = \frac{h_w t_w}{100}$$

a) When $A_p \geq A_w' + A_f$, the plastic neutral axis PNA is assumed to be tangent to the edge of the attached plate closest to the stiffener.

$$Z_{pl} = \frac{A_p' x_p + A_w' x_w + A_f x_f}{10}$$

where:

A_p' : Net cross-sectional area of the stiffener, in cm^2 , taken equal to:

$$A_p' = A_w' + A_f$$

x_p : Distance, in mm, between the centre of gravity of area A_p and PNA, taken equal to:

$$x_p = \text{Min} \left(100 \frac{A_w' + A_f}{2 s} ; \frac{t_p}{2} \right)$$

x_w : Distance, in mm, between the centre of gravity of area A_w' and PNA, taken equal to:

$$x_w = \frac{h_w \sin \varphi_w}{2}$$

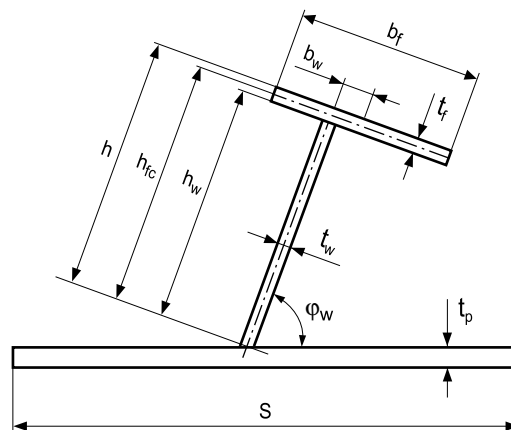
x_f : Distance, in mm, between the centre of gravity of area A_f and PNA, taken equal to:

$$x_f = h_{fc} \sin \varphi_w - b_w \cos \varphi_w$$

h_{fc} : Height, in mm, of the stiffener, measured up to the centre of the flange area, see Fig 14

b_w : Distance, in mm, from the mid-thickness plane of the stiffener web to the centre of the flange area, see Fig 14.

Figure 14 : Dimensions of a built section



b) When $A_p < A_w' + A_f$ the plastic neutral axis PNA is located at a distance z_a above the attached plate, in mm, given by:

$$z_a = \frac{(100 A_f + h_w t_w - t_p s) \sin \varphi_w}{2 t_w}$$

$$Z_{pl} = \frac{(A_p x_p + A_{wa} x_{wa} + A_{wb} x_{wb} + A_f x_f)}{10}$$

where:

x_p : Distance, in mm, between the centre of gravity of area A_p and PNA, taken equal to:

$$x_p = z_a + \frac{t_p}{2}$$

A_{wa} : Net cross-sectional area, in cm^2 , of the part of the stiffener located above PNA, taken equal to:

$$A_{wa} = \left(h_w - \frac{z_a}{\sin \phi_w} \right) \frac{t_w}{100}$$

x_{wa} : Distance, in mm, between the centre of gravity of area A_{wa} and PNA, taken equal to:

$$x_{wa} = \left(h_w - \frac{z_a}{\sin \phi_w} \right) \frac{\sin \phi_w}{2}$$

A_{wb} : Net cross-sectional area, in cm^2 , of the part of ordinary stiffener located below the PNA, taken equal to:

$$A_{wb} = \frac{t_w z_a}{100 \sin \phi_w}$$

x_{wb} : Distance, in mm, between the centre of gravity of area A_{wb} and PNA, taken equal to:

$$x_{wb} = \frac{z_a}{2}$$

x_f : Distance, in mm, between the centre of gravity of area A_f and PNA, taken equal to:

$$x_f = h_{fc} \sin \phi_w - b_w \cos \phi_w - z_a$$

1.4.9 Primary supporting member web not perpendicular to attached plating

Where the web of a primary supporting member is not perpendicular to the attached plating, the actual net shear area A_{sh-n50} , in cm^2 , and the actual net section modulus Z_{n50} , in cm^3 , may be obtained from the following formulae:

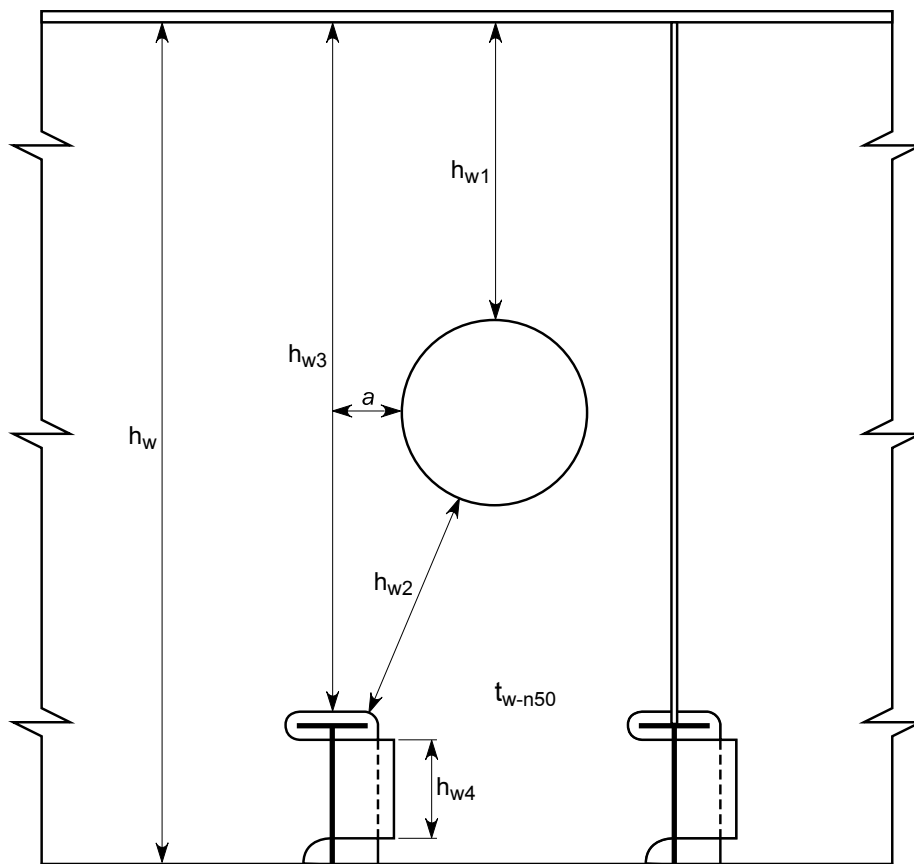
- actual net shear area: $A_{sh-n50} = A_{sh-0-n50} \sin \phi_w$
- actual net section modulus: $Z_{n50} = Z_{perp-n50} \sin \phi_w$

where:

$A_{sh-0-n50}$: Actual net shear area, in cm^2 , of the primary supporting member assumed to be perpendicular to the attached plating, to be taken equal to: $A_{sh-0-n50} = (h_{eff} + t_{f-n50} + t_{p-n50}) t_{w-n50} \cdot 10^{-2}$

$Z_{perp-n50}$: Actual section modulus, in cm^3 , with attached plating, of the primary supporting member assumed to be perpendicular to the attached plating.

Figure 15 : Dimensions h_{w1} , h_{w2} , h_{w3} and h_{w4} in way of web openings



1.4.10 Shear area of primary supporting members with web openings

The effective web height h_{eff} , in mm, to be considered for the calculation of the effective net shear area A_{sh-n50} is to be taken as the lesser of:

$$h_{eff} = h_w$$

$$h_{eff} = h_{w3} + h_{w4}$$

$$h_{eff} = h_{w1} + h_{w2} + h_{w4}$$

calculated at a distance 'a' less than $h_w/3$ on each side of the considered cross-section,

where:

h_w : Web height of the primary supporting member, in mm

$h_{w1}, h_{w2}, h_{w3}, h_{w4}$: Dimensions, in mm, as shown in Fig 15.

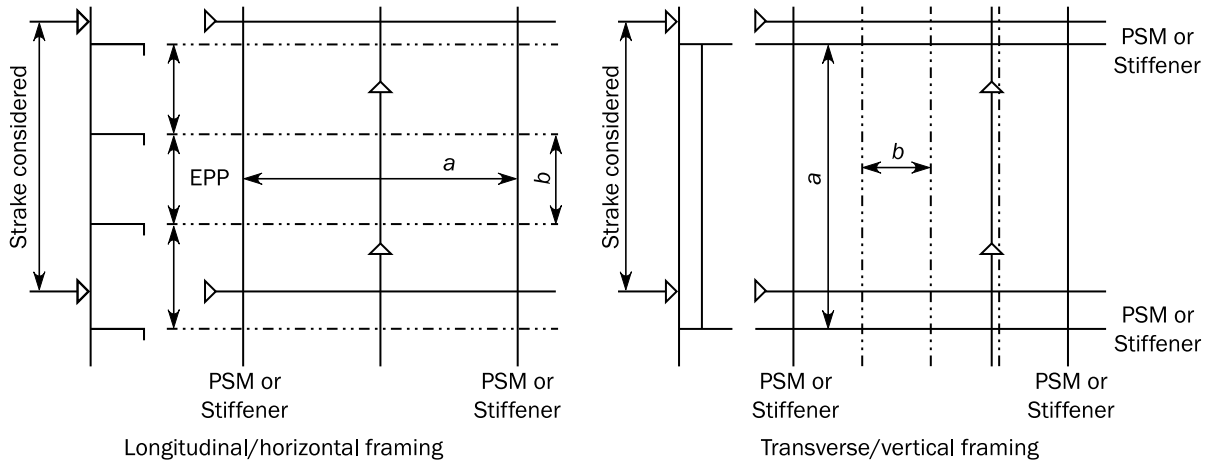
2 Plates

2.1 Idealisation of EPP

2.1.1 EPP

An Elementary Plate Panel (EPP) is the unstiffened part of the plating between stiffeners and/or primary supporting members. The plate panel length, a , and breadth, b , of the EPP are defined respectively as the longer and the shorter plate edges, as shown in Fig 16.

Figure 16 : Elementary Plate Panel (EPP) definition



2.1.2 Strake required thickness

The required thickness of a strake is to be taken as the greatest value required for each EPP within that strake. The requirements given in Tab 1 are to be applied for the selection of strakes to be considered, as shown in Fig 17, where:

a_1 : Distance, in mm, measured inside the considered strake in the direction of the long edge of the EPP, between the strake boundary weld seam and the EPP edge.

The maximum corrosion addition within a strake is to be applied according to Ch 4, Sec 3, [1.2.5].

2.1.3 For direct strength assessment, the EPP is idealised with the mesh arrangement in the finite element model.

2.2 Load Calculation Point

2.2.1 Yielding

For the yielding check, the local pressure and the hull girder stress, used for the calculation of the local scantling requirements, are to be taken at the LCP (Load Calculation Point) having coordinates x, y and z as defined in Tab 2.

2.2.2 Ultimate buckling capacity

The load calculation points of the stiffener attached plating, to be considered for the stiffener ultimate buckling capacity check according to NR615, Sec 5, [2.3.4], are defined in Ch 4, Sec 6, [2].

2.2.3 Buckling

For the prescriptive buckling check of the EPP according to Ch 9, Sec 1, the LCP for the pressure and for the hull girder stresses are defined in Tab 3.

For the finite element buckling check, Ch 9, Sec 1 is applicable.

Figure 17 : Strake considered in a given EPP

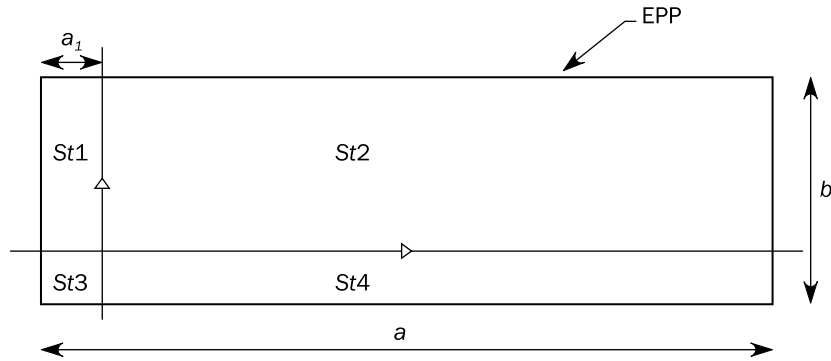


Table 1 : Strake considered in a given EPP

	$a/b > 2$	$a/b \leq 2$
$a_1 > b/2$	All strakes (St1, St2, St3, St4)	All strakes (St1, St2, St3, St4)
$a_1 \leq b/2$	Strakes St2 and St4	All strakes (St1, St2, St3, St4)

Table 2 : LCP coordinates for yielding

LCP coordinates	General(1)		Horizontal plating		Vertical transverse structure and transverse stool plating	
	Longitudinal framing (Fig 18)	Transverse framing (Fig 19)	Longitudinal framing	Transverse framing	Horizontal framing (Fig 20)	Vertical framing (Fig 21)
x coordinate	Mid-length of the EPP		Mid-length of the EPP		Corresponding to y and z coordinates	
y coordinate	Corresponding to x and z coordinates		Outboard y coordinate of the EPP		Outboard y coordinate of the EPP, taken at z level(2)	
z coordinate	EPP lower edge	The greater of the EPP lower edge or strake lower edge (3)	Corresponding to x and y coordinates		EPP lower edge	The greater of the EPP lower edge or strake lower edge (3)

- (1) All structures other than horizontal platings or vertical transverse structures.
 (2) For transom plate, the y coordinate of the load calculation point is to be taken corresponding to the y value at side shell at z level of the load calculation point, for the external dynamic pressure calculation.
 (3) For plating subject to sloshing loads, the LCP z coordinate is to be taken as the one associated to the maximum lateral pressure among the following:
- EPP upper edge
 - The point corresponding to the tank filling level (if applicable)
 - The greater of the EPP lower edge or strake lower edge.

Table 3 : LCP coordinates for plate buckling

LCP coordinates	LCP for pressure	LCP for hull girder stresses (Fig 22)		
		Bending stresses (1)		Shear stresses
		Non horizontal plate	Horizontal plate	
x coordinate	Same coordinates as LCP for yielding. See Tab 2	Mid-length of the EPP		
y coordinate		Corresponding to x and z coordinates	Outboard and inboard ends of the EPP (points A1 and A2)	Mid-point of EPP (point B)
z coordinate		Both upper and lower ends of the EPP (points A1 and A2)	Corresponding to x and y coordinates	

- (1) The bending stress for curved plate panel is the mean value of the stresses calculated at points A1 and A2.

Figure 18 : Load calculation point (LCP) for longitudinal framing

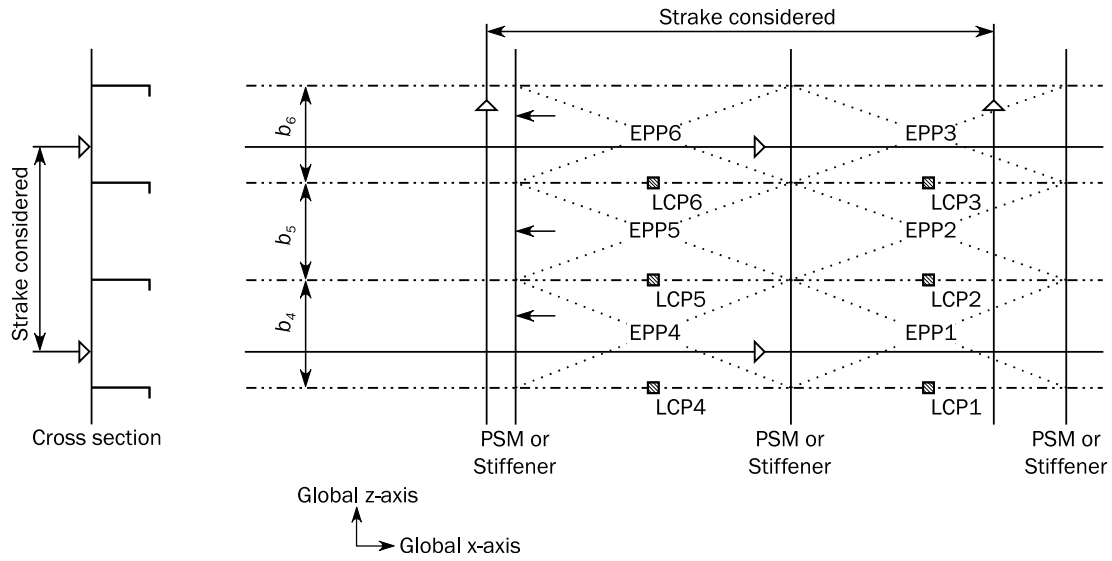


Figure 19 : Load calculation point for transverse framing

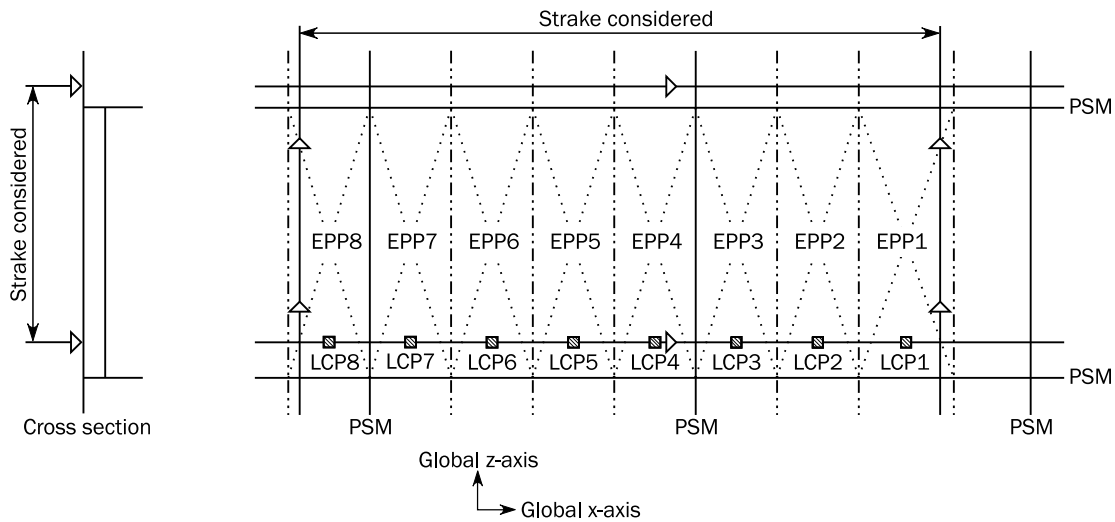


Figure 20 : Load calculation point for horizontal framing on transverse vertical structure

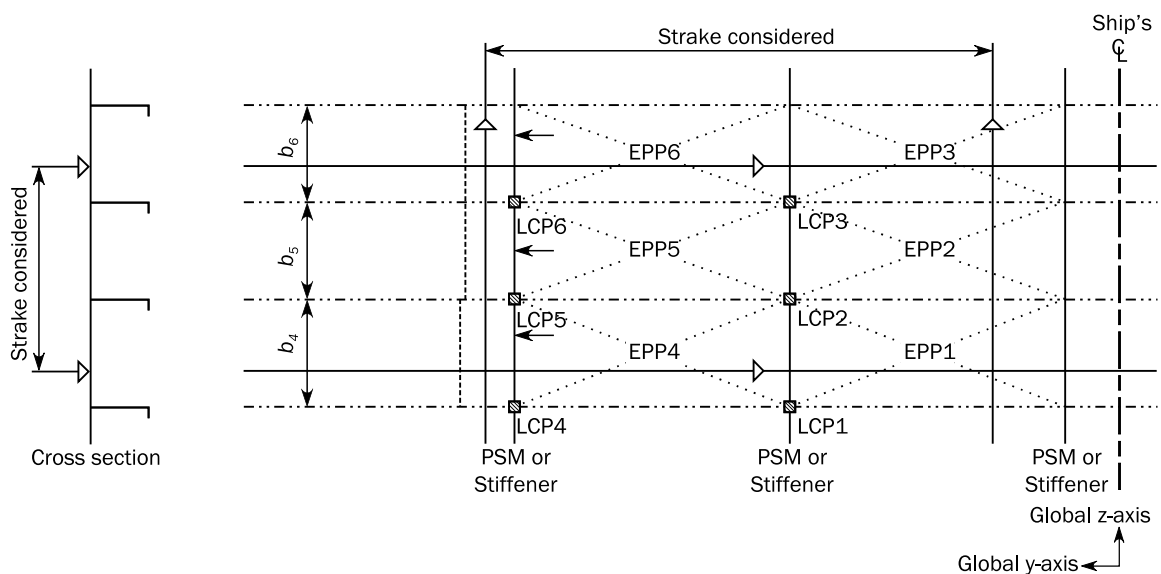


Figure 21 : Load calculation point for vertical framing on transverse vertical structure

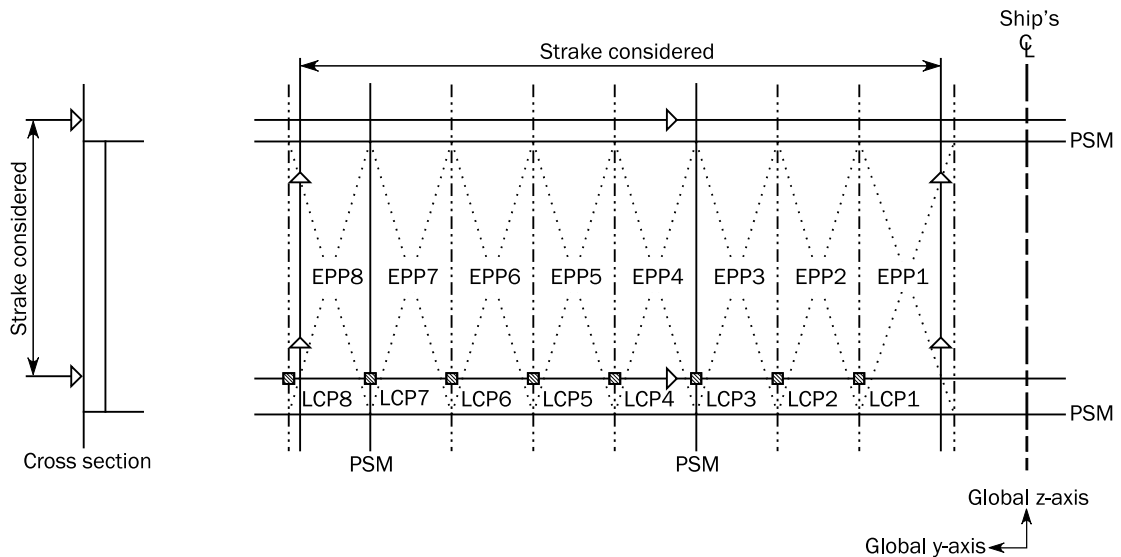
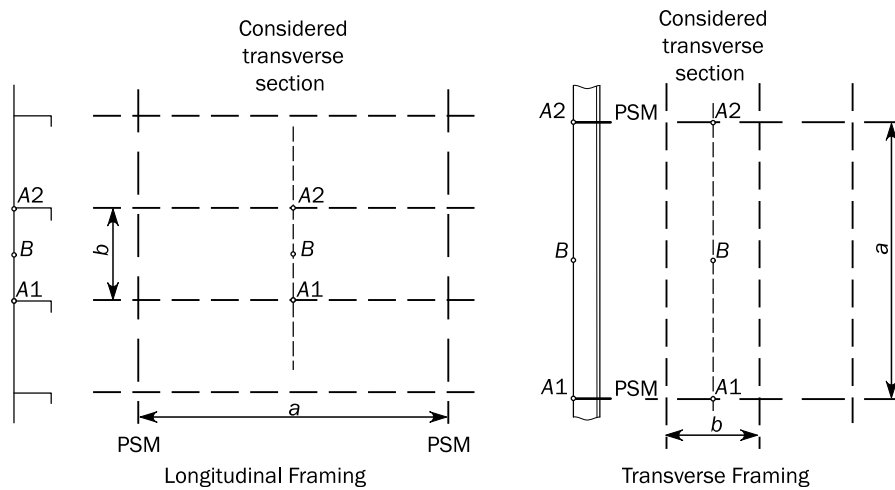


Figure 22 : Load calculation point for plate buckling – Hull girder stresses



3 Stiffeners

3.1 Reference point

3.1.1 The requirements of stiffener section modulus relate to the reference point giving the minimum section modulus. This reference point is located as shown in Fig 23 for typical profiles.

3.2 Load calculation point

3.2.1 LCP for pressure

The load calculation point for the pressure is located at the:

- middle of the full length ℓ of the considered stiffener
- intersection point between the stiffener and its attached plate.

For stiffeners located on transom plate, the y coordinate of the load calculation point is to be taken corresponding to the y value at side shell at z level of the load calculation point, for the external dynamic pressure calculation.

3.2.2 LCP for hull girder bending stress

The load calculation point for the hull girder bending stress is defined as follows:

- for prescriptive yielding verification according Ch 7, Sec 5 and Ch 11, Sec 4:
 - at the middle of the full length ℓ of the considered stiffener
 - at the reference point given in Fig 23.

- for prescriptive buckling requirements according to Ch 9, Sec 1:
 - at the middle of the full length ℓ of the considered stiffener
 - at the intersection point between the stiffener and its attached plate.

3.2.3 Non-horizontal stiffeners

The lateral pressure P , in kN/m^2 , is to be calculated as the maximum between the value obtained at the middle of the full length ℓ and the value obtained from the following formulae:

- when the upper end of the vertical stiffener is below the lowest zero pressure level:

$$P = \frac{P_U + P_L}{2}$$

- when the upper end of the vertical stiffener is at or above the lowest zero pressure level (see Fig 24):

$$P = \frac{\ell_1}{\ell} \frac{P_L}{2}$$

where:

- ℓ_1 : Distance, in m, between the lower end of vertical stiffener and the lowest zero pressure level
- P_U, P_L : Lateral pressures, in kN/m^2 , at the upper and lower ends of the vertical stiffener span ℓ , respectively.

Figure 23 : Reference point for calculation of section modulus and hull girder stress for local scantling assessment

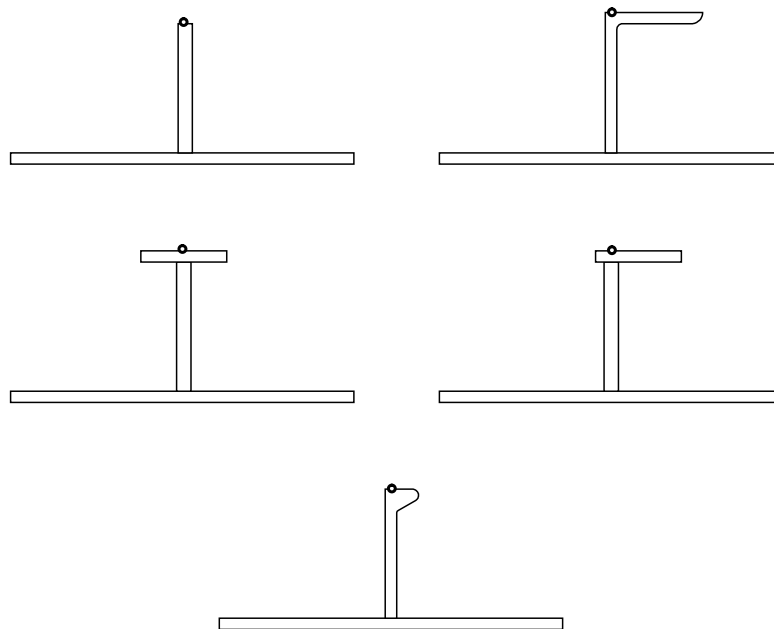
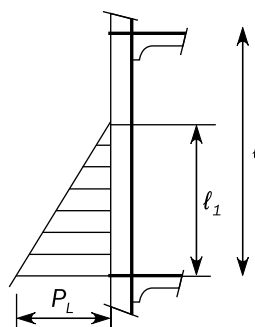


Figure 24 : Definition of pressure for non-horizontal stiffeners



4 Primary supporting members

4.1 Load calculation point

4.1.1 The load calculation point is located at the middle of the full length ℓ , at the attachment point of the primary supporting member with its attached plate.

For primary supporting members located on transom plate, the y coordinate of the load calculation point is to be taken corresponding to y value at side shell at z level of load calculation point for the external dynamic pressure calculation.

Part B

Hull and Stability

CHAPTER 5

DESIGN LOADS

Section 1	Introduction
Section 2	Dynamic Load Cases
Section 3	Ship Motions and Accelerations
Section 4	Hull Girder Loads
Section 5	Environmental Loads
Section 6	Internal Loads and cargo loads
Section 7	Design Load Scenarios
Section 8	Loading Conditions

Section 1 Introduction

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

1 General

1.1 Definition

1.1.1 Scope

This Chapter provides the design loads for strength and fatigue assessments.

The load combinations are to be derived for the design load scenarios specified in Ch 5, Sec 7. This Section uses the concept of design load scenarios to specify consistent design load sets which cover relevant operating modes.

1.1.2 Equivalent Design Wave (EDW)

The dynamic loads associated to each dynamic load case are based on the Equivalent Design Wave (EDW) concept. The EDW concept applies a consistent set of dynamic loads to the ship such that a specified dominant load response is equivalent to the required long term response value.

1.1.3 Probability levels for strength and fatigue assessments

In this Chapter, the assessments are to be understood as follows:

- Strength assessment means the assessment for strength criteria, excluding fatigue, for seagoing conditions, ballast water exchange conditions, harbour conditions and flooded conditions, based on loads corresponding to a return period of 25 years (probability level approximately of 10^{-8})
- Fatigue assessment means the assessment for fatigue criteria based on loads corresponding to the probability level of 10^{-2} .

1.1.4 Loads for strength assessment

The strength assessment is to be undertaken for all design load scenarios. The final assessment is to be made on the most demanding strength requirement.

Each design load scenario for strength assessment is composed of a static load case or a static + dynamic load case, where the static and dynamic loads depend on the loading condition being considered.

The static loads are defined in the following Sections:

- still water hull girder loads in Ch 5, Sec 4
- environmental loads in Ch 5, Sec 5
- internal and cargo loads in Ch 5, Sec 6.

The EDWs for the strength assessment and the dynamic load combination factors for global loads are listed in Ch 5, Sec 2, [2].

The dynamic loads are defined in the following Sections:

- dynamic hull girder loads in Ch 5, Sec 4
- environmental loads in Ch 5, Sec 5
- internal and cargo loads in Ch 5, Sec 6.

1.1.5 Loads for fatigue assessment

Each design load scenario for fatigue assessment is composed of a static + dynamic load case, where the static and dynamic loads depend on the loading condition being considered.

The static loads are defined in the following Sections:

- still water hull girder loads in Ch 5, Sec 4
- environmental loads in Ch 5, Sec 5
- internal and cargo loads in Ch 5, Sec 6.

The EDWs for the fatigue assessment and the dynamic load combination factors for global loads are listed in Ch 5, Sec 2, [3].

The dynamic loads are defined in the following Sections:

- dynamic hull girder loads in Ch 5, Sec 4
- environmental loads in Ch 5, Sec 5
- internal and cargo loads in Ch 5, Sec 6.

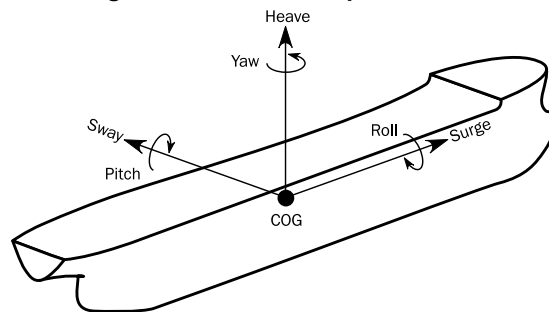
1.2 Sign convention

1.2.1 Sign convention for ship motions

The ship motions are defined with respect to the ship's centre of gravity (COG) as shown in Fig 1, where:

- positive surge is translation in the X-axis direction (positive forward)
- positive sway is translation in the Y-axis direction (positive towards portside of ship)
- positive heave is translation in the Z-axis direction (positive upwards)
- positive roll motion is positive rotation about a longitudinal axis through the COG (starboard down and portside up)
- positive pitch motion is positive rotation about a transverse axis through the COG (bow down and stern up)
- positive yaw motion is positive rotation about a vertical axis through the COG (bow moving to portside and stern to starboard).

Figure 1 : Definition of positive motions

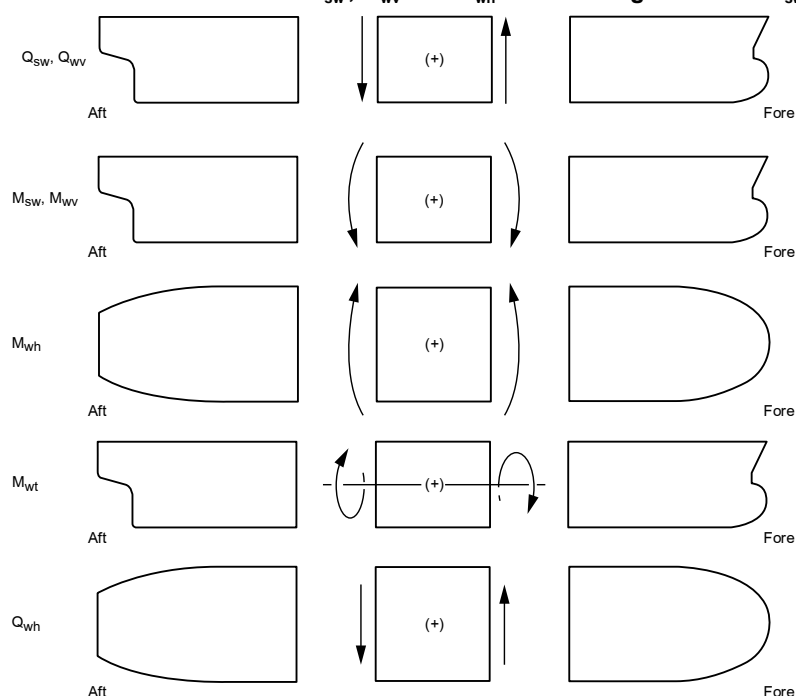


1.2.2 Sign conventions for hull girder loads

The sign conventions of vertical and horizontal bending moments, and vertical and horizontal shear forces, at any ship transverse section, are as shown in Fig 2, namely the:

- vertical shear forces Q_{sw} and Q_{wv} are positive in the case of downward resulting forces acting aft of the transverse section and upward resulting forces acting forward of the transverse section under consideration
- vertical bending moments M_{sw} and M_{wv} are positive when they induce tensile stresses in the strength deck (hogging bending moment) and negative when they induce tensile stresses in the bottom (sagging bending moment)
- horizontal bending moment M_{wh} is positive when it induces tensile stresses in the starboard side and negative when it induces tensile stresses in the portside
- torsional moment M_{wt} is positive in the case of resulting moment acting aft of the transverse section following negative rotation around the X-axis, and of resulting moment acting forward of the transverse section following positive rotation around the X-axis
- horizontal shear force Q_{wh} is positive in the case of resulting forces acting toward starboard side aft of the transverse section and resulting force acting toward portside forward of the the transverse section under consideration.

Figure 2 : Sign conventions for shear forces Q_{sw} , Q_{wv} and Q_{wh} and bending moments M_{sw} , M_{wv} , M_{wh} and M_{wt}



Section 2 Dynamic Load Cases

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

a_{surge} , a_{sway} , a_{heave} , a_{roll} , a_{pitch} , a_{yaw} : Acceleration components, as defined in Ch 5, Sec 3

$a_{\text{roll-y}}$, $a_{\text{roll-z}}$, $a_{\text{pitch-x}}$, $a_{\text{pitch-z}}$, $a_{\text{yaw-x}}$, $a_{\text{yaw-y}}$: Acceleration components, as defined in Ch 5, Sec 3

f_{TL} : Ratio between draught at the considered loading condition and rule length, to be taken as:

$$f_{\text{TL}} = T_{\text{LC}} / L$$

f_{lp} : Factor depending on the longitudinal position along the ship, to be taken as follows:

- $f_{\text{lp}} = 1,0$ for $x \leq 0,4 L$
- $f_{\text{lp}} = -1,0$ for $x \geq 0,6 L$

Intermediate values of f_{lp} are to be obtained by linear interpolation

Load combination factors, to be applied to the:

C_{WV} : Vertical wave bending moment

C_{QV} : Vertical wave shear force

C_{WT} : Wave torsional moment

C_{WH} : Horizontal wave bending moment

C_{QH} : Horizontal wave shear force

C_{XS} : Surge acceleration

C_{XP} : Longitudinal acceleration due to pitch

C_{XY} : Longitudinal acceleration due to yaw

C_{XG} : Gravitational acceleration due to pitch

C_{YS} : Sway acceleration

C_{YR} : Transverse acceleration due to roll

C_{YY} : Transverse acceleration due to yaw

C_{YG} : Gravitational acceleration due to roll

C_{ZH} : Heave acceleration

C_{ZR} : Vertical acceleration due to roll

C_{ZP} : Vertical acceleration due to pitch

$C_{\text{B-LC}}$: Block coefficient at considered loading condition draught T_{LC} , as defined in Ch 1, Sec 3, [2.1.9]. For flooded loading conditions, the value of $C_{\text{B-LC}}$ is to be taken as for the full load condition unless provided in the loading manual

$C_{\text{W-LC}}$: Waterplane coefficient at considered loading condition draught T_{LC} , as defined in Ch 1, Sec 3, [2.1.10]. For flooded loading conditions, the value of $C_{\text{W-LC}}$ is to be taken as for the full load condition unless provided in the loading manual

T_{R} : Dimensionless roll period, to be taken as: $T_{\text{R}} = T\theta (g / L)^{0,5}$
without being taken greater than $75/L^{0,5}$

ω_{R} : Roll angular frequency, in rad/s, to be taken as: $\omega_{\text{R}} = 2\pi / T\theta$

1 General

1.1 Definition of EDW and dynamic load cases

1.1.1 The Equivalent Design Waves (EDW) and the dynamic load cases to be used for structural assessment are defined in Tab 1.

1.2 Application

1.2.1 General load cases

The dynamic load cases described in [1.3] are to be applied for the structural assessments that do not require complete ship modeling i.e.:

a) strength assessment:

- for plating, ordinary stiffeners and primary supporting members by prescriptive methods
- for the direct strength method (FE analysis) assessment of structural members, based on partial ship models

b) fatigue assessment:

- for structural details covered by simplified stress analysis
- for structural details covered by FE stress analysis bases on partial ship models.

These dynamic load cases are to be used for design load scenarios described in Ch 5, Sec 7.

1.2.2 Load cases for structural analyses based on complete ship models

When primary supporting members are to be analysed through complete ship models, according to Ch 7, Sec 6, [1.1.2], specific load cases are to be considered.

These load cases are to be defined considering the ship as sailing in regular waves with different length, height and heading angle, each wave being selected in order to maximise a design load parameter. The procedure for the determination of these load cases is specified in Ch 8, App 3, [3] and Ch 8, App 3, [4].

1.3 Description of dynamic load cases

1.3.1 Tab 2 to Tab 7 describe the ship motion responses and the global loads corresponding to each dynamic load case to be considered for the strength and fatigue assessments.

Table 1 : Definition of Equivalent Design Waves (EDW) and dynamic load cases

EDW	Load case	Definition
HVM	HVM1	Head sea with maximum negative vertical bending moment (sagging) amidships(3)
	HVM2	Head sea with maximum positive vertical bending moment (hogging) amidships(3)
HVMf (1)	HVMf1	Head sea with maximum negative vertical bending moment (sagging) at 0,25 L from AE(3)
	HVMf2	Head sea with maximum positive vertical bending moment (hogging) at 0,25 L from AE(3)
FVM (2)	FVM1	Following sea with maximum negative vertical bending moment (sagging) at 0,25 L from AE(3)
	FVM2	Following sea with maximum positive vertical bending moment (hogging) at 0,25 L from AE(3)
BR	BR1-P	Beam sea with maximum negative roll motion
	BR2-P	Beam sea with maximum positive roll motion
	BR1-S	Beam sea with maximum positive roll motion
	BR2-S	Beam sea with maximum negative roll motion
BP	BP1-P	Beam sea with maximum negative hydrodynamic pressure at the waterline amidships
	BP2-P	Beam sea with maximum positive hydrodynamic pressure at the waterline amidships
	BP1-S	Beam sea with maximum negative hydrodynamic pressure at the waterline amidships
	BP2-S	Beam sea with maximum positive hydrodynamic pressure at the waterline amidships
OHM	OHM1-P	Oblique sea with maximum negative horizontal bending moment amidships
	OHM2-P	Oblique sea with maximum positive horizontal bending moment amidships
	OHM1-S	Oblique sea with maximum positive horizontal bending moment amidships
	OHM2-S	Oblique sea with maximum negative horizontal bending moment amidships
OHS (2)	OHS1-P	Oblique sea with maximum negative horizontal shear force and torsion at 0,75 L from AE
	OHS2-P	Oblique sea with maximum positive horizontal shear force and torsion at 0,75 L from AE
	OHS1-S	Oblique sea with maximum positive horizontal shear force and torsion at 0,75 L from AE
	OHS2-S	Oblique sea with maximum negative horizontal shear force and torsion at 0,75 L from AE
OVA (2)	OVA1-P	Oblique sea with maximum negative vertical acceleration at L from AE
	OVA2-P	Oblique sea with maximum positive vertical acceleration at L from AE
	OVA1-S	Oblique sea with maximum negative vertical acceleration at L from AE
	OVA2-S	Oblique sea with maximum positive vertical acceleration at L from AE

(1) Applicable to fatigue assessment only.

(2) Applicable to strength assessment only.

(3) The vertical shear force is also maximised with the dominant load component

Note 1: 1 and 2 denote the maximum positive or negative value of the dominant load component for each load case.

Note 2: P and S denote that the weather side (side of the ship exposed to the incoming waves) is on portside and on starboard side, respectively. The lee side (sheltered side of the ship away from the incoming waves) is on the opposite side.

Table 2 : Ship responses for HVM, HVMf and FVM load cases

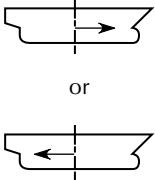
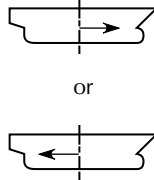






Loadcase	HVM1 / HVMf1	HVM2 / HVMf2	FVM1	FVM2
EDW	HVM / HVMf		FVM	
Wave heading	Head sea at 180 deg		Following sea at 0 deg	
Effect	Maximum bending moment		Maximum bending moment	
VWBM	Sagging	Hogging	Sagging	Hogging
VWSF	Negative-aft Positive-fore	Positive-aft Negative-fore	Negative-aft Positive-fore	Positive-aft Negative-fore
HWBM	-	-	-	-
HWSF	-	-	-	-
TM	-	-	-	-
Surge	To stern or to bow		To stern or to bow	
a_{surge}				
Sway	-	-	-	-
a_{sway}	-	-	-	-
Heave	Down	Up	Down	Up
a_{heave}				
Roll	-	-	-	-
a_{roll}	-	-	-	-
Pitch	Bow down	Bow up	-	-
a_{pitch}			-	-
Yaw	-	-	-	-
a_{yaw}	-	-	-	-

Table 3 : Ship responses for BR load cases

Load case	BR1-P	BR2-P	BR1-S	BR2-S
EDW	BR			
Wave heading	Beam sea at 270 deg		Beam sea at 90 deg	
Effect	Maximum roll			
VWBM	–	–	–	–
VWSF	–	–	–	–
HWBM	Starboard tensile	Portside tensile	Portside tensile	Starboard tensile
HWSF	–	–	–	–
TM	–	–	–	–
Surge	–	–	–	–
a_{surge}	–	–	–	–
Sway	To portside or to starboard		To portside or to starboard	
a_{sway}				
Heave	Down or up		Up or down	
a_{heave}				
Roll	Portside down	Portside up	Starboard down	Starboard up
a_{roll}				
Pitch	–	–	–	–
a_{pitch}	–	–	–	–
Yaw	–	–	–	–
a_{yaw}	–	–	–	–

Table 4 : Ship responses for BP load cases

Load case	BP1-P	BP2-P	BP1-S	BP2-S
EDW	BP			
Wave heading	Beam sea at 270 deg		Beam sea at 90 deg	
Effect	Maximum pressure at waterline			
VWBM	Hogging	Sagging	Hogging	Sagging
VWSF	Positive–aft Negative–fore	Negative–aft Positive–fore	Positive–aft Negative–fore	Negative–aft Positive–fore
HWBM	Portside tensile	Starboard tensile	Starboard tensile	Portside tensile
HWSF	–	–	–	–
TM	–	–	–	–
Surge	–	–	–	–
a_{surge}	–	–	–	–
Sway	To starboard	To portside	To portside	To starboard
a_{sway}				
Heave	Up	Down	Up	Down
a_{heave}				
Roll	Portside up or portside down		Starboard up or starboard down	
a_{roll}	 or 		 or 	
Pitch	–	–	–	–
a_{pitch}	–	–	–	–
Yaw	To starboard	To portside	To portside	To starboard
a_{yaw}				

Table 5 : Ship responses for OHM load cases

Load case	OHM1-P	OHM2-P	OHM1-S	OHM2-S
EDW	OHM			
Wave heading	Oblique sea at 240 deg		Oblique sea at 120 deg	
Effect	Maximum horizontal bending moment			
VWBM	Sagging	Hogging	Sagging	Hogging
VWSF	Negative-aft Positive-fore	Positive-aft Negative-fore	Negative-aft Positive-fore	Positive-aft Negative-fore
HWBM	Port tensile	Stbd tensile	Stbd tensile	Port tensile
HWSF	Positive-aft Negative-fore	Negative-aft Positive-fore	Negative-aft Positive-fore	Positive-aft Negative-fore
TM	Negative-aft Positive-fore	Positive-aft Negative-fore	Positive-aft Negative-fore	Negative-aft Positive-fore
Surge	To stern	To bow	To stern	To bow
a_{surge}				
Sway	To starboard	To portside	To portside	To starboard
a_{sway}				
Heave	Up	Down	Up	Down
a_{heave}				
Roll	Portside up or portside down		Starboard down or starboard up	
a_{roll}	 or 		 or 	
Pitch	Bow down	Bow up	Bow down	Bow up
a_{pitch}				
Yaw	To portside or to starboard			
a_{yaw}	 or 			

Table 6 : Ship responses for OHS load cases

Load case	OHS1-P	OHS2-P	OHS1-S	OHS2-S
EDW	OHS			
Wave heading	Oblique sea at 300 deg		Oblique sea at 60 deg	
Effect	Maximum horizontal shear force			
VWBM	Sagging	Hogging	Sagging	Hogging
VWSF	Negative-aft Positive-fore	Positive-aft Negative-fore	Negative-aft Positive-fore	Positive-aft Negative-fore
HWBM	Port tensile	Stbd tensile	Stbd tensile	Port tensile
HWSF	Positive-aft Negative-fore	Negative-aft Positive-fore	Negative-aft Positive-fore	Positive-aft Negative-fore
TM	Negative-aft Positive-fore	Positive-aft Negative-fore	Positive-aft Negative-fore	Negative-aft Positive-fore
Surge	To bow	To stern	To bow	To stern
a_{surge}				
Sway	To starboard or to portside		To starboard or to portside	
a_{sway}				
Heave	Up	Down	Up	Down
a_{heave}				
Roll	Portside up or portside down		Starboard down or starboard up	
a_{roll}				
Pitch	Bow up	Bow down	Bow up	Bow down
a_{pitch}				
Yaw	To portside or to starboard			
a_{yaw}				

Table 7 : Ship responses for OVA load cases

Load case	OVA1-P	OVA2-P	OVA1-S	OVA2-S
EDW	OVA			
Wave heading	Oblique sea at 240 deg		Oblique sea at 120 deg	
Effect	Maximum vertical acceleration			
VWBM	Hogging	Sagging	Hogging	Sagging
VWSF	Positive-aft Negative-fore	Negative-aft Positive-fore	Positive-aft Negative-fore	Negative-aft Positive-fore
HWBM	Stbd tensile	Port tensile	Port tensile	Stbd tensile
HWSF	Negative-aft Positive-fore	Positive-aft Negative-fore	Positive-aft Negative-fore	Negative-aft Positive-fore
TM	Positive-aft Negative-fore	Negative-aft Positive-fore	Negative-aft Positive-fore	Positive-aft Negative-fore
Surge	To bow	To stern	To bow	To stern
a_{surge}				
Sway	To portside	To starboard	To starboard	To portside
a_{sway}				
Heave	Up	Down	Up	Down
a_{heave}				
Roll	Portside up or portside down		Starboard up or starboard down	
a_{roll}	 or 		 or 	
Pitch	Bow up	Bow down	Bow up	Bow down
a_{pitch}				
Yaw	To starboard	To portside	To portside	To starboard
a_{yaw}				

2 Dynamic load cases for strength assessment

2.1 Selection of EDW

2.1.1 The following Equivalent Design Waves are to be considered for the strength assessment:

- HVM
- FVM
- BR
- BP
- OHM
- OHS
- OVA

2.2 Load combination factors

2.2.1 The load combinations factors LCFs for the determination of each load component to be used for strength assessment are defined in Tab 8 to Tab 13.

Table 8 : Load combination factors LCFs for HVM and FVM load cases - Strength assessment

Load component		LCF	HVM1	HVM2	FVM1	FVM2
Hull girder loads	M_{wv}	C_{wv}	- 1	1	- 1	1
	Q_{wv}	C_{qv}	- f_{ip}	f_{ip}	- f_{ip}	f_{ip}
	M_{wh}	C_{wh}	0	0	0	0
	Q_{wh}	C_{qh}	0	0	0	0
	M_{wt}	C_{wt}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{xs}	$0,60 - 10 f_{TL}$	$10 f_{TL} - 0,60$	$0,32 - 7,60 f_{TL}$	$7,60 f_{TL} - 0,32$
	$a_{pitch-x}$	C_{xp}	- 0,38	0,38	0	0
	a_{yaw-x}	C_{xy}	0	0	0	0
	$g \sin\phi$	C_{xg}	0,36	- 0,36	0	0
Transverse accelerations	a_{sway}	C_{ys}	0	0	0	0
	a_{roll-y}	C_{yr}	0	0	0	0
	a_{yaw-y}	C_{yy}	0	0	0	0
	$g \sin\theta$	C_{yg}	0	0	0	0
Vertical accelerations	a_{heave}	C_{zh}	$0,10 + 5,70 f_{TL}$	$- 0,10 - 5,70 f_{TL}$	0,10	- 0,10
	a_{roll-z}	C_{zr}	0	0	0	0
	$a_{pitch-z}$	C_{zp}	- 0,38	0,38	0	0

Table 9 : Load combination factors LCFs for BR load cases - Strength assessment

Load component		LCF	BR1-P	BR2-P	BR1-S	BR2-S
Hull girder loads	M_{wv}	C_{wv}	0	0	0	0
	Q_{wv}	C_{qv}	0	0	0	0
	M_{wh}	C_{wh}	$1,20 - 16 f_{TL}$	$16 f_{TL} - 1,20$	$16 f_{TL} - 1,20$	$1,20 - 16 f_{TL}$
	Q_{wh}	C_{qh}	0	0	0	0
	M_{wt}	C_{wt}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{xs}	0	0	0	0
	$a_{pitch-x}$	C_{xp}	0	0	0	0
	a_{yaw-x}	C_{xy}	0	0	0	0
	$g \sin\phi$	C_{xg}	0	0	0	0
Transverse accelerations	a_{sway}	C_{ys}	$1,71 \omega_R - 0,73$	$0,73 - 1,71 \omega_R$	$0,73 - 1,71 \omega_R$	$1,71 \omega_R - 0,73$
	a_{roll-y}	C_{yr}	1	- 1	- 1	1
	a_{yaw-y}	C_{yy}	0	0	0	0
	$g \sin\theta$	C_{yg}	- 1	1	1	- 1
Vertical accelerations	a_{heave}	C_{zh}	$0,88 - 0,15 T_R$	$0,15 T_R - 0,88$	$0,88 - 0,15 T_R$	$0,15 T_R - 0,88$
	a_{roll-z}	C_{zr}	1	- 1	- 1	1
	$a_{pitch-z}$	C_{zp}	0	0	0	0

Table 10 : Load combination factors LCFs for BP load cases - Strength assessment

Load component		LCF	BP1-P	BP2-P	BP1-S	BP2-S
Hull girder loads	M_{wv}	C_{wv}	0,2	- 0,2	0,2	- 0,2
	Q_{wv}	C_{qv}	$0,2 f_{ip}$	- 0,2 f_{ip}	$0,2 f_{ip}$	- 0,2 f_{ip}
	M_{wh}	C_{wh}	$19 f_{TL} - 1,30$	$1,30 - 19 f_{TL}$	$1,30 - 19 f_{TL}$	$19 f_{TL} - 1,30$
	Q_{wh}	C_{qh}	0	0	0	0
	M_{wt}	C_{wt}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{xs}	0	0	0	0
	$a_{pitch-x}$	C_{xp}	0	0	0	0
	a_{yaw-x}	C_{xy}	0,10	- 0,10	- 0,10	0,10
	$g \sin\phi$	C_{xg}	0	0	0	0
Transverse accelerations	a_{sway}	C_{ys}	$1,73 - 2,11 \omega_R$	$2,11 \omega_R - 1,73$	$2,11 \omega_R - 1,73$	$1,73 - 2,11 \omega_R$
	a_{roll-y}	C_{yr}	$0,39 T_R - 1,82$	$1,82 - 0,39 T_R$	$1,82 - 0,39 T_R$	$0,39 T_R - 1,82$
	a_{yaw-y}	C_{yy}	0,10	- 0,10	- 0,10	0,10
	$g \sin\theta$	C_{yg}	$1,35 - 0,27 T_R$	$0,27 T_R - 1,35$	$0,27 T_R - 1,35$	$1,35 - 0,27 T_R$
Vertical accelerations	a_{heave}	C_{zh}	- 1	1	- 1	1
	a_{roll-z}	C_{zr}	$0,39 T_R - 1,82$	$1,82 - 0,39 T_R$	$1,82 - 0,39 T_R$	$0,39 T_R - 1,82$
	$a_{pitch-z}$	C_{zp}	0	0	0	0

Table 11 : Load combination factors LCFs for OHM load cases - Strength assessment

Load component		LCF	OHM1-P	OHM2-P	OHM1-S	OHM2-S
Hull girder loads	M_{wv}	C_{wv}	$7,70 f_{TL} - 0,85(1)$	$0,50 - 7,70 f_{TL}(2)$	$7,70 f_{TL} - 0,85(1)$	$0,50 - 7,70 f_{TL}(2)$
	Q_{wv}	$C_{qv}(3)$	$(7,70 f_{TL} - 0,85) f_{ip}$	$(0,50 - 7,70 f_{TL}) f_{ip}$	$(7,70 f_{TL} - 0,85) f_{ip}$	$(0,50 - 7,70 f_{TL}) f_{ip}$
	M_{wh}	C_{wh}	- 1	1	1	- 1
	Q_{wh}	C_{qh}	f_{ip}	- f_{ip}	- f_{ip}	f_{ip}
	M_{wt}	C_{wt}	- f_{ip}	f_{ip}	f_{ip}	- f_{ip}
Longitudinal accelerations	a_{surge}	C_{xs}	0,23	- 0,23	0,23	- 0,23
	$a_{pitch-x}$	C_{xp}	$6 f_{TL} - 0,80$	$0,80 - 6 f_{TL}$	$6 f_{TL} - 0,80$	$0,80 - 6 f_{TL}$
	a_{yaw-x}	C_{xy}	$0,67 - 17,50 f_{TL}$	$17,50 f_{TL} - 0,67$	$17,50 f_{TL} - 0,67$	$0,67 - 17,50 f_{TL}$
	$g \sin\phi$	C_{xg}	0,37	- 0,37	0,37	- 0,37
Transverse accelerations	a_{sway}	C_{ys}	0,23	- 0,23	- 0,23	0,23
	a_{roll-y}	C_{yr}	$13,3 f_{TL} - 0,80$	$0,80 - 13,3 f_{TL}$	$0,80 - 13,3 f_{TL}$	$13,3 f_{TL} - 0,80$
	a_{yaw-y}	C_{yy}	$0,67 - 17,50 f_{TL}$	$17,50 f_{TL} - 0,67$	$17,50 f_{TL} - 0,67$	$0,67 - 17,50 f_{TL}$
	$g \sin\theta$	C_{yg}	$0,7 - 10,20 f_{TL}$	$10,20 f_{TL} - 0,7$	$10,20 f_{TL} - 0,7$	$0,7 - 10,20 f_{TL}$
Vertical accelerations	a_{heave}	C_{zh}	- 0,17	0,17	- 0,17	0,17
	a_{roll-z}	C_{zr}	$13,3 f_{TL} - 0,80$	$0,80 - 13,3 f_{TL}$	$0,80 - 13,3 f_{TL}$	$13,3 f_{TL} - 0,80$
	$a_{pitch-z}$	C_{zp}	$6 f_{TL} - 0,80$	$0,80 - 6 f_{TL}$	$6 f_{TL} - 0,80$	$0,80 - 6 f_{TL}$

- (1) C_{wv} is to be not greater than 0
(2) C_{wv} is to be not less than 0
(3) When $C_{wv} = 0$, C_{qv} is to be taken equal to 0.

Table 12 : Load combination factors LCFs for OHS load cases - Strength assessment

Load component		LCF	OHS1-P	OHS2-P	OHS1-S	OHS2-S
Hull girder loads	M_{wv}	C_{wv}	$0,41 - C_{w-LC}(1)$	$C_{w-LC} - 0,76(2)$	$0,41 - C_{w-LC}(1)$	$C_{w-LC} - 0,76(2)$
	Q_{wv}	$C_{Qv}(3)$	$(0,41 - C_{w-LC}) f_{ip}$	$(C_{w-LC} - 0,76) f_{ip}$	$(0,41 - C_{w-LC}) f_{ip}$	$(C_{w-LC} - 0,76) f_{ip}$
	M_{wh}	C_{wh}	- 1	1	1	- 1
	Q_{wh}	C_{QH}	f_{ip}	- f_{ip}	- f_{ip}	f_{ip}
	M_{wt}	C_{WT}	- f_{ip}	f_{ip}	f_{ip}	- f_{ip}
Longitudinal accelerations	a_{surge}	C_{XS}	$0,06 - 0,60 C_{B-LC}$	$0,60 C_{B-LC} - 0,06$	$0,06 - 0,60 C_{B-LC}$	$0,60 C_{B-LC} - 0,06$
	$a_{pitch-x}$	C_{XP}	$1,16 CB-LC - 0,32$	$0,32 - 1,16 CB-LC$	$1,16 CB-LC - 0,32$	$0,32 - 1,16 CB-LC$
	a_{yaw-x}	C_{XY}	$7,60 f_{TL} - 0,43$	$0,43 - 7,60 f_{TL}$	$0,43 - 7,60 f_{TL}$	$7,60 f_{TL} - 0,43$
	$g \sin\phi$	C_{XG}	$0,11 - 0,77 C_{B-LC}$	$0,77 C_{B-LC} - 0,11$	$0,11 - 0,77 C_{B-LC}$	$0,77 C_{B-LC} - 0,11$
Transverse accelerations	a_{sway}	C_{YS}	$1,12 C_{w-LC} - 0,80$	$0,80 - 1,12 C_{w-LC}$	$0,80 - 1,12 C_{w-LC}$	$1,12 C_{w-LC} - 0,80$
	a_{roll-y}	C_{YR}	$11,80 f_{TL} - 0,65$	$0,65 - 11,80 f_{TL}$	$0,65 - 11,80 f_{TL}$	$11,80 f_{TL} - 0,65$
	a_{yaw-y}	C_{YY}	$7,60 f_{TL} - 0,43$	$0,43 - 7,60 f_{TL}$	$0,43 - 7,60 f_{TL}$	$7,60 f_{TL} - 0,43$
	$g \sin\theta$	C_{YG}	$0,60 - 10,20 f_{TL}$	$10,20 f_{TL} - 0,60$	$10,20 f_{TL} - 0,60$	$0,60 - 10,20 f_{TL}$
Vertical accelerations	a_{heave}	C_{ZH}	- 0,15	0,15	- 0,15	0,15
	a_{roll-z}	C_{ZR}	$11,80 f_{TL} - 0,65$	$0,65 - 11,80 f_{TL}$	$0,65 - 11,80 f_{TL}$	$11,80 f_{TL} - 0,65$
	$a_{pitch-z}$	C_{ZP}	$1,16 CB-LC - 0,32$	$0,32 - 1,16 CB-LC$	$1,16 CB-LC - 0,32$	$0,32 - 1,16 CB-LC$

(1) C_{wv} is to be not greater than 0
(2) C_{wv} is to be not less than 0
(3) When $C_{wv} = 0$, C_{Qv} is to be taken equal to 0.

Table 13 : Load combination factors LCFs for OVA load cases - Strength assessment

Load component		LCF	OVA1-P	OVA2-P	OVA1-S	OVA2-S
Hull girder loads	M_{wv}	C_{wv}	$0,60 - 3,15 f_{TL}(2)$	$3,15 f_{TL} - 0,60(1)$	$0,60 - 3,15 f_{TL}(2)$	$3,15 f_{TL} - 0,60(1)$
	Q_{wv}	$C_{Qv}(3)$	$(0,60 - 3,15 f_{TL}) f_{ip}$	$(3,15 f_{TL} - 0,60) f_{ip}$	$(0,60 - 3,15 f_{TL}) f_{ip}$	$(3,15 f_{TL} - 0,60) f_{ip}$
	M_{wh}	C_{wh}	0,46	- 0,46	- 0,46	0,46
	Q_{wh}	C_{QH}	- 0,46 f_{ip}	0,46 f_{ip}	0,46 f_{ip}	- 0,46 f_{ip}
	M_{wt}	C_{WT}	0,46 f_{ip}	- 0,46 f_{ip}	- 0,46 f_{ip}	0,46 f_{ip}
Longitudinal accelerations	a_{surge}	C_{XS}	$8,40 f_{TL} - 0,81$	$0,81 - 8,40 f_{TL}$	$8,40 f_{TL} - 0,81$	$0,81 - 8,40 f_{TL}$
	$a_{pitch-x}$	C_{XP}	1	- 1	1	- 1
	a_{yaw-x}	C_{XY}	$0,30 + 13,3 f_{TL}$	- 0,3 - 13,3 f_{TL}	- 0,3 - 13,3 f_{TL}	$0,30 + 13,3 f_{TL}$
	$g \sin\phi$	C_{XG}	- 0,70	0,70	- 0,70	0,70
Transverse accelerations	a_{sway}	C_{YS}	- 0,36	0,36	0,36	- 0,36
	a_{roll-y}	C_{YR}	$0,50 - 1,20 \omega_R$	$1,20 \omega_R - 0,50$	$1,20 \omega_R - 0,50$	$0,50 - 1,20 \omega_R$
	a_{yaw-y}	C_{YY}	$0,30 + 13,30 f_{TL}$	- 0,30 - 13,30 f_{TL}	- 0,30 - 13,30 f_{TL}	$0,30 + 13,30 f_{TL}$
	$g \sin\theta$	C_{YG}	$1,20 \omega_R - 0,50$	$0,50 - 1,20 \omega_R$	$0,50 - 1,20 \omega_R$	$1,20 \omega_R - 0,50$
Vertical accelerations	a_{heave}	C_{ZH}	- 0,17 - 7,40 f_{TL}	$0,17 + 7,40 f_{TL}$	- 0,17 - 7,40 f_{TL}	$0,17 + 7,40 f_{TL}$
	a_{roll-z}	C_{ZR}	$0,50 - 1,20 \omega_R$	$1,20 \omega_R - 0,50$	$1,20 \omega_R - 0,50$	$0,50 - 1,20 \omega_R$
	$a_{pitch-z}$	C_{ZP}	1	- 1	1	- 1

(1) C_{wv} is to be not greater than 0
(2) C_{wv} is to be not less than 0
(3) When $C_{wv} = 0$, C_{Qv} is to be taken equal to 0.

3 Dynamic load cases for fatigue assessment

3.1 Selection of EDW

3.1.1 The following Equivalent Design Waves are to be considered for the fatigue assessment:

- HVM
- HVMf
- BR
- BP
- OHM

3.2 Load combination factors

3.2.1 The load combinations factors LCFs for the determination of each load component to be used for fatigue assessment are defined in Tab 14 to Tab 17.

Table 14 : Load combination factors LCFs for HVM and HVMf load cases - Fatigue assessment

Load component		LCF	HVM1	HVM2	HVMf1	HVMf2
Hull girder loads	M_{wv}	C_{wv}	- 1	1	- 1	1
	Q_{wv}	C_{Qv}	- f_{ip}	f_{ip}	- f_{ip}	f_{ip}
	M_{wh}	C_{WH}	0	0	0	0
	Q_{wh}	C_{QH}	0	0	0	0
	M_{wt}	C_{WT}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	0,80 - 12 f_{TL}	12 f_{TL} - 0,80	1,00 - 16,50 f_{TL}	16,50 f_{TL} - 1,00
	$a_{pitch-x}$	C_{XP}	0,70 C_{B-LC} - 1,15	1,15 - 0,70 C_{B-LC}	11,70 f_{TL} - 1,07	1,07 - 11,70 f_{TL}
	a_{yaw-x}	C_{XY}	0	0	0	0
	$g \sin\phi$	C_{XG}	0,57	- 0,57	0,91 - 9,82 f_{TL}	9,82 f_{TL} - 0,91
Transverse accelerations	a_{sway}	C_{YS}	0	0	0	0
	a_{roll-y}	C_{YR}	0	0	0	0
	a_{yaw-y}	C_{YY}	0	0	0	0
	$g \sin\theta$	C_{YG}	0	0	0	0
Vertical accelerations	a_{heave}	C_{ZH}	0,27 + 3,60 f_{TL}	- 0,27 - 3,60 f_{TL}	0,06 + 7,86 f_{TL}	- 0,06 - 7,86 f_{TL}
	a_{roll-z}	C_{ZR}	0	0	0	0
	$a_{pitch-z}$	C_{ZP}	0,70 C_{B-LC} - 1,15	1,15 - 0,70 C_{B-LC}	11,70 f_{TL} - 1,07	1,07 - 11,70 f_{TL}

Table 15 : Load combination factors LCFs for BR load cases - Fatigue assessment

Load component		LCF	BR1-P	BR2-P	BR1-S	BR2-S
Hull girder loads	M_{wv}	C_{wv}	0	0	0	0
	Q_{wv}	C_{Qv}	0	0	0	0
	M_{wh}	C_{WH}	1,20 - 16 f_{TL}	16 f_{TL} - 1,20	16 f_{TL} - 1,20	1,20 - 16 f_{TL}
	Q_{wh}	C_{QH}	0	0	0	0
	M_{wt}	C_{WT}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	0	0	0	0
	$a_{pitch-x}$	C_{XP}	0	0	0	0
	a_{yaw-x}	C_{XY}	0	0	0	0
	$g \sin\phi$	C_{XG}	0	0	0	0
Transverse accelerations	a_{sway}	C_{YS}	1,71 ω_R - 0,73	0,73 - 1,71 ω_R	0,73 - 1,71 ω_R	1,71 ω_R - 0,73
	a_{roll-y}	C_{YR}	1	- 1	- 1	1
	a_{yaw-y}	C_{YY}	0	0	0	0
	$g \sin\theta$	C_{YG}	- 1	1	1	- 1
Vertical accelerations	a_{heave}	C_{ZH}	0,88 - 0,15 T_R	0,15 T_R - 0,88	0,88 - 0,15 T_R	0,15 T_R - 0,88
	a_{roll-z}	C_{ZR}	1	- 1	- 1	1
	$a_{pitch-z}$	C_{ZP}	0	0	0	0

Table 16 : Load combination factors LCFs for BP load cases - Fatigue assessment

Load component		LCF	BP1-P	BP2-P	BP1-S	BP2-S
Hull girder loads	M_{wv}	C_{wv}	0,2	- 0,2	0,2	- 0,2
	Q_{wv}	C_{qv}	$0,2 f_{ip}$	- 0,2 f_{ip}	$0,2 f_{ip}$	- 0,2 f_{ip}
	M_{wh}	C_{wh}	$19 f_{TL} - 1,30$	$1,30 - 19 f_{TL}$	$1,30 - 19 f_{TL}$	$19 f_{TL} - 1,30$
	Q_{wh}	C_{qh}	0	0	0	0
	M_{wt}	C_{wt}	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{xs}	0	0	0	0
	$a_{pitch-x}$	C_{xp}	0	0	0	0
	a_{yaw-x}	C_{xy}	0,10	- 0,10	- 0,10	0,10
	$g \sin\phi$	C_{xg}	0	0	0	0
Transverse accelerations	a_{sway}	C_{ys}	$1,73 - 2,11 \omega_R$	$2,11 \omega_R - 1,73$	$2,11 \omega_R - 1,73$	$1,73 - 2,11 \omega_R$
	a_{roll-y}	C_{yr}	$0,39 T_R - 1,82$	$1,82 - 0,39 T_R$	$1,82 - 0,39 T_R$	$0,39 T_R - 1,82$
	a_{yaw-y}	C_{yy}	0,10	- 0,10	- 0,10	0,10
	$g \sin\theta$	C_{yg}	$1,35 - 0,27 T_R$	$0,27 T_R - 1,35$	$0,27 T_R - 1,35$	$1,35 - 0,27 T_R$
Vertical accelerations	a_{heave}	C_{zh}	- 1	1	- 1	1
	a_{roll-z}	C_{zr}	$0,39 T_R - 1,82$	$1,82 - 0,39 T_R$	$1,82 - 0,39 T_R$	$0,39 T_R - 1,82$
	$a_{pitch-z}$	C_{zp}	0	0	0	0

Table 17 : Load combination factors LCFs for OHM load cases - Fatigue assessment

Load component		LCF	OHM1-P	OHM2-P	OHM1-S	OHM2-S
Hull girder loads	M_{wv}	C_{wv}	$7,70 f_{TL} - 0,60(1)$	$0,60 - 7,70 f_{TL}(2)$	$7,70 f_{TL} - 0,60(1)$	$0,60 - 7,70 f_{TL}(2)$
	Q_{wv}	$C_{qv}(3)$	$(7,70 f_{TL} - 0,60) f_{ip}$	$(0,60 - 7,70 f_{TL}) f_{ip}$	$(7,70 f_{TL} - 0,60) f_{ip}$	$(0,60 - 7,70 f_{TL}) f_{ip}$
	M_{wh}	C_{wh}	- 1	1	1	- 1
	Q_{wh}	C_{qh}	f_{ip}	- f_{ip}	- f_{ip}	f_{ip}
	M_{wt}	C_{wt}	- f_{ip}	f_{ip}	f_{ip}	- f_{ip}
Longitudinal accelerations	a_{surge}	C_{xs}	0,20	- 0,20	0,20	- 0,20
	$a_{pitch-x}$	C_{xp}	- 0,39	0,39	- 0,39	0,39
	a_{yaw-x}	C_{xy}	$0,53 - 16 f_{TL}$	$16 f_{TL} - 0,53$	$16 f_{TL} - 0,53$	$0,53 - 16 f_{TL}$
	$g \sin\phi$	C_{xg}	0,31	- 0,31	0,31	- 0,31
Transverse accelerations	a_{sway}	C_{ys}	0,30	- 0,30	- 0,30	0,30
	a_{roll-y}	C_{yr}	$12 f_{TL} - 0,90$	$0,90 - 12 f_{TL}$	$0,90 - 12 f_{TL}$	$12 f_{TL} - 0,90$
	a_{yaw-y}	C_{yy}	$0,53 - 16 f_{TL}$	$16 f_{TL} - 0,53$	$16 f_{TL} - 0,53$	$0,53 - 16 f_{TL}$
	$g \sin\theta$	C_{yg}	$0,7 - 10,20 f_{TL}$	$10,20 f_{TL} - 0,7$	$10,20 f_{TL} - 0,7$	$0,7 - 10,20 f_{TL}$
Vertical accelerations	a_{heave}	C_{zh}	- 0,26	0,26	- 0,26	0,26
	a_{roll-z}	C_{zr}	$12 f_{TL} - 0,90$	$0,90 - 12 f_{TL}$	$0,90 - 12 f_{TL}$	$12 f_{TL} - 0,90$
	$a_{pitch-z}$	C_{zp}	- 0,39	0,39	- 0,39	0,39

- (1) C_{wv} is to be not greater than 0
(2) C_{wv} is to be not less than 0
(3) When $C_{wv} = 0$, C_{qv} is to be taken equal to 0.

Section 3 Ship Motions and Accelerations

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

- α : Parameter used for the calculation of L_{ref} and defined throughout Ch 5, Sec 3, Ch 5, Sec 4 and Ch 5, Sec 5 for the motion, acceleration or load under consideration
- $a_{pitch-x}$: Longitudinal acceleration due to pitch, in m/s^2 , as defined in [3.2.2]
- $a_{pitch-z}$: Vertical acceleration due to pitch, in m/s^2 , as defined in [3.2.4]
- a_{roll-y} : Transverse acceleration due to roll, in m/s^2 , as defined in [3.2.3]
- a_{roll-z} : Vertical acceleration due to roll, in m/s^2 , as defined in [3.3.2]
- A_{WP-LC} : Waterplane area at considered loading condition draught T_{LC} , in m^2
- a_{yaw-x} : Longitudinal acceleration due to yaw, in m/s^2 , as defined in [3.2.2]
- a_{yaw-y} : Transverse acceleration due to yaw, in m/s^2 , as defined in [3.2.3]
- C_α : Parameter defined throughout the Rules for the motion, acceleration or load under consideration
- C_{B-LC} : Block coefficient at considered loading condition draught T_{LC} , as defined in Ch 1, Sec 3, [2.1.9].
For flooded loading conditions, the value of C_{B-LC} is to be taken as for the full load condition unless provided in the loading manual
- C_S : Parameter defined for the considered load
- C_{W-LC} : Waterplane coefficient at considered loading condition draught T_{LC} , as defined in Ch 1, Sec 3, [2.1.10].
For flooded loading conditions, the value of C_{W-LC} is to be taken as for the full load condition unless provided in the loading manual
- $C_{XG}, C_{XS}, C_{XP}, C_{XY}, C_{YG}, C_{YS}, C_{YR}, C_{YY}, C_{ZH}, C_{ZR}$ and C_{ZP} : Load combination factors, as defined in Ch 5, Sec 2
- F : Froude's number at 0,75 V, to be taken as: $F = 0,123 V / L^{0,5}$
- $F_{5,0}$: Froude's number at 5 knots, to be taken as: $F_{5,0} = 0,82 / L^{0,5}$
- f_α : Speed effect coefficient for the reference length, to be taken as, unless otherwise specified:
 - for strength assessment: $f_\alpha = 1,0$
 - for fatigue assessment: $f_\alpha = 1,0 + C_\alpha (F - F_{5,0})$
- f_β : Heading correction factor to be taken as:
 - for the extreme sea and the ballast water exchange design load scenario:
 - for BR and BP: $f_\beta = 0,80$
 - for the other EDWs: $f_\beta = 1,00$
 - for fatigue assessment: $f_\beta = 1,00$
- f_{BL} : Ratio between moulded breadth and rule length, to be taken as: $f_{BL} = B / L$
- f_{nl} : Non-linear factor to be taken as 1,0
- f_p : Coefficient to be taken as, unless otherwise specified:
 - for strength assessment: $f_p = f_{ps}$
 - for fatigue assessment:
 - for fatigue due to high-cycle wave loads only: $f_p = 1$
 - for fatigue due to loading/unloading, as applicable according to Ch 10, Sec 1, [1.3]: $f_p = f_{pLU}$
- f_{pLU} : Coefficient for loading/unloading fatigue assessments which depend on the cycle period T_{LU} , in days, and operational limit h_{LU} , in m, to be taken as:

$$f_{pLU} = a_{LU} + b_{LU} \times \ln T_{LU}$$
where:

$$a_{LU} = 1,6 - 0,35 e^{-0,2 h_{LU}^2}$$

$$b_{LU} = 0,25 + \frac{0,23}{\pi} \operatorname{atan}\left(\frac{h_{LU} - 7}{2}\right)$$
- f_{ps} : Coefficient for strength assessments which depend on the applicable design load scenario specified in Ch 5, Sec 7, to be taken as:
 - for the extreme sea design load scenario: $f_{ps} = 1,0$
 - for the ballast water exchange design load scenario: $f_{ps} = 0,8$

- f_R : Routing factor to be taken as:
- for strength assessment of ships assigned with the navigation notation **unrestricted navigation** or the operating area notation **unrestricted dredging area**:
 $f_R = 0,85$
 - for strength assessment of ships having a navigation notation other than **unrestricted navigation** or any restricting operating area notation:
 $f_R = 1,00$
 - for fatigue assessment:
 $f_R = 1,00$
- f_S : Speed effect coefficient, to be taken as:
- for strength assessment: $f_S = 1,0$
 - for fatigue assessment: $f_S = 1,0 + C_S (F - F_{5,0})$
- f_{TL} : Ratio between draught at the considered loading condition and rule length, to be taken as:
 $f_{TL} = T_{LC} / L$
- GM : Metacentric height, in m, for the considered loading condition, as defined in [2.1.1]
- H : Wave parameter, in m, as defined in [1.1.1]
- h_{LU} : Reference height for loading/unloading fatigue assessment, in m, associated to the navigation notation, as given in Tab 1.
- L_c : Length, in m, as defined in Tab 1
- L_{ref} : Reference length, in m, to be taken as: $L_{ref} = \alpha f_\alpha L_c$
- T_{LU} : Loading/unloading cycle period, in days, to be submitted by the Designer, not to be taken greater than 15 days nor less than 0,5 days
- x y z : X, Y and Z coordinates, in m, of the considered point with respect to the coordinate system, as defined in Ch 1, Sec 3, [2.6]
- x_G : Longitudinal coordinate, in m, of the ship's centre of gravity, for the considered loading condition, to be taken as:
 $x_G = 0,57 C_{B-LC}^{0,4} L$
- z_G : Vertical coordinate, in m, of the ship's centre of gravity, for the considered loading condition, to be taken as:
 $z_G = 1,08 \left(\frac{T_{LC}}{2} + \frac{B^2}{12 T_{LC}} \right) - GM$

1 General

1.1 Definitions

1.1.1 Wave parameter

The wave parameter H, in m, is to be taken as:

- for $L \leq L_{ref}$:

$$H = f_p A_0 \left[1 - A_1 \left(1 - \sqrt{\frac{L}{L_{ref}}} \right)^{e_1} \right]$$

- for $L > L_{ref}$:

$$H = f_p A_0 \left[1 - A_2 \left(\sqrt{\frac{L}{L_{ref}}} - 1 \right)^{e_2} \right]$$

where:

A_0, A_1, A_2, e_1, e_2 : Coefficients defined in Tab 1 for strength and for fatigue assessment

L_{ref} : Reference length calculated with α and f_α values as defined for the considered acceleration, motion or load.

Where specific designation of the geographical area and/or the most unfavorable sea conditions considered are added to the navigation notation as per Pt A, Ch 1, Sec 2, [5.2.6], the wave parameter H is to be calculated using **unrestricted navigation** parameters unless a specific value for H has been determined by the Society based on the scatter diagram corresponding to the geographical area or the sea condition considered.

1.1.2 Navigation coefficient

For the strength assessment, the navigation coefficient n is to be taken according to Tab 2.

For the fatigue assessment, the navigation coefficient n is to be taken according to Tab 3.

Where specific designation of the geographical area and/or the most unfavorable sea conditions considered are added to the navigation notation as per Pt A, Ch 1, Sec 2, [5.2.6], the navigation coefficient n is to be taken as $n = 1,00$ unless a specific value for n has been determined by the Society based on the scatter diagram corresponding to the geographical area or the sea conditions considered.

Table 1 : Wave parameter coefficients for strength and fatigue assessment

Navigation notation	Assessment	A ₀	A ₁	e ₁	A ₂	e ₂	L _c	h _{lu} (1)
unrestricted navigation	Strength	1,00	1,50	2,20	0,45	1,70	486	–
	Fatigue	0,16	1,66	1,96	0,49	1,43	243	12,5
summer zone	Strength	0,70	1,55	2,12	0,35	1,75	354	–
	Fatigue	0,16	1,66	1,96	0,49	1,43	243	12,5
tropical zone	Strength	0,60	1,68	2,40	0,40	1,80	350	–
	Fatigue	0,16	1,66	1,96	0,49	1,43	243	12,5
coastal area	Strength	0,60	1,68	2,40	0,40	1,80	350	–
	Fatigue	0,16	1,66	1,96	0,49	1,43	243	12,5
sheltered area	Strength	0,38	1,65	2,45	0,35	1,80	280	–
	Fatigue	0,13	1,76	2,02	0,44	1,33	200	4,5

(1) Reference height for loading/unloading fatigue assessment, in m, to be considered for the calculation of f_{plu} according to Ch 5, Sec 3

Table 2 : Navigation coefficient for strength assessment

Navigation notation	Navigation coefficient n
unrestricted navigation	1
other navigation notations	$\frac{H}{0,85H_{s,unrestricted}}$

Note 1:
H : Wave parameter as defined in [1.1.1] for the strength assessment and corresponding to the concerned navigation notation
H_{s,unrestricted} : Wave parameter as defined in [1.1.1] for the strength assessment and corresponding to the navigation notation
unrestricted navigation

Table 3 : Navigation coefficient for fatigue assessment

Navigation notation	Navigation coefficient n	
	High-cycle fatigue assessment	Fatigue assessment due to loading /unloading
unrestricted navigation	1	$\frac{H_{f-LU}}{H_{f-H,unrestricted}}$
other navigation notations	$\frac{H_{f-H}}{H_{f-H,unrestricted}}$	

Note 1:
H_{f-H} : Wave parameter as defined in [1.1.1] for the high cycle fatigue assessment and corresponding to the concerned navigation notation
H_{f-LU} : Wave parameter as defined in [1.1.1] for the loading/unloading fatigue assessment and corresponding to the concerned navigation notation
H_{f-H,unrestricted} : Wave parameter as defined in [1.1.1] for the high cycle fatigue assessment and corresponding to the navigation notation
unrestricted navigation

2 Ship motions and accelerations

2.1 Ship motions

2.1.1 Roll motion

The roll period T_θ, in s, is to be taken as:

$$T_{\theta} = \frac{2,3\pi k_r}{\sqrt{g \cdot GM}}$$

The roll angle θ, in deg, is to be taken as:

$$\theta = \frac{9000(1,25 - 0,025T_{\theta})}{(B + 75)\pi} \cdot f_{ia} \cdot f_{BK}$$

without being taken less than:

$$\frac{1862}{B + 75} \cdot f_{ia} \cdot f_{BK}$$

where:

- f_{ia} : Coefficient, to be taken as:
- for strength assessment: $f_{ia} = f_{ps} \cdot n$
 - for fatigue assessment: $f_{ia} = 0,9 (0,23 - 4 \cdot 10^{-4} B f_T) n$
- f_T : Ratio between draught at the considered loading condition and scantling draught, to be taken as:
 $f_T = \max (T_{LC} / T_{SC} ; 0,5)$
 without being taken greater than 1.
- f_{BK} : To be taken as:
- for ships without bilge keel: $f_{BK} = 1,2$
 - for ships with bilge keel: $f_{BK} = 1,0$
- GM : Metacentric height, in m, for the considered loading condition, as defined in Tab 4, unless a different value is given in the loading manual.
- k_r : Roll radius of gyration, in m, for the considered loading condition, as defined in Tab 4
- n : Navigation coefficient as defined in [1.1.2] for a reference length L_{ref} calculated with:
- $$\alpha = \frac{4,6}{T_R^2}$$
- $$f_\alpha = 1,0$$

2.1.2 Pitch motion

The pitch period T_ϕ , in s, is to be taken as:

$$T_\phi = 0,8 \sqrt{L}$$

The pitch angle ϕ , in deg, is to be taken as:

$$\phi = \frac{1970 \cdot f_R \cdot f_S \cdot f_{nl} \cdot H}{L \cdot C_{W-LC}^{0,75}}$$

where:

H : Wave parameter for a reference length L_{ref} calculated with:

$$\alpha = 0,56$$

f_α calculated with $C_\alpha = -0,85$ for fatigue assessment

f_S : Speed effect coefficient calculated with $C_S = 0,9$ for fatigue assessment.

2.2 Accelerations at the centre of gravity

2.2.1 Surge acceleration

The longitudinal acceleration due to surge, in m/s^2 , is to be taken as:

$$a_{surge} = \frac{115 \cdot f_R \cdot f_S \cdot f_{nl} \cdot H}{L \cdot f_{TL}^{0,2} \cdot C_{B-LC}^{0,6}}$$

where:

H : Wave parameter for a reference length L_{ref} calculated with:

$$\alpha = \frac{0,37}{C_{W-LC}^{0,9}}$$

$$f_\alpha = 1,0$$

f_S : Speed effect coefficient to be taken as $f_S = 1,0$.

2.2.2 Sway acceleration

The transverse acceleration due to sway, in m/s^2 , is to be taken as:

$$a_{sway} = \frac{115 \cdot f_R \cdot f_S \cdot f_{nl} \cdot H}{L \cdot f_{TL}^{0,15} \cdot f_{BL}^{0,5}}$$

where:

H : Wave parameter for a reference length L_{ref} calculated with:

$$\alpha = \frac{0,24}{f_{BL}^{0,65}}$$

$$f_\alpha = 1,0$$

f_S : Speed effect coefficient to be taken as $f_S = 1,0$.

Table 4 : Values of k_r and GM

Loading condition (1) (2)	service notation	T_{LC}	k_r	GM
Full load condition	oil tanker bulk carrier, bulk carrier ESP, self-unloading bulk carrier ESP ore carrier ESP	T_{SC}	0,35 B	0,12 B
	Other ships			0,07 B
Full load condition with reduced draught	oil tanker bulk carrier, bulk carrier ESP, self-unloading bulk carrier ESP ore carrier ESP	Actual draught	0,35 B	0,12 B
	Other ships			0,07 B
Design fatigue condition	container ship	$0,85 T_{SC}$	0,35 B	0,07 B
Partial load condition	oil tanker	$0,6T_{SC}$	0,40 B	0,24 B
	FLS tanker, asphalt carrier chemical tanker tanker combination carrier			0,07 B
Full load / homogeneous heavy cargo condition	bulk carrier, bulk carrier ESP, self-unloading bulk carrier ESP ore carrier ESP	T_{SC}	0,42 B	0,25 B
Steel coils condition	bulk carrier, bulk carrier ESP, self-unloading bulk carrier ESP	T_{SC}	0,42 B	0,25 B
Alternate heavy cargo condition	bulk carrier, bulk carrier ESP, self-unloading bulk carrier ESP ore carrier ESP	T_{SC}	0,40 B	0,20 B
Alternate light cargo condition	bulk carrier, bulk carrier ESP, self-unloading bulk carrier ESP ore carrier ESP	T_{SC}	0,35 B	0,12 B
Heavy ballast condition	bulk carrier, bulk carrier ESP, self-unloading bulk carrier ESP ore carrier ESP	T_{BAL-H}	0,40 B	0,25 B
Normal ballast condition	oil tanker bulk carrier, bulk carrier ESP, self-unloading bulk carrier ESP ore carrier ESP	T_{BAL}	0,45 B	0,33 B
	Other ships			0,18 B
<p>(1) For flooded loading conditions, the values of k_r and GM are to be taken as for the full load condition unless provided in the loading manual.</p> <p>(2) For Multi-port (MP) of bulk carrier, bulk carrier ESP, self-unloading bulk carrier ESP, ore carrier ESP and combination carrier (limited to direct strength analysis):</p> <ul style="list-style-type: none"> loading conditions with draught amidships greater than or equal to $0.9 T_{SC}$, the values of k_r and GM, unless provided in the loading manual, are to be taken as those from the most appropriate full load condition. loading conditions with draught amidships between T_{BAL-H} and $0.9 T_{SC}$, the values of k_r and GM, unless provided in the loading manual, are to be obtained by linear interpolation, based on the draught, between the heavy ballast condition and the most appropriate full load condition. loading conditions with a draught amidships below T_{BAL-H}, the values of k_r and GM for the heavy ballast condition are to be used. 				

2.2.3 Heave acceleration

The vertical acceleration due to heave, in m/s^2 , is to be taken as:

$$a_{heave} = \frac{350 \cdot f_R \cdot f_S \cdot f_{nl} \cdot H}{L \cdot f_{BL}^{0,5}}$$

where:

H : Wave parameter for a reference length L_{ref} calculated with:

$$\alpha = \frac{0,35}{f_{TL}^{0,35}}$$

f_α calculated with $C_\alpha = (-16,3 f_{TL} - 1,10)$ for fatigue assessment

f_S : Speed effect coefficient calculated with $C_S = (19,7 f_{TL} + 0,55)$ for fatigue assessment.

2.2.4 Roll acceleration

The roll acceleration, a_{roll} , in rad/s^2 , is to be taken as:

$$a_{roll} = \theta \frac{\pi}{180} \left(\frac{2\pi}{T_\theta} \right)^2$$

2.2.5 Pitch acceleration

The pitch acceleration, a_{pitch} , in rad/s^2 , is to be taken as:

$$a_{pitch} = 6 \cdot 10^4 \cdot \frac{\pi}{180} \cdot \frac{f_R \cdot f_S \cdot f_{nl} \cdot H}{L^2 \cdot f_{BL}^{0,5} \cdot C_{W-LC}^{1,5}}$$

where:

H : Wave parameter for a reference length L_{ref} calculated with:

$$\alpha = \frac{0,24}{f_{BL}^{0,8}}$$

f_{α} calculated with $C_{\alpha} = (2,83 - 9,13 C_{B-LC})$ for fatigue assessment

f_S : Coefficient calculated with $C_S = 2,11$ for fatigue assessment.

2.2.6 Yaw acceleration

The yaw acceleration, a_{yaw} , in rad/s^2 , is to be taken as:

$$a_{yaw} = 200,4 \cdot 10^2 \cdot \frac{\pi}{180} \cdot \frac{f_R \cdot f_S \cdot f_{nl} \cdot H}{L^2 \cdot f_{BL}^{0,73}}$$

where:

H : Wave parameter for a reference length L_{ref} calculated with:

$$\alpha = \frac{1,14}{C_{B-LC}^{0,7}}$$

$f_{\alpha} = 1,0$

f_S : Coefficient to be taken as $f_S = 1,0$ for fatigue assessment.

3 Accelerations at any position

3.1 General

3.1.1 The accelerations used to derive the inertial loads at any position are defined with respect to the ship fixed coordinate system. Hence the acceleration values defined in [3.2.2] and [3.2.3] include the gravitational acceleration components due to the instantaneous roll and pitch angles.

3.1.2 The accelerations to be applied for the dynamic load cases defined in Ch 5, Sec 2 are given in [3.2].

3.1.3 The envelope accelerations as defined in [3.3] may be used for design purpose when the maximum design acceleration values are required.

3.2 Accelerations for dynamic load cases

3.2.1 General

The accelerations to be applied for the dynamic load cases defined in Ch 5, Sec 2 are given in [3.2.2] to [3.2.4].

3.2.2 Longitudinal acceleration

The longitudinal acceleration a_x at any position for each dynamic load case, in m/s^2 , is to be taken as:

$$a_x = -C_{XG} g \sin(f_{\beta}\phi) + f_{\beta} (C_{XS} a_{surge} + C_{XP} a_{pitch-x} - C_{XY} a_{yaw-x})$$

where:

$a_{pitch-x}$: Longitudinal acceleration due to pitch, in m/s^2 : $a_{pitch-x} = a_{pitch} (z - z_G)$

a_{yaw-x} : Longitudinal acceleration due to yaw, in m/s^2 : $a_{yaw-x} = a_{yaw} y$

3.2.3 Transverse acceleration

The transverse acceleration a_y at any position for each dynamic load case, in m/s^2 , is to be taken as:

$$a_y = C_{YG} g \sin \theta + f_{\beta} (C_{YS} a_{sway} + C_{YY} a_{yaw-y}) - C_{YR} a_{roll-y}$$

where:

a_{roll-y} : Transverse acceleration due to roll, in m/s^2 : $a_{roll-y} = a_{roll} (z - z_G)$

a_{yaw-y} : Transverse acceleration due to yaw, in m/s^2 : $a_{yaw-y} = a_{yaw} (x - x_G)$

3.2.4 Vertical acceleration

The vertical acceleration a_z at any position for each dynamic load case, in m/s^2 , is to be taken as:

$$a_z = f_{\beta} (C_{ZH} a_{heave} - C_{ZP} a_{pitch-z}) + C_{ZR} a_{roll-z}$$

where:

- $a_{\text{roll-z}}$: Vertical acceleration due to roll, in m/s^2 : $a_{\text{roll-z}} = a_{\text{roll}} y$
 $a_{\text{pitch-z}}$: Vertical acceleration due to pitch, in m/s^2 : $a_{\text{pitch-z}} = a_{\text{pitch}} (x - x_G)$

3.3 Envelope accelerations for equipment

3.3.1 Longitudinal acceleration

The envelope longitudinal acceleration $a_{x\text{-env}}$, in m/s^2 , at any position, is the maximum longitudinal acceleration calculated with [3.2.2] for the following EDW:

- HVM load cases
- FVM load cases
- OHM load cases
- OHS load cases
- OVA load cases, and
- a specific load case, with:
 - $C_{XG} = 1,5 - 2,5 C_{B-LC}$
 - $C_{XS} = -0,1$
 - $C_{XP} = 3,5 C_{B-LC} - 2$
 - $C_{XY} = 0$

3.3.2 Transverse acceleration

The envelope transverse acceleration $a_{y\text{-env}}$, in m/s^2 , at any position, is the maximum transverse acceleration calculated with [3.2.3] for the following EDW:

- BR load cases
- BP load cases
- OHM load cases
- OHS load cases
- OVA load cases.

3.3.3 Vertical acceleration

The envelope vertical acceleration $a_{z\text{-env}}$, in m/s^2 , at any position, is the maximum vertical acceleration calculated with [3.2.4] for the following EDW:

- HVM load cases
- FVM load cases
- BR load cases
- BP load cases
- OHM load cases
- OHS load cases
- OVA load cases, and
- Two specific load cases $SPLC_{\text{max}}$ and $SPLC_{\text{min}}$:
 - $SPLC_{\text{max}}$ is defined with the following LCFs:
$$C_{ZH} = 10,72 f_{TL} - 0,28$$
$$C_{ZR} = 0$$
$$C_{ZP} = 1,2 - 6,84 f_{TL}$$
 - $SPLC_{\text{min}}$ is defined with the following LCFs:
$$C_{ZH} = 0,28 - 10,72 f_{TL}$$
$$C_{ZR} = 0$$
$$C_{ZP} = 6,84 f_{TL} - 1,2$$

Section 4 Hull Girder Loads

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

C : Wave coefficient:

$$C = (118 - 0,36L) \frac{L}{1000} \text{ for } 65 \text{ m} \leq L < 90 \text{ m}$$

$$C = 10,75 - \left(\frac{300 - L}{100} \right)^{1,5} \text{ for } 90 \text{ m} \leq L < 300 \text{ m}$$

$$C = 10,75 \text{ for } 300 \text{ m} \leq L \leq 350 \text{ m}$$

$$C = 10,75 - \left(\frac{L - 350}{150} \right)^{1,5} \text{ for } L > 350 \text{ m}$$

C_{B-LC} : Block coefficient, as defined in Ch 5, Sec 3

F : Froude's number at 0,75 V, as defined in Ch 5, Sec 3

f_{BL} : Ratio between moulded breadth and rule length as defined in Ch 5, Sec 3

f_{β} : Heading correction factor as defined in Ch 5, Sec 3

H : Wave parameter, as defined in Ch 5, Sec 3

ΔQ_{swf} : Shear force correction at the transverse section considered, in kN, taken as:

- For ships carrying dry bulk cargo, ΔQ_{md-fwd} as defined in Ch 8, App 1, [4.3.4].
- For other ships, $\Delta Q_{swf} = 0$.

1 Application

1.1 General

1.1.1 The hull girder loads for the static design load scenarios are to be taken as the still water loads defined in Article [2].

1.1.2 The total hull girder loads for the static + dynamic design load scenarios are to be derived for each dynamic load case and are to be taken as the sum of the still water loads defined in [2] and the dynamic loads defined in [3.6].

2 Still water loads

2.1 General

2.1.1 Still water load calculation

Still water loads are to be calculated for all the design loading conditions defined in Ch 5, Sec 8 and subdivided into departure and arrival conditions.

The longitudinal distributions of still water bending moment and shear force are to be calculated, for each of the loading conditions, on the basis of realistic data related to the amount of cargo, ballast, fuel, lubricating oil and fresh water.

Where the amount and disposition of consumables at any intermediate stage of the voyage are considered more severe, calculations for such intermediate conditions are to be submitted in addition to those for departure and arrival conditions. Also, where any ballasting and/or deballasting is intended during voyage, calculations of the intermediate condition just before and just after ballasting and/or deballasting any ballast tank are to be submitted and, where approved, included in the loading manual for guidance.

The actual hull lines and lightweight distribution are to be taken into account in the calculations. The lightweight distribution may be replaced, if the actual values are not available, by a statistical distribution of weights accepted by the Society.

The designer is to supply the data necessary to verify the calculations of still water loads.

2.1.2 Seagoing and harbour/sheltered water conditions

The designer is to provide the permissible still water bending moment and shear force distributions for seagoing and harbour/sheltered water operations.

The permissible still water hull girder loads are to be given, as a minimum:

- at each transverse bulkhead in the cargo hold region
- at the collision bulkhead

- at the engine room forward bulkhead, and
- at the mid-point between the forward and aft engine room bulkheads.

The permissible hull girder bending moments and shear forces at any other position may be obtained by linear interpolation. Distributions of permissible still water bending moments and shear forces are to be provided in the loading manual.

2.1.3 Still water loads for the fatigue assessment

The still water bending moments, M_{sw} , to be used for the fatigue assessment are to be taken as defined in Tab 1 for each loading condition representative of the intended operation of the ship, given in Ch 10, Sec 1, [2].

Table 1 : Still water bending moment for fatigue assessment

Service notation	Loading condition	M_{sw}
ro-ro cargo ship, PCT carrier passenger ship or ro-ro passenger ship	Full load condition	1,00 M_{sw-max}
container ship	Loaded at 0,85 T_{sc}	1,00 M_{sw-max}
bulk carrier, bulk carrier ESP self-unloading bulk carrier ESP ore carrier ESP combination carrier ESP	Heavy ballast condition	<ul style="list-style-type: none"> • 0,75 M_{sw-min} in way of ballasted hold • 0,45 M_{sw-max} in way of other cargo holds • linear interpolation between 0,75 M_{sw-min} and 0,45 M_{sw-max} for cargo holds adjacent to ballasted hold
all other service notations	Full load condition	1,00 M_{sw-min}
	Normal ballast condition	1,00 M_{sw-max}
M_{sw-max} , M_{sw-min} : permissible vertical still water bending moments in seagoing condition as defined in [2.2.1].		

2.2 Vertical still water bending moments

2.2.1 Permissible vertical still water bending moments in seagoing condition

The permissible vertical still water bending moments in seagoing condition M_{sw-max} and M_{sw-min} , at any longitudinal position, are to envelop:

- the maximum and minimum still water bending moments calculated, respectively, for all seagoing loading conditions defined in Ch 5, Sec 8. Loading conditions encountered during ballast water exchange need not to be considered for the flooded condition.
- the still water bending moments for all seagoing loading conditions defined in the loading manual.

2.2.2 Permissible vertical still water bending moments in harbour/sheltered water condition

The permissible vertical still water bending moments in harbour/sheltered water condition $M_{sw-p-max}$ and $M_{sw-p-min}$, at any longitudinal position, are to envelop:

- the maximum and minimum still water bending moments, respectively, for all harbour/sheltered water loading conditions defined in Ch 5, Sec 8
- the still water bending moments for all harbour/sheltered water loading conditions defined in the loading manual
- the permissible still water bending moment in seagoing condition, defined in [2.2.1].

2.2.3 Preliminary still water bending moment

When the permissible still water bending moments are not defined, as a guidance at a preliminary stage, M_{sw-max} and M_{sw-min} , in kN·m, may be taken as:

$$M_{sw-max} = f_{sw} \left(190 \frac{1+n}{2} C \cdot L^2 \cdot B(C_B + 0,7) 10^{-3} - M_{wv-h-mid} \right)$$

$$M_{sw-min} = -f_{sw} \left(190 \frac{1+n}{2} C \cdot L^2 \cdot B(C_B + 0,7) 10^{-3} + M_{wv-s-mid} \right)$$

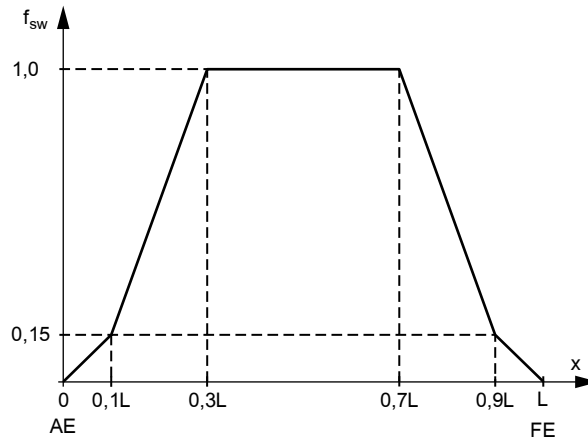
where:

f_{sw} : Distribution factor along the ship length, to be taken as follows (see Fig 1):

- $f_{sw} = 0,0$ for $x \leq 0$
- $f_{sw} = 0,15$ at $x = 0,1 L$
- $f_{sw} = 1,00$ for $0,3 L \leq x \leq 0,7 L$
- $f_{sw} = 0,15$ at $x = 0,9 L$
- $f_{sw} = 0,0$ for $x \geq L$

Intermediate values of f_{sw} are to be obtained by linear interpolation

Figure 1 : Distribution factor f_{sw}



$M_{wv-h-mid}$: Vertical wave bending moment for strength assessment in hogging condition, as defined in:

- ships assigned the service notation **container ship**:
Pt D, Ch 2, Sec 2, [4.2.1], calculated with $f_{m-h} = 1,0$ and $f_{ps} = 1,0$
- other ships:
[3.1.1], calculated with $F_M = 1,0$ and $f_{ps} = 1,0$

$M_{wv-s-mid}$: Vertical wave bending moment for strength assessment in sagging condition, as defined in:

- ships assigned the service notation **container ship**:
Pt D, Ch 2, Sec 2, [4.2.1], calculated with $f_{m-s} = 1,0$ and $f_{ps} = 1,0$
- other ships:
[3.1.1], calculated with $F_M = 1,0$ and $f_{ps} = 1,0$

n : navigation coefficient, as defined in [3.1.1].

Note 1: For ships always in hogging condition such as container ships, M_{sw-min} may be taken as 0.

2.3 Vertical still water shear forces

2.3.1 Permissible still water shear forces in seagoing condition

The permissible vertical still water shear forces Q_{sw-max} and Q_{sw-min} in seagoing condition, at any longitudinal position, are to envelop the corrected still water shear forces for the seagoing loading conditions defined in the loading manual.

The corrected shear force values for each loading condition are to be obtained by deducting the shear force correction ΔQ_{swf} from the values given by the loading manual.

Loading conditions encountered during ballast water exchange need not to be considered for the flooded condition.

2.3.2 Permissible still water shear forces in harbour/ sheltered water and tank testing condition

The permissible vertical still water shear forces $Q_{sw-p-max}$ and $Q_{sw-p-min}$ in harbour/sheltered water and tank testing conditions, at any longitudinal position, are to envelop:

- the corrected still water shear forces for the harbour/sheltered water loading conditions defined in the loading manual
- the permissible still water shear forces in seagoing condition as defined in [2.3.1].

The corrected shear force values for each loading condition are to be obtained by deducting the shear force correction ΔQ_{swf} from the values given by the loading manual.

3 Wave loads

3.1 Vertical wave bending moments

3.1.1 Vertical wave bending moments for strength assessment

For strength assessment purposes the vertical wave bending moments M_{wv-h} and M_{wv-s} at any longitudinal position in kN.m, are to be taken as:

- hogging conditions:
 $M_{wv-h} = 190 F_M f_{ps} n C L^2 B C_B 10^{-3}$
- sagging conditions:
 $M_{wv-s} = - 110 F_M f_{ps} n C L^2 B (C_B + 0,7) 10^{-3}$

where:

F_M : Distribution factor along the ship length, to be taken as follows (see Fig 2):

- $F_M = 0,0$ for $x \leq 0$
- $F_M = 1,0$ for $0,4L \leq x \leq 0,65L$
- $F_M = 0,0$ for $x \geq L$

Intermediate values of F_M are to be obtained by linear interpolation

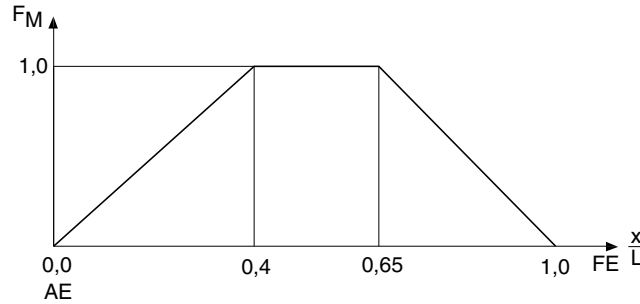
f_{ps} : Coefficient for strength assessments as defined in Ch 5, Sec 3

n : Navigation coefficient as defined in Ch 5, Sec 3, [1.1.2] for a reference length calculated with:

$$\alpha = \frac{315}{486} \cdot \frac{1}{C_w^{1,3}}$$

$$f_\alpha = 1,0$$

Figure 2 : Distribution factor F_M



3.1.2 Bow flare impact

The sagging wave bending moment for strength assessment is to be increased according to [3.1.3] in order to account for the effect of bow flare impact where all the following conditions occur:

- $120 \text{ m} \leq L \leq 200 \text{ m}$
- $V \geq 17,5$ knots
- $\frac{400F(A_{DK} - A_{WL})}{3LB} > 1$

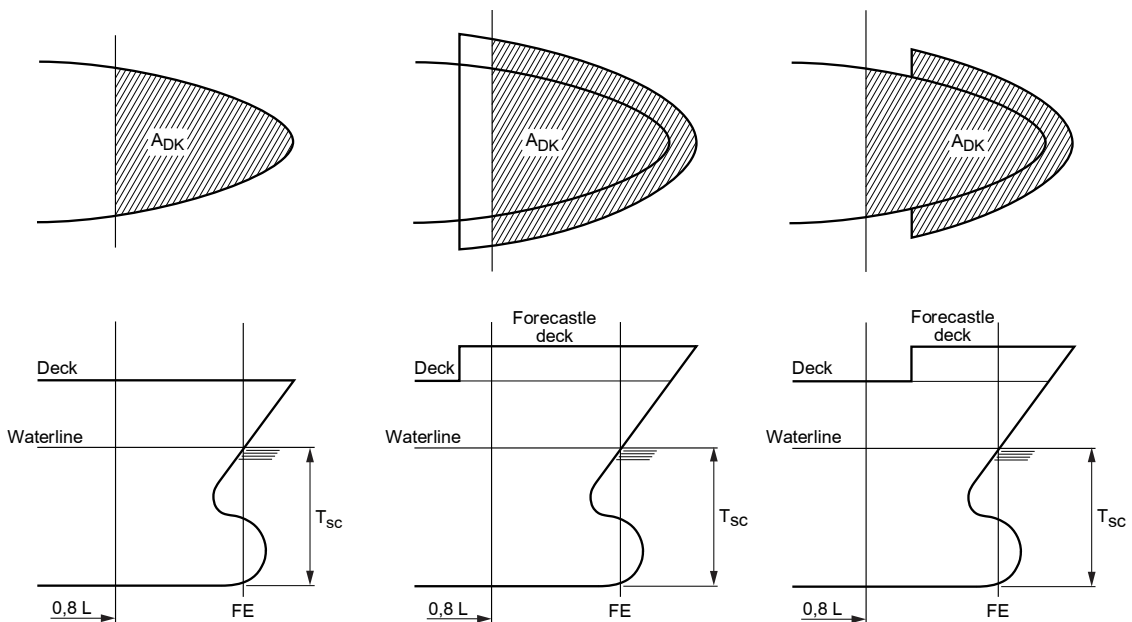
A_{DK} : Projected area to the horizontal plane of decks, in m^2 , including the forecastle deck, extending from $0,8 L$ forward (see Fig 3)

A_{WL} : Waterplane area, in m^2 , at scantling draught T_{sc} , extending from $0,8 L$ forward

The Society may require the effects of bow flare impact to be considered also when one of the above conditions does not occur, if deemed necessary on the basis of the ship's characteristics. In such cases, the increase in sagging wave bending moment is defined on a case by case basis.

Note 1: This requirement is not applicable to ships assigned the service notation **container ship**.

Figure 3 : Projected area A_{DK}



3.1.3 Increase of the vertical wave bending moment due to bow flare impact

The sagging wave bending moment for strength assessment at any longitudinal position, defined in [3.1.1], is to be multiplied by the coefficient F_D obtained from the formulae in Tab 2, which takes into account the dynamic effects of bow flare impact.

Where at least one of the conditions in [3.1.2] does not occur, the coefficient F_D may be taken equal to 1.

As an alternative to the above formulae, the Society may accept the evaluation of the effects of bow flare impact from direct calculations, when justified on the basis of the ship's characteristics and intended service. The calculations are to be submitted to the Society for approval.

Table 2 : Coefficient F_D

Hull transverse section location	Coefficient F_D
$0 \leq x < 0,4 L$	1
$0,4 L \leq x < 0,5 L$	$1 + 10(C_D - 1)\left(\frac{x}{L} - 0,4\right)$
$0,5 L \leq x \leq L$	C_D
Note 1: $C_D = 262,5 \frac{A_{DK} - A_{WL}}{CLB(C_B + 0,7)} - 0,6$ with $1,0 \leq C_D \leq 1,2$ A_{DK} and A_{WL} are defined in [3.1.2]	

3.1.4 Vertical wave bending moments for fatigue assessment

For fatigue assessment purpose, the vertical wave bending moments M_{wv-h} and M_{wv-s} in kN-m, at any longitudinal position, are to be taken as:

- in hogging condition: $M_{wv-h} = 1,5 f_{m-h} H L^3 C_W f_{BL}^{0,8}$
- in sagging condition: $M_{wv-s} = -1,5 f_{m-s} H L^3 C_W f_{BL}^{0,8}$

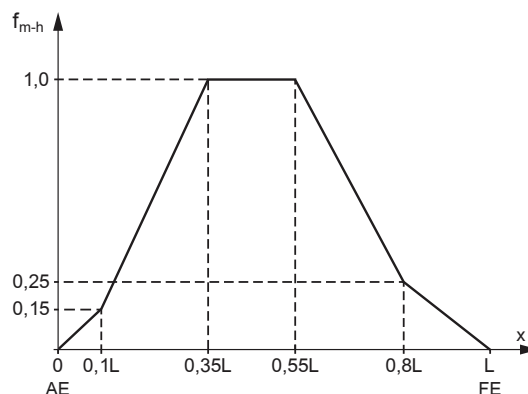
where:

f_{m-h} : Distribution factor for vertical wave bending moment in hogging condition along the ship's length, to be taken as follows (see Fig 4):

- $f_{m-h} = 0,0$ for $x \leq 0$
- $f_{m-h} = 0,15$ for $x = 0,1 L$
- $f_{m-h} = 1,00$ for $0,35 L \leq x \leq 0,55 L$
- $f_{m-h} = 0,25$ for $x = 0,8 L$
- $f_{m-h} = 0,0$ for $x \geq L$

Intermediate values of f_{m-h} are to be obtained by linear interpolation.

Figure 4 : Distribution factor f_{m-h}

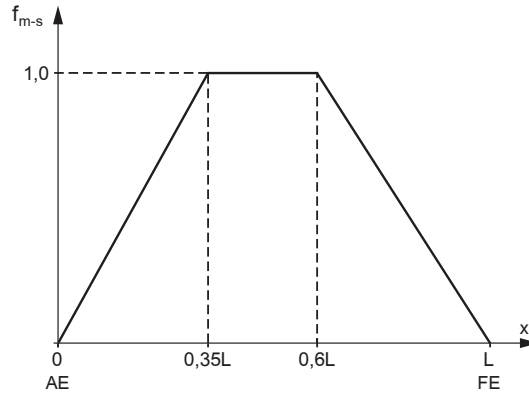


f_{m-s} : Distribution factor for vertical wave bending moment in sagging condition along the ship's length, to be taken as follows (see Fig 5):

- $f_{m-s} = 0,0$ for $x \leq 0$
- $f_{m-s} = 1,0$ for $0,35 L \leq x \leq 0,6 L$
- $f_{m-s} = 0,0$ for $x \geq L$

Intermediate values of f_{m-s} are to be obtained by linear interpolation

Figure 5 : Distribution factor f_{m-s}



H : Wave parameter for a reference length L_{ref} calculated with:

$$\alpha = \frac{315}{486} \cdot \frac{1}{C_W^{1,3}}$$

$$f_\alpha = 1,0$$

3.2 Vertical wave shear force

3.2.1 Vertical wave shear force for strength assessment

For strength assessment purposes, the vertical wave shear forces Q_{wv-pos} and Q_{wv-neg} , in kN, at any longitudinal position, are to be taken as:

$$Q_{wv-pos} = 30 F_{Q-pos} f_{ps} n C L B (C_B + 0,7) 10^{-2}$$

$$Q_{wv-neg} = 30 F_{Q-neg} f_{ps} n C L B (C_B + 0,7) 10^{-2}$$

where:

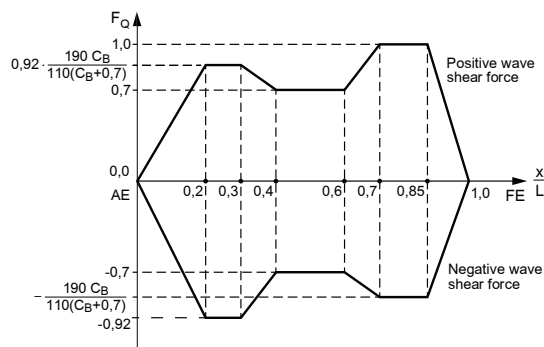
F_{Q-pos} : Distribution factor along the ship length for positive shear force, to be taken as (see Fig 6):

- $F_{Q-pos} = 0,0$ for $x \leq 0$
- $F_{Q-pos} = 0,92 \cdot \frac{190C_B}{110(C_B + 0,7)}$ for $0,2L \leq x \leq 0,3L$
- $F_{Q-pos} = 0,7$ for $0,4L \leq x \leq 0,6L$
- $F_{Q-pos} = 1,0$ for $0,7L \leq x \leq 0,85L$
- $F_{Q-pos} = 0,0$ for $x \geq L$

F_{Q-neg} : Distribution factor along the ship length for negative shear force, to be taken as (see Fig 6):

- $F_{Q-neg} = 0,0$ for $x \leq 0$
- $F_{Q-neg} = -0,92$ for $0,2L \leq x \leq 0,3L$
- $F_{Q-neg} = -0,7$ for $0,4L \leq x \leq 0,6L$
- $F_{Q-neg} = -\frac{190C_B}{110C_B + 0,7}$ for $0,7L \leq x \leq 0,85L$
- $F_{Q-neg} = 0,0$ for $x \geq L$

Figure 6 : Distribution factor F_{Q-pos} and F_{Q-neg}



n : Navigation coefficient as defined in Ch 5, Sec 3, [1.1.2] for a reference length calculated with:

$$\alpha = \frac{330}{486} \cdot \frac{1}{C_W^{1,3}}$$

$$f_\alpha = 1,0$$

3.2.2 Vertical wave shear force for fatigue assessment

For fatigue assessment purposes, the vertical wave shear forces Q_{wv-pos} and Q_{wv-neg} , in kN, at any longitudinal position, are to be taken as:

$$Q_{wv-pos} = f_{q-pos} H L^2 C_W f_{BL}^{0,8}$$

$$Q_{wv-neg} = - f_{q-neg} H L^2 C_W f_{BL}^{0,8}$$

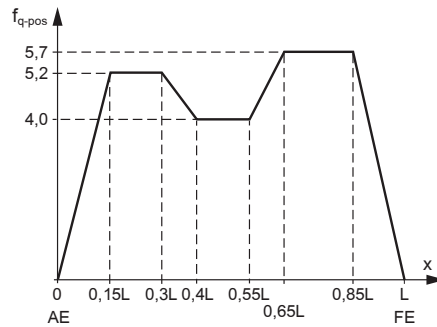
where:

f_{q-pos} : Distribution factor along the ship length for positive wave shear force, to be taken as (see Fig 7):

- $f_{q-pos} = 0,0$ for $x \leq 0$
- $f_{q-pos} = 5,2$ for $0,15L \leq x \leq 0,3L$
- $f_{q-pos} = 4,0$ for $0,4L \leq x \leq 0,55L$
- $f_{q-pos} = 5,7$ for $0,65L \leq x \leq 0,85L$
- $f_{q-pos} = 0,0$ for $x \geq L$

Intermediate values of f_{q-pos} are to be obtained by linear interpolation.

Figure 7 : Distribution factor f_{q-pos}



f_{q-neg} : Distribution factor along the ship length for negative wave shear force, to be taken as (see Fig 8):

- $f_{q-neg} = 1,3$ for $x \leq 0$
- $f_{q-neg} = 5,2$ for $0,15L \leq x \leq 0,3L$
- $f_{q-neg} = 4,0$ for $0,4L \leq x \leq 0,50L$
- $f_{q-neg} = 5,7$ for $0,6L \leq x \leq 0,75L$
- $f_{q-neg} = 0,0$ for $x \geq L$

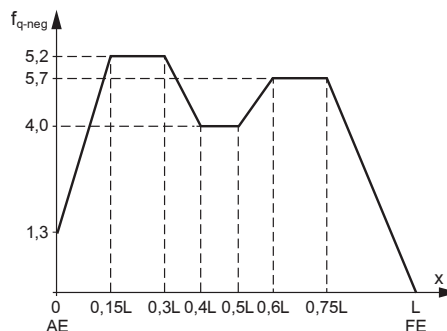
Intermediate values of f_{q-neg} are to be obtained by linear interpolation

H : Wave parameter for a reference length L_{ref} calculated with:

$$\alpha = \frac{330}{486} \cdot \frac{1}{C_W^{1,3}}$$

$$f_\alpha = 1,0$$

Figure 8 : Distribution factor f_{q-neg}



3.3 Horizontal wave bending moment

3.3.1 The horizontal wave bending moment M_{wh} , in kN·m, at any longitudinal position, is to be taken as:

$$M_{wh} = 2,6 \cdot f_R \cdot f_S \cdot f_{nl} \cdot f_m \cdot H \cdot L^3 \cdot C_{B-LC}^{0,3} \cdot \left(\frac{T_{LC}}{L}\right)^{0,8}$$

where:

f_R : Routing factor as defined in Ch 5, Sec 3

f_S : Speed effect coefficient as defined in Ch 5, Sec 3 and to be taken as $f_S = 1,0$

f_{nl} : Coefficient considering non-linear effects and to be taken equal to 1,0

f_m : Distribution factor for horizontal wave bending moment along the ship length, to be taken as (see Fig 9):

- $f_m = 0,0$ for $x \leq 0$
- $f_m = 0,25$ for $x = 0,15 L$
- $f_m = 1,00$ for $0,4 L \leq x \leq 0,6 L$
- $f_m = 0,20$ for $x = 0,85 L$
- $f_m = 0,0$ for $x \geq L$

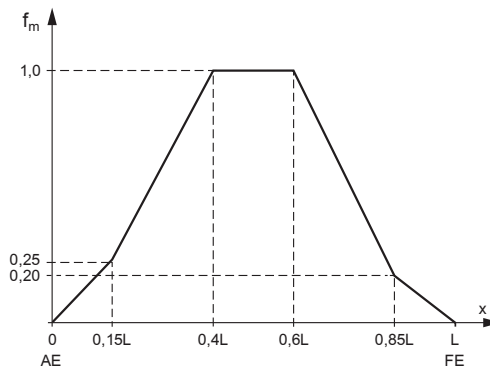
Intermediate values of f_m are to be obtained by linear interpolation

H : Wave parameter for a reference length L_{ref} calculated with:

$$\alpha = 0,65 \left(\frac{T_{LC}}{L}\right)^{-0,3}$$

$$f_\alpha = 1,0$$

Figure 9 : Distribution factor f_m



3.4 Horizontal wave shear force

3.4.1 The horizontal wave shear force Q_{wh} , in kN, at any longitudinal position, is to be taken as: $Q_{wh} = Q_{wh-a} + Q_{wh-f}$

where:

$$Q_{wh-a} = 10,2 \cdot f_R \cdot f_S \cdot f_{q-a} \cdot f_{nl} \cdot H \cdot L^2 \cdot C_{B-LC}^{0,6} \cdot \left(\frac{T_{LC}}{L}\right)^{0,8}$$

$$Q_{wh-f} = 19,2 \cdot f_R \cdot f_S \cdot f_{q-f} \cdot f_{nl} \cdot H \cdot L^2 \cdot C_{B-LC}^{0,8} \cdot \frac{T_{LC}}{L}$$

with:

f_R : Routing factor as defined in Ch 5, Sec 3

f_S : Speed effect coefficient as defined in Ch 5, Sec 3 and to be taken as $f_S = 1,0$

f_{nl} : Coefficient considering non-linear effects and to be taken equal to 1,0

f_{q-a} : Distribution factor for the aft part of the horizontal wave shear force along the ship length, to be taken as (see Fig 10):

- $f_{q-a} = 0,0$ for $x \leq 0$
- $f_{q-a} = 1,0$ for $0,20 L \leq x \leq 0,35 L$
- $f_{q-a} = 0,4$ for $0,45 L \leq x \leq 0,55 L$
- $f_{q-a} = 0,0$ for $x \geq 0,65 L$

Intermediate values of f_{q-a} are to be obtained by linear interpolation.

- f_{q-f} : Distribution factor for the fore part of the horizontal wave shear force along the ship length, to be taken as (see Fig 11):
- $f_{q-f} = 0,0$ for $x \leq 0,35 L$
 - $f_{q-f} = 0,4$ for $0,45 L \leq x \leq 0,55 L$
 - $f_{q-f} = 1,0$ for $0,65 L \leq x \leq 0,80 L$
 - $f_{q-f} = 0,0$ for $x \geq L$

Intermediate values of f_{q-f} are to be obtained by linear interpolation

- H : Wave parameter for a reference length L_{ref} calculated with:

$$\alpha = 0,68 \left(\frac{T_{LC}}{L} \right)^{-0,3}$$

$$f_{\alpha} = 1,0$$

Figure 10 : Distribution factor f_{q-a}

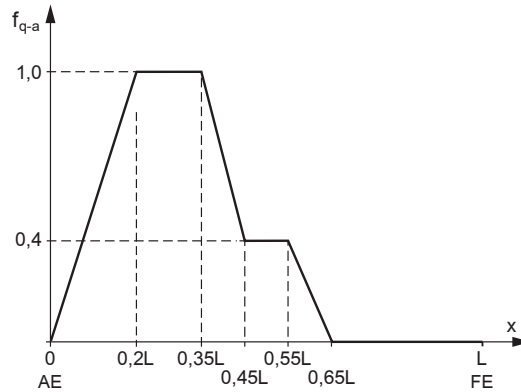
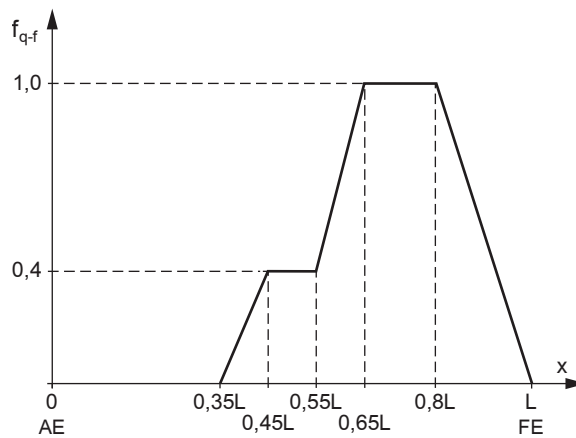


Figure 11 : Distribution factor f_{q-f}



3.5 Wave torsional moment

3.5.1 The wave torsional moment M_{wt} , in kN·m, at any longitudinal position with respect to the horizontal shear centre, is to be taken as: $M_{wt} = M_{wt-a} + M_{wt-f}$

where:

$$M_{wt-a} = \text{Max}(M_{wt-a, \text{min}}, Q_{wh-a} |z_T - 0,45B|)$$

$$M_{wt-a, \text{min}} = 2,50 \cdot f_{q-a} \cdot f_R \cdot f_S \cdot H \cdot L^{0,7} \cdot B^{2,3}$$

$$M_{wt-f} = \text{Max}(M_{wt-f, \text{min}}, Q_{wh-f} |z_T - 0,30B|)$$

$$M_{wt-f, \text{min}} = 1,16 \cdot f_{q-f} \cdot f_R \cdot f_S \cdot H \cdot L \cdot B^2$$

with:

Q_{wh-a} , Q_{wh-f} : Horizontal wave shear forces as defined in [3.4.1]

z_T : Vertical coordinate from baseline, in m, of the horizontal shear centre at the transverse section under consideration. When z_T is not known, the value is to be taken equal to $-0,35 B$ for ships having large openings in the strength decks as defined in Ch 6, Sec 1, [1.6]

f_R : Routing factor as defined in Ch 5, Sec 3

f_S : Coefficient as defined in Ch 5, Sec 3 and to be taken as $f_S = 1,0$ for fatigue assessment

f_{q-a}, f_{q-f} : Distribution factors in the fore and aft part as defined in [3.4.1]

H : Wave parameter for a reference length L_{ref} calculated with:

$$\alpha = 0,68 \left(\frac{T_{LC}}{L} \right)^{-0,3}$$

$$f_\alpha = 1,0$$

3.6 Hull girder loads for dynamic load cases

3.6.1 Vertical wave bending moment

The vertical wave bending moment M_{wv-LC} , in kN·m, to be used for each dynamic load case in Ch 5, Sec 2, is defined in Tab 3.

3.6.2 Vertical wave shear force

The vertical wave shear force, Q_{wv-LC} , in kN, to be used for each dynamic load case in Ch 5, Sec 2, is defined in Tab 4.

3.6.3 Horizontal wave bending moment

The horizontal wave bending moment M_{wh-LC} , in kN·m, to be used for each dynamic load case defined in Ch 5, Sec 2, is to be taken as:

$$M_{wh-LC} = f_\beta C_{WH} M_{wh}$$

where:

C_{WH} : Load combination factor for horizontal wave bending moment, to be taken as specified in Ch 5, Sec 2

M_{wh} : Horizontal wave bending moment taking account of the appropriate design load scenario, as defined in [3.3.1].

3.6.4 Horizontal wave shear force

The horizontal wave shear force Q_{wh-LC} , in kN, to be used for each dynamic load case defined in Ch 5, Sec 2, is to be taken as:

$$Q_{wh-LC} = f_\beta C_{QH} Q_{wh}$$

where:

C_{QH} : Load combination factor for horizontal wave bending shear force, to be taken as specified in Ch 5, Sec 2

Q_{wh} : Horizontal wave shear force taking account of the appropriate design load scenario, as defined in [3.4.1].

3.6.5 Wave torsional moment

The wave torsional moment M_{wt-LC} , in kN·m, to be used for each dynamic load case defined in Ch 5, Sec 2, is to be taken as:

$$M_{wt-LC} = f_\beta C_{WT} M_{wt}$$

where:

C_{WT} : Load combination factor for wave torsional moment, to be taken as specified in Ch 5, Sec 2

M_{wt} : Wave torsional moment taking account of the appropriate design load scenario, as defined in [3.5.1].

Table 3 : Vertical wave bending moment M_{wv-LC} for dynamic load cases

$C_{WV} \geq 0$	$M_{wv-LC} = f_\beta C_{WV} M_{wv-h}$
$C_{WV} < 0$	$M_{wv-LC} = f_\beta C_{WV} M_{wv-s} $

Note 1:

C_{WV} : Load combination factor for vertical wave bending moment, to be taken as specified in Ch 5, Sec 2

M_{wv-h}, M_{wv-s} : Hogging and sagging vertical wave bending moments taking account of the considered design load scenario, as defined in [3.1.1]

Table 4 : Vertical wave shear force Q_{wv-LC} for dynamic load cases

$C_{QV} \geq 0$	$Q_{wv-LC} = f_\beta C_{QV} Q_{wv-pos}$
$C_{QV} < 0$	$Q_{wv-LC} = f_\beta C_{QV} Q_{wv-neg} $

Note 1:

C_{QV} : Load combination factor for vertical wave shear force, to be taken as specified in Ch 5, Sec 2

Q_{wv-pos}, Q_{wv-neg} : Positive and negative vertical wave shear forces taking account of the considered design load scenario, as defined in [3.2.1]

Section 5 Environmental Loads

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

- B_x : Moulded breadth at the waterline (T_{LC}), in m, at the considered cross-section
 $B_{x,max}$: Greatest moulded breadth, in m, measured at the considered cross-section below the weather deck
 C_{B-LC} : Block coefficient at the considered loading condition draught, as defined in Ch 1, Sec 3, [2.1.9]
 C_{W-LC} : Waterplane coefficient at the considered loading condition draught, as defined in Ch 1, Sec 3, [2.1.10]
 f_β : Heading correction factor as defined in Ch 5, Sec 3
 f_{BL}, f_{TL} : Ratios as defined in Ch 5, Sec 3
 f_R : Routing factor as defined in Ch 5, Sec 3
 f_{yB} : Ratio between Y-coordinate of the load point and B_x , to be taken as:

$$f_{yB} = \frac{|2y|}{B_x}$$

without being taken greater than 1,0

$$f_{yB} = 1,0 \text{ when } B_x = 0$$

- f_{zT} : Ratio between Z-coordinate of the load point and draught T_{LC} , to be taken as:

$$f_{zT} = \frac{Z}{T_{LC}}$$

without being taken less than 0

- h_W : Water head equivalent to the pressure at the waterline, in m, to be taken as:

$$h_W = \frac{P_{W,WL}}{\rho g}$$

- $P_{W,WL}$: Wave pressure at the waterline (T_{LC}), in kN/m^2 , for the considered load case, to be taken as: $P_{W,WL} = \text{Max}(P_W; 0)$ with P_W calculated at $z = T_{LC}$ and:

- $y = B_x/2$ when $y \geq 0$
- $y = -B_x/2$ when $y < 0$

- T_R : Dimensionless roll period, as defined in Ch 5, Sec 2.

1 Sea pressure

1.1 Total pressure

1.1.1 The external pressure P_{ex} at any load point of the hull, in kN/m^2 , for the static design load scenarios, is to be taken as:

$$P_{ex} = P_S$$

The total pressure P_{ex} at any load point of the hull, for the static + dynamic design load scenarios, is to be derived for each load case and is to be taken as:

$$P_{ex} = P_S + P_W$$

without being taken less, for static + dynamic load scenarios other than fatigue, than:

- $2,5 \text{ kN/m}^2$ for prescriptive strength assessment
- 0 kN/m^2 for direct strength analysis

where:

P_S : Hydrostatic pressure, in kN/m^2 , defined in [1.2]

P_W : Hydrodynamic pressure, in kN/m^2 , defined in [1.3] and [1.4].

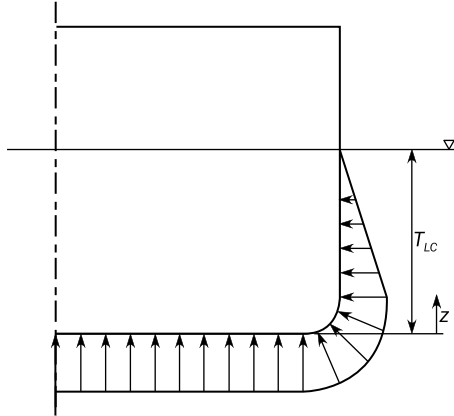
1.2 Hydrostatic pressure

1.2.1 The hydrostatic pressure P_S at any load point, in kN/m^2 , is obtained from Tab 1. See also Fig 1.

Table 1 : Hydrostatic pressure P_S

Location	P_{Sr} in kN/m^2
$z < T_{LC}$	$\rho g (T_{LC} - z)$
$z \geq T_{LC}$	0

Figure 1 : Distribution of hydrostatic pressure P_S



1.3 External dynamic pressure for strength assessment

1.3.1 Hydrodynamic pressure for all load cases

The hydrodynamic pressure P_w at any load point, in kN/m^2 , is to be obtained, for all load cases, from Tab 2.

Table 2 : Hydrodynamic pressure P_w in kN/m^2 - Strength assessment

Load case as defined in Ch 5, Sec 2, Tab 1	$z \leq T_{LC}$	$T_{LC} < z \leq h_w + T_{LC}$	$z > h_w + T_{LC}$
HVM1 FVM1 BP1-P BP1-S OHM2-P OHM2-S OHS2-P OHS2-S OVA1-P OVA1-S	$-P_{EDW}$	$P_{w,WL} - \rho g(z - T_{LC})$	0,0
HVM2 FVM2 BP2-P BP2-S OHM1-P OHM1-S OHS1-P OHS1-S OVA2-P OVA2-S	P_{EDW}		
BR1-P BR1-S	$-P_{EDW} + P_{SR}$		
BR2-P BR2-S	$P_{EDW} + P_{SR}$		
Note 1:			
P_{EDW} : Hydrodynamic pressure defined in [1.3.2]			
P_{SR} : Hydrostatic pressure, in kN/m^2 , due to the roll motion, to be taken as:			
$P_{SR} = -\rho g y \frac{C_{YG} \theta}{180} \pi$			
C_{YG} : Load combination factor for the gravitational acceleration due to roll, as defined in Ch 5, Sec 2			

1.3.2 Hydrodynamic pressure at any point

The hydrodynamic pressure P_{EDW} for each EDW as defined in Ch 5, Sec 2, Tab 1, at any load point of the hull, in kN/m^2 , is to be taken as:

- when $f_{yB} \geq f_{zT}$:

$$P_{EDW} = (1 - f_{yB})P_{CL} + (f_{yB} - f_{zT})P_{BL} + f_{zT}P_{WL}$$
- when $f_{yB} < f_{zT}$:

$$P_{EDW} = (1 - f_{zT})P_{CL} + (f_{zT} - f_{yB})P_M + f_{yB}P_{WL}$$

where:

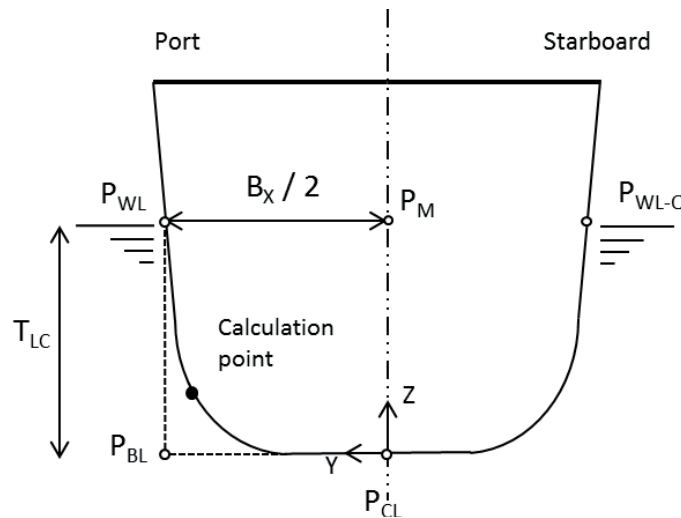
- P_{CL} : Hydrodynamic pressure at the bottom centreline (see Fig 2) defined in [1.3.3], for the considered EDW
- P_{BL} : Hydrodynamic pressure at the bilge line (see Fig 2) defined in [1.3.3], for the considered EDW
- P_{WL} : Hydrodynamic pressure at the waterline (see Fig 2) defined in [1.3.3], for the considered EDW
- P_M : Intermediate hydrodynamic pressure (see Fig 2), to be taken as:

$$P_M = 0,5 (P_{WL} + P_{WL-O})$$
- P_{WL-O} : Hydrodynamic pressure at the waterline on the opposite side (see Fig 2), to be taken as:

$$P_{WL-O} = P_{WL}$$
 with P_{WL} as defined in [1.3.3], for the considered EDW, calculated on the side opposite to the load point. When the load point is located on the centreline ($y = 0$), the lee side is to be considered as the opposite side.

Note 1: Weather side and lee side are detailed in Ch 5, Sec 2, Tab 2 to Ch 5, Sec 2, Tab 7 for each load case.

Figure 2 : Hydrodynamic pressures



1.3.3 Hydrodynamic pressures at the centreline, bilge and waterline

The hydrodynamic pressures at the bottom centreline P_{CL} , at the bilge line P_{BL} and at the waterline P_{WL} , for each EDW, in kN/m^2 , is to be taken as:

$$P_i = \rho g f_R f_{nl} f_\beta H f_{k,i}$$

where:

$$f_{k,i} = k_i + k_{T,i} f_{TL} + k_{CB,i} C_{B-LC} + k_{CW,i} C_{W-LC} + k_{B,i} f_{BL} + k_{R,i} T_R$$

i : Location where the hydrodynamic pressure is calculated, to be taken as:

- CL at the bottom centreline
- BL at the bilge line
- WL at the waterline

H : Wave parameter defined in Ch 5, Sec 3, for a reference length L_{ref} calculated with α to be taken in Tab 3, for the considered EDW

f_{nl} : Coefficient considering non-linear effects, to be taken in Tab 3, for the considered EDW and design load scenario

$k_i, k_{T,i}, k_{CB,i}, k_{CW,i}, k_{B,i}, k_{R,i}$: Coefficients in the longitudinal direction, to be taken in Tab 6 to Tab 17, for the considered EDW. Intermediate values are obtained by linear interpolation.

- When portside is the weather side for the considered load case:
 - for load points located on portside ($y > 0$), the coefficients for the weather side are to be used
 - for load points located on starboard side ($y < 0$), the coefficients for the lee side are to be used

- When starboard side is the weather side for the considered load case:
 - for load points located on starboard side ($y < 0$), the coefficients for the weather side are to be used
 - for load points located on portside ($y > 0$), the coefficients for the lee side are to be used
- When load points are located at centreline ($y = 0$), the coefficients for the weather side are to be used.

1.3.4 Envelope of dynamic pressure

The envelope of dynamic pressure at any point P_{ex-max} is to be taken as the greatest pressure value obtained from any of the load cases in accordance with [1.3.1].

1.4 External dynamic pressure for fatigue assessment

1.4.1 Hydrodynamic pressure for all load cases

The hydrodynamic pressure P_w for all load cases, at any load point, in kN/m^2 , is to be taken as:

$$P_w = f_{iw} P_{wf}$$

where:

P_{wf} : hydrodynamic pressure, in kN/m^2 , as defined in Tab 18

f_{iw} : factor accounting for the non-linearity due to intermittent wetting, to be taken as defined in Tab 19.

Table 3 : Coefficients for hydrodynamic pressure strength assessment

EDW	α	$f_{nl}(1)$
HVM	$0,65 C_{W-LC}^{-1,3}$	f_{nl-1}
FVM	$0,65 C_{W-LC}^{-1,3}$	f_{nl-2}
BR	$4,6 T_R^{-2}$	f_{nl-3}
BP	$0,55 f_{TL}^{-0,4}$	f_{nl-4}
OHM	$0,65 f_{TL}^{-0,3}$	f_{nl-5}
OHS	$0,68 f_{TL}^{-0,3}$	f_{nl-5}
OVA	$0,24 f_{BL}^{-0,8}$	f_{nl-6}

(1) f_{nl-1} to f_{nl-6} are to be taken from:

- Tab 4 for extreme sea design load scenario
- Tab 5 for ballast water exchange design load scenario.

Table 4 : Non-linear coefficients f_{nl} for extreme sea design load scenario

f_{nl}	$x/L=0$	$x/L=0,3$	$x/L=0,7$	$x/L=1,0$
f_{nl-1}	0,7	0,9	0,9	0,6
f_{nl-2}	0,9	0,9	0,9	0,9
f_{nl-3}	1,0	1,0	1,0	1,0
f_{nl-4}	0,6	0,8	0,8	0,6
f_{nl-5}	0,8	0,8	0,8	0,8
f_{nl-6}	0,5	0,8	0,8	0,6

Note 1: Intermediate values are obtained by linear interpolation.

Table 5 : Non-linear coefficients f_{nl} for ballast water exchange design load scenario

f_{nl}	$x/L=0$	$x/L=0,3$	$x/L=0,7$	$x/L=1,0$
f_{nl-1}	0,85	0,95	0,95	0,80
f_{nl-2}	0,95	0,95	0,95	0,95
f_{nl-3}	1,00	1,00	1,00	1,00
f_{nl-4}	0,60	0,80	0,80	0,60
f_{nl-5}	0,90	0,90	0,90	0,90
f_{nl-6}	0,75	0,90	0,90	0,80

Note 1: Intermediate values are obtained by linear interpolation.

Table 6 : Coefficients for HVM load cases on weather and lee sides Strength assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}	17,0	3,27	-3,98	-3,54	0,274	3,18	2,02	-5,09	-18,1	-33,4	-41,3
	$k_{T,CL}$	-31,5	0,777	9,99	-2,12	-27,0	-54,4	-76,9	-93,3	-108	-124	-136
	$k_{CB,CL}$	1,10	-4,01	-8,74	-10,1	-8,00	-3,37	2,93	10,5	18,6	23,3	9,13
	$k_{CW,CL}$	-20,9	-3,07	9,79	13,1	10,0	4,90	1,01	0,778	5,19	13,9	29,0
	$k_{B,CL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,CL}$	0	0	0	0	0	0	0	0	0	0	0
BL	k_{BL}	17,4	4,10	-3,88	-3,25	1,94	5,28	1,94	-8,38	-20,9	-32,2	-40,9
	$k_{T,BL}$	-31,4	-2,78	7,71	-12,5	-51,2	-93,1	-128	-149	-152	-143	-120
	$k_{CB,BL}$	1,63	-5,02	-11,5	-13,0	-9,77	-3,30	4,33	11,4	13,9	10,0	6,12
	$k_{CW,BL}$	-21,8	-3,21	12,1	16,4	12,2	5,75	3,10	5,87	12,6	22,7	30,0
	$k_{B,BL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,BL}$	0	0	0	0	0	0	0	0	0	0	0
WL	k_{WL}	17,0	2,59	-8,14	-6,20	1,90	6,66	2,22	-8,72	-21,0	-33,0	-37,0
	$k_{T,WL}$	-41,8	-11,6	15,9	14,6	-12,2	-57,9	-113	-163	-192	-205	-273
	$k_{CB,WL}$	1,17	-6,54	-16,8	-19,3	-14,6	-5,76	4,01	11,5	9,98	0,723	-1,97
	$k_{CW,WL}$	-22,0	-1,34	20,4	24,9	17,2	7,98	5,13	8,20	17,9	33,4	36,2
	$k_{B,WL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,WL}$	0	0	0	0	0	0	0	0	0	0	0

Table 7 : Coefficients for FVM load cases on weather and lee sides Strength assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}	-21,7	-21,2	-10,8	-2,05	2,51	2,88	0,371	-3,89	-8,95	-12,7	-11,8
	$k_{T,CL}$	20,3	30,0	18,9	1,63	-12,8	-21,6	-24,4	-23,5	-21,4	-16,4	-0,699
	$k_{CB,CL}$	-21,8	-20,0	-13,8	-7,93	-2,24	2,46	5,85	8,43	10,2	9,45	0,391
	$k_{CW,CL}$	33,0	34,7	22,4	10,9	2,78	-1,46	-2,65	-1,95	0,0681	2,53	6,35
	$k_{B,CL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,CL}$	0	0	0	0	0	0	0	0	0	0	0
BL	k_{BL}	-21,1	-22,7	-13,2	-1,79	4,03	3,73	-0,209	-5,06	-9,20	-11,7	-11,9
	$k_{T,BL}$	19,8	41,7	28,0	-0,845	-21,6	-32,1	-34,4	-31,2	-24,4	-13,9	-2,86
	$k_{CB,BL}$	-20,4	-23,5	-18,0	-9,18	-1,52	4,19	7,77	9,08	7,69	4,69	0,773
	$k_{CW,BL}$	31,0	38,3	28,2	12,7	1,98	-2,64	-3,03	-1,31	1,75	4,61	6,27
	$k_{B,BL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,BL}$	0	0	0	0	0	0	0	0	0	0	0
WL	k_{WL}	-24,5	-27,6	-15,8	-1,32	6,12	5,08	-0,089	-4,85	-9,08	-11,7	-11,1
	$k_{T,WL}$	13,2	63,7	73,4	46,6	18,0	-5,60	-25,7	-39,1	-46,7	-44,0	-8,12
	$k_{CB,WL}$	-24,2	-28,5	-21,8	-9,95	0,259	7,08	10,9	10,5	5,64	2,70	8,46
	$k_{CW,WL}$	36,8	46,5	33,4	13,1	-1,20	-6,00	-5,37	-2,39	3,81	6,89	-1,81
	$k_{B,WL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,WL}$	0	0	0	0	0	0	0	0	0	0	0

Table 8 : Coefficients for BR load cases on weather side Strength assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}	-3,10	-3,02	-2,38	-1,72	-1,27	-1,04	-1,21	-1,84	-2,54	-2,52	-0,97
	$k_{T,CL}$	-22,7	-23,6	-23,8	-23,3	-23,0	-23,7	-26,4	-30,7	-35,9	-40,9	-44,0
	$k_{CB,CL}$	-1,52	-0,856	-0,49	-0,755	-1,11	-1,32	-1,07	-0,491	0,137	-0,232	-3,03
	$k_{CW,CL}$	2,21	2,22	1,68	1,42	1,37	1,40	1,39	1,49	1,63	2,04	3,20
	$k_{B,CL}$	-2,94	-0,885	0,751	1,58	1,74	1,71	2,03	2,75	2,97	1,43	-2,80
	$k_{R,CL}$	0,714	0,529	0,384	0,293	0,248	0,23	0,25	0,301	0,378	0,451	0,467
BL	k_{BL}	-2,86	-3,43	-1,56	-0,968	-1,19	-0,905	-0,226	-0,744	-2,36	-2,69	-1,08
	$k_{T,BL}$	-17,2	-26,7	-32,9	-31,3	-31,5	-32,4	-35,3	-40,6	-48,8	-51,4	-45,7
	$k_{CB,BL}$	-1,90	-2,17	-1,29	-0,859	-0,644	-1,11	-1,52	-1,93	-1,37	-0,992	-2,94
	$k_{CW,BL}$	2,50	4,24	2,06	0,947	0,98	1,38	1,46	2,59	3,69	3,47	3,30
	$k_{B,BL}$	-1,48	1,16	0,493	-0,433	-0,908	-1,30	-1,38	0,605	2,96	1,85	-2,34
	$k_{R,BL}$	0,454	0,263	0,216	0,241	0,26	0,211	0,144	0,0925	0,173	0,335	0,454
WL	k_{WL}	0,196	-0,151	3,89	2,73	-0,504	-0,508	3,66	4,78	1,39	-1,58	0,197
	$k_{T,WL}$	6,85	-12,5	-31,2	-29,9	-31,8	-33,9	-29,5	-32,2	-44,4	-45,6	-24,0
	$k_{CB,WL}$	-3,80	-3,09	-0,731	-0,0209	0,985	-0,0628	-3,97	-7,46	-6,33	-3,66	-4,14
	$k_{CW,WL}$	3,07	3,75	-3,45	-4,00	-1,81	-0,301	-0,167	2,52	4,79	5,34	4,40
	$k_{B,WL}$	-1,86	0,987	-1,20	-8,49	-10,9	-11,5	-13,5	-11,7	-2,46	3,53	-3,21
	$k_{R,WL}$	-0,155	-0,253	0,133	0,587	0,805	0,713	0,40	0,161	0,143	0,116	0,0294

Table 9 : Coefficients for BR load cases on lee side Strength assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL} , $k_{T,CL}$, $k_{CB,CL}$, $k_{CW,CL}$, $k_{B,CL}$ and $k_{R,CL}$ are identical to the coefficients on weather side.											
BL	k_{BL}	-2,62	-2,23	-6,08	-7,43	-7,42	-7,28	-6,70	-3,38	1,56	2,90	-0,623
	$k_{T,BL}$	-36,9	-30,7	-15,9	-13,4	-13,1	-13,4	-13,6	-9,44	-3,33	-12,9	-37,9
	$k_{CB,BL}$	1,35	2,23	-0,601	-2,13	-3,02	-3,26	-3,12	-4,27	-6,95	-6,98	-3,61
	$k_{CW,BL}$	-1,27	-4,05	1,72	4,84	5,96	6,18	5,45	3,30	1,34	1,05	3,21
	$k_{B,BL}$	-5,24	-8,45	-13,0	-15,2	-16,0	-16,5	-17,1	-20,1	-23,3	-17,7	-4,38
	$k_{R,BL}$	1,16	1,54	1,70	1,67	1,61	1,58	1,59	1,51	1,24	0,888	0,47
WL	k_{WL}	1,06	0,176	-6,99	-8,37	-7,07	-6,77	-7,29	-3,42	3,58	6,19	1,53
	$k_{T,WL}$	-34,0	-39,4	-29,7	-30,6	-27,3	-26,1	-29,6	-24,9	-11,8	-11,6	-28,9
	$k_{CB,WL}$	3,81	5,74	2,10	-0,121	-1,84	-2,03	-0,622	-0,62	-4,89	-7,41	-5,73
	$k_{CW,WL}$	-5,99	-9,86	0,0271	4,18	5,05	5,13	4,27	0,355	-2,15	-1,28	4,47
	$k_{B,WL}$	-5,11	-7,07	-12,4	-13,9	-15,9	-17,1	-17,3	-20,8	-26,7	-21,6	-6,42
	$k_{R,WL}$	0,995	1,82	2,16	2,08	1,91	1,87	1,96	1,91	1,54	0,972	0,177

Table 10 : Coefficients for BP load cases on weather side Strength assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}	3,20	5,13	4,24	2,72	1,74	1,55	2,57	5,07	7,07	5,10	1,90
	$k_{T,CL}$	67,9	56,0	54,8	59,1	65,9	74,8	84,9	96,0	107	119	179
	$k_{CB,CL}$	14,2	7,75	3,75	4,93	7,25	8,29	6,98	2,86	-2,53	-1,79	14,7
	$k_{CW,CL}$	-10,9	-8,65	-5,00	-4,77	-5,92	-6,67	-6,50	-5,24	-2,27	-0,484	-10,9
	$k_{B,CL}$	-16,7	-13,0	-14,0	-15,7	-17,0	-19,0	-22,5	-27,7	-32,9	-35,3	-41,8
	$k_{R,CL}$	0,273	0,126	0,0321	-0,0166	-0,0402	-0,0346	0,00217	0,0798	0,263	0,559	0,483
BL	k_{BL}	-18,3	-6,49	15,3	21,1	23,2	23,9	22,3	11,5	-9,27	-22,9	0,263
	$k_{T,BL}$	173	-13,2	-77,0	-84,5	-68,8	-54,0	-47,5	-63,6	-88,7	-49,5	87,1
	$k_{CB,BL}$	-35,6	-12,9	7,91	11,7	12,8	13,7	14,8	17,9	33,3	47,4	24,6
	$k_{CW,BL}$	59,1	40,0	-0,942	-11,0	-14,9	-16,5	-15,5	-6,39	0,678	0,088	-14,4
	$k_{B,BL}$	-1,80	32,1	59,4	68,8	70,1	66,4	60,7	59,8	63,5	44,9	-22,0
	$k_{R,BL}$	-1,64	-2,58	-2,67	-2,73	-2,79	-2,77	-2,63	-2,23	-1,36	-0,693	0,448
WL	k_{WL}	-31,9	-21,5	-0,379	10,7	22,7	24,5	12,8	-2,11	-20,9	-31,6	-3,56
	$k_{T,WL}$	200	2,29	-39,9	-37,0	10,9	42,6	31,2	17,2	18,7	60,7	108
	$k_{CB,WL}$	-46,5	-18,5	8,86	18,1	18,7	21,2	31,6	53,8	75,0	85,6	36,8
	$k_{CW,WL}$	81,3	62,8	21,2	0,709	-15,0	-19,7	-14,9	-18,9	-19,3	-20,6	-24,3
	$k_{B,WL}$	-17,3	9,34	26,3	52,8	59,7	51,1	41,9	42,9	38,0	11,7	-18,2
	$k_{R,WL}$	-1,02	-1,47	-1,21	-1,31	-1,50	-1,39	-1,06	-0,85	-0,451	-0,279	0,395

Table 11 : Coefficients for BP load cases on lee side Strength assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL} , $k_{T,CL}$, $k_{CB,CL}$, $k_{CW,CL}$, $k_{B,CL}$ and $k_{R,CL}$ are identical to the coefficients on weather side.											
BL	k_{BL}	16,9	6,67	-7,90	-10,8	-10,8	-10,3	-9,59	-4,40	6,67	15,8	2,68
	$k_{T,BL}$	-38,9	100	134	149	165	180	192	210	240	256	255
	$k_{CB,BL}$	48,5	26,6	15,1	14,8	15,8	16,5	17,0	15,3	4,59	-9,26	7,03
	$k_{CW,BL}$	-58,0	-38,4	-12,5	-9,4	-11,0	-12,2	-13,0	-16,3	-17,5	-13,5	-7,91
	$k_{B,BL}$	-29,3	-54,8	-70,8	-73,8	-75,0	-77,8	-81,8	-87,6	-94,0	-89,6	-58,2
	$k_{R,BL}$	2,24	3,16	3,32	3,42	3,47	3,45	3,40	3,20	2,61	1,84	0,547
WL	k_{WL}	9,33	1,25	-11,0	-12,5	-11,6	-10,5	-9,66	-5,50	4,57	13,1	-1,49
	$k_{T,WL}$	-62,0	92,7	150	195	227	250	267	289	314	300	299
	$k_{CB,WL}$	44,8	20,0	14,7	18,0	20,0	21,4	24,2	28,0	20,8	4,92	11,1
	$k_{CW,WL}$	-50,1	-26,7	-7,35	-10,3	-14,9	-17,5	-19,4	-25,9	-29,2	-23,4	-7,84
	$k_{B,WL}$	-20,3	-54,2	-80,9	-87,8	-88,5	-92,7	-99,3	-103	-105	-97,8	-76,2
	$k_{R,WL}$	2,01	2,51	3,03	3,55	3,80	3,74	3,46	2,89	2,00	1,45	0,821

Table 12 : Coefficients for OHM load cases on weather side Strength assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}	-39,6	-19,1	-6,91	-3,11	-2,37	-2,10	-1,08	1,77	8,16	14,0	9,36
	$k_{T,CL}$	91,4	-17,6	-43,1	-31,2	-10,1	4,72	7,62	2,30	-5,07	-31,3	-140
	$k_{CB,CL}$	-30,9	-13,7	-5,56	-4,04	-4,87	-6,66	-10,0	-16,7	-27,7	-40,4	-30,4
	$k_{CW,CL}$	57,3	30,6	13,1	7,08	5,51	5,89	8,14	12,4	17,0	25,8	33,8
	$k_{B,CL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,CL}$	0	0	0	0	0	0	0	0	0	0	0
BL	k_{BL}	-37,8	-26,4	-30,8	-33,6	-36,1	-35,2	-29,9	-20,5	-8,04	1,82	5,81
	$k_{T,BL}$	119	26,8	-0,433	38,7	98,1	136	121	73,7	29,4	-10,1	-133
	$k_{CB,BL}$	-23,4	-11,8	-18,7	-24,8	-30,1	-34,7	-39,1	-42,2	-42,5	-38,3	-31,2
	$k_{CW,BL}$	47,3	32,2	43,7	47,8	49,9	50,7	52,3	52,3	47,0	39,3	38,2
	$k_{B,BL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,BL}$	0	0	0	0	0	0	0	0	0	0	0
WL	k_{WL}	-45,7	-23,6	-24,6	-30,2	-35,5	-31,8	-22,4	-18,2	-12,2	-2,96	-15,5
	$k_{T,WL}$	219	31,0	-56,2	-60,2	-26,6	4,18	3,23	1,51	43,1	89,7	-135
	$k_{CB,WL}$	-29,6	-7,77	-19,0	-33,1	-41,7	-46,1	-52,7	-51,0	-34,1	-31,0	-70,7
	$k_{CW,WL}$	59,4	30,5	42,7	54,1	58,8	54,2	54,7	59,9	47,3	38,8	103
	$k_{B,WL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,WL}$	0	0	0	0	0	0	0	0	0	0	0

Table 13 : Coefficients for OHM load cases on lee side Strength assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL} , $k_{T,CL}$, $k_{CB,CL}$, $k_{CW,CL}$, $k_{B,CL}$ and $k_{R,CL}$ are identical to the coefficients on weather side.											
BL	k_{BL}	-38,8	-12,5	9,53	18,7	24,9	30,3	33,2	28,8	20,8	17,0	12,8
	$k_{T,BL}$	56,4	-62,6	-101	-123	-142	-158	-175	-202	-227	-218	-150
	$k_{CB,BL}$	-32,9	-23,6	-13,4	-9,75	-8,62	-7,84	-7,45	-7,90	-8,83	-20,7	-29,3
	$k_{CW,BL}$	59,6	33,2	4,97	-4,97	-10,1	-14,5	-15,9	-8,17	3,33	17,5	29,5
	$k_{B,BL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,BL}$	0	0	0	0	0	0	0	0	0	0	0
WL	k_{WL}	-42,7	-10,5	11,2	17,6	25,8	32,5	32,1	25,0	18,7	18,5	4,41
	$k_{T,WL}$	75,6	-56,1	-106	-141	-163	-187	-217	-252	-283	-297	-162
	$k_{CB,WL}$	-38,6	-27,4	-16,9	-16,7	-15,8	-14,9	-11,1	-2,70	0,92	-19,8	-45,0
	$k_{CW,WL}$	69,3	34,8	7,05	4,27	-2,08	-7,47	-7,63	-4,55	0,0669	17,2	54,3
	$k_{B,WL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,WL}$	0	0	0	0	0	0	0	0	0	0	0

Table 14 : Coefficients for OHS load cases on weather side Strength assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}	12,3	7,12	3,87	2,55	1,38	0,364	0,55	2,51	2,67	-12,4	-44,6
	$k_{T,CL}$	-49,6	-13,6	-13,7	-18,0	-13,1	-4,19	-11,5	-43,8	-85,2	-107	-55,2
	$k_{CB,CL}$	37,1	17,2	7,26	3,34	1,33	-0,0341	-0,421	-0,337	-2,16	-8,38	-21,8
	$k_{CW,CL}$	-33,4	-17,6	-7,93	-4,34	-3,04	-2,62	-2,67	-2,66	1,67	24,0	62,7
	$k_{B,CL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,CL}$	0	0	0	0	0	0	0	0	0	0	0
BL	k_{BL}	12,8	-5,20	-25,2	-31,8	-34,6	-35,5	-29,7	-13,2	-1,21	-17,4	-48,1
	$k_{T,BL}$	12,8	60,0	38,0	38,8	65,0	96,1	90,1	12,3	-104	-138	-61,4
	$k_{CB,BL}$	44,7	32,9	17,5	5,85	-2,20	-7,25	-11,3	-13,4	-15,8	-18,4	-22,7
	$k_{CW,BL}$	-43,4	-19,3	14,5	27,9	31,2	29,8	25,3	15,9	16,4	40,5	67,8
	$k_{B,BL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,BL}$	0	0	0	0	0	0	0	0	0	0	0
WL	k_{WL}	16,0	-6,82	-27,2	-33,2	-35,5	-31,9	-16,3	0,317	3,40	-21,4	-59,3
	$k_{T,WL}$	-27,9	61,0	61,1	47,1	17,2	-12,3	-34,7	-95,6	-163	-76,9	-131
	$k_{CB,WL}$	49,2	36,7	22,4	5,55	-8,15	-14,0	-23,1	-36,0	-26,0	-27,6	-45,6
	$k_{CW,WL}$	-49,0	-20,3	13,3	30,1	36,3	28,8	17,3	21,7	27,8	57,5	105
	$k_{B,WL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,WL}$	0	0	0	0	0	0	0	0	0	0	0

Table 15 : Coefficients for OHS load cases on lee side Strength assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL} , $k_{T,CL}$, $k_{CB,CL}$, $k_{CW,CL}$, $k_{B,CL}$ and $k_{R,CL}$ are identical to the coefficients on weather side.											
BL	k_{BL}	10,7	19,6	37,1	41,6	39,5	33,6	26,7	20,1	11,3	-5,84	-40,4
	$k_{T,BL}$	-103	-93,8	-88,2	-108	-114	-90,5	-85,2	-110	-136	-132	-23,3
	$k_{CB,BL}$	27,1	14,2	17,9	17,9	12,5	3	-4,89	-10,9	-17,6	-25	-25,7
	$k_{CW,BL}$	-20,3	-23,7	-47,5	-51,4	-44,7	-33,6	-21,6	-9,23	5,89	28,5	58,8
	$k_{B,BL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,BL}$	0	0	0	0	0	0	0	0	0	0	0
WL	k_{WL}	16,2	20,7	38,2	45,3	45,0	37,4	25,6	18,5	11,5	-8,50	-46,9
	$k_{T,WL}$	-195	-157	-140	-133	-121	-86,6	-84,3	-117	-145	-154	-36,7
	$k_{CB,WL}$	33,2	9,44	16,6	24,0	19,7	2,46	-11,0	-21,1	-34,3	-39,6	-41,0
	$k_{CW,WL}$	-28,4	-21,2	-48,0	-59,6	-54,4	-35,4	-13,6	2,81	21,4	45,9	80,2
	$k_{B,WL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,WL}$	0	0	0	0	0	0	0	0	0	0	0

Table 16 : Coefficients for OVA load cases on weather side Strength assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}	-25,5	-10,5	-1,91	-0,26	-1,39	-2,49	-1,55	3,61	14,7	29,5	35,2
	$k_{T,CL}$	60,0	9,67	10,7	33,8	61,7	84,1	98,9	113	136	167	165
	$k_{CB,CL}$	-4,00	0,827	6,19	7,88	7,13	4,51	-0,323	-8,63	-22,7	-38,4	-19,8
	$k_{CW,CL}$	25,2	9,37	-4,10	-8,70	-8,30	-5,51	-2,06	0,328	1,68	2,66	-8,89
	$k_{B,CL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,CL}$	0	0	0	0	0	0	0	0	0	0	0
BL	k_{BL}	-22,1	-5,51	-2,87	-4,19	-6,49	-5,38	1,38	9,28	14,4	20,2	34,5
	$k_{T,BL}$	41,5	-48,7	-27,3	39,6	108	154	163	139	108	110	109
	$k_{CB,BL}$	7,03	19,7	22,8	24,6	23,6	19,0	13,7	9,46	9,70	7,79	-11,6
	$k_{CW,BL}$	12,0	-11,4	-18,8	-23,0	-22,4	-19,1	-17,7	-16,0	-14,9	-15,0	-11,0
	$k_{B,BL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,BL}$	0	0	0	0	0	0	0	0	0	0	0
WL	k_{WL}	-23,8	0,807	6,04	1,70	-5,74	-6,46	1,16	7,59	12,3	20,6	19,5
	$k_{T,WL}$	34,8	-103	-103	-31,8	75,2	182	239	225	189	199	252
	$k_{CB,WL}$	2,07	19,5	26,4	32,1	33,0	26,8	20,0	23,2	32,9	24,3	-44,1
	$k_{CW,WL}$	21,8	-13,8	-29,7	-37,3	-35,6	-30,4	-28,0	-28,7	-33,9	-31,5	33,6
	$k_{B,WL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,WL}$	0	0	0	0	0	0	0	0	0	0	0

Table 17 : Coefficients for OVA load cases on lee side Strength assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL} , $k_{T,CL}$, $k_{CB,CL}$, $k_{CW,CL}$, $k_{B,CL}$ and $k_{R,CL}$ are identical to the coefficients on weather side.											
BL	k_{BL}	-25,0	-13,7	-4,56	-0,107	1,76	2,73	3,31	4,80	13,6	29,7	35,5
	$k_{T,BL}$	75,1	96,4	98,1	103	120	141	157	170	200	237	198
	$k_{CB,BL}$	-6,03	-13,3	-12,7	-11,5	-12,4	-14,6	-16,7	-18,9	-23,1	-34,5	-22,6
	$k_{CW,BL}$	25,9	20	10,4	5,17	3,97	4,83	6,43	7,22	1,31	-4,47	-8,97
	$k_{B,BL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,BL}$	0	0	0	0	0	0	0	0	0	0	0
WL	k_{WL}	-26,4	-12,4	-0,0823	2,54	2,82	2,83	0,648	0,0939	10,8	31,0	27,9
	$k_{T,WL}$	106	116	98,2	103	134	175	193	193	216	280	327
	$k_{CB,WL}$	-5,46	-13,1	-10,4	-9,67	-12,1	-14,4	-12,6	-4,38	-1,43	-21,8	-37,2
	$k_{CW,WL}$	28,8	19,9	4,87	1,29	2,51	3,64	4,64	-1,50	-16,6	-20,6	8,91
	$k_{B,WL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,WL}$	0	0	0	0	0	0	0	0	0	0	0

Table 18 : Hydrodynamic pressure P_{wf} in kN/m² Fatigue assessment

Load case	$z \leq T_{LC}$	$z > T_{LC}$
HVM1 HVMf1 BP1-P BP1-S OHM2-P OHM2-S	$- P_{EDW}$	$P_{W,WL}$
HVM2 HVMf2 BP2-P BP2-S OHM1-P OHM1-S	P_{EDW}	
BR1-P BR1-S	$- P_{EDW} + P_{SR}$	
BR2-P BR2-S	$P_{EDW} + P_{SR}$	
Note 1:		
P_{EDW} : Hydrodynamic pressure as defined in [1.3.2] with P_{CL} , P_{BL} , P_{WL} and P_{WL-O} as defined in [1.3.3], calculated with coefficients to be taken in Tab 20 to Tab 28. P_{SR} : Hydrostatic pressure due to the roll motion as defined in Tab 2.		

Table 19 : Factor f_{iw} for intermittent wetting

P_{wf}	$z \leq T_{LC}$	$z > T_{LC}$
$P_{wf} = 0$	0	0
$P_{wf} > 0$	1	10^a
$P_{wf} < 0$	$1 - 10^b$	0
Note 1:		
a, b : Coefficients to be taken as: $a = -\frac{2}{3} \left(\frac{z - T_{LC}}{h_w} \right)$ $b = -1,2 \left[\frac{\rho g (z - T_{LC})}{P_{wf}} \right]^{1,2}$		

Table 20 : Coefficients for hydrodynamic pressure Fatigue assessment

EDW	α	$f\alpha$	f_{nt}
HVM	$0,65 C_{W-LC}^{-1,3}$	1,0	1,0
HVMf	$0,65 C_{W-LC}^{-1,3}$		
BR	$4,6 T_R^{-2}$		
BP	$0,55 \left(\frac{T_{LC}}{L} \right)^{-0,4}$		
OHM	$0,65 \left(\frac{T_{LC}}{L} \right)^{-0,3}$		

Table 21 : Coefficients for HVM load cases on weather and lee sides Fatigue assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}	29,5	9,78	-1,68	-1,73	2,60	5,87	3,98	-5,98	-24,7	-45,3	-50,9
	$k_{T,CL}$	-86,1	-15,2	8,53	-3,38	-33,2	-64,7	-90,0	-110	-130	-139	-104
	$k_{CB,CL}$	5,37	-0,418	-8,14	-11,3	-10,5	-6,22	1,80	14,9	33,5	51,6	34,0
	$k_{CW,CL}$	-32,1	-11,4	6,92	12,0	9,71	4,66	0,107	-1,83	-0,44	0,826	10,9
	$k_{B,CL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,CL}$	0	0	0	0	0	0	0	0	0	0	0
BL	k_{BL}	29,6	11,7	1,42	1,73	5,22	5,63	-0,766	-14,0	-29,3	-43,2	-50,1
	$k_{T,BL}$	-86,2	-27,5	-1,08	-20,2	-64,8	-109	-137	-149	-148	-135	-74,6
	$k_{CB,BL}$	4,53	-2,73	-10,9	-11,9	-6,54	1,82	11,5	21,8	28,7	31,0	28,9
	$k_{CW,BL}$	-31,4	-10,8	6,76	10,3	5,99	0,652	-1,62	0,105	5,21	11,7	12,4
	$k_{B,BL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,BL}$	0	0	0	0	0	0	0	0	0	0	0
WL	k_{WL}	31,2	8,85	-3,19	1,52	7,44	7,20	0,297	-12,5	-28,3	-45,2	-32,7
	$k_{T,WL}$	-109	-49,9	-2,72	-6,70	-45,7	-101	-144	-184	-220	-241	-272
	$k_{CB,WL}$	7,92	-6,64	-21,3	-20,2	-8,79	5,15	16,6	21,0	18,3	21,1	54,8
	$k_{CW,WL}$	-36,9	-5,19	20,3	18,5	7,29	-1,52	-5,30	0,801	15,2	25,5	-27,4
	$k_{B,WL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,WL}$	0	0	0	0	0	0	0	0	0	0	0

Table 22 : Coefficients for HVMf load cases on weather and lee sides Fatigue assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}	27,1	3,77	-4,09	-1,30	2,70	4,54	2,70	-5,04	-21,0	-41,7	-52,3
	$k_{T,CL}$	-164	-55,5	-24,9	-39,1	-64,4	-85,0	-101	-115	-123	-103	8,38
	$k_{CB,CL}$	-7,65	-10,8	-15,1	-14,4	-10,2	-4,12	3,42	13,1	27,1	45,8	48,4
	$k_{CW,CL}$	-17,1	5,31	17,6	16,7	11,1	4,62	-0,566	-2,08	0,772	1,98	-1,36
	$k_{B,CL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,CL}$	0	0	0	0	0	0	0	0	0	0	0
BL	k_{BL}	27,4	4,87	-0,151	5,32	7,17	3,67	-3,11	-13,0	-26,0	-41,4	-51,4
	$k_{T,BL}$	-166	-86,1	-78,2	-109	-135	-146	-149	-151	-135	-85,3	38,7
	$k_{CB,BL}$	-8,73	-18,0	-22,6	-17,7	-8,21	2,28	11,8	19,6	24,1	30,4	43,2
	$k_{CW,BL}$	-16,4	12,0	23,6	17,7	9,64	3,49	-0,233	0,09	5,57	10,4	-0,0756
	$k_{B,BL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,BL}$	0	0	0	0	0	0	0	0	0	0	0
WL	k_{WL}	27,2	-5,07	-5,64	5,63	9,32	4,00	-2,29	-11,0	-25,0	-44,3	-42,8
	$k_{T,WL}$	-152	-78,6	-73,1	-113	-133	-149	-171	-201	-205	-170	-157
	$k_{CB,WL}$	-2,10	-27,0	-37,8	-29,0	-11,8	5,32	16,7	17,3	9,89	13,3	52,7
	$k_{CW,WL}$	-24,9	29,1	43,8	30,7	13,8	2,85	-3,75	1,85	19,2	31,4	-13,9
	$k_{B,WL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,WL}$	0	0	0	0	0	0	0	0	0	0	0

Table 23 : Coefficients for BR load cases on weather side Fatigue assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}	-3,70	-2,99	-2,21	-1,47	-0,887	-0,481	-0,457	-0,876	-1,37	-0,857	1,44
	$k_{T,CL}$	-31,0	-27,6	-25,6	-23,8	-22,6	-22,7	-24,5	-28,5	-34,2	-41,1	-49,4
	$k_{CB,CL}$	-3,76	-2,21	-1,10	-0,841	-0,847	-0,847	-0,631	0,0509	1,01	1,49	-1,13
	$k_{CW,CL}$	4,26	3,27	2,00	1,22	0,802	0,564	0,501	0,384	0,102	-0,69	-0,327
	$k_{B,CL}$	-3,88	-0,58	1,68	3,03	3,22	3,13	3,23	3,63	3,64	2,13	-0,863
	$k_{R,CL}$	1,12	0,626	0,371	0,218	0,123	0,0561	0,0286	0,0581	0,12	0,172	0,101
BL	k_{BL}	-3,29	-2,50	-0,469	0,261	0,428	1,12	1,75	1,48	0,488	0,848	1,69
	$k_{T,BL}$	-26,5	-30,5	-33,5	-30,8	-28,9	-28,5	-30,1	-34,4	-41,4	-45,8	-49,9
	$k_{CB,BL}$	-4,57	-4,24	-2,47	-0,817	-0,173	-0,372	-0,834	-0,696	-0,28	0,294	-1,15
	$k_{CW,BL}$	5,41	5,60	2,61	0,414	-0,20	-0,117	0,398	1,08	1,73	0,264	-0,362
	$k_{B,BL}$	-1,92	3,43	3,13	1,45	0,907	0,622	0,853	1,93	3,48	3,07	-0,044
	$k_{R,BL}$	0,604	-0,0623	-0,266	-0,289	-0,372	-0,582	-0,804	-0,927	-0,865	-0,612	-0,019
WL	k_{WL}	-0,684	1,76	5,31	3,27	0,924	1,85	5,55	5,96	3,77	2,95	5,36
	$k_{T,WL}$	-1,06	-16,6	-36,8	-39,9	-39,5	-38,1	-32,8	-34,8	-41,7	-39,3	-10,2
	$k_{CB,WL}$	-7,00	-4,23	-0,408	0,403	1,32	0,46	-3,68	-9,59	-9,45	-3,25	-2,11
	$k_{CW,WL}$	7,16	3,14	-4,84	-4,68	-3,04	-2,10	-0,841	5,17	7,53	2,64	-0,598
	$k_{B,WL}$	-0,898	4,44	-0,643	-8,99	-11,1	-11,7	-12,7	-10,9	-3,39	3,45	-0,535
	$k_{R,WL}$	-0,218	-0,652	-0,0948	0,531	0,564	0,187	-0,345	-0,717	-0,913	-1,10	-1,28

Table 24 : Coefficients for BR load cases on lee side Fatigue assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL} , $k_{T,CL}$, $k_{CB,CL}$, $k_{CW,CL}$, $k_{B,CL}$ and $k_{R,CL}$ are identical to the coefficients on weather side.											
BL	k_{BL}	-2,97	-3,55	-7,27	-7,88	-7,18	-6,55	-5,60	-2,36	1,92	3,18	1,38
	$k_{T,BL}$	-43,9	-42,6	-32,5	-30,1	-28,8	-28,0	-27,2	-22,5	-17,1	-25,0	-45,8
	$k_{CB,BL}$	0,667	-0,0293	-4,10	-5,32	-5,36	-4,94	-4,64	-4,93	-7,15	-6,92	-1,52
	$k_{CW,BL}$	-1,72	-1,82	4,82	6,99	6,91	6,25	5,13	2,28	0,503	0,465	-0,19
	$k_{B,BL}$	-7,36	-16,1	-23,0	-25,2	-25,6	-25,7	-25,7	-27,4	-27,0	-17,9	-1,67
	$k_{R,BL}$	1,94	2,74	3,19	3,11	2,89	2,73	2,64	2,46	2,03	1,28	0,161
WL	k_{WL}	0,337	-4,17	-11,2	-11,2	-8,87	-8,01	-7,83	-3,81	2,18	4,48	2,74
	$k_{T,WL}$	-39,9	-56,8	-56,8	-58,8	-54,4	-52,1	-52,8	-45,9	-32,3	-29,9	-43,9
	$k_{CB,WL}$	5,64	0,0561	-7,69	-9,75	-9,48	-8,20	-6,08	-4,76	-8,75	-11,6	0,827
	$k_{CW,WL}$	-8,76	-2,23	10,8	13,6	12,1	10,7	8,76	3,52	1,52	3,54	-2,58
	$k_{B,WL}$	-6,92	-19,1	-28,0	-29,7	-31,3	-32,1	-31,5	-32,6	-32,7	-22,2	-0,356
	$k_{R,WL}$	1,90	3,79	4,69	4,54	4,10	3,83	3,72	3,47	2,86	1,70	-0,114

Table 25 : Coefficients for BP load cases on weather side Fatigue assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}	3,81	4,50	3,76	2,14	0,883	0,186	0,656	2,58	4,04	1,27	-3,13
	$k_{T,CL}$	72,1	57,2	49,6	47,7	50,2	54,8	61,0	69,3	79,2	92,7	146
	$k_{CB,CL}$	13,9	6,98	2,49	2,88	4,75	5,80	5,14	1,97	-3,32	-4,72	13,1
	$k_{CW,CL}$	-12,4	-8,07	-3,88	-2,66	-3,20	-3,61	-3,72	-3,05	-0,0293	4,18	-6,20
	$k_{B,CL}$	-15,7	-12,9	-12,3	-13,6	-14,1	-14,6	-16,0	-18,6	-21,3	-22,6	-29,8
	$k_{R,CL}$	0,377	0,27	0,114	0,0903	0,107	0,147	0,203	0,279	0,452	0,746	0,83
BL	k_{BL}	-20,7	-7,90	14,0	19,6	20,6	19,9	18,9	10,4	-9,48	-24,9	-4,61
	$k_{T,BL}$	166	14,8	-35,7	-47,7	-42,0	-35,7	-32,0	-44,1	-74,7	-58,0	68,3
	$k_{CB,BL}$	-48,6	-27,1	-8,13	-4,41	-3,22	-2,22	-1,48	-1,40	10,3	34,4	21,0
	$k_{CW,BL}$	72,2	51,0	12,8	3,52	0,735	0,0956	0,196	9,00	19,5	12,7	-7,21
	$k_{B,BL}$	-6,60	18,7	40,9	48,9	51,4	50,9	48,6	49,2	51,6	36,4	-20,6
	$k_{R,BL}$	-1,02	-1,73	-2,23	-2,32	-2,33	-2,24	-2,09	-1,75	-0,981	-0,241	0,779
WL	k_{WL}	-29,9	-24,5	-3,68	10,4	20,1	19,3	11,8	0,714	-20,2	-36,3	-10,2
	$k_{T,WL}$	192	33,9	-0,503	6,99	36,4	56,2	52,2	37,7	13,4	29,1	44,8
	$k_{CB,WL}$	-51,2	-31,3	-10,4	1,62	5,44	8,85	17,9	33,8	50,1	70,4	36,8
	$k_{CW,WL}$	81,4	71,9	37,2	11,7	-4,08	-7,48	-7,83	-10,6	-3,21	-5,32	-18,9
	$k_{B,WL}$	-12,9	4,90	22,5	43,8	48,8	46,0	43,4	43,9	40,2	14,1	-9,51
	$k_{R,WL}$	-0,774	-0,668	-0,978	-1,19	-1,09	-0,925	-0,644	-0,361	0,288	0,734	0,913

Table 26 : Coefficients for BP load cases on lee side Fatigue assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL} , $k_{T,CL}$, $k_{CB,CL}$, $k_{CW,CL}$, $k_{B,CL}$ and $k_{R,CL}$ are identical to the coefficients on weather side.											
BL	k_{BL}	21,8	7,83	-7,46	-10,9	-11,7	-12,1	-12,4	-8,40	1,97	10,8	-2,54
	$k_{T,BL}$	-18,9	82,2	100	110	120	128	133	146	173	203	210
	$k_{CB,BL}$	63,2	41,0	29,3	28,4	28,8	29,2	29,8	29,6	18,9	-4,34	6,17
	$k_{CW,BL}$	-77,9	-52,9	-26,9	-23,1	-23,4	-23,6	-23,7	-27,6	-29,0	-16,3	-4,49
	$k_{B,BL}$	-21,3	-36,6	-46,4	-47,6	-48,1	-49,2	-50,3	-53,0	-58,0	-59,1	-37,8
	$k_{R,BL}$	1,76	2,59	2,96	3,14	3,26	3,29	3,26	3,11	2,69	2,05	0,928
WL	k_{WL}	14,6	6,62	-7,47	-10,0	-11,1	-11,0	-11,1	-8,79	0,65	8,90	-5,18
	$k_{T,WL}$	-48,6	74,3	118	161	180	192	201	213	232	237	264
	$k_{CB,WL}$	53,7	39,0	35,3	38,5	39,2	39,5	40,8	43,3	37,0	12,8	-11,5
	$k_{CW,WL}$	-64,3	-49,8	-30,9	-33,0	-34,7	-35,5	-36,0	-39,8	-43,6	-29,7	16,2
	$k_{B,WL}$	-12,7	-30,2	-47,3	-53,9	-54,2	-55,0	-56,8	-58,2	-61,4	-62,2	-52,5
	$k_{R,WL}$	1,44	1,46	2,00	2,70	3,19	3,22	2,98	2,57	1,98	1,59	0,0168

Table 27 : Coefficients for OHM load cases on weather side Fatigue assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	k_{CL}	-23,6	-11,9	-6,32	-4,57	-3,99	-3,49	-1,98	2,74	11,1	15,8	6,43
	$k_{T,CL}$	58,2	-21,0	-38,9	-30,1	-15,1	-2,54	4,21	7,85	6,63	-15,7	-125
	$k_{CB,CL}$	-16,5	-4,49	0,939	1,98	1,76	0,85	-2,29	-10,0	-24,1	-35,9	-8,06
	$k_{CW,CL}$	30,1	14,9	6,19	2,91	1,31	0,693	1,66	3,81	8,48	17,5	15,0
	$k_{B,CL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,CL}$	0	0	0	0	0	0	0	0	0	0	0
BL	k_{BL}	-17,3	-13,4	-21,9	-25,4	-25,8	-24,0	-18,0	-6,51	5,39	7,32	4,38
	$k_{T,BL}$	70,0	7,05	2,87	35,8	80,4	113	113	83,9	50,3	-0,373	-94,9
	$k_{CB,BL}$	11,0	20,7	13,3	7,72	2,82	-2,62	-8,69	-16,5	-25,5	-27,0	-11,4
	$k_{CW,BL}$	-2,40	-10,7	3,75	8,56	9,14	9,91	10,7	10,5	12,4	19,9	18,2
	$k_{B,BL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,BL}$	0	0	0	0	0	0	0	0	0	0	0
WL	k_{WL}	-22,5	-10,4	-17,9	-25,8	-25,6	-20,0	-10,2	0,769	6,05	2,52	-29,2
	$k_{T,WL}$	161	11,5	-54,2	-66,9	-56,1	-36,3	-28,4	-12,1	35,5	77,6	-183
	$k_{CB,WL}$	0,707	23,6	17,7	6,22	-2,12	-10,3	-18,4	-26,5	-37,5	-47,0	-95,9
	$k_{CW,WL}$	10,7	-12,7	-0,534	12,4	13,0	10,7	10,4	13,7	25,9	44,6	141
	$k_{B,WL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,WL}$	0	0	0	0	0	0	0	0	0	0	0

Table 28 : Coefficients for OHM load cases on lee side Fatigue assessment

i	Coef.	x/L=0	x/L=0,1	x/L=0,2	x/L=0,3	x/L=0,4	x/L=0,5	x/L=0,6	x/L=0,7	x/L=0,8	x/L=0,9	x/L=1,0
CL	$k_{CL}, k_{T,CL}, k_{CB,CL}, k_{CW,CL}, k_{B,CL}$ and $k_{R,CL}$ are identical to the coefficients on weather side.											
BL	k_{BL}	-26,2	-8,79	4,97	12,1	18,2	22,3	24,0	22,1	20,1	15,4	8,47
	$k_{T,BL}$	42,6	-49,8	-88,4	-113	-135	-154	-168	-187	-202	-204	-114
	$k_{CB,BL}$	-35,5	-30,5	-24,8	-23,8	-22,7	-20,3	-18,3	-19,1	-20,8	-26,2	-11,3
	$k_{CW,BL}$	50,6	35,6	20,3	14,9	9,85	5,07	2,68	6,85	11,5	22,0	14,5
	$k_{B,BL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,BL}$	0	0	0	0	0	0	0	0	0	0	0
WL	k_{WL}	-25,1	-4,16	5,33	10,8	20,4	25,6	24,2	22,2	21,4	16,3	-9,62
	$k_{T,WL}$	55,0	-42,1	-87,7	-121	-159	-197	-238	-272	-293	-304	-233
	$k_{CB,WL}$	-38,7	-32,0	-31,0	-35,4	-34,1	-29,1	-20,1	-13,2	-22,8	-46,0	-53,3
	$k_{CW,WL}$	52,6	32,2	26,0	28,3	20,5	13,0	8,82	6,37	16,3	42,0	77,7
	$k_{B,WL}$	0	0	0	0	0	0	0	0	0	0	0
	$k_{R,WL}$	0	0	0	0	0	0	0	0	0	0	0

2 Sea chests

2.1 Design pressure

2.1.1 In addition to the sea pressure P_{ex} in kN/m^2 , as calculated in Article [1] for sides and bottom, the pressure P_{sc} defined by the designer to cover the hazard of an overpressure due to the inlet grating cleaning system is to be considered for the scantling of sea chests without being taken less than 200 kN/m^2 .

3 External pressure on exposed decks

3.1 Application

3.1.1 External pressure on exposed decks is only to be applied for strength assessment.

3.1.2 Green sea pressure defined in [3.2] for exposed decks is to be considered independently of the pressure due to:

- distributed cargo or other equipment loads, and
- any concentrated forces due to cargo or other unit equipment loads,

defined in Ch 5, Sec 6, [6.1] and Ch 5, Sec 6, [6.2] respectively.

3.2 Green sea loads

3.2.1 Pressure on exposed deck

The external dynamic pressure due to green sea P_d at any point of an exposed deck, in kN/m^2 , for the static + dynamic design load scenarios is to be derived for each dynamic load case and is to be taken as defined in [3.2.3] to [3.2.4].

The external dynamic pressure due to green sea P_d at any point of an exposed deck for the static design load scenario is zero.

3.2.2 If a breakwater is fitted on the exposed deck, no reduction of the external dynamic pressure due to green sea is allowed for the area of the exposed deck located aft of the breakwater.

3.2.3 HVM and FVM load cases

The external pressure P_d for HVM and FVM load cases at any load point of an exposed deck, in kN/m^2 , is to be obtained from the following formula:

$$P_d = \max(P_{W,d}, \chi P_{W,d-\min})$$

where:

$P_{W,d}$: Pressure, in kN/m^2 , obtained at the side of the ship ($y = \pm B_{x,\max}/2$) at considered deck height for HVM and FVM load cases as defined in [1.3]

χ : Coefficient defined in Tab 29

$P_{W,d-\min}$: Pressure to be taken as:

- $P_{W,d-\min} = 0$ for direct strength analysis according to Part B, Chapter 8
- The value defined in Tab 30 for the other analyses.

3.2.4 BR, BP, OHM, OHS and OVA load cases

The external pressure P_d for BR, BP, OHM, OHS and OVA load cases, as defined in Ch 5, Sec 2, Tab 1 at any load point of an exposed deck, in kN/m^2 , is to be obtained by linear interpolation between the pressure values at port and starboard side:

$$P_{d,\text{stb}} = P_{W,d-\text{stb}}$$

$$P_{d,\text{pt}} = P_{W,d-\text{pt}}$$

where:

$P_{W,d-\text{stb}}$: Pressure obtained at starboard side of the ship at considered deck height, to be calculated for BR, BP, OHM, OHS or OVA load cases as per [1.3] as appropriate, considering:

- x = longitudinal coordinate of the calculation point
- $y = -B_{x,\max}/2$
- z = vertical coordinate of the calculation point

$P_{W,d-\text{pt}}$: Pressure obtained at port side at considered deck height for BR, BP, OHM, OHS, and OVA load cases as defined in [1.3], as appropriate, considering:

- x = longitudinal coordinate of the calculation point
- $y = B_{x,\max}/2$
- z = vertical coordinate of the calculation point.

Table 29 : Coefficient χ for pressure on exposed decks

Exposed deck location	χ
Freeboard deck and within the lowest tier	1,00
Within the second tier	0,75
Within the third tier	0,56
Within the fourth tier	0,42
Within the fifth tier	0,32
Within the sixth tier	0,25
Within the seventh tier	0,20
Within the eighth tier	0,15
Top of eighth tier and above	0,10

Note 1: When a deck is located at the limit between two tiers, the coefficient from the tier above is to be considered.

Table 30 : Minimum pressure on exposed deck $P_{W,d-min}$

Load line length L_{LL} , in m	Longitudinal position	Minimum pressure on exposed deck $P_{W,d-min}$, in kN/m ²
$L_{LL} < 100$	$0 \leq x \leq 0,75 L_{LL}$	$14,9 + 0,195 L_{LL}$
	$0,75 L_{LL} < x \leq L_{LL}$	$15,8 + \frac{L_{LL}}{3} \left(1 - \frac{5(L_{LL}-x)}{L_{LL}} \right) - \left(3,6 \frac{(L_{LL}-x)}{L_{LL}} \right)$
$L_{LL} \geq 100$	$0 \leq x \leq 0,75 L_{LL}$	34,3
	$0,75 L_{LL} < x \leq L_{LL}$	$34,3 + \frac{P_{WP} - 34,3}{0,25} \left(\frac{x}{L_{LL}} - 0,75 \right)$

Note 1:
 p_{WP} : Pressure, in kN/m², at the forward perpendicular, to be taken equal to:
 • 49,1 + 0,0726 ($L_{LL} - 100$) for type B ships
 • 49,1 + 0,3560 ($L_{LL} - 100$) for type A, type B-60 or type B-100 ships
 Type A, type B, type B-60 and type B-100 ships are defined in Ch 1, Sec 3, [2.3]
 x : Longitudinal coordinate, in m, of the assessed structural member mid-point, measured from the aft end of length L or L_{LL} , as applicable.

3.2.5 Envelope of dynamic pressure on exposed deck

The envelope of dynamic pressure at any point of an exposed deck P_{d-max} is to be taken as the greatest pressure value obtained from any of the load cases in accordance with [3.2.3] and [3.2.4].

3.3 Load carried on exposed deck

3.3.1 If loads are carried on an exposed deck, for example containers, cargo or equipment, the static and dynamic pressures due to these loads are to be considered as per Ch 5, Sec 6, [6] and Ch 5, Sec 6, [8].

4 External impact pressure

4.1 Application

4.1.1 Impact pressure is only to be applied for strength assessment.

4.2 Bottom and stern slamming impact pressures

4.2.1 Bottom slamming

The bottom impact pressures P_{SLI} due to slamming are to be obtained, in kN/m², from the following formula, without being taken less than 0:

$$P_{SLI} = 100 \frac{h_{SL}^2 - (z - T_F)^2}{T_{RZ}^2 \tan \beta}$$

where:

T_F : Minimum draught at the forward perpendicular, in m, among those foreseen in operation in ballast conditions or conditions of partial loading

h_{SL} : Maximum relative wave elevation, in m, to be taken as follows:

- for $x/L < 0,7$: $h_{SL} = 0$
- for $x/L = 0,7$: $h_{SL} = 4 f_R H C_{B-LC}^{-0,7}$
- for $x/L \geq 0,9$: $h_{SL} = f_c 19 f_R H C_{B-LC}^{-0,7}$

For intermediate values of x/L , h_{SL} is to be obtained by linear interpolation

f_c : Correction factor, taken equal to 0,7

H : Wave parameter defined in Ch 5, Sec 3, for a reference length calculated with:

$$\alpha = 0,34 \left(\frac{T_{LC}}{L} \right)^{-0,28}$$

$$f\alpha = 1,0$$

T_{LC} : Draught amidships, in m, at the loading condition where T_F occurs

T_{RZ} : Mean up crossing period, in s, to be taken as: $T_{RZ} = 1,2 L^{0,40}$

β : Longitudinal or transverse deadrise angle at the calculation point, whichever is the greater, but not to be taken less than 10 deg (see Fig 3).

4.2.2 Stern slamming

The stern impact pressures P_{SLI} due to slamming are to be obtained, in kN/m^2 , from the following formula, without being taken less than 0:

$$P_{SLI} = 100 \frac{h_{SL}^2 - (z - T_{LC})^2}{T_{RZ}^2 \tan \beta}$$

where:

h_{SL} : Maximum relative wave elevation, in m, to be taken as follows:

- for $x/L = 0$: $h_{SL} = 13,7 f_R H C_{B-LC}^{2,5} C_{W-LC}^{-4,9}$
- for $x/L = 0,2$: $h_{SL} = 2,7 f_R H C_{B-LC}^{2,5} C_{W-LC}^{-4,9}$
- for $x/L > 0,2$: $h_{SL} = 0$

For intermediate values of x/L , h_{SL} is to be obtained by linear interpolation.

with:

C_{B-LC} : Block coefficient at considered loading condition draught T_{LC}

C_{W-LC} : Waterplane coefficient at considered loading condition draught T_{LC}

H : Wave parameter defined in Ch 5, Sec 3, for a reference length calculated with:

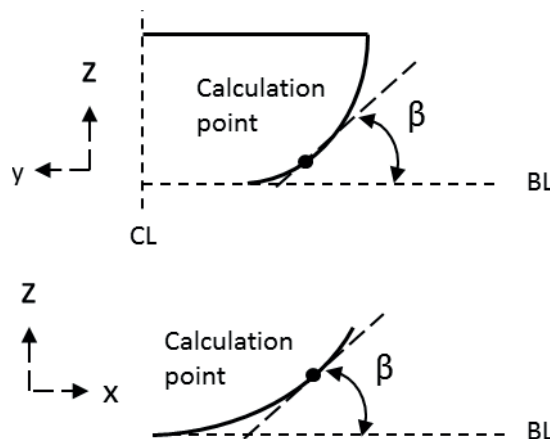
$$\alpha = 0,86$$

$$f\alpha = 1,0$$

T_{RZ} : Mean up crossing period, in s, to be taken as: $T_{RZ} = 3 L^{0,26}$

β : Longitudinal or transverse deadrise angle at the calculation point, whichever is the greater, but not to be taken less than 10 deg (see Fig 3).

Figure 3 : Definition of deadrise angle β



4.3 Bow flare impact pressure

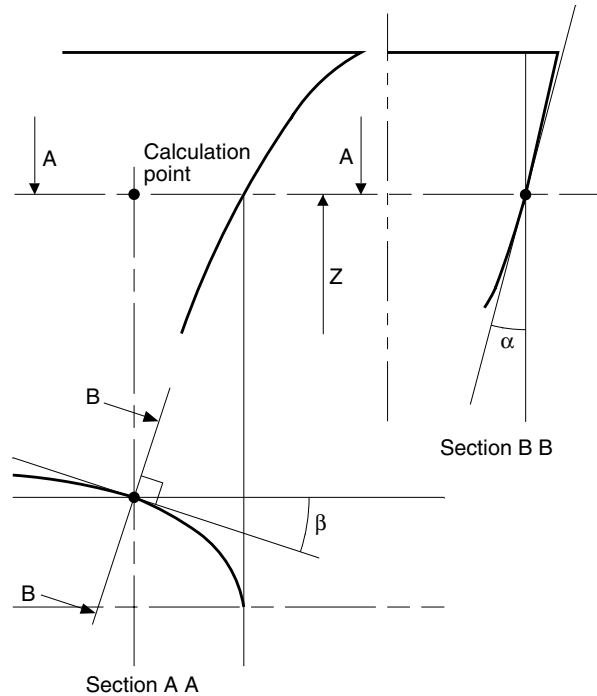
4.3.1 The bow flare impact pressure P_{FI} is to be obtained, in kN/m^2 , from the following formula:

$$P_{FI} = n C_S C_Z (0,22 + 0,15 \tan \alpha) (0,4 V \sin \beta + 0,6 \sqrt{L})^2$$

where:

- C_s : Coefficient depending on the type of structures on which the bow flare impact pressure is considered to be acting:
 - $C_s = 1,8$ for plating and ordinary stiffeners
 - $C_s = 1,1$ for primary supporting members
- C_z : Coefficient depending on the distance between the draught for the considered loading condition and the calculation point:
 - for $z \geq 21,5 H + T_{LC} - 11$:
 $C_z = 10,75 H - 0,5 (z - T_{LC})$, not to be taken smaller than 0
 - for $z < 21,5 H + T_{LC} - 11$:
 $C_z = 5,5$
- H : Wave parameter defined in Ch 5, Sec 3, for a reference length calculated with:
 $\alpha = 0,65 C_{W-LC}^{-1,3}$
 $f\alpha = 1,0$
- α : Flare angle at the calculation point, defined as the angle between a vertical line and the tangent to the side plating, measured in a vertical plane normal to the horizontal tangent to the shell plating (see Fig 4)
- β : Entry angle at the calculation point, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane (see Fig 4).

Figure 4 : Definition of angles α and β



4.4 Berthing impact pressure

4.4.1 Application

The impact pressure induced by the contact of the fenders on the side shell during berthing operations, as defined in [4.4.2], is to be applied to the part of the side shell extending from the ballast draught T_{BAL} to $0,25 T_{SC}$ (minimum 2,2 m) above T_{SC} , in areas where the breadth of the ship is greater than $0,9 B$.

4.4.2 The berthing impact pressure P_{BI} , in kN/m^2 , is to be taken as defined in Tab 31.

Table 31 : Berthing impact pressure

Ship moulded displacement Δ at T_{SC} , in t	P_{BI}
$0 < \Delta \leq 5000$	170
$50000 < \Delta \leq 150000$	180
$150000 < \Delta \leq 250000$	190
$250000 < \Delta \leq 400000$	190
$\Delta > 400000$	210

5 External pressure on front, side and aft bulkheads of superstructures and deckhouses

5.1 Application

5.1.1 External pressure on front, side and aft bulkheads of superstructures and deckhouses is only to be applied for strength assessment.

5.2 Definitions

5.2.1 Superstructures

Superstructures are defined in Ch 1, Sec 3.

5.2.2 Deckhouses

Deckhouses are defined in Ch 1, Sec 3.

5.2.3 Tiers of superstructures and deckhouses

Tiers of superstructures and deckhouses are defined in Ch 1, Sec 3, [2.2.10].

The lowest tier is normally that tier which is directly situated above the uppermost continuous deck to which the moulded depth D is measured. However, when $(D - T_{sc})$ exceeds the minimum non-corrected tabular freeboard (according to ICLL as amended) by at least one standard superstructure height (as defined in Ch 1, Sec 3, Tab 5), then this tier may be defined as the 2nd tier and the tier above as the 3rd tier.

5.3 Superstructures side bulkheads

5.3.1 Lateral pressure

The lateral pressure is to be obtained as defined in Article [1].

When the side is a tank boundary, the internal lateral pressure, as defined in Ch 5, Sec 6, is also to be considered.

5.4 Deckhouses side and end bulkheads and superstructures end bulkheads

5.4.1 Lateral pressure

The lateral pressure to be used for the determination of scantlings of front, side and aft bulkheads of deckhouses and of front and aft bulkheads of superstructures is to be obtained, in kN/m^2 , from the following formula:

$$P_{sd} = 10 n_D a c [b f - (z - T_{sc})]$$

to be taken not less than P_{sd-min}

where:

n_D : Navigation coefficient as defined in Tab 32

a : Coefficient defined in Tab 33

c : Coefficient taken equal to:

$$c = 0,3 + 0,7 \frac{b_1}{B_1}$$

For exposed parts of machinery casings, c is to be taken equal to 1,0

b_1 : Breadth of the superstructure or deckhouse, in m, at the position considered, to be taken not less than $0,25 B_1$

B_1 : Actual maximum breadth of the ship at the exposed weather deck level, in m, at the position considered

b : Coefficient defined in Tab 35

f : Coefficient defined in Tab 34

P_{sd-min} : Minimum lateral pressure, in kN/m^2 , defined in Tab 36.

Table 32 : Navigation coefficient

Navigation notation	Navigation coefficient n_D
unrestricted navigation	1,00
summer zone	0,90
tropical zone	0,80
coastal area	0,80
sheltered area	0,50

Note 1: Where specific designation of the geographical area and/or the most unfavorable sea conditions considered are added to the navigation notation as per Pt A, Ch 1, Sec 2, [5.2.6], the value of n_D for **unrestricted navigation** is to be used unless a specific assessment has been performed by the Society based on the scatter diagram corresponding to the geographical area or the sea conditions considered

Table 33 : Coefficient a - Lateral pressure for superstructures and deckhouses

Type of bulkhead	Location	Coefficient a	Maximum value of a
Unprotected front (2)	Lowest tier	$2 + \frac{L}{120}$	4,5
	Second tier	$1 + \frac{L}{120}$	3,5
	Third tier	$0,5 + \frac{L}{150}$	2,5
	Fourth tier	$0,9 \left(0,5 + \frac{L}{150} \right)$	2,25
	Fifth tier and above	$0,8 \left(0,5 + \frac{L}{150} \right)$	2,0
Protected front (2)	Lowest, second and third tiers	$0,5 + \frac{L}{150}$	2,5
	Fourth tier	$0,9 \left(0,5 + \frac{L}{150} \right)$	2,25
	Fifth tier and above	$0,8 \left(0,5 + \frac{L}{150} \right)$	2,0
Side (1)	Lowest, second and third tiers	$0,5 + \frac{L}{150}$	2,5
	Fourth tier	$0,9 \left(0,5 + \frac{L}{150} \right)$	2,25
	Fifth tier and above	$0,8 \left(0,5 + \frac{L}{150} \right)$	2,0
Aft end	All tiers, when $x/L \leq 0,5$	$0,7 + \frac{L}{1000} - 0,8 \frac{x}{L}$	$1 - 0,8 \frac{x}{L}$
	All tiers, when $x/L > 0,5$	$0,5 + \frac{L}{1000} - 0,4 \frac{x}{L}$	$0,8 - 0,4 \frac{x}{L}$

(1) Applicable only to deckhouses side bulkheads
(2) The front bulkhead of a superstructure or deckhouse may be considered as protected when it is located less than B_x behind another superstructure or deckhouse, and the width of the front bulkhead being considered is less than the width of the aft bulkhead of the superstructure or deckhouse forward of it. B_x is the local breadth of the ship at the front bulkhead.

Table 34 : Coefficient f - Lateral pressure for superstructures and deckhouses

Ship length	Coefficient f
$L < 150$	$\frac{L}{10} e^{-L/300} - \left[1 - \left(\frac{L}{150} \right)^2 \right]$
$150 \leq L < 300$	$\frac{L}{10} e^{-L/300}$
$L \geq 300$	11,03

Table 35 : Coefficient b - Lateral pressure for superstructures and deckhouses

Location of bulkhead(1)	Coefficient b
$\frac{x}{L} \leq 0,45$	$1 + \left(\frac{\frac{x}{L} - 0,45}{C_B + 0,2} \right)^2$
$\frac{x}{L} > 0,45$	$1 + 1,5 \left(\frac{\frac{x}{L} - 0,45}{C_B + 0,2} \right)^2$

(1) For deckhouse sides, the deckhouse is to be subdivided into parts of approximately equal length, not exceeding 0,15 L each, and x is to be taken as the co-ordinate of the centre of each part considered.

Note 1:
 C_B : Block coefficient, with $0,6 \leq C_B \leq 0,8$

Table 36 : Minimum lateral pressure P_{sd-min} for superstructures and deckhouses

Location and type of bulkhead	P_{sd-min} in kN/m ²
Lowest tier of unprotected fronts	$30 \leq 25,0 + 0,10L \leq 50$
Elsewhere:	
• if $z \leq T_{SC} + 0,5 B A_R + 0,5 h_w$	$15 \leq 12,5 + 0,05L \leq 25$
• if $T_{SC} + 0,5 B A_R + 0,5 h_w < z$ and $z \leq T_{SC} + 0,5 B A_R + h_w$	linear interpolation
• if $z > T_{SC} + 0,5 B A_R + h_w$	2,5

Note 1:
 A_R : Roll amplitude for the full load condition, in rad, taken as:

$$A_R = \theta \cdot \frac{\pi}{180}$$
 h_w : Relative wave elevation for the full load condition, in m, at the waterline:
 • for $y \geq 0$, calculated on portside of BR1-P
 • for $y < 0$, calculated on starboard side of BR1-S

6 External pressures on hatch covers and coamings

6.1 Application

6.1.1 The external pressures on hatch covers and coamings are to be applied for strength assessment only.

6.2 Green sea loads

6.2.1 Vertical weather design load

The pressure p_w , in kN/m², on the hatch cover panels is to be taken as $P_{W,d-min}$ defined in [3.2.3] and Tab 30.

6.2.2 Horizontal weather design load

The horizontal weather design load p_A , in kN/m², for determining the scantlings of outer edge girders (skirt plates) of weather deck hatch covers and of hatch coamings is not to be taken less than the greater of:

- the minimum values p_{Amin} given in Tab 37
- $p_A = 10 a c (b c_L f - z)$

where:

- a : Coefficient defined in Tab 38
- c : Coefficient taken equal to $0,3 + 0,7 b'/B_1$
with b'/B_1 to be taken not less than 0,25
- b' : Breadth of coaming, in m, at the position considered
- B_1 : Actual maximum breadth of ship, in m, on the exposed weather deck at the position considered

b : Coefficient taken equal to:

- for $x'/L < 0,45$:

$$b = 1,0 + \left(\frac{\frac{x'}{L} - 0,45}{C_B + 0,2} \right)^2$$

- for $x'/L \geq 0,45$:

$$b = 1,0 + 1,5 \left(\frac{\frac{x'}{L} - 0,45}{C_B + 0,2} \right)^2$$

with $0,6 \leq C_B \leq 0,8$. When determining scantlings of aft ends of coamings and aft hatch cover skirt plates forward of amidships, C_B need not be taken less than 0,8

c_L : Coefficient taken equal to:

$$c_L = \sqrt{\frac{L}{90}} \text{ for } L < 90\text{m}$$

$$c_L = 1 \text{ for } L \geq 90\text{m}$$

x' : Distance, in m, between the transverse coaming or the hatch cover skirt plate considered and aft end of the length L. When determining side coamings or side hatch cover skirt plates, the side is to be subdivided into parts of approximately equal length, not exceeding 0,15 L each, and x' is to be taken as the distance between aft end of the length L and the centre of each part considered

f : Wave parameter, taken equal to:

$$f = \frac{L}{25} + 4,1 \text{ for } L < 90\text{m}$$

$$f = 10,75 - \left(\frac{300 - L}{100} \right)^{1,5} \text{ for } 90\text{m} \leq L < 300\text{m}$$

$$f = 10,75 \text{ for } 300\text{m} \leq L \leq 350\text{m}$$

$$f = 10,75 - \left(\frac{L - 350}{150} \right)^{1,5} \text{ for } L > 350\text{m}$$

z : Vertical distance, in m, from the summer load line to the midpoint of the stiffener span or to the middle of the plate field.

Note 1: The horizontal weather design load need not be included in the direct strength calculation of the hatch cover, unless it is utilised for the design of substructures of horizontal support according to Ch 11, Sec 9, [8.7].

Table 37 : Minimum design load p_{Amin}

		Ship length L		
		L ≤ 50	50 < L < 250	L ≥ 250
p_{Amin} , in kN/m ²	For unprotected fronts	30	25 + L/10	50
	Elsewhere	15	12,5 + L/20	25

Table 38 : Coefficient a Horizontal weather design load for hatch covers and coamings

Location	Coefficient a	Maximum value of a
Unprotected front coamings and hatch cover skirt plates	$2 + \frac{L}{120}$	4,5
Unprotected front coamings and hatch cover skirt plates, where the distance from the actual freeboard deck to the summer load line exceeds the minimum non-corrected tabular freeboard according to ICLL by at least one standard superstructure height h_s , as defined in Ch 1, Sec 3, [2.2.9]	$1 + \frac{L}{120}$	3,5
Side and protected front coamings and hatch cover skirt plates	$0,5 + \frac{L}{150}$	2,5
Aft ends of coamings and aft hatch cover skirt plates abaft amidships	$0,7 + \frac{L}{1000} - 0,8 \frac{x}{L}$	$1 - 0,8 \frac{x}{L}$
Aft ends of coamings and aft hatch cover skirt plates forward of amidships	$0,5 + \frac{L}{1000} - 0,4 \frac{x}{L}$	$0,8 - 0,4 \frac{x}{L}$

7 External pressure on shell doors

7.1 Bow doors

7.1.1 Design external pressure

The design external pressure to be considered for the scantlings of primary supporting members and securing and supporting devices of bow doors is to be not less than that obtained, in kN/m², from the following formula:

$$p_E = 0,5 n_D C_L C_Z (0,22 + 0,15 \tan \alpha) (0,4V \sin \beta + 0,6\sqrt{L_1})^2$$

where:

n_D : Navigation coefficient, defined in Tab 39

C_L : Coefficient depending on the ship's length:

$$C_L = 0,0125L \text{ for } L < 80\text{m}$$

$$C_L = 1,0 \text{ for } L \geq 80\text{m}$$

L_1 : Length as defined in Ch 1, Sec 3

V : Maximum ahead service speed, in knots

C_Z : Coefficient defined in [4.3.1], to be taken equal to 5,5

α : Flare angle at the calculation point, defined as the angle between a vertical line and the tangent to the side plating, measured in a vertical plane normal to the horizontal tangent to the shell plating (see Fig 5)

β : Entry angle at the calculation point, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane (see Fig 5).

Figure 5 : Definition of angles α and β

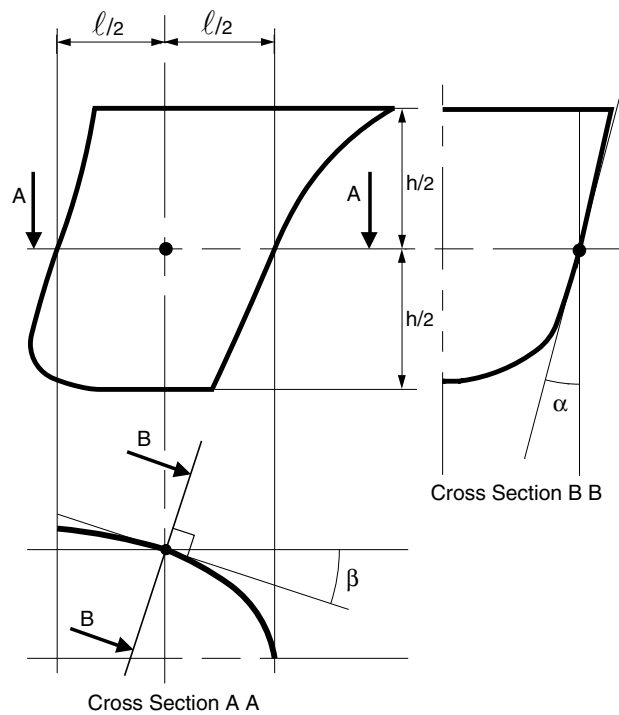


Table 39 : Navigation coefficient

Navigation notation	Navigation coefficient n_D
unrestricted navigation	1,00
coastal area	0,80
sheltered area	0,50

Note 1: Where specific designation of the geographical area and/or the most unfavorable sea conditions considered are added to the navigation notation as per Pt A, Ch 1, Sec 2, [5.2.6], the value of n_D for **unrestricted navigation** is to be used unless a specific assessment has been performed by the Society based on the scatter diagram corresponding to the geographical area or the sea conditions considered

7.1.2 Design external forces

The design external forces F_X , F_Y , F_Z to be considered for the scantlings of securing and supporting devices of bow doors are to be not less than those obtained, in kN, from the following formulae:

$$F_X = p_E A_X$$

$$F_Y = p_E A_Y$$

$$F_Z = p_E A_Z$$

where:

- p_E : External pressure, in kN/m², to be calculated according to [7.1.1], assuming the angles α and β measured at the point on the bow door located $\ell/2$ aft of the stem line on the plane $h/2$ above the bottom of the door, as shown in Fig 5
- h : Height, in m, to be taken as the lesser of h_1 and h_2
- h_1 : Height, in m, of the door between the levels of its bottom and the upper deck
- h_2 : Height, in m, of the door between its bottom and top
- ℓ : Length, in m, of the door at a height $h/2$ above the bottom of the door
- A_X : Area, in m², of the transverse vertical projection of the door between the levels of the bottom of the door and the top of the upper deck bulwark or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser. In determining the height from the bottom of the door to the upper deck or to the top of the door, the bulwark is to be excluded
- A_Y : Area, in m², of the longitudinal vertical projection of the door between the levels of the bottom of the door and the top of the upper deck bulwark or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser
- A_Z : Area, in m², of the horizontal projection of the door between the bottom of the door and the top of the upper deck bulwark or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is lesser. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser.

For bow doors, including bulwark, of unusual form or proportions, e.g. ships with a rounded nose and large stem angles, the areas and angles used for determination of the design values of external forces will be considered on a case by case basis.

7.1.3 Closing moment

For visor doors, the closing moment under external loads is to be obtained, in kN.m, from the following formula:

$$M_Y = F_X a + 10 W c - F_Z b$$

where:

- W : Mass of the visor door, in t
- a : Vertical distance, in m, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Fig 6
- b : Horizontal distance, in m, from visor pivot to the centroid of the horizontal projected area of the visor door, as shown in Fig 6
- c : Horizontal distance, in m, from visor pivot to the centre of gravity of visor mass, as shown in Fig 6.

7.1.4 Forces acting on the lifting arms

The lifting arms of a visor door and its supports are to be dimensioned for the static and dynamic forces applied during the lifting and lowering operations, and a minimum wind pressure of 1,5 kN/m² is to be taken into account.

7.2 Side and stern doors**7.2.1 Design forces in intact ship conditions**

The design external forces F_E and the design internal forces F_I to be considered for the scantlings of primary supporting members and securing and supporting devices of side doors and stern doors are to be obtained, in kN, from the formulae in Tab 40.

7.2.2 Design pressure in damaged ship conditions

In damaged ship conditions, where doors are located partly or totally below the deepest equilibrium waterline, the following external design pressures, in kN/m², are to be considered:

- points at or below the deepest equilibrium waterline: $p_E = \rho g d_f$
- points above the deepest equilibrium waterline: $p_E = 0$

where:

d_F : Distance, in m, from the calculation point to the deepest equilibrium waterline in the damaged condition at y or from the calculation point to the bulkhead deck at side, whichever is the greater.
The deepest equilibrium waterlines are to be provided by the Designer under his own responsibility.

Figure 6 : Bow doors of visor type

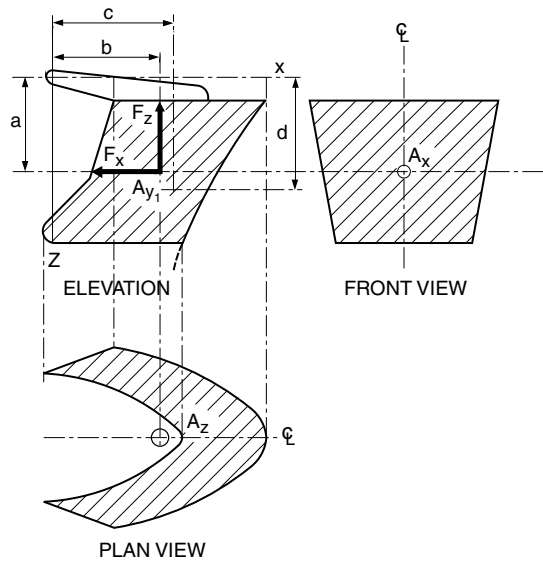


Table 40 : Design forces for side and stern doors

Structural elements	External force F_E , in kN	Internal force F_I , in kN
Securing and supporting devices of doors opening inwards	$A p_E + F_P$	$F_0 + 10 W$
Securing and supporting devices of doors opening outwards	$A p_E$	$F_0 + 10 W + F_P$
Primary supporting members(1)	$A p_E$	$F_0 + 10 W$

(1) The design force to be considered for the scantlings of the primary supporting members is the greater of F_E and F_I .

Note 1:

A : Area, in m^2 , of the door opening
 W : Mass of the door, in t
 F_P : Total packing force, in kN; the packing line pressure is normally to be taken not less than 5 N/mm
 F_0 : The greater of F_C and 5 A , in kN
 F_C : Accidental force, in kN, due to loose cargoes etc., to be uniformly distributed over the area A and to be taken not less than 300 kN. For small doors such as bunker doors and pilot doors, the value of F_C may be appropriately reduced. However, the value of F_C may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental forces due to loose cargoes.
 p_E : External design pressure determined at the centre of gravity of the door opening and to be taken not less than that obtained, in kN/m^2 , from the following formulae:
 $p_E = 10 (T - Z_G) + 25$ for $Z_G < T$
 $p_E = 25$ for $Z_G \geq T$
 Moreover, for stern doors of ships fitted with bow doors, p_E is to be taken not less than that obtained, in kN/m^2 , from the following formula:
 $p_E = 0,6n_D C_L (0,8 + 0,6\sqrt{L_1})^2$
 T : Draught, in m, at the highest subdivision load line
 Z_G : Height of the centre of the area of the door, in m, above the baseline
 n_D : Navigation coefficient, defined in Tab 39
 C_L : Coefficient depending on the ship's length:
 $C_L = 0,0125L$ for $L < 80m$
 $C_L = 1,0$ for $L \geq 80m$
 L_1 : Length as defined in Ch 1, Sec 3

8 External loads on containers

8.1 Wind forces

8.1.1 The forces due to the effect of the wind, applied to one container stowed above deck at tier "i", are to be obtained, in kN, from the following formulae:

- in x direction: $F_{x,wind,i} = 1,2 h_C b_C$
- in y direction: $F_{y,wind,i} = 1,2 h_C l_C$

where:

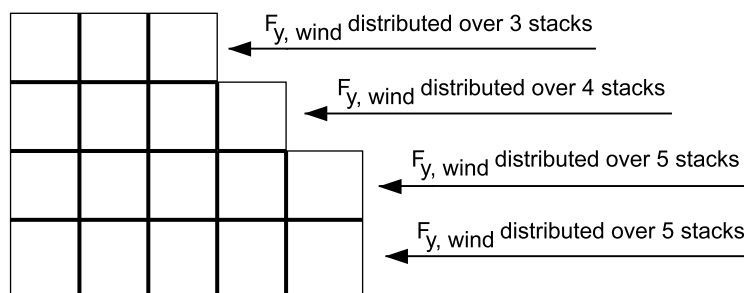
h_C : Height, in m, of a container

$l_C b_C$: Dimensions, in m, of the container stack in the ship longitudinal and transverse directions, respectively.

These forces only act on a stack exposed to wind. In the case of M juxtaposed and connected stacks of the same height, the wind forces are to be distributed over the M stacks.

In the case of juxtaposed and connected stacks of different heights, the wind forces are to be distributed taking into account the number of stacks at the tier considered (see example on Fig 7).

Figure 7 : Distribution of wind forces in the case of connected stacks



Section 6 Internal Loads and cargo loads

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

- a_x, a_y, a_z : Longitudinal, transverse and vertical accelerations, in m/s^2 , calculated at the centre of gravity of the considered compartment, x_C, y_C, z_C , as defined in Ch 5, Sec 3, [3.2]
- b_C : Transverse distance, in m, between longitudinal watertight bulkheads or longitudinal wash bulkheads, if any, or between a longitudinal watertight bulkhead and the adjacent longitudinal wash bulkhead
- B_H : Breadth of the cargo hold, in m, measured at mid-length of the cargo hold and at the mid height between the top of hopper tank and the bottom of topside tank, see Fig 3
- B_{IB} : Breadth of inner bottom, in m, measured at mid-length of the cargo hold, see Fig 3
- D_1 : Distance, in m, from the base line to the freeboard deck at side amidships
- d_F : Filling level of a tank, in m, to be taken as the vertical distance measured with the ship at rest, from the lowest point of the tank to the free surface of the liquid
- d_{sc} : Diameter, in m, of a steel coil
- f_β : Heading correction factor defined in Ch 5, Sec 3
- g : Gravity acceleration, in m/s^2 , defined in Ch 5, Sec 5
- h_{air} : Height of air pipe or overflow pipe above the top of the tank, in m
- h_{BC} : Height of bulk cargo, in m, from the inner bottom to the upper surface of bulk cargo, as defined in [3.3.1] or [3.3.2]
- h_{DB} : Height, in m, of the double bottom at the centreline, measured at mid-length of the cargo hold, see Fig 3
- h_{HPL} : Vertical distance, in m, from the inner bottom at centreline to the upper intersection of hopper tank and side shell or inner side for double side bulk carriers, determined at mid length of the considered cargo hold, as shown in Fig 3
 $h_{HPL} = 0$ if there is no hopper tank.
- h_{HPU} : Vertical distance, in m, from the inner bottom at centreline to the lower intersection of topside tank and side shell or inner side for double side bulk carriers, determined at mid length of the cargo hold at midship, as shown in Fig 3
- h_{LS} : Mean height, in m, of the lower stool, measured from the inner bottom
- H : Height, in m, of a tank, to be taken as the vertical distance from the bottom to the top of the tank, excluding any small hatchways
- K_C : Coefficient taken equal to:
- $K_C = \cos^2 \alpha_p + (1 - \sin \Psi) \sin^2 \alpha_p$
for inner bottom, hopper tank, transverse and longitudinal bulkheads, lower stool, vertical upper stool, inner side and side shell
 - $K_C = 0$
for topside tank, main deck and sloped upper stool
- l_C : Longitudinal distance, in m, between transverse watertight bulkheads or transverse wash bulkheads, if any, or between a transverse watertight bulkhead and the adjacent transverse wash bulkhead
- l_H : Length of the cargo hold, in m, at the centreline between the transverse bulkheads. This is to be measured to the mid-depth of the corrugated bulkhead(s) if fitted
- l : Distance, in m, between floors, see Fig 11
- l_{ip} : Distance, in m, between outermost dunnage per EPP in the ship X direction, see Fig 12
- l_{st} : Length, in m, of a steel coil
- M : Mass, in t, of the bulk cargo being considered
- M_{Full} : Cargo mass, in t, in a cargo hold corresponding to the volume up to the top of the hatch coaming with a density of the greater of:
 M_H/V_{Full} or $1,0 t/m^3$.
 $M_{Full} = 1,0 V_{Full}$ but not less than M_H
- M_H : Cargo mass, in t, in a cargo hold that corresponds to the homogeneously loaded condition at maximum draught with 50% consumables
- M_{HD} : Maximum allowable cargo mass, in t, in a cargo hold according to design loading conditions with specified holds empty at maximum draught with 50% consumables and all ballast water tanks in cargo hold region empty
- M_{sc-ib} : Equivalent mass of a steel coil, in t, on inner bottom, as defined in [5.3.1]

- M_{sc-hs} : Equivalent mass of a steel coil, in t, on hopper side, as defined in [5.3.2]
- n_1 : Number of tiers of steel coils
- n_2 : Number of load points per EPP of the inner bottom, see [5.1.3]
- n_3 : Number of dunnages supporting one row of steel coils
- P_{drop} : Overpressure, in kN/m², due to sustained liquid flow through air pipe or overflow pipe in case of overflowing or filling during flow through ballast water exchange
 When the total area of tank overflow openings is more than twice the sectional area of the related filling pipe, P_{drop} may be taken equal to 0
 Otherwise, P_{drop} is to be defined by the designer, but not to be taken less than 25 kN/m²
- P_{pv} : Design vapour pressure in kN/m².
 Where a pressure relief valve is fitted, P_{pv} is to be taken equal to:
- 1,1 times the safety valve setting pressure, in general
 - 1,0 times the safety valve setting pressure in case of liquefied gas cargo tank or liquefied gas fuel tank.
- Where no pressure relief valve is fitted, P_{pv} is to be taken as 0 kN/m²
- perm : Permeability of cargo, to be taken as:
 perm = 0,3 for iron ore, coal cargoes and cement
 perm = 0 for steel coils and steel packed products
- R : Vertical coordinate of the ship rotation centre, to be taken as:

$$R = \min\left(\frac{D}{4} + \frac{T_{LC}}{2}, \frac{D}{2}\right)$$
- s_{CG} : Spacing of corrugations, in m; see Ch 4, Sec 5, Fig 27
- T θ : Roll period, in s, as defined in Ch 5, Sec 3, [2.1.1]
- V_{Full} : Volume, in m³, of cargo hold up to top of the hatch coaming, taken as: $V_{Full} = V_H + V_{HC}$
- V_H : Volume, in m³, of cargo hold up to level of the intersection of the main deck with the hatch coaming excluding the volume enclosed by hatch coaming, see Fig 3
- V_{HC} : Volume, in m³, of the hatch coaming, from the level of the intersection of the main deck with the hatch side coaming to the top of the hatch coaming, determined for the cargo hold at midship, as shown in Fig 3
- V_{TS} : Total volume, in m³, of the portion of the lower bulkhead stools within the cargo hold length l_H and inboard of the hopper tanks, as shown in Fig 3
- W : Mass, in t, of a steel coil
- x, y, z : X, Y and Z coordinates, in m, of the load point with respect to the reference coordinate system defined in Ch 1, Sec 3, [2.6.1]
- x_C, y_C, z_C : X, Y and Z coordinates, in m, of the centre of gravity of the considered compartment, with respect to the reference coordinate system defined in Ch 1, Sec 3, [2.6.1]
- x_G, y_G, z_G : X, Y and Z coordinates, in m, of the volumetric centre of gravity of the tank or fully filled cargo hold, i.e. V_{Full} , considered with respect to the reference coordinate system defined in Ch 1, Sec 3, [2.6.1].
 In case of partially filled cargo hold, x_G, y_G, z_G to be taken as follows:
- x_G, y_G : Volumetric centre of gravity of the cargo hold
 - $z_G = h_{DB} + h_{BC-CL} / 2$
 h_{BC-CL} is the height of cargo at the centreline, as defined in [3.3.2]
- z_{BC} : Height of the upper surface of the cargo above the baseline in way of the load point, in m, as defined in [3.3.1] and [3.3.2] to be taken as: $z_{BC} = h_{DB} + h_{BC}$
- z_{top} : Z coordinate of the highest point of tank, excluding small hatchways, in m
- z_{min} : Z coordinate of the lowest point of tank, in m
- α_p : Angle, in deg, between panel considered and the horizontal plane
- θ : Roll angle, in deg, defined in Ch 5, Sec 3, [2.1.1]
- θ_h : Angle, in deg, between inner bottom plate and hopper sloping plate or inner hull, as shown in Fig 3. In general θ_h is such that:
- $$\tan\theta_h = \frac{2h_{HPL}}{B_H - B_{IB}}$$
- ρ : Sea water density defined in Ch 5, Sec 5
- ρ_L : Density of liquid, in t/m³, typically:
- 1,025 for ballast water
 - 1,0 for fresh water
 - 0,5 for liquefied natural gas

- ρ_c : Density of bulk cargo, in t/m³, as defined in [3.3.3]
 ρ_{ST} : Density of steel, in t/m³, to be taken as 7,85
 φ : Pitch angle, in deg, defined in Ch 5, Sec 3, [2.1.2]
 ψ : Assumed angle of repose, in deg, of bulk cargo (considered drained and removed); to be taken as:
 $\psi = 30^\circ$ in general
 $\psi = 35^\circ$ for iron ore
 $\psi = 25^\circ$ for cement.

1 Pressures due to liquids

1.1 Application

1.1.1 Pressures for the strength and fatigue assessments in intact conditions

The internal pressure P_{in} due to liquid acting on any load point of a tank boundary, in kN/m², for the static design load scenarios given in Ch 5, Sec 7, is to be taken as:

$$P_{in} = P_{ls}$$

The internal pressure P_{in} due to liquid acting on any load point of a tank boundary, in kN/m², for the static + dynamic design load scenarios is to be derived for each dynamic load case and is to be taken as:

$$P_{in} = P_{ls} + P_{ld} \text{ without being taken less than } 0$$

where:

- P_{ls} : Static pressure due to liquid in tank, in kN/m², as defined in [1.2]
 P_{ld} : Dynamic pressure due to liquid in tank, in kN/m², as defined in [1.3].

1.1.2 Pressures for the strength assessment in flooded conditions

The internal pressure P_{in} in flooded condition, in kN/m², acting on any load point of the structural watertight boundaries intended to stop vertical and horizontal flooding, for the flooded static design load scenarios given in Ch 5, Sec 7, is to be taken as:

$$P_{in} = P_{fs}$$

where:

- P_{fs} : Static pressure of seawater in flooded condition in the compartment, in kN/m², as defined in [1.4].

For corrugations of vertically corrugated transverse bulkheads separating cargo holds of ships intended for the carriage of dry cargoes in bulk, the flooded pressures and forces specified in [4.1] for bulk cargoes in flooded conditions are to be applied.

For double bottom in cargo holds of ships intended for the carriage of dry cargoes in bulk, the flooded pressures and forces specified in [4.2] for bulk cargoes in flooded conditions are to be applied.

1.2 Static liquid pressure in intact conditions

1.2.1 Normal operations at sea and harbour/sheltered water operations

The static pressure P_{ls} due to liquid in tanks during normal operations at sea and harbour/sheltered water operations, in kN/m², is to be taken as:

$$P_{ls} = \rho_L g (z_{top} - z) + P_{pv}$$

1.2.2 Sequential ballast water exchange

The static pressure P_{ls} due to liquid in ballast tanks associated with ballast water exchange operations by sequential method is to be taken as defined for normal operations at sea in [1.2.1].

1.2.3 Flow through ballast water exchange

The static pressure P_{ls} due to liquid in ballast tanks associated with flow through ballast water exchange operations, in kN/m², is to be taken as:

$$P_{ls} = \rho_L g (z_{top} - z + h_{air}) + P_{drop}$$

1.2.4 Ballast water exchange by dilution

The static pressure P_{ls} due to liquid in ballast tanks associated with ballasting operations by means of dilution is to be taken as defined for sequential ballast exchange in [1.2.2].

The ship designer has to inform the Society if the ballast water exchange system implies additional pressure to be considered such as P_{drop} in addition to the pressure defined in [1.2.2].

1.2.5 Ballasting using ballast water treatment system

The static pressure P_{ls} due to liquid in ballast tanks associated with ballasting operations using a ballast water treatment system is to be taken as defined for sequential ballast exchange in [1.2.2]. The ship designer has to inform the Society if the ballast water treatment system implies additional pressure to be considered such as P_{drop} , in addition to the pressure defined in [1.2.2].

1.2.6 Static liquid pressure for the fatigue assessment

The static pressure P_{is} due to liquid in tanks to be used for the fatigue assessment, in kN/m^2 , is to be taken as follows, depending on their filling level defined in Ch 10, Sec 1, [2.1.1]:

- fully filled tanks:
 $P_{is} = \rho_L g (z_{top} - z)$
- consumable tanks filled at 50%:
 $P_{is} = \rho_L g (0,5 (z_{min} + z_{top}) - z)$ without being taken less than 0.

1.3 Dynamic liquid pressure in intact conditions**1.3.1 Dynamic pressure on watertight bulkheads**

The dynamic pressure P_{id} due to liquid in tanks, in kN/m^2 , is to be taken as:

$$P_{id} = \rho_L [a_x (x_0 - x) + a_y (y_0 - y) + a_z (z_0 - z)]$$

where:

- x_0 : X coordinate, in m, of the reference point.
- y_0 : Y coordinate, in m, of the reference point.
- z_0 : Z coordinate, in m, of the reference point.

The reference point is to be taken as the point with the highest value of V_j , calculated for all the points that define the upper boundary of the tank, as follows:

$$V_j = a_x (x_j - x_c) + a_y (y_j - y_c) + (a_z + g) (z_j - z_c)$$

where:

- x_j : X coordinate, in m, of the point j on the upper boundary of the tank
- y_j : Y coordinate, in m, of the point j on the upper boundary of the tank
- z_j : Z coordinate, in m, of the point j on the upper boundary of the tank.

1.3.2 Dynamic pressure in consumable tanks for the fatigue assessment

The dynamic pressure P_{id} , in kN/m^2 , due to liquid in consumable tanks filled at 50% according to Ch 10, Sec 1, [2.1.1], is to be taken as follows:

- as calculated in [1.3.1] for $z \leq 0,5 z_{top}$
- equal to 0 for $z > 0,5 z_{top}$

1.4 Static pressure in flooded conditions**1.4.1 Ships for which damage stability calculations are required**

The static pressure P_{fs} , in kN/m^2 , acting on structural watertight elements defined as per the Internal Watertight Plan and located below the deepest equilibrium waterline (excluding side shell structural elements) which constitute boundaries intended to stop vertical and horizontal flooding, is to be taken as:

$$P_{fs} = \rho g d_{FL} \text{ without being taken less than } 0$$

where:

- d_{FL} : Distance, in m, from the calculation point to the deepest equilibrium waterline in the damaged condition at y or from the calculation point to the bulkhead deck at side, whichever is the greater.

The deepest equilibrium waterlines are to be provided by the Designer under his own responsibility.

1.4.2 Ships for which damage stability calculations are not required

The static pressure P_{fs} , in kN/m^2 , acting on structural watertight elements (excluding side shell structural elements) which constitute boundaries intended to stop vertical and horizontal flooding, is to be obtained from the formula in [1.4.1], where d_f is the vertical distance, in m, from the calculation point to the bulkhead deck at side.

2 Partly filled tanks intended for the carriage of liquid or ballast**2.1 Application****2.1.1 General**

Slushing assessment is to be carried for all liquid cargo, ballast and other liquid tanks with volume exceeding 100m^3 , if required by Ch 11, Sec 4, [1.5].

Slushing assessment is to be carried out for all liquefied gas tanks for which partial filling is contemplated, whatever their volume.

2.1.2 Membrane tanks

Sloshing pressure in membrane tanks of ships having the service notation **liquefied gas carrier** or **LNG bunkering ship** is defined in Pt D, Ch 9, App 1, [2].

Sloshing pressure in membrane tanks of ships having the additional service feature **LNGfuel** is defined in Pt D, Ch 9, App 1, [2] as per NR529 C6.4.9.4.1.3.

2.2 Pressure definition

2.2.1 Sloshing pressure

The sloshing pressure P_{sl} , in kN/m^2 , due to liquid motion in the longitudinal or transverse direction, acting on bulkheads in tanks intended for the carriage of liquid or ballast, is to be taken as:

$$P_{sl} = P_{S-SL} + P_{W-SL}$$

where:

P_{S-SL} : Static pressure, in kN/m^2 , as defined in [2.3.1]

P_{W-SL} : Dynamic sloshing pressure, in kN/m^2 , as defined in [2.4.1] or [2.4.2].

The sloshing pressure, P_{sl} is not to be taken less than 12 kN/m^2 .

2.2.2 Impact pressure

The impact pressure P_{im} , in kN/m^2 , due to liquid motion in the longitudinal or transverse direction, acting on bulkheads in tanks intended for the carriage of liquid or ballast, is to be taken as:

$$P_{im} = P_{S-I} + P_{W-I}$$

where:

P_{S-I} : Static pressure, in kN/m^2 , as defined in [2.3.2]

P_{W-I} : Dynamic impact pressure, in kN/m^2 , as defined in [2.5.1].

2.3 Static pressure

2.3.1 Static pressure to be used in combination with the dynamic sloshing pressure

The static pressure P_{S-SL} to be used in combination with the dynamic sloshing pressure defined in [2.4] is to be obtained, in kN/m^2 , from the following formulae:

- for $z < d_F + z_{min}$: $P_{S-SL} = \rho_L g (d_F + z_{min} - z) + P_{pv}$
- for $z \geq d_F + z_{min}$: $P_{S-SL} = P_{pv}$

2.3.2 Static pressure to be used in combination with the dynamic impact pressure

The static pressure P_{S-I} to be used in combination with the dynamic impact pressure defined in [2.5] is to be obtained, in kN/m^2 , from the following formulae:

- for $z < 0,7 H + z_{min}$: $P_{S-I} = \rho_L g (0,7 H + z_{min} - z) + P_{pv}$
- for $z \geq 0,7 H + z_{min}$: $P_{S-I} = P_{pv}$

2.4 Dynamic sloshing pressure

2.4.1 The sloshing pressure P_{W-SL} is obtained, in kN/m^2 , from the following formulae (see Fig 1):

$$P_{W-SL} = 0 \quad \text{for } z \leq 0,8 d_F + z_{min}$$

$$P_{W-SL} = \left(5 \frac{z - z_{min}}{d_F} - 4 \right) \alpha P_0 \quad \text{for } 0,8 d_F + z_{min} < z \leq d_F + z_{min}$$

$$P_{W-SL} = \left(6 - 5 \frac{z - z_{min}}{d_F} \right) \alpha P_0 \quad \text{for } d_F + z_{min} < z < 1,2 d_F + z_{min}$$

$$P_{W-SL} = 0 \quad \text{for } z \geq 1,2 d_F + z_{min}$$

where:

P_0 : Reference pressure defined in Tab 1 for longitudinal and transverse liquid motion.

α : Coefficient taken equal to (see Fig 2):

$$\alpha = \frac{d_F}{0,6H} \quad \text{for } d_F < 0,6H$$

$$\alpha = 1 \quad \text{for } 0,6H \leq d_F \leq 0,7H$$

$$\alpha = \frac{H - d_F}{0,3H} \quad \text{for } d_F > 0,7H$$

Figure 1 : Sloshing pressure P_{W-SL}

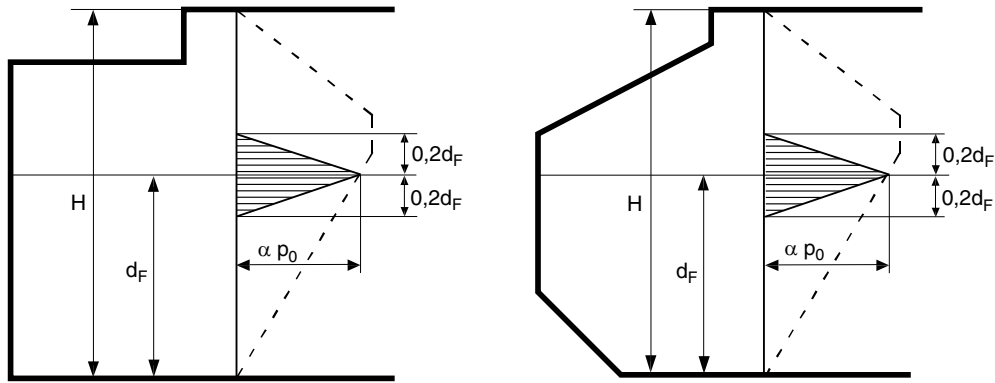


Figure 2 : Coefficient α

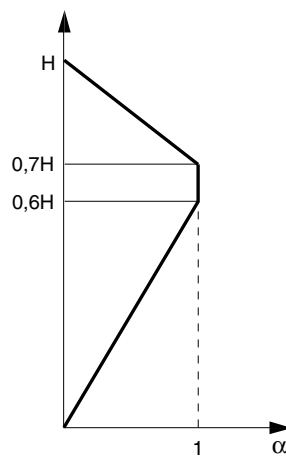


Table 1 : Reference pressure P_0 for calculation of sloshing, and dynamic impact pressure P_{W-I}

Liquid motion direction	Reference pressure P_0 , in kN/m^2	Dynamic impact pressure P_{W-I} , in kN/m^2
Longitudinal	$0,84 \varphi_P \rho_L g S \ell_C \varphi \frac{\pi}{180}$	$\varphi_P \rho_L g \ell_C \left(0,9 + \frac{\ell_C}{L}\right) (5 + 0,015 L) \varphi \frac{\pi}{180}$
Transverse	$1,93 \varphi_R \rho_L g b_C \sqrt{B} \left(1 - 0,3 \frac{B}{b_C}\right) \theta \frac{\pi}{180}$	$0,61 \varphi_R \rho_L g (0,75 B - 8) b_C \theta \frac{\pi}{180}$

Note 1:

- φ_P : Coefficient defined as follows:
- $\varphi_P = 1,0$ in the case of smooth tanks or tanks with bottom transverses whose height, in m, measured from the tank bottom, is less than $0,1 H$
 - $\varphi_P = 0,4$ in the case of tanks with bottom transverses whose height, in m, measured from the tank bottom, is not less than $0,1 H$
- S : Coefficient defined as follows:
- $S = 1 + 0,02 L$ if $L \leq 200$ m
 - $S = 3 + 0,01 L$ if $L > 200$ m
- φ_R : Coefficient defined as follows:
- if $b_C / B \leq 0,3$: $\varphi_R = 0$
 - if $b_C / B > 0,3$:
 - $\varphi_R = 1,0$ in case of smooth tanks or tanks with bottom girders whose height, in m, measured from the tank bottom, is less than $0,1 H$
 - $\varphi_R = 0,4$ in case of tanks with bottom girders whose height, in m, measured from the tank bottom, is not less than $0,1 H$

2.4.2 Sloshing pressure on tank bottom transverses in the case of longitudinal liquid motion

The sloshing pressure P_{W-SL} to be considered as acting on tank bottom transverses is obtained, in kN/m^2 , from the following formula:

$$P_{W-SL} = 0,84 \rho_L g (1,95 - 0,12 n) (z - z_{min})$$

where:

n : Number of bottom transverses in the tank.

2.5 Dynamic impact pressure

2.5.1 The dynamic impact pressure P_{W-I} is obtained, in kN/m^2 , from the formulae defined in Tab 1 for longitudinal and transverse liquid motions.

Where the upper part of a transverse bulkhead or longitudinal bulkhead, inner side or side is sloped, the dynamic impact pressure P_{W-I} may be multiplied by the coefficient ϕ , to be obtained from the following formula:

$$\phi = 1 - \frac{h_T}{0,3H}$$

without being taken less than 0

where:

h_T : Height, in m, of the sloped part of the transverse or longitudinal bulkhead, inner side or side.

2.6 Alternative methods

2.6.1 The Society may accept that the dynamic impact pressure or dynamic sloshing pressure are evaluated on the basis of dynamic calculation procedures, where deemed necessary in relation to the tank dimensions and the ship characteristics. The calculations are to be submitted to the Society for verification.

3 Pressures and forces due to dry bulk cargo

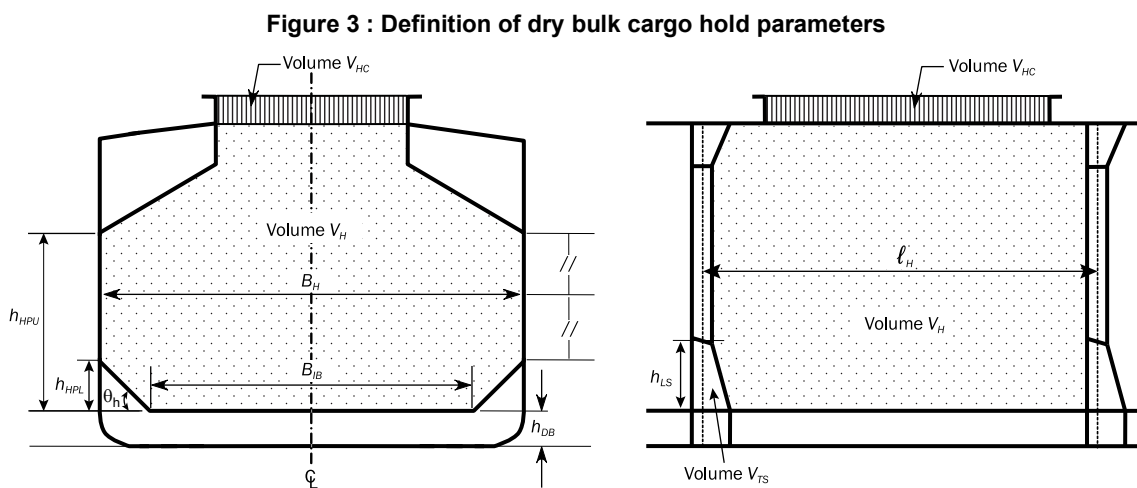
3.1 Application

3.1.1 The pressures and forces due to dry cargo in bulk in a cargo hold are to be determined both for fully and partially filled cargo holds according to [3.4] and [3.5].

3.2 Hold definitions

3.2.1 Geometrical characteristics

The main geometrical elements of a dry bulk cargo hold are given in Fig 3.



3.2.2 Fully and partially filled cargo holds

The definitions of a fully and partially filled dry bulk cargo holds are as follow:

a) Fully filled hold:

The dry bulk cargo density is such that the cargo hold is filled up to the top of the hatch coaming, as shown in Fig 4.

The upper surface of the cargo and its effective height in the hold h_{BC} are to be determined in accordance with [3.3.1].

b) Partially filled hold:

The cargo density is such that the cargo hold is not filled up to the top of the hatch coaming, as shown in Fig 5 or Fig 6. The upper surface of the cargo and its effective height in the hold h_{BC} are to be determined in accordance with [3.3.2].

3.3 Dry cargo characteristics

3.3.1 Definition of the upper surface of dry bulk cargo for full cargo holds

For a fully filled cargo hold as defined in [3.2.2], including non-prismatic holds, the effective upper surface of the cargo is an equivalent horizontal surface at h_{BC} , in m, above inner bottom at centreline as shown in Fig 4.

The value of h_{BC} is to be calculated at mid length of the cargo hold at the midship, is to be kept constant over the cargo hold region area and is determined as follows:

$$h_{BC} = h_{HPU} + h_0$$

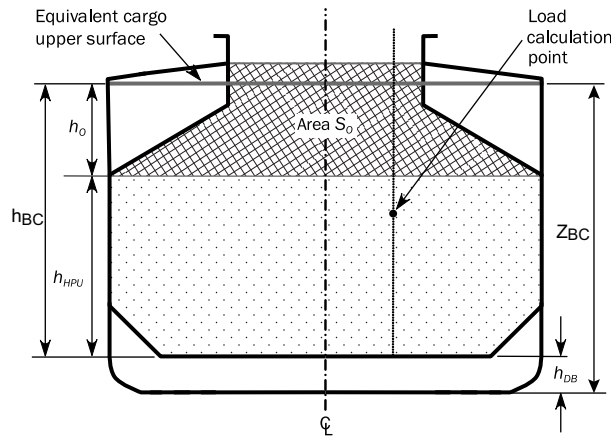
where:

$$h_0 = \frac{S_A}{B_H}$$

$$S_A = S_0 + \frac{V_{HC}}{\ell_H}$$

S_0 : Shaded area, in m², above the lower intersection of topside tank and side shell or inner side, as the case may be, and up to the level of the intersection of the main deck with the hatch coaming, determined for the cargo hold at the midship as shown in Fig 4.

Figure 4 : Definition of effective upper surface of cargo for a full cargo hold



3.3.2 Definition of upper surface of dry bulk cargo for partially filled cargo holds

For any partially filled cargo hold, as defined in [3.2.2], including non-prismatic holds, the effective upper surface of the cargo is to be made of three parts:

- One central horizontal surface of breadth $B_H/2$, in m, at a height h_{BC-CL} , in m, above the inner bottom
- A sloped surface at each side with an angle $\psi/2$, in degrees, between the central horizontal surface, and the side shell or inner hull, as shown in Fig 5, or the hopper plating, as shown in Fig 6, as the case may be.

The height of cargo surface h_{BC} , in m, is to be calculated at mid length of the considered cargo hold and is to be taken as constant over the length of the hold as follows:

$$\text{For } |y| \leq \frac{B_H}{4} \quad ; h_{BC} = h_{BC-CL}$$

$$\text{For } \frac{B_H}{4} < |y| \leq \frac{B_2}{2} \quad ; h_{BC} = h_{BC-CL} - \left(|y| - \frac{B_H}{4} \right) \tan \frac{\psi}{2}$$

$$\text{For } |y| > \frac{B_2}{2} \quad ; h_{BC} = 0$$

where:

h_{BC-CL} : Height, in m, of the cargo surface at the centreline, as shown in Fig 5 and Fig 6

B_2 : Maximum breadth of the cargo, in m, as shown in Fig 5 and Fig 6

h_1 : Height, in m, to be taken as:

$$h_1 = \frac{M}{\rho_C \cdot B_H \ell_H} - \left(\frac{B_H + B_{IB}}{2 B_H} \right) h_{HPL} - \frac{3}{16} B_H \tan \frac{\psi}{2} + \frac{V_{TS}}{B_H \ell_H}$$

- For $h_1 \geq 0$ as shown in Fig 5:

$$h_{BC-CL} = h_{HPL} + h_1 + h_2$$

$$h_2 = \frac{B_H}{4} \tan \frac{\psi}{2}$$

$$B_2 = B_H$$

- For $h_1 < 0$ as shown in Fig 6

$$h_{BC-CL} = h_{11} + h_{22}$$

$$h_{11} = h_{HPL} \left(\frac{B_2 - B_{IB}}{B_H - B_{IB}} \right)$$

$$h_{22} = \left(\frac{B_2 - B_H}{2} - \frac{B_H}{4} \right) \tan \frac{\psi}{2}$$

$$B_2 = \sqrt{\frac{\frac{1}{\ell_H} \left(\frac{M}{\rho_C} + V_{TS} \right) + \frac{1}{2} \left(\frac{h_{HPL} \cdot B_{IB}^2}{B_H - B_{IB}} \right) + \frac{B_H^2}{16} \tan \frac{\psi}{2}}{\frac{1}{2} \left[\left(\frac{h_{HPL}}{B_H - B_{IB}} \right) + \frac{1}{2} \tan \frac{\psi}{2} \right]}}$$

Figure 5 : Definition of the effective upper surface of cargo for a partially filled cargo hold when $h_1 \geq 0$

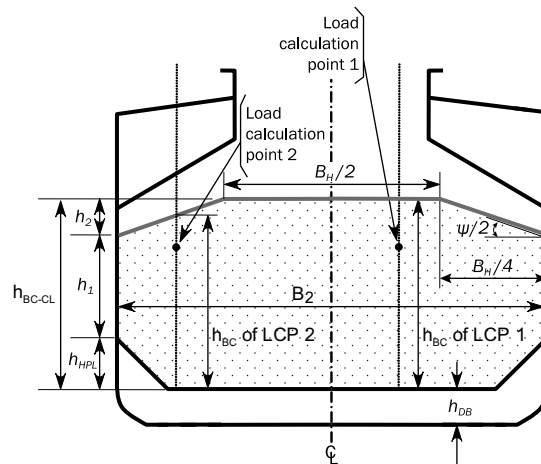
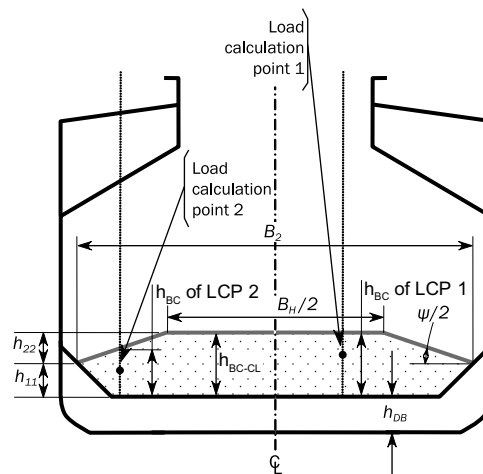


Figure 6 : Definition of the effective upper surface of cargo for a partially filled cargo hold when $h_1 < 0$



3.3.3 Mass and density

The dry cargo mass and the density are to be taken as specified in Tab 2.

Table 2 : Dry bulk cargo mass (M) and density (ρ_c)

	Homogeneous loading condition		Alternate loading condition(3)	
	Fully filled hold	Partially filled hold(1)	Fully filled hold	Partially filled hold
Strength assessment	$M = M_{Full}$ <ul style="list-style-type: none"> if $\rho_{C-lm} \leq 1,0$ $\rho_c = \rho_{C-lm}$ if $\rho_{C-lm} > 1,0$ $\rho_c = \max\left(\frac{M_{Full}}{V_{Full}}; 1, 0\right)$ 	$M = M_H$ $\rho_c = 3,0(2)$	$M = M_{HD} + 0,1 M_H$ $\rho_c = \frac{M_{HD} + 0,1 \cdot M_H}{V_{Full}}$	$M = M_{HD} + 0,1 M_H$ $\rho_c = 3,0(2)$
Fatigue assessment	$M = M_H$ <ul style="list-style-type: none"> if $\rho_{C-lm} \leq 1,0$ $\rho_c = \rho_{C-lm}$ if $\rho_{C-lm} > 1,0$ $\rho_c = \frac{M_{Full}}{V_{Full}}$ 	NA	NA	$M = M_{HD}$ $\rho_c = 3,0(2)$
Strength assessment in flooded conditions	$M = M_H$ <ul style="list-style-type: none"> if $\rho_{C-lm} \leq 1,0$ $\rho_c = \rho_{C-lm}$ if $\rho_{C-lm} > 1,0$ $\rho_c = \frac{M_{Full}}{V_{Full}}$ 	$M = M_H$ $\rho_c = 3,0(2)$	$M = M_{HD}$ $\rho_c = \frac{M_{HD}}{V_{Full}}$	$M = M_{HD}$ $\rho_c = 3,0(2)$

(1) Applicable only if ρ_{C-lm} is greater than 1,0
(2) To be taken as 3,0 unless an alternative maximum cargo density is specified in the loading manual.
(3) $\rho_c=1,78t/m^3$ is to be considered for the specific alternate loading condition «hold loaded with $\rho_c \leq 1,78t/m^3$ »
Note 1:
 ρ_{C-lm} : Maximum cargo density specified in the loading manual.

3.3.4 FE application

The following process is to be applied for the bulk cargo pressure loads used in FE analysis:

- a) Determine h_{BC} according to [3.3.1] for fully filled cargo hold or [3.3.2] for partially filled cargo hold.
- b) Determine the corresponding static pressure as defined in [3.4.2] and static shear pressure as defined in [3.5.2] using ρ_c and apply them in the FE model.
- c) Calculate the actual mass of cargo, M_{actual} , in t.
- d) Determine the effective cargo density, in t/m^3 :

$$\rho_{eff} = \frac{M}{M_{actual}} \rho_c$$

- e) Calculate the final pressure distribution and shear load using ρ_{eff} instead of ρ_c .

3.4 Dry bulk cargo pressures

3.4.1 Total pressure

The total pressure due to dry bulk cargo acting on any load point of a cargo hold boundary, in kN/m^2 , is to be taken as:

- For strength assessment in intact condition for static design load scenarios given in Ch 5, Sec 7:
 $P_{in} = P_{bs}$
- For strength assessment in intact condition and fatigue assessment for static + dynamic design load scenarios given in Ch 5, Sec 7:
 $P_{in} = P_{bs} + P_{bd}$

but not less than 0.

where:

P_{bs} : Static pressure due to dry bulk cargo, in kN/m^2 , as defined in [3.4.2]
 P_{bd} : Dynamic inertial pressure due to dry bulk cargo in cargo holds, in kN/m^2 , as defined in [3.4.3].

Static and dynamic pressures as defined in [3.4.2] and [3.4.3] for FE analysis are to be determined using ρ_{eff} instead of ρ_c .

3.4.2 Static pressure

The dry bulk cargo static pressure P_{bs} , in kN/m^2 , is to be taken as:

$$P_{bs} = \rho_c g K_C (z_{BC} - z)$$

but not less than 0.

3.4.3 Dynamic pressure

The dry bulk cargo dynamic pressure P_{bd} , in kN/m^2 , for each load case is to be taken as:

- For $z \leq z_{BC}$:

$$P_{bd} = \rho_c \left[\frac{a_x (x_G - x) + a_y (y_G - y)}{4} + f_{dc} K_C a_z (z_{BC} - z) \right]$$

- For $z > z_{BC}$:

$$P_{bd} = 0$$

Where:

f_{dc} : Dry cargo factor, taken as 1,0 for strength assessment and 0,5 for fatigue assessment

3.5 Shear load

3.5.1 Application

For FE strength assessment and FE fatigue assessment, the following shear load pressures are to be considered in addition to the dry bulk cargo pressures defined in [3.4] when the load point elevation, z , is lower or equal to z_{BC}

- For static (S) design load scenarios, given in Ch 5, Sec 7: Static shear load, P_{bs-s} , due to gravitational forces acting on hopper tanks and lower stools plating, as defined in [3.5.2].
- For static plus dynamic (S+D) design load scenarios, given in Ch 5, Sec 7: The following dynamic shear load pressures:
 - $P_{bs-s} + P_{bs-d}$
for the hopper tank and the lower stool plating, as defined in [3.5.3]
 - P_{bs-dx}
for the inner bottom plating in the longitudinal direction, as defined in [3.5.4]
 - P_{bs-dy}
for the inner bottom plating in the transverse direction, as defined in [3.5.4].

Shear loads as defined in [3.5.2] to [3.5.4] for FE analysis are to be determined using ρ_{eff} instead of ρ_c .

3.5.2 Static shear load on the hopper tank and lower stool plating

The static shear load pressure, P_{bs-s} (positive downward to the plating) due to dry bulk cargo gravitational forces acting on hopper tank and lower stool plating, in kN/m^2 , is to be taken as:

$$P_{bs-s} = \rho_c g \frac{(1 - K_C) (z_{BC} - z)}{\tan \alpha_p}$$

3.5.3 Dynamic shear load on the hopper tank and lower stool plating

The dynamic shear load pressure, P_{bs-d} (positive downward to the plating) due to dry bulk cargo forces on the hopper tank and lower stool plating, in kN/m^2 , for each dynamic load case is to be taken as:

$$P_{bs-d} = \rho_c a_z \frac{(1 - K_C) (z_{BC} - z)}{\tan \alpha_p}$$

3.5.4 Dynamic shear load along the inner bottom plating for FE analyses

The dynamic shear load pressures, P_{bs-dx} in the longitudinal direction (positive to bow) due to dry bulk cargo forces acting along the inner bottom plating, in kN/m^2 , for each dynamic load case is to be taken respectively as:

$$P_{bs-dx} = -0.75 \rho_c a_x h_{BC}$$

The dynamic shear load pressures, P_{bs-dy} in the transverse direction (positive to port) due to dry bulk cargo forces acting along the inner bottom plating, in kN/m^2 , for each dynamic load case is to be taken respectively as

$$P_{bs-dy} = -0.75 \rho_c a_y h_{BC}$$

The dynamic shear load pressures P_{bs-dx} and P_{bs-dy} are only used for FE strength assessment.

4 Pressures and forces due to dry cargoes in flooded conditions

4.1 Local loads on vertically corrugated transverse bulkheads in flooded conditions

4.1.1 Application

The pressure defined in this sub-article applies to vertically corrugated transverse watertight bulkheads of the cargo holds of ships intended for the carriage of dry cargoes in bulk for flooded condition assessment.

Each cargo hold is to be considered individually flooded, see Fig 7, Fig 8 and Fig 9.

Figure 7 : Flooded level below upper surface of bulk cargo

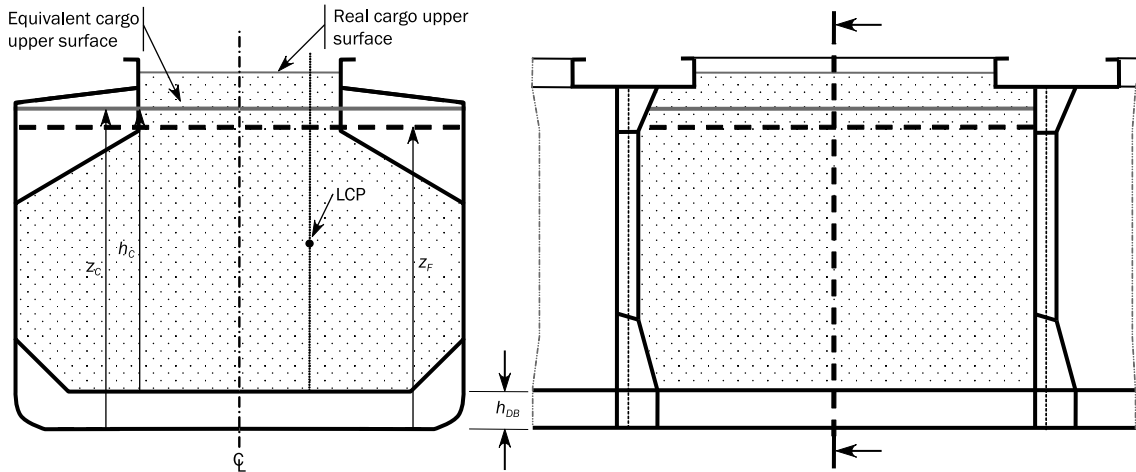


Figure 8 : Flooded level above upper surface of bulk cargo

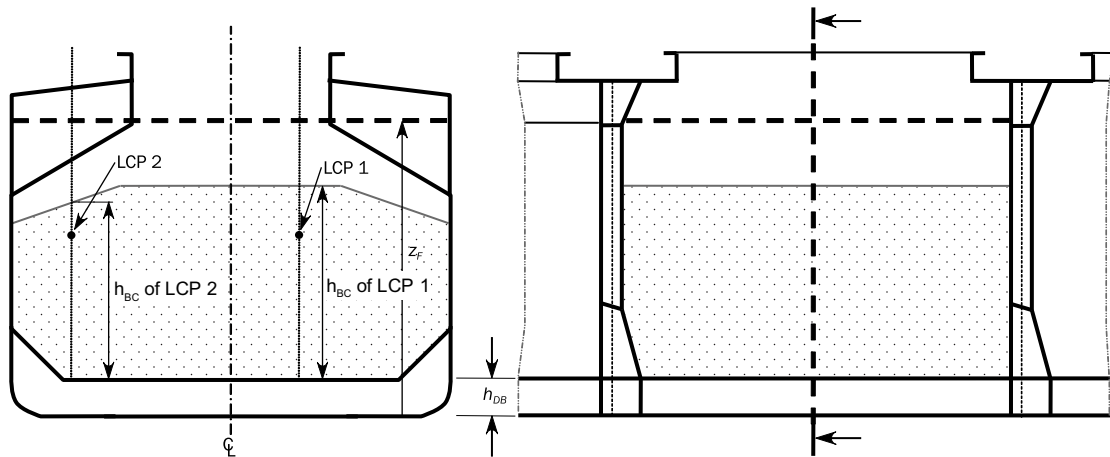
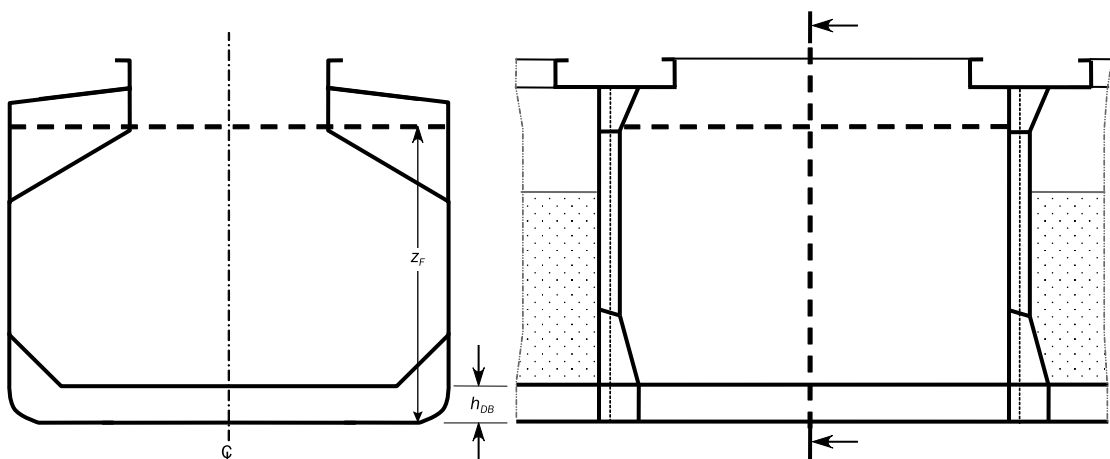


Figure 9 : Flooded cargo hold without cargo



4.1.2 General

The loads to be considered as acting on each bulkhead are those given by the combination of those induced by cargo loads with those induced by the flooding of one hold adjacent to the bulkhead under examination. In any case, the pressure due to the flooding water alone is to be considered. This application is to be applied to **self-unloading bulk carrier ESP** where the unloading system maintains the watertightness during seagoing operations. In **self-unloading bulk carrier ESP** with unloading systems that do not maintain watertightness, the combination loads acting on the bulkheads in the flooded conditions are to be considered using the extent to which the flooding may occur.

The most severe combinations of cargo induced loads and flooded loads are to be used for the check of the scantlings of each bulkhead, depending on the loading conditions included in the loading manual considering the individual flooded condition of both loaded and empty holds:

- Homogeneous loading conditions
- Non-homogeneous loading conditions.

For the purpose of this article, the following items are defined as:

- Design load limits:

The specified design load limits for the cargo holds are to be represented by loading conditions defined by the designer in the loading manual.

- Maximum cargo mass to consider:

Unless the ship is intended to carry, in non-homogeneous conditions, only iron ore or cargo having bulk density equal to or greater than 1,78 t/m³, the maximum mass of cargo which may be carried in the hold is also to be considered to fill that hold up to the top of the hatch coaming.

- Homogeneous loading conditions:

Homogeneous loading condition means a loading condition in which the ratio between the highest and the lowest filling level, evaluated for each hold, does not exceed 1,20, to be corrected for different cargo densities.

- Packed cargoes:

Holds carrying packed cargoes (such as steel mill products) are to be considered as empty.

- Unconsidered loading conditions:

Non-homogeneous partially filled loading conditions associated with Multi-port (MP) loading and unloading operations do not need to be considered for the verification of these requirements.

4.1.3 Flooded level

The flooded level z_f is the distance, in m, measured vertically from the baseline with the ship in the upright position, and obtained from Tab 3.

4.1.4 Flooded patterns

Three different flooded patterns are to be considered:

- the flooded level is below the upper surface of the cargo, (see Fig 7: $z_{BC} > z_f$)
- the flooded level is above the upper surface of the cargo, (see Fig 8: $z_{BC} \leq z_f$)
- the flooded hold is empty, (see Fig 9: $z_{BC} = h_{DB}$).

4.1.5 Pressures and forces on vertically corrugated transverse bulkheads of flooded cargo holds

The static pressure P_{bf-sr} in kN/m², at any point of the vertically corrugated transverse bulkhead located at a level z from the baseline is given in Tab 4 for each flooded pattern defined in [4.1.4].

The force F_{bf-sr} in kN, acting on a corrugation of a transverse bulkhead is given by Tab 5 for each flooded pattern defined in [4.1.4].

where:

$P_{bf-s-LE}$: Static pressure calculated according to Tab 4 for: $z = h_{LS} + h_{DB}$.

Table 3 : Flooded level z_f , in m, for vertically corrugated transverse bulkheads

Ship type	Loading condition	Vertically corrugated transverse bulkhead position	
		Foremost	Others
Ships less than 50,000 t deadweight with Type B freeboard	Non-homogeneous loading conditions with cargo density less than 1,78 t/m ³	$z_f = 0,9 D_1$	$z_f = 0,8 D_1$
	Other cases	$z_f = 0,95 D_1$	$z_f = 0,85 D_1$
Other ships	Non-homogeneous loading conditions with cargo density less than 1,78 t/m ³	$z_f = 0,95 D_1$	$z_f = 0,85 D_1$
	Other cases	$z_f = D_1$	$z_f = 0,9 D_1$

Table 4 : Static pressure on vertically corrugated transverse bulkhead of a flooded cargo hold P_{bf-s}

Flooded case	Load point position	Pressure P_{bf-s} in kN/m ²
$z_{BC} > z_F$	$z > z_{BC}$	$P_{bf-s} = 0$
	$z_{BC} \geq z \geq z_F$	$P_{bf-s} = \rho_C g (z_{BC} - z) K_{C-f}$
	$z_F > z \geq h_{DB}$	$P_{bf-s} = \rho g (z_F - z) + [\rho_C (z_{BC} - z) - \rho (1 - perm) (z_F - z)] g K_{C-f}$
$h_{DB} \leq z_{BC} \leq z_F$	$z > z_F$	$P_{bf-s} = 0$
	$z_F \geq z \geq z_{BC}$	$P_{bf-s} = \rho g (z_F - z)$
	$z_{BC} > z \geq h_{DB}$	$P_{bf-s} = \rho g (z_F - z) + [\rho_C - \rho (1 - perm)] g (z_{BC} - z) K_{C-f}$

Table 5 : Force acting on a corrugation in the flooded cargo holds F_{bf-s}

Flooded case	Force F_{bf-s} in kN
$z_{BC} > z_F$	$F_{bf-s} = s_{cg} \left\{ \rho_C g \frac{(z_{BC} - z_F)^2}{2} K_{C-f} + \left[\frac{\rho_C g (z_{BC} - z_F) K_{C-f} + P_{bf-s-LE}}{2} \right] (z_F - h_{DB} - h_{LS}) \right\}$
$z_F \geq z_{BC}$	$F_{bf-s} = s_{cg} \left\{ \rho g \frac{(z_F - z_{BC})^2}{2} + \left[\frac{\rho g (z_F - z_{BC}) + P_{bf-s-LE}}{2} \right] (z_{BC} - h_{DB} - h_{LS}) \right\}$

4.1.6 Pressures and forces on vertically corrugated transverse bulkheads of non-flooded cargo holds

The static pressure P_{bs} , in kN/m², at a point of the vertically corrugated transverse bulkhead, located at the level z from the baseline, due to dry bulk cargo of a non-flooded cargo hold acting on the intact side of the transverse bulkhead which is flooded on the other side is to be taken as:

$$P_{bs} = \rho_C g K_{C-f} (z_{BC} - z)$$

but not less than 0.

The resultant force F_{bs} , in kN, acting on a corrugation is to be taken as:

$$F_{bs} = \rho_C g s_{cg} \frac{(z_{BC} - h_{DB} - h_{LS})^2}{2} K_{C-f}$$

4.1.7 Resultant pressures and forces on vertically corrugated transverse bulkheads of flooded cargo holds

The resultant pressure P_R , in kN/m², at each point of the bulkhead, and the resultant force F_R , in kN, acting on a corrugation, given in Tab 6, are to be considered for the assessment in flooded conditions of vertically corrugated transverse bulkhead structures, where:

- P_{bf-s} : Pressure in the flooded cargo holds, in kN/m², as defined in [4.1.5]
- P_{bs} : Pressure in the non-flooded cargo holds, in kN/m², as defined in [4.1.6]
- F_{bf-s} : Force acting on a corrugation in the flooded cargo holds, in kN, as defined in [4.1.5]
- F_{bs} : Force acting on a corrugation in the non-flooded cargo holds, in kN, as defined in [4.1.6].

Table 6 : Resultant pressure P_R and resultant force F_R on vertically corrugated transverse bulkhead in flooded condition

Loading condition	Resultant pressure P_R in kN/m ²	Resultant force F_R in kN
Homogeneous	$P_R = P_{bf-s} - 0,8 P_{bs}$	$F_R = F_{bf-s} - 0,8 F_{bs}$
Alternate	$P_R = P_{bf-s}$	$F_R = F_{bf-s}$

4.2 Local loads on double bottom in flooded conditions

4.2.1 Application

The pressure defined in this sub-article applies to the double bottom in cargo holds of ships intended for the carriage of dry cargoes in bulk for flooded condition assessment.

Each cargo hold is to be considered individually flooded.

4.2.2 General

The loads to be considered as acting on the double bottom are those given by the external sea pressures and the combination of the cargo loads with those induced by the flooding of the hold to which the double bottom belongs.

The most severe combinations of cargo induced loads and flooded loads are to be used, depending on the loading conditions included in the loading manual:

- Homogeneous loading conditions;
- Non-homogeneous loading conditions;
- Packed cargo conditions (such as in the case of steel mill products).

For each loading condition, the maximum dry bulk cargo density to be carried is to be considered in calculating the allowable hold loading.

4.2.3 Flooded level

The flooded level z_F is the distance, in m, measured vertically from the baseline with the ship in the upright position, and obtained from Tab 7.

Table 7 : Flooded level z_F , for double bottom in cargo hold region

Ship type	Cargo hold	
	Foremost	Others
Ships less than 50,000 t deadweight with Type-B freeboard	$z_F = 0,95 D_1$	$z_F = 0,85 D_1$
Other ships	$z_F = D_1$	$z_F = 0,9 D_1$

5 Steel Coil Loads

5.1 General

5.1.1 Application

The provision is determined by assuming Fig 10 as the standard means of securing steel coils loaded on wooden dunnage.

It is assumed that all the steel coils have the same characteristics.

In cases where steel coils are lined up in two or more tiers, formulae in [5.1.3] and [5.2] can be applied assuming that only the lowest tier of steel coils is in contact with hopper sloping plate or inner side plate. In other cases, scantling requirements are to be determined on a case-by-case basis.

5.1.2 Arrangement of steel coils on inner bottom

The two following arrangements of steel coils on the inner bottom are considered:

- The steel coils are positioned without respect to the location of the inner bottom floors, as shown in Fig 11. In this case, n_2 and l_{ip} are given by Tab 8 and Tab 9.
- The steel coils are positioned with respect to the location of the inner bottom floors, as shown in Fig 12.

5.1.3 Arrangement of steel coils independently of the floor locations

For steel coils loaded without respect to the location of floors in the inner bottom, see Fig 11:

- The number n_2 of load point dunnages per elementary plate panels is to be found in comply with Tab 8.
- The distance l_{ip} , in m, between outermost load point dunnages per elementary plate panel is to be found in comply with Tab 9.

Figure 10 : Inner bottom loaded by steel coils

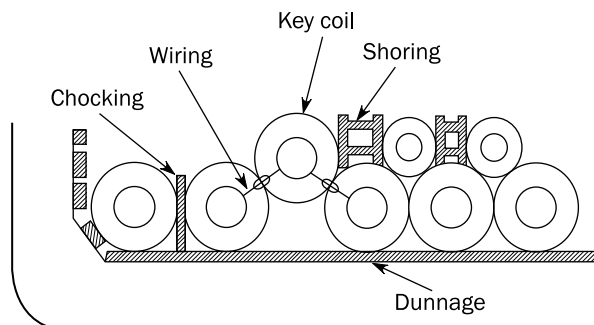


Figure 11 : Steel coils loaded independently of inner bottom floors locations

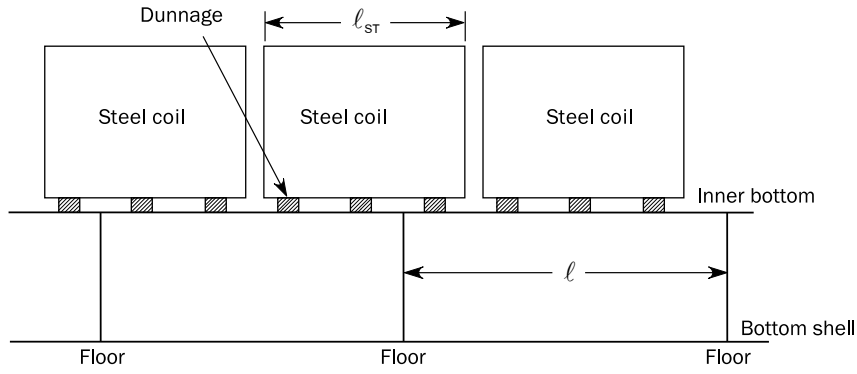


Figure 12 : Steel coils loaded between inner bottom floors

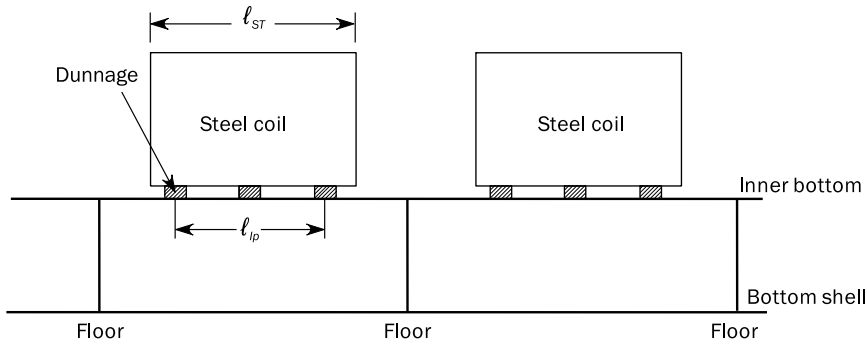


Table 8 : Number n_2 of load point dunnages per elementary plate panel

n_2	n_3			
	2	3	4	5
1	$0 < \frac{l}{l_{st}} \leq 0.5$	$0 < \frac{l}{l_{st}} \leq 0.33$	$0 < \frac{l}{l_{st}} \leq 0.25$	$0 < \frac{l}{l_{st}} \leq 0.2$
2	$0.5 < \frac{l}{l_{st}} \leq 1.2$	$0.33 < \frac{l}{l_{st}} \leq 0.67$	$0.25 < \frac{l}{l_{st}} \leq 0.5$	$0.2 < \frac{l}{l_{st}} \leq 0.4$
3	$1.2 < \frac{l}{l_{st}} \leq 1.7$	$0.67 < \frac{l}{l_{st}} \leq 1.2$	$0.5 < \frac{l}{l_{st}} \leq 0.75$	$0.4 < \frac{l}{l_{st}} \leq 0.6$
4	$1.7 < \frac{l}{l_{st}} \leq 2.4$	$1.2 < \frac{l}{l_{st}} \leq 1.53$	$0.75 < \frac{l}{l_{st}} \leq 1.2$	$0.6 < \frac{l}{l_{st}} \leq 0.8$
5	$2.4 < \frac{l}{l_{st}} \leq 2.9$	$1.53 < \frac{l}{l_{st}} \leq 1.87$	$1.2 < \frac{l}{l_{st}} \leq 1.45$	$0.8 < \frac{l}{l_{st}} \leq 1.2$
6	$2.9 < \frac{l}{l_{st}} \leq 3.6$	$1.87 < \frac{l}{l_{st}} \leq 2.4$	$1.45 < \frac{l}{l_{st}} \leq 1.7$	$1.2 < \frac{l}{l_{st}} \leq 1.4$
7	$3.6 < \frac{l}{l_{st}} \leq 4.1$	$2.4 < \frac{l}{l_{st}} \leq 2.73$	$1.7 < \frac{l}{l_{st}} \leq 1.95$	$1.4 < \frac{l}{l_{st}} \leq 1.6$
8	$4.1 < \frac{l}{l_{st}} \leq 4.8$	$2.73 < \frac{l}{l_{st}} \leq 3.07$	$1.95 < \frac{l}{l_{st}} \leq 2.4$	$1.6 < \frac{l}{l_{st}} \leq 1.8$
9	$4.8 < \frac{l}{l_{st}} \leq 5.3$	$3.07 < \frac{l}{l_{st}} \leq 3.6$	$2.4 < \frac{l}{l_{st}} \leq 2.65$	$1.8 < \frac{l}{l_{st}} \leq 2.0$
10	$5.3 < \frac{l}{l_{st}} \leq 6.0$	$3.6 < \frac{l}{l_{st}} \leq 3.93$	$2.65 < \frac{l}{l_{st}} \leq 2.9$	$2.0 < \frac{l}{l_{st}} \leq 2.4$

Table 9 : Distance between outermost load point dunnages per elementary plate panel, l_{ip} , in m

n_2	n_3			
	2	3	4	5
1	Actual breadth of dunnages			
2	$0,5l_{st}$	$0,33l_{st}$	$0,25l_{st}$	$0,2l_{st}$
3	$1,2l_{st}$	$0,67l_{st}$	$0,50l_{st}$	$0,4l_{st}$
4	$1,7l_{st}$	$1,20l_{st}$	$0,75l_{st}$	$0,6l_{st}$
5	$2,4l_{st}$	$1,53l_{st}$	$1,20l_{st}$	$0,8l_{st}$
6	$2,9l_{st}$	$1,87l_{st}$	$1,45l_{st}$	$1,2l_{st}$
7	$3,6l_{st}$	$2,40l_{st}$	$1,70l_{st}$	$1,4l_{st}$
8	$4,1l_{st}$	$2,73l_{st}$	$1,95l_{st}$	$1,6l_{st}$
9	$4,8l_{st}$	$3,07l_{st}$	$2,40l_{st}$	$1,8l_{st}$
10	$5,3l_{st}$	$3,60l_{st}$	$2,65l_{st}$	$2,0l_{st}$

5.1.4 Arrangement of steel coils between floors

For steel coils loaded with respect to the locations of floors in the inner bottom, see Fig 12:

- The number n_2 of load point dunnages per elementary plate panels is to be taken as: $n_2 = n_3$
- The distance l_{ip} between outermost load point dunnages per elementary plate panel is to be taken as the distance between the outermost dunnage supporting one row of steel coils.

5.1.5 Centre of gravity of steel coil cargo

The centre of gravity of the steel coil cargo of the considered cargo hold is to be taken at the following position:

a) Longitudinal position

x_{Gsc} is the X coordinate, in m, of the volumetric centre of gravity of the considered cargo hold with respect to the reference coordinate system defined in Ch 1, Sec 3, [2.6.1].

b) Transverse position

$$y_{Gsc} = \varepsilon \frac{B_H}{4}$$

c) Vertical position

$$z_{Gsc} = h_{DB} + \left[1 + (n_t - 1) \frac{\sqrt{3}}{2} \right] \frac{d_{sc}}{2}$$

where:

- ε : Coefficient to be taken as:
- $\varepsilon = 1,0$ when a port side structural member is assessed
 - $\varepsilon = -1,0$ when a starboard side structural member is assessed.

5.2 Total loads

5.2.1 Total load on the inner bottom

The total load F_{sc-ib} in kN, due to steel coil cargoes on the inner bottom is to be taken as:

$$F_{sc-ib} = \cos(f_\beta C_{XG} \varphi) \cos(C_{YG} \theta) F_{sc-ib-s} + F_{sc-ib-d}$$

but not less than 0

where:

- $F_{sc-ib-s}$: Static load, in kN, on the inner bottom, given in [5.3.1]
- $F_{sc-ib-d}$: Dynamic load, in kN, on the inner bottom, given in [5.4.1]
- C_{XG}, C_{YG} : Load combination factors, as defined in Ch 5, Sec 2, [2.2].

5.2.2 Total load on the hopper side and the inner hull

The total load F_{sc-hs} in kN, due to steel coil cargoes on the hopper side and the inner hull is to be taken as:

$$F_{sc-hs} = \frac{\cos(\theta_h + \varepsilon C_{YG} \theta) \cos(f_\beta C_{XG} \varphi)}{\cos \theta_h} F_{sc-hs-s} + F_{sc-hs-d}$$

but not less than 0.

where:

- $F_{sc-hs-s}$: Static load, in kN, on the hopper side and the inner hull given in [5.3.2]
 $F_{sc-hs-d}$: Dynamic load, in kN, on the hopper side and the inner hull given in [5.4.2]
 C_{XG}, C_{YG} : Load combination factors, as defined in Ch 5, Sec 2, [2.2].

5.3 Static loads

5.3.1 Static loads on the inner bottom

The static load $F_{sc-ib-s}$ in kN, on the inner bottom due to steel coils is to be taken as:

$$F_{sc-ib-s} = M_{sc-ib} g$$

where:

M_{sc-ib} : Equivalent mass of steel coils, in t, to be taken as:

$$M_{sc-ib} = K_S W \frac{n_1 n_2}{n_3} \text{ for } n_2 \leq 10 \text{ and } n_3 \leq 5$$

$$M_{sc-ib} = K_S W n_1 \frac{\ell}{\ell_{st}} \text{ for } n_2 > 10 \text{ or } n_3 > 5$$

K_S : Coefficient to be taken as:

$K_S = 1,4$ when steel coils are lined up in one tier with a key coil.

$K_S = 1,0$ in other cases.

5.3.2 Static load on the hopper side and the inner hull

The static load $F_{sc-hs-s}$ in kN, on the hopper side and the inner hull due to steel coils is to be taken as:

$$F_{sc-hs-s} = \cos \theta_h \cdot M_{sc-hs} \cdot g$$

where:

M_{sc-hs} : Equivalent mass of steel coils, in t, to be taken as:

$$M_{sc-hs} = C_k W \frac{n_2}{n_3} \text{ for } n_2 \leq 10 \text{ and } n_3 \leq 5$$

$$M_{sc-hs} = C_k W \frac{\ell}{\ell_{st}} \text{ for } n_2 > 10 \text{ or } n_3 > 5$$

C_k : Coefficient to be taken as:

$C_k = 3,2$ when steel coils are lined up two or more tiers, or when steel coils are lined up one tier and key coil is located second or 3rd from hopper sloping plate or inner hull plate

$C_k = 2,0$ for other cases.

5.4 Dynamic loads

5.4.1 Dynamic load on the inner bottom

The dynamic load $F_{sc-ib-d}$ in kN, on the inner bottom due to steel coils is to be taken as:

$$F_{sc-ib-d} = M_{sc-ib} a_z$$

where:

a_z : Vertical acceleration, in m/s^2 , as defined in Ch 5, Sec 3, [3.2.4], calculated at the centre of gravity of the steel coil cargo of the considered cargo hold, given in [5.1.5].

5.4.2 Dynamic load on the hopper side and the inner hull

The dynamic load $F_{sc-hs-d}$ in kN, on the hopper side and the inner hull due to steel coils is to be taken as:

$$F_{sc-hs-d} = \varepsilon \cdot M_{sc-hs} [C_{YR} a_{roll} \Omega - f_{\beta} C_{YS} a_{sway} \sin \theta_h]$$

where:

Ω : Geometrical coefficient defined as:

$$\Omega = \sqrt{y_{Gsc}^2 + (R - z_{Gsc})^2} \cdot \sin \left(\tan^{-1} \left| \frac{y_{Gsc}}{R - z_{Gsc}} \right| - \theta_h \right)$$

C_{YS}, C_{YR} : Load combination factors, defined in Ch 5, Sec 2, [2.2]

a_{roll} : Roll acceleration, in rad/s^2 , defined in Ch 5, Sec 3, [2.2.4]

a_{sway} : Sway acceleration, in m/s^2 , as defined in Ch 5, Sec 3, [2.2.2]

ε : Coefficient defined in [5.1.5]

y_{Gsc} : Y coordinate, in m, of the centre of gravity of the steel coil cargo of the considered cargo hold, given in [5.1.5]

z_{Gsc} : Z coordinate, in m, of the centre of gravity of the steel coil cargo of the considered cargo hold, given in [5.1.5].

6 Loads on decks and platforms

6.1 Pressure due to distributed load

6.1.1 In accommodation and machinery spaces and when a uniform cargo is carried on deck, a distributed load is to be applied. The static and dynamic pressure due to this distributed load is to be considered.

The total pressure P_{dl} , in kN/m², due to accommodation or machinery loads or uniform cargo for the static design load scenarios is to be taken as:

$$P_{dl} = P_{dl-s}$$

The total pressure P_{dl} , in kN/m², due to accommodation or machinery loads or uniform cargo for the static + dynamic design load scenario is to be derived for each dynamic load case and is to be taken as:

$$P_{dl} = P_{dl-s} + P_{dl-d}$$

where:

P_{dl-s} : Static pressure, in kN/m², due to accommodation or machinery loads or uniform cargo, to be defined by the Designer without being less than the values given in Tab 10.

For deck loaded with dry uniform cargo, when the P_{dl-s} value is not specified by the designer, it may be taken equal to $6,9 h_{TD}$

P_{dl-d} : Dynamic pressure, in kN/m², due to uniform cargo, to be taken as:

$$P_{dl-d} = P_{dl-s} \frac{a_z}{g}$$

a_z : Vertical acceleration, in m/s², at the load position being considered, for the considered load case, to be obtained according to Ch 5, Sec 3, [3]

h_{TD} : compartment tweendeck height at side, in m.

6.1.2 Ships with additional service feature heavy cargo

For ships with the additional service feature **heavy cargo** [AREA, X1 kN/m² - AREA, X2 kN/m² - ...] (see Pt A, Ch 1, Sec 2, [4.2.2]), the values of p_{dl-s} , in kN/m², are to be specified by the Designer for each AREAi, according to [6.1.1], and introducing as Xi values in the above service feature.

6.2 Concentrated force due to unit cargo

6.2.1 When a unit cargo is carried on a deck, a concentrated load is to be applied. The static and dynamic concentrated forces due to this unit cargo are to be considered, when a direct analysis is applied for stiffeners or for primary supporting members, such as in Ch 7, Sec 5, [1.7] or in Ch 7, Sec 6, [2.2], respectively.

The concentrated force F_{u-s} , in kN, due to this unit cargo for the static design load scenarios is to be taken, in the z direction, as:

$$F_{u-s} = -m_U g$$

The concentrated force F_{u-d} , in kN, due to this unit cargo for the static + dynamic design load scenarios is to be derived from the dynamic load cases, with components to be taken as defined in Tab 11.

Table 10 : Minimum static pressure due to distributed loads

Type of compartment	P_{dl-s} in kN/m ²
Large public spaces, such as restaurants, halls, cinemas, lounges	5,0
Muster stations	5,0
Large rooms, such as: <ul style="list-style-type: none"> rooms with fixed furniture games and hobbies rooms, hospitals 	3,0
Cabins	3,0
Other accommodation compartments	2,5
Storage rooms	5,0
Machinery spaces	10,0
Technical spaces, such as AC rooms, elevators machinery space, electrical facilities, pump rooms	5,0
Other decks and platforms	10,0
Dry uniform cargo	10,0

Table 11 : Force F_{u-d} due to unit cargo

Direction	F_{u-d} in kN, on exposed deck	F_{u-d} in kN, on non-exposed deck
x	$-m_U a_x$	$-m_U a_{x-env}$
y	$-m_U a_y$	$-m_U a_{y-env}$
z	$-m_U (a_z + g)$	$-m_U (a_{z-env} + g)$

Note 1:
 m_U : Mass of the unit cargo carried, in t
 a_x, a_y, a_z : Accelerations, in m/s^2 , at the centre of gravity of the unit cargo carried for the considered load case, to be obtained according to Ch 5, Sec 3, [3.2].
 $a_{x-env}, a_{y-env}, a_{z-env}$: Envelope of accelerations, in m/s^2 , at the centre of gravity of the unit cargo carried for the considered load case, to be obtained according to Ch 5, Sec 3, [3.3].

7 Wheeled cargo

7.1 Application

7.1.1 General

Caterpillar trucks and unusual vehicles are considered by the Society on a case by case basis.

The load supported by the crutches of semi-trailers, handling machines and platforms is considered by the Society on a case by case basis.

7.1.2 Tyred vehicles

The forces transmitted through the tyres are considered as uniformly distributed pressure on the tyre print area, which dimensions are to be given by the Designer together with the arrangement of wheels on axles, the load per axle and the tyre pressure.

For the assessment of stiffeners and primary supporting members, such forces are considered as concentrated in the tyre print centre.

The forces acting on primary supporting members are to be determined taking into account the area of influence of each member and the way ordinary stiffeners transfer the forces transmitted through the tyres.

7.1.3 Non-tyred vehicles

The requirements of [7.1.2] also apply to tracked vehicles; in this case the print to be considered is that below each wheel or wheelwork.

For vehicles on rails, all the forces transmitted are to be considered as concentrated at the contact area centre.

7.2 Forces due to wheeled cargo

7.2.1 Total force induced by a single wheel

The total wheel force P_0 , in kN, for the static design load scenarios is to be taken as:

$$P_0 = F_{W-S}$$

The total wheel force P_0 , in kN, for the dynamic design load scenarios is to be taken as:

$$P_0 = F_{W-S} + F_{W-D}$$

where:

F_{W-S} : Static wheel force defined in [7.2.2]

F_{W-D} : Dynamic wheel force defined in [7.2.3].

7.2.2 Static force

The static wheel force F_{W-S} , in kN, for the static design load scenarios is to be taken, in the z direction, as:

$$F_{W-S} = -Mg$$

Where:

M : Mass supported by a single wheel, in t, taken equal to:

$$M = \frac{Q_A}{n_W}$$

Q_A : Axle load, in t

n_W : Number of individual wheels for the axle considered.

7.2.3 Dynamic force

The dynamic wheel force F_{W-D} , in kN, for the static + dynamic design load scenarios is to be derived from the dynamic load cases, with components to be taken as defined in Tab 12.

Table 12 : Dynamic forces due to wheeled cargo

Direction	F_{W-D} , in kN, General(1)	F_{W-D} , in kN, Racking analysis(2)
x	–	–
y	–	$-M a_y$
z	$-\alpha M a_z$	$-\alpha M a_z$

(1) This condition defines the force, applied by one wheel, to be considered for the determination of scantlings of plating, ordinary stiffeners and primary supporting members, as defined in Part B, Chapter 6.

(2) This condition is to be considered for the racking analysis of ships granted with the service notation **PCT carrier, ro-ro cargo ship or ro-ro passenger ship**, as defined in Ch 7, App 1, with M taken equal to the mass, in t, of wheel loads located on the structural member under consideration.

Note 1:

M : Mass of the unit cargo carried, in t

a_y, a_z : Accelerations, in m/s^2 , at the centre of gravity of the considered vehicle for the considered load case, to be obtained according to Ch 5, Sec 3, [3.2].

α : Coefficient accounting for shock absorbers, taken equal to:

- 0,5 in general
- 1,0 for landing gears of trailers.

8 Loads due to containers

8.1 Forces applied to containers

8.1.1 Centre of gravity of a container

The centre of gravity of each container with its cargo is to be taken at 45% of the container height.

8.1.2 Static and dynamic forces

The static and dynamic forces applied to one container located at tier “i”, as defined in Fig 13, are to be obtained, in kN, as specified in Tab 13.

8.2 Stacks of containers

8.2.1 Static and dynamic forces

The static and dynamic forces and the wind force are to be considered as defined in [8.1.2] and Ch 5, Sec 5, [8.1], respectively, and the forces transmitted at the corners of a stack are to be obtained as specified in Tab 14 (see also Fig 14).

8.2.2 Empty containers

When empty containers are stowed at the top of a stack, static and dynamic forces are to be derived considering the weight of empty containers equal to:

- 2,5 t for twenty feet containers
- 3,5 t for forty feet containers
- 3,5 t for forty-five feet containers.

For other container sizes, the weight of empty containers is to be taken equal to 0,14 times the maximum gross weight of the container.

8.2.3 Effect of cell guides

Where cell guides support the containers stowed in holds, absolute value of $R_{W,MY}$ calculated according to [8.2.1], may be assumed not to be greater than 160 kN, provided that arrangements of cell guides and horizontal transverse cross-ties effectively block the container corners.

Any other arrangement may be accepted, to the Society’s satisfaction.

Table 13 : Container at tier “i” - Static and dynamic forces, in kN

Direction	Static force	Dynamic force
x	–	$F_{W,x,i} = -M_i a_{x-env}$
y	–	$F_{W,y,i} = -M_i a_{y-env}$
z	$F_{S,i} = -M_i g$	$F_{W,z,i} = -M_i a_{z-env}$

Note 1:

M_i : Mass, in t, of the container at tier “i”

$a_{x-env}, a_{y-env}, a_{z-env}$: Envelope of accelerations, in m/s^2 , at the centre of gravity of the container, to be obtained according to Ch 5, Sec 3, [3.3].

Figure 13 : Container levels in a stack

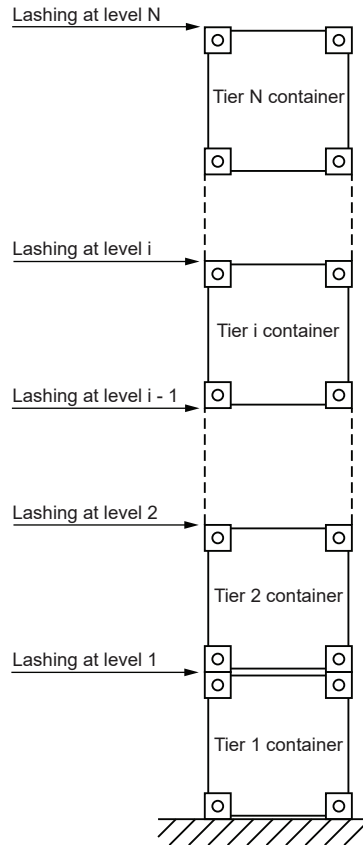


Table 14 : Containers - Static, dynamic and wind forces

	Static force F_S and dynamic and wind force F_W , in kN, acting on each container stack	Vertical static force R_S and dynamic and wind force R_W , in kN, transmitted at the corners of each container stack(1)
Static force	$F_S = \sum_{i=1}^{N_C} F_{S,i}$	$R_S = \frac{F_S}{4}$
Dynamic forces	<ul style="list-style-type: none"> in x direction: $F_{W,x} = \sum_{i=1}^{N_C} (F_{W,x,i} + F_{x,wind,i})$ in y direction: $F_{W,y} = \sum_{i=1}^{N_C} (F_{W,y,i} + F_{y,wind,i})$ in z direction: $F_{W,z} = \sum_{i=1}^{N_C} F_{W,z,i}$ 	$R_{W,1} = \frac{F_{W,z}}{4} + R_{W,MY} + R_{W,MX}$ $R_{W,2} = \frac{F_{W,z}}{4} - R_{W,MY} - R_{W,MX}$ $R_{W,3} = \frac{F_{W,z}}{4} - R_{W,MY} + R_{W,MX}$ $R_{W,4} = \frac{F_{W,z}}{4} + R_{W,MY} - R_{W,MX}$ $R_{W,MY} = \frac{N_C h_C F_{W,x}}{4 \ell_C}$ $R_{W,MX} = \frac{N_C h_C F_{W,y}}{4 b_C}$

(1) Effect of cell guides may be taken into consideration according to [8.2.3].

Note 1:

$F_{x,wind,i}$: Wind force in the longitudinal direction as defined in Ch 5, Sec 5, [8.1]

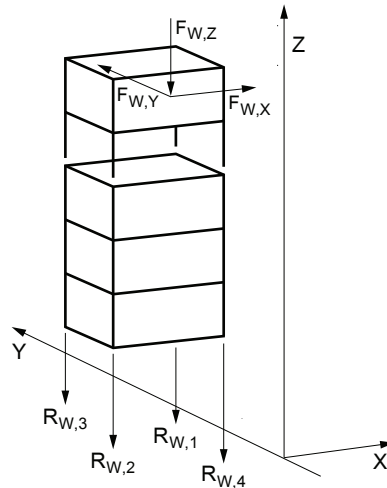
$F_{y,wind,i}$: Wind force in the transverse direction as defined in Ch 5, Sec 5, [8.1]

N_C : Number of containers per stack

h_C : Height, in m, of a container

ℓ_C, b_C : Dimensions, in m, of the container stack in the ship longitudinal and transverse directions, respectively.

Figure 14 : Stack of containers and forces



9 Loads on hatch covers

9.1 Application

9.1.1 The loads on hatch covers and coamings are to be applied for strength assessment only.

9.2 Cargo loads

9.2.1 Distributed loads

The distributed load on hatch covers p_L , in kN/m^2 , due to uniform cargo loads and resulting from heave and pitch (i.e. ship in upright condition), is to be determined according to the following formula:

$$p_L = p_C (1 + \alpha_v)$$

where:

- p_C : Uniform cargo load, in kN/m^2
- α_v : Vertical acceleration addition, taken equal to: $\alpha_v = m F$
- m : Coefficient taken equal to:

- for $0 \leq x/L \leq 0,2$:

$$m = m_0 - 5(m_0 - 1) \frac{x}{L}$$

- for $0,2 < x/L \leq 0,7$:

$$m = 1$$

- for $0,7 < x/L \leq 1,0$:

$$m = 1 + \left(\frac{m_0 + 1}{0,3} \right) \left(\frac{x}{L} - 0,7 \right)$$

- m_0 : Coefficient taken equal to: $m_0 = 1,5 + F$

- F : Coefficient taken equal to:

$$F = 0,11 \frac{V_0}{\sqrt{L}}$$

- V_0 : Maximum speed, in knots, at summer load line draught, to be taken not less than $L^{1/2}$.

9.2.2 Concentrated loads

The concentrated load P , in kN , due to unit cargo (except container) and resulting from heave and pitch (i.e. ship in upright condition), is to be determined as follows:

$$P = -P_S (1 + \alpha_v)$$

where:

- P_S : Concentrated force due to unit cargo, in kN
- α_v : Vertical acceleration addition, as defined in [9.2.1].

9.2.3 Container loads in upright condition

Where containers are stowed on hatch covers, the load P, in kN, applied at each corner of a container stack and resulting from heave and pitch (i.e. ship in upright condition), is to be determined as follows:

$$P = -9,81 \frac{M}{4} (1 + \alpha_v)$$

where:

- M : Maximum designed mass of the container stack, in t
- α_v : Vertical acceleration addition, as defined in [9.2.1].

9.2.4 Container loads in heel condition

Where containers are stowed on hatch covers, the following loads A_z , B_z and B_y , in kN, applied at each corner of a container stack and resulting from heave, pitch and rolling motion (i.e. ship in heel condition), are to be determined as follows (see Fig 15):

A_z, B_z : Support forces in z-direction at the forward and aft stack corners, taken respectively equal to:

$$A_z = -9,81 \frac{M}{2} (1 + \alpha_v) \left(0,45 - 0,42 \frac{h_m}{b} \right)$$

$$B_z = -9,81 \frac{M}{2} (1 + \alpha_v) \left(0,45 + 0,42 \frac{h_m}{b} \right)$$

B_y : Support force in y-direction at the forward and aft stack corners, taken equal to:

$$B_y = -2,4 M$$

where:

- M : Maximum designed mass of the container stack, in t, taken as:

$$M = \sum_i W_i$$

- α_v : Vertical acceleration addition, as defined in [9.2.1]
- h_m : Designed height of the centre of gravity of the stack above hatch cover top, in m, calculated as weighted mean value of the stack, where the centre of gravity of each tier is assumed to be located at the centre of each container:

$$h_m = \sum_i \frac{z_i W_i}{M}$$

- z_i : Distance from hatch cover top to the centre of ith container, in m
- W_i : Weight of ith container, in t
- b : Distance between midpoints of foot points, in m.

When strength of the hatch cover structure is assessed by grillage analysis, h_m and z_i need to be taken above the hatch cover supports. Forces B_y does not need to be considered in this case.

Values of A_z and B_z applied for the assessment of hatch cover strength are to be shown in the drawings of the hatch covers.

Note 1: It is recommended that container loads as calculated above are considered as limit for foot point loads of container stacks in the calculations of cargo securing (container lashing).

9.2.5 Load cases with partial loading

The loads defined in [9.2.1], [9.2.2] and [9.2.4] are also to be considered for partial non homogeneous loading which may occur in practice, e.g. where specified container stack places are empty. For each hatch cover, the heel directions, as shown in Tab 15, are to be considered.

The load case “partial loading of container hatch covers” can be evaluated using a simplified approach, where the hatch cover is loaded without the outermost stacks that are located completely on the hatch cover. If there are additional stacks that are supported partially by the hatch cover and partially by container stanchions then the loads from these stacks are also to be neglected (see Tab 15).

In addition, the case where only the stack places supported partially by the hatch cover and partially by container stanchions are left empty is to be assessed in order to consider the maximum loads in the vertical hatch cover supports.

It may be necessary to also consider partial load cases where more or different container stack places are left empty. The Society may require that additional partial load cases are to be considered.

9.2.6 Mixed stowage of 20’ and 40’ container on hatch cover

In the case of mixed stowage (20’ and 40’ container combined stack), the foot point forces at the fore and aft end of the hatch cover are not to be higher than resulting from the design stack weight for 40’ containers, and the foot point forces at the middle of the cover are not to be higher than resulting from the design stack weight for 20’ containers.

Figure 15 : Forces due to container loads

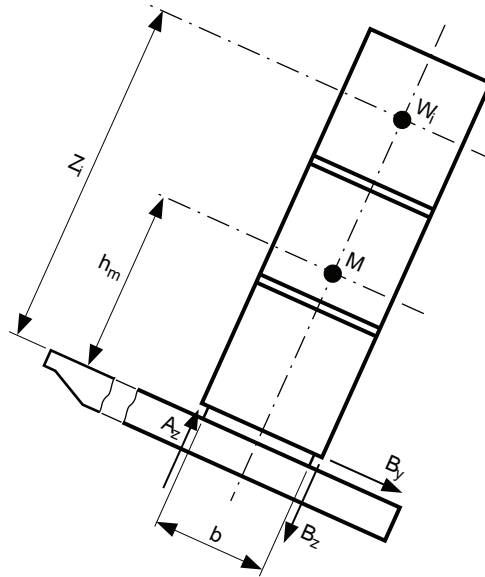


Table 15 : Partial loading of container hatch covers

Heel direction	< (Heel towards coaming)	> (Heel opposite to coaming)
Hatch covers supported by the longitudinal hatch coaming with all container stacks located completely on the hatch cover		
Hatch covers supported by the longitudinal hatch coaming with the outermost container stacks supported partially by the hatch cover and partially by container stanchions		
Hatch covers not supported by the longitudinal hatch coaming (center hatch covers)		

10 Design pressure for tank testing

10.1 Definition

10.1.1 In order to assess the structure, static design pressures, P_{ST} , in kN/m^2 , are to be considered, as obtained from the formulae in Tab 16.

Table 16 : Tank testing design pressures

Compartment	Still water pressure P_{ST} , in kN/m ²
Double bottom tanks Double side tanks	The greater of the following: $P_{ST} = 10 [(z_{top} - z) + h_{air}]$ $P_{ST} = 10 [(z_{top} - z) + 2,4]$ $P_{ST} = 10 (z_{bd} - z)$
Fuel oil tanks	The greater of the following: $P_{ST} = 10 [(z_{top} - z) + h_{air}]$ $P_{ST} = 10 [(z_{top} - z) + 2,4]$ $P_{ST} = 10 [(z_{top} - z) + 0,1 P_{pv}]$ $P_{ST} = 10 (z_{bd} - z)$
Cargo oil tanks	The greater of the following: $P_{ST} = 10 [(z_{top} - z) + h_{air}]$ $P_{ST} = 10 [(z_{top} - z) + 2,4]$ $P_{ST} = 10 [(z_{top} - z) + 0,1 P_{pv}]$
Ballast holds of ships with service notation bulk carrier, bulk carrier ESP, self-unloading bulk carrier ESP, ore carrier ESP or combination carrier ESP	The greater of the following: $P_{ST} = 10 [(z_{top} - z) + h_{air}]$ $P_{ST} = 10 (z_h - z)$
Ballast ducts	The greater of the following: $P_{ST} = 10 [(z_{top} - z) + 0,1 P_{pv}]$ Ballast pump maximum pressure
Deep tanks Peak tanks	The greater of the following: $P_{ST} = 10 [(z_{top} - z) + h_{air}]$ $P_{ST} = 10 [(z_{top} - z) + 2,4]$
Integral or independent cargo tanks of ships with service notation chemical tanker	The greater of the following: $P_{ST} = 10 [(z_{top} - z) + 2,4]$ $P_{ST} = 10 [(z_{top} - z) + 0,1 P_{pv}]$
Chain locker	$P_{ST} = 10 (z_{cp} - z)$
Fuel chemical tanks	The greater of the following: $P_{ST} = 10 [(z_{top} - z) + 2,4]$ $P_{ST} = 10 [(z_{top} - z) + 0,1 P_{pv}]$
Note 1: z_{bd} : Z coordinate, in m, of the bulkhead deck z_{cp} : Z coordinate, in m, of the top of chain pipe. z_h : Z co-ordinate, in m, of the top of hatch coaming	

Section 7 Design Load Scenarios

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

F_u	: Design force due to unit cargo, in kN
F_{W-D}	: Dynamic wheel force, in kN, as defined in Ch 5, Sec 6, [7.2.3]
F_{W-S}	: Static wheel force, in kN, as defined in Ch 5, Sec 6, [7.2.2]
HBM	: Design horizontal bending moment, in kN·m
HSF	: Design horizontal shear force, in kN
M_{sw}	: Permissible maximum and minimum vertical still water bending moment in seagoing operation, in kN·m, at the hull transverse section considered, defined in Ch 5, Sec 4, [2.2.1]
M_{sw-p}	: Permissible maximum and minimum vertical still water bending moment for harbour/sheltered water operation, in kN·m, as defined in Ch 5, Sec 4, [2.2.2]
$M_{sw-t-LC}$: Permissible torsional still water moment for seagoing operation, in kN·m, as defined in Pt D, Ch 2, Sec 2
M_{sw-t-p}	: Permissible torsional still water moment for harbour/sheltered water operation, in kN·m, as defined in Pt D, Ch 2, Sec 2
M_{wh-LC}	: Horizontal wave bending moment for a considered dynamic load case, in kN·m, as defined in Ch 5, Sec 4, [3.6.3]
M_{wt-LC}	: Wave torsional moment for a considered dynamic load case, in kN·m, as defined in Ch 5, Sec 4, [3.6.5]
M_{ww-LC}	: Vertical wave bending moment for the considered dynamic load case, in kN·m, as defined in Ch 5, Sec 4, [3.6.1]
P_0	: Design force due to wheel loads, in kN, as defined in Ch 5, Sec 6, [7.2.1]
P_{bs}	: Dry bulk cargo static pressure, in kN/m ² , as defined in Ch 5, Sec 6, [3.4.2]
P_{bd}	: Dry bulk cargo dynamic pressure for the considered dynamic load case, in kN/m ² , as defined in Ch 5, Sec 6, [3.4.3]
P_{bf-s}	: Static pressure in dry cargo holds under flooded conditions, in kN/m ² , as defined in Ch 5, Sec 6, [4.1.5]
P_{dk}	: Design pressure due to uniform cargo, in kN/m ²
P_{dl-s}	: Static pressure on decks and platforms, in kN/m ² , as defined in Ch 5, Sec 6, [6.1.1]
P_{dl-d}	: Dynamic pressure on decks platforms for a considered dynamic load case, in kN/m ² , as defined in Ch 5, Sec 6, [6.1.1]
P_{im}	: Impact pressure due to liquid motion, in kN/m ² , as defined in Ch 5, Sec 6, [2.2.2].
P_{sd}	: Lateral pressure on sides of superstructures or deckhouses not contributing to the longitudinal strength, in kN/m ² , as defined in Ch 5, Sec 5, [5.4.1]
Q_{sw}	: Permissible hull girder maximum and minimum still water shear force limits for seagoing operation, in kN, as defined in Ch 5, Sec 4, [2.3.1]
Q_{sw-p}	: Permissible hull girder maximum and minimum still water shear force limits for harbour/sheltered water operation, in kN, as defined in Ch 5, Sec 4, [2.3.2]
Q_{wh-LC}	: Horizontal wave shear force for the considered dynamic load case, in kN, as defined in Ch 5, Sec 4, [3.6.4]
Q_{ww-LC}	: Vertical wave shear force for a considered dynamic load case, in kN, as defined in Ch 5, Sec 4, [3.6.2]
TM	: Design torsional moment, in kN·m
VBM	: Design vertical bending moment, in kN·m
VSF	: Design vertical shear force, in kN.

1 General

1.1 Application

1.1.1 This Section describes the design load scenarios to be used for:

- strength assessment by prescriptive and direct analysis (Finite Element Analysis or beam models), as given in [2]
- fatigue assessment by prescriptive and direct analysis (Finite Element Analysis), as given in [3].

1.1.2 For the strength assessment, the principal design load scenarios are associated either to the qualifier S or S+D.

In addition, specific design load scenarios are to be considered relating to impact loads and sloshing loads in partly filled tanks.

1.1.3 For fatigue assessment, the design load scenarios are S+D (Static + Dynamic) loads, with the prefix 'F' for Fatigue.

2 Design load scenarios for strength assessment

2.1 Principal design load scenarios

2.1.1 The principal design load scenarios for strength assessment are given in Tab 1.

2.2 Design load scenarios for impact and sloshing

2.2.1 The additional design load scenarios relating to impact loads and sloshing loads to be considered are:

- bottom or stern slamming impact
- bow flare impact
- sloshing loads in partly filled tanks
- impact loads in partly filled tanks.

2.2.2 Design load scenarios for bottom or stern slamming impact

For the design load scenarios for bottom or stern slamming impact, only the pressure P_{SLI} , as defined in Ch 5, Sec 5, [4.2], is to be applied to the outer shell.

2.2.3 Design load scenario for bow flare impact

For the design load scenario for bow flare impact, only the pressure P_{FI} , as defined in Ch 5, Sec 5, [4.3], is to be applied to the outer shell.

Table 1 : Principal design load scenarios for strength assessment

Load components		Design load scenario					
		Harbour, sheltered water (H: S) (1)	Tank testing (T: S)	Seagoing conditions with extreme sea loads (N: S+D)	Ballast water exchange (BWE: S+D) (1)	Flooded conditions (A: S)	
Hull girder	VBM	M_{sw-p}	M_{sw-p}	$M_{sw} + M_{wv-LC}$	$M_{sw} + M_{wv-LC}$	M_{sw}	
	HBM	–	–	M_{wh-LC}	M_{wh-LC}	–	
	VSF	Q_{sw-p}	Q_{sw-p}	$Q_{sw} + Q_{wv-LC}$	$Q_{sw} + Q_{wv-LC}$	–	
	HSF	–	–	Q_{wh-LC}	Q_{wh-LC}	–	
	TM (4)	M_{sw-t-p}	M_{sw-t-p}	$M_{sw-t-LC} + M_{wt-LC}$	$M_{sw-t-LC} + M_{wt-LC}$	–	
Local loads	P_{ex}	Exposed decks	–	–	P_d	–	–
		Outer shell	P_s	P_s	$P_s + P_w$	$P_s + P_w$	–
		Sides of superstructures and deckhouses	–	–	$P_s + P_w$ (2)	–	–
	P_{in}	Ballast tanks	P_{ls}	P_{ST}	$P_{ls} + P_{ld}$	$P_{ls} + P_{ld}$	–
		Liquid cargo tanks				–	–
		Other tanks				–	–
		Watertight boundaries	–	–	–	–	P_{fs}
		Wash bulkheads	–	–	$P_{ls} + P_{ld}$	–	–
		Dry bulk cargo holds	P_{bs}	–	$P_{bs} + P_{bd}$	–	P_{bf-s}
	P_{dk}	Decks below accommodation and machinery spaces and decks supporting uniform cargo	P_{dl-s}	–	$P_{dl-s} + P_{dl-d}$	–	–
	F_u	Decks supporting unit cargo	F_{u-s}	–	F_{u-d}	–	–
	P_0	Decks submitted to wheeled loads	F_{w-s}	–	$F_{w-s} + F_{w-d}$	–	–
<p>(1) Applicable to prescriptive assessment only. (2) Contributing to the longitudinal strength. (3) Not contributing to the longitudinal strength. (4) Still water torsional moment M_{sw-t} is only applicable to ships assigned with the service notation container ship.</p>							

2.2.4 Design load scenario for sloshing in partly filled tanks

For the design load scenario for sloshing, the sloshing pressure P_{sl} , as defined in Ch 5, Sec 6, [2.2.1], is to be applied combined with the still water vertical bending moment for seagoing M_{sw} .

2.2.5 Design load scenario for impact in partly filled tanks

For the design load scenario for impact in partly filled tanks, only the impact pressure P_{im} , as defined in Ch 5, Sec 6, [2.2.2], is to be applied.

3 Design load scenario for fatigue assessment

3.1 Design load scenario

3.1.1 The design load scenario for fatigue assessment is given in Tab 2.

Table 2 : Design load scenario for fatigue assessment

Load components		Fatigue (F: S+D)	
Hull girder	VBM	$M_{sw} + M_{wv-LC}$	
	HBM	M_{wh-LC}	
	VSF	$Q_{sw} + Q_{wv-LC}$	
	HSF	Q_{wh-LC}	
	TM (3)	$M_{sw-t-LC} + M_{wt-LC}$	
Local loads	P_{ex}	Exposed decks	–
		Outer shell	$P_s + P_w$
		Sides of superstructures and deckhouses	–
	P_{in}	Ballast tanks (1)	$P_{ls} + P_{ld}$
		Liquid cargo tanks(1)	
		Other tanks(1)	
		Watertight boundaries	–
		Wash bulkheads	–
	P_{dk}	Dry bulk cargo holds	$P_{bs} + P_{bd}$
	F_u	Decks supporting uniform cargo	–
	F_u	Decks supporting unit cargo	–
P_0	Decks submitted to wheeled loads(2)	$F_{W-S} + F_{W-D}$	
<p>(1) Applicability and filling levels for each loading condition are defined in Ch 10, Sec 1, [2.1.1]</p> <p>(2) If needed considering the frequency of loading-unloading operations, the Society may require a specific fatigue assessment of structural elements subjected to wheeled loads in harbour conditions.</p> <p>(3) Still water torsional moment M_{sw-t} is only applicable to ships assigned with the service notation container ship.</p>			

Section 8 Loading Conditions

1 Application

1.1 Loading conditions for strength assessment

1.1.1 The typical loading conditions to be considered for strength assessment are given in [3].

1.1.2 The loading conditions to be considered for the assessment of longitudinal strength and primary supporting members are to envelop the most critical loading combinations the ship can be subject to when operated in accordance with loading manual. The loading conditions are to be defined with consideration to:

- all intact loading conditions in loading manual
- operational limitations in loading guidance information
- the ship arrangement and possible combination of local loading and global loading.

1.1.3 Loading conditions from the loading manual which are not covered in this Section are to be considered.

1.2 Loading conditions for fatigue assessment

1.2.1 The loading conditions to be considered for fatigue assessment are given in [4].

1.3 Specific loading conditions

1.3.1 Part D and Part E may specify additional loading conditions which are to be considered depending on the ship type.

2 General

2.1 Definitions

2.1.1 In general, the design cargo and ballast loading conditions to be considered for the longitudinal strength assessment are to be assessed for both departure and arrival conditions.

Where the amount and disposition of consumables at any intermediate stage of the voyage are considered more severe, calculations for such intermediate conditions are to be submitted in addition to those for departure and arrival conditions.

2.1.2 Departure conditions

The departure conditions are to be based on bunker tanks not taken less than 95% full and other consumables (fresh water and stores) taken at 100% capacity.

2.1.3 Arrival conditions

The arrival conditions are to be based on 10% of the maximum capacity of bunker, fresh water and stores.

3 Standard loading conditions for strength assessment

3.1 Seagoing conditions

3.1.1 For all ships, the following seagoing loading conditions are to be included, as a minimum, in the loading manual:

- Full load/homogeneous cargo loading conditions including a condition at the scantling draught.
- Ballast conditions where the ballast tanks may be full or empty. All cargo holds are to be empty. The propeller is to be fully immersed.

Ballast loading conditions involving partially filled peak and/or other ballast tanks at departure, arrival or during intermediate conditions are not permitted to be used as design conditions unless:

- the allowable stress limits and buckling criteria defined in Ch 6, Sec 1, [3.5] and Ch 6, Sec 1, [3.7] are satisfied for all filling levels between empty and full and
- for ships with the service notation **bulk carrier**, **bulk carrier ESP** or **self-unloading bulk carrier ESP**, the requirements in Pt D, Ch 4, Sec 3, [3.1], as applicable, are complied with all filling levels between empty and full.

To demonstrate compliance with all filling levels between empty and full, it is acceptable if, in each condition at departure, arrival and any intermediate condition required in Ch 5, Sec 4, [2.1.1], the tanks intended to be partially filled are assumed to be:

- empty
- full
- partially filled at intended level.

Where multiple tanks are intended to be partially filled, all combinations of empty, full or partially filled at intended level for those tanks are to be investigated.

However, for conventional ore carriers with large wing water ballast tanks in cargo area, where empty or full ballast water filling levels of one or maximum two pairs of these tanks lead to the ship's trim exceeding one of the following conditions, it is sufficient to demonstrate compliance with maximum, minimum and intended partial filling levels of these one or maximum two pairs of ballast tanks such that the ship's condition does not exceed any of these trim limits. Filling levels of all other wing ballast tanks are to be considered between empty and full. The trim conditions mentioned above are:

- trim by stern of 3,0% of the ship's length, or
- trim by bow of 1,5% of the ship's length, or
- any trim that cannot maintain propeller immersion (l/D) not less than 25%, where:
l : Distance, in m, from propeller centerline to the waterline
D : Propeller diameter, in m.

The maximum and minimum filling levels of the above mentioned pairs of side ballast tanks are to be indicated in the loading manual.

Note 1: Annex 1 of IACS Unified Requirement UR S11, as amended, contains a guidance for partially filled ballast tanks in ballast loading conditions.

c) Non homogeneous cargo loading conditions.

For cargo loading conditions involving partially filled peak and/or other ballast tanks, the requirements specified in item b apply to the peak tanks only.

d) Special loadings (e.g. light load conditions at less than the maximum draught, deck cargo conditions, etc.), where applicable.

e) When relevant, conditions covering ballast water exchange procedures with the calculations of intermediate conditions just before and just after ballasting and/or deballasting any ballast tank.

For ships with the service notation **general cargo ship** completed by the additional service feature **nonhomload**, the loading conditions to be considered are to include the cases where the selected holds are empty at draught T, according to the indications specified in the ship notation.

3.2 Harbour and sheltered water conditions

3.2.1 The following harbour and sheltered water conditions are to be included in the loading manual:

a) Docking condition afloat.

b) Loading and unloading transitory conditions, where applicable.

For cargo loading conditions involving partially filled peak and/or other ballast tanks, the requirements specified in item b of requirement [3.1.1] apply to the peak tanks only.

c) Short voyage conditions, where applicable.

4 Standard loading conditions for fatigue assessment

4.1 General

4.1.1 The standard loading conditions to be applied for fatigue assessment are defined in Ch 10, Sec 1, [2].

Part B

Hull and Stability

CHAPTER 6

HULL GIRDER STRENGTH

Section 1	Hull Girder Yield and Buckling Strength
Section 2	Hull Girder Ultimate Strength
Appendix 1	Direct Calculation of Shear Flow
Appendix 2	Hull Girder Ultimate Bending Capacity

Section 1 Hull Girder Yield and Buckling Strength

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

- M_{sw} : Permissible maximum and minimum vertical still water bending moment in seagoing operation, in kN·m, at the hull transverse section considered, defined in Ch 5, Sec 4, [2.2.1]
- M_{sw-p} : Permissible maximum and minimum vertical still water bending moment for harbour/sheltered water operation, in kN·m, as defined in Ch 5, Sec 4, [2.2.2]
- M_{ww} : Vertical wave bending moment in seagoing operation, in kN·m, at the hull transverse section considered, defined in Ch 5, Sec 4, [3.1.1]
- M_{ww-LC} : Vertical wave bending moment for a considered dynamic load case, in kN·m, as defined in Ch 5, Sec 4, [3.6.1]
- M_{wh} : Horizontal wave bending moment in seagoing operation, in kN·m, at the hull transverse section considered, defined in Ch 5, Sec 4, [3.3.1]
- M_{wh-LC} : Horizontal wave bending moment for a considered dynamic load case, in kN·m, as defined in Ch 5, Sec 4, [3.6.3]
- M_{wt} : Wave torsional moment in seagoing operation, in kN·m, at any longitudinal position defined in Ch 5, Sec 4, [3.5.1]
- n : Navigation coefficient as defined in Ch 5, Sec 3, [1.1.2] for a reference length calculated with the parameters given in Ch 5, Sec 4, [3.1.1]
- Q_{sw} : Permissible maximum or minimum still water shear force for seagoing operation, in kN, at the hull transverse section considered, as defined in Ch 5, Sec 4, [2.3.1]
- Q_{sw-p} : Permissible maximum or minimum still water shear force for harbour/sheltered operation, in kN, at the hull transverse section considered, as defined in Ch 5, Sec 4, [2.3.2]
- Q_{ww} : Vertical wave shear force in seagoing condition, in kN, at the hull transverse section considered, defined in Ch 5, Sec 4, [3.2.1]
- Q_{ww-LC} : Vertical wave shear force for a considered dynamic load case, in kN, as defined in Ch 5, Sec 4, [3.6.2]
- Q_{wh-LC} : Horizontal wave shear force for a considered dynamic load case, in kN, as defined in Ch 5, Sec 4, [3.6.4]
- z_n : Z coordinate, in m, of horizontal neutral axis of the hull transverse section with net scantling defined in [1.2], with respect to the reference coordinate system defined in Ch 1, Sec 3, [2.6]

1 Strength characteristics of hull girder transverse sections

1.1 General

1.1.1 This Article specifies the criteria for calculating the hull girder strength characteristics to be used for the hull girder strength assessment in Article [3], in association with the hull girder loads specified in Ch 5, Sec 4.

1.2 Hull girder transverse sections

1.2.1 General

Hull girder transverse sections are to be considered as being constituted by all the members contributing to the hull girder longitudinal strength, taking into account the requirements in [1.2.2] to [1.2.13].

1.2.2 Net scantling

The members contributing to the hull girder longitudinal strength are to be considered using net offered scantlings based on gross offered thickness reduced by $0,5 t_c$, as defined in Ch 4, Sec 3, when the hull girder strength characteristics are used for the hull girder yielding and buckling check according to Article [3].

1.2.3 Structural members not contributing to hull girder sectional area

The following members are not to be considered in the calculation as they are considered not contributing to the hull girder sectional area:

- superstructures and deckhouses which do not comply with [1.3.2]
- vertically corrugated bulkheads, according to [1.2.7]
- bulwarks and gutter plates
- bilge keels
- sniped or non-continuous longitudinal stiffeners
- non-continuous hatch coamings.

1.2.4 Continuous trunks and longitudinal continuous hatch coamings

Continuous trunks and longitudinal continuous hatch coamings may be included in the hull girder transverse sections, provided that they are effectively supported by longitudinal bulkheads or primary supporting members.

1.2.5 Longitudinal stiffeners or girders welded above the strength deck

Longitudinal stiffeners or girders welded above the strength deck, including the deck of any trunk fitted as specified in [1.2.4], are to be included in the hull girder transverse sections.

1.2.6 Longitudinal girders between hatchways

Where longitudinal girders are fitted between hatchways, the sectional area A_{EFF} that can be included in the hull girder transverse sections is obtained, in m^2 , from the following formula:

$$A_{EFF} = A_{LG} a$$

where:

A_{LG} : Sectional area, in m^2 , of longitudinal girders

a : Coefficient:

- for longitudinal girders effectively supported by longitudinal bulkheads or primary supporting members: $a = 1$
- for longitudinal girders not effectively supported by longitudinal bulkheads or primary supporting members and having dimensions and scantlings such that $\ell_0 / r \leq 60$:

$$a = 0,6 \left(\frac{s}{b_1} + 0,15 \right)^{0,5}$$

- for longitudinal girders not effectively supported by longitudinal bulkheads or primary supporting members and having dimensions and scantlings such that $\ell_0 / r > 60$:

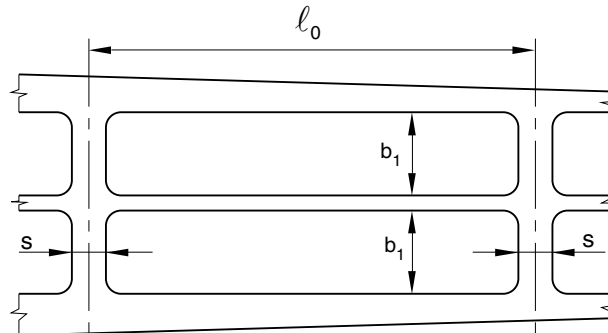
$$a = 0$$

ℓ_0 : Span, in m, of longitudinal girders, to be taken as shown in Fig 1

r : Minimum radius of gyration, in m, of the longitudinal girder transverse section

s, b_1 : Dimensions, in m, defined in Fig 1.

Figure 1 : Longitudinal girders between hatchways



1.2.7 Longitudinal bulkheads with vertical corrugations

For longitudinal bulkheads with vertical corrugations, the vertical corrugations are not to be included in the hull girder transverse section. Longitudinal bulkheads with vertical corrugations are not effective for hull girder bending, but they are effective for hull girder shear force.

1.2.8 Members in materials other than steel

Where a member contributing to the longitudinal strength is made of material other than steel with a Young's modulus E equal to $2,06 \cdot 10^5$ N/mm², the steel equivalent net sectional area A_{SE-n50} that may be included in the hull girder transverse section is obtained, in m^2 , from the following formula:

$$A_{SE-n50} = \frac{E}{2,06 \cdot 10^5} A_{M-n50}$$

where:

A_{M-n50} : Net sectional area, in m^2 , of the member under consideration.

1.2.9 Definitions of openings

Openings include:

- a) Large openings, i.e. openings which are:
 - elliptical openings exceeding 2,5 m in length or 1,2 m in breadth
 - circular openings exceeding 0,9 m in diameter.
- b) Small openings (manholes, lightening holes, single scallops in way of seams, etc.), i.e. openings which are not large openings
- c) Isolated openings, i.e. openings spaced not less than 1 m apart in the ship transverse/vertical direction.

1.2.10 Large openings and nearby small openings

Large openings are to be deducted from the sectional area used in the hull girder moment of inertia and section modulus. When small openings are spaced less than 1 m apart, in the ship transverse/vertical direction, from large openings, their total breadth is to be deducted from the sectional area.

Additionally, small openings not complying with the arrangement requirements given in Ch 4, Sec 5, [6.3.2] are to be deducted from the sectional areas included in the hull girder transverse sections.

1.2.11 Isolated small openings

Isolated small openings in one transverse section in the strength deck or bottom area need not be deducted from the sectional areas included in the hull girder transverse sections, provided that:

$$\Sigma b_s \leq 0,06 (B - \Sigma b)$$

where:

- Σb_s : Total breadth of isolated small openings, in m, in the strength deck or bottom area at the transverse section considered, determined as indicated in Fig 2, not deducted from the section area as per [1.2.10]
- Σb : Total breadth of large openings, in m, at the transverse section considered, determined as indicated in Fig 2, deducted from the section area as defined in [1.2.10].

Where the total breadth of isolated small openings Σb_s does not fulfil the above criteria, only the excess of breadth is to be deducted from the sectional areas included in the hull girder transverse sections.

1.2.12 Lightening holes, draining holes and single scallops

Lightening holes, draining holes and single scallops in longitudinals need not be deducted if their height is less than 0,25 h_w , without being greater than 75 mm, where h_w is the web height, in mm, defined in Ch 4, Sec 2.

Otherwise, the excess is to be deducted from the sectional area or compensated.

1.2.13 Non-continuous decks and longitudinal bulkheads

When calculating the effective area in way of non-continuous decks and longitudinal bulkheads, the effective area is to be taken as shown in Fig 3. The shadow area, which indicates the non-effective area, is obtained by drawing two tangent lines with an angle of 15 deg to the longitudinal axis of the ship.

Figure 2 : Calculation of Σb and Σb_s

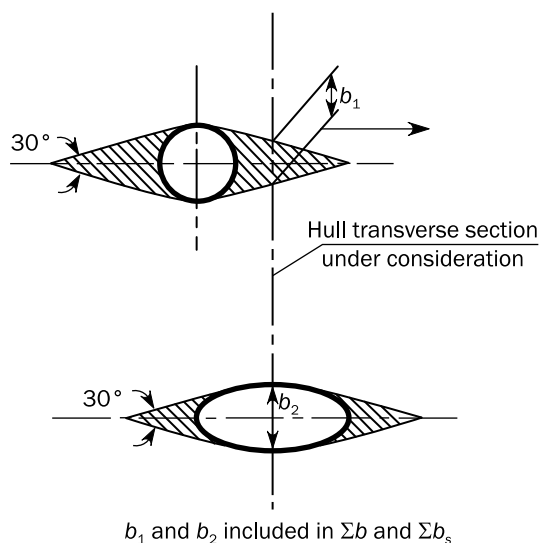
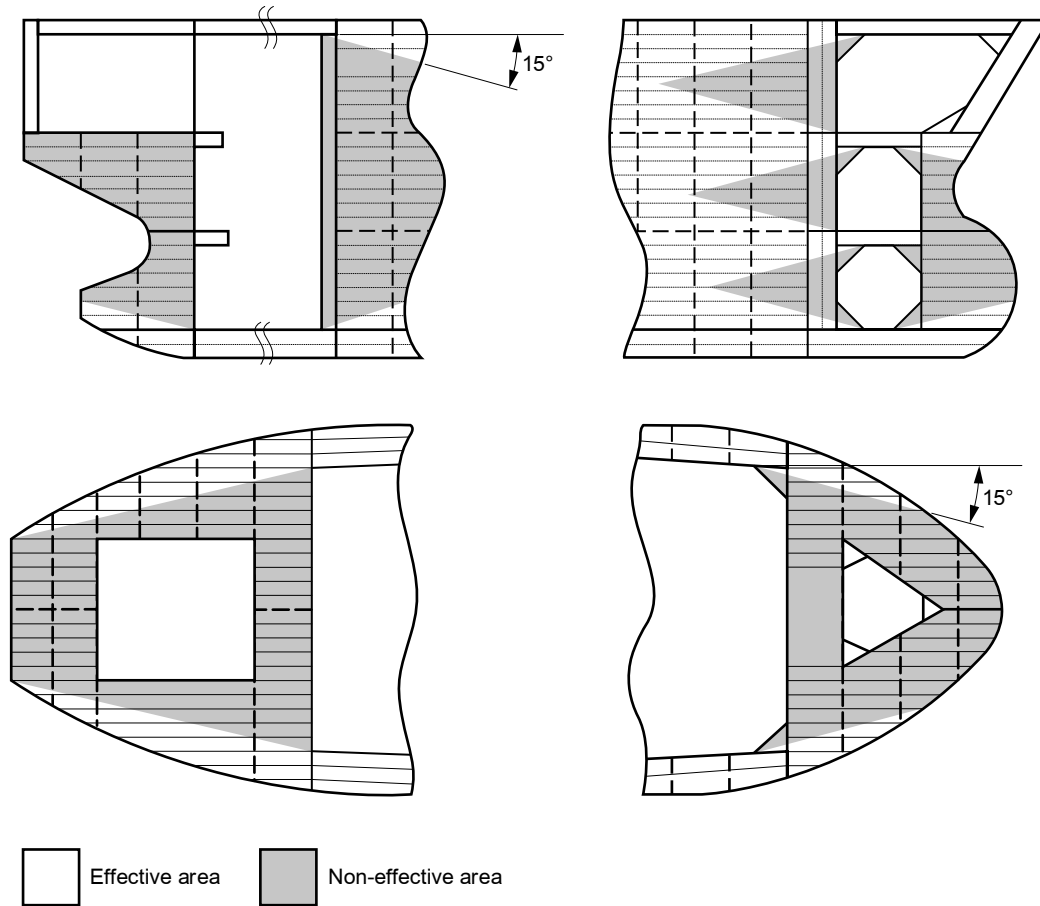


Figure 3 : Effective area in way of non-continuous decks and bulkheads



1.3 Structures contributing to the longitudinal strength

1.3.1 Strength deck

The strength deck is, in general, the uppermost continuous deck. In the case of a superstructure or deckhouses contributing to the longitudinal strength, the strength deck is the deck of the superstructure or the deck of the uppermost deckhouse.

1.3.2 Other structures

A superstructure extending at least 0,15 L within 0,4 L amidships may generally be considered as contributing to the longitudinal strength. For the other superstructures and for deckhouses, their contribution to the longitudinal strength is to be assessed on a case-by-case basis, through a finite element analysis of the whole ship, which takes into account the general arrangement of the longitudinal structural members (side, decks, bulkheads).

The presence of openings in the side shell and longitudinal bulkheads is to be taken into account in the analysis. This may be done in two ways:

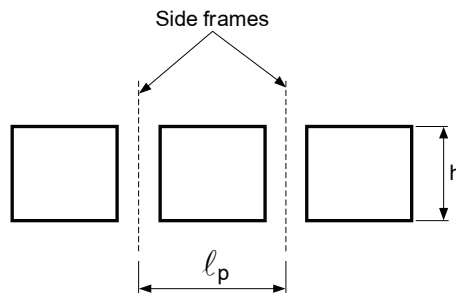
- by including these openings in the finite element model
- by assigning to the plate panel, between the side frames beside each opening, an equivalent thickness, t_{EQ} , in mm, obtained from the following formula:

$$t_{EQ} = 10^3 \left[\ell_p \left(\frac{Gh^2}{12EI_j} + \frac{1}{A_j} \right) \right]^{-1}$$

where (see Fig 4):

- ℓ_p : Longitudinal distance, in m, between the frames beside the opening
- h : Height, in m, of the openings
- I_j : Moment of inertia, in m^4 , of the opening jamb about the transverse axis y-y
- A_j : Shear area, in m^2 , of the frame between two openings in the direction of the longitudinal axis x-x
- G : Coulomb's modulus, in N/mm^2 , of the material used for the frame between two openings, to be taken equal to:
 - for steels: $G = 8,0 \cdot 10^4 \text{ N/mm}^2$
 - for aluminium alloys: $G = 2,7 \cdot 10^4 \text{ N/mm}^2$

Figure 4 : Side openings



1.4 Section modulus

1.4.1 The net section modulus at any point of a hull transverse section is obtained, in m^3 , from the following formula:

$$Z_A = \frac{I_{y-n50}}{|z-z_n|}$$

1.4.2 The net section moduli at bottom and at the equivalent deck line are obtained, in m^3 , from the following formulae:

- at bottom:

$$Z_{AB} = \frac{I_{y-n50}}{z_n}$$

- at the equivalent deck line:

$$Z_{AD} = \frac{I_{y-n50}}{V_D}$$

where:

V_D : Vertical distance to the equivalent deck line, in m:

- when no effective longitudinal members specified in [1.2.4] and [1.2.5] are positioned above a line extending from strength deck at side to a position $(z_D - N)/0,9$ from the neutral axis at the centreline:

$$V_D = z_D - z_n$$

where:

z_D : Z co-ordinate, in m, of strength deck, defined in [1.3], with respect to the reference co-ordinate system defined in Ch 1, Sec 3, [2.6]

- when effective longitudinal members as specified in [1.2.4] and [1.2.5] are positioned above a line extending from strength deck at side to a position $(z_D - N)/0,9$ from the neutral axis at the centreline:

$$V_D = (z_T - z_n) \left(0,9 + 0,2 \frac{y_T}{B} \right) \geq z_D - z_n$$

where:

y_T, z_T : Y and Z co-ordinates, in m, of the top of continuous trunk or hatch coaming or longitudinal ordinary stiffeners or girders welded above the strength deck, with respect to the reference co-ordinate system defined in Ch 1, Sec 3, [2.6]; y_T and z_T are to be measured for the point which maximises the value of V_D

1.5 Moments of inertia

1.5.1 The net moments of inertia I_{y-n50} and I_{z-n50} , in m^4 , are those, calculated about the horizontal and vertical neutral axes respectively, of the hull transverse sections defined in [1.2].

1.6 Ships having large openings in the strength deck

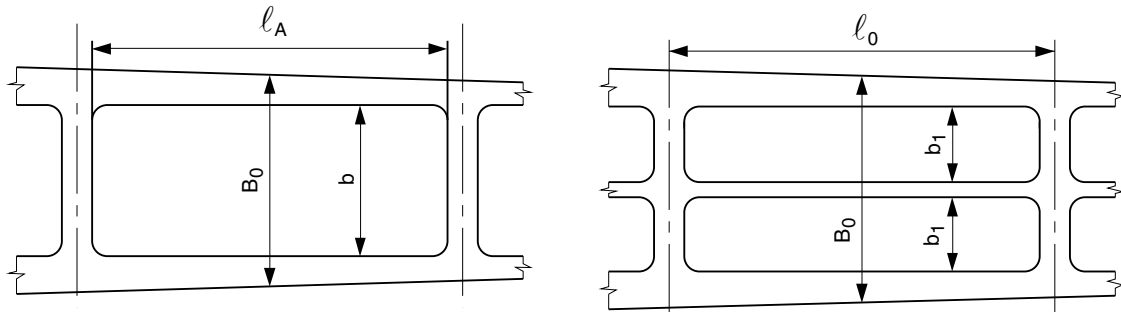
1.6.1 Definition

Ships having large openings in the strength decks are ships for which at least one of the three following conditions occur:

- $b / B_0 > 0,7$
- $l_A / l_0 > 0,89$
- $b / B_0 > 0,6$ and $l_A / l_0 > 0,7$

where b, B_0, l_A and l_0 are the dimensions defined in Fig 5. In the case of two or more openings in the same hull transverse section, b is to be taken as the sum of the breadth b_i of each opening.

Figure 5 : Ships with large openings



2 Hull girder stresses

2.1 Normal stress

2.1.1 Normal stress induced by bending moments

The normal stress σ_L induced, at any point, by bending moments is to be obtained, in N/mm², from the following formulae:

- for seagoing operation:

$$\sigma_L = \left(\frac{M_{sw} + M_{wv-LC}}{I_{y-n50}} (z - z_n) - \frac{M_{wh-LC}}{I_{z-n50}} y \right) 10^{-3}$$

- for harbour/sheltered operation:

$$\sigma_L = \frac{M_{sw-p}}{I_{y-n50}} (z - z_n) 10^{-3}$$

2.1.2 Normal stress induced by torque and bending moments

The normal stresses induced by torque and bending moments are to be considered for ships having large openings in the strength decks, as defined in [1.6.1].

The normal stress σ_L induced, at any point, by torque and bending moments is to be obtained, in N/mm², from the following formulae:

- for seagoing operation:

$$\sigma_L = \left(\frac{M_{sw} + M_{wv-LC}}{I_{y-n50}} (z - z_n) - \frac{M_{wh-LC}}{I_{z-n50}} y \right) 10^{-3} + \sigma_\Omega$$

- for harbour/sheltered operation:

$$\sigma_L = \frac{M_{sw-p}}{I_{y-n50}} (z - z_n) 10^{-3} + \sigma_\Omega$$

where:

σ_Ω : Warping stress, in N/mm², induced by the wave torsional moment M_{wt} as defined in Ch 5, Sec 4 and obtained through direct calculation analyses based on a structural model in accordance with Article [4].

2.1.3 Material other than steel

In a member made in material other than steel with a Young's modulus E equal to $2,06 \cdot 10^5$ N/mm² and included in the hull girder transverse sections as specified in [1.2.8], the normal stress σ_L , in N/mm², is to be obtained from the following formula:

$$\sigma_L = \frac{E}{2,06 \cdot 10^5} \sigma_{Ls}$$

where:

σ_{Ls} : Normal stress, in N/mm², in the member under consideration, calculated according to [2.1.1] or [2.1.2] considering this member as having the steel equivalent sectional area A_{SE-n50} defined in [1.2.8].

2.2 Shear stress

2.2.1 Shear stress induced by vertical shear forces

The hull girder shear stress τ_L , in N/mm², induced by vertical shear forces is to be determined, at the load calculation point under consideration, from the following formulae:

- for seagoing operation:

$$\tau_L = \frac{Q_{sw} + Q_{wv-LC}}{t_{n50} / q_{vi}} 10^{-3}$$

- for harbour/sheltered operation:

$$\tau_L = \frac{Q_{sw-p}}{t_{n50}/q_{vi}} 10^3$$

where:

- q_{vi} : Contribution ratio for hull girder shear force per mm, in mm^{-1} , for the plate i based on net scantlings obtained with half the corrosion addition t_c , which is equal to the unit shear flow per mm, in N/mm , for a unit vertical shear force, from a numerical calculation based on thin-walled beam theory according to Ch 6, App 1.

2.2.2 Shear stress induced by shear forces and torque

For ships having large openings in the strength deck, the hull girder shear stress τ_L , in N/mm^2 , induced by shear forces and torque is to be determined, at the load calculation point under consideration, from the following formulae:

- for seagoing operation:

$$\tau_L = \left(\frac{Q_{sw} + Q_{wv-LC}}{t_{n50}/q_{vi}} + \frac{Q_{wh-LC}}{t_{n50}/q_{hi}} \right) 10^3 + \tau_\Omega$$

- for harbour/sheltered operation:

$$\tau_L = \frac{Q_{sw-p}}{t_{n50}/q_{vi}} 10^3 + \tau_\Omega$$

where:

- q_{vi} : Ratio as defined in [2.2.1]
- q_{hi} : Contribution ratio for hull girder shear force per mm, in mm^{-1} , for the plate i based on net scantlings obtained with half the corrosion addition t_c , which is equal to the unit shear flow per mm, in N/mm , for a unit horizontal shear force, from a numerical calculation based on thin-walled beam theory according to Ch 6, App 1
- τ_Ω : Shear stress, in N/mm^2 , induced by the wave torsional moment M_{wtr} as defined in Ch 5, Sec 4 and obtained through direct calculation analyses based on a structural model in accordance with Article [4].

3 Hull girder strength assessment

3.1 General

3.1.1 The k material factors are to be defined with respect to the materials used for the bottom and deck members contributing to the longitudinal strength according to [1]. When material factors for higher strength steels are used, the requirements in [3.6] apply.

3.2 Longitudinal extent

3.2.1 The yield strength and buckling strength assessments are to be carried out in way of 0,2L to 0,75L with due consideration given to locations where there are significant changes in hull cross-section, e.g. changes of framing system and the fore and aft ends of the forward superstructure in case of twin island designs.

3.2.2 In addition, yield strength and buckling assessments are to be carried out outside this area. As a minimum, these assessments are to be carried out at forward end of the foremost cargo hold, at aft end of the aftermost cargo hold and at forward end of the engine room.

3.2.3 In addition, for ships with large openings in the strength deck, sections at, or near to, the aft and forward quarter length positions are to be checked. For such ships with cargo holds aft of the superstructure, deckhouse or engine room, strength checks of sections in way of the aft end of the aft-most holds, and the aft end of the deckhouse or engine room are to be performed.

3.2.4 Scantlings of members contributing to the longitudinal strength (see [1.3]) are to be maintained within 0,4 L amidships.

3.3 Hull girder stiffness

3.3.1 Minimum net moment of inertia

The net moment of inertia I_{y-n50} , in m^4 , of the hull transverse section within 0,4L amidships is to be not less than I_{y-min} , obtained from the following formula:

$$I_{y-min} = 3,0 \cdot \frac{2n}{n+1} Z'_{R,MIN} L \cdot 10^{-2}$$

where $Z'_{R,MIN}$ is the required net midship section modulus $Z_{R,MIN}$, in m^3 , calculated as specified in [3.4.1], but assuming $k = 1$.

3.4 Hull girder minimum section modulus

3.4.1 The net section moduli, in m^3 , Z_{AB} and Z_{AD} at the midship section are to be not less than:

$$Z_{R,MIN} = 0,9 \cdot \frac{1+n}{2} \cdot C \cdot L^2 \cdot B \cdot (C_B + 0,7) \cdot k \cdot 10^{-6}$$

where

C : Coefficient defined in Ch 5, Sec 4

3.4.2 The scantlings of all continuous longitudinal members are to be maintained within 0,4L amidships based on the modulus requirement as specified in [3.4.1].

However, in special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the end of the 0,4L part, bearing in mind the desire not to inhibit the vessel's loading flexibility.

3.5 Yield strength assessment

3.5.1 General acceptance criteria

It is to be checked that the equivalent Von Mises stress σ_{eq} , in N/mm^2 , calculated with the load combinations given in [3.5.2] and [3.5.3] for seagoing operations in extreme conditions and for harbour operations, is in compliance with the following formula:

$$\sigma_{eq} < \sigma_{perm}$$

where:

σ_{eq} : Equivalent Von Mises stress, in N/mm^2 :

$$\sigma_{eq} = \sqrt{\sigma_L^2 + 3\tau_L^2}$$

σ_{perm} : Permissible hull girder normal stress, in N/mm^2 :

$$\sigma_{perm} = \frac{R_{eH}}{\gamma_1 \gamma_2}$$

σ_L : Normal stress, in N/mm^2 , calculated according to:

- [2.1.1] for head sea design waves
- [2.1.2] for OHS, OHM and OVA design waves, applicable to ships having large strength deck openings

τ_L : Shear stress, in N/mm^2 , calculated according to:

- [2.2.1] for head sea design waves
- [2.2.2] for OHS, OHM and OVA design waves, applicable to ships having large strength deck openings

γ_1 : Partial safety factor for material:

$$\gamma_1 = k \frac{R_{eH}}{235}$$

γ_2 : Partial safety factor for load combinations and permissible stress:

- $\gamma_2 = 1,24$ for bending strength assessment in seagoing operation
- $\gamma_2 = 1,65$ for bending strength assessment in harbour/sheltered operation
- $\gamma_2 = 1,13$ for shear strength assessment in seagoing operation
- $\gamma_2 = 1,29$ for shear strength assessment in harbour/sheltered operation.

3.5.2 Bending strength assessment

The bending strength is to be assessed at the following locations of the cross-section:

- at bottom
- at equivalent deck line
- at any point where there is a change of steel yield strength
- at top of continuous hatch coaming for ships assigned the service notation **container ship**.

The assessment is to be performed according to [3.5.1], considering a shear stress τ_L equal to 0.

3.5.3 Shear strength assessment

The shear strength is to be assessed for all structural elements contributing to the hull girder shear strength capability.

The assessment is to be performed according to [3.5.1], considering a normal stress σ_L equal to 0.

3.6 Extent of higher strength steel

3.6.1 When a material factor for higher strength steel is used in calculating the required section modulus at bottom or at the equivalent deck line according to [1.4] and when the distribution of vertical bending stress across the hull girder transverse section

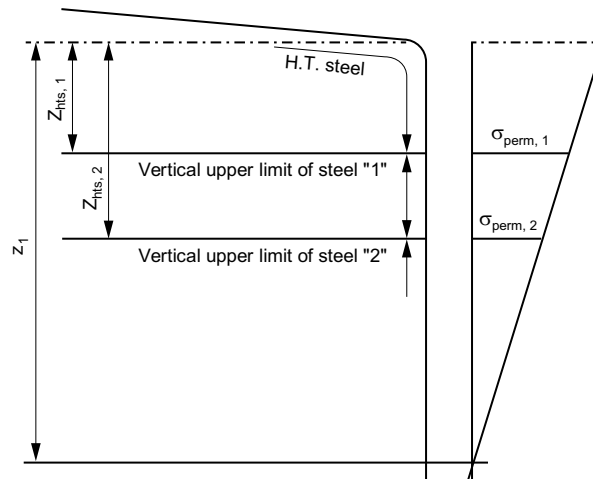
can be assumed to be linear, the vertical extent of higher strength steel, $z_{hts,i}$ used in the deck zone or bottom zone and measured respectively from the equivalent deck line or baseline is not to be taken less the value obtained from the following formula:

$$z_{hts,i} = z_1 \left(1 - \frac{\sigma_{perm,i}}{\sigma_L} \right)$$

where:

- σ_L : Normal stress, in N/mm², at the equivalent deck line or at bottom respectively, calculated according to [2.1]
- z_1 : Distance from horizontal neutral axis to the equivalent deck line, defined in [1.4.2], or to the baseline respectively, in m.
- $\sigma_{perm,i}$: Allowable normal stress defined in [3.5.1], in N/mm², for the adjacent zone of steel having lower strength (see Fig 6)

Figure 6 : Vertical extent of higher strength steel



3.6.2 The relevant higher strength steel is to be adopted for all members contributing to the longitudinal strength (see [1]) within the extent defined in [3.6.1].

3.6.3 The higher strength steel is to extend in length at least throughout 0,4 L amidships where it is required for strength purposes according to the provisions of Part B.

3.6.4 Longitudinal members not contributing to the hull girder longitudinal strength and welded to the strength deck or bottom plating and bilge strake, such as longitudinal hatch coamings, gutter bars, strengthening of deck openings, bilge keel, are to be made of steel with the same specified minimum yield stress as the strength deck or bottom structure steel.

3.6.5 The requirement in [3.6.4] is also applicable to non-continuous longitudinal stiffeners welded to the web of a primary structural member contributing to the hull girder longitudinal strength such as hatch coamings, stringers and girders or on the inner bottom when the hull girder stress in those members is higher than the permissible stress as defined in [3.5.1] for normal strength steel.

3.7 Buckling strength assessment

3.7.1 Buckling strength of members contributing to the longitudinal strength and subjected to compressive and shear stresses is to be assessed according to Chapter 8.

4 Structural models for the calculation of normal warping stress and shear stress

4.1 Calculation methods

4.1.1 The calculation of normal warping stress and shear stress induced by torque may be achieved by means of thin-walled beam models.

4.1.2 An alternative methodology such as complete ship FE model (see Ch 8, App 3) for evaluation of warping stress and shear stress induced by torque may be applied, subject to the satisfaction of the Society.

Section 2 Hull Girder Ultimate Strength

1 Application

1.1 General

1.1.1 The requirements of this Section apply to ships with length L equal to or greater than 150 m.

1.1.2 The hull girder ultimate strength is to be assessed between 0,2L and 0,75L.

1.1.3 The hull girder ultimate bending capacity is to be checked to ensure that it satisfies the checking criteria given in Article [2]. Such criteria are applicable to intact ship structures for both hogging and sagging conditions, in seagoing and harbour/sheltered water conditions.

2 Checking criteria

2.1 General

2.1.1 The vertical hull girder ultimate bending capacity at any hull transverse section is to comply with the following criteria:

$$M \leq \frac{M_U}{\gamma_M \gamma_{DB}}$$

where:

M : Vertical bending moment, in kN·m, to be obtained as specified in [2.2.1]

M_U : Hull girder ultimate bending moment capacity, in kN·m, to be obtained as specified in [2.3]

γ_M : Partial safety factor covering material, geometric and strength prediction uncertainties, to be taken equal to 1,05

γ_{DB} : Partial safety factor covering the effect of double bottom bending under lateral loads, to be taken equal to:

- for hogging conditions:
 - 1,25 for empty holds of ships assigned with the service notation:
general cargo ship,
bulk carrier,
bulk carrier ESP or
combination carrier/OBO ESP
and which may operate in alternate conditions at scantling draught
 - 1,15 otherwise
- for sagging conditions: 1,0.

For hull transverse sections where the breadth of the inner bottom is less than the one amidships, or where the double bottom structure differs from the one amidships (e.g. engine room sections), the factor γ_{DB} for hogging condition may be reduced, based upon agreement with the Society.

2.2 Hull girder ultimate bending loads

2.2.1 The vertical hull girder bending moment M, in kN·m, in hogging and sagging conditions, to be considered in the ultimate strength check, is to be taken as:

$$M = \gamma_S M_{sw} + \gamma_W M_{ww}$$

where:

M_{sw} : Permissible hogging and sagging vertical still water bending moment, in kN·m, at the hull transverse section considered, defined in Ch 5, Sec 4, [2.2.1] and Ch 5, Sec 4, [2.2.2]

M_{ww} : Vertical wave bending moment in seagoing operation, in kN·m, at the hull transverse section considered, defined in Ch 5, Sec 4, [3.1.1]

γ_S : Partial safety factor for the still water bending moment, to be taken equal to 1,0

γ_W : Partial safety factor for the vertical wave bending moment, to be taken equal to 1,2.

2.3 Hull girder ultimate bending moment capacity

2.3.1 General

The hull girder ultimate bending moment capacity M_U is defined as the maximum bending moment capacity of the hull girder beyond which the hull structure collapses.

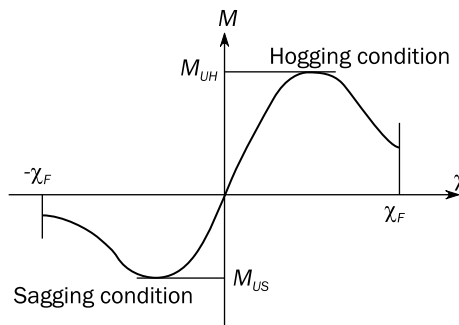
2.3.2 Determination of hull girder ultimate bending moment capacity

The ultimate bending moment capacities of a hull girder transverse section, in hogging and sagging conditions, are defined as the maximum values of the curve of bending moment M versus the curvature χ of the transverse section considered (M_{UH} for hogging condition and M_{US} for sagging condition, see Fig 1). The curvature χ is positive for hogging condition and negative for sagging condition.

The hull girder ultimate bending moment capacity M_U is to be calculated according to Ch 6, App 2.

2.3.3 The effective area to be considered for the hull girder ultimate strength capacity assessment is specified in Ch 6, App 2.

Figure 1 : Bending moment capacity versus curvature χ



Appendix 1 Direct Calculation of Shear Flow

Symbols

For symbols not defined in this Appendix, refer to Ch 1, Sec 3.

1 Calculation formula

1.1 General

1.1.1 This Appendix describes the procedures for direct calculation of shear flow around a ship cross-section due to hull girder vertical shear force. The shear flow q_v , at each location in the cross-section, is calculated considering the cross-section subjected to a unit vertical shear force of 1 N.

The unit shear flow per mm q_v , in N/mm, is to be taken as: $q_v = q_D + q_i$

where:

q_D : Determinate shear flow, as defined in [1.2]

q_i : Indeterminate shear flow which circulates around the closed cells, as defined in [1.3].

In the calculation of the unit shear flow q_v , the longitudinal stiffeners are to be taken into account.

1.2 Determinate shear flow q_D

1.2.1 The determinate shear flow q_D , in N/mm, at each location in the cross-section is to be obtained from the following line integration:

$$q_D(s) = -\frac{1}{10^6 I_{y-n50}} \int_0^s (z - z_n) t_{n50} ds$$

where:

s : Coordinate value of the running coordinate along the cross-section, in m

I_{y-n50} : Net moment of inertia of the cross-section, in m^4

t_{n50} : Net thickness of plating, in mm.

1.2.2 It is assumed that the cross-section is composed of line segments as shown in Fig 1, where each line segment has a constant plate net thickness. The determinate shear flow is obtained by the following equation:

$$q_{Dk} = -\frac{t_{n50} \cdot \ell}{2 \cdot 10^6 I_{y-n50}} (z_k + z_i - 2z_n) + q_{Di}$$

where:

q_{Dk}, q_{Di} : Determinate shear flow, at node k and node i respectively, in N/mm

ℓ : Length of line segments, in m

z_i, z_k : Z coordinates, in m, of the end points i and k of a line segment, as defined in Fig 1.

1.2.3 Where the cross-section includes closed cells as shown in Fig 2, the closed cells are to be cut with virtual slits, as shown in Fig 3 in order to obtain the determinate shear flow.

These virtual slits are not to be located in walls which form part of another closed cell.

Figure 1 : Definition of line segment

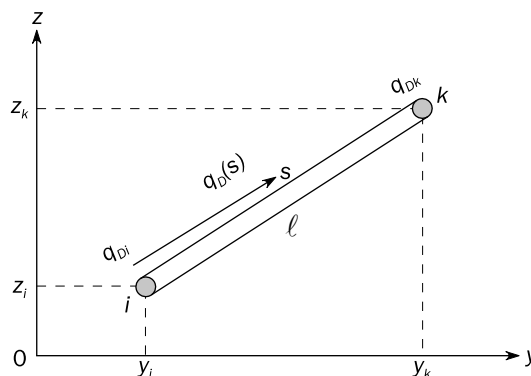


Figure 2 : Closed cells and common wall

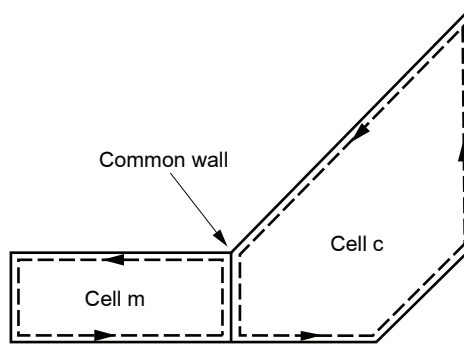
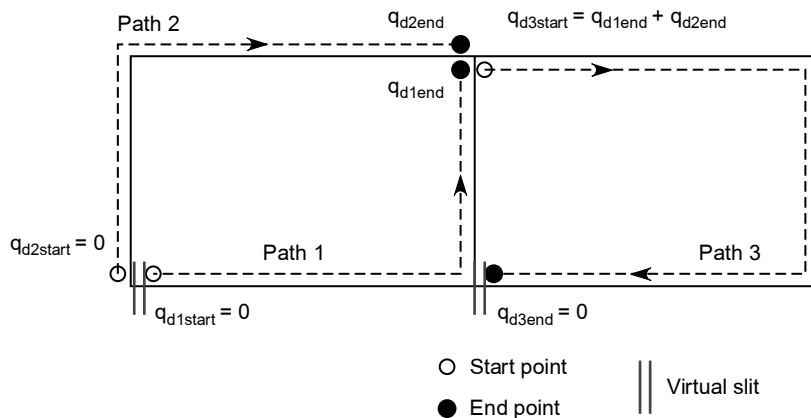


Figure 3 : Placement of virtual slits and calculation of determinate shear flow at bifurcation points



1.2.4 Determinate shear flow at bifurcation points is to be calculated by water flow calculations or similar, as shown in Fig 3.

1.3 Indeterminate shear flow q_i

1.3.1 The indeterminate shear flow q_i around the closed cells of a cross-section is considered as a constant value within the same closed cell. The following system of equations for determination of indeterminate shear flows can be developed. In the equations, contour integrations of several parameters around all the closed cells are performed.

$$q_{ic} \oint_c \frac{1}{t_{n50}} ds - \sum_{m=1}^{N_w} \left(q_{im} \oint_{cm} \frac{1}{t_{n50}} ds \right) = - \oint_c \frac{q_D}{t_{n50}} ds$$

where (see Fig 2):

N_w : Number of common walls shared by cell c and all the other cells

cm : Common wall shared by cells c and m

q_{ic}, q_{im} : Indeterminate shear flows around the closed cells c and m respectively, in N/mm.

1.3.2 Under the assumption of the assembly of line segments as shown in Fig 1 and constant plate thickness of each line segment, the equation in [1.3.1] is expressed as follows:

$$q_{ic} \sum_{j=1}^{N_c} \left(\frac{\ell}{t_{n50}} \right)_j - \sum_{m=1}^{N_w} \left\{ q_{im} \left[\sum_{j=1}^{N_m} \left(\frac{\ell}{t_{n50}} \right)_{j|m} \right] \right\} = - \sum_{j=1}^{N_c} \phi_j$$

$$\phi_j = \left[- \frac{\ell^2}{6 \cdot 10^3 I_{y-n50}} (z_k + 2z_i - 3z_n) + \frac{\ell}{t_{n50}} q_{Di} \right]$$

where (see Fig 2):

N_c : Number of line segments in cell c

N_m : Number of line segments on the common wall shared by cells c and m

q_{Di} : Determinate shear flow, in N/mm, calculated according to [1.2.2].

The difference in the directions of running coordinates specified in [1.2] and the present [1.3] is to be considered.

1.4 Computation of sectional properties

1.4.1 Properties of the cross-section are to be obtained by the following formulae, where the cross-section is assumed to be made of the assembly of line segments:

$$\ell = \sqrt{(y_k - y_i)^2 + (z_k - z_i)^2}$$

$$a_{n50} = 10^{-3} \ell t_{n50}$$

$$A_{n50} = \sum a_{n50}$$

$$s_{y-n50} = \frac{a_{n50}}{2} (z_k + z_i)$$

$$S_{y-n50} = \sum s_{y-n50}$$

$$i_{y0-n50} = \frac{a_{n50}}{3} (z_k^2 + z_k z_i + z_i^2)$$

$$I_{y0-n50} = \sum i_{y0-n50}$$

where:

y_i, z_i : Y and Z coordinates of start point i of a line segment, in m, as defined in Fig 1

y_k, z_k : Y and Z coordinates of end point k of a line segment, in m, as defined in Fig 1

a_{n50}, A_{n50} : Areas of the line segment and the cross-section respectively, in m²

s_{y-n50}, S_{y-n50} : First moments of the line segment and the cross-section about the baseline, in m³

i_{y0-n50}, I_{y0-n50} : Moments of inertia of the line segment and the cross-section about the baseline, in m⁴.

1.4.2 The height of the horizontal neutral axis z_n , in m, is to be obtained as follows:

$$z_n = \frac{S_{y-n50}}{A_{n50}}$$

1.4.3 The moment of inertia about the horizontal neutral axis, in m⁴, is to be obtained as follows:

$$I_{y-n50} = I_{y0-n50} - z_n^2 A_{n50}$$

Appendix 2 Hull Girder Ultimate Bending Capacity

Symbols

For symbols not defined in this Appendix, refer to Ch 1, Sec 3.

Z_{B-n50} : Net section moduli at bottom, in m^3 , to be taken as:

$$Z_{B-n50} = \frac{I_{y-n50}}{Z_n}$$

Z_{D-n50} : Net section moduli at deck, in m^3 , to be taken as:

$$Z_{D-n50} = \frac{I_{y-n50}}{|Z_D - Z_n|}$$

Z_D : Z coordinate, in m, of the strength deck at side, defined in Ch 6, Sec 1, [1.3]

Z_n : Z coordinate, in m, of horizontal neutral axis of the hull transverse section, defined in Ch 6, Sec 1

R_{eHs} : Minimum yield stress, in N/mm^2 , of the material of the considered stiffener

R_{eHp} : Minimum yield stress, in N/mm^2 , of the material of the considered plate

A_{s-n50} : Net sectional area, in cm^2 , of stiffener, without attached plating

A_{p-n50} : Net sectional area, in cm^2 , of attached plating.

1 General

1.1 Application

1.1.1 This Appendix provides the criteria to obtain the ultimate longitudinal bending moment capacity M_U to be used in the hull girder ultimate capacity check according to Ch 6, Sec 2.

1.1.2 M_U is defined as the maximum bending moment capacity of the hull girder beyond which the hull structure collapses. Hull girder failure is controlled by buckling, ultimate strength and yielding of longitudinal structural elements.

1.2 Methods

1.2.1 Incremental-iterative method

The hull girder ultimate bending moment capacity is to be assessed by the incremental-iterative method defined in [2].

1.2.2 Alternative methods

Principles for alternative methods for the calculation of the hull girder ultimate bending moment capacity, e.g. the non-linear finite element analysis, are given in [3].

Application of alternative methods is to be agreed by the Society prior to commencement. Documentation of the analysis methodology and detailed comparison of its results are to be submitted for review and acceptance. The use of such methods may require the partial safety factors to be recalibrated.

1.3 General assumptions

1.3.1 The method for calculating the ultimate hull girder bending capacity is to identify the critical failure modes of all the main longitudinal structural elements.

1.3.2 Structures compressed beyond their buckling limit have reduced load carrying capacity. All relevant failure modes for individual structural elements, such as plate buckling, torsional stiffener buckling, stiffener web buckling, lateral or global stiffener buckling and their interactions, are to be considered in order to identify the weakest inter-frame failure mode.

1.3.3 Only vertical bending is considered, except for ships having large openings in the strength decks for which the effects of shear force, torsional loading, horizontal bending moment and lateral pressure are to be considered.

2 Incremental-iterative method

2.1 Assumptions

2.1.1 In applying the procedure described in [2.2], the following assumptions are generally to be made:

- the ultimate strength is calculated at hull transverse sections between two adjacent transverse webs
- the hull girder transverse section remains plane during each curvature increment

- the hull material has an elasto-plastic behaviour
- the hull girder transverse section is divided into a set of elements which are considered to act independently.

These elements are:

- transversely framed plating panels and/or stiffeners with attached plating, whose structural behaviour is described in [2.3.1]
- hard corners, constituted by plating crossing, whose structural behaviour is described in [2.3.2].

According to the iterative procedure, the bending moment M_i acting on the transverse section at each curvature value χ_i is obtained by summing the contribution given by the stress σ acting on each element. The stress σ corresponding to the element strain ε is to be obtained, for each curvature increment, from the non-linear load-end shortening curves σ - ε of the element.

These curves are to be calculated, for the failure mechanisms of the element, from the formulae specified in [2.2]. The stress σ is selected as the lowest value among those obtained from each of the considered load-end shortening curves σ - ε .

The procedure is to be repeated until the value of the imposed curvature reaches the value χ_F , in m^{-1} , in hogging and sagging conditions, obtained from the following formula:

$$\chi_F = \pm 0,003 \frac{M_Y}{EI_{Y-n50}}$$

where:

M_Y : The lesser of the following values M_{Y1} and M_{Y2} , in kN·m:

$$M_{Y1} = 10^3 R_{eH} Z_{B-n50}$$

$$M_{Y2} = 10^3 R_{eH} Z_{D-n50}$$

If the value χ_F is not sufficient to evaluate the peaks of the curve M - χ , the procedure is to be repeated until the value of the imposed curvature permits the calculation of the maximum bending moments of the curve.

2.2 Procedure

2.2.1 General

The curve M - χ is to be obtained by means of an incremental-iterative approach, summarised in the flow chart of Fig 1.

In this procedure, the hull girder ultimate bending moment capacity M_U is defined as the peak value of the curve with vertical bending moment M versus the curvature χ of the ship cross-section as shown in Fig 1.

Each step of the incremental procedure is represented by the calculation of the bending moment M_i which acts on the hull transverse section as the effect of an imposed curvature χ_i .

For each step, the value χ_i is to be obtained by summing an increment of curvature $\Delta\chi$ to the value relevant to the previous step χ_{i-1} . This increment of curvature corresponds to an increment of the rotation angle of the hull girder transverse section around its horizontal neutral axis.

This rotation increment induces axial strains ε in each hull structural element, whose value depends on the position of the element. In hogging condition, the structural elements above the neutral axis are lengthened, while the elements below the neutral axis are shortened, and vice-versa in sagging condition.

The stress σ induced in each structural element by the strain ε is to be obtained from the load-end shortening curve σ - ε of the element, which takes into account the behaviour of the element in the non-linear elasto-plastic domain.

The distribution of the stresses induced in all the elements composing the hull transverse section determines, for each step, a variation of the neutral axis position, due to the non-linear σ - ε relationship. The new position of the neutral axis relevant to the step considered is to be obtained by means of an iterative process, imposing the equilibrium among the stresses acting in all the hull elements on the transverse section.

Once the position of the neutral axis is known and the relevant element stress distribution in the section is obtained, the bending moment of the section M_i around the new position of the neutral axis, which corresponds to the curvature χ_i imposed in the step considered, is to be obtained by summing the contribution given by each element stress.

The main steps of the incremental-iterative approach described above are summarised as follows (see also Fig 1):

- Step 1: Divide the transverse section of hull into stiffened plate elements
- Step 2: Define stress-strain relationships for all the elements, as shown in Tab 1
- Step 3: Initialise curvature χ_1 and neutral axis for the first incremental step with the value of the incremental curvature (i.e. curvature that induces a stress equal to 1% of yield strength in strength deck):

$$\chi_1 = \Delta\chi = 0,01 \frac{R_{eH}}{E} \cdot \frac{1}{z_D - z_n}$$

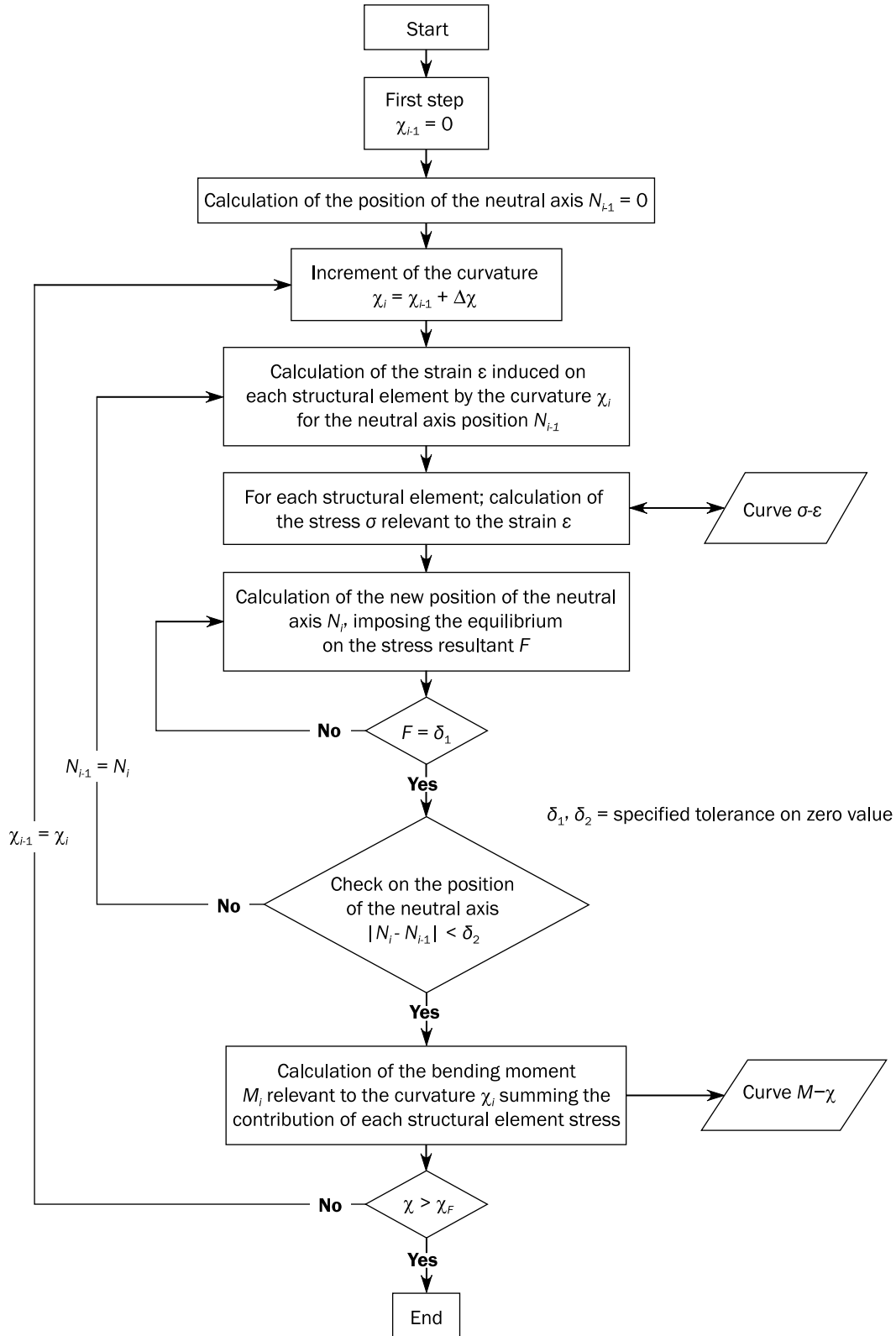
where:

z_D : Z coordinate, in m, of the strength deck at side, with respect to the reference coordinate system defined in Ch 1, Sec 3, [2.6]

z_n : Z coordinate, in m, of the horizontal neutral axis of the hull transverse section, with respect to the reference coordinate system defined in Ch 1, Sec 3, [2.6]

- Step 4: Calculate, for each element, the corresponding strain $\epsilon_i = \chi (z_i - z_n)$ and the corresponding stress σ_i
- Step 5: Determine the neutral axis z_{NA_cur} at each incremental step by establishing force equilibrium over the whole transverse section:
 $\Sigma (A_{i-n50} \sigma_i) = \Sigma (A_{j-n50} \sigma_j)$,
 the i-th element being under compression and the j-th element under tension

Figure 1 : Flow chart of the procedure for the evaluation of the curve M- χ



- Step 6: Calculate the corresponding moment by summing the contributions of all the elements:

$$M_U = \sum \sigma_{Ui} A_{i-n50} |z_i - z_{NA_{cur}}|$$

- Step 7: Compare the moment in the current incremental step with the moment in the previous incremental step. If the slope in $M-\chi$ relationship is less than a negative fixed value, terminate the process and define the peak value M_U . Otherwise, increase the curvature by the amount of $\Delta\chi$ and go to Step 4.

2.2.2 Modeling of the hull girder cross-section

Hull girder transverse sections are to be considered as being constituted by the members contributing to the hull girder ultimate strength.

Sniped stiffeners are also to be modeled, taking account of the fact that they do not contribute to the hull girder strength.

The structural members are categorised into a stiffener element, a stiffened plate element or a hard corner element.

The plate panel including web plate of girder or side stringer is idealised into either a stiffened plate element, an attached plate of a stiffener element, or a hard corner element.

The plate panel is categorised into the following two kinds:

- longitudinally stiffened panel, the longer side of which is in the ship longitudinal direction, and
- transversely stiffened panel, the longer side of which is in the direction perpendicular to the ship longitudinal direction.

a) Hard corner element

Hard corner elements are sturdier elements composing the hull girder transverse section, which collapse mainly according to an elasto-plastic mode of failure (material yielding); they are generally constituted by two plates not lying in the same plane.

The extent of a hard corner element from the point of intersection of the plates is taken equal to (see Fig 2):

- $20 t_{n50}$ on a transversely stiffened panel, and
- $0,5 s$ on a longitudinally stiffened panel,

where:

- t_{n50} : Net offered thickness of the plate, in mm
- s : Spacing of the adjacent longitudinal stiffener, in mm.

Sheer strake-deck stringer elements, girder-deck connections and face plate-web connections on large girders are typical hard corners. Enlarged stiffeners, with or without web stiffening, used for Permanent Means of Access (PMA) are not to be considered as a large girder, so the attached plate/web connection is only considered as a hard corner, see Fig 3.

b) Stiffener element

The stiffener constitutes a stiffener element together with the attached plate.

The attached plate width is, in principle, equal to:

- the mean spacing of the stiffener, when the panels on both sides of the stiffener are longitudinally stiffened, or
- the width of the longitudinally stiffened panel, when the panel on one side of the stiffener is longitudinally stiffened and the other panel is transversely stiffened, see Fig 2.

c) Stiffened plate element

The plate between stiffener elements, between a stiffener element and a hard corner element or between hard corner elements is to be treated as a stiffened plate element, see Fig 2.

The typical examples of modeling of hull girder section are illustrated in Fig 3. Notwithstanding the foregoing principle, these figures are to be applied to the modeling in the vicinity of upper deck, sheer strake and hatch coaming.

Figure 2 : Extension of the breadth of an attached plating and hard corner element

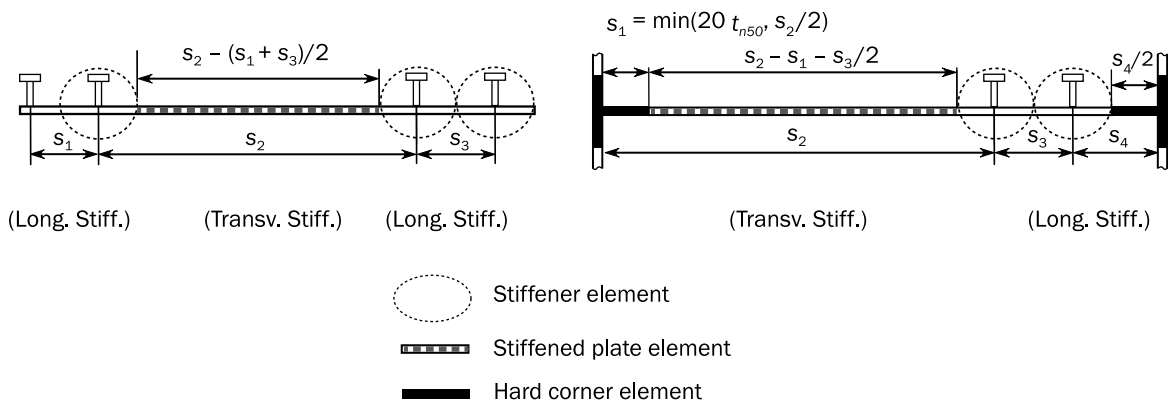
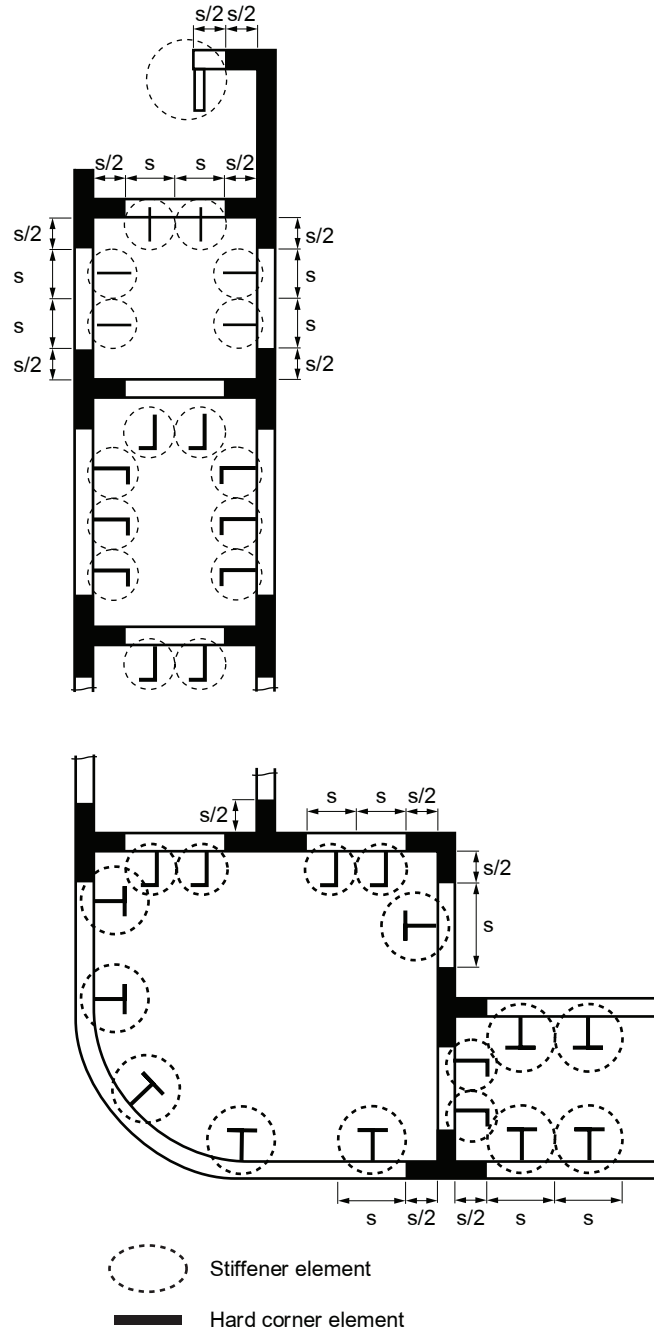


Figure 3 : Examples of the configuration of stiffened plate elements, stiffener elements and hard corner elements on a hull section



- in case of knuckle points as shown in Fig 4, the plating area adjacent to the knuckles in a plating having an angle greater than 30° is defined as a hard corner. The extent, from the knuckle point, of one side of the corner is taken equal to 20 t_{n50} on transversely framed panels and to 0,5 s on longitudinally framed panels
- where plate elements are stiffened by non-continuous longitudinal stiffeners, the non-continuous stiffeners are considered only as dividing a plate into various elementary plate panels
- where openings are provided in stiffened plate elements, the openings are to be considered in accordance with Ch 6, Sec 1, [1.2.9]
- where an attached plating is made of steels having different thicknesses and/or yield stresses, an average thickness and/or average yield stress, obtained from the following formulae, are to be used for the calculation:

$$t_{n50} = \frac{t_{1-n50} s_1 + t_{2-n50} s_2}{s}$$

$$R_{eHp} = \frac{R_{eHp1} t_{1-n50} s_1 + R_{eHp2} t_{2-n50} s_2}{t_{n50} s}$$

where:

R_{eHp1} , R_{eHp2} , t_{1-n50} , t_{2-n50} , s_1 , s_2 , s : As shown in Fig 5.

Figure 4 : Plating with knuckle point

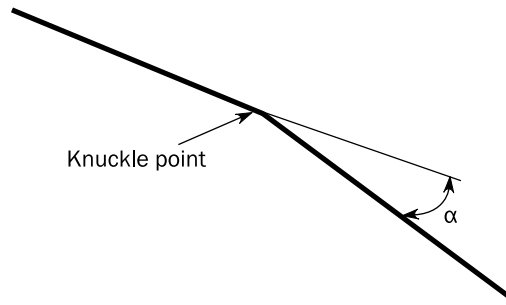
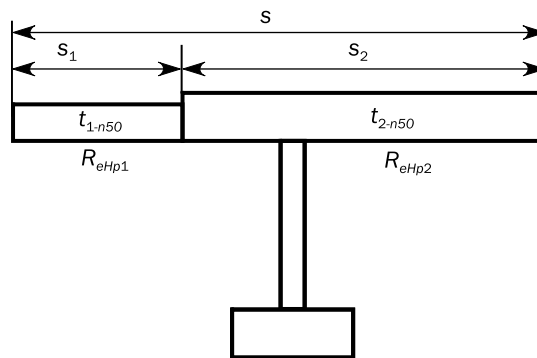


Figure 5 : Element with different thickness and/or different yield strength



2.3 Load-end shortening curves

2.3.1 Stiffened plate element and stiffener element

Stiffened plate element and stiffener element composing the hull girder transverse sections may collapse, following one of the modes of failure specified in Tab 1.

- where the plate elements are stiffened by non-continuous longitudinal stiffeners, the stress of the element is to be obtained in accordance with [2.3.3] to [2.3.8], taking account of the non-continuous longitudinal stiffener. In the calculation of the total forces for checking the hull girder ultimate strength, the area of the non-continuous longitudinal stiffener is to be assumed as zero.
- where an opening is provided in the stiffened plate element, the considered area of the stiffened plate element is to be obtained by deducting the opening area from the plating in the calculation of the total forces for checking the hull girder ultimate strength. The consideration of the opening is in accordance with the requirement in Ch 6, Sec 1, [1.2.9] to Ch 6, Sec 1, [1.2.13].
- for the stiffened plate element, the effective width of plate for the load shortening portion of the stress-strain curve is to be taken as the full plate width, i.e. to the intersection of the other plate or longitudinal stiffener – neither from the end of the hard corner element nor from the attached plating of the stiffener element, if any. In the calculation of the total forces for checking the hull girder ultimate strength, the area of the stiffened plate element is to be taken between the hard corner element and the stiffener element or between the hard corner elements, as applicable.

Table 1 : Modes of failure of stiffened plate elements and stiffener elements

Elements	Mode of failure	Curve σ - ϵ defined in
Lengthened stiffened plate elements or lengthened stiffener elements	Elasto-plastic collapse	[2.3.3]
Shortened stiffener elements	Beam column buckling	[2.3.4]
	Torsional buckling	[2.3.5]
	Web local buckling of flanged profiles	[2.3.6]
	Web local buckling of flat bars	[2.3.7]
Shortened stiffened plate elements	Plate buckling	[2.3.8]

2.3.2 Hard corner element

The relevant load-end shortening curve σ - ε is to be obtained for lengthened and shortened hard corners according to [2.3.3].

2.3.3 Elasto-plastic collapse of structural elements (hard corner element)

The load-end shortening curve σ - ε for the elasto-plastic collapse of structural elements composing the hull girder transverse section is to be obtained from the following formula, valid for both positive (shortening) and negative (lengthening) strains (see Fig 6):

$$\sigma = \Phi R_{eHA}$$

where:

R_{eHA} : Equivalent minimum yield stress, in N/mm², of the considered element, obtained by the following formula:

$$R_{eHA} = \frac{R_{eHp} A_{p-50} + R_{eHs} A_{s-n50}}{A_{p-n50} + A_{s-n50}}$$

Φ : Edge function, equal to:

$$\Phi = -1 \quad \text{for } \varepsilon < -1$$

$$\Phi = \varepsilon \quad \text{for } -1 \leq \varepsilon \leq 1$$

$$\Phi = 1 \quad \text{for } \varepsilon > 1$$

ε : Relative strain, equal to:

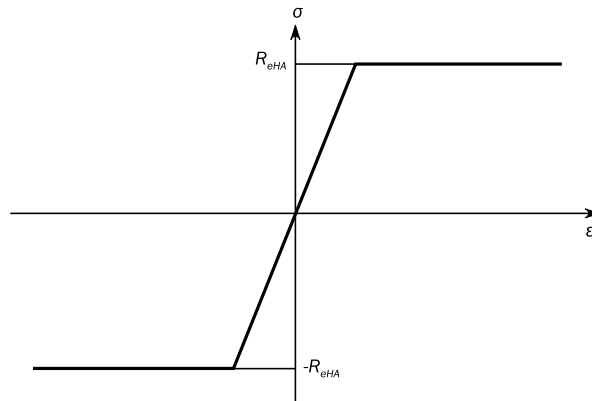
$$\varepsilon = \frac{\varepsilon_E}{\varepsilon_Y}$$

ε_E : Element strain

ε_Y : Strain at yield stress in the element, equal to:

$$\varepsilon_Y = \frac{R_{eHA}}{E}$$

Figure 6 : Load-end curve σ - ε for elasto-plastic collapse



2.3.4 Beam column buckling

The load-end shortening curve σ_{CR1} - ε for the beam column buckling of stiffeners composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR1} = \Phi \sigma_{C1} \frac{A_{s-n50} + A_{pE-n50}}{A_{s-n50} + A_{p-n50}}$$

where:

Φ : Edge function, as defined in [2.3.3]

σ_{C1} : Critical stress, in N/mm², equal to:

- for $\sigma_{E1} \leq \frac{R_{eHB}}{2} \varepsilon$:

$$\sigma_{C1} = \frac{\sigma_{E1}}{\varepsilon}$$

- for $\sigma_{E1} > \frac{R_{eHB}}{2} \varepsilon$:

$$\sigma_{C1} = R_{eHB} \left(1 - \frac{R_{eHB} \varepsilon}{4 \sigma_{E1}} \right)$$

R_{eHB} : Equivalent minimum yield stress, in N/mm², of the considered element, obtained by the following formula:

$$R_{eHB} = \frac{R_{eHp} A_{pEI-n50} \ell_{pE} + R_{eHs} A_{s-n50} \ell_{sE}}{A_{pEI-n50} \ell_{pE} + A_{s-n50} \ell_{sE}}$$

$A_{pEI-n50}$: Effective area, in cm², equal to: $A_{pEI-n50} = 10 b_{E1} t_{n50}$

ℓ_{pE} : Distance, in mm, measured from the neutral axis of the stiffener with attached plate of width b_{E1} to the bottom of the attached plate

ℓ_{sE} : Distance, in mm, measured from the neutral axis of the stiffener with attached plating of width b_{E1} to the top of the stiffener

ε : Relative strain, as defined in [2.3.3]

σ_{E1} : Euler column buckling stress, in N/mm², equal to:

$$\sigma_{E1} = \pi^2 E \frac{I_{E-n50}}{A_{E-n50} \ell^2} 10^{-4}$$

I_{E-n50} : Net moment of inertia of stiffeners, in cm⁴, with attached plating of width b_{E1}

A_{E-n50} : Net area, in cm², of stiffeners with attached plating of width b_E

b_{E1} : Effective width corrected for relative strain, in m, of the attached plating, equal to:

- for $\beta_E > 1,0$:

$$b_{E1} = \frac{s}{\beta_E} 10^{-3}$$

- for $\beta_E \leq 1,0$:

$$b_{E1} = 10^{-3} s$$

$$\beta_E = \frac{s}{t_{n50}} \sqrt{\frac{\varepsilon R_{eHp}}{E}}$$

A_{pE-n50} : Net sectional area, in cm², of attached plating of width b_E , equal to: $A_{pE-n50} = 10 b_E t_{n50}$

b_E : Effective width, in m, of the attached plating, equal to:

- for $\beta_E > 1,25$:

$$b_E = 10^{-3} \left(\frac{2,25}{\beta_E} - \frac{1,25}{\beta_E^2} \right) s$$

- for $\beta_E \leq 1,25$:

$$b_E = 10^{-3} s$$

2.3.5 Torsional buckling

The load-end shortening curve $\sigma_{CR2-\varepsilon}$ for the flexural-torsional buckling of stiffeners composing the hull girder transverse section is to be obtained according to the following formula:

$$\sigma_{CR2} = \Phi \frac{A_{s-n50} \sigma_{C2} + A_{p-n50} \sigma_{CP}}{A_{s-n50} + A_{p-n50}}$$

where:

Φ : Edge function, as defined in [2.3.3]

σ_{C2} : Critical stress, in N/mm², equal to:

- for $\sigma_{E2} \leq \frac{R_{eHs}}{2} \varepsilon$:

$$\sigma_{C2} = \frac{\sigma_{E2}}{\varepsilon}$$

- for $\sigma_{E2} > \frac{R_{eHs}}{2} \varepsilon$:

$$\sigma_{C2} = R_{eHs} \left(1 - \frac{R_{eHs} \varepsilon}{4 \sigma_{E2}} \right)$$

σ_{E2} : Euler column buckling stress, in N/mm², taken equal to σ_{ET} , as defined in Ch 9, Sec 1.

ε : Relative strain, as defined in [2.3.3]

σ_{CP} : Buckling stress of the attached plating, in N/mm², equal to:

- for $\beta_E > 1,25$:

$$\sigma_{CP} = \left(\frac{2,25}{\beta_E} - \frac{1,25}{\beta_E^2} \right) R_{eHp}$$

- for $\beta_E \leq 1,25$: $\sigma_{CP} = R_{eHp}$

β_E : Coefficient, as defined in [2.3.4].

2.3.6 Web local buckling of stiffeners made of flanged profiles

The load-end shortening curve $\sigma_{CR3-\varepsilon}$ for the web local buckling of flanged stiffeners composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR3} = \Phi \frac{10^3 b_E t_{n50} R_{eHp} + (h_{we} t_{w-n50} + b_f t_{f-n50}) R_{eHs}}{s t_{n50} + h_w t_{w-n50} + b_f t_{f-n50}}$$

where:

- Φ : Edge function, as defined in [2.3.3]
- b_E : Effective width, in m, of the attached shell plating, as defined in [2.3.4]
- h_{we} : Effective height of the web, in mm, equal to:

- for $\beta_w > 1,25$:

$$h_{we} = \left(\frac{2,25}{\beta_w} - \frac{1,25}{\beta_w^2} \right) h_w$$

- for $\beta_w \leq 1,25$:

$$h_{we} = h_w$$

$$\beta_w = \frac{h_w}{t_{w-n50}} \sqrt{\frac{\varepsilon R_{eHs}}{E}}$$

- ε : Relative strain, as defined in [2.3.3].

2.3.7 Web local buckling of stiffeners made of flat bars

The load-end shortening curve $\sigma_{CR4-\varepsilon}$ for the web local buckling of flat bar stiffeners composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR4} = \Phi \frac{A_{p-n50} \sigma_{CP} + A_{s-n50} \sigma_{C4}}{A_{p-n50} + A_{s-n50}}$$

where:

- Φ : Edge function, as defined in [2.3.3]
- σ_{CP} : Buckling stress of the attached plating, in N/mm², as defined in [2.3.5]
- σ_{C4} : Critical stress, in N/mm², equal to:

- for $\sigma_{E4} \leq \frac{R_{eHs}}{2} \varepsilon$:

$$\sigma_{C4} = \frac{\sigma_{E4}}{\varepsilon}$$

- for $\sigma_{E4} > \frac{R_{eHs}}{2} \varepsilon$:

$$\sigma_{C4} = R_{eHs} \left(1 - \frac{R_{eHs} \varepsilon}{4 \sigma_{E4}} \right)$$

- σ_{E4} : Local Euler buckling stress, in N/mm², equal to:

$$\sigma_{E4} = 160000 \left(\frac{t_{w-n50}}{h_w} \right)^2$$

- ε : Relative strain, as defined in [2.3.3].

2.3.8 Plate buckling

The load-end shortening curve $\sigma_{CR5-\varepsilon}$ for the buckling of transversely stiffened panels composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR5} = \Phi R_{eHp} \left[\frac{s}{\ell} \left(\frac{2,25}{\beta_E} - \frac{1,25}{\beta_E^2} \right) 10^{-3} + 0,1 \left(1 - \frac{s}{\ell} 10^{-3} \right) \left(1 + \frac{1}{\beta_E^2} \right)^2 \right]$$

without being taken greater than ΦR_{eHp} ,

where:

- Φ : Edge function, as defined in [2.3.3]
- β_E : Coefficient, as defined in [2.3.4].
- s : Plate breadth, in mm, taken as the spacing between the stiffeners
- ℓ : Longer side of the plate, in m.

3 Alternative methods

3.1 General

3.1.1 The bending moment-curvature relationship $M-\chi$ may be established by alternative methods. Such models are to consider all the relevant effects important to the non-linear response, with due consideration to:

- a) non-linear geometrical behaviour
- b) inelastic material behaviour
- c) geometrical imperfections and residual stresses (geometrical out-of-flatness of plate and stiffeners)
- d) simultaneously acting loads:
 - bi-axial compression
 - bi-axial tension
 - shear and lateral pressure
- e) boundary conditions
- f) interactions between buckling modes
- g) interactions between structural elements such as plates, stiffeners, girders, etc
- h) post-buckling capacity
- i) overstressed elements on the compression side of hull girder cross-section possibly leading to local permanent sets/buckle damages in plating, stiffeners etc (double bottom effects or similar).

3.2 Non-linear finite element analysis

3.2.1 Advanced non-linear finite element analysis models may be used for the assessment of the hull girder ultimate capacity. Such models are to consider the relevant effects important to the non-linear responses, with due consideration to the items listed in [3.1.1].

3.2.2 Particular attention is to be given to modeling the shape and size of geometrical imperfections. It is to be ensured that the shape and size of geometrical imperfections trigger the most critical failure modes.

Part B

Hull and Stability

CHAPTER 7

HULL SCANTLINGS

Section 1	General
Section 2	Load Application
Section 3	Minimum Thickness
Section 4	Plating
Section 5	Stiffeners
Section 6	Primary Supporting Members and Pillars
Appendix 1	Analyses of Primary Supporting Members Subject to Wheeled Loads

Section 1 General

1 Application

1.1 Application

1.1.1 This Chapter applies to hull structure over the full length of the ship including fore end, cargo hold region, machinery space, aft end, side shell, engine casing, exposed and internal decks.

1.1.2 This Chapter provides requirements for evaluation of plating, stiffeners and primary supporting members (PSM) subject to lateral pressure, local loads and hull girder loads, as applicable. Requirements are specified in:

- Ch 7, Sec 2 for load application
- Ch 7, Sec 3 for minimum thickness of plates, stiffeners and PSM
- Ch 7, Sec 4 for plating
- Ch 7, Sec 5 for stiffeners
- Ch 7, Sec 6 for PSM and pillars.

1.1.3 Required scantlings

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

1.1.4 Additional local strength requirements

Additional local strength requirements are provided as listed below:

- fore part, bow flare impact and bottom forward slamming: Ch 11, Sec 1
- machinery space: Ch 11, Sec 2
- aft part and stern impact: Ch 11, Sec 3
- sloshing: Ch 11, Sec 4.
- superstructures, deckhouses and companionways: Ch 11, Sec 5

1.2 Acceptance criteria

1.2.1 Acceptance criteria sets are to be selected as defined in Ch 7, Sec 2, Tab 1 to Ch 7, Sec 2, Tab 4.

Section 2 Load Application

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

P_{ex}	: Design external pressure, in kN/m ² , defined in Ch 5, Sec 5
P_{in}	: Design internal pressure, in kN/m ² , defined in Ch 5, Sec 6
P_d	: Green sea pressure for a considered dynamic load case, in kN/m ² , as defined in Ch 5, Sec 5
P_{dl}	: Design pressure due to uniform cargo, in kN/m ² , defined in Ch 5, Sec 6
P_{sc}	: Overpressure due to the inlet grating cleaning system, in kN/m ² , defined in Ch 5, Sec 5
F_{sc}	: Load due to steel coil cargoes, in kN, taken equal to $F_{sc-ib-s}$, F_{sc-ib} , $F_{sc-hs-s}$ or F_{sc-hs} , as defined in Ch 5, Sec 6
F_u	: Design force due to unit cargo, in kN, taken equal to F_{u-s} or F_{u-d} , as defined in Ch 5, Sec 6
R	: Vertical force at the corners of container stacks, in kN, taken equal to R_s , R_w , as defined in Ch 5, Sec 6.

1 Load combination

1.1 Hull girder

1.1.1 Normal stress

The hull girder normal stress σ_L , in N/mm², is to be calculated according to Ch 6, Sec 1, [2.1] at the considered position for each design load set defined in [2].

1.2 Pressure combination

1.2.1 Elements of the outer shell

The static and dynamic lateral pressures to be considered are the differences between the internal pressures and the external sea pressures at the corresponding loading condition. At least the two following cases are to be considered:

- combination of the maximum external pressure with the minimum internal pressure (generally full load with empty ballast)
- combination of the minimum external pressure with the maximum internal pressure (generally ballast loading condition).

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

1.2.2 Elements other than those of the outer shell

The static and dynamic lateral pressures on an element separating two adjacent compartments are those obtained considering the two compartments individually loaded.

2 Design load sets

2.1 Application of load components

2.1.1 Application

These requirements apply to:

- plating and stiffeners along the full length of the ship
- the primary supporting members assessed by means of prescriptive analysis or beam model according to Pt B, Ch 7, Sec 6 (see Ch 7, Sec 6, Tab 1).

2.1.2 Load components

The static and dynamic load components are to be determined in accordance with Ch 5, Sec 7, Tab 1.

Radius of gyration k_r and metacentric height GM are to be in accordance with Ch 5, Sec 3, Tab 4 for the considered loading conditions specified in the design load sets given in Tab 1.

2.1.3 Design load sets

Design load sets are defined in Tab 1 for:

- plating and stiffeners along the full length of the ship
- primary supporting members located outside the cargo hold region
- primary supporting members along the full length of non-cargo ships.

For primary supporting members located within the cargo hold region of ships carrying containers, dry bulk or liquid cargo, design load sets are defined respectively in Tab 2, Tab 3 and Tab 4.

Only the design load sets corresponding to the loading conditions defined in Ch 5, Sec 8 for the considered ship type are to be applied.

Table 1 : Design load sets

Item	Design load set	Load component	Draught	Acceptance criteria (7)	Design load scenario / Loading condition
Outer shell, superstructure walls and exposed deck	SEA-1	P_{ex}, P_d	T_{SC}	AC-2	Sea-going / Full load condition
	SEA-2 (1)	P_{ex}	T_{SC}	AC-1	Harbour condition
Water ballast tank	WB-1	$P_{in} - P_{ex}$ (2)	T_{BAL}	AC-2	Sea-going / Normal ballast condition
	WB-2	$P_{in} - P_{ex}$ (2)	T_{BAL}	AC-2	Water ballast exchange / Normal ballast condition
	WB-3	$P_{in} - P_{ex}$ (2)	$0,25 T_{SC}$ (10)	AC-1	Harbour condition
	WB-4	$P_{in} - P_{ex}$ (2)	$0,25 T_{SC}$ (10)	AC-3	Tank testing condition
Water ballast tank and bulk cargo hold assigned as ballast hold	WB-5	$P_{in} - P_{ex}$ (2)	T_{BAL-H} (6)	AC-2	Sea-going / Heavy ballast condition
	WB-6 (8)	$P_{in} - P_{ex}$ (2) (11)	T_{BAL-H} (6)	AC-2	Water ballast exchange / Heavy ballast condition
	WB-7 (9)	P_{in}	–	AC-1	Harbour condition
	WB-8 (9)	P_{in}	–	AC-3	Tank testing condition
Liquid cargo hold	LC-1	P_{in}	T_{SC}	AC-2	Sea-going / Full load condition
	LC-2	P_{in}	$0,6 T_{SC}$	AC-2	Sea-going / Partial load condition
	LC-3	P_{in}	–	AC-1	Harbour condition
	LC-4	P_{in}	–	AC-3	Tank testing condition
Dry bulk cargo hold	FBC-0	P_{in} (12)	–	AC-3 (13)	Flooded / flooded and opposite holds empty
	BC-1	P_{in}	T_{SC}	AC-2	Sea-going / Homogeneous loading, fully filled
	FBC-1	P_{in} (12)	–	AC-3 (13)	Flooded / Homogeneous, flooded and opposite holds fully filled
	BC-2	P_{in}	–	AC-1	Harbour / Homogeneous loading, fully filled
	BC-3	P_{in}	T_{SC}	AC-2	Sea-going / Homogeneous heavy cargo, partially filled
	FBC-3 (14)	P_{in} (12)	–	AC-3 (13)	Flooded / Homogeneous heavy cargo, flooded and opposite holds partially filled
	BC-4	P_{in}	–	AC-1	Harbour / Homogeneous heavy cargo, partially filled
	BC-5	P_{in}	T_{SC}	AC-2	Sea-going / Alternate light cargo, fully filled
	FBC-5 (15)	P_{in} (12)	–	AC-3 (13)	Flooded / Alternate light, flooded hold fully filled, opposite hold empty
	BC-6	P_{in}	–	AC-1	Harbour / Alternate light cargo, fully filled
	BC-7	P_{in}	T_{SC}	AC-2	Sea-going / Alternate heavy cargo, partially filled
	FBC-7 (15)	P_{in} (12)	–	AC-3 (13)	Flooded / Alternate heavy, flooded hold partially filled, opposite hold empty
	BC-8	P_{in}	–	AC-1	Harbour / Alternate heavy cargo, partially filled
	BC-9	F_{sc-ib} or F_{sc-hs}	T_{SC}	AC-2	Sea-going / Steel Coils condition
BC-10	$F_{sc-ib-s}$ or $F_{sc-hs-s}$	T_{SC}	AC-1	Harbour / Steel Coils condition	

Item	Design load set	Load component	Draught	Acceptance criteria (7)	Design load scenario / Loading condition
Other tanks (fuel oil tank, fresh water tank, bilge tank, drain storage tank)	TK-1	$P_{in} - P_{ex}$ (2)	T_{BAL}	AC-2	Sea-going / Normal ballast condition
	TK-2	$P_{in} - P_{ex}$ (2)	$0,25 T_{SC}$ (10)	AC-1	Harbour condition
	TK-3 (5)	$P_{in} - P_{ex}$ (2) (11)	$0,25 T_{SC}$ (10)	AC-3	Tank testing condition
Sea chest	SC-1	P_{sc}	–	AC-1	Harbour / Inlet grating cleaning overpressure
Structural watertight boundaries intended to stop vertical and horizontal flooding	FD-1 (4)	P_{in}	T_{SC}	AC-3	Flooded condition
Exposed deck, internal decks or platforms	DL-1 (3)	P_{dl}, F_U	T_{SC}	AC-2	Sea-going / Full load condition
	DL-2 (3)	P_{dl}, F_U	–	AC-1	Harbour condition

(1) For outer shell only
 (2) P_{ex} is to be considered for external shell only
 (3) Distributed or concentrated loads only. Need not be combined with simultaneously occurring green sea pressure
 (4) Not applicable to external shell and to vertically corrugated transverse bulkheads separating dry bulk cargo holds
 (5) Not applicable to gas fuel tanks
 (6) Minimum draught among heavy ballast conditions is to be used
 (7) See acceptance criteria definition in Ch 1, Sec 2, [3.4]
 (8) Not to be applied to bulk cargo hold assigned as ballast hold
 (9) Dry bulk cargo hold only
 (10) $0,7 T_{SC}$ is to be used for ships assigned with service notations **ro-ro cargo ship, PCT carrier, ro-ro passenger ship or passenger ship**
 (11) P_{ex} is not to be considered for tanks tested in dry dock conditions
 (12) Loads for the flooded hold and opposite hold are defined in Ch 5, Sec 6, [4.1.7]
 (13) Applicable only to plane bulkheads. For vertically corrugated bulkheads, specific criteria are given in Ch 7, Sec 4, [2]
 (14) Applicable only to homogeneous heavy cargo loading condition
 (15) Applicable only to non homogeneous loading conditions.

Table 2 : Design load sets for primary supporting members within container holds

Item	Design load set	Load component	Draught	Acceptance criteria	Design load scenario / Loading condition
Double bottom floors and girders	PC-1	$R - P_{ex}$	$0,9 T_{SC}$	AC-2	Sea-going / Containers stacks forces and sea pressure
	SEA-2	P_{ex}	T_{SC}	AC-1	Harbour condition / Sea pressure only
Side transverses and stringers	SEA-1	P_{ex}	T_{SC}	AC-2	Sea-going / Full load condition

Note 1: For the other primary supporting members, design load sets listed in Tab 1 are to be considered.

Table 3 : Design load sets for primary supporting members within dry bulk cargo holds

Item	Design load set	Load component	Draught	Acceptance criteria(3)	Design load scenario / Loading condition
Bulk cargo hold assigned as ballast hold	WB-5	$P_{in} - P_{ex}$ (1)	T_{BAL-H}	AC-2	Sea-going / Heavy ballast condition
	WB-7	P_{in}	–	AC-1	Harbour condition
	WB-8	P_{in}	–	AC-3	Tank testing condition
Dry bulk cargo hold	BC-11	$P_{in} - P_{ex}$ (1)	T_{SC}	AC-2	Cargo loading condition
	BC-12	$P_{in} - P_{ex}$ (1)	–	AC-1	Harbour condition
	FBC-0	P_{in} (4)	–	AC-3(5)	Flooded / flooded and opposite holds empty
	FBC-1	P_{in} (4)	–	AC-3(5)	Flooded / Homogeneous, flooded and opposite holds fully filled
	FBC-3(6)	P_{in} (4)	–	AC-3(5)	Flooded / Homogeneous heavy cargo, flooded and opposite holds partially filled
	FBC-5(7)	P_{in} (4)	–	AC-3(5)	Flooded / Alternate light, flooded hold fully filled, opposite hold empty
	FBC-7(7)	P_{in} (4)	–	AC-3(5)	Flooded / Alternate heavy, flooded hold partially filled, opposite hold empty
Structural watertight boundaries intended to stop vertical and horizontal flooding	FD-1 (2)	P_{in}	T_{SC}	AC-3	Flooded condition

(1) P_{ex} is to be considered for external shell only
(2) Not applicable to external shell and vertically corrugated transverse bulkheads separating dry bulk cargo holds
(3) See acceptance criteria definition in Ch 1, Sec 2, [3.4]
(4) Loads for the flooded hold and opposite hold are defined in Ch 5, Sec 6, [4.1.7]
(5) Applicable only to plane bulkheads. For vertically corrugated bulkheads, specific criteria are given in Ch 7, Sec 6, [4.7]
(6) Applicable only to homogeneous heavy cargo loading condition
(7) Applicable only to non-homogeneous loading conditions.

Table 4 : Design load sets for primary supporting members within liquid cargo holds

Item	Design load set(4)	Load component	Draught	Acceptance criteria(5)	Design load scenario / Loading condition
Double bottom floors and girders(2)	SEA-1	P_{ex}	0,9 T_{SC} (1)	AC-2	Sea-going / Full load condition
	SEA-2	P_{ex}	T_{SC}	AC-1	Harbour / Full load condition
	LC-2	$P_{in} - P_{ex}$	0,6 T_{SC}	AC-2	Sea-going / Partial load condition
	LC-6	$P_{in} - P_{ex}$	(3)	AC-1	Harbour / Partial load condition
Side transverses(2)	SEA-1	P_{ex}	0,9 T_{SC}	AC-2	Sea-going / Full load condition
	SEA-2	P_{ex}	T_{SC}	AC-1	Harbour / Full load condition
	LC-1	P_{in}	T_{SC}	AC-2	Sea-going / Full load condition
	LC-2	P_{in}	0,6 T_{SC}	AC-2	Sea-going / Partial load condition
	LC-3	P_{in}	–	AC-1	Harbour condition
	LC-4	P_{in}	–	AC-3	Tank testing condition
Deck transverses	SEA-1	P_{ex} (6)	T_{SC}	AC-2	Sea-going / Full load condition
	LC-1	P_{in}	T_{SC}	AC-2	Sea-going / Full load condition
	LC-2	P_{in}	0,6 T_{SC}	AC-2	Sea-going / Partial load condition
	LC-3	P_{in}	–	AC-1	Harbour condition
	LC-4	P_{in}	–	AC-3	Tank testing condition

Item	Design load set(4)	Load component	Draught	Acceptance criteria(5)	Design load scenario / Loading condition
Vertical web frames on longitudinal bulkheads, horizontal stringers on transverse bulkheads and corrugations on corrugated bulkheads	LC-1	P_{in}	T_{SC}	AC-2	Sea-going / Full load condition
	LC-2	P_{in}	$0,6 T_{SC}$	AC-2	Sea-going / Partial load condition
	LC-3	P_{in}	–	AC-1	Harbour condition
	LC-4	P_{in}	–	AC-3	Tank testing condition
Cross ties in centre tanks(7)	LC-1	$\frac{P_{in-p} + P_{in-s}}{2}$	T_{SC}	AC-2	Sea-going / Full load condition
	LC-2	$\frac{P_{in-p} + P_{in-s}}{2}$	$0,6 T_{SC}$	AC-2	Sea-going / Partial load condition
	LC-3	P_{in}	–	AC-1	Harbour condition
	LC-4	P_{in}	–	AC-3	Tank testing condition
Cross ties in wing tanks(8)	LC-7	$\frac{P_{in} + P_{ex}}{2}$	T_{SC}	AC-2	Sea-going / Full load condition
	LC-8	$\frac{P_{in} + P_{ex}}{2}$	$0,6 T_{SC}$	AC-2	Sea-going / Partial load condition
	LC-9	$\frac{P_{in} + P_{ex}}{2}$	T_{SC}	AC-1	Harbour condition
	LC-10	$\frac{P_{in} + P_{ex}}{2}$	T_{SC}	AC-3	Tank testing condition
Structural watertight boundaries intended to stop vertical and horizontal flooding	FD-1(9)	P_{in}	T_{SC}	AC-3	Flooded condition

P_{in-p} : Design pressure from port side wing cargo tank, in kN/m².

P_{in-s} : Design pressure from starboard side wing cargo tank, in kN/m².

- (1) If the loading condition where the combination of an empty cargo tank and a mean ship's draught greater than $0,9 T_{SC}$ is included in ship's loading manual, the maximum corresponding draught is to be considered
- (2) Draughts specified for bottom floors, girders and side transverses are based on operational limits specified in Chapter 4. Where the optional loading conditions exceed the minimum Rule required loading conditions, the draughts will be subject to special consideration.
- (3) For ships with two watertight or oil-tight longitudinal bulkheads, the draught is to be taken as $0,25 T_{SC}$. For ships with a centreline bulkhead, the draught is to be taken as $0,33 T_{SC}$.
- (4) When the ship's configuration cannot be described by the structural members or structural configurations identified above, the applicable Design Load Sets to determine the scantling requirements of primary supporting member are to be selected so as to cover the following cases, as applicable:
 - A full tank on one side of the member with the tank or space on the other side empty.
 - A full tank on one side of the member with the external pressure minimised.
 - External pressure maximised with the adjacent tank or space empty.

The boundary is to be evaluated for loading from both sides. Design Load Sets are to be selected based on the tank or space contents and are to maximise the net pressure on the structural boundary, the draught to use is to be taken in accordance with the Design Load Set and this table. Design Load Sets covering the AC-1 and AC-2 acceptance criteria are to be selected.
- (5) See acceptance criteria definition in Ch 1, Sec 2, [3.4]
- (6) Green sea pressure only or other loads on deck
- (7) Full wing cargo tanks, centre tank empty
- (8) Full centre tank, wing cargo tanks empty
- (9) Not applicable to external shell and vertically corrugated transverse bulkheads separating dry bulk cargo holds.

Section 3 Minimum Thickness

1 General

1.1 Minimum thickness requirements

1.1.1 The gross thickness, in mm, of all structural elements including plating, web and face plate, if any, of stiffeners and tripping brackets, web plating and flange of primary supporting members, is to be not less than 5,0 mm.

1.1.2 Stiffener minimum thickness

Where minimum thickness requirements are specified for stiffeners in addition to the requirement of [1.1.1], the net thickness of the web and face plate, if any, of stiffeners and tripping brackets, in mm, is to comply with those minimum net thickness requirements.

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

- not less than 40% of the net required thickness of the attached plating, to be determined according to Ch 7, Sec 4.
- less than twice the net offered thickness of the attached plating.

Section 4 Plating

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

α_p : Correction factor for the panel aspect ratio, to be taken as follows:

$$\alpha_p = 1,2 - \frac{b}{2,1 a}$$

without being taken greater than 1,0

K_{corr} : Coefficient to take into account the corrosion:

- In general: $K_{corr} = 1,0$
- For tank testing: $K_{corr} = 1,2$

P : Pressure for the considered design load set (see Ch 7, Sec 2, [2]), in kN/m², calculated at the load calculation point defined in Ch 4, Sec 6, [2.2]

σ_L : Hull girder normal stress, in N/mm², as defined in Ch 7, Sec 2, [1.1], calculated at the load calculation point as defined in Ch 4, Sec 6, [2.2]

χ : Coefficient taken equal to:

- in intact condition: $\chi = 1,00$
- in flooded condition:
 - $\chi = 1,00$ for collision bulkheads
 - $\chi = 1,15$ for other watertight boundaries of compartments.

1 Plating subject to lateral pressure

1.1 Yielding check

1.1.1 Plating

The net thickness t , in mm, of plate panels subject to lateral pressure is to be not less than the greatest of the values obtained, for all the applicable design load sets defined in Ch 7, Sec 2, [2.1.3], from the following formula:

$$t = 0,0158 \alpha_p b \sqrt{\frac{|P|}{\chi C_a R_{eH}}}$$

where:

C_a : Permissible bending stress coefficient for plate, taken equal to:

$$C_a = K_{corr} \beta - \alpha \frac{|\sigma_L|}{R_{eH}}$$

without being taken greater than $K_{corr} C_{a-max}$

β, α : Coefficients as defined in Tab 1

C_{a-max} : Maximum permissible bending stress coefficient, as defined in Tab 1.

Table 1 : Coefficients β , α and C_{a-max}

Acceptance criteria set	Structural member		β	α	C_{a-max}
AC-1	Longitudinal strength members	Longitudinally stiffened plating	0,9	0,5	0,8
		Transversely stiffened plating		1,0	
	Other members		0,8	0	
AC-2	Longitudinal strength members	Longitudinally stiffened plating	1,05	0,5	0,95
		Transversely stiffened plating		1,0	
	Other members		1,0	0	1,0
AC-3	Longitudinal strength members	Longitudinally stiffened plating	1,1	0,5	1,0
		Transversely stiffened plating		1,0	
	Other members		1,0	0	

1.2 Plating of corrugated bulkheads

1.2.1 Cold and hot formed corrugations

The net plate thickness t , in mm, of corrugated bulkheads is not to be taken less than the greatest value calculated for all applicable design load sets, as defined in Ch 7, Sec 2, [2.1.3], given by:

$$t = 0,0158b_p \sqrt{\frac{|P|}{C_{CB} R_{eH}}}$$

where:

b_p : Plate width, in mm, taken as the width of the corrugation flange b_{f-cg} or the web b_{w-cg} , see Ch 4, Sec 5, Fig 27

C_{CB} : Permissible bending stress coefficient for corrugated bulkhead plating taken equal to:

- For acceptance criteria set AC-1 for transverse corrugated bulkheads and vertically corrugated longitudinal bulkheads:

$$C_{CB} = 0,75$$

- For acceptance criteria set AC-2 for transverse corrugated bulkheads and vertically corrugated longitudinal bulkheads:

$$C_{CB} = 0,90$$

- For acceptance criteria set AC-3 for transverse corrugated bulkheads and vertically corrugated longitudinal bulkheads:

$$C_{CB} = K_{corr} 0,95$$

- For horizontally corrugated longitudinal bulkheads, without being greater than C_{CB-max} :

$$C_{CB} = K_{corr} \beta_{CB} - \alpha_{CB} \frac{|\sigma_i|}{R_{eH}}$$

β_{CB} : Coefficient as defined in Tab 2

α_{CB} : Coefficient as defined in Tab 2

C_{CB-max} : Maximum permissible bending stress coefficient as defined in Tab 2.

Table 2 : Coefficients β_{CB} , α_{CB} and C_{CB-max}

Acceptance criteria set	Structural member	β_{CB}	α_{CB}	C_{CB-max}
AC-1	Horizontally corrugated longitudinal bulkheads	0,9	0,5	0,75
AC-2		1,05	0,5	0,9
AC-3		1,1	0,5	0,95

1.2.2 Built-up corrugations

In addition to [1.2.1], the net required thickness of the wider plating of built-up corrugations, t_w in mm, is to be taken as the greatest value calculated for all applicable design load sets, as defined in Ch 7, Sec 2, [2.1.3], given by:

$$t_w = \sqrt{\frac{5b_w^2 |P| 10^{-4}}{C_{CB} R_{eH}} - t_N^2}$$

t_N : Net required thickness of the narrower plating, either flange or web, in mm, as obtained in [1.2.1]

b_w : Plate width, in mm, of the wider plating, taken as the width of the corrugation flange b_{f-cg} or the web b_{w-cg} , whichever is greater, see Ch 4, Sec 5, Fig 27

1.3 Buckling check

1.3.1 The buckling check of plate panels is to be performed according to Ch 9, Sec 1.

2 Transverse vertically corrugated bulkheads separating dry bulk cargo holds in flooded condition

2.1 Application

2.1.1 These requirements apply to vertically corrugated transverse watertight bulkheads of the cargo holds of ships intended for the carriage of dry cargoes in bulk.

2.2 Net thickness of corrugation

2.2.1 Cold and hot formed corrugations

The net plate thickness t , in mm, of transverse vertically corrugated watertight bulkheads separating cargo holds is not to be taken less than:

$$t = 0,0149 b_p \sqrt{\frac{1,05 P_R}{R_{eH}}}$$

where:

b_p : Plate width, in mm, taken as the width of the corrugation flange b_{f-cg} or the web b_{w-cg} , see Ch 4, Sec 5, Fig 27

P_R : Resultant pressure, in kN/m², as defined in Ch 5, Sec 6, [4.1.7].

The net thickness is also to comply with the requirements given in [1.2.1].

2.2.2 Built-up corrugations

Where the thicknesses of the flange and web of built-up corrugations of transverse vertically corrugated watertight bulkheads separating cargo holds are different, the net plate thicknesses are not to be taken less than that obtained from the following formula.

The net thickness t_N , in mm, of the narrower plating is not to be taken less than that calculated according to [2.2.1] with b_p taken as the width of the corrugation flange b_{f-cg} or the web b_{w-cg} , whichever is smaller.

The net thickness t_W , in mm, of the wider plating is not to be taken less than the greater of:

a) The thickness calculated according to [2.2.1] with b_p taken as the width of the corrugation flange b_{f-cg} or the web b_{w-cg} , whichever is greater.

$$b) t_W = \sqrt{\frac{4,62 b_W^2 P_R 10^{-4}}{R_{eH}}} - t_{NO}^2$$

where:

t_{NO} : Net offered thickness of the narrower plating, in mm, not to be taken greater than that obtained in a)

b_W : Plate width, in mm, of the wider plating, taken as the width of the corrugation flange b_{f-cg} or the web b_{w-cg} , whichever is greater, see Ch 4, Sec 5, Fig 27.

The net thickness is also to comply with the requirements given in [1.2.2].

2.2.3 Lower part of corrugation

The net thickness of the lower part of corrugations is to be maintained for a distance of not less than $0,15 \ell_C$ measured from the top of the lower stool, or from the inner bottom where no lower stool is fitted. The span of the corrugations ℓ_C , in m, is to be taken as given in Ch 4, Sec 5, [10.3.5].

2.2.4 Middle part of corrugation

The net thickness of the middle part of corrugations is to be maintained for a distance not greater than $0,3 \ell_C$ from the bottom of the upper stool, or from the deck if no upper stool is fitted. The net thickness is also to comply with the requirements in Ch 7, Sec 6, [4.7.2] and [1.2].

3 Strength check of plating supporting wheeled cargo

3.1 General

3.1.1 The requirements of this Article apply for the strength check of plating supporting wheeled cargo.

3.1.2 If deemed necessary, the Society may require a fatigue assessment of plating supporting wheeled cargo.

3.2 Load model

3.2.1 General

Static and dynamic forces induced by relevant types of wheeled cargo are to be considered.

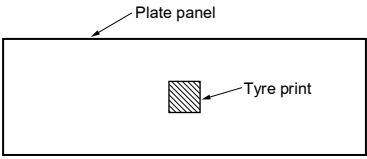
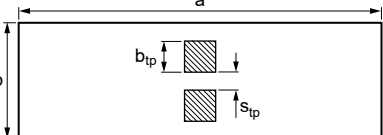
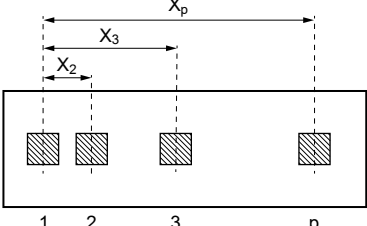
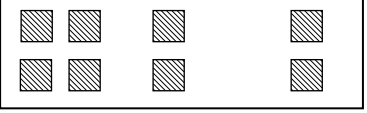
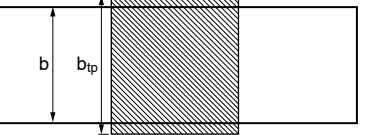
3.2.2 Tyre print

For the purpose of applying the requirements in [3.3], a single tyre print is to be considered for wheels that belong to the same axle and are separated from each other by not more than half of their individual width.

3.2.3 Forces due to wheeled cargo

The wheel force P_0 induced by a single wheel, in kN, is to be taken as defined in Ch 5, Sec 6, [7.2] considering dynamic forces in the vertical direction only.

Table 3 : Tyre print arrangements on plate panel

Tyre print arrangement	Total load on plate panel	m	α	δ	C_i
	$n P_0$	1	$\frac{A_T}{ab} 10^6$	1	1
	$2 n P_0$	2	$\frac{A_T}{ab} 10^6$	$\frac{\delta_1 + \delta_2}{2}$	1
	$p n P_0$ $p \geq 2$	1	$\frac{A_T}{ab} 10^6$	1	$\max \left(1 + \sum_{\substack{i=1 \\ i \neq j}}^p \beta_i, j \in [1;p] \right)$
	$2 p n P_0$ $p \geq 2$	2	$\frac{A_T}{ab} 10^6$	$\frac{\delta_1 + \delta_2}{2}$	$\max \left(1 + \sum_{\substack{i=1 \\ i \neq j}}^p \beta_i, j \in [1;p] \right)$
	$\delta n P_0$	1	$\frac{A_T}{ab_{tp}} 10^6$	$\frac{b}{b_{tp}}$	1

Note 1:

A_T : Tyre print area, in m^2 , as defined in [3.3.2]

$$\delta_1 = 1 - \frac{s_{tp}}{b - b_{tp}}$$

$$\delta_2 = 1 - \frac{3s_{tp}^2 + 6s_{tp}b_{tp}}{3b^2 - 4b_{tp}^2}$$

s_{tp} : Distance, in mm, between the two tyre prints

b_{tp} : Tyre print breadth, in mm

β_i : Coefficient for the considered tyre print:

- for $\alpha_i < 2$: $\beta_i = 0,8 (1,2 - 2,02 \alpha_i + 1,17 \alpha_i^2 - 0,23 \alpha_i^3)$
- for $\alpha_i \geq 2$: $\beta_i = 0$

with:

$$\alpha_i = \frac{x_i}{b}$$

x_i : Distance, in mm, from the considered tyre print (i) to the reference tyre print (j)

p : Number of tyre prints along the panel length.

Note 2: For multiple tyre prints arrangements, all tyre prints are to be identical. Tyre prints with various characteristics acting simultaneously on a plate panel are considered by the Society on a case by case basis.

3.3 Plating

3.3.1 Net thickness

The net thickness t , in mm, of plate panels supporting wheeled cargo is to be not less than the value obtained from the following formula:

$$t = 0,9 C_{WL} \sqrt{\frac{mn|P_0|k}{C_a} \delta C_1}$$

where:

C_{WL} : Coefficient to be taken equal to:

$$C_{WL} = 2,15 - 0,05 \frac{a}{b} + 0,02 \left(4 - \frac{a}{b}\right) \alpha^{0,5} - 1,75 \alpha^{0,25}$$

where a/b is to be taken not greater than 3

α : Coefficient to be taken as given in Tab 3

m : Number of tyre prints over the panel breadth, to be taken as given in Tab 3

n : Number of wheels per tyre print

P_0 : Wheel force, in kN, as defined in [3.2.3].

C_a : Permissible bending stress coefficient for plate, as defined in [1.1.1].

δ : Coefficient to be taken as given in Tab 3

C_1 : Coefficient to be taken as given in Tab 3

3.3.2 Tyre print area

The tyre print area, A_T , in m^2 , is to be taken as indicated by the Designer but not greater than:

$$A_T = 9,81 \frac{nQ_A}{n_W p_T}$$

where:

n : number of wheels per tyre print

Q_A : Axle load, in t

n_W : Number of individual wheels for the axle considered

p_T : Tyre pressure, in kN/m². When the tyre pressure is not indicated by the designer, it may be taken as defined in Tab 4.

When the tyre print consists of several wheels (see [3.2.2]), A_T is the total print area, including the area in between single wheels.

Table 4 : Tyre pressures p_T for vehicles

Vehicle type	Tyre pressure p_T , in kN/m ²	
	Pneumatic tyres	Solid rubber tyres
Private cars	250	Not applicable
Vans	600	Not applicable
Trucks and trailers	800	Not applicable
Handling machines	1100	1600

4 Plating subject to impact loads

4.1 General

4.1.1 Unless otherwise specified, the net thickness of plate panels subject to impact is to be not less than the value obtained, in mm, from the following formula:

$$t = \frac{0,0158 \alpha_p b}{C_d} \sqrt{\frac{P_i}{C_a R_{eH}}}$$

where:

C_d : Plate capacity correction coefficient:

- for impact on flat bottom forward, on flat area of the bottom aft and for berthing impact on the side shell:
 $C_d = 1,3$
- for sloshing:
 $C_d = 1,0$
- for impact on bow flare:
 $C_d = 1,2$

C_a : Permissible bending stress coefficient taken as: for acceptance criteria AC-4:
 $C_a = 1,0$

P_1 : Any impact pressure defined in the Rules, including:

- bottom impact pressure, as defined in Ch 5, Sec 5, [4.2.1]
- bow impact pressure, as defined in Ch 5, Sec 5, [4.3.1]
- sloshing impact pressure, as defined in Ch 5, Sec 6, [2.2.2]
- stern impact pressure, as defined in Ch 5, Sec 5, [4.2.2]
- berthing impact pressure, as defined in Ch 5, Sec 5, [4.4]

If deemed necessary by the Society and depending on specific natures of loadings, different calculation methods may be applied, on a case-by-case basis.

5 Strength check of plating supporting steel coils on wooden dunnage

5.1 General

5.1.1 The net thickness of inner bottom plating, hopper side plating and inner hull plating for ships intended to carry steel coils is to comply with [5.2.1] up to a height not less than the one corresponding to the top of upper tier in touch with hopper or inner hull plating.

5.2 Yielding check

5.2.1 The net thickness t , in mm, of plating of longitudinally framed inner bottom, bilge hopper sloping plate and inner hull is not to be taken less than:

$$t = K_1 \sqrt{\frac{F_{sc} \times 10^3}{C_a R_{eH}}}$$

where:

K_1 : Coefficient taken as:

$$K_1 = \sqrt{\frac{1.7 \frac{s}{1000} \ell K_2 - 0.73 \left(\frac{s}{1000}\right)^2 K_2^2 - (\ell - \ell_{ip})^2}{2 \ell_{ip} \left(2 \frac{s}{1000} + 2 \ell K_2\right)}}$$

K_2 : Coefficient taken as:

$$K_2 = -\frac{s}{1000 \ell} + \sqrt{\left(\frac{s}{1000 \ell}\right)^2 + 1.37 \left(\frac{1000 \ell}{s}\right)^2 \left(1 - \frac{\ell_{ip}}{\ell}\right)^2 + 2.33}$$

F_{sc} : Load due to steel coil cargoes, taken equal to $F_{sc-ib-s}$, F_{sc-ib} , $F_{sc-hs-s}$ or F_{sc-hs} as defined in Ch 5, Sec 6, [5], depending on the considered design load set (see Ch 7, Sec 2, [2])

C_a : Permissible bending stress coefficient, as defined in [1.1.1].

6 Special requirements

6.1 Minimum thickness of keel plating

6.1.1 The net thickness of the keel plating is not to be taken less than the offered net thickness of the adjacent 2 m width bottom plating, measured from the edge of the keel strake.

The width of the keel is defined in Ch 4, Sec 5, [7.2.1].

6.2 Bilge plating

6.2.1 Bilge plate thickness

- a) The net thickness of bilge plating is not to be taken less than the offered net thickness for the adjacent bottom shell or adjacent side shell plating, whichever is greater.
- b) The net thickness of rounded bilge plating t , in mm, is not to be taken less than:

$$t = 6,45 \cdot 10^{-4} (P_{ex} s_b)^{0,4} R^{0,6}$$

where:

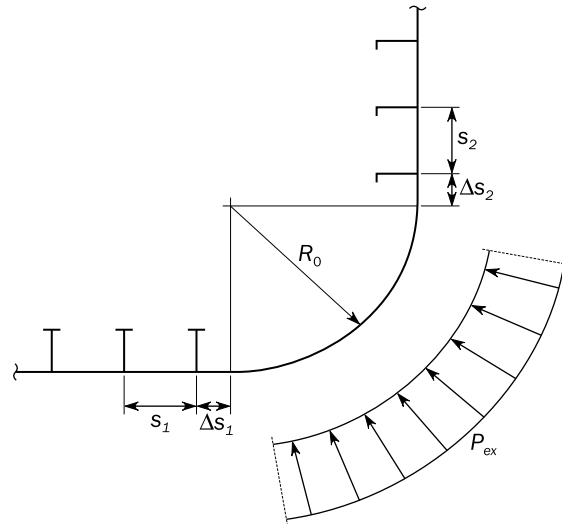
P_{ex} : Sea pressure for the design load set SEA-1 as defined in Ch 7, Sec 2, [2.1.3], calculated at the lower turn of the bilge, in kN/m²

R : Effective bilge radius in mm: $R = R_0 + 0,5 (\Delta s_1 + \Delta s_2)$

R_0 : Radius of curvature, in mm (see Fig 1)

- Δs_1 : Distance between the lower turn of bilge and the outermost bottom longitudinal, in mm, see Fig 1. Where the outermost bottom longitudinal is within the curvature, this distance is to be taken as zero
 - Δs_2 : Distance between the upper turn of bilge and the lowest side longitudinal, in mm, see Fig 1. Where the lowest side longitudinal is within the curvature, this distance is to be taken as zero
 - s_b : Distance between transverse stiffeners, webs or bilge brackets, in mm.
- c) Longitudinally stiffened bilge plating is to be assessed as regular stiffened plating. The bilge thickness is not to be less than the lesser of the values obtained by [1.1.1] and item b). A bilge keel is not considered as an effective 'longitudinal stiffening' member.

Figure 1 : Transverse stiffened bilge plating



6.2.2 Transverse extension of bilge minimum plate thickness

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

6.2.3 Hull envelope framing in bilge area

For transversely stiffened bilge plating, a longitudinal is to be fitted at the bottom and at the side close to the position where the curvature of the bilge plate starts. The scantling of those longitudinals is to be not less than the one of the closer adjacent stiffener. The distance Δs_1 between the lower turn of bilge and the outermost bottom longitudinal is generally not to be greater than one-third of the spacing between the two outermost bottom longitudinals s_1 . Similarly, the distance Δs_2 between the upper turn of the bilge and the lowest side longitudinal is generally not to be greater than one-third of the spacing between the two lowest side longitudinals s_2 . See Fig 1.

6.3 Inner bottom of cargo holds intended to carry dry cargo

6.3.1 For ships with one of the following service notations:

- **general cargo ship**, intended to carry dry bulk cargo in holds
- **bulk carrier**
- **bulk carrier ESP**
- **self-unloading bulk carrier ESP**
- **ore carrier ESP**
- **combination carrier ESP**

the inner bottom net thickness is to be increased by 2 mm unless it is protected by a continuous wooden ceiling.

6.4 Sheer strake

6.4.1 General

The minimum width of the sheer strake is defined in Ch 4, Sec 5, [8.1.4].

6.4.2 Welded sheer strake

The net thickness of a welded sheer strake is not to be less than the offered net thickness of the adjacent side plating, provided this adjacent side plating is located entirely within the top wing tank or the double side tank, as the case may be.

6.4.3 Rounded sheer strake

The net thickness of a rounded sheer strake is not to be less than:

- the offered net thickness of the adjacent 2 m width deck plating, or
- the offered net thickness of the adjacent 2 m width side plating,

whichever is greater.

6.5 Deck stringer plating

6.5.1 The minimum width of deck stringer plating is defined in Ch 4, Sec 5, [9.1.2].

6.5.2 Within 0,6 L amidships, the net thickness of the deck stringer plate is not to be less than the offered net thickness of the adjacent deck plating.

6.6 Deck plating protected by wood sheathing or deck composition

6.6.1 The net thickness of deck plating protected by wood sheathing, deck composition or other arrangements deemed suitable by the Society may be reduced on a case by case basis. In no case this net thickness is to be less than the minimum value as given in Ch 7, Sec 3.

6.6.2 The sheathing is to be secured to the deck to the satisfaction of the Society.

6.7 Supporting structure in way of corrugated bulkheads

6.7.1 General

Requirements for the arrangement of bulkhead as given in Ch 4, Sec 5, [10.3] are to be considered together with [6.7.2] to [6.7.4].

6.7.2 Lower stool

- a) The net thickness of the stool top plate is not to be less than that required for the attached corrugated bulkhead and is to be of at least the same material yield strength as the attached corrugation. The extension of the top plate beyond the corrugation is not to be less than the as-built flange thickness of the corrugation.
- b) The net thickness of the stool side plate, within the region of the corrugation depth from the stool top plate, is not to be less than the greater of the following:
 - the net thickness obtain from [1.1]
 - the corrugated bulkhead flange net actual thickness at the lower end.If material of different yield strength are used, the required thickness is to be adjusted by the ratio of the two material factors as defined in Ch 4, Sec 1, [2.2].
- c) Continuity between corrugation web and lower stool supporting brackets is to be maintained inside the stool.
- d) The net thickness of supporting bracket is not to be less than 80% of the required net thickness of the corrugation webs and is to be of at least the same material yield strength.
- e) The net thickness of supporting floors or girders is not to be less than the net required thickness of the stool side plating connected to the inner bottom and is to be of at least the same material yield strength. If material of different yield strength is used, the required thickness is to be adjusted by the ratio of the two material factors k , as defined in Ch 4, Sec 1, [2.2].
- f) Where a lower stool is fitted, particular attention is to be given to the through-thickness properties, and arrangements for continuity of strength, at the connection of the bulkhead stool to the inner bottom. For requirements for plates with specified through-thickness properties, see Ch 4, Sec 1, [2.6].

6.7.3 Upper stool

- a) The net thickness of the stool bottom plate is not to be less than that required for the attached corrugated bulkhead and is to be of at least the same material yield strength as the attached corrugation. The extension of the top plate beyond the corrugation is not to be less than the as-built flange thickness of the corrugation.
- b) The net thickness of the lower portion of stool side plating is not to be less than the greater of the following:
 - the net thickness obtain from [1.1]
 - 80% of the upper part of the bulkhead plating as required by [1.2]
 - the corrugated bulkhead flange net actual thickness at the upper end.If material of different yield strength are used, the required thickness is to be adjusted by the ratio of the two material factors as defined in Ch 4, Sec 1, [2.2].

6.7.4 Local supporting structure in way of corrugated bulkheads without a lower stool

- a) The net thickness of the supporting floors or girders and pipe tunnel beams in way of a corrugated bulkhead are not to be less than the required net thickness of the corrugation flanges and are to be of at least the same material yield strength. The inner bottom and hopper tank in way of the corrugation is to be of at least the same material yield strength as the attached corrugation, and Z grade steel as defined in Ch 4, Sec 1, [2.6.1] is to be used unless through thickness properties are documented for approval.
- b) Brackets/carlings arranged in line with the corrugation web are to have a depth of not less than 0.5 times the corrugation depth and a net thickness not less than 80% of the net thickness of the corrugation webs and are to be of at least the same material yield strength. Where support is provided by gussets with shedder plates instead of brackets/carlings, the height of the gusset plate is to be at least equal to the corrugation depth. The gusset plates are to be fitted in line with and between the corrugation flanges. The net thickness of the gusset and shedder plates is not to be less than 100% and 80%, respectively, of the net thickness of the corrugation flange and is to be of at least the same material yield strength.

6.8 Aft peak bulkhead

6.8.1 The net thickness of the aft peak bulkhead plating in way of the stern tube penetration is to be at least 1,6 times the required thickness for the bulkhead plating.

Section 5 Stiffeners

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

- d_{shr} : Effective shear depth, in mm, as defined in Ch 4, Sec 6, [1.4.4]
 f_{bdg} : Bending moment factor taken as:
- for continuous stiffeners with fixed ends, f_{bdg} is to be taken equal to:
 - $f_{bdg} = 12$ for horizontal stiffeners and upper end of vertical stiffeners
 - $f_{bdg} = 10$ for lower end of vertical stiffeners
 - for stiffeners with reduced end fixity, variable load or being part of grillage, the requirements in [1.7] applies
- K_{corr} : Coefficient to take into account the corrosion, as defined in Ch 7, Sec 4
 l_{bdg} : Effective bending span, in m, as defined in Ch 4, Sec 6, [1.1.2]
 l_{shr} : Effective shear span, in m, as defined in Ch 4, Sec 6, [1.1.3]
 l_{ip} : Distance, in m, between outermost dunnage per EPP in the ship X direction, as defined in Ch 5, Sec 6
 P : Design pressure for the design load set being defined in Ch 7, Sec 2 and calculated at the load calculation point defined in Ch 4, Sec 6, [3.2], in kN/m²
 χ : Coefficient as defined in Ch 7, Sec 4.

1 General

1.1 Yielding check of stiffeners subject to lateral pressure

1.1.1 Web plating

The net web thickness t_w , in mm, of stiffeners subject to lateral pressure is not to be taken less than the greatest of the values calculated for all applicable design load sets as defined in Ch 7, Sec 2, [2], as obtained from the following formulae:

$$t_w = \frac{f_{shr} |P| s l_{shr}}{d_{shr} K_{corr} \chi C_t \tau_{eH}}$$

with χC_t not to be taken greater than 1,0

where:

- f_{shr} : Shear force distribution factor taken as:
- for continuous stiffeners with fixed ends, f_{shr} is to be taken equal to:
 - $f_{shr} = 0,5$ for horizontal stiffeners and upper end of vertical stiffeners
 - $f_{shr} = 0,7$ for lower end of vertical stiffeners
 - for stiffeners with reduced end fixity or being part of grillage, the requirements in [1.7] applies
- C_t : Permissible shear stress coefficient for the design load set being considered, as defined in Tab 2.

1.1.2 Section modulus

The net section modulus, Z in cm³, of stiffeners subject to lateral pressure is not to be taken less than the greatest of the values calculated for all applicable design load sets as defined in Ch 7, Sec 2, [2.1.3], as obtained from the following formulae:

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

with χC_s not to be taken greater than K_{corr}

where:

- C_s : Permissible bending stress coefficient as defined in Tab 1 for the design load set being considered
 σ_L : Hull girder normal stress, in N/mm², as defined in Ch 7, Sec 2, [1.1], calculated at the load calculation point as defined in Ch 4, Sec 6, [2.2]
 $\beta_s, \alpha_s, C_{s-max}$: Coefficients as defined in Tab 2.

1.1.3 Group of stiffeners

Where stiffeners of equal scantlings are sequentially placed on a single stiffened panel, between primary supporting members, the scantling of every stiffener of the designated group may alternatively be taken as the greatest of the following:

- the average of the scantlings individually required for every stiffener within the group according to [1.1.1] and [1.1.2]
- 90% of the maximum scantling individually required for any of the stiffeners within the group according to [1.1.1] and [1.1.2].

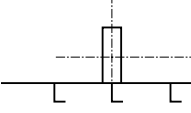
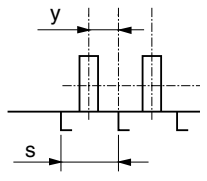
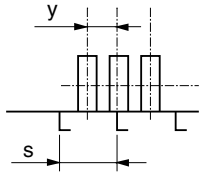
Table 1 : Definition of C_s

Sign of hull girder bending stress σ_L	Lateral pressure acting on	Coefficient C_s
Tension (positive)	stiffener side	$C_s = K_{corr} \beta_s - \alpha_s \frac{ \sigma_L }{R_{eH}}$ but not to be taken greater than $K_{corr} C_{s-max}$
Compression (negative)	plate side	
Tension (positive)	plate side	$C_s = K_{corr} C_{s-max}$
Compression (negative)	stiffener side	

Table 2 : Coefficients β_s , α_s , C_{s-max} , C_t and C_{comb}

Acceptance criteria set	Structural member	β_s	α_s	C_{s-max}	C_t	C_{comb}
AC-1	Longitudinal strength member	0,85	1,0	0,75	0,75	0,75
	Transverse or vertical member	0,75	0			
AC-2	Longitudinal strength member	1,00	1,0	0,9	0,9	0,9
	Transverse or vertical member	0,90	0			
AC-3	Longitudinal strength member	1,10	1,0	1,0	1,0	1,0
	Transverse or vertical member	1,00	0			

Table 3 : Wheeled cargo - Coefficient α_w

Single wheel configuration	Double wheels configuration	Triple wheels configuration
 $\alpha_w = 1$	 $\alpha_w = 2 \left(1 - \frac{y}{s} \right)$	 $\alpha_w = 3 - 2 \frac{y}{s}$
<p>Note 1: y : Distance, in mm, from the external wheel to the stiffener under consideration, to be taken equal to half the distance between the middle of the external wheels.</p>		

1.2 Yielding check of stiffeners supporting wheeled cargo

1.2.1 General

Static and dynamic forces induced by relevant types of wheeled cargo are to be considered.

1.2.2 Forces due to wheeled cargo

The wheel force P_0 induced by a single wheel, in kN, is to be taken as defined in Ch 5, Sec 6, [7.2] considering dynamic forces only in the vertical direction.

1.2.3 Web plating

The net web thickness t_w , in mm, of stiffeners supporting wheeled cargo is not to be taken less than the greatest of the values calculated for all applicable design load sets, as obtained from the following formulae:

$$t_w = \frac{\alpha_w K_T |P_0|}{d_{shr} C_t \tau_{eH}} 10^3$$

where:

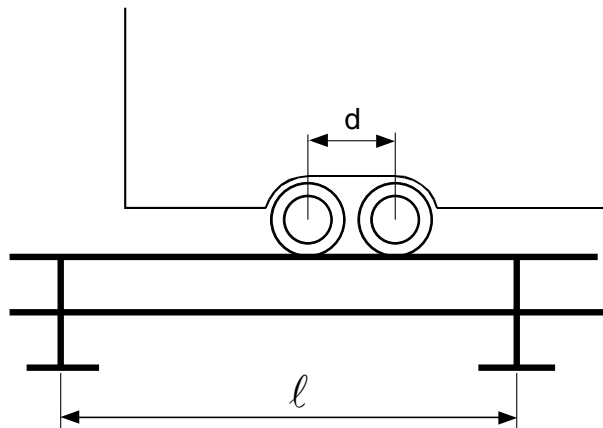
- α_w : Coefficient taking into account the number of individual wheels per axle considered as acting on the stiffener, defined in Tab 3, without being taken less than 1,0
- K_S, K_T : Coefficients taking account of the number of axles considered as acting on the stiffener, defined in Tab 4
- C_t : Permissible shear stress coefficient defined in [1.1.1].

Table 4 : Wheeled cargo - Coefficients K_S and K_T

Coefficient	Configuration	
	Single axle	Double axles
K_S	1	<ul style="list-style-type: none"> if $d \leq \ell/\sqrt{3}$ $\frac{172}{81} - \frac{4d}{3\ell} - \frac{d^2}{\ell^2} + \frac{d^4}{\ell^4}$ <ul style="list-style-type: none"> if $d > \ell/\sqrt{3}$ $\frac{4}{3} - \frac{4d}{3\ell} + \frac{3d^2}{\ell^2} - \frac{8d^3}{3\ell^3}$
K_T	1	$2 - \frac{d}{2\ell} - \frac{3d^2}{2\ell^2} + \frac{d^3}{\ell^3}$

Note 1:
 d : Distance, in m, between two axles (see Fig 1).

Figure 1 : Wheeled cargo on stiffeners - Double axles



1.2.4 Section modulus

The minimum net section modulus, Z in cm^3 , of stiffeners supporting wheeled cargo is not to be taken less than the greatest of the values calculated for all applicable design load sets, as obtained from the following formulae:

$$Z = \frac{\alpha_w K_S |P_0| \ell_{bdg}}{6 C_s R_{eH}} 10^3$$

where:

C_s : Permissible bending stress coefficient defined in [1.1.2]

α_w, K_S, K_T : Coefficients defined in [1.2.3]

1.2.5 Multispan stiffeners

For multispan stiffeners supporting wheeled cargo and for stiffeners supporting more than 2 axles, it is to be checked that the normal stress σ and the shear stress τ , determined by a direct calculation, are in compliance with the requirements in [1.7].

1.3 Net section modulus and net shear sectional area of ordinary stiffeners subject to impact loads

1.3.1 Single span longitudinal, transverse and vertical ordinary stiffeners

Unless otherwise specified, the net plastic section modulus Z_{pl} , in cm^3 , as defined in Ch 4, Sec 6, [1.4.8] and the net web thickness t_w , in mm, of stiffeners subject to impact loads are to be not less than the values obtained from the following formulae:

$$Z_{pl} = \frac{P_1 S \ell_{bdg}^2}{8(1 + n_s/2) C_s R_{eH}}$$

$$t_w = \frac{P_1 S \ell_{shr}}{2 d_{shr} C_t \tau_{eH}}$$

where:

- C_s : Permissible bending stress coefficient taken equal to 0,9 for acceptance criteria set AC-4
 C_t : Permissible shear stress coefficient taken equal to 1,0 for acceptance criteria set AC-4
 P_1 : Any impact pressure defined in the Rules, including:
- bottom impact pressure, as defined in Ch 5, Sec 5, [4.2.1]
 - bow impact pressure, as defined in Ch 5, Sec 5, [4.3.1]
 - sloshing impact pressure, as defined in Ch 5, Sec 6, [2.2.2]
 - stern impact pressure, as defined in Ch 5, Sec 5, [4.2.2]
 - berthing impact pressure, as defined in Ch 5, Sec 5, [4.4.1]
- n_s : End fixation factor taken as:
- $n_s = 0$ for both ends with low end fixity (simply supported)
 - $n_s = 1$ for one end fixed and one end simply supported
 - $n_s = 2$ for continuous members or members with bracketed fitted at both ends

If deemed necessary by the Society and depending on specific natures of loadings, different calculation methods may be applied, on a case-by-case basis.

1.4 Yielding check of stiffeners supporting steel coils on wooden dunnage

1.4.1 General

The net section modulus and the net shear sectional area of longitudinal stiffeners on inner bottom, bilge hopper sloping plate and inner hull for ships intended to carry steel coils are to comply with [1.4.2] up to a height not less than the one corresponding to the top of upper tier in touch with hopper or inner hull plating.

1.4.2 Yielding check

The net section modulus Z , in cm^3 , and the net web thickness, t_w , in mm, of single span stiffeners located on inner bottom, bilge hopper sloping plate and inner hull are not to be taken less than:

$$Z = K_3 \frac{F_{sc}}{8 C_s R_{eH}} 10^3$$

$$t_w = \frac{0,5 F_{sc}}{d_{shr} C_t \tau_{eH}} 10^3$$

where:

- K_3 : Span parameter, in m, as defined in Tab 5
 n_2 : Number of load points per EPP of the inner bottom, see Ch 5, Sec 6, [5.1.3]
 F_{sc} : Load due to steel coil cargoes, taken equal to $F_{sc-ib-sr}$, F_{sc-ib} , $F_{sc-hs-s}$ or F_{sc-hs} as defined in Ch 5, Sec 6, [5], depending on the considered design load set (see Ch 7, Sec 2, [2])
 C_s : Permissible bending stress coefficient defined in [1.1.2]
 C_t : Permissible shear stress coefficient for the design load set being considered, to be taken as:
- 0,85 for acceptance criteria set AC-1
 - 1,00 for acceptance criteria set AC-2

Table 5 : Coefficient K_3

$n_2 = 1$	$n_2 = 2$	$n_2 = 3$	$n_2 = 4$	$n_2 = 5$	$n_2 = 6$
$K_3 = \ell_{bdg}$	$K_3 = \ell_{bdg} - \frac{\ell_{ip}^2}{\ell_{bdg}}$	$K_3 = \ell_{bdg} - \frac{2 \ell_{ip}^2}{3 \ell_{bdg}}$	$K_3 = \ell_{bdg} - \frac{5 \ell_{ip}^2}{9 \ell_{bdg}}$	$K_3 = \ell_{bdg} - \frac{\ell_{ip}^2}{2 \ell_{bdg}}$	$K_3 = \ell_{bdg} - \frac{7 \ell_{ip}^2}{15 \ell_{bdg}}$
$n_2 = 7$	$n_2 = 8$	$n_2 = 9$	$n_2 = 10$	$n_2 > 10$	
$K_3 = \ell_{bdg} - \frac{4 \ell_{ip}^2}{9 \ell_{bdg}}$	$K_3 = \ell_{bdg} - \frac{3 \ell_{ip}^2}{7 \ell_{bdg}}$	$K_3 = \ell_{bdg} - \frac{5 \ell_{ip}^2}{12 \ell_{bdg}}$	$K_3 = \ell_{bdg} - \frac{11 \ell_{ip}^2}{27 \ell_{bdg}}$	$K_3 = 2 \ell_{bdg} / 3$	

1.5 Deck stiffeners in way of launching appliances used for survival craft or rescue boat

1.5.1 The scantlings of deck stiffeners are to be determined by direct calculations.

1.5.2 The loads exerted by launching appliance are to correspond to the SWL of the launching appliance.

1.5.3 The combined stress, in N/mm^2 , is not to exceed the smaller of $R_{eH}/2,2$ and $R_m/4,5$ where R_m is the ultimate minimum tensile strength of the stiffener material, in N/mm^2 .

1.6 Plate and stiffener of different materials

1.6.1 When the minimum specified yield stress of a stiffener exceeds the minimum specified yield stress of the attached plate by more than 35%, the following criterion is to be satisfied:

$$R_{eH+S} \leq \left(R_{eH+P} - \frac{\alpha_s |\sigma_L|}{\beta_s} \right) \frac{Z_P}{Z} + \frac{\alpha_s |\sigma_L|}{\beta_s}$$

where:

- R_{eH+S} : Minimum specified yield stress of the material of the stiffener, in N/mm²
- R_{eH+P} : Minimum specified yield stress of the material of the attached plate, in N/mm²
- σ_L : Hull girder normal stress, in N/mm², as defined in Ch 7, Sec 2, [1.1] with $|\sigma_L|$ not to be taken less than $0,4 R_{eH+P}$
- Z : Net section modulus, in cm³, in way of face plate/free edge of the stiffener
- Z_P : Net section modulus, in cm³, in way of the attached plate of stiffener
- α_s, β_s : Coefficients defined in Tab 2.

1.7 Beam analysis

1.7.1 Model definition

The maximum normal bending stress σ and shear stress τ in a stiffener using net properties with reduced end fixity, variable load or being part of grillage are to be determined by direct calculations taking into account:

- the distribution of static and dynamic pressures and forces, if any
- the distribution of static and dynamic hull girder stresses, if any
- the number and position of intermediate supports (e.g. decks, girders, etc)
- the condition of fixity at the ends of the stiffener and at intermediate supports
- the geometrical characteristics of the stiffener on the intermediate spans.

1.7.2 Stress criteria

The stress is to comply with the following criteria:

a) for isolated beam analysis:

$$\tau \leq \chi K_{corr} C_t \tau_{eH}$$

$$\sigma \leq \chi C_s P_{eH}$$

b) for grillage analysis: $\sigma_{eq} \leq \chi K_{corr} C_{comb} R_{eH}$

where:

- C_t, C_s : Permissible shear and bending stress coefficients defined in [1.1]
- C_{comb} : Permissible combined stress coefficient for the design load set being considered, as defined in Tab 2
- σ_{eq} : Equivalent Von Mises stress, in N/mm²:

$$\sigma_{eq} = \sqrt{\sigma^2 + 3\tau^2}$$

1.8 Buckling check

1.8.1 The buckling check of stiffeners is to be performed according to Ch 9, Sec 1.

Section 6 Primary Supporting Members and Pillars

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

- K_{corr} : Coefficient to take into account the corrosion as defined in Ch 7, Sec 4
 P : Design pressure, in kN/m², for the design load set being considered as defined in Ch 7, Sec 2 and calculated at the load calculation point as defined in Ch 4, Sec 6, [4.1.1]
 l_{bdg} : Effective bending span, in m, as defined in Ch 4, Sec 6, [1.1.6]
 l_{shr} : Effective shear span, in m, as defined in Ch 4, Sec 6, [1.1.7]
 χ : Coefficient as defined in Ch 7, Sec 4
 C_t : Permissible shear stress coefficient for the acceptance criteria set being considered, as given in Tab 2
 C_s : Permissible bending stress coefficient for the acceptance criteria set, as given in Tab 2
 ϕ_H : Depth of the opening measured in the direction parallel to the web height, in m
 α : The greater of a or S1, in m, where a and S1 are defined in [4.4.1].

1 Application

1.1 Application

1.1.1 General requirements

The requirements in Article [2] apply to primary supporting members other than those covered by Article [3] and Article [4] subject to lateral pressure and/or concentrated loads, and to pillars subject to compressive and tensile axial loads.

The yielding and buckling checks are also to be carried out for members subject to any other specific loads.

1.1.2 Type of structural models

Depending on the service notation, ship type, structural arrangement and length, the supporting members are to be verified according to the requirements specified in Tab 1.

1.1.3 Requirements for holds intended to carry liquid cargo

The requirements in Article [3] apply to primary supporting members and vertical corrugations of bulkheads in holds intended to carry liquid cargo.

Table 1 : Primary supporting members applicable requirements

Ship type / length / structural arrangement	Structural models	Applicable requirements
general cargo ship ro-ro cargo ship PCT carrier ro-ro passenger ship passenger ship	L < 150 m	Over whole ship length: Prescriptive or beam models (isolated beam model or grillage as applicable)
	L ≥ 150 m	Over whole ship length: Complete ship model
All other cargo ships	L < 150 m	Over whole ship length: Prescriptive or beam models (isolated beam model or grillage as applicable)
	L ≥ 150 m	<ul style="list-style-type: none"> • Within cargo area: cargo hold models • Outside cargo area: Prescriptive or beam model
	L ≥ 250 m with large deck openings	<ul style="list-style-type: none"> • Within cargo area: cargo hold models • Over whole ship length: Complete ship model
(1) Specific prescriptive requirements in [4.7] and [4.8] applicable to dry bulk cargo holds are to be verified in addition to any direct strength analysis.		

Table 2 : Permissible bending and shear stress coefficients for primary supporting members

Acceptance criteria set	Structure attached to PSM	C_s	C_t	C_{comb}
AC-1	All boundaries, including decks and flats	0,70	0,70	0,70
AC-2		0,85	0,85	0,85
AC-3		0,90	0,90	0,90

1.1.4 Requirements for holds intended to carry dry bulk cargo

The requirements in Article [4] apply to primary supporting members and vertical corrugations of bulkheads in holds intended to carry dry bulk cargo.

1.1.5 Alternative to prescriptive requirements

Primary supporting members verified by direct strength analysis need not to comply with the requirements of this Section for all the design load scenarios already covered by such direct analysis (see typical design load scenarios for strength assessment in Ch 5, Sec 7, [2.1]).

However, the specific requirements in [4.7] and [4.8] related to the strength of corrugated bulkheads and double bottom in flooded conditions are to be applied for any hold intended to carry dry bulk cargo, irrespective of the achievement of direct strength analysis.

2 General

2.1 Scantling requirements

2.1.1 Net section modulus

The net section modulus Z_{n50} , in cm^3 , of primary supporting members subject to lateral pressure is not to be taken less than the greatest value given by the following formula for all applicable design load sets defined in Ch 7, Sec 2, [2]:

$$Z_{n50} = 1000 \frac{|P| S \ell_{bdg}^2}{\chi f_{bdg} C_s R_{eH}}$$

where:

f_{bdg} : Bending moment distribution factor, as given in Tab 3

2.1.2 Net shear area

The net shear area, $A_{shr-n50}$ in cm^2 , of primary supporting members subject to lateral pressure is not to be taken less than the greatest value given by the following formula for all applicable design load sets defined in Ch 7, Sec 2, [2]:

$$A_{shr-n50} = 10 \frac{f_{shr} |P| S \ell_{shr}}{\chi C_t \tau_{eH}}$$

where:

f_{shr} : Shear force distribution factor, as given in Tab 3.

2.2 Wheeled loads

2.2.1 For primary supporting members subject to wheeled loads, the yielding check may be carried out according to [2.1] considering uniform pressures equivalent to the distribution of vertical concentrated forces, when such forces are closely located. For the determination of the equivalent uniform pressures, the most unfavourable case, i.e. where the maximum number of axles is located on the same primary supporting member according to Fig 1 to Fig 3, is to be considered.

The equivalent static pressure P_{w-s} in kN/m^2 , is to be obtained from the following formula:

$$P_{w-s} = 10 \frac{n_V Q_A}{\ell S} \left(3 - \frac{X_1 + X_2}{S} \right)$$

where:

- n_V : Maximum number of vehicles possible located on the primary supporting member
- Q_A : Maximum axle load, in t, defined in Ch 5, Sec 6, [7.2.2]
- X_1 : Minimum distance, in m, between two consecutive axles (see Fig 2 and Fig 3)
- X_2 : Minimum distance, in m, between axles of two consecutive vehicles (see Fig 3)
- ℓ : Length of the primary supporting members (see Fig 1)
- S : Primary supporting member spacing (see Fig 2)

The corresponding dynamic pressure P_{w-dr} in kN/m², is to be calculated for the HVM and FVM load cases by using the following formula:

$$P_{w-d} = \alpha P_{w-s} \frac{a_z}{g}$$

where:

α : Coefficient taken equal to:

- 0,5 in general
- 1,0 for landing gears of trailers.

For arrangements different from those shown in Fig 1 to Fig 3, the yielding check of primary supporting members is to be carried out by a direct calculation analysis according to the requirements of Ch 7, App 1.

Table 3 : Bending moment and shear force distribution factors f_{bdg} and f_{shr}

Load and boundary condition				Bending moment and shear force distribution factors (based on load at mid-span, where load varies)		
Load model	Position 1 Support	Position 2 Field	Position 3 Support	Position 1	Position 2	Position 3
A				$f_{bdg1} = 12,0$ $f_{shr1} = 0,50$	$f_{bdg2} = 24,0$ -	$f_{bdg3} = 12,0$ $f_{shr3} = 0,50$
B				- $f_{shr1} = 0,38$	$f_{bdg2} = 14,2$ -	$f_{bdg3} = 8,0$ $f_{shr3} = 0,63$
C				- $f_{shr1} = 0,50$	$f_{bdg2} = 8,0$ -	- $f_{shr3} = 0,50$
D				$f_{bdg1} = 15,0$ $f_{shr1} = 0,30$	$f_{bdg2} = 23,3$ -	$f_{bdg3} = 10,0$ $f_{shr3} = 0,70$
E				- $f_{shr1} = 0,20$	$f_{bdg2} = 16,8$ -	$f_{bdg3} = 7,50$ $f_{shr3} = 0,80$
F				- -	- -	$f_{bdg3} = 2,0$ $f_{shr3} = 1,0$

Note 1: The bending moment distribution factor f_{bdg} for the support positions is applicable for a distance of $0,2 \ell_{bdg}$ from the end of the effective bending span of the primary supporting member.

Note 2: The shear force distribution factor f_{shr} for the support positions is applicable for a distance of $0,2 \ell_{shr}$ from the end of the effective shear span of the primary supporting member.

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

The section modulus requirement within $0,2 \ell_{bdg}$ from the end of the effective span is to be determined using the applicable f_{bdg1} and f_{bdg3} , however f_{bdg} is not to be taken greater than 12.

The section modulus of mid-span area is to be determined using $f_{bdg} = 24$, or f_{bdg2} from the Table if lesser.

The shear area requirement of end connections within $0,2 \ell_{shr}$ from the end of the effective span is to be determined using $f_{shr} = 0,5$ or the applicable f_{shr1} or f_{shr3} , whichever is greater.

For models A through F, the value of f_{shr} may be gradually reduced outside of $0,2 \ell_{shr}$ towards $0,5 f_{shr}$ at mid-span, where f_{shr} is the greater value of f_{shr1} and f_{shr3} .

Figure 1 : Wheeled loads - Distribution of vehicles on a primary supporting member

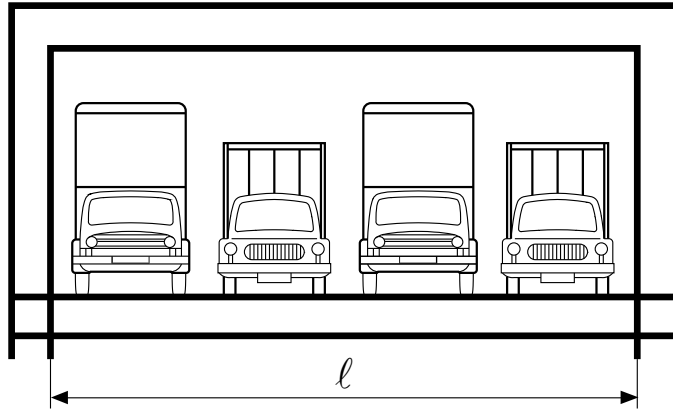


Figure 2 : Wheeled loads Distance between two consecutive axles

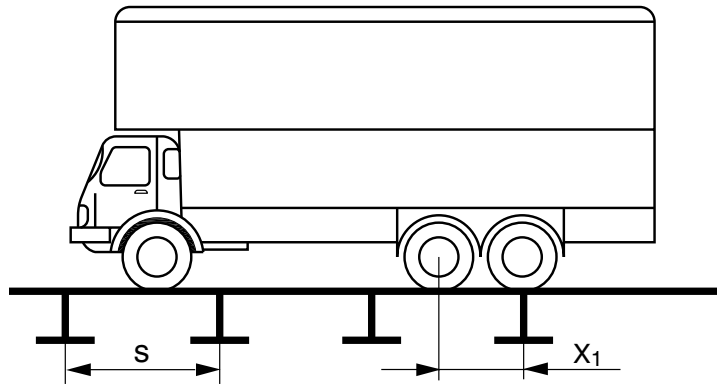
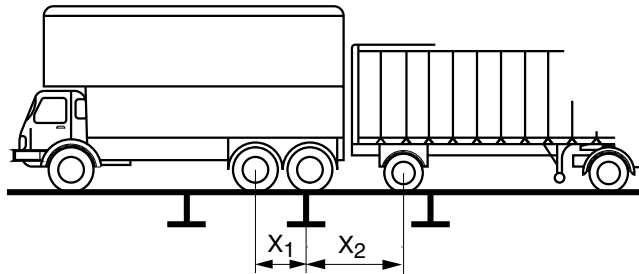


Figure 3 : Wheeled loads Distance between axles of two consecutive vehicles



2.3 Primary members subject to impact loads

2.3.1 The net section modulus Z_{n50} , in cm^3 , of primary supporting members and their net shear area $A_{shr-n50}$, in cm^2 , at any position along their span are not to be less than the values obtained from the following formulae:

$$Z_{n50} = \frac{f_{cb} P_1 f_{pb} \ell_{bdg}^2 b_1}{f_{bdg} C_s R_{eH}} 10^3$$

$$A_{shr-n50} = 10 \frac{\sqrt{3} Q_1}{0,9 R_{eH}}$$

where:

f_{cb} : Correction factor for the bending moment at the ends and considering the patch load, taken as:

$$f_{cb} = 3f_{pb}^3 - 8f_{pb}^2 + 6f_{pb}$$

C_s : 0,8 for acceptance criteria AC-4

P_1 : Any impact pressure defined in the Rules, including:

- bottom impact pressure, as defined in Ch 5, Sec 5, [4.2.1]
- bow impact pressure, as defined in Ch 5, Sec 5, [4.3.1]
- sloshing impact pressure, as defined in Ch 5, Sec 6, [2.2.2]
- stern impact pressure, as defined in Ch 5, Sec 5, [4.2.2]

f_{pb} : Patch load modification factor for bending, taken as:

$$f_{pb} = \frac{\ell_1}{\ell_{bdg}}$$

Q_1 : Shear force, in kN, taken as: $Q_1 = f_{cs} f_{dist} P_1 \ell_1 b_1$

ℓ_1 : Extent of impact load area, in m, along the span:

$$\ell_1 = \sqrt{A_1}$$

not to be taken greater than:

- $0,5 \ell_{shr}$ for the calculation of Q_1
- ℓ_{bdg} for the calculation of f_{pb}

f_{cs} : Correction factor for the proportion of patch load acting on a single primary supporting member, taken as:

$$f_{cs} = 0,5(f_{ps}^3 - 2f_{ps}^2 + 2)$$

f_{dist} : Coefficient for shear force distribution along the span, as defined in Fig 4

f_{ps} : Patch load modification factor for shear, taken as:

$$f_{ps} = 0,5 \frac{b_1}{S}$$

f_{bdg} : 12 for primary supporting members with end fixed continuous flange or where brackets at both ends are fitted in accordance with Ch 4, Sec 5, [4.4]

b_1 : Breadth of impact area supported by primary supporting member, in m, taken as:

$$b_1 = \sqrt{A_1}$$

not to be taken greater than S

$$A_1 = 1,1 L B C_B 10^{-3}$$

For complex arrangements of primary supporting members, especially where grillage effect may not be ignored, for primary supporting members having variable cross sections, or for primary supporting members subject to berthing impact pressure as defined in Ch 5, Sec 5, [4.4], direct calculation is to be performed.

It is to be checked that the maximum obtained equivalent stress is not greater than $0,85 R_{eH}$ when applying:

- in general: the load Q_1 on a square area A_1 to various locations on the model
- in case of berthing impact pressure: the pressure P_{BI} on an area corresponding to the fender contact zone, as specified in Tab 4.

Figure 4 : Distribution of f_{dist} along the span of simple primary supporting members

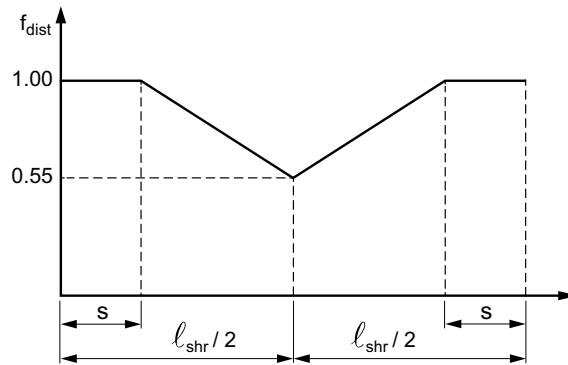


Table 4 : Berthing impact area

Ship moulded displacement Δ at T_{SC} , in t	Patch dimensions (m)	
	Length	Height
$0 < \Delta \leq 5000$	3,5	2,4
$5000 < \Delta \leq 150000$	4	3
$150000 < \Delta \leq 250000$	5,5	3
$250000 < \Delta \leq 400000$	6,5	4
$\Delta > 400000$	10,6	4

2.4 Deck primary members in way of launching appliances used for survival craft or rescue boat

2.4.1 The scantlings of deck primary supporting members are to be determined by direct calculations.

2.4.2 The loads exerted by launching appliance are to correspond to the SWL of the launching appliance.

2.4.3 The combined stress, in N/mm², is not to exceed the smaller of $R_{eH}/2,2$ and $R_m/4,5$ where R_m is the ultimate minimum tensile strength of the primary supporting member material, in N/mm².

2.5 Buckling check

2.5.1 The buckling check of primary supporting members is to be performed according to Ch 9, Sec 1.

2.6 Pillars subject to compressive axial load

2.6.1 Criteria

The maximum applied compressive axial load on a pillar F_{pill} , in kN, is to be taken as the greatest value calculated for all the applicable design load sets defined in Ch 7, Sec 2, [2], and is given by the following formula:

$$F_{pill} = P b_{a-sup} \ell_{a-sup} + \sum r_i F_{pill-i}$$

where:

b_{a-sup} : Mean breadth of area supported, in m

ℓ_{a-sup} : Mean length of area supported, in m

F_{pill-i} : Axial load from the i^{th} pillar above the pillar considered, in kN, if any

r_i : Coefficient which depends on the relative position of each pillar above the one considered, to be taken equal to $0,9^i$ for the i^{th} pillar of the line above the pillar considered, to be taken not less than 0,478

$A_{pill-n50}$: Net cross-section area of the pillar, in cm².

2.6.2 Buckling check

The buckling check of pillars is to be performed according to Ch 9, Sec 1, with σ_{av} , in N/mm², taken equal to:

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

2.7 Pillars subject to tensile axial load

2.7.1 Criteria

Pillars and PSM members subject to tensile axial load are to satisfy the criteria given in [5.1.4].

3 Primary supporting members in holds intended to carry liquid cargo

3.1 Floors in double bottom

3.1.1 Structural arrangement

Plate floors are to be arranged in way of transverse bulkheads and bulkhead stools.

3.1.2 Net shear area

The net shear area,

$A_{shr-n50}$ in cm², of the floors at any position in the floor is not to be less than:

$$A_{shr-n50} = \frac{8,5Q}{C_t \tau_{eH}}$$

where:

Q : Design shear force, in kN.

$$Q = f_{shr} P S \ell_{shr}$$

f_{shr} : Shear force distribution factor, taken as:

$$f_{shr} = f_{shr-i} \left(1 - \frac{2y_i}{\ell_{shr}} \right)$$

without being taken less than 0,2

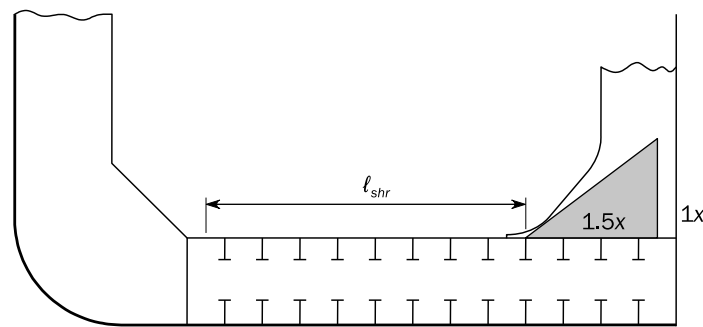
f_{shr-i} : Shear force distribution factor at the end of the span, ℓ_{shr} , as given in Tab 5

Table 5 : Shear force distribution factors of floors

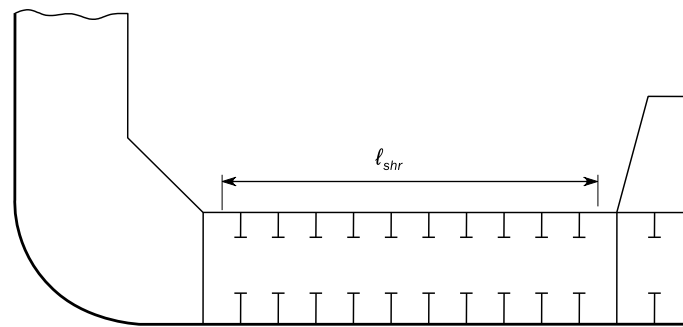
Structural configuration	Centre tank (f_{shr3} in Fig 6)	Wing tank	
		At inboard end (f_{shr2} in Fig 6)	At hopper knuckle end (f_{shr1} in Fig 6)
Ships with centreline longitudinal bulkhead	–	0,40	0,60
Ships with two longitudinal bulkheads	0,50	0,50	0,65

- l_{shr} : Effective shear span, of the double bottom floor, in m, as shown in Fig 5. In way of bracket ends, the effective shear span is measured to the toes of the effective end bracket, as defined in Ch 4, Sec 6, [1.1.7]. Where the floor ends on a girder at a hopper or stool structure, the effective shear span is measured to a point that is one-half of the distance from the girder to the adjacent bottom and inner-bottom longitudinal, as shown in Fig 5
- y_i : Distance from the considered cross section of the floor to the nearest end of the effective shear span, l_{shr} in m.
- P : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, calculated at mid point of effective shear span, l_{shr} of a floor located midway between transverse bulkheads or transverse bulkhead and wash bulkhead, where fitted, in kN/m².

Figure 5 : Effective shear span of floors

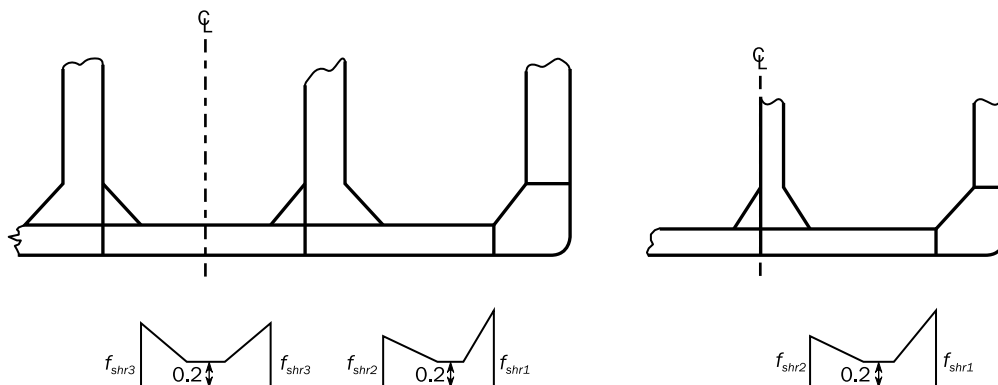


Typical arrangement with hopper and end bracket



Typical arrangement with hopper and stool

Figure 6 : Shear force distribution factors of floors



3.2 Girders in double bottom

3.2.1 Structural arrangement

Continuous double bottom girders are to be arranged at the centreline or duct keel, at the hopper side, in way of longitudinal bulkheads and bulkhead stools and in way of flanges of vertically corrugated bulkheads without stools.

3.2.2 Net shear area of centre girders

For double bottom centre girders where no longitudinal bulkhead is fitted above, the net shear area, $A_{shr-n50}$ in cm^2 , of the double bottom centre girder in way of the first bay from each transverse bulkhead and wash bulkhead, where fitted, is not to be less than:

$$A_{shr-n50} = \frac{8,5Q}{C_1 \tau_{eH}}$$

where:

Q : Design shear force, in kN, taken as:

$$Q = 0,21 n_1 n_2 P \ell_{shr}^2$$

ℓ_{shr} : Effective shear span as defined in [3.1.2]

P : Design pressure, in kN/m^2 , as defined in [3.1.2]

n_1 : Coefficient taken as:

$$n_1 = 0,00935 \left(\frac{\ell_{shr}}{S} \right)^2 - 0,163 \left(\frac{\ell_{shr}}{S} \right) + 1,289$$

n_2 : Coefficient taken as:

$$n_2 = 1,3 - \left(\frac{S}{12} \right)$$

S : Double bottom floor spacing, in m, as defined in Ch 4, Sec 6, [1.2.2].

3.2.3 Net shear area of side girders

For double bottom side girders where no longitudinal bulkhead is fitted above, the net shear area, $A_{shr-n50}$ in cm^2 , of the double bottom side girder in way of the first bay from each transverse bulkhead and wash bulkhead, where fitted, is not to be less than:

$$A_{shr-n50} = \frac{8,5Q}{C_1 \tau_{eH}}$$

where:

Q : Design shear force, in kN.

$$Q = 0,14 n_3 n_4 P \ell_{shr}^2$$

n_3 : Coefficient taken as:

$$n_3 = 1,072 - 0,0357 \left(\frac{\ell_{shr}}{S} \right)$$

n_4 : Coefficient taken as:

$$n_4 = 1,2 - \left(\frac{S}{18} \right)$$

S : Double bottom floor spacing, in m, as defined in Ch 4, Sec 6, [1.2.2]

ℓ_{shr} : Effective shear span as defined in [3.1.2]

P : Design pressure, in kN/m^2 , as defined in [3.1.2].

3.3 Deck transverses

3.3.1 Web depth

The web depth of deck transverses fitted under the deck is not to be less than:

- 0,20 ℓ_{bdg-dt} for deck transverses in the wing cargo tanks of ships with two longitudinal bulkheads
- 0,13 ℓ_{bdg-dt} for deck transverses in the centre cargo tanks of ships with two longitudinal bulkheads. The web depth of deck transverses in the centre cargo tank is not to be less than 90% of that of the deck transverses in the wing cargo tank
- 0,10 ℓ_{bdg-dt} for the deck transverses of ships with a centreline longitudinal bulkhead
- 2,5 times the depth of the slots for stiffeners if slots are not closed.

The web depth of deck transverses fitted above the deck is not to be less than:

- 0,10 ℓ_{bdg-dt}
- 2,5 times the depth of the slots for stiffeners if slots are not closed.

where:

ℓ_{bdg-dt} : Effective bending span, in m, as defined in [3.3.2].

3.3.2 Net section modulus of deck transverses fitted below the upper deck

The net section modulus of deck transverses fitted below the upper deck, in cm^3 , is not to be less than Z_{in-n50} and Z_{ex-n50} as given by the following formulae.

The net section modulus of the deck transverses fitted below the upper deck in the wing cargo tanks is also not to be less than required for the deck transverses fitted below the upper deck in the centre tanks.

$$Z_{in-n50} = \frac{850 M_{in}}{C_s R_{eH}}$$

$$Z_{ex-n50} = \frac{850 M_{ex}}{C_s R_{eH}}$$

where:

M_{in} : Design bending moment due to cargo pressure, in kNm, taken as:

- For deck transverses in wing cargo tanks of ships with two longitudinal bulkheads, and for deck transverses in cargo tanks of ships with a centreline longitudinal bulkhead:

$$M_{in} = 0,042 \varphi_t P_{in-dt} S \ell_{bdg-dt}^2 + M_{st}$$

without being taken less than M_0

- For deck transverses in centre cargo tank of ships with two longitudinal bulkheads:

$$M_{in} = 0,042 \varphi_t P_{in-dt} S \ell_{bdg-dt}^2 + M_{vw}$$

without being taken less than M_0

M_{st} : Bending moment transferred from the side transverse, in kNm:

$$M_{st} = c_{st} \beta_{st} P_{in-st} S \ell_{bdg-st}^2$$

where a cross tie is fitted in a wing cargo tank and $\ell_{bdg-st-ct}$ is greater than $0,7 \ell_{bdg-str}$ then ℓ_{bdg-st} in the above formula may be taken as $\ell_{bdg-st-ct}$

M_{vw} : Bending moment transferred from the vertical web frame on the longitudinal bulkhead, in kNm:

$$M_{vw} = c_{vw} \beta_{vw} P_{in-vw} S \ell_{bdg-vw}^2$$

where $\ell_{bdg-vw-ct}$ is greater than $0,7 \ell_{bdg-vw}$ then ℓ_{bdg-vw} in the above formula may be taken as $\ell_{bdg-vw-ct}$. For vertically corrugated bulkheads, M_{vw} is to be taken equal to bending moment in upper end of corrugation over the spacing between deck transverses

M_0 : Minimum bending moment, in kNm

$$M_0 = 0,083 P_{in-dt} S \ell_{bdg-dt}^2$$

M_{ex} : Design bending moment due to green sea pressure, in kNm

$$M_{ex} = 0,067 P_{ex-dt} S \ell_{bdg-dt}^2$$

P_{in-dt} : Design cargo pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, calculated at mid-point of effective bending span, ℓ_{bdg-dt} of the deck transverse located at mid tank, in kN/m^2

P_{in-st} : Corresponding design cargo pressure in wing cargo tank for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, calculated at the mid-point of effective bending span, ℓ_{bdg-st} of the side transverse located at mid-tank, in kN/m^2

P_{in-vw} : Corresponding design cargo pressure in the centre cargo tank of ships with two longitudinal bulkheads for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, calculated at mid-point of effective bending span, ℓ_{bdg-vw} of the vertical web frame on the longitudinal bulkhead located at mid-tank, in kN/m^2

P_{ex-dt} : Design green sea pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, calculated at mid-point of effective bending span, ℓ_{bdg-dt} of the deck transverse located at mid tank, in kN/m^2

φ_t : Coefficient taken as:

$$\varphi_t = 1 - 5 \left(\frac{y_{toe}}{\ell_{bdg-dt}} \right)$$

without being taken less than 0,6

y_{toe} : Distance from the end of effective bending span, ℓ_{bdg-dt} to the toe of the end bracket of the deck transverse, in m

β_{st} : Coefficient taken as:

$$\beta_{st} = \left(0,9 \left(\frac{\ell_{bdg-st}}{\ell_{bdg-dt}} \right) \left(\frac{\ell_{dt-n50}}{\ell_{st-n50}} \right) \right)$$

without being taken less than 0,10 or greater than 0,65

β_{vw} : Coefficient taken as:

$$\beta_{vw} = 0.9 \left(\frac{\ell_{bdg-vw}}{\ell_{bdg-dt}} \right) \left(\frac{I_{dt-n50}}{I_{vw-n50}} \right)$$

without being taken less than 0,10 or greater than 0,50

ℓ_{bdg-dt} : Effective bending span of the deck transverse, in m, see Ch 4, Sec 6, [1.1.6] and Fig 7, but is not to be taken as less than 60% of the breadth of the tank at the location being considered

ℓ_{bdg-st} : Effective bending span of the side transverse, in m, between the deck transverse and the bilge hopper, see Ch 4, Sec 6, [1.1.6] and Fig 7

$\ell_{bdg-st-ct}$: Effective bending span of the side transverse, in m, between the deck transverse and the mid depth of the cross tie, where fitted in wing cargo tank, see Ch 4, Sec 6, [1.1.6]

ℓ_{bdg-vw} : Effective bending span of the vertical web frame on the longitudinal bulkhead, in m, between the deck transverse and the bottom structure, see Ch 4, Sec 6, [1.1.6] and Fig 7

$\ell_{bdg-vw-ct}$: Effective bending span of the vertical web frame on longitudinal bulkhead, in m, between the deck transverse and the mid depth of the cross tie, see Ch 4, Sec 6, [1.1.6]

I_{dt-n50} : Net moment of inertia of the deck transverse at mid-span with an effective breadth of attached plating specified in Ch 4, Sec 6, [1.3.2], in cm^4

I_{st-n50} : Net moment of inertia of the side transverse at mid-span with an effective breadth of attached plating specified in Ch 4, Sec 6, [1.3.2], in cm^4

I_{vw-n50} : Net moment of inertia of the longitudinal bulkhead vertical web frame at mid-span with an effective breadth of attached plating specified in Ch 4, Sec 6, [1.3.2], in cm^4

C_{st} : Coefficient given in Tab 6

C_{vw} : Coefficient given in Tab 6.

Figure 7 : Definition of spans of deck, side transverses, vertical web frames on longitudinal bulkheads and horizontal stringers on transverse bulkheads

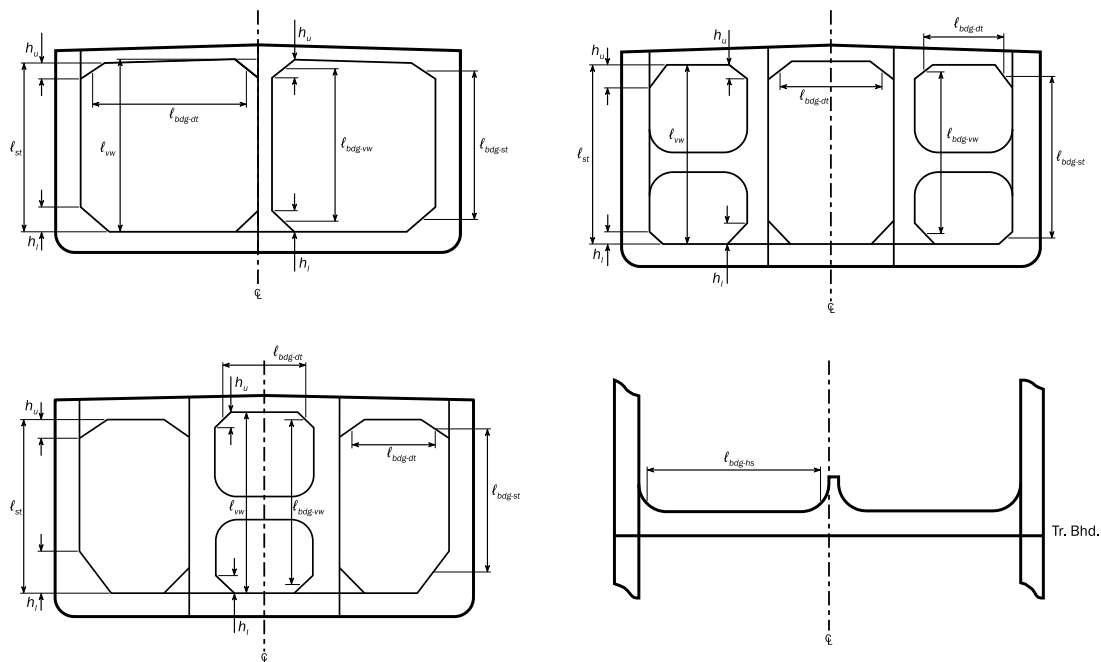


Table 6 : Values of c_{st} and c_{vw} for deck transverses

Structural configuration		C_{st}	C_{vw}	
Ships with centreline longitudinal bulkhead		0,056	-	
Ships with two longitudinal bulkheads	Cross tie in centre cargo tank	M_{vw} based on $\ell_{bdg-vw-ct}$	0,044	
		M_{st} based on ℓ_{bdg-st} or M_{vw} based on ℓ_{bdg-vw}	0,044	
	Cross ties in wing cargo tanks	M_{st} based on $\ell_{bdg-st-ct}$ or M_{vw} based on $\ell_{bdg-vw-ct}$	0,044	0,044
		M_{st} based on ℓ_{bdg-st} or M_{vw} based on ℓ_{bdg-vw}	0,041	0,015

3.3.3 Net shear area of deck transverses fitted below the upper deck

The net shear area of deck transverses fitted below the upper deck, in cm², is not to be less than $A_{shr-in-n50}$ and $A_{shr-ex-n50}$ as given by:

$$A_{shr-in-n50} = \frac{8,5 Q_{in}}{C_1 \tau_{eH}}$$

$$A_{shr-ex-n50} = \frac{8,5 Q_{ex}}{C_1 \tau_{eH}}$$

where:

Q_{in} : Design shear force due to cargo pressure, in kN

$$Q_{in} = 0,65 P_{in-dt} S \ell_{shr} + c_1 D b_{ctr} S \rho_L g$$

Q_{ex} : Design shear force due to green sea pressure, in kN

$$Q_{ex} = 0,65 P_{ex-dt} S \ell_{shr}$$

P_{in-dt} : Design pressure in kN/m², defined in [3.3.2]

P_{ex-dt} : Design pressure in kN/m², defined in [3.3.2]

ℓ_{bdg-dt} : Effective span, in m, defined in [3.3.2]

ℓ_{shr} : Effective shear span, of the deck transverse, in m, see Ch 4, Sec 6, [1.1.7]

C_1 : Coefficient taken as:

- $c_1 = 0,04$ in way of wing cargo tanks of ships with two longitudinal bulkheads
- $c_1 = 0,00$ in way of centre tank of ships with two longitudinal bulkheads
- $c_1 = 0,00$ for ships with a centreline longitudinal bulkhead

b_{ctr} : Breadth of the centre tank, in m.

3.3.4 Deck transverses fitted above the upper deck

When deck transverses are fitted above the upper deck, the net section modulus and shear area of deck transverses are not to be less than Z_{n50} and $A_{shr-n50}$, in cm³ and cm² respectively, as given by the following formulae. The required section modulus and shear area are to be maintained over the full length of span.

$$Z_{n50} = \frac{850 |P| S \ell_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

$$A_{shr-n50} = \frac{8,5 f_{shr} |P| S \ell_{shr}}{C_1 \tau_{eH}}$$

where:

P : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, calculated at midpoint of effective bending span, ℓ_{bdg} of the deck transverse located at mid tank, in kN/m²

f_{bdg} : Coefficient taken as:

$f_{bdg} = 12$ for design load set LC-1, LC-2, LC-3 and LC-4 as defined in Ch 7, Sec 2, Tab 4

$f_{bdg} = 15$ for design load set SEA-1 as defined in Ch 7, Sec 2, Tab 4

f_{shr} : Coefficient taken as: $f_{shr} = 0,5$

ℓ_{bdg} : Effective bending span of the deck transverse fitted above upper deck, in m, measured from inner hull welded to deck to longitudinal bulkhead, or upper stool plating where upper stool is fitted

ℓ_{shr} : Effective shear span of the deck transverse fitted above upper deck, in m, measured from inner hull welded to deck to longitudinal bulkhead, or upper stool plating where upper stool is fitted

As an alternative, the required section modulus and shear area may be obtained by finite element method in accordance with Part B, Chapter 8 considering the following loading patterns with draught equal to T_{sc} and cargo density of 1,025 t/m³:

- For ships with two longitudinal oil-tight bulkheads:
 - aft-holds and fore-holds full, mid-holds empty on both sides and full on center
 - aft-holds and fore-holds full, mid-holds full on sides and empty on center
- For ships with one centerline oil-tight bulkhead:
 - aft-holds and fore-holds full, mid-holds empty on portside and full on starboard
 - aft-holds and fore-holds full, mid-holds full on portside and empty on starboard.

3.3.5 Deck transverse adjacent to transverse bulkhead

The scantling of deck transverse adjacent to the transverse bulkhead is to comply with the requirements of [3.3.2] to [3.3.4] for design green sea pressure only.

3.4 Side transverses

3.4.1 Net shear area

The net shear area, $A_{shr-n50}$ in cm^2 , of side transverses is not to be less than:

$$A_{shr-n50} = \frac{8,5Q}{C_t \tau_{eH}}$$

where:

Q : Design shear force as follows, in kN:

$Q = Q_u$ for upper part of the side transverse

$Q = Q_l$ for lower part of the side transverse

Q_u : Shear force, in kN, taken as:

$$Q_u = S [c_u \ell_{st} (P_u + P_l) - h_u P_u]$$

where a cross tie is fitted in a wing cargo tank and ℓ_{st-ct} is greater than $0,7 \ell_{st}$, then ℓ_{st} in the above formula is taken as ℓ_{st-ct}

Q_l : Shear force, in kN, taken as the greater of the following:

- $S [c_l \ell_{st} (P_u + P_l) - h_l P_l]$

- $0,35 c_l S \ell_{st} (P_u + P_l)$

- $1,2 Q_u$

where a cross tie is fitted in a wing cargo tank and ℓ_{st-ct} is greater than $0,7 \ell_{st}$, then ℓ_{st} in the above formula is taken as ℓ_{st-ct}

P_u : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, in kN/m^2 , calculated at mid length of tank and at mid height of h_u

P_l : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, calculated at mid height h_l located at mid length of tank, in kN/m^2

ℓ_{st} : Length of the side transverse, in m, taken as follows:

- where deck transverses are fitted below deck, ℓ_{st} is the length between the flange of the deck transverse and the inner bottom, see Fig 7

- where deck transverses are fitted above deck, ℓ_{st} is the length between the elevation of the deck at side and the inner bottom

ℓ_{st-ct} : Length of the side transverse, in m, taken as follows:

- where deck transverses are fitted below deck, ℓ_{st-ct} is the length between the flange of the deck transverse and mid depth of cross tie, where fitted in wing cargo tank

- where deck transverses are fitted above deck, ℓ_{st-ct} is the length between the elevation of the deck at side and mid depth of the cross tie, where fitted in wing cargo tank

h_u : Effective length of upper bracket of the side transverse, in m, taken as follows:

- where deck transverses are fitted below deck, h_u is as shown in Fig 7

- where deck transverses are fitted above deck:

- when an inner hull longitudinal bulkhead is arranged with a top wing structure as follows, h_u is taken as the distance between the deck at side and the lower end of slope plate of the top wing structure:

- the breadth at top of the wing structure is greater than 1,5 times the breadth of the double side and

- the angle along a line between the point at base of the slope plate at its intersection with the inner hull longitudinal bulkhead and the point at the intersection of top wing structure and deck is 30 deg or more to vertical

- in the other cases: h_u is taken as 0

h_l : Height of bilge hopper, in m, as shown in Fig 7

c_u : Coefficient defined in Tab 7

c_l : Coefficient defined in Tab 7.

Table 7 : Values of c_u and c_l for side transverses

Structural configuration			c_u		c_l	
Number of side stringers			< three	\geq three	< three	\geq three
Ships with a centreline longitudinal bulkhead						
Ships with two longitudinal bulkheads	Cross tie in centre cargo tank		0,12	0,09	0,29	0,21
	Cross ties in wing cargo tanks	Q_u or Q_l based on ℓ_{st-ct}				
		Q_u or Q_l based on ℓ_{st}	0,08	0,20		

3.4.2 Shear area over the length of the side transverse

The shear area over the length of the side transverse is to comply with the following. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

- a) The required shear area for the upper part is to be maintained over the upper $0,2 \ell_{shr}$.
- b) The required shear area for the lower part is to be maintained over the lower $0,2 \ell_{shr}$.
- c) Where Q_u and Q_l are determined based on ℓ_{st-ctr} the required shear area for the lower part is also to be maintained below the cross tie.
- d) For ships without cross ties in the wing cargo tanks, the required shear area between the upper and lower parts is to be reduced linearly towards 50% of the required shear area for the lower part at mid-span.
- e) For ships with cross ties in the wing cargo tanks, the required shear area along the span is to be tapered linearly between the upper and lower parts.

where:

ℓ_{shr} : Effective shear span of the side transverse, in m

$$\ell_{shr} = \ell_{st} - h_u - h_l$$

where Q_u and Q_l are determined based on ℓ_{st}

$$\ell_{shr} = \ell_{st-ct} - h_u$$

where Q_u and Q_l are determined based on ℓ_{st-ct}

$\ell_{st}, \ell_{st-ctr}, h_u, h_l, Q_u, Q_l$: Parameters defined in [3.4.1].

3.5 Vertical web frames on longitudinal bulkhead

3.5.1 Web depth

The web depth of the vertical web frame on the longitudinal bulkhead is not to be less than:

- $0,14 \ell_{bdg-vw}$ for ships with a centreline longitudinal bulkhead
- $0,09 \ell_{bdg-vw}$ for ships with two longitudinal bulkheads
- 2,5 times the depth of the slots for stiffeners if slots are not closed.

where:

ℓ_{bdg-vw} : Effective bending span, in m, defined in [3.5.2].

3.5.2 Net section modulus

The net section modulus, Z_{n50} in cm^3 , of the vertical web frame is not to be less than:

$$Z_{n50} = \frac{850M}{C_s R_{eH}}$$

where:

M : Design bending moment, in kNm, as follows:

$$M = c_u P S \ell_{bdg-vw}^2$$

- for upper part of the web frame:

$$M = c_l P S \ell_{bdg-vw}^2$$

- for lower part of the web frame:

where a cross tie is fitted and $\ell_{bdg-vw-ct}$ is greater than $0,7 \ell_{bdg-vw}$ then ℓ_{bdg-vw} in the above formula is to be taken as $\ell_{bdg-vw-ct}$.

P : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, calculated at mid-point of the effective bending span, ℓ_{bdg-vw} of the vertical web frame located at mid tank, in kN/m^2

ℓ_{bdg-vw} : Effective bending span of the vertical web frame on the longitudinal bulkhead, between the deck transverse and the bottom structure, in m, see Fig 7

$\ell_{bdg-vw-ct}$: Effective bending span of the vertical web frame on longitudinal bulkhead, between the deck transverse and mid-depth of the cross tie on ships with two longitudinal bulkheads, in m

c_u : Coefficient defined in Tab 8

c_l : Coefficient defined in Tab 8.

Table 8 : Values of c_u and c_l for vertical web frame on longitudinal bulkheads

Structural configuration		c_u	c_l
Ships with a centreline longitudinal bulkhead		0,057	0,071
Ships with two longitudinal bulkheads	Cross tie in centre cargo tank	M based on $l_{bdg-vw-ct}$	0,057
		M based on l_{bdg-vw}	0,012
	Cross ties in wing cargo tanks	M based on $l_{bdg-vw-ct}$	0,057
		M based on l_{bdg-vw}	0,016

3.5.3 Section modulus over the length of the vertical web frame

The section modulus over the length of the vertical web frame on the longitudinal bulkhead is to comply with the following. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

- a) The required section modulus for the upper part is to be maintained over the upper $0,2 l_{bdg-vw}$ or $0,2 l_{bdg-vw-ct}$ as applicable.
- b) The required section modulus for the lower part is to be maintained over the lower $0,2 l_{bdg-vw}$ or $0,2 l_{bdg-vw-ct}$ as applicable.
- c) Where the required section modulus is determined based on $l_{bdg-vw-ct}$, the required section modulus for the lower part is also to be maintained below the cross tie.
- d) The required section modulus between the upper and lower parts is to be reduced linearly to 70% of the required section modulus for the lower part at mid-span.

where:

l_{bdg-vw} , $l_{bdg-vw-ct}$: Effective bending span, in m, defined in [3.5.2].

3.5.4 Net shear area

The net shear area, $A_{shr-n50}$ in cm^2 , of the vertical web frame is not to be less than:

$$A_{shr-n50} = \frac{8,5Q}{C_t \tau_{eH}}$$

where:

Q : Design shear force as follows, in kN:

Q = Q_u for upper part of the web frame

Q = Q_l for lower part of the web frame

Q_u : Shear force, in kN, taken as:

$$Q_u = S [c_u l_{vw} (P_u + P_l) - h_u P_u]$$

where a cross tie is fitted in a centre or wing cargo tank and l_{vw-ct} is greater than $0,7 l_{vw}$ then l_{vw} in the above formula is to be taken as l_{vw-ct}

Q_l : Shear force, in kN, taken as the greater of the following:

- $S [c_l l_{vw} (P_u + P_l) - h_l P_l]$
- $c_w S c_l l_{vw} (P_u + P_l)$
- $1,2 Q_u$

where a cross tie is fitted in a centre or wing cargo tank and l_{vw-ct} is greater than $0,7 l_{vw}$ then l_{vw} in the above formula is to be taken as l_{vw-ct}

P_u : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, calculated at mid-height of upper bracket of the vertical web frame, h_u located at mid tank, in kN/m^2

P_l : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, calculated at mid-height of lower bracket of the vertical web frame, h_l located at mid tank, in kN/m^2

l_{vw} : Length of the vertical web frame, in m, between the flange of the deck transverse and the inner bottom, see Fig 7

l_{vw-ct} : Length of the vertical web frame, in m, between the flange of the deck transverse and mid-depth of the cross tie, where fitted

h_u : Effective length of upper bracket of the vertical web frame, in m, as shown in Fig 7

h_l : Effective length of lower bracket of the vertical web frame, in m, as shown in Fig 7

c_u : Coefficient defined in Tab 9

c_l : Coefficient defined in Tab 9

c_w : Coefficient taken as:

- $c_w = 0,57$ for ships with a centreline longitudinal bulkhead,
- $c_w = 0,50$ for ships with two longitudinal bulkheads.

Table 9 : Values of c_u and c_l for vertical web frame on longitudinal bulkhead

Structural configuration		c_u	c_l
Ships with a centreline longitudinal bulkhead		0,17	0,28
Ships with two longitudinal bulkheads	Q_u or Q_l based on l_{vw-ct}		
	Q_u or Q_l based on l_{vw}	0,075	0,18

3.5.5 Shear area over the length of the vertical web frame

The shear area over the length of the vertical web frame on the longitudinal bulkhead is to comply with the following. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

- a) The required shear area for the upper part is to be maintained over the upper $0,2 l_{shr}$.
- b) The required shear area for the lower part is to be maintained over the lower $0,2 l_{shr}$.
- c) Where Q_u and Q_l are determined based on l_{vw-ctr} the required shear area for the lower part is also to be maintained below the cross tie.
- d) For ships without cross ties in the wing or centre cargo tanks, the required shear area between the upper and lower parts is to be reduced linearly towards 50% of the required shear area for the lower part at mid-span.
- e) For ships with cross ties in the wing or centre cargo tanks, the required shear area along the span is to be tapered linearly between the upper and lower parts.

where:

l_{shr} : Effective shear span of the vertical web frame, in m.

$$l_{shr} = l_{vw} - h_u - h_l$$

where Q_u and Q_l are determined based on l_{vw}

$$l_{shr} = l_{vw-ct} - h_u$$

where Q_u and Q_l are determined based on l_{vw-ct}

l_{vw} , l_{vw-ctr} , h_u , h_l , Q_u , Q_l : Parameters defined in [3.5.4].

3.6 Horizontal stringers on transverse bulkheads

3.6.1 Web depth

The web depth of horizontal stringers on transverse bulkhead is not to be less than:

- $0,28 l_{bdg-hs}$ for horizontal stringers in wing cargo tanks of ships with two longitudinal bulkheads
- $0,20 l_{bdg-hs}$ for horizontal stringers in centre tanks of ships with two longitudinal bulkheads, but the web depth of horizontal stringers in centre tank is not to be less than required depth for a horizontal stringer in wing cargo tanks
- $0,20 l_{bdg-hs}$ for horizontal stringers of ships with a centreline longitudinal bulkhead
- 2,5 times the depth of the slots for stiffeners if slots are not closed.

where:

l_{bdg-hs} : Effective bending span, in m, defined in [3.6.2].

3.6.2 Net section modulus

The net section modulus, Z_{n50} in cm^3 , of the horizontal stringer over the end $0,2 l_{bdg-hs}$ is not to be less than:

$$Z_{n50} = \frac{850M}{C_s R_{eH}}$$

where:

M : Design bending moment, in kNm

$$M = c P S l_{bdg-hs}^2$$

P : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, calculated at mid-point of effective bending span, l_{bdg-hs} and at mid-point of the spacing, S of the horizontal stringer, in kN/m^2

l_{bdg-hs} : Effective bending span of the horizontal stringer, in m, but is not to be taken as less than 50% of the breadth of the tank at the location being considered, see Fig 7

c : Coefficient taken as:

- $c = 0,073$ for horizontal stringers in cargo tanks of ships with a centreline bulkhead
- $c = 0,083$ for horizontal stringers in wing cargo tanks of ships with two longitudinal bulkheads
- $c = 0,063$ for horizontal stringers in the centre tank of ships with two longitudinal bulkheads.

3.6.3 Section modulus over the length of horizontal stringers

The required section modulus at mid effective bending span is to be taken as 70% of that required at the ends, intermediate values are to be obtained by linear interpolation. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

3.6.4 Net shear area

The net shear area, $A_{shr-n50}$ in cm^2 , of the horizontal stringer over the end $0,2 \ell_{shr}$ is not to be less than:

$$A_{shr-n50} = \frac{8,5Q}{C_t \tau_{eH}}$$

where:

- Q : Design shear force, in kN
 $Q = 0,5P S_{hs} \ell_{shr}$
- P : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 4, calculated at mid-point of effective bending span, ℓ_{bdg-hs} and at mid-point of the spacing, S of the horizontal stringer, in kN/m^2
- S_{hs} : Spacing, in m, defined in [3.6.2]
- ℓ_{shr} : Effective shear span of the horizontal stringer, in m.

3.6.5 Shear area at mid effective shear span

The required shear area at mid effective shear span is to be taken as 50% of that required in the ends, intermediate values are to be obtained by linear interpolation. When materials of different yield stress are employed, appropriate adjustments are to be made to account for differences in material yield stress.

3.7 Cross ties

3.7.1 Maximum applied design axial load

The maximum applied design axial load on cross ties, W_{ct} is to be less than or equal to the permissible load, $W_{ct-perm}$ as given by:

$$W_{ct} \leq W_{ct-perm}$$

where:

- W_{ct} : Applied axial load, in kN.
 $W_{ct} = P b_{ct} S$
- $W_{ct-perm}$: Permissible load, in kN.
 $W_{ct-perm} = 0.12 A_{ct-n50} \eta_{all} \sigma_{cr}$
- P : Maximum design pressure for all the applicable design load sets being considered as defined in Ch 7, Sec 2, Tab 4, calculated at centre of the area supported by the cross tie located at mid tank, in kN/m^2
- b_{ct} : Span, in m, taken as:
 - Cross tie fitted in centre cargo tank:
 $b_{ct} = 0,5 \ell_{bdg-vw}$
 - Cross ties fitted in wing cargo tanks:
 - $b_{ct} = 0.5 \ell_{bdg-vw}$ for design cargo pressure from the centre cargo tank
 - $b_{ct} = 0.5 \ell_{bdg-st}$ for design sea pressure
- ℓ_{bdg-vw} : Effective bending span, in m, defined in [3.3.2]
- ℓ_{bdg-st} : Effective bending span, in m, defined in [3.3.2]
- η_{all} : Allowable buckling utilisation factor as defined in Ch 9, Sec 1, [1.2]
- σ_{cr} : Critical buckling stress in compression of the cross tie, in N/mm^2 , as calculated using the net sectional properties in accordance with NR615, Sec 5, [3.1.1]
- A_{ct-n50} : Net cross sectional area of the cross tie, in cm^2 .

3.7.2 Welded connections

Special attention is to be paid to the adequacy of the welded connections for the transmission of the forces, and also to the stiffening arrangements, in order to provide effective means for transmission of the compressive forces into the webs.

Particular attention is to be paid to the welding at the toes of all end brackets of the cross ties.

3.7.3 Horizontal stiffeners

Horizontal stiffeners are to be located in line with, and attached to, the longitudinals at the ends of the cross ties.

3.8 Vertically corrugated bulkheads separating liquid cargo holds

3.8.1 Application

In addition to the requirements of Ch 7, Sec 4, [1.2], vertically corrugated bulkheads separating liquid cargo holds are also to comply with the requirements of [3.8.2] to [3.8.5].

3.8.2 Net plate thickness over the height

The net plate thicknesses as required by [3.8.4] is to be maintained for two thirds of the corrugation length, ℓ_{cg} from the lower end. Above that, the net plate thickness may be reduced by 20% from the net thickness required in [3.8.4] for the mid part of the corrugation provided that the net section modulus of the upper end of the corrugation complies with [3.8.5].

3.8.3 Net web plating thickness over the height

The net web plating thickness of the lower 15% of the corrugation, t_w in mm, is to be taken as the greatest value calculated for all applicable design load sets, as given in Ch 7, Sec 2, [2], and given by the following. This requirement is not applicable to corrugated bulkheads without a lower stool.

$$t_w = \frac{1000|Q_{cg}|}{d_{cg}K_{corr}\chi C_{t-cg}\tau_{eH}}$$

where:

Q_{cg} : Design shear force imposed on the web plating at the lower end of the corrugation, in kN

$$Q_{cg} = \frac{s_{cg} \ell_{cg} |3P_l + P_u|}{8000}$$

P_l : Design pressure given in Ch 7, Sec 2, Tab 1 for the design load set being considered, calculated at the lower end of the corrugation, in kN/m²

P_u : Design pressures given in Ch 7, Sec 2, Tab 1 for the design load set being considered, calculated at the upper end of the corrugation, in kN/m²

d_{cg} : Depth of corrugation, in mm, see Fig 8

C_{t-cg} : Permissible shear stress coefficient:

- $C_{t-cg} = 0,75$ for acceptance criteria set AC-1
- $C_{t-cg} = 0,90$ for acceptance criteria set AC-2
- $C_{t-cg} = 0,95$ for acceptance criteria set AC-3.

3.8.4 Net thicknesses of the flanges over the height

The net thicknesses of the flanges of corrugated bulkheads, t_f in mm, for two thirds of the corrugation length from the lower end are to be taken as the greatest value calculated for all applicable design load sets, as given in Ch 7, Sec 2, [2], and given by the following. This requirement is not applicable to corrugated bulkheads without a lower stool.

$$t_f = \frac{6,57 b_{f-cg} \sqrt{\sigma_{bdg-max}}}{C_f} 10^{-3}$$

where:

$\sigma_{bdg-max}$: Maximum value of the vertical bending stresses in N/mm² in the flange. The bending stress is to be calculated at the lower end and at the mid span of the corrugation length:

$$\sigma_{bdg-max} = \frac{M_{cg}}{Z_{cg-act}} 10^3$$

M_{cg} : Vertical bending moment, in kNm, as defined in [3.8.5]

Z_{cg-act} : Actual net section modulus at the lower end and at the mid length of a unit corrugation, in cm³

b_{f-cg} : Breadth of flange plating, in mm. See Fig 8

b_{w-cg} : Breadth of web plating, in mm. See Fig 8

C_f : Coefficient taken as:

$$C_f = 7,65 - \left(0,26 \left(\frac{b_{w-cg}}{b_{f-cg}}\right)^3\right)$$

3.8.5 Net section modulus over the height

The net section modulus at the lower and upper ends and at the mid length of the corrugation ($\ell_{cg} / 2$) of a unit corrugation of vertically corrugated bulkheads separating liquid cargo holds, Z_{cg} are to be taken as the greatest value calculated for all applicable design load sets, as given in Ch 7, Sec 2, [2] and given by the following.

$$Z_{cg} = \frac{1000M_{cg}}{K_{corr}C_{s-cg}R_{eH}}$$

where:

M_{cg} : Vertical bending moment in kNm

$$M_{cg} = \frac{C_i |P| s_{cg} \ell_o^2}{12000}$$

P : Averaged pressure in kN/m²

$$P = \frac{P_u + P_l}{2}$$

P_l, P_u : Design pressure given in Ch 7, Sec 2, Tab 1 for the design load set being considered, calculated at the lower and upper ends of the corrugation, respectively, in kN/m²:

- for transverse corrugated bulkheads, the pressures are to be calculated at a section located at $b_{tk} / 2$ from the longitudinal bulkheads of each tank
- for longitudinal corrugated bulkheads, the pressures are to be calculated at the ends of the tank, i.e. the intersection of the forward and aft transverse bulkheads and the longitudinal bulkhead.

b_{tk} : Maximum breadth of tank under consideration measured at the bulkhead, in m

ℓ_o : Effective bending span of the corrugation, in m, measured from the mid depth of the lower stool to the mid depth of the upper stool. Where no lower or upper stool is fitted, ℓ_o is to be measured to lower or upper end. See Fig 8

C_i : Bending moment coefficient given in Tab 10

Table 10 : Values of C_i

Bulkhead	At lower end of ℓ_{cg}	At mid-length of ℓ_{cg}	At upper end of ℓ_{cg}
Transverse bulkhead	C_1	C_{m1}	$0,65 C_{m1}$
Longitudinal bulkhead	C_3	C_{m3}	$0,65 C_{m3}$

C_{s-cg} : Permissible bending stress coefficient at the mid-length of the corrugation length, ℓ_{cg} :

- $C_{s-cg} = c_e$ but not to be taken as greater than 0,75 for acceptance criteria set AC-1
- $C_{s-cg} = c_e$ but not to be taken as greater than 0,90 for acceptance criteria set AC-2
- $C_{s-cg} = c_e$ but not to be taken as greater than 0,95 for acceptance criteria set AC-3

At the lower and upper ends of the corrugation length, ℓ_{cg} :

- $C_{s-cg} = 0,75$ for acceptance criteria set AC-1
- $C_{s-cg} = 0,90$ for acceptance criteria set AC-2
- $C_{s-cg} = 0,95$ for acceptance criteria set AC-3

c_e : Coefficient taken as:

- for $\beta \geq 1,25$:

$$c_e = \frac{2,25}{\beta} - \frac{1,25}{\beta^2}$$

- for $\beta < 1,25$:

$$c_e = 1,0$$

β : Coefficient taken as:

$$\beta = \frac{b_{f-cg}}{t_f} \sqrt{\frac{R_{eH}}{E}}$$

b_{f-cg} : Breadth of flange plating, in mm, see Fig 8

t_f : Net thickness of the corrugation flange, in mm

where:

C_1 : Coefficient taken as:

- In general:

$$C_1 = a_1 + b_1 \sqrt{\frac{A_{dt}}{b_{dk}}}$$

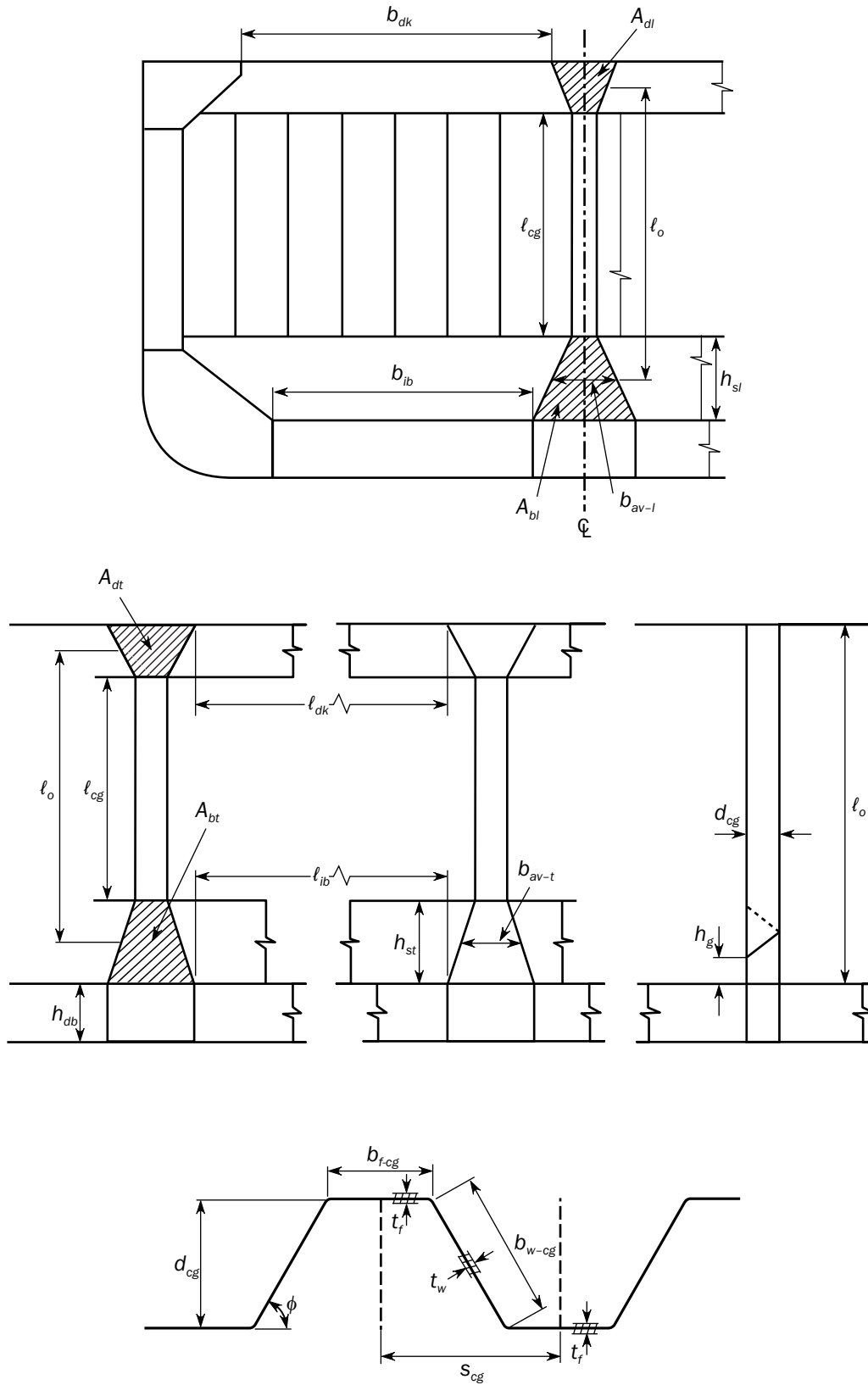
without being taken less than 0,60

- for transverse bulkhead with no lower stool:

$$C_1 = a_1 - b_1 \sqrt{\frac{A_{dt}}{b_{dk}}}$$

without being taken less than 0,55

Figure 8 : Definition of parameters for corrugated bulkhead (Tankers with longitudinal bulkhead at centreline)



a_1 : Coefficient taken as:

- In general:

$$a_1 = 0,95 - \frac{0,41}{R_{bt}}$$

- for transverse bulkhead with no lower stool:

$$a_1 = 1,0$$

b_1 : Coefficient taken as:

- In general:

$$b_1 = -0,20 + \frac{0,078}{R_{bt}}$$

- for transverse bulkhead with no lower stool:

$$b_1 = 0,13$$

C_{m1} : Coefficient taken as:

- In general:

$$C_{m1} = a_{m1} + b_{m1} \sqrt{\frac{A_{dt}}{b_{dk}}}$$

without being taken less than 0,55

- for transverse bulkhead with no lower stool:

$$C_{m1} = a_{m1} - b_{m1} \sqrt{\frac{A_{dt}}{b_{dk}}}$$

without being taken less than 0,60

a_{m1} : Coefficient taken as:

- In general:

$$a_{m1} = 0,63 + \frac{0,25}{R_{bt}}$$

- for transverse bulkhead with no lower stool:

$$a_{m1} = 0,85$$

b_{m1} : Coefficient taken as:

- In general:

$$b_{m1} = -0,25 - \frac{0,11}{R_{bt}}$$

- for transverse bulkhead with no lower stool:

$$b_{m1} = 0,34$$

C_3 : Coefficient taken as:

- In general:

$$C_3 = a_3 + b_3 \sqrt{\frac{A_{dl}}{\ell_{dk}}}$$

without being taken less than 0,60

- for longitudinal bulkhead with no lower stool:

$$C_3 = a_3 - b_3 \sqrt{\frac{A_{dl}}{\ell_{dk}}}$$

without being taken less than 0,55

a_3 : Coefficient taken as:

- In general:

$$a_3 = 0,86 - \frac{0,35}{R_{bl}}$$

- for longitudinal bulkhead with no lower stool:

$$a_3 = 1,0$$

b_3 : Coefficient taken as:

- In general:

$$b_3 = -0,17 + \frac{0,10}{R_{bl}}$$

- for longitudinal bulkhead with no lower stool:

$$b_3 = 0,13$$

C_{m3} : Coefficient taken as:

- In general:

$$C_{m3} = a_{m3} + b_{m3} \sqrt{\frac{A_{dl}}{\ell_{dk}}}$$

without being taken less than 0,55

- for longitudinal bulkhead with no lower stool:

$$C_{m3} = a_{m3} - b_{m3} \sqrt{\frac{A_{dl}}{\ell_{dk}}}$$

without being taken less than 0,60

a_{m3} : Coefficient taken as:

- In general:

$$a_{m3} = 0,32 + \frac{0,24}{R_{bl}}$$

- for longitudinal bulkhead with no lower stool:

$$a_{m3} = 0,85$$

b_{m3} : Coefficient taken as:

- In general:

$$b_{m3} = -0,12 - \frac{0,10}{R_{bl}}$$

- for longitudinal bulkhead with no lower stool:

$$b_{m3} = 0,19$$

R_{bt} : Coefficient for transverse bulkheads, taken as:

$$R_{bt} = \frac{A_{bt}}{b_{ib}} \left(1 + \frac{\ell_{ib}}{b_{ib}} \right) \left(1 + \frac{b_{av-t}}{h_{st}} \right)$$

R_{bl} : Coefficient for longitudinal bulkheads, taken as:

$$R_{bl} = \frac{A_{bl}}{l_{ib}} \left(1 + \frac{\ell_{ib}}{b_{ib}} \right) \left(1 + \frac{b_{av-l}}{h_{sl}} \right)$$

A_{dt} : Cross sectional area enclosed by the moulded lines of the transverse bulkhead upper stool, in m². See Fig 8

$A_{dt} = 0$ if no upper stool is fitted

A_{dl} : Cross sectional area enclosed by the moulded lines of the longitudinal bulkhead upper stool, in m². See Fig 8

$A_{dl} = 0$ if no upper stool is fitted

A_{bt} : Cross sectional area enclosed by the moulded lines of the transverse bulkhead lower stool, in m². See Fig 8

A_{bl} : Cross sectional area enclosed by the moulded lines of the longitudinal bulkhead lower stool, in m². See Fig 8

b_{av-t} : Average width of transverse bulkhead lower stool, in m. See Fig 8

b_{av-l} : Average width of longitudinal bulkhead lower stool, in m. See Fig 8

h_{st} : Height of transverse bulkhead lower stool, in m. See Fig 8

h_{sl} : Height of longitudinal bulkhead lower stool, in m. See Fig 8

b_{ib} : Breadth of cargo tank at the inner bottom level between hopper tanks, or between the hopper tank and centreline lower stool, in m. See Fig 8

b_{dk} : Breadth of cargo tank at the deck level between upper wing tanks, or between the upper wing tank and centreline deck box or between the corrugation flanges if no upper stool is fitted, in m. See Fig 8

ℓ_{ib} : Length of cargo tank at the inner bottom level between transverse lower stools, in m. See Fig 8

ℓ_{dk} : Length of cargo tank at the deck level between transverse upper stools or between the corrugation flanges if no upper stool is fitted, in m. See Fig 8.

4 Primary supporting members in holds intended to carry dry bulk cargo

4.1 Centre girders and side girders

4.1.1 Net web thickness

The net thickness of girders in double bottom structure, in mm, is not to be less than the greater of the value t_1 and t_2 specified in the followings according to each location:

$$t_1 = C_1 \frac{|P| S |x - x_c|}{(d_0 - d_1) C_1 \tau_{eH}} \left\{ 1 - 4 \left(\frac{y}{B_{DB}} \right)^2 \right\}$$

where $|x - x_c|$ is less than $0,25 \ell_{DB}$, $|x - x_c|$ is to be taken as $0,25 \ell_{DB}$.

$$t_2 = 1,753 \sqrt{\frac{H^2 a^2 C_1 \tau_{eH}}{C'_1}} t_1$$

where:

- P : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 3, calculated at mid-point of a floor located midway between transverse bulkheads or transverse bulkhead and toe of stool, where fitted
- S : Distance between the centres of the two spaces adjacent to the centre or side girder under consideration, in m
- d_0 : Depth of the centre or side girder under consideration, in m
- d_1 : Depth of the opening, if any, at the point under consideration, in m
- C_1 : Coefficient given in Tab 11 depending on B_{DB}/ℓ_{DB} . For intermediate values of B_{DB}/ℓ_{DB} , C_1 is to be obtained by linear interpolation.
- a : Depth of girders at the point under consideration, in m. However, where longitudinal stiffeners are fitted on the girder, a is the breadth of the EPP under consideration
- S_1 : Spacing, in m, of vertical stiffeners or floors
- C'_1 : Coefficient given in Tab 12 depending on S_1/a
For intermediate values of S_1/a , C'_1 is to be determined by linear interpolation
- H : Value obtained from the following formulae:
 - where the girder is provided with an unreinforced opening:

$$H = 1 + 0,5 \frac{\phi_H}{\alpha}$$
 - in other cases:

$$H = 1,0.$$

Table 11 : Coefficient C_1

B_{DB}/ℓ_{DB}	0,4 and under	0,6	0,8	1,0	1,2	1,4	1,6 and over
C_1	0,5	0,71	0,83	0,88	0,95	0,98	1,00

Table 12 : Coefficient C'_1

S_1/a	0,3 and under	0,4	0,5	0,6	0,7	0,8	0,9	1,0	1,2	1,4 and over
C'_1	64	38	25	19	15	12	10	9	8	7

4.2 Floors

4.2.1 Net web thickness

The net thickness of floors in the double bottom structure, in mm, is not to be less than the greatest of values t_1 and t_2 specified in the following according to each location:

$$t_1 = C_2 \frac{|P| S B_{DB}}{(d_0 - d_1) C_1 \tau_{eH}} \left(\frac{2|y|}{B'_{DB}} \right) \left\{ 1 - 2 \left(\frac{x - x_c}{\ell_{DB}} \right)^2 \right\}$$

where $|x - x_c|$ is less than $0,5 \ell_{DB}$, $|x - x_c|$ is to be taken as $0,25 \ell_{DB}$ and where $|y|$ is less than $B'_{DB}/4$, $|y|$ is to be taken as $B'_{DB}/4$.

$$t_2 = 1,753 \sqrt{\frac{H^2 a^2 C_1 \tau_{eH}}{C'_2}} t_1$$

where:

- P : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 3, calculated at mid-point of a floor located midway between transverse bulkheads or transverse bulkhead and toe of stool, where fitted

- S : Spacing of solid floors, in m
- d_0 : Depth of the solid floor at the point under consideration in m
- d_1 : Depth of the opening, if any, at the point under consideration in m
- B'_{DB} : Distance between toes of hopper tanks at the position of the solid floor under consideration, in m
- C_2 : Coefficient given in Tab 13 depending on B_{DB}/ℓ_{DB} . For intermediate values of B_{DB}/ℓ_{DB} , C_2 is to be obtained by linear interpolation
- a : Depth of the solid floor at the point under consideration, in m. However, where horizontal stiffeners are fitted on the floor, a is the breadth of the EPP under consideration
- S_1 : Spacing, in m, of vertical stiffeners or girders
- C'_2 : Coefficient given in Tab 14 depending on S_1/d_0 . For intermediate values of S_1/d_0 , C'_2 is to be determined by linear interpolation.
- H : Value obtained from the following formulae:
- where openings with reinforcement or no opening are provided on solid floors:
 - where slots without reinforcement are provided:

$$H = \sqrt{4,0 \frac{d_2}{S_1} - 1,0}$$
 without being taken less than 1,0.
 - where slots with reinforcement are provided: $H = 1,0$.
 - where openings without reinforcement are provided on solid floors:
 - where slots without reinforcement are provided:

$$H = \left(1 + 0,5 \frac{\phi_H}{d_0}\right) \sqrt{4,0 \frac{d_2}{S_1} - 1,0}$$
 without being taken less than:

$$1 + 0,5 \frac{\phi_H}{d_0}$$
 - where slots with reinforcement are provided:

$$H = 1 + 0,5 \frac{\phi_H}{d_0}$$
- d_2 : Depth of slots without reinforcement provided at the upper and lower parts of solid floors, in m, whichever is greater.

Table 13 : Coefficient C_2

B_{DB}/ℓ_{DB}	0,4 and under	0,6	0,8	1,0	1,2	1,4	1,6 and over
C_2	0,48	0,47	0,45	0,43	0,40	0,37	0,34

Table 14 : Coefficient C'_2

S_1/d_0	0,3 and under	0,4	0,5	0,6	0,7	0,8	0,9	1,0	1,2	1,4 and over
C'_2	64	38	25	19	15	12	10	9	8	7

4.3 Stringer of double side structure

4.3.1 Net web thickness

The net thickness of stringers in double side structure, in mm, is not to be less than the greater of the value t_1 and t_2 specified in the followings according to each location:

$$t_1 = C_3 \frac{|P| S |x - x_c|}{(d_0 - d_1) C_t \tau_{eH}}$$

where $|x - x_c|$ is under $0,25 \ell_{DS}$, $|x - x_c|$ is to be taken as $0,25 \ell_{DS}$

$$t_2 = 1,75 \sqrt[3]{\frac{H^2 a^2 C_t \tau_{eH} t_1}{C'_3}}$$

where:

- P : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 3, as measured vertically at the upper end of hopper tank, longitudinally at the centre of ℓ_{DS}
- S : Breadth of part supported by stringer, in m
- d_0 : Depth of stringers, in m

- d_1 : Depth of opening, if any, at the point under consideration, in m
- ℓ_{DS} : Length of the double side structure between the transverse bulkheads under consideration, in m
- h_{DS} : Height of the double side structure between the upper end of hopper tank and the lower end of topside tank located midway between transverse bulkheads of hold under consideration, in m
- C_3 : Coefficient given in Tab 15 depending on h_{DS}/ℓ_{DS} . For intermediate values of h_{DS}/ℓ_{DS} , C_3 is to be obtained by linear interpolation
- a : Depth of stringers at the point under consideration, in m. However, where longitudinal stiffeners are fitted on the stringer, a is the breadth of the EPP under consideration
- S_1 : Spacing, in m, of transverse stiffeners or web frames
- C'_3 : Coefficient given in Tab 16 depending on S_1/a . For intermediate values of S_1/a , C'_3 is to be obtained by linear interpolation
- H : Value obtained from the following formulae:
 - where the stringer is provided with an unreinforced opening:

$$H = 1 + 0,5 \frac{\phi_H}{\alpha}$$
 - in other cases:

$$H = 1,0$$

Table 15 : Coefficient C_3

h_{DS}/ℓ_{DS}	0,5 and under	0,6	0,7	0,8	0,9	1,0	1,1	1,2	1,3 and over
C_3	0,16	0,23	0,30	0,36	0,41	0,44	0,47	0,50	0,54

Table 16 : Coefficient C'_3

S_1/a	0,3 and under	0,4	0,5	0,6	0,7	0,8	0,9	1,0	1,2	1,4 and over
C'_3	64	38	25	19	15	12	10	9	8	7

4.4 Transverse web in double side structure

4.4.1 Net web thickness

The net thickness of transverse webs in double side structure, in mm, is not to be less than the greater of the value t_1 and t_2 specified in the followings according to each location:

$$t_1 = C_4 \frac{|P| S h_{DS}}{(d_0 - d_1) C_1 \tau_{eH}} \left(1 - 1,75 \frac{z - z_{BH}}{h'_{DS}} \right)$$

where

$z - z_{BH}$ is greater than $0,4 h'_{DS}$, $z - z_{BH}$ is to be taken as $0,4 h'_{DS}$.

$$t_2 = 1,75 \sqrt[3]{\frac{H^2 a^2 C_1 \tau_{eH}}{C'_4}} t_1$$

where:

- P : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 3, as measured vertically at the upper end of hopper tank, longitudinally at the centre of ℓ_{DS}
- S : Breadth of part supported by transverses, in m
- d_0 : Depth of transverses, in m
- d_1 : Depth of opening at the point under consideration, in m
- C_4 : Coefficient given in Tab 17 depending on h_{DS}/ℓ_{DS} . For intermediate values of h_{DS}/ℓ_{DS} , C_4 is to be obtained by linear interpolation
- z_{BH} : Z coordinate, in m, of the upper end of hopper tank with respect to the reference coordinate system defined in Ch 1, Sec 3, [2.6]
- h_{DS} : As defined in the requirements of [4.3.1]
- h'_{DS} : Height of the double side structure between the upper end of hopper tank and the lower end of topside tank at the position under consideration, in m
- ℓ_{DS} : As defined in the requirements of [4.3.1]
- a : Depth of transverses at the point under consideration, in m. However, where vertical stiffeners are fitted on the transverse, a is the distance from the vertical stiffener under consideration to the side shell or the longitudinal bulkhead of double side hull or the distance between the vertical stiffeners under consideration
- S_1 : Spacing, in m, of horizontal stiffeners or stringers

- C'_4 : Coefficient given in Tab 18 depending on S_1/a . For intermediate values of S_1/a , C'_4 is to be obtained by linear interpolation
- H : Value obtained from the following formulae:
- where the transverse is provided with an unreinforced opening:

$$H = 1 + 0,5 \frac{\phi_H}{\alpha}$$
 - in other cases:

$$H = 1,0.$$
- α : The greater of a or S_1 , in m.

Table 17 : Coefficient C_4

h_{DS}/ℓ_{DS}	0,5 and under	0,6	0,7	0,8	0,9	1,0	1,1	1,2	1,3 and over
C_4	0,62	0,61	0,59	0,55	0,52	0,49	0,46	0,43	0,41

Table 18 : Coefficient C'_4

S_1/a	0,3 and under	0,4	0,5	0,6	0,7	0,8	0,9	1,0	1,2	1,4 and over
C'_4	64	38	25	19	15	12	10	9	8	7

4.5 Primary supporting member in bilge hopper tanks and topside tanks

4.5.1 Boundary conditions

The requirements of this sub-article apply to primary supporting members considered as clamped at both ends. For boundary conditions deviated from the above, the yielding check is to be considered on a case-by-case basis.

4.5.2 Net section modulus, net shear sectional area and web thickness

The net section modulus Z , in cm^3 , the net shear sectional area A_{shr} , in cm^2 , and the net web thickness t_w , in mm, subject to lateral pressure are not to be less than the values obtained from the following formulae:

$$Z = \frac{|P| S \ell_{bdg}^2}{f_{bdg} C_s R_{eH}} 10^3$$

$$A_{shr} = \frac{5 |P| S \ell_{shr}}{C_t \tau_{eH}}$$

$$t_w = 1,75 \sqrt[3]{\frac{h_w C_t \tau_{eH} A_{shr}}{10^4 C_s}}$$

where:

- P : Design pressure for the design load set being considered as defined in Ch 7, Sec 2, Tab 3, calculated at the mid-point of span ℓ of a web frame located midway between transverse bulkheads of holds
- S : Spacing of primary supporting members, in m
- ℓ_{bdg} : Effective bending span, in m, of primary supporting members, measured between the supporting members as defined in Ch 4, Sec 6, [1.1.6]
- ℓ_{shr} : Effective shear span, in m, of primary supporting members, measured between the supporting members as defined in Ch 4, Sec 6, [1.1.7]
- f_{bdg} : Bending moment factor:
- For continuous primary supporting members and where end connections are fitted consistent with idealisation of the primary supporting members as having fixed ends and is not to be taken higher than:
 $f_{bdg} = 10$
 - For primary supporting members with reduced end fixity, the yield check is to be considered on a case-by-case basis
- C_s : Permissible bending stress coefficient for primary supporting members taken equal to:
 $C_s = 0,70$ for AC-1
 $C_s = 0,85$ for AC-2
- h_w : Web height, in mm
- C_5 : Coefficient defined in Tab 19 according to s_1 and d_0 . For intermediate values of s_1/d_0 , coefficient C_5 is to be obtained by linear interpolation
- s_1 : Spacing of stiffeners or tripping brackets on web plate, in m
- d_0 : Spacing of stiffeners parallel to shell plate on web plate, in m.

Table 19 : Coefficient C_5

s_1/d_0	0,3 and less	0,4	0,5	0,6	0,7	0,8	0,9	1,0	1,5	2,0 and over
C_5	60,0	40,0	26,8	20,0	16,4	14,4	13,0	12,3	11,1	10,2

4.6 Transverse vertically corrugated bulkheads separating holds assigned as ballast holds

4.6.1 Application

These requirements apply to transverse vertically corrugated watertight bulkheads of the cargo holds of ships of less than 150m in length intended for the carriage of dry cargoes in bulk and assigned as ballast holds.

4.6.2 Section modulus

The net section modulus Z at the lower and upper ends, in cm^3 , of transverse vertically corrugated bulkheads of dry bulk cargo holds assigned as ballast holds, subject to lateral pressure are not to be less than the values obtained from the following formula:

$$Z = K \frac{P s_{cg} \ell^2}{f_{bdg} C_s R_Y}$$

where:

- K : Coefficient given in Tab 20 and Tab 21, according to the type of end connection. When $d_H < 2,5 d_0$ (see Fig 9), both section modulus per half pitch of corrugated bulkhead and section modulus of lower stool at inner bottom are to be calculated
- P : Design pressure for the WB design load sets as defined in Ch 7, Sec 2, Tab 3 and calculated at the load calculation point defined in Ch 4, Sec 6, [3.2], in kN/m^2
- s_{cg} : Half pitch length, in mm, of the corrugation, as defined in Ch 4, Sec 5, Fig 27
- ℓ : Length, in m, between the supports, as indicated in Fig 9
- C_s : Coefficient defined in Ch 7, Sec 5, [1.1.2]
- f_{bdg} : Coefficient defined in Ch 7, Sec 5 for lower and upper ends of corrugation.

The effective width of the corrugation flange in compression is to be considered according to [4.6.3] when the net section modulus of corrugated bulkhead is calculated.

Figure 9 : Measurement of ℓ

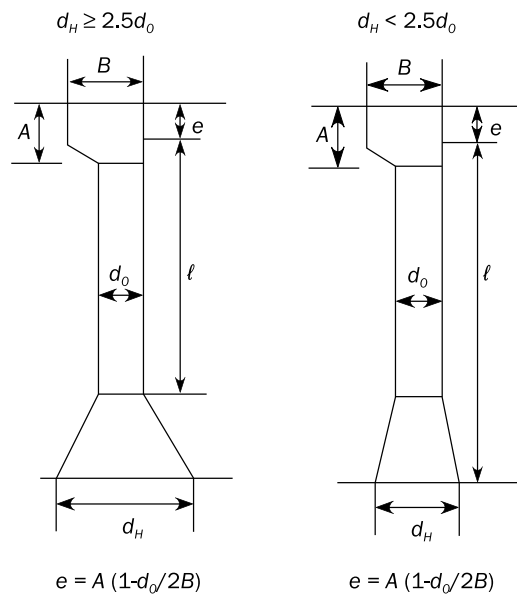


Table 20 : Values of K, in case $d_H \geq 2,5d_0$

Upper end support	
Welded directly to deck	Welded to stool efficiently supported by ship structure
1,00	0,83

Table 21 : Values of K, in case $d_H < 2,5d_0$

Section modulus of	Upper end support	
	Connected to deck	Connected to stool
Corrugated bulkhead	0,71	0,65
Stool at bottom	1,25	1,13

4.6.3 Effective flange width

The net section modulus of the corrugations is to be calculated with the compression flange having an effective flange width b_{eff} not larger than the following formula:

$$b_{eff} = C_E b_{f-cg}$$

where:

C_E : Coefficient taken equal to:

- for $\beta \geq 1,25$:

$$C_E = \frac{2,25}{\beta} - \frac{1,25}{\beta^2}$$

- for $\beta < 1,25$:

$$C_E = 1,0$$

β : Coefficient to be taken equal to:

$$\beta = \frac{b_{f-cg}}{t_f} \sqrt{\frac{R_{eH}}{E}}$$

b_{f-cg} : Width, in mm, of the corrugation flange as shown in Ch 4, Sec 5, Fig 27

t_f : Net flange thickness, in mm.

4.7 Transverse vertically corrugated bulkheads in flooded conditions

4.7.1 Application

These requirements apply to vertically corrugated transverse watertight bulkheads of the cargo holds of ships intended for the carriage of dry cargoes in bulk.

4.7.2 Bending capacity and shear capacity

The bending capacity and the shear capacity of the corrugations of transverse watertight corrugated bulkheads separating cargo holds are to comply with the following formulae:

$$0,5W_{LE} + W_M \geq \frac{M}{0,95 R_{eH}} 10^3$$

$$\tau \leq \frac{R_{eH}}{2}$$

where:

M : Bending moment in a corrugation, in kNm, taken as:

$$M = \frac{F_R \ell_C}{8}$$

F_R : Resultant force, in kN, given in Ch 5, Sec 6, [4.1.7]

ℓ_C : Span of the corrugations, in m, as given in Ch 4, Sec 5, [10.3.5]

W_{LE} : Net section modulus, in cm^3 , of one half pitch corrugation, to be calculated at the lower end of the corrugations according to [4.6.3], not to be taken greater than:

$$W_{LE,M} = W_G + \frac{Q h_G 10^3 - 0,5 h_G^2 s_{cR} P_R}{R_{eH}}$$

W_G : Net section modulus, in cm^3 , of one half pitch corrugation, to be calculated in way of the upper end of shedder or gusset plates, as applicable, according to [4.6.3]

Q : Shear force, in kN, at the lower end of a corrugation, to be taken as:

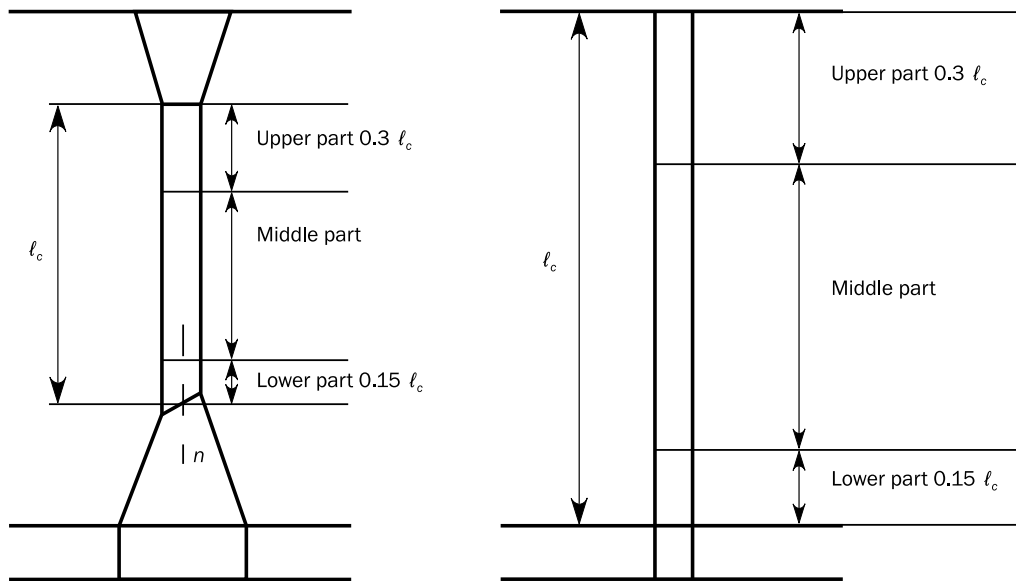
$$Q = 0,8 F_R$$

h_G : Height, in m, of shedders or gusset plates, as applicable as shown in Fig 11 to Fig 13

P_R : Resultant pressure, in kN/m^2 , to be calculated in way of the middle of the shedders or gusset plates, as applicable, according to Ch 5, Sec 6, [4.1.7]

- W_M : Net section modulus, in cm^3 , of one half pitch corrugation, to be calculated at the mid-span of corrugations according to [4.6.3] without being taken greater than $1,15 W_{LE}$
- s_{cg} : Half pitch, in mm, of the corrugation flange as defined in Ch 4, Sec 5, [10.3.2]
- τ : Shear stress, in N/mm^2 , in the corrugation to be taken as:
- $$\tau = 10 \frac{Q}{A_{shr}}$$
- A_{shr} : Net shear area, in cm^2 , of one half pitch corrugation. The calculated net shear area is to consider possible reduced shear efficiency due to non-straight angles between the corrugation webs and flanges. In general, the reduced shear area may be obtained by multiplying the web sectional area by $\sin \phi$
- ϕ : Angle between the web and the flange, see Ch 4, Sec 5, Fig 27.
- The net section modulus of the corrugations in the upper part of the bulkhead, as defined in Fig 10, is not to be taken less than 75% of that of the middle part complying with this requirement and Ch 7, Sec 4, [1.2], corrected for different minimum yield stresses.

Figure 10 : Parts of corrugation



4.7.3 Shear buckling check of the bulkhead corrugation webs

This requirement is to be applied in lieu of the shear buckling strength criteria for corrugated bulkheads given in NR615, Section 3.

The shear stress τ , calculated according to [4.7.2], is to comply with the following formula: $\tau \leq \tau_c$

where:

τ_c : Critical shear buckling stress, in N/mm^2 , to be taken as:

- $\tau_c = \tau_E$
for

$$\tau_E \leq \frac{R_{eH}}{2\sqrt{3}}$$

- $\tau_c = \frac{R_{eH}}{\sqrt{3}} \left(1 - \frac{R_{eH}}{4\sqrt{3} \tau_E}\right)$
for

$$\tau_E > \frac{R_{eH}}{2\sqrt{3}}$$

τ_E : Euler shear buckling stress, in N/mm^2 , to be taken as:

$$\tau_E = 0,9k_t E \left(\frac{t_w}{b_{w-cg}}\right)^2$$

k_t : Coefficient, to be taken equal to 6,34

t_w : Net thickness, in mm, of the corrugation webs

b_{w-cg} : Width, in mm, of the corrugation webs as shown in Ch 4, Sec 5, Fig 27.

4.7.4 Webs not supported by local brackets

Unless welded to a sloping stool top plate as defined in [4.7.7], if the corrugation webs are not supported by local brackets below the stool top plate (or below the inner bottom) in the lower part, the section modulus of the corrugations is to be calculated considering the corrugation webs 30% effective.

4.7.5 Effective shedder plates

Provided that effective shedder plates are fitted as shown in Fig 11, when calculating the section modulus at the lower end of the corrugations ("Sections 1" in Fig 11), the net area, in cm², of flange plates may be increased by I_{SH} to be taken as:

$$I_{SH} = 2,5 \cdot 10^{-3} b_{f-cg} \sqrt{t_f t_{SH}}$$

without being taken greater than $2,5 b_{f-cg} t_f 10^{-3}$

where:

b_{f-cg} : Width, in mm, of the corrugation flange as shown in Ch 4, Sec 5, Fig 27.

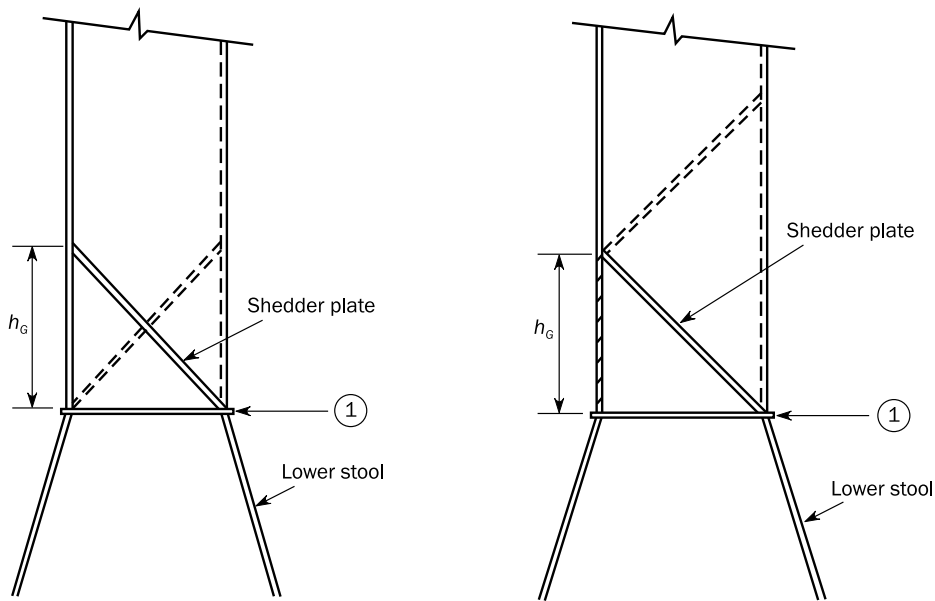
t_{SH} : Net shedder plate thickness, in mm.

t_f : Net flange thickness, in mm.

Effective shedder plates are those which:

- are not knuckled
- are welded to the corrugations and the lower stool top plate according to Ch 13, Sec 3, [3.3.5]
- are fitted with a minimum slope of 45°, their lower edge being in line with the lower stool side plating
- have net thickness not less than 75% of the net required for the corrugation flanges
- have material properties not less than those required for the flanges.

Figure 11 : Symmetrical and unsymmetrical shedder plates



4.7.6 Effective gusset plates

Provided that effective gusset plates are fitted, when calculating the section modulus at the lower end of the corrugations (Sections '1' in Fig 12 and Fig 13), the net area, in cm², of flange plates may be increased by I_G to be taken as:

$$I_G = 7 h_G t_f$$

where:

h_G : Height, in m, of gusset plates as shown in Fig 12 and Fig 13 but not to be taken greater than:

$$\frac{10 S_{GU}}{7}$$

S_{GU} : Width, in m, of gusset plates.

t_f : Net flange thickness, in mm.

Figure 12 : Symmetrical and unsymmetrical gusset / shedder plates

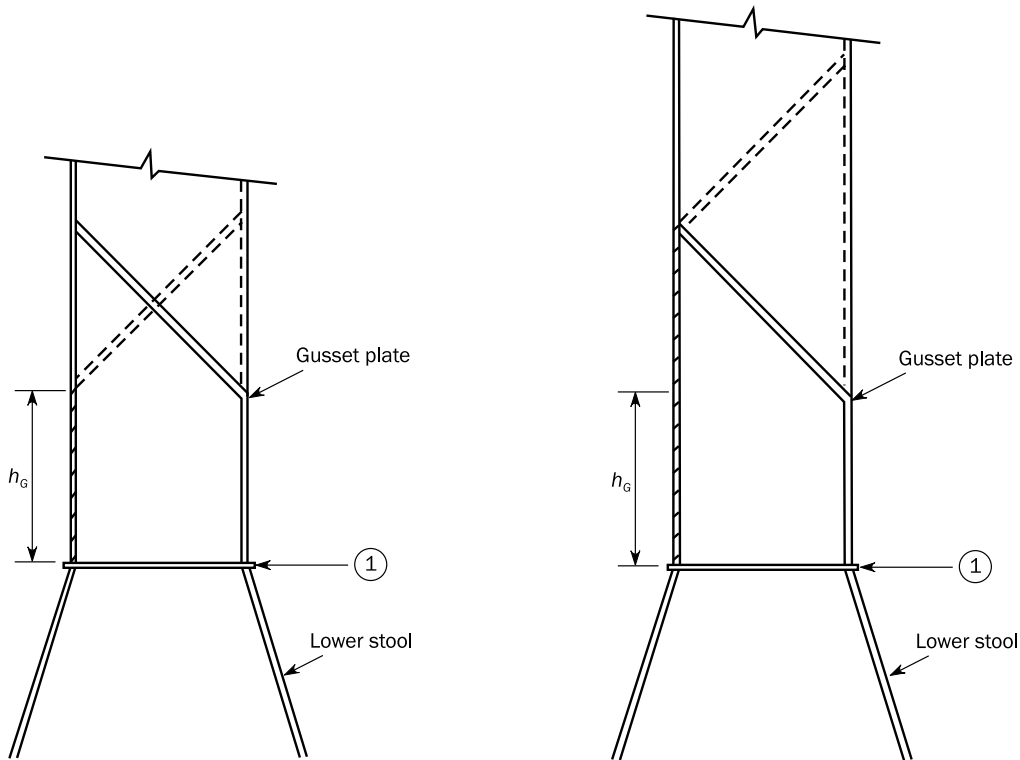
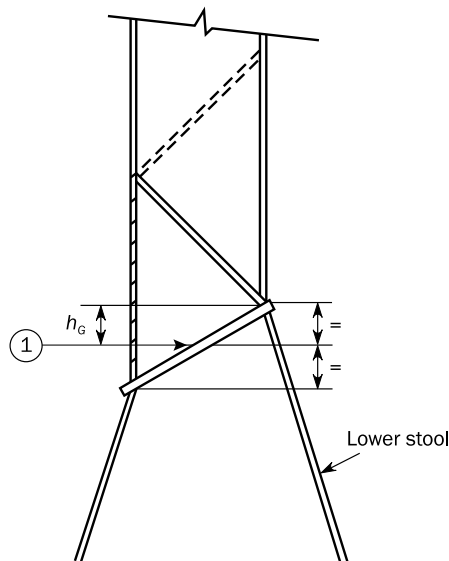


Figure 13 : Asymmetrical gusset / shedder plates



Effective gusset plates are those which:

- are in combination with shedder plates having thickness, material properties and welded connections as requested for shedder plates in [4.7.5]
- have a height not less than half of the flange width
- are fitted in line with the lower stool side plating
- are welded to the lower stool top plate, corrugations and shedder plates according to Ch 13, Sec 3, [3.3.5]
- have net thickness and material properties not less than those net required for the flanges.

4.7.7 Sloping stool top plate

Where the corrugation webs are welded to a sloping stool top plate which has an angle not less than 45° with the horizontal plane, the section modulus at the lower end of the corrugations may be calculated considering the corrugation webs fully effective. For angles less than 45°, the effectiveness of the web may be obtained by linear interpolation between 30% efficient for 0° and 100% efficient for 45°.

Where effective gusset plates are fitted, when calculating the net section modulus of corrugations, the net area of flange plates may be increased as specified in [4.7.6]. No credit may be given to shedder plates only.

4.7.8 Effective flange width

The net section modulus of the corrugations is to be calculated with the compression flange having an effective flange width b_{eff} as defined in [4.6.3].

4.8 Double bottom capacity in flooded conditions

4.8.1 Application

These requirements apply to the double bottom in cargo holds of ships intended for the carriage of dry cargoes in bulk.

4.8.2 Shear capacity of the double bottom

The shear capacity of the double bottom is to be calculated as the sum of the shear strength at each end of:

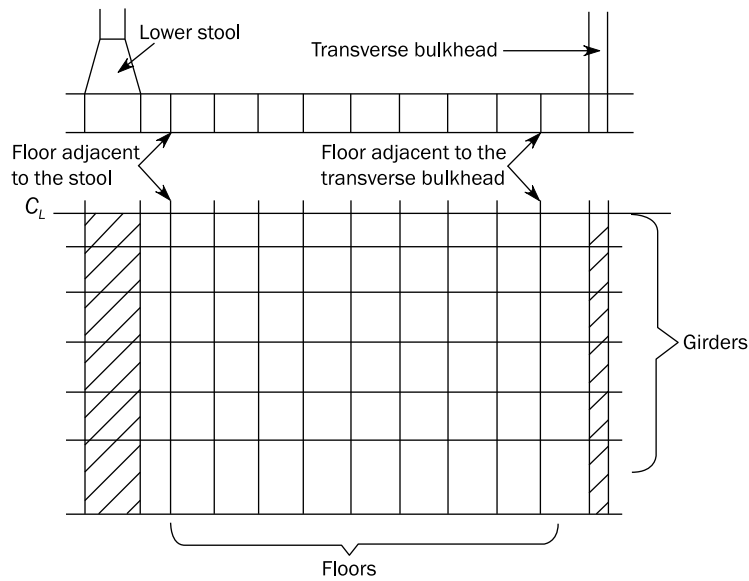
- Floors connected to hopper tanks, less one half of the shear strength of the two floors adjacent to each stool, or transverse bulkhead if no stool is fitted as shown in Fig 14. The shear strength of floors is to be calculated according to [4.8.3]
- Double bottom girders connected to stools, or transverse bulkheads if no stool is fitted. The shear strength of girders is to be calculated according to [4.8.4].

The floors and girders to be considered when calculating the shear capacity of the double bottom are those inside the hold boundaries formed by the hopper tanks and stools or transverse bulkheads if no stool is fitted. Where both ends of girders or floors are not directly connected to the hold boundaries, their strength is to be evaluated for the connected end only.

The hopper tank side girders and the floors directly below the connection of the stools or transverse bulkheads if no stool is fitted to the inner bottom may not be included.

For special double bottom designs, the shear capacity of the double bottom is to be calculated by means of direct calculations carried out in accordance with requirements specified in [5] Part B, Chapter 8, as applicable.

Figure 14 : Double bottom structure



4.8.3 Floor shear strength

The floor shear strength, in kN, is to be taken as given in the following formulae:

- in way of the floor panel adjacent to the hopper tank:

$$S_{f1} = A_f \frac{\tau_A}{\eta_1} 10^{-3}$$

- in way of the openings in the outermost bay (i.e., that bay which is closer to the hopper tank):

$$S_{f2} = A_{f,h} \frac{\tau_A}{\eta_2} 10^{-3}$$

where:

- A_f : Net sectional area, in mm^2 , of the floor panel adjacent to the hopper tank
- $A_{f,h}$: Net sectional area, in mm^2 , of the floor panels in way of the openings in the outermost bay (i.e., the bay which is closer to the hopper tank)
- τ_A : Allowable shear stress, in N/mm^2 , to be taken as the lesser of:

$$\tau_A = 0,645 \frac{R_{eH}^{0.6}}{(s/t)^{0.8}}$$

and

$$\tau_A = \frac{R_{eH}}{\sqrt{3}}$$

For floors adjacent to the stools or transverse bulkheads, τ_A is taken as:

$$\frac{R_{eH}}{\sqrt{3}}$$

- t : Floor web net thickness, in mm
s : Spacing, in m, of stiffening members of the panel considered
 η_1 : Coefficient to be taken equal to 1,1
 η_2 : Coefficient to be taken equal to 1,2. It may be reduced to 1,1 where appropriate reinforcements are fitted in way of the openings in the outermost bay, to be examined by the Society on a case-by-case basis.

4.8.4 Girder shear strength

The girder shear strength, in kN, is to be taken as given in the following formulae:

- in way of the girder panel adjacent to the stool or transverse bulkhead, if no stool is fitted:

$$S_{g1} = A_g \frac{\tau_A}{\eta_1} 10^{-3}$$

- in way of the largest opening in the outermost bay (i.e., that bay which is closer to the stool) or transverse bulk-head, if no stool is fitted:

$$S_{g2} = A_{g,h} \frac{\tau_A}{\eta_2} 10^{-3}$$

- A_g : Net sectional area, in mm², of the girder panel adjacent to the stool (or transverse bulkhead, if no stool is fitted)
 $A_{g,h}$: Net sectional area, in mm², of the girder panel in way of the largest opening in the outermost bay (i.e. that bay which is closer to the stool) or transverse bulkhead, if no stool is fitted
 τ_A : Allowable shear stress, in N/mm², as defined in [4.8.3] where t is the girder web net thickness
 η_1 : Coefficient to be taken equal to 1,1
 η_2 : Coefficient to be taken equal to 1,15. It may be reduced to 1.1 where appropriate reinforcements are fitted in way of the largest opening in the outermost bay, to be examined by the Society on a case-by-case basis.

4.8.5 Allowable hold loading

The allowable hold loading, in t, is to be taken as:

$$W = \rho_C V \frac{1}{F}$$

where:

- ρ_C : Density of the dry bulk cargo, in t/m³, as defined Ch 5, Sec 6, [3.3.3]
V : Volume, in m³, occupied by the cargo up to the level h_B
F : Coefficient to be taken as:

F = 1,1 in general.

F = 1,05 for steel mill products.

- h_B : Level of cargo, in m, to be taken as:

$$h_B = \frac{P}{\rho_C g}$$

- P : Pressure, in kN/m², to be taken as:

- For dry bulk cargoes, the lesser of:

$$P = \frac{Z + \rho g (z_F - (0,1 D_1) - h_F)}{1 + \frac{\rho}{\rho_C} (\text{perm} - 1)}$$

$$P = Z + \rho g (z_F - (0,1 D_1) - h_F \text{ perm})$$

- For steel mill products:

$$P = \frac{Z + \rho g (z_F - (0,1 D_1) - h_F)}{1 - \frac{\rho}{\rho_{ST}}}$$

- D_1 : Distance, in m, from the baseline to the freeboard deck at side amidships

- h_F : Inner bottom flooded height, in m, measured vertically with the ship in the upright position, from the inner bottom to the flooded level z_F
- z_F : Flooded level, in m, as defined in Ch 5, Sec 6, [4.1.3]
- perm : Permeability of cargo, which need not be taken greater than 0,3.
- ρ_{ST} : Density of steel, in t/m³, to be taken as 7,85.
- Z : Pressure, in kN/m², to be taken as the lesser of:

$$Z = \frac{C_H}{A_{DB,H}}$$

$$Z = \frac{C_E}{A_{DB,E}}$$

- C_H : Shear capacity of the double bottom, in kN, to be calculated according to [4.8.2], considering, for each floor, the lesser of the shear strengths S_{f1} and S_{f2} as defined in [4.8.3] and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} as defined in [4.8.4]

- $A_{DB,H}$: Area, in m², taken as:

$$A_{DB,H} = \sum_{i=1}^n S_i B_{DB,i}$$

- C_E : Shear capacity of the double bottom, in kN, to be calculated according to [4.8.2], considering, for each floor, the shear strength S_{f1} as defined in [4.8.3] and, for each girder, the lesser of the shear strengths S_{g1} and S_{g2} as defined in [4.8.4]

- $A_{DB,E}$: Area, in m², taken as:

$$A_{DB,E} = \sum_{i=1}^n S_i (B_{DB} - s)$$

- n : Number of floors between stools or transverse bulkheads, if no stool is fitted.

- S_i : Space of i-th floor, in m.

- $B_{DB,i}$: Length, in m, to be taken equal to:

$$B_{DB,i} = B_{DB} - s \text{ for floors for which } S_{f1} < S_{f2}.$$

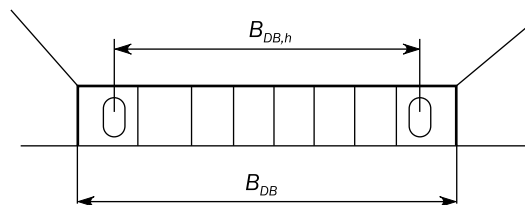
$$B_{DB,i} = B_{DB,h} \text{ for floors for which } S_{f1} \geq S_{f2}.$$

- B_{DB} : Breadth, in m, of double bottom between the hopper tanks as shown in Fig 15

- $B_{DB,h}$: Distance, in m, between the two openings considered as shown in Fig 15

- s : Spacing, in m, of inner bottom longitudinal ordinary stiffeners adjacent to the hopper tanks.

Figure 15 : Dimensions B_{DB} and $B_{DB,h}$



5 Grillage structure

5.1 General

5.1.1 Application

Where the structure is arranged as a grillage, the scantlings are to be checked using beam models in 2 or 3 dimensions, taking into account the requirements in [5.1.2] to [5.1.4].

5.1.2 Structural modelling

The model is to be built considering:

- the number and position of intermediate supports (e.g. decks, girders, pillars, etc)
- the conditions of fixity at the model boundaries and at intermediate supports
- the geometrical characteristics of the primary supporting members on the intermediate spans.

5.1.3 Design loads

The distribution of static pressures and forces and of still water hull girder stresses, as applicable, are to be applied to the model for all the loading conditions defined in Ch 5, Sec 8 and considered relevant for the assessment of the modeled structure.

Unless otherwise specified by the Society, for each of the considered seagoing loading conditions, the still water and static loads are to be combined with the dynamic pressures and forces and with the wave hull girder stresses, if any of all the dynamic load cases defined in Ch 5, Sec 2.

5.1.4 Analysis criterion

The calculated stress values are to comply with the following criterion:

a) For isolated beam analysis:

$$\tau \leq \chi K_{corr} C_t \tau_{eH}$$

$$\sigma \leq \chi K_{corr} C_s R_{eH}$$

b) For grillage analysis: $\sigma_{eq} \leq \chi K_{corr} C_{comb} R_{eH}$

where:

σ_{eq} : Equivalent Von Mises stress, in N/mm²:

$$\sigma_{eq} = \sqrt{\sigma^2 + 3\tau^2}$$

C_t, C_s, C_{comb} : Permissible stress coefficients defined in Tab 2 for the acceptance criteria selected according to Tab 22

Table 22 : Acceptance criterias for grillage structure analysis

Acceptance criteria	Loading condition
AC-1	Harbour condition
AC-2	Any seagoing condition
AC-3	Tank testing condition Flooded condition

Appendix 1 Analyses of Primary Supporting Members Subject to Wheeled Loads

1 General

1.1 Scope

1.1.1 The requirements of this Appendix apply to the analysis criteria, structural modelling, load modelling and stress calculation of primary supporting members subject to wheeled loads.

1.1.2 The purpose of these structural analyses is to determine:

- the distribution of the forces induced by the vertical acceleration acting on wheeled cargoes, among the various primary supporting members of decks, sides and possible bulkheads
- the behaviour of the above primary supporting members under the racking effects due to the transverse forces induced by the transverse acceleration acting on wheeled cargoes, when the number or location of transverse bulkheads are not sufficient to avoid such effects,

and to calculate the stresses in primary supporting members.

The above calculated stresses are to be used in the yielding and buckling checks.

In addition, the results of these analyses may be used, where deemed necessary by the Society, to determine the boundary conditions for finer mesh analyses of the most highly stressed areas.

1.1.3 When the behaviour of primary supporting members under the racking effects, due to the transverse forces induced by the transverse acceleration, is not to be determined, the stresses in deck primary supporting members may be calculated according to the simplified analysis in [6], provided that the conditions for its application are fulfilled (see [6.1]).

1.2 Application

1.2.1 The requirements of this Appendix apply to ships whose structural arrangement is such that the following assumptions may be considered as being applicable:

- primary supporting members of side and possible bulkheads may be considered fixed in way of the double bottom (this is generally the case when the stiffness of floors is at least three times that of the side primary supporting members)
- under transverse inertial forces, decks behave as beams loaded in their plane and supported at the ship ends; their effect on the ship transverse rings (side primary supporting members and deck beams) may therefore be simulated by means of elastic supports in the transverse direction or transverse displacements assigned at the central point of each deck beam.

1.2.2 When the assumptions in [1.2.1] are considered by the Society as not being applicable, the analysis criteria are defined on a case by case basis, taking into account the ship's structural arrangement and loading conditions. In such cases, the analysis is generally to be carried out on the basis of a finite element model of the whole ship, built according to the requirements in Ch 8, App 3, as far as applicable.

1.3 Information required

1.3.1 To perform these structural analyses, the following characteristics for every vehicle to be loaded are necessary:

- load per axle
- arrangement of wheels on axles
- tyre dimensions.

1.4 Lashing of vehicles

1.4.1 The presence of lashing for vehicles is generally to be disregarded, but may be given consideration by the Society, on a case by case basis, at the request of the interested parties.

2 Analysis criteria

2.1 Finite element model analyses

2.1.1 General

Areas which appear, from the primary supporting member analysis, to be highly stressed may be required to be further analysed through local FE models according to Ch 8, App 2.

2.1.2 Criteria

Primary supporting members analyzed through FE models are to comply with the criteria in Ch 8, App 1, [5] or Ch 8, App 3, [5] as relevant.

2.2 Beam model analyses

2.2.1 General

Beam models, built according to Ch 7, Sec 6, [5.1], may be adopted in lieu of the finite element models, provided that:

- primary supporting members are not so stout that the beam theory is deemed inapplicable by the Society
- their behaviour is not substantially influenced by the transmission of shear stresses through the shell plating.

In any case, FE models may need to be adopted when deemed necessary by the Society on the basis of the ship’s structural arrangement.

2.2.2 Criteria

Primary supporting members analyzed through beam models are to comply with the criteria in Ch 7, Sec 6, [5.1.4].

3 Primary supporting members structural modelling

3.1 Model construction

3.1.1 Elements

The structural model is to represent the primary supporting members with the plating to which they are connected. In particular, the following primary supporting members are to be included in the model:

- deck beams
- side primary supporting members
- primary supporting members of longitudinal and transverse bulkheads, if any
- pillars
- deck beams, deck girders and pillars supporting ramps and deck openings, if any.

3.1.2 Net scantlings

All the elements in [3.1.1] are to be modelled with their net scantlings according to Ch 4, Sec 2.

3.2 Model extension

3.2.1 The structural model is to represent a hull portion which includes the zone under examination and which is repeated along the hull. The non-modelled hull parts are to be considered through boundary conditions as specified in [3.3].

In addition, the longitudinal extension of the structural model is to be such that the results in the areas to be analysed are not influenced by the unavoidable inaccuracy in the modelling of the boundary conditions.

3.2.2 Double bottom structures are not required to be included in the model, based on the assumptions in [1.2.1].

3.3 Boundary conditions of the three dimensional model

3.3.1 Boundary conditions at the lower ends of the model

The lower ends of the model (i.e. the lower ends of primary supporting members of side and possible bulkheads) are to be considered as being clamped in way of the inner bottom.

3.3.2 Boundary conditions at the fore and aft ends of the model

Symmetry conditions are to be applied at the fore and aft ends of the model, as specified in Tab 1.

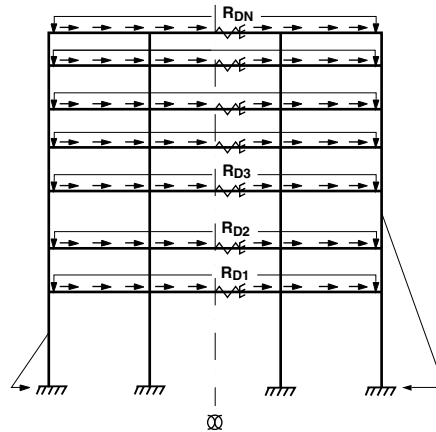
3.3.3 Additional boundary conditions at the fore and aft ends of models subject to transverse loads

When the model is subject to transverse loads, i.e. when load cases corresponding to beam and oblique sea (as defined in Ch 5, Sec 2) are applied to the model, the transverse displacements of the deck beams are to be obtained by means of a racking analysis and applied at the fore and aft ends of the model, in way of each deck beam.

Table 1 : Symmetry conditions at the model fore and aft ends

DISPLACEMENTS in directions (1):			ROTATION around axes (1):		
X	Y	Z	X	Y	Z
fixed	free	free	free	fixed	fixed
(1) X, Y and Z directions and axes are defined with respect to the reference co-ordinate system in Ch 1, Sec 3, [2.6].					

Figure 1 : Springs at the fore and aft ends of models subject to transverse loads



For ships with a traditional arrangement of fore and aft parts, a simplified approximation may be adopted, when deemed acceptable by the Society, defining the boundary conditions without taking into account the racking calculation and introducing springs, acting in the transverse direction, at the fore and aft ends of the model, in way of each deck beam (see Fig 1). The stiffness of each spring, simulating the effects of the deck in way of which it is modelled, is to be obtained, in kN/m, from the following formula:

$$R_{D,i} = \frac{24EJ_{D,i}s_a 10^3}{2x^4 - 4L_Dx^3 + L_D^2\left(x^2 + 15,6\frac{J_{D,i}}{A_{D,i}}\right) + L_D^3x}$$

where:

- $J_{D,i}$: Net moment of inertia, in m^4 , of the average cross-section of the deck i , with the attached side shell plating, about its vertical neutral axis
- $A_{D,i}$: Net area, in m^2 , of the average cross-section of deck i plating
- s_a : Spacing of side vertical primary supporting members, in m
- x_i : Longitudinal distance, in m , measured from the transverse section at mid-length of the model to any end of deck i
- $L_{D,i}$: Length of the deck i , in m , to be taken equal to the ship's length. Special cases in which such value may be reduced will be considered by the Society on a case by case basis.

4 Load model

4.1 General

4.1.1 Hull girder and local loads

Only local loads are to be directly applied to the structural model.

The stresses induced by hull girder loads are to be calculated separately and added to the stresses induced by local loads.

4.1.2 Loading conditions and load cases: wheeled cargoes

The still water and dynamic loads are to be calculated for the most severe loading conditions as given in the loading manual, with a view on maximising the stresses in primary supporting members.

The loads transmitted by vehicles are to be applied taking into account the most severe axle positions for the ship structures.

The dynamic local loads and hull girder loads are to be calculated for the following sets of dynamic load cases defined in Ch 5, Sec 2, maximizing the vertical and transverse accelerations a_x and a_y according to Ch 5, Sec 3, [3.3]:

- BP2-P, BP2-S, OVA2-P and OVA2-S load cases for maximum vertical acceleration (OVA2-P and OVA2-S load cases are only relevant for models extending forward of 0,6L)
- BR2-P and BR1-S load cases for maximum transverse acceleration.

Other load cases may be disregarded for the purposes of the structural analyses dealt with in this Appendix.

4.1.3 Loading conditions and load cases: dry uniform cargoes

When the ship's decks are also designed to carry dry uniform cargoes, the loading conditions foreseeing the transportation of such cargoes are also to be considered. The still water and dynamic loads induced by these cargoes are to be calculated for the most severe loading conditions, with a view to maximising the stresses in primary supporting members.

The dynamic local loads and hull girder loads are to be calculated for the dynamic load cases specified in [4.1.2].

4.2 Local loads

4.2.1 General

Still water loads include:

- the still water sea pressure, defined in Ch 5, Sec 5, [1.2]
- the static forces defined in Ch 5, Sec 6, [7] and Ch 5, Sec 6, [6] for wheeled cargoes and dry uniform cargoes when relevant.

Dynamic loads include:

- the dynamic pressures, defined in Ch 5, Sec 5, [1], Ch 5, Sec 5, [3] and Ch 5, Sec 5, [5]
- the dynamic forces defined in Ch 5, Sec 6, [7] and Ch 5, Sec 6, [6] for wheeled cargoes and dry uniform cargoes when relevant.

4.2.2 Tyred vehicles

For the purpose of primary supporting members analyses, the forces transmitted through the tyres may be considered as concentrated loads in the tyre print centre.

The forces acting on primary supporting members are to be determined taking into account the area of influence of each member and the way ordinary stiffeners transfer the forces transmitted through the tyres.

4.2.3 Non-tyred vehicles

The requirements in [4.2.2] also apply to tracked vehicles. In this case, the print to be considered is that below each wheel or wheelwork.

For vehicles on rails, the loads transmitted are to be applied as concentrated loads.

4.2.4 Distributed loads

In the analyses carried out on the basis of beam models or membrane finite element models, the loads distributed perpendicularly to the plating panels are to be applied on the primary supporting members proportionally to their areas of influence.

5 Stress calculation

5.1 Normal stress induced by hull girder loads

5.1.1 The normal stress σ_L , in N/mm², induced by the hull girder loads is to be calculated according to Ch 6, Sec 1, [2.1] for the relevant load cases and added to the stresses induced by local loads as calculated by the direct strength analysis.

5.2 Analyses based on beam models

5.2.1 Stress calculation points

Stresses are to be calculated at least in the following points of each primary supporting member:

- in the primary supporting member span where the maximum bending moment occurs
- at the connection of the primary supporting member with other structures, assuming as resistant section that formed by the member, the bracket (if any and if represented in the model) and the attached plating
- at the toe of the bracket (if any and if represented in the model) assuming as resistant section that formed by the member and the attached plating.

The values of the stresses calculated in the above points are to be used for carrying out the checks required.

6 Grillage analysis of primary supporting members of decks

6.1 Application

6.1.1 For the sole purpose of calculating the stresses in deck primary supporting members due to the forces induced by the vertical accelerations acting on wheeled cargoes (the racking effect is not to be considered), the simplified two dimensional analysis described in [6.2] may be considered.

This analysis is generally considered as being acceptable for standard structural typology where there are neither pillar lines nor longitudinal bulkheads, but sufficient transverse bulkheads to prevent racking effect.

6.2 Structural model

6.2.1 Members to be modelled

The structural model used to represent the deck primary supporting members is a beam grillage model.

6.2.2 Model extension

The structural model is to represent a hull portion which includes the zone under examination and which is repeated along the hull. The non-modelled hull parts are to be considered through boundary conditions as specified in [6.3].

6.3 Boundary conditions

6.3.1 Boundary conditions at the fore and aft ends of the model

Symmetry conditions are to be applied at the fore and aft ends of the model, as specified in Tab 1.

6.3.2 Boundary conditions at the connections of deck beams with side vertical primary supporting members

Vertical supports are to be fitted at the nodes positioned in way of the connection of deck beams with side primary supporting members.

The contribution of flexural stiffness supplied by the side primary supporting members to the deck beams is to be simulated by springs, applied at their connections, having rotational stiffness, in the plane of the deck beam webs, obtained, in kN.m/rad, from the following formulae:

- for intermediate decks:

$$R_F = \frac{3E(J_1 + J_2)(l_1 + l_2)}{l_1^2 + l_2^2 - l_1 l_2} 10^{-5}$$

- for the uppermost deck:

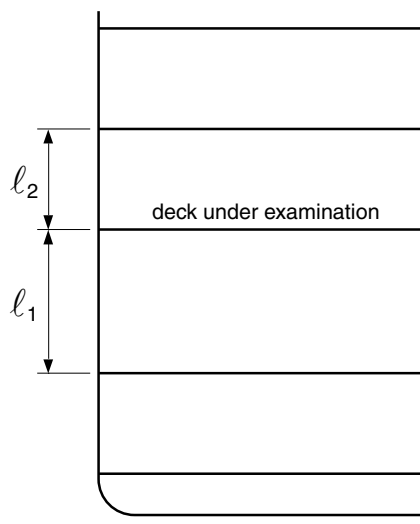
$$R_F = \frac{6EJ_1}{l_1} 10^{-5}$$

where:

l_1, l_2 : Height, in m, of the 'tweendecks, respectively below and above the deck under examination (see Fig 2)

J_1, J_2 : Net moments of inertia, in cm^4 , of side primary supporting members with attached shell plating, relevant to the 'tweendecks, respectively below and above the deck under examination.

Figure 2 : Heights of 'tweendecks for grillage analysis of deck primary supporting members



6.4 Load model

6.4.1 Hull girder and local loads are to be calculated and applied to the model according to [4].

The dynamic local loads and hull girder loads are to be calculated for the load cases maximizing the vertical acceleration according to Ch 5, Sec 3, [3.3], and are to be applied to the model according to [4].

6.5 Stress calculation

6.5.1 Stress components are to be calculated according to [5.1] and [5.2].

Part B

Hull and Stability

CHAPTER 8

DIRECT STRENGTH ANALYSIS

Section 1	Direct Strength Assessment
Appendix 1	Cargo Hold Structural Strength Analysis
Appendix 2	Local Structural Strength Analysis
Appendix 3	Full Length Structural Strength Analysis

Section 1 Direct Strength Assessment

1 General

1.1 Application

1.1.1 This Chapter provides requirements to assess the scantlings of the hull structure using finite element analysis, mandatory only for ships defined in Ch 7, Sec 6, [1.1.1].

1.1.2 Direct strength assessment may cover the following types of analysis:

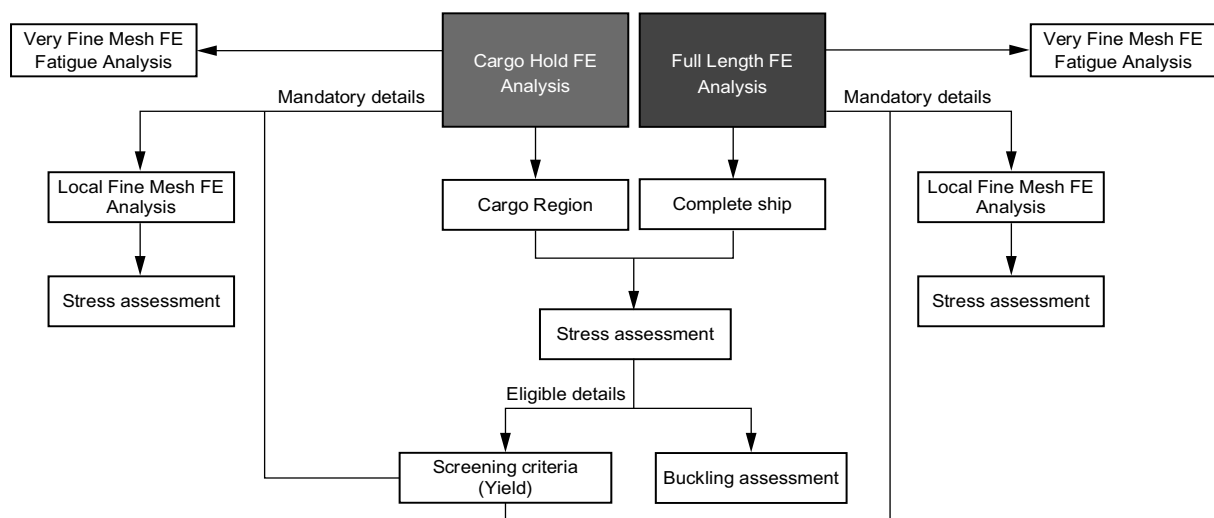
- cargo hold analysis to assess the strength of longitudinal hull girder structural members, primary supporting structural members and bulkheads, performed according to Ch 8, App 1
- complete ship structural analysis to assess the primary supporting members, performed according to Ch 8, App 3
- fine mesh analysis to assess detailed stress levels in local structural details, performed according to Ch 8, App 2
- very fine mesh analysis to assess the fatigue capacity of the structural details according to Ch 9.

1.1.3 The analysis is to verify that:

- stress levels are within the acceptance criteria for yielding
- buckling capability of plates and stiffened panels are within the acceptance criteria for buckling defined in Ch 9, Sec 1
- fatigue capacity of the structural details is within the acceptance criteria defined in Ch 10, Sec 1.

1.1.4 A flow diagram showing the minimum requirement of finite element analysis is shown in Fig 1.

Figure 1 : Flow diagram of finite element analysis



2 Net scantling

2.1 Net scantling application

2.1.1 Models for cargo hold FE analyses, local fine mesh FE analyses and very fine mesh FE analyses are to be based on the net scantling approach, applying the corrosion addition as defined in Ch 4, Sec 2, Tab 1.

All the buckling capacity assessments are to be based on the net scantling approach, applying the corrosion addition as defined in Ch 4, Sec 2, Tab 1.

3 Finite element types

3.1 Finite element types to be used

3.1.1 The structural assessment is to be based on linear finite element analysis of three-dimensional structural models. The general types of finite elements to be used in the finite element analysis are given in Tab 1.

Table 1 : Types of finite elements

Type of finite element	Description
Rod (or truss) element	Line element with axial stiffness only and constant cross-sectional area along the length of the element
Beam element	Line element with axial, torsional and bi-directional shear and bending stiffness and with constant properties along the length of the element
Shell (or plate) element	Shell element with in-plane stiffness and out-of-plane bending stiffness with constant thickness

3.1.2 Two node line elements and four node shell elements are, in general, considered sufficient for the representation of the hull structure. The mesh requirements given in this Chapter are based on the assumption that these elements are used in the finite element models. However, higher order elements may also be used.

4 Acceptance criteria

4.1 Definition

4.1.1 Acceptance criteria are to be selected as defined in Tab 2.

Table 2 : Acceptance criteria

Acceptance criteria	Design load scenario / Loading condition(1)
AC-1	Harbour condition
AC-2	Any seagoing condition
AC-3	Tank testing condition Flooded condition(2) Static heel 30° condition Collision condition
<p>(1) The detailed loading conditions are defined in Ch 5, Sec 8.</p> <p>(2) In this Chapter, flooded condition is to be considered for watertight boundaries of compartments not intended to carry liquid (except for corrugated bulkheads).</p>	

5 Submission of results

5.1 Detailed report

5.1.1 A detailed report of the structural analysis is to be submitted by the designer/builder to demonstrate compliance with the specified structural design criteria. This report is to include the following information:

- a) list of plans used including dates and versions
- b) detailed description of structural modeling including all modeling assumptions and any deviations in geometry and arrangement of structure compared with plans
- c) plots to demonstrate correct structural modeling and assigned properties
- d) details of material properties, plate thickness, beam properties used in the model
- e) details of boundary conditions
- f) details of all loading conditions reviewed with calculated hull girder shear force, bending moment and torsional moment distributions
- g) details of applied loads and confirmation that individual and total applied loads are correct
- h) plots and results that demonstrate the correct behaviour of the structural model under the applied loads
- i) summaries and plots of global and local deflections
- j) summaries and sufficient plots of stresses to demonstrate that the design criteria are not exceeded in any member
- k) plate and stiffened panel buckling analysis and results
- l) tabulated results showing compliance, or otherwise, with the design criteria
- m) proposed amendments to structure where necessary, including revised assessment of stresses, buckling and fatigue properties showing compliance with design criteria
- n) reference of the finite element computer program, including its version and date.

6 Computer programs

6.1 Use of computer programs

6.1.1 Any finite element computation program may be employed to determine the stress and deflection of the hull structure, provided that the combined effects of bending, shear, axial and torsional deformations are considered.

Appendix 1 Cargo Hold Structural Strength Analysis

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

- M_{sw} : Permissible vertical still water bending moment, in kN·m, as defined in Ch 5, Sec 4
 M_{ww} : Vertical wave bending moment, in kN·m, in hogging or sagging condition, as defined in Ch 5, Sec 4
 M_{wh} : Horizontal wave bending moment, in kN·m, as defined in Ch 5, Sec 4
 M_{wt} : Wave torsional moment in seagoing condition, in kNm, as defined in Ch 5, Sec 4.
 Q_{sw} : Permissible still water shear force, in kN, at the considered bulkhead position, as provided in Ch 5, Sec 4
 Q_{ww} : Vertical wave shear force, in kN, as defined in Ch 5, Sec 4
 X_{b-aft} , X_{b-fwd} : X-coordinate, in m, of, respectively, the aft and forward bulkheads of the mid-hold
 X_{aft} : X-coordinate, in m, of the aft end support of the FE model
 X_{fore} : X-coordinate, in m, of the fore end support of the FE model
 X_i : X-coordinate, in m, of web frame station i
 Q_{aft} : Vertical shear force, in kN, at the aft bulkhead of the mid-hold, as defined in [4.4.6]
 Q_{fwd} : Vertical shear force, in kN, at the forward bulkhead of the mid-hold, as defined in [4.4.6]
 $Q_{targ-aft}$: Target shear force, in kN, at the aft bulkhead of the mid-hold, as defined in [4.3.3]
 $Q_{targ-fwd}$: Target shear force, in kN, at the forward bulkhead of the mid-hold, as defined in [4.3.3].

1 Objective and scope

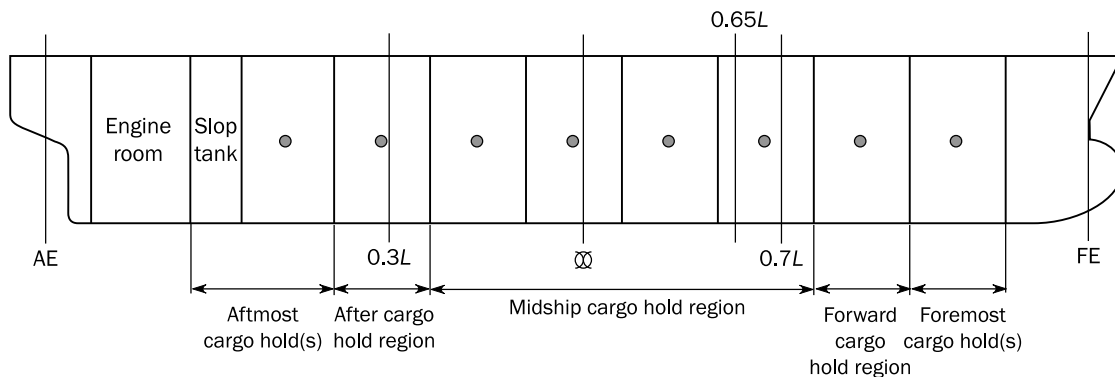
1.1 General

1.1.1 This Section gives the requirements for cargo hold structural strength analysis used for the assessment of scantlings of longitudinal hull girder structural members, primary supporting members and bulkheads within the cargo hold region.

1.1.2 For the purpose of FE structural assessment and load application, the cargo hold region contains the following cargo hold regions, which may vary depending on the ship length and cargo hold arrangement, as defined in Fig 1:

- midship cargo hold region
- forward cargo hold region
- after cargo hold region
- foremost cargo hold(s)
- aftmost cargo hold(s).

Figure 1 : Definition of the cargo hold regions for FE structural assessment



Holds in the forward cargo hold region are defined as holds having their longitudinal centre of gravity position located forward of 0.7 L from AE, except foremost cargo hold.

Holds in the midship cargo hold region are defined as holds having their longitudinal centre of gravity position located at or forward of 0.3 L from AE and at or aft of 0.7 L from AE.

Holds in the after cargo hold region are defined as holds having their longitudinal centre of gravity position located aft of 0.3 L from AE, except aftmost cargo hold.

Foremost cargo hold(s) is (are) defined as hold(s) in the foremost location of the cargo hold region.

Aftmost cargo hold(s) is (are) defined as hold(s) in the aftmost location of the cargo hold region.

1.1.3 Cargo hold structural strength analysis is mandatory for each typical cargo tank or cargo hold representative of the cargo hold regions defined in [1.1.2] including the aft bulkhead of the aftmost cargo hold and the collision bulkhead. The evaluation areas are defined in [5.1].

1.2 Cargo hold structural strength analysis procedure

1.2.1 Procedure description

The structural FE analysis is to be performed in accordance with the following:

- model: three cargo hold model with:
 - extent as given in [2.2]
 - finite element types as given in [2.3]
 - structural modeling as defined in [2.4]
- boundary conditions as defined in [2.5]
- FE load combinations as defined in [3]
- load application as defined in [4]
- evaluation area as defined in [5.1]
- strength assessment as defined in [5.2] and [5.3].

1.2.2 Mid-hold definition

For the purpose of the FE analysis, the mid-hold is defined as the middle hold(s) of the three cargo hold length FE model.

1.2.3 Scantling assessment

The scantling assessment is carried out according to Ch 8, Sec 1 for each individual cargo hold of the covered regions using the FE load combinations defined in [3] applicable to the considered cargo hold. The FE analysis results are applicable to the evaluation area, as defined in [5.1.1], of the considered cargo hold.

The individual transverse bulkhead structural elements, including plating, stiffeners and horizontal stringers, are to be assessed considering two cargo hold finite element analyses, i.e. the analysis for the hold forward and the one for the hold aft of the considered transverse bulkhead.

For ships having the service notation **container ship**, when the results of the full length model are not deemed sufficient by the Society, in particular to account for conditions with one bay empty, results from the midship cargo hold region analysis may also be extrapolated with special care to the other cargo hold areas.

2 Structural model

2.1 Members to be modeled

2.1.1 All the main longitudinal and transverse structural elements are to be modeled. These ones include:

- inner and outer shell
- upper deck
- double bottom floors and girders
- transverse and vertical web frames
- hatch coamings
- stringers and lower decks
- transverse and longitudinal bulkheads structures
- other primary supporting members
- other structural members which contribute to hull girder strength.

All plates and stiffeners on the structure, including web stiffeners, are to be modeled. Brackets which contribute to the primary supporting member strength and the size of which is not less than the typical mesh size (s-by-s) described in [2.4.2] are to be modeled.

2.2 Extent of model

2.2.1 Longitudinal extent

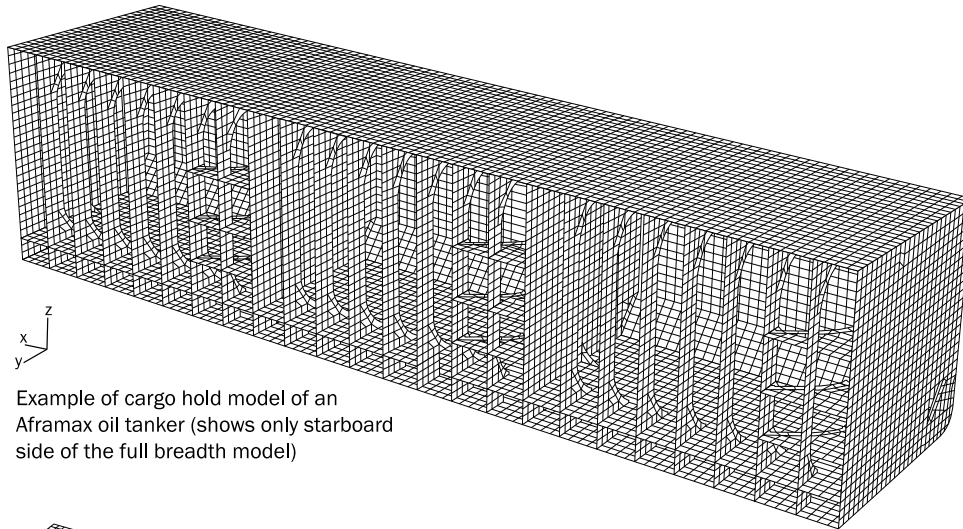
Except the foremost and aftermost cargo hold models, the longitudinal extent of the cargo hold FE model is to cover three cargo hold lengths. The transverse bulkheads at the ends of the model are to be modeled. Where corrugated bulkheads are fitted, the model is to include the extent of the bulkhead steel structure forward and aft of the tanks/holds at the model ends. Typical finite element models representing the midship cargo hold region are shown in Fig 2 to Fig 4.

The foremost and the aftmost cargo holds are located at the middle of the FE models as follows:

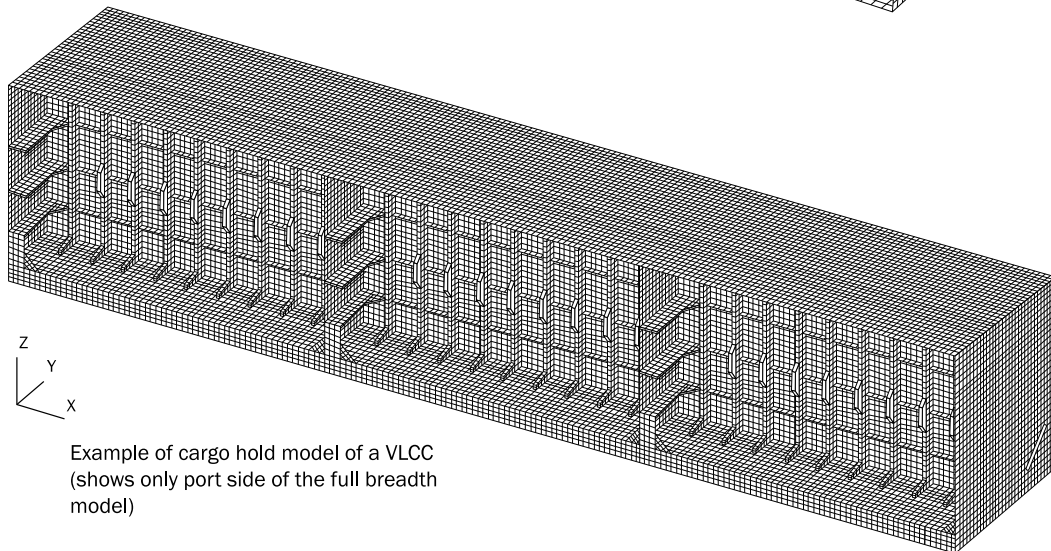
- foremost cargo hold: from the after bulkhead of the cargo hold no. 2 to the ship's foremost cross section where the reinforced ring or web frame remains continuous from the base line to the strength deck
- aftermost cargo hold: from the after bulkhead of the engine room to the forward bulkhead of no. N-1 cargo hold, where N is the number of holds or sets of holds numbered from forward to aft.

Examples of finite element models representing the foremost and aftermost cargo holds of different ship type configurations are shown in Fig 5 and Fig 6

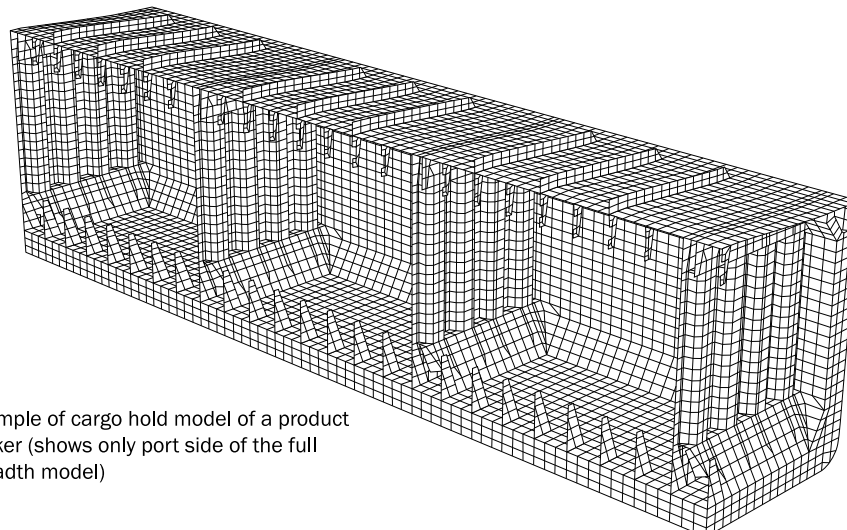
Figure 2 : Example of 3 cargo hold model within midship region of oil tankers



Example of cargo hold model of an Aframax oil tanker (shows only starboard side of the full breadth model)

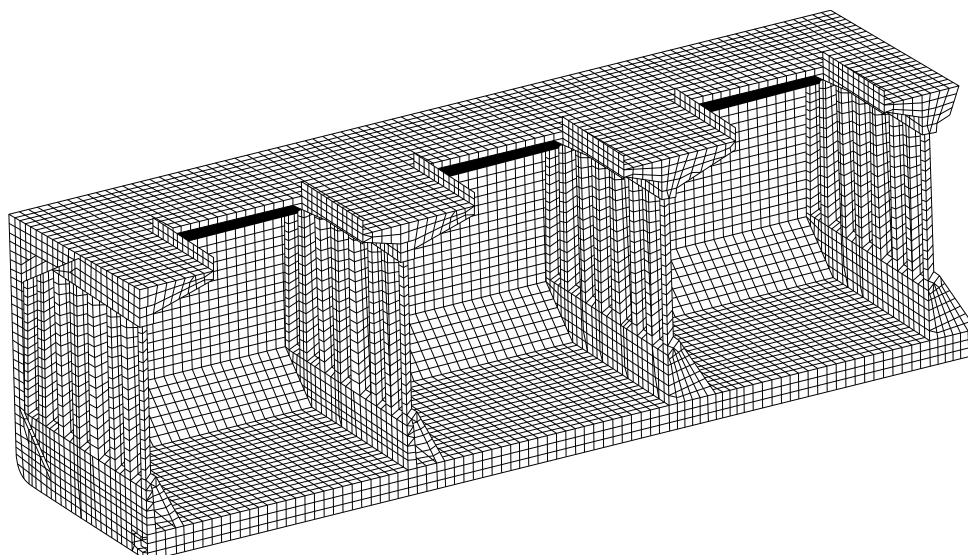


Example of cargo hold model of a VLCC (shows only port side of the full breadth model)



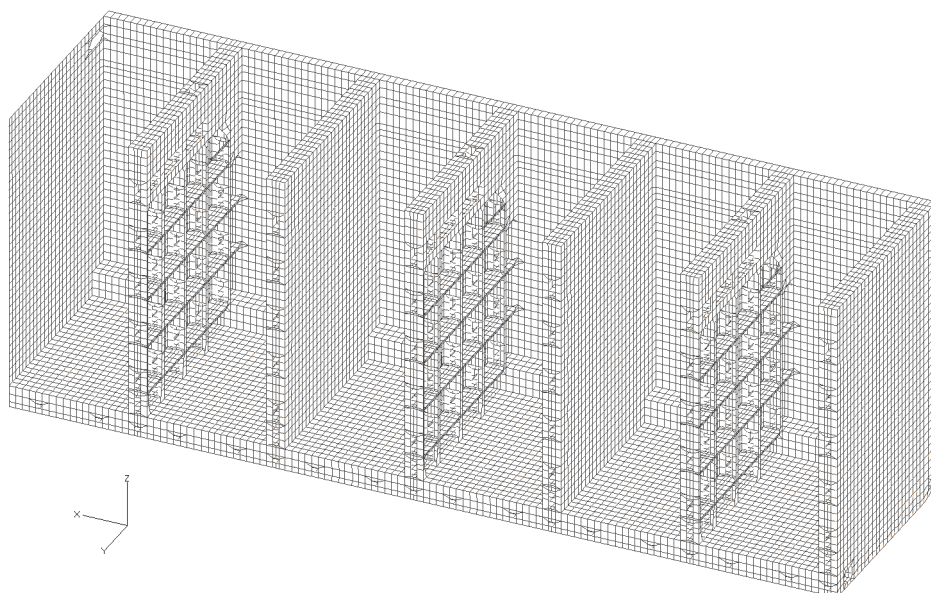
Example of cargo hold model of a product tanker (shows only port side of the full breadth model)

Figure 3 : Example of 3 cargo hold model within midship region of a bulk carrier



Example of cargo hold model of a bulk carrier (shows only port side of the full breadth model)

Figure 4 : Example of 3 cargo hold model within midship region of container ship



Example of cargo hold model of a container ship (shows only port side of the full breadth model)

Figure 5 : Example of FE model for the foremost cargo hold structure of an oil tanker

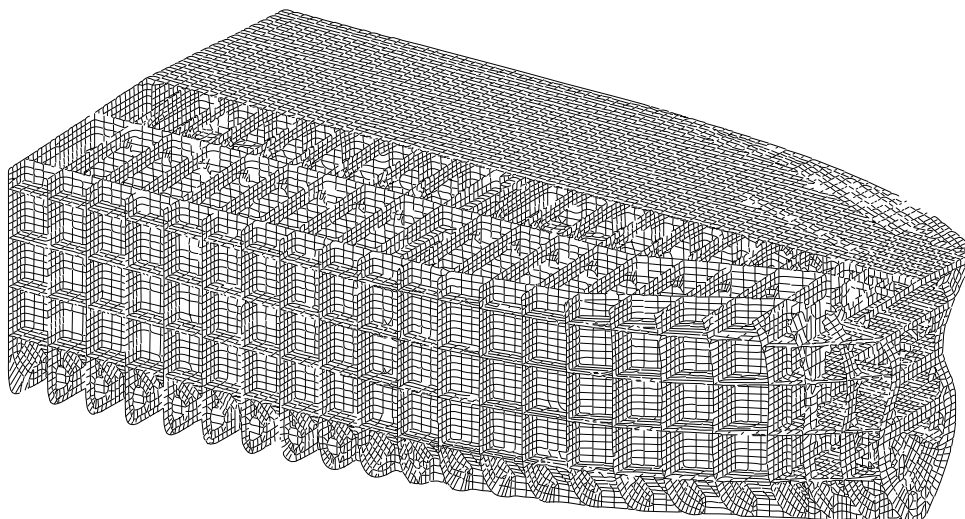
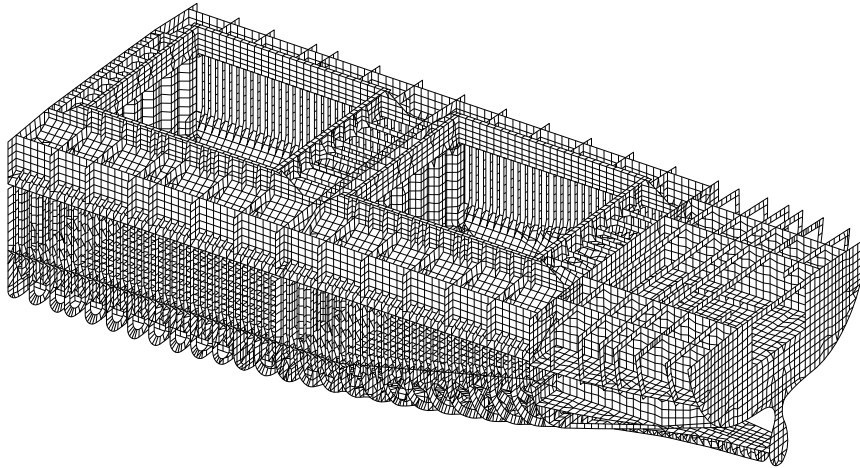


Figure 6 : Example of FE model for the aftermost cargo hold structure of a bulk carrier



2.2.2 Hull form modeling

In general, the finite element model is to represent the geometry of the hull form. In the midship cargo hold region, the finite element model may be prismatic, provided the mid-hold has a prismatic shape.

In the foremost cargo hold model, the hull form forward of the transverse section at the middle of the fore part up to the model end as defined in [2.2.1] may be modeled with a simplified geometry. The transverse section at the middle of the fore part up to the model end may be extruded out to the fore model end.

In the aftmost cargo hold model, the hull form aft of the middle of the machinery space may be modeled with a simplified geometry. The section at the middle of the machinery space may be extruded out to its aft bulkhead.

2.2.3 Transverse extent

Both port and starboard sides of the ship are to be modeled.

2.2.4 Vertical extent

The full depth of the ship is to be modeled including primary supporting members above the upper deck, trunks, forecastle and/or cargo hatch coaming, if any.

The superstructure or deck house in way of the machinery space, if any, and the bulwark are not required to be included in the model.

2.3 Finite element types

2.3.1 Shell elements are to be used to represent plating.

2.3.2 All the stiffeners are to be modeled with beam elements. The eccentricity of the neutral axis is to be modeled.

2.3.3 Face plates of primary supporting members and brackets are to be modeled using rod or beam elements.

2.4 Structural modeling

2.4.1 Aspect ratio

The aspect ratio of the shell elements is in general not to exceed 3. The use of triangular shell elements is to be kept to a minimum. Where possible, the aspect ratio of the shell elements, in areas where there are likely to be high stresses or a high stress gradient, is to be kept close to 1 and the use of triangular elements is to be avoided.

2.4.2 Mesh

The shell element mesh is to follow the stiffening system as far as practicable, hence representing the actual plate panels between stiffeners. In general, the shell element mesh is to satisfy the following requirements:

- a) One element between every ordinary stiffener, see Fig 7 and Fig 8. Longitudinally, the element length is not to be greater than two longitudinal spaces, with a minimum of three elements between primary supporting members
- b) At least three elements over the height of primary supporting members webs, see Fig 7 and Fig 8
For primary supporting members with a small web depth, modeling using two elements over the depth is acceptable provided that there is at least one element between every web stiffener. The mesh size of adjacent structure is to be adjusted accordingly
- c) The curvature of the free edge on large brackets of primary supporting members is to be modeled to avoid unrealistic high stress due to geometry discontinuities. In general, a mesh size equal to the stiffener spacing is acceptable. The bracket toe may be terminated at the nearest nodal point, provided that the modeled length of the bracket arm does not exceed the actual bracket arm length. The bracket flange is not to be connected to the plating, as shown in Fig 9. The modeling of the tapering part of the flange is to be in accordance with [2.4.8]. An example of acceptable mesh is shown in Fig 9. A finer mesh is to be used for the determination of detailed stress at the bracket toe, as given in Ch 8, App 2.

Figure 7 : Typical finite element mesh on web frame of an oil tanker and a bulk carrier

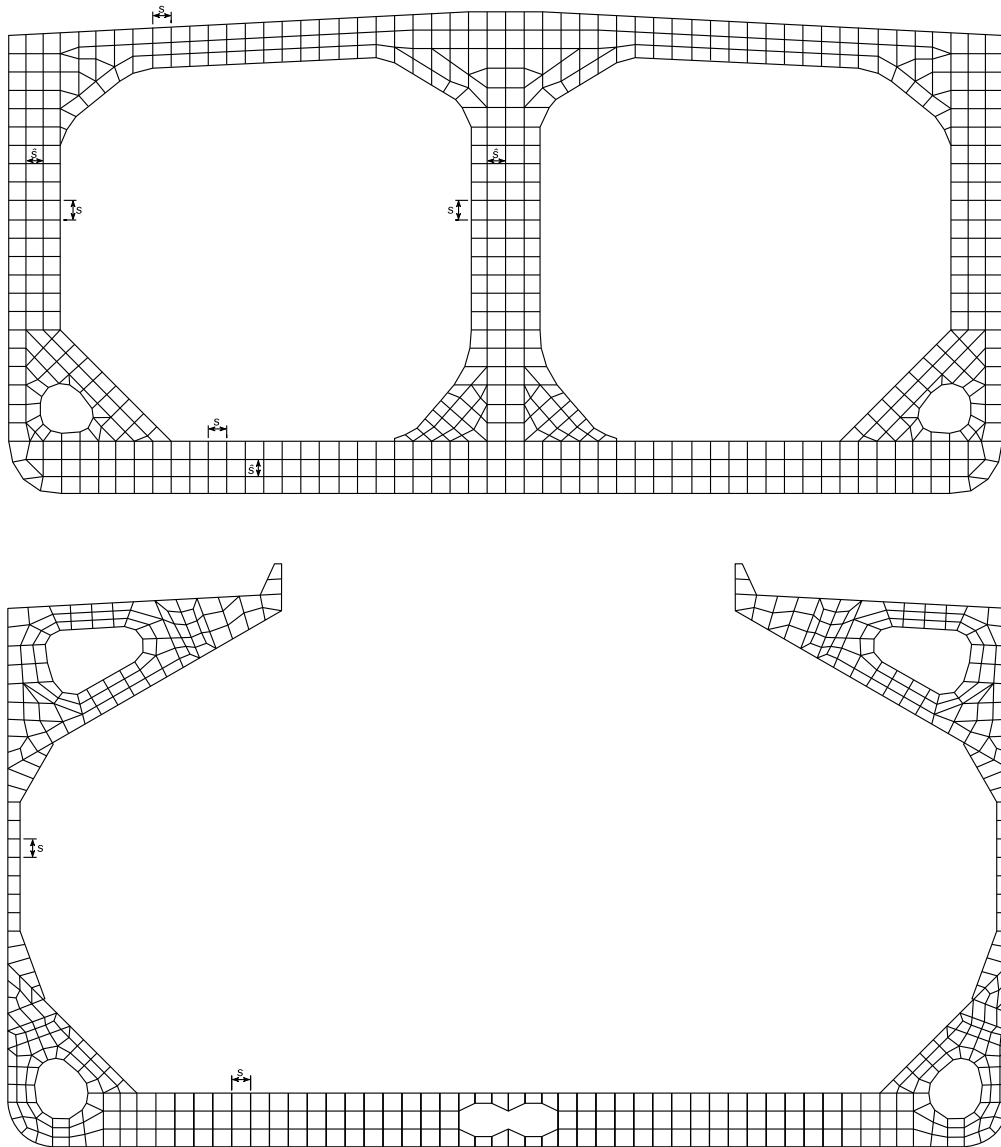


Figure 8 : Typical finite element mesh on web frame of a container ship

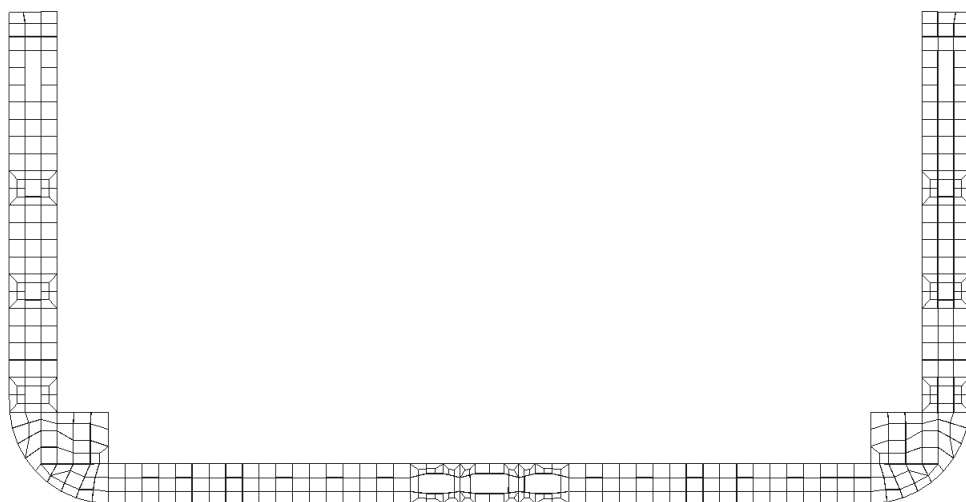
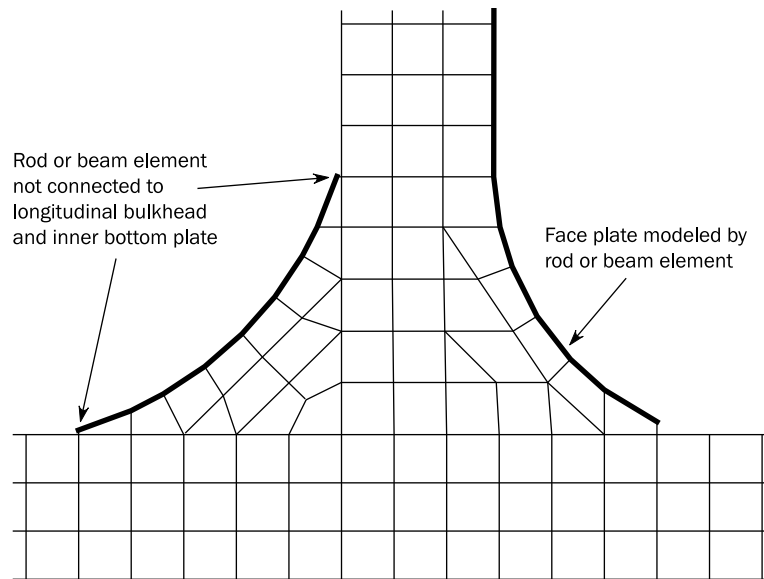


Figure 9 : Typical finite element mesh on large brackets of primary supporting member



2.4.3 Finer mesh

Where the geometry cannot be adequately represented in the cargo hold model and the stress exceeds the cargo hold mesh acceptance criteria, a finer mesh may be used for such geometry, to demonstrate satisfactory scantlings. The mesh size required for such analysis can be governed by the geometry. In such cases, the average stress within an area equivalent to that specified in [2.4] is to comply with the requirements given in [5.2].

2.4.4 Corrugated bulkhead

Diaphragms in the stools, supporting structure of corrugated bulkheads and internal longitudinal and vertical stiffeners on the stool plating are to be included in the model. Modeling is to be carried out as follows:

- a) the corrugation is to be modeled with its geometric shape
- b) the mesh on the flange and web of the corrugation is in general to follow the stiffener spacing inside the bulkhead stool
- c) the mesh on the longitudinal corrugated bulkhead is to follow longitudinal positions of transverse web frames where the corrections to hull girder vertical shear forces are applied in accordance with [4.4.7]
- d) the aspect ratio of the mesh in the corrugation is not to exceed 2 with a minimum of 2 elements for the flange breadth and the web height
- e) where difficulty occurs in matching the mesh on the corrugations directly with the mesh on the stool, it is acceptable to adjust the mesh on the stool in way of the corrugations
- f) for a corrugated bulkhead without an upper stool and/or lower stool, it may be necessary to adjust the geometry in the model. The adjustment is to be made such that the shape and position of the corrugations and primary supporting members are retained. Hence, the adjustment is to be made on stiffeners and plate seams if necessary
- g) when corrugated bulkhead is subjected to liquid cargo or ballast, dummy rod elements with a cross sectional area of 1 mm² are to be modeled at the corrugation knuckle between the flange and the web. Dummy rod elements are to be used as minimum at the two corrugation knuckles closest to the intersection between:
 - transverse and longitudinal bulkheads
 - transverse bulkhead and inner hull
 - transverse bulkhead and side shell.
- h) manholes in diaphragms are to be modeled according to [2.4.9].

2.4.5 Examples of mesh arrangement of the cargo hold structure are shown in Fig 10 to Fig 13.

2.4.6 Sniped stiffener

Non continuous stiffeners are to be modeled as continuous stiffeners, i.e. the height web reduction in way of the sniped ends are not to be modeled.

2.4.7 Web stiffeners of primary supporting members

Web stiffeners of primary supporting members are to be modeled. Where these stiffeners are not in line with the primary FE mesh, it is sufficient to place the line element along the nearby nodal points, provided that the adjusted distance does not exceed 0,2 times the stiffener spacing under consideration. The stresses and buckling utilisation factors obtained need not be corrected for the adjustment. Buckling stiffeners on large brackets, deck transverses and stringers parallel to the flange are to be modeled. These stiffeners may be modeled using rod elements.

Figure 10 : Example of FE cargo hold structure mesh arrangements for a container ship

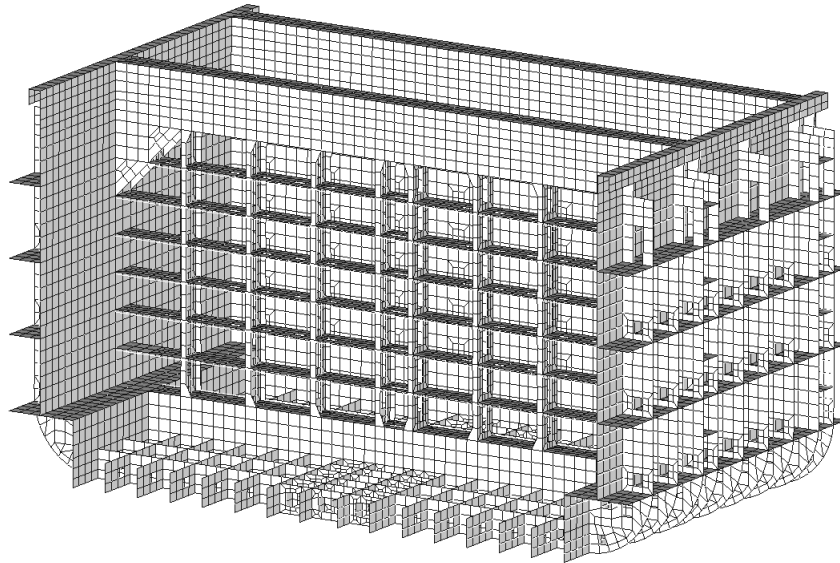


Figure 11 : Example of FE mesh arrangements of cargo hold structure for a bulk carrier

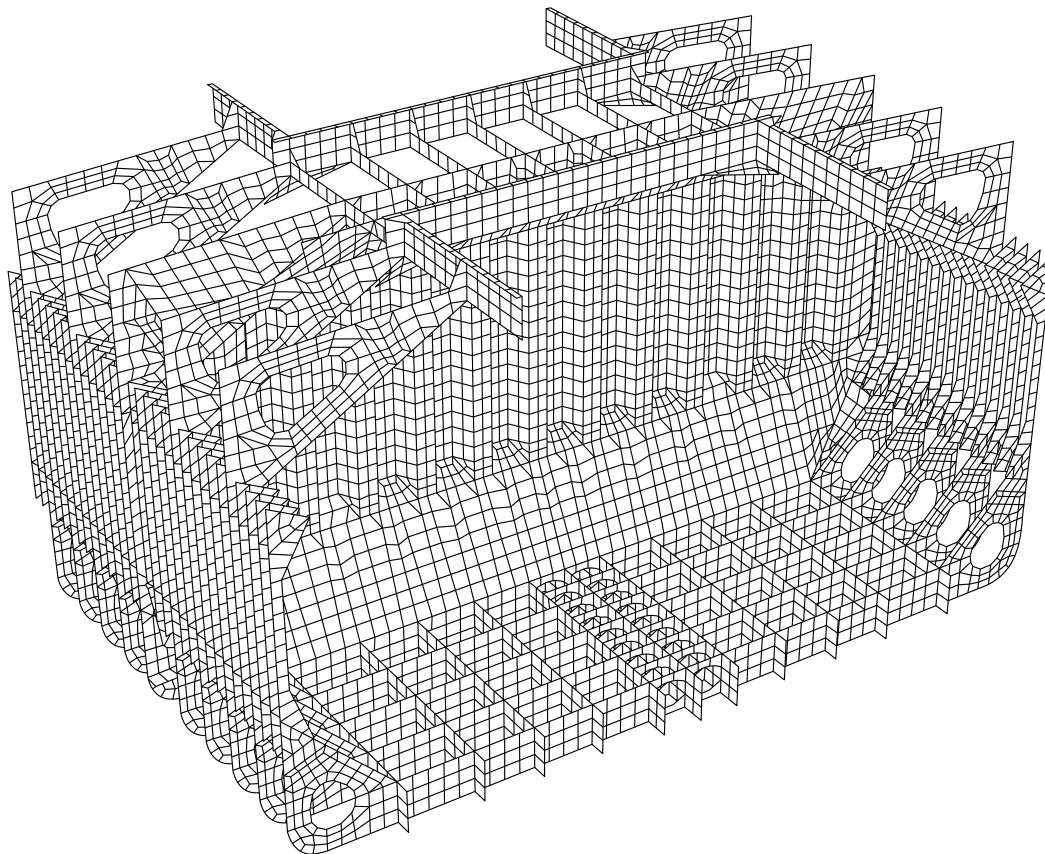


Figure 12 : Example of FE mesh on transverse corrugated bulkhead structure

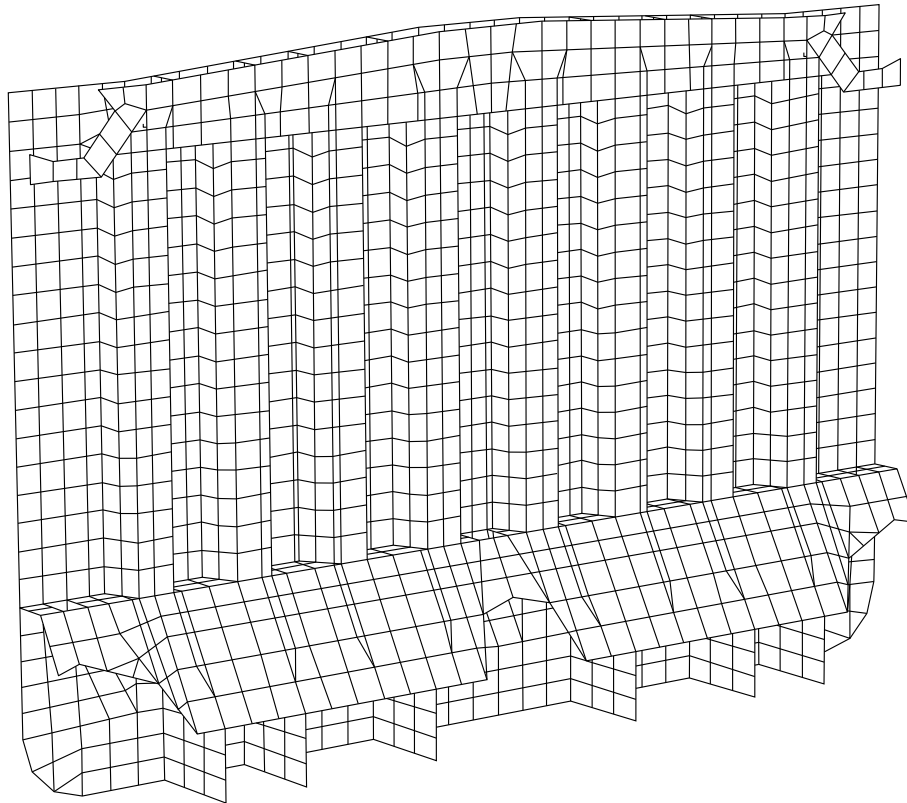
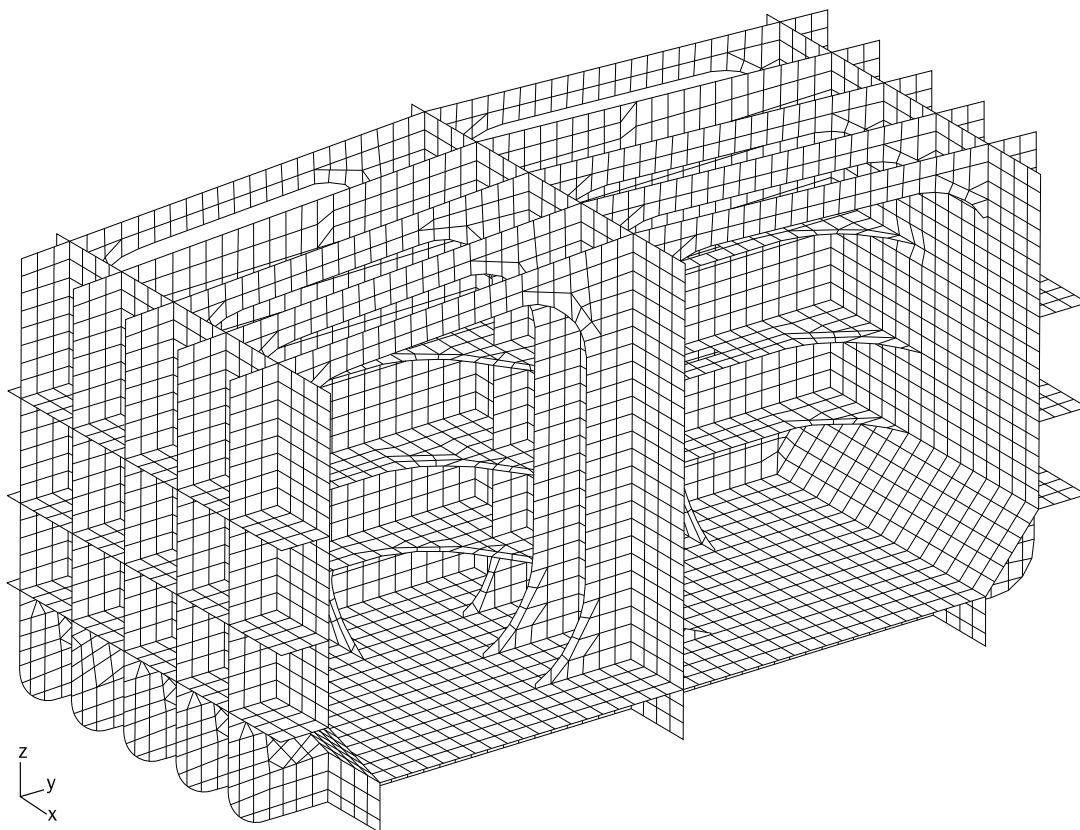


Figure 13 : Example of FE mesh arrangements of cargo tank structure for an aframax tanker



2.4.8 Face plate of primary supporting member

The effective cross-sectional area at the curved part of the face plate of primary supporting members and brackets is to be calculated in accordance with Ch 4, Sec 6. The cross-sectional area of a rod or beam element representing the tapering part of the face plate is to be based on the average cross-sectional area of the face plate in way of the element length.

2.4.9 Openings

Methods of representing openings and manholes in webs of primary supporting members are to be in accordance with Tab 1. Regardless of size, manholes are to be modeled by removing the appropriate elements.

Figure 14 : Openings in web

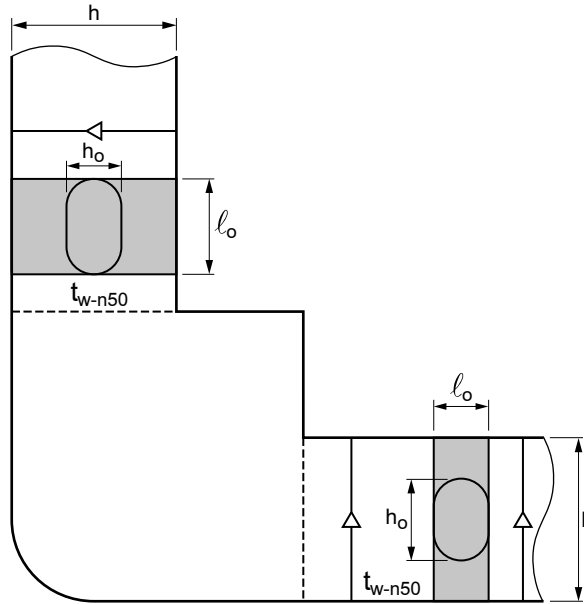


Figure 15 : Length l_o for sequential openings with $d_o < h/4$

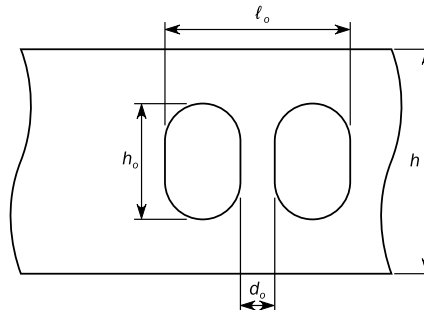


Table 1 : Representation of openings in primary supporting member webs

Criteria	Modeling decision	Analysis
$h_o/h < 0,5$ and $g_o < 2,0$	Openings do not need to be modeled	–
Manholes	The geometry of the opening is to be modeled by removing the adequate elements	To be evaluated by fine mesh if listed in Ch 8, App 2, [1.2.1]
$h_o/h \geq 0,5$ or $g_o \geq 2,0$	The geometry of the opening is to be modeled	

Note 1:

$$g_o = \left(1 + \frac{l_o^2}{2,6(h - h_o)^2} \right)$$

- l_o : Length, in m, of the opening parallel to the primary supporting member web direction, see Fig 14. For sequential openings where the distance d_o between openings is less than $(0,25 h)$, l_o is to be taken as the length across openings, as shown in Fig 15
- h_o : Height of the opening parallel to the web depth, in m, see Fig 14 and Fig 15
- h : Web height of the primary supporting member in way of the opening, in m, see Fig 14 and Fig 15.

2.5 Boundary conditions

2.5.1 General

All boundary conditions described in this Section are in accordance with the global coordinate system defined in Ch 5, Sec 1.

2.5.2 Application

The boundary conditions given in [2.5.3] are applicable to cargo hold finite element model analyses in cargo hold region.

2.5.3 Boundary conditions

The boundary conditions consist of rigid links, point constraints and end-beams at model ends. The rigid links connect the nodes on the longitudinal members at the model ends to an independent point at neutral axis in centreline.

The boundary conditions to be applied at the ends of the cargo hold FE model are given in Tab 2, except for the foremost cargo hold model, for which they are given in Tab 3.

Table 2 : Boundary constraints at model ends except the foremost cargo hold model

Location	Translation			Rotation		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Independent point(1) at aft end	–	fix	fix	M_{T-end}	–	–
Independent point(1) at fore end	–	fix	fix	fix	–	–
Intersection of centerline and inner bottom (1) at fore end	fix	–	–	–	–	–
Cross section at both ends	–	rigid link	rigid link	rigid link	–	–
	End beam, see [2.5.4]					

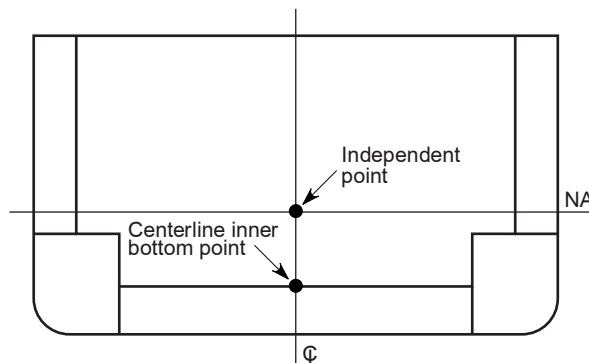
Note 1: [–] means no constraint applied (free).
(1) See Fig 16.

Table 3 : Boundary constraints at model ends of the foremost cargo hold model

Location	Translation			Rotation		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Independent point (1) at aft end	–	fix	fix	fix	–	–
Intersection of centerline and inner bottom (1) at aft end	fix	–	–	–	–	–
Independent point (1) at fore end	–	fix	fix	M_{T-end}	–	–
Cross section at aft end	–	rigid link	rigid link	rigid link	–	–
	End beam, see [2.5.4]					
Cross section at fore end	–	rigid link	rigid link	rigid link	–	–

Note 1: [–] means no constraint applied (free).
Note 2: The fore end constraints are to be located at the most forward reinforced ring or web frame which remains continuous from the base line to the strength deck.
(1) See Fig 16.

Figure 16 : Boundary conditions applied at the model end sections



NA : neutral axis of the model end sections

2.5.4 End constraint beams

End constraint beams are to be modeled at both end sections of the model along all longitudinally continuous structural members and along the cross deck plating of ships with large deck openings. An example of end beams at one end for a double hull bulk carrier is shown in Fig 17.

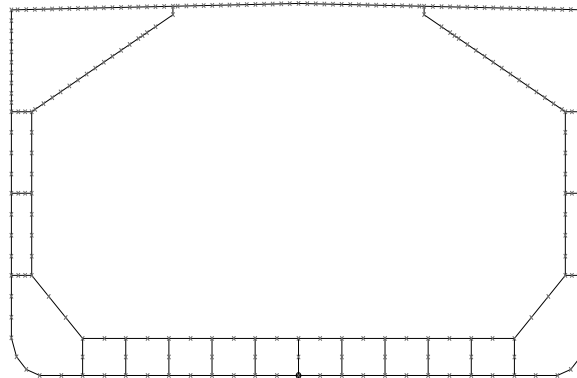
The properties of beams are calculated at fore and after sections separately and all beams at each end section have identical properties as follows:

- Net moment of inertia: $I_{yy-n50} = I_{zz-n50} = I_{xx-n50} (J) = 1/25$ of the vertical hull girder moment of inertia of fore/aft end cross sections based on the net FE model
- Net cross sectional area: A_{y-n50} and $A_{z-n50} = 1/80$ of the fore/aft end cross sectional areas based on the net FE model.

where:

- I_{yy-n50} : Moment of inertia about local beam Y axial, in m^4
- I_{zz-n50} : Moment of inertia about local beam Z axial, in m^4
- $I_{xx-n50} (J)$: Torsional inertia, in m .
- A_{y-n50} : Shear area in local beam Y direction, in m^2
- A_{z-n50} : Shear area in local beam Z direction, in m^2 .

Figure 17 : End constraint beams



3 FE load combinations

3.1 Design load combinations

3.1.1 FE load combination definition

A FE load combination is defined as a loading pattern, a draught, a roll radius of gyration, a metacentric height, a value of still water bending moment and of still water shear force, associated with a given dynamic load case.

3.1.2 Mandatory load combinations

For cargo hold structural strength analysis, the design load combinations specified in the applicable Part D or Part E chapter are to be used for the considered ship type and cargo hold regions.

Each load combination requires the application of the structural weight, internal and external loads and hull girder loads. For seagoing condition, both static and dynamic load components are applied. For tank testing and flooding condition, only the static load components are applied.

3.1.3 Additional loading conditions

Where the loading conditions specified by the designer are not covered by the load combinations given the applicable Part D or Part E chapter, these additional loading conditions are to be examined according to the procedure in [4].

4 Load application

4.1 General

4.1.1 Structural weight

Effect of the weight of hull structure is to be included in the static loads, but is not to be included in the dynamic loads. Density of steel is to be taken as given in Ch 5, Sec 6.

4.1.2 Sign convention

Unless otherwise mentioned in this Section, the sign of the moments and shear forces is to be in accordance with the sign convention defined in Ch 5, Sec 1.

4.2 External and internal loads

4.2.1 External loads

The external pressures are to be calculated for each load case in accordance with Ch 5, Sec 5. They include static sea pressure, wave pressure and green sea pressure.

The effect of the hatch cover self weight is to be ignored in the loads applied to the ship structure.

4.2.2 Internal loads

The internal loads are to be calculated for each load case in accordance with Ch 5, Sec 6 for design load scenarios given in Ch 5, Sec 7, Tab 1. They include static dry and liquid cargo (including containers on deck if any), ballast and other liquid pressure, setting pressure on relief valve and dynamic pressure of dry and liquid cargo (including containers on deck if any), ballast and other liquid pressure due to acceleration.

4.2.3 Pressure application on FE element

A constant pressure, calculated at the element's centroid, is applied to the shell element of the loaded surfaces, e.g. outer shell and deck for the external pressure and tank/hold boundaries for the internal pressure. Alternately, the pressure can be calculated at the element nodes applying linear pressure distribution within the elements.

4.3 Hull girder loads

4.3.1 General

Each loading condition is to be associated with the corresponding hull girder loads to be applied to the model according to the procedure described in [4.4] for shear force and bending moment and in [4.5] for torsional moment.

The hull girder loads are the combinations of the still water hull girder loads and the wave induced hull girder loads as specified in Ch 5, Sec 8.

For each required FE load combination:

- the combination between still water bending moment and still water shear force may be adjusted by the use of relevant coefficients, in line with the loading manual and to the satisfaction of the Society
- the wave induced hull girder loads are to be calculated with the load combination factors (LCFs) specified in Ch 5, Sec 2.

4.3.2 Target hull girder vertical bending moment

The target hull girder vertical bending moment M_{v-targ} , in kN-m, at a longitudinal position for a given FE load combination, is taken as: $M_{v-targ} = M_{sw} + M_{wv-LC}$

where:

M_{sw} : Maximum and minimum permissible vertical still water bending moments at the considered longitudinal position, in seagoing conditions, in kN-m, as defined in Ch 5, Sec 4

M_{wv-LC} : Vertical wave bending moment, in kN-m, for the dynamic load case under consideration, calculated in accordance with Ch 5, Sec 4, [3.6.1].

Within the midship cargo hold region, the value of M_{v-targ} is taken as the maximum hull girder bending moment within the mid-hold, for each given FE load combination.

Outside the midship cargo hold region, the values of M_{v-targ} are taken at all web frames and transverse bulkhead positions of the FE model under consideration.

4.3.3 Target hull girder vertical shear forces

The target hull girder vertical shear forces $Q_{targ-aft}$ and $Q_{targ-fwd}$ at the aft and forward transverse bulkheads of the mid-hold, in kN, for a given FE load combination, are taken as:

- if $Q_{fwd} \geq Q_{aft}$:

$$Q_{targ-aft} = Q_{sw-aft} - \Delta Q_{sw-aft} + |C_{QV}| Q_{wv-neg}$$

$$Q_{targ-fwd} = Q_{sw-fwd} + \Delta Q_{sw-fwd} + |C_{QV}| Q_{wv-pos}$$
- if $Q_{fwd} < Q_{aft}$:

$$Q_{targ-aft} = Q_{sw-aft} + \Delta Q_{sw-aft} + |C_{QV}| Q_{wv-pos}$$

$$Q_{targ-fwd} = Q_{sw-fwd} - \Delta Q_{sw-fwd} + |C_{QV}| Q_{wv-neg}$$

where:

Q_{fwd} , Q_{aft} : Vertical shear forces, in kN, due to the local loads, respectively at the forward and aft bulkhead positions of the mid-hold, as defined in [4.4.6]

Q_{sw-aft} , Q_{sw-fwd} : Aft and forward permissible still water shear forces, in kN, at any longitudinal position for seagoing conditions as defined in Ch 5, Sec 4

C_{QV} : Load combination factor for vertical wave shear force, as given in Ch 5, Sec 2

Q_{wv-pos} , Q_{wv-neg} : Positive and negative vertical wave shear forces, in kN, as defined in Ch 5, Sec 4, [3.2.1].

ΔQ_{sw-fwd} : Shear force correction, in kN, for the considered FE loading pattern at the forward bulkhead taken as:

- For bulk carriers and ore carriers:

Minimum of the absolute values of ΔQ_{md-fwd} as defined in [4.3.4] calculated at forward bulkhead for the mid-hold and the value calculated at aft bulkhead of the forward cargo hold taken as:

$$\Delta Q_{sw-fwd} = \text{Min}(|\Delta Q_{md-fwd}|_{Mid}, |\Delta Q_{md-fwd}|_{Fwd})$$

- For other ships:

$$\Delta Q_{sw-fwd} = 0$$

ΔQ_{sw-aft} : Shear force correction, in kN, for the considered FE loading pattern at the aft bulkhead taken as:

- For bulk carriers and ore carriers:

Minimum of the absolute values of ΔQ_{md-fwd} as defined in [4.3.4] calculated at aft bulkhead for the mid-hold and the value calculated at forward bulkhead of the aft cargo hold taken as:

$$\Delta Q_{sw-aft} = \text{Min}(|\Delta Q_{md-fwd}|_{Mid}, |\Delta Q_{md-fwd}|_{Aft})$$

- For other ships:

$$\Delta Q_{sw-aft} = 0$$

The values of $Q_{\text{targ-aft}}$ and $Q_{\text{targ-fwd}}$ are to be taken at the aft and forward transverse bulkheads of the mid-hold under consideration.

4.3.4 Shear force correction for bulk carriers and ore carriers

For bulk carriers and ore carriers, shear force correction, which takes into account the portion of loads transmitted by the double bottom longitudinal girders to the transverse bulkheads, is to be considered.

For the considered cargo hold, the shear force correction at the considered transverse section is to be obtained, in kN, from the following formula:

$$\Delta Q_{md-fwd} = C_d \alpha \left(\frac{M}{B_H \ell_H} - \rho T_{LC, mh} \right)$$

where:

C_d : Distribution coefficient taken as:

- $C_d = -1$ at the aft end of the considered cargo hold except for aftmost cargo hold
- $C_d = 1$ at the fore end of the considered cargo hold except for foremost cargo hold
- $C_d = 0$ at mid-length of the cargo hold
- $C_d = 0$ at the aft bulkhead of the aftmost cargo hold
- $C_d = 0$ at the fore bulkhead of the foremost cargo hold
- C_d : Linearly distributed at other locations

α : Coefficient taken as:

$$\alpha = g \frac{\ell_o b_o}{2 + \varphi \frac{\ell_o}{b_o}}$$

M : Mass, in t, in the hold in way of the considered transverse section for the considered loading condition. M is to include the mass of ballast water and fuel oil located directly below the flat portion of the inner bottom, if any, excluding the portion under the bulkhead stool

φ : Coefficient taken as:

$$\varphi = 1,38 + 1,55 \frac{\ell_o}{b_o}$$

without being taken greater than 3,7

B_H : Breadth of the cargo hold, in m, as defined in Ch 5, Sec 6

ℓ_H : Length of the cargo hold, in m, as defined in Ch 5, Sec 6

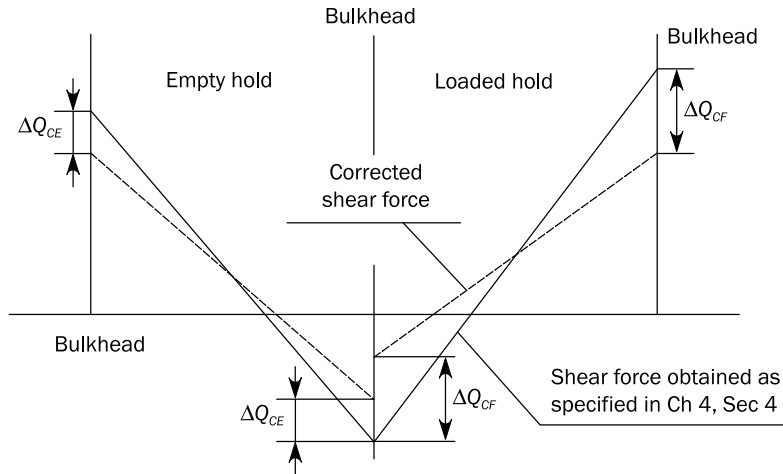
ℓ_o, b_o : Length and breadth, respectively, in m, of the flat portion of the double bottom in way of the hold considered; b_o is to be measured on the hull transverse section at the middle of the hold

$T_{LC, mh}$: Draught, in m, measured vertically on the hull transverse section at the middle of the hold considered, from the moulded baseline to the waterline in the loading condition considered

ΔQ_{CF} : Shear force correction for the full hold (see Fig 18)

ΔQ_{CE} : Shear force correction for the empty hold (see Fig 18).

Figure 18 : Shear force correction, ΔQ_c



4.3.5 Target hull girder horizontal bending moment

The target hull girder horizontal bending moment M_{h-targ} , in kN·m, for a given FE load combination is taken as:

$$M_{h-targ} = M_{wh-LC}$$

where:

M_{wh-LC} : Horizontal wave bending moment, in kN·m, for the dynamic load case under consideration, calculated in accordance with Ch 5, Sec 4, [3.6.3].

Within the midship cargo hold region, the value of M_{wh-LC} is taken as the maximum hull girder bending moment within the mid-hold(s) for each individual cargo hold for each given FE load combination.

Outside the midship cargo hold region, the values of M_{wh-LC} are taken at all web frames and transverse bulkhead positions of the FE model under consideration.

4.3.6 Target hull girder torsional moment

For ships with large deck openings only, the target hull girder torsional moment, $M_{wt-targ}$ in kNm, for the dynamic load cases OHM, OHS and OVA is the value at the target location taken as:

$$M_{wt-targ} = M_{wt-LC}(x_{targ})$$

where:

$M_{wt-LC}(x)$: Wave torsional moment, in kNm, for the dynamic load cases OHM, OHS and OVA, defined in Ch 5, Sec 4, [3.6.5], calculated at x position

x_{targ} : Target location for hull girder torsional moment taken as:

- For midship cargo hold region:
 - If $x_{mid} \leq 0,5 L$: after bulkhead of the mid-hold
 - If $x_{mid} > 0,5 L$: forward bulkhead of the mid-hold

- Outside midship cargo hold region:

The transverse bulkhead of mid-hold where the following formula is minimum:

$$\frac{M_{wt-LC}(x_{bhd})}{|M_{wt-LC}(x_{bhd})|} \cdot [M_{wt-LC}(x_{bhd}) - M_{T-FEM}(x_{bhd})]$$

x_{mid} : X-coordinate, in m, of the mid-hold centre

x_{bhd} : X-coordinate, in m, of the after or forward transverse bulkhead of mid-hold.

For dynamic load cases of ships with large deck openings other than OHM, OHS and OVA and for all dynamic load cases of other types of ships, the hull girder torsional moment $M_{wt-targ}$ at middle of mid-hold is to be adjusted to zero.

4.4 Procedure to adjust hull girder shear forces and bending moments

4.4.1 General

The procedure given in this sub-article describes how to adjust the hull girder horizontal bending moment, vertical shear force and vertical bending moment distribution on the three cargo hold FE model, in order to achieve the required target values defined in [4.3] at the following target locations:

- at the transverse bulkheads of the mid-hold for vertical shear force
- at the centre of the mid-hold, in general, for hull girder bending moments.

The final adjusted loads at the target location should not exceed the target loads.

4.4.2 Local load distribution

The following local loads are to be applied:

- ship structural steel weight distribution over the length of the cargo hold model (static loads)
- static sea pressure, dynamic wave pressure and, where applicable, green sea load
- weight of cargo/containers, ballast and fuel oil (static loads)
- dynamic loads for cargo/containers, ballast and fuel oil in seagoing operation.

The 3D nodal forces obtained by applying the above local loads to the FE model are lumped to each longitudinal station, in order to generate the one dimension local load distribution.

The longitudinal stations are located at transverse bulkheads/frames and typical nodal locations in between the frames according to the cargo hold model mesh size requirement.

Any intermediate nodes created for modeling structural details are not treated as longitudinal stations for the purpose of local load distribution.

The nodal forces are to be lumped to the nearest longitudinal station, the lumping process being done separately for vertical and horizontal nodal forces in order to obtain both vertical and horizontal local loads f_{vi} and f_{hi} at each longitudinal station i .

4.4.3 Hull girder forces and bending moments due to local loads

The model is considered simply supported at both ends. The reaction forces at model ends and the hull girder shear forces and bending moments induced by local loads at any longitudinal station are determined by the following formulae:

$$R_{V_fore} = - \frac{\sum_i (X_i - X_{aft}) f_{vi}}{X_{fore} - X_{aft}}$$

$$R_{V_aft} = \sum_i f_{vi} + R_{V_fore}$$

$$R_{H_fore} = \frac{\sum_i (X_i - X_{aft}) f_{hi}}{X_{fore} - X_{aft}}$$

$$R_{H_aft} = -\sum_i f_{hi} + R_{H_fore}$$

$$F_l = \sum_i f_{li}$$

and, when $x_i < x_j$:

$$Q_{V_FEM}(x_j) = R_{V_aft} - \sum_i f_{vi}$$

$$Q_{H_FEM}(x_j) = R_{H_aft} + \sum_i f_{hi}$$

$$M_{V_FEM}(x_j) = (x_j - X_{aft}) R_{V_aft} - \sum_i (x_j - x_i) f_{vi}$$

$$M_{H_FEM}(x_j) = (x_j - X_{aft}) R_{H_aft} + \sum_i (x_j - x_i) f_{hi}$$

where:

R_{V_aft} , R_{V_fore} , R_{H_aft} , R_{H_fore} : Vertical and horizontal reaction forces at the aft and fore ends, in kN

X_{aft} : X-coordinate of the aft end support, in m

X_{fore} : X-coordinate of the fore end support, in m

f_{vi} : Lumped vertical local load at longitudinal station i , in kN, as defined in [4.4.2]

f_{hi} : Lumped horizontal local load at longitudinal station i , in kN, as defined in [4.4.2]

F_l : Total longitudinal force of the model, in kN

f_{li} : Lumped longitudinal local load at longitudinal station i , in kN, as defined in [4.4.2]

x_j : X-coordinate, in m, of the considered longitudinal station j

x_i : X-coordinate, in m, of longitudinal station i

$Q_{V_FEM}(x_j)$, $Q_{H_FEM}(x_j)$, $M_{V_FEM}(x_j)$, $M_{H_FEM}(x_j)$: Vertical and horizontal shear forces, in kN, and bending moments, in kN·m, at longitudinal station x_j created by the local loads applied on the FE model. According to the sign convention, positive reaction forces create a positive shear force.

4.4.4 Longitudinal unbalanced force

In case the total longitudinal force of the model F_1 is not equal to zero, the counter longitudinal force $(F_x)_j$ is to be applied at the model end where the translation in X-direction δ_x is fixed. $(F_x)_j$ is to be distributed among all the bending effective hull girder longitudinal elements, as follows:

$$(F_x)_j = \frac{F_1}{A_{x-n50}} \frac{A_{j-n50}}{n_j}$$

where:

- $(F_x)_j$: Axial force, in kN, applied to a node of the j-th element
- F_1 : Total longitudinal force of the model, in kN, as defined in [4.4.3]
- A_{j-n50} : Net cross-sectional area of the j-th element, in m²
- A_{x-n50} : Net cross-sectional area of the fore end section, in m²:

$$A_{x-n50} = \sum_j A_{j-n50}$$

- n_j : Number of nodal points of the j-th element on the cross-section:
 - $n_j = 1$ for beam element
 - $n_j = 2$ for 4-node shell element.

4.4.5 Hull girder shear force adjustment procedure

The hull girder shear force adjustment procedure defined in this requirement applies to all the FE load combinations. The FE load combinations not directly covered by the applicable Part D or Part E chapter are to be considered on a case-by-case basis.

The two following methods are used for shear force adjustment:

- method 1 (M1): shear force adjustment at one of the mid-hold bulkheads, as given in [4.4.6]
- method 2 (M2): shear force adjustment at both mid-hold bulkheads, as given in [4.4.7]

The method to be applied for one given FE load combination is to be selected as follows:

- no shear force adjustment is requested when the shear forces at both bulkheads are lower than, or equal to, the target values. This applies to cargo hold analysis in whole cargo area except for aft most and foremost cargo hold.

For aft most and foremost cargo hold analyses, the shear force adjustment is to be applied with method 1. The target hull girder vertical shear force at the aft and forward transverse bulkheads, $Q_{\text{targ-aft}}$ and $Q_{\text{targ-fwd}}$ are to be set to values of vertical shear force due to local loads Q_{aft} and Q_{fwd} accordingly:

$$Q_{\text{targ-fwd}} = Q_{\text{fwd}}$$

$$Q_{\text{targ-aft}} = Q_{\text{aft}}$$

- method 1 applies when the shear force exceeds the target value at one bulkhead. At the other bulkhead, the shear force adjusted according to method 1 is not to exceed the target value, otherwise method 2 is to be applied
- method 2 applies when the shear forces exceed the target values at both bulkheads.

4.4.6 Method 1 for vertical shear force adjustment at one bulkhead

The required adjustments in shear force at aft or forward transverse bulkhead of the mid-hold are to be made by applying vertical bending moments, $M_{y_{\text{aft}}}$, $M_{y_{\text{fore}}}$ at model ends. For aft most cargo and foremost cargo hold models, the following additional vertical loads are to be applied at the transverse frame positions as shown in Tab 7:

- for aft most cargo hold model: $\delta w'_1$
- for foremost cargo hold model: $\delta w'_3$

The required adjustments in shear force at mid-hold aft and forward bulkheads are given by:

- aft bulkhead:

$$M_{y_{\text{aft}}} = M_{y_{\text{fore}}} = \frac{(X_{\text{fore}} - X_{\text{aft}})}{2} (Q_{\text{targ-aft}} - Q_{\text{aft}}) - M'_{1-\text{aft}}$$

$$\Delta Q_{\text{aft}} = \Delta Q_{\text{fwd}} = 0$$

- for aftmost cargo hold model only:

$$\delta w'_1 = \frac{Q_{\text{targ-aft}} - Q_{\text{aft}} + R_{y_{\text{aft}}}}{(n_1 - 1)}$$

- for foremost cargo hold model only:

$$\delta w'_3 = \frac{Q_{\text{targ-aft}} - Q_{\text{aft}} + R_{y_{\text{fore}}}}{(n_3 - 1)}$$

- forward bulkhead:

$$M_{y_{\text{aft}}} = M_{y_{\text{fore}}} = \frac{(X_{\text{fore}} - X_{\text{aft}})}{2} (Q_{\text{targ-fwd}} - Q_{\text{fwd}}) - M'_{1-\text{fwd}}$$

$$\Delta Q_{aft} = \Delta Q_{fwd} = 0$$

- for aftmost cargo hold model only:

$$\delta w'_1 = \frac{Q_{targ-fwd} - Q_{fwd} + R_{v-aft}}{(n_1 - 1)}$$

- for foremost cargo hold model only:

$$\delta w'_3 = \frac{Q_{targ-fwd} - Q_{fwd} + R_{v-fore}}{(n_3 - 1)}$$

where:

M_{Y_aft} , M_{Y_fore} : Vertical bending moments, in kN·m, to be applied at the aft and fore ends in accordance with [4.4.10], in order to enforce the hull girder vertical shear force adjustment as shown in Tab 4. The sign convention is that of the FE model.

Q_{aft} : Vertical shear force, in kN, due to the local loads at mid-hold aft bulkhead location x_{b_aft} resulting from the local loads calculated according to [4.4.3]

Since the vertical shear force is discontinued at the transverse bulkhead location, Q_{aft} is the maximum absolute shear force between the stations located right after and right forward the mid-hold aft bulkhead

Q_{fwd} : Vertical shear force, in kN, due to the local loads at mid-hold forward bulkhead location x_{b_fwd} resulting from the local loads calculated according to [4.4.3]

Since the vertical shear force is discontinued at the transverse bulkhead location, Q_{fwd} is the maximum absolute shear force between the stations located right after and right forward the mid-hold forward bulkhead.

M'_{1-aft} , M'_{1-fwd} : Additional vertical bending moment, in kNm, applicable for aftmost and foremost cargo hold analysis only, taken as:

- aft most cargo hold model:

$$M'_{1-aft} = \frac{\ell_1}{4}(Q_{targ-aft} - Q_{aft} + R_{v-aft})$$

$$M'_{1-fwd} = \frac{\ell_1}{4}(Q_{targ-fwd} - Q_{fwd} + R_{v-aft})$$

- foremost cargo hold model:

$$M'_{1-aft} = \frac{\ell_3}{4}(Q_{targ-aft} - Q_{aft} + R_{v-fore})$$

$$M'_{1-fwd} = \frac{\ell_3}{4}(Q_{targ-fwd} - Q_{fwd} + R_{v-fore})$$

$\delta w'_1$: Distributed load, in kN, at frame in the modelled engine room of aftmost cargo hold model, see also Tab 7

$\delta w'_3$: Distributed load, in kN, at frame in the modelled forepeak of foremost cargo hold model, see also Tab 7

ΔQ_{aft} , ΔQ_{fwd} : Shear force adjustments, as given in Tab 7

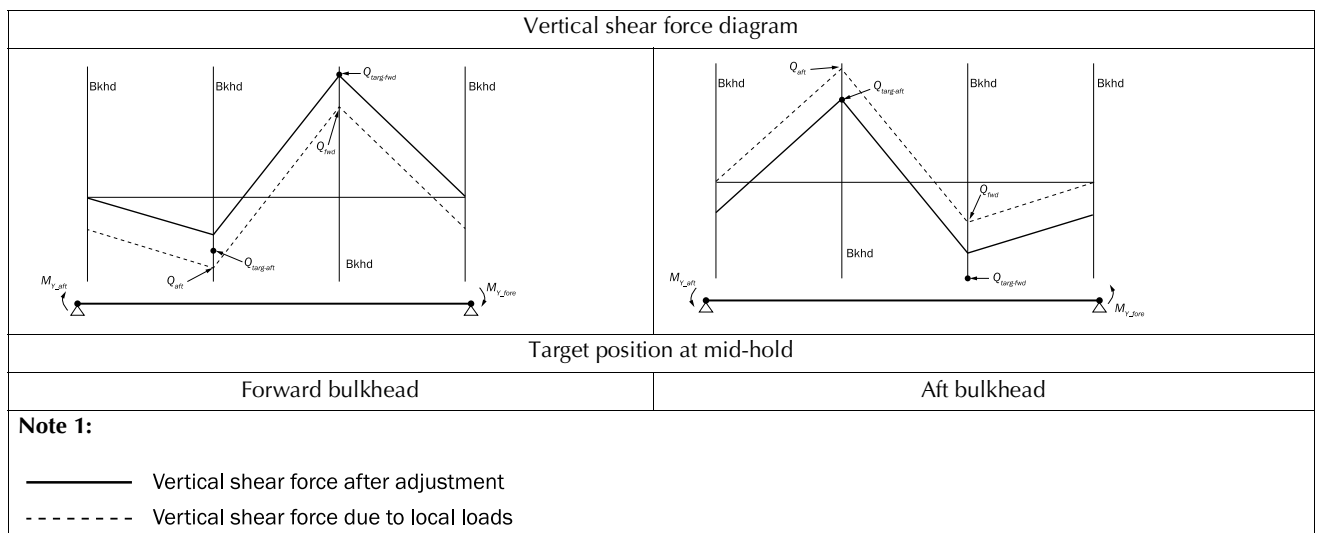
R_{v_aft} , R_{v_fore} : Reaction forces at the aft and fore end, in kN, as defined in [4.4.3]

ℓ_1 : Length of the modelled engine room in aftmost cargo hold model, in m. (see also Tab 7)

ℓ_3 : Length of the modelled forepeak in foremost cargo hold model, in m. (see also Tab 7)

n_1 , n_3 : Number of frame spaces (see also Tab 7)

Table 4 : Vertical shear force adjustment by application of vertical bending moments M_{Y_aft} and M_{Y_fore} for method



4.4.7 Method 2 for vertical shear force adjustment at both bulkheads

The required adjustments in shear force at both mid-hold transverse bulkheads are to be made by applying:

- vertical bending moments M_{Y_aft} and M_{Y_fore} at model ends, and
- vertical loads at the transverse frame positions as shown in Tab 6, in order to generate vertical shear forces ΔQ_{aft} and ΔQ_{fwd} at the transverse bulkhead positions.
- for aft most cargo and foremost cargo hold models, the following additional vertical loads are to be applied at the transverse frame positions as shown in Tab 6:
 - for aft most cargo hold model: $\delta w'_1$
 - for foremost cargo hold model: $\delta w'_3$

Tab 5 shows application examples of the shear force adjustment by means of vertical bending moments and vertical loads.

$$M_{Y_aft} = M_{Y_fore} = \frac{(x_{fore} - x_{aft})(Q_{targ-fwd} - Q_{fwd} + Q_{targ-aft} - Q_{aft})}{2} - M'_2$$

$$M_{Y_fore} = M_{Y_aft}$$

$$\Delta Q_{fwd} = \frac{Q_{targ-fwd} - Q_{fwd} - (Q_{targ-aft} - Q_{aft})}{2}$$

$$\Delta Q_{aft} = -\Delta Q_{fwd}$$

For aft most cargo hold model:

$$\delta w'_1 = \frac{[(Q_{targ-aft} - Q_{aft})(\ell - \ell_2 - \ell_1) + (Q_{targ-fwd} - Q_{fwd})(\ell - \ell_2 - \ell_3) + R_{Vaft}]}{2\ell - \ell_1 - 2\ell_2 - \ell_3} \cdot \frac{1}{n_1 - 1}$$

For foremost cargo hold model:

$$\delta w'_3 = \frac{[(Q_{targ-fwd} - Q_{fwd})(\ell - \ell_2 - \ell_3) + (Q_{targ-aft} - Q_{aft})(\ell - \ell_2 - \ell_1) + R_{Vfore}]}{2\ell - \ell_1 - 2\ell_2 - \ell_3} \cdot \frac{1}{n_3 - 1}$$

where:

M_{Y_aft} , M_{Y_fore} : Vertical bending moments, in kN·m, to be applied at the aft and fore ends in accordance with [4.4.10], in order to enforce the hull girder vertical shear force adjustment. The sign convention is that of the FE model

ΔQ_{aft} : Shear force adjustment, in kN, at mid-hold aft bulkhead

ΔQ_{fwd} : Shear force adjustment, in kN, at mid-hold forward bulkhead.

Table 5 : Target and required shear force adjustment by applying vertical forces

Vertical shear force diagram	Aft bulkhead	Forward bulkhead
	Target shear force	Target shear force
	$Q_{targ-aft} (-ve)$	$Q_{targ-fwd} (+ve)$
	$Q_{targ-aft} (+ve)$	$Q_{targ-fwd} (-ve)$
<p>Note 1: -ve means negative, +ve means positive.</p> <p>———— Vertical shear force after both adjustments</p> <p>----- Vertical shear force after adjustment by use of M_{Y_aft} and M_{Y_fore}</p> <p>..... Vertical shear force due to local loads</p>		

M'_2 : Additional vertical bending moment, in kNm, applicable for aftmost and foremost cargo hold analysis only, taken as:

- aftmost cargo hold model

$$M'_2 = \frac{\ell_1(n_1-1)\delta w'_1}{4}$$

- foremost cargo hold model

$$M'_2 = \frac{\ell_3(n_3-1)\delta w'_3}{4}$$

$\delta w'_1$: Distributed load, in kN, at frame in the modelled engine room of aftmost cargo hold model, see also Tab 7

$\delta w'_3$: Distributed load, in kN, at frame in the modelled forepeak of foremost cargo hold model, see also Tab 7

R_{v_aft} , R_{v_fore} : Reaction forces at the aft and fore ends, in kN, as defined in [4.4.3]

ℓ_1 : Length of the modelled engine room in aftmost cargo hold model, in m. (see also Tab 7)

ℓ_3 : Length of the modelled forepeak in foremost cargo hold model, in m. (see also Tab 7)

n_1 , n_3 : Number of frame spaces (see also Tab 7)

The shear force adjustments ΔQ_{aft} and ΔQ_{fwd} are to be generated at transverse bulkhead positions by applying vertical loads at the transverse frame positions, as shown in Tab 6.

Vertical correction loads are not to be applied to any transverse tight bulkheads, any frames forward of the forward cargo hold nor any frames aft of the aft cargo hold of the FE model.

The vertical loads applied to each transverse frame in order to generate the increase/decrease in shear force at bulkheads may be calculated as shown in Tab 6.

In case of uniform frame spacing, the amount of vertical force to be distributed at each transverse frame may be calculated in accordance with Tab 7.

Where non-uniform frame spacing is used within a hold i , the average frame spacing ℓ_{av-i} is used to calculate the average frame load δw_{av-i} according to Tab 7. δw_{av-i} is then redistributed among the non-uniform frames, as follows:

$$\delta w_i^k = \delta w_{av-i} \frac{\ell_{av-i}^k}{\ell_{av-i}}$$

where:

$k = 1, 2, \dots, n_i-1$, for each frame in cargo hold i , with $i = 1, 2, 3$

ℓ_{av-i} : Average frame spacing, in m, equal to: $\ell_{av-i} = \ell_i / n_i$, in cargo hold i , with $i = 1, 2, 3$

ℓ_i : Length, in m, of the cargo hold i , with $i = 1, 2, 3$, as defined in Tab 7

n_i : Number of frame spacings in cargo hold i , with $i = 1, 2, 3$, as defined in Tab 7

δw_{av-i} : Average frame load calculated, according to Tab 7, with the average frame spacing ℓ_{av-i} in cargo hold i , with $i = 1, 2, 3$

δw_i^k : Distributed load, in kN, for non-uniform frame k in cargo hold i

ℓ_{av-i}^k : Equivalent frame spacing, in m, for each frame k , with $k = 1, 2, \dots, n_i-1$, in cargo hold i , taken equal to:

- for $k = 1$ (first frame), in cargo hold i :

$$\ell_{av-i}^k = \ell_i - \frac{\ell_{av-i} \ell_i^1}{\ell_i^1 + \ell_i^{n_i}} + \frac{\ell_i^2}{2}$$

- for $k = 2, 3, \dots, n_i-2$, in cargo hold i :

$$\ell_{av-i}^k = \frac{\ell_i^k}{2} + \frac{\ell_i^{k+1}}{2}$$

- for $k = n_i-1$ (last frame), in cargo hold i :

$$\ell_{av-i}^k = \ell_i - \frac{\ell_{av-i} \ell_i^{n_i}}{\ell_i^1 + \ell_i^{n_i}} + \frac{\ell_i^{n_i-1}}{2}$$

ℓ_i^k : Frame spacing, in m, between the frames $k-1$ and k , in the cargo hold i .

The vertical correction loads, δw_i for a uniform frame spacing or δw_i^k for a non-uniform frame spacing, are to be applied, following the shear flow distribution at the considered cross-section, as described in Ch 6, App 1. For a frame section under the vertical load δw_i , the shear flow q_f , at the middle point of the element, is calculated as follows:

$$q_{f-k} = \frac{\delta w_i}{I_{y-n50} \cdot 10^{12}} Q_{k-n50}$$

where:

q_{f-k} : Shear flow calculated at the middle of the k -th element of the transverse frame, in N/mm

δw_i : Distributed load at each transverse frame location, in N, for the i -th cargo hold ($i = 1, 2, 3$), as defined in Tab 7

Q_{k-n50} : First moment, about the neutral axis, of the accumulative section area starting from the open end (shear stress free end) of the cross-section to the point s_k for shear flow q_{f-k} , in mm^3 , taken as:

$$Q_{k-n50} = \int_0^{S_k} z_{neu} t_{n50} ds$$

z_{neu} : Vertical distance, in mm, from the integral point s to the vertical neutral axis

t_{n50} : Net thickness, in mm, of the plate at the integral point of the cross-section

The distributed shear force F_{j-grid} at the j -th FE grid of the transverse frame, in N, is obtained from the shear flow of the connected elements, as follows:

$$F_{j-grid} = \sum_{k=1}^n q_{t-k} \frac{\ell_k}{2}$$

where:

ℓ_k : Length, in mm, of the k -th element of the transverse frame connected to grid j

n : Total number of elements connected to grid j .

The shear flow has direction along the cross-section and therefore the distributed force F_{j-grid} is a vector force. For vertical hull girder shear correction, the vertical and horizontal force components calculated with the above mentioned shear flow method need to be applied to the cross-section.

4.4.8 Procedure to adjust vertical and horizontal bending moments for midship cargo hold region

In case the target vertical bending moment needs to be reached, an additional vertical bending moment M_{v-end} is to be applied at both FE model ends, according to [4.4.10], in order to generate this target value within the mid-hold. This additional vertical bending moment is to be taken, in kN·m, equal to:

$$M_{v-end} = M_{v-targ} - M_{v-peak}$$

where:

M_{v-targ} : Hogging (positive) or sagging (negative) vertical bending moment, in kN·m, as specified in [4.3.2]

M_{v-peak} : Maximum or minimum bending moment, in kN·m, within the mid-hold length induced by the local loads as described in [4.4.3] and the shear force adjustment as defined in [4.4.5].

M_{v-peak} is to be taken as the maximum bending moment if M_{v-targ} is hogging (positive) and as the minimum bending moment if M_{v-targ} is sagging (negative).

M_{v-peak} is to be calculated as follows, based on a simply supported beam model:

$$M_{v-peak} = \text{Extremum} \left\{ M_{V-FEM}(x) + M_{lineload} + M_{Y-aft} \left(2 \frac{x - X_{aft}}{X_{fore} - X_{aft}} - 1 \right) \right\}$$

$M_{V-FEM}(x)$: Vertical bending moment, in kN·m, at position x , induced by the local loads as described in [4.4.3]

M_{Y-aft} : Aft bending moment, in kN·m, to be taken equal to:

- when method 1 is applied: the value defined in [4.4.6]
- when method 2 is applied: the value defined in [4.4.7]
- otherwise: $M_{Y-aft} = 0$

$M_{lineload}$: Vertical bending moment, in kN·m, at position x , induced by the application of vertical loads at frames according to method 2, to be taken equal to:

$$M_{lineload} = -(x - X_{aft})F - \sum_i (x - x_i) \delta w_i \text{ when } x_i < x$$

F : Reaction force, in kN, at model ends induced by the application of vertical loads to frames as defined in Tab 6

x : X-coordinate, in m, of frame in way of the mid-hold

δw_i : Vertical load, in kN, at web frame station i applied to generate required shear force.

In case the target horizontal bending moment needs to be reached, an additional horizontal bending moment M_{h-end} is to be applied at both FE model ends, according to [4.4.10], in order to generate this target value within the mid-hold. The additional horizontal bending moment, in kN·m, is to be taken equal to: $M_{h-end} = M_{h-targ} - M_{h-peak}$

where:

M_{h-targ} : Horizontal bending moment, as defined in [4.3.5]

M_{h-peak} : Maximum or minimum horizontal bending moment, in kN·m, within the mid-hold length induced by the local loads described in [4.4.3].

M_{h-peak} is to be taken as the maximum horizontal bending moment if M_{h-targ} is positive (starboard side in tension) and as the minimum horizontal bending moment if M_{h-targ} is negative (port side in tension).

M_{h-peak} is to be calculated as follows, based on a simply supported beam model:

$$M_{h-peak} = \text{Extremum} \{ M_{H-FEM}(x) \}$$

$M_{H-FEM}(x)$: Horizontal bending moment, in kN·m, at position x , induced by the local loads as described in [4.4.3].

The vertical and horizontal bending moments are to be calculated over the mid-hold length in order to identify the position and value of each maximum/minimum bending moment.

Table 6 : Distribution of adjusting vertical force at frames and resulting shear force distributions

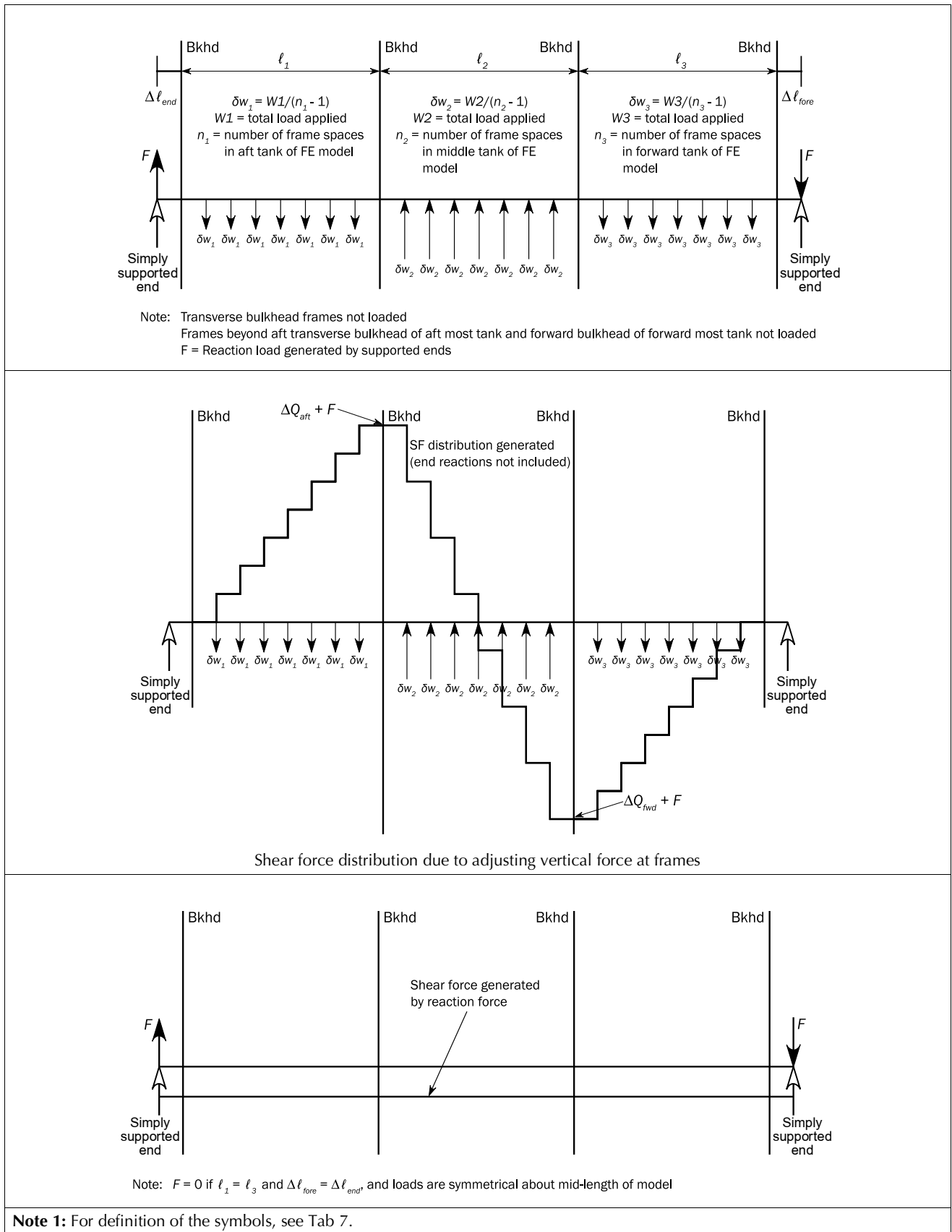


Table 7 : Formulae for calculation of vertical loads for adjusting vertical shear forces

δw_1	: Distributed load, in kN, at frame in the aft cargo hold of the FE model $\delta w_1 = \frac{\Delta Q_{aft} (2\ell - \ell_2 - \ell_3) + \Delta Q_{fwd} (\ell_2 + \ell_3)}{(n_1 - 1) (2\ell - \ell_1 - 2\ell_2 - \ell_3)} + \delta w'_1$
δw_2	: Distributed load, in kN, at frame in the mid-hold of the FE model $\delta w_2 = \frac{(W1 + W3)}{(n_2 - 1)} = \frac{(\Delta Q_{aft} - \Delta Q_{fwd})}{(n_2 - 1)}$
δw_3	: Distributed load, in kN, at frame in the forward cargo hold of the FE model $\delta w_3 = \frac{-\Delta Q_{fwd} (2\ell - \ell_1 - \ell_2) - \Delta Q_{aft} (\ell_1 + \ell_2)}{(n_3 - 1) (2\ell - \ell_1 - 2\ell_2 - \ell_3)} = \delta w'_3$
F	: End reactions, in kN, due to application of vertical loads to frames: <ul style="list-style-type: none"> In general $F = F_{aft} = F_{fwd} = 0,5 \left(\frac{W1 \ell_2 + \ell_1 - W3 \ell_2 + \ell_3}{\ell} \right)$ For aftmost and foremost cargo hold FE model $F = F_{aft} = \frac{W1(\Delta \ell_{fore} + \ell_3 + \ell_2 + 0,5\ell_1) + W2(\Delta \ell_{fore} + \ell_3 + 0,5\ell_2) + W3(\Delta \ell_{fore} + 0,5\ell_3)}{\ell}$
where:	
ΔQ_{aft}	: Required adjustment in shear force, in kN, at the aft bulkhead of the mid-hold, see [4.4.7]
ΔQ_{fwd}	: Required adjustment in shear force, in kN, at fore bulkhead of the mid-hold, see [4.4.7]
ℓ	: Total length, in m, of FE model including portions beyond end bulkheads: $\ell = \ell_1 + \ell_2 + \ell_3 + \Delta \ell_{end} + \Delta \ell_{fore}$
ℓ_1	: Length of the aft cargo hold of the model, in m
ℓ_2	: Length of the mid-hold of the model, in m
ℓ_3	: Length of the forward cargo hold of the model, in m
n_1	: Number of frame spaces in the aft cargo hold of the FE model
n_2	: Number of frame spaces in the mid-hold of the FE model
n_3	: Number of frame spaces in the forward cargo hold of the FE model
$\delta w'_1$: Additional distributed load, in kN, at frame in the modelled engine room of aftmost cargo hold model. Formulae of $\delta w'_1$ are given in [4.4.6] and [4.4.7] for shear force adjustment method 1 and method 2 accordingly
$\delta w'_3$: Additional distributed load, in kN, at frame in the modelled forepeak of foremost cargo hold model. Formulae of $\delta w'_3$ are given in [4.4.6] and [4.4.7] for shear force adjustment method 1 and method 2 accordingly
W1	: Total evenly distributed vertical load, in kN, applied to the aft hold of the FE model: $W1 = (n_1 - 1) \delta w_1$
W2	: Total evenly distributed vertical load, in kN, applied to the mid-hold of the FE model: $W2 = (n_2 - 1) \delta w_2$
W3	: Total evenly distributed vertical load, in kN, applied to the forward hold of the FE model: $W3 = (n_3 - 1) \delta w_3$
$\Delta \ell_{end}$: Distance, in m, between the aft bulkhead of the aft cargo hold to the aft end of the FE model $\Delta \ell_{end} = 0$ in the aftmost cargo hold model
$\Delta \ell_{fore}$: Distance, in m, between the forward bulkhead of the forward cargo hold to the forward end of the FE model $\Delta \ell_{fore} = 0$ in the foremost cargo hold model
Note 1: In the above formulae, positive direction of loads, shear forces and adjusting vertical forces is in accordance with Tab 5 and Tab 6.	
Note 2: $W1 + W3 = W2$ (not applicable for aftmost and foremost cargo FE model)	
Note 3: The above formulae are applicable only if a uniform frame spacing is used within each hold. The length and frame spacing of individual cargo holds may be different.	

4.4.9 Procedure to adjust vertical and horizontal bending moments outside midship cargo hold region

To reach the vertical hull girder target values at each frame and transverse bulkhead position, as defined in [4.3.2], the vertical bending moment adjustments, m_{vi} , are to be applied at web frames and transverse bulkhead positions of the finite element model, as shown in Fig 19. The vertical bending moment adjustment at each longitudinal location, i , is to be calculated as follows:

$$f(i) = M_{v-targ}(i) - M_{v-FEM}(i) - M_{lineload}(i) - M_{Y-aft} \cdot \left(\frac{2(X_i - X_{aft})}{X_{fore} - X_{aft}} - 1 \right)$$

$$m_{vi} = \frac{f(i) + f(i+1)}{2} - \sum_{j=0}^{i-1} m_{vj}$$

$$m_{v_end} = - \sum_{j=0}^{n_t} m_{vj}$$

where:

- i : Index corresponding to the i -th station, starting from $i=1$ at the aft end section up to n_t
- n_t : Total number of longitudinal stations where the vertical bending moment adjustment, m_{vi} , is applied
- m_{vi} : Vertical bending moment adjustment, in kN.m, to be applied at transverse frame or bulkhead at station i
- m_{v_end} : Vertical bending moment adjustment, in kN.m, to be applied, at the fore end section (n_t+1 station)
- m_{vj} : Argument of summation to be taken as:
 - $m_{v0} = 0$ when $j = 0$
 - $m_{vj} = m_{vi}$ when $j = i$

$M_{v-targ}(i)$: Required target vertical bending moment, in kN.m, at station i , calculated in accordance with [4.3.2]

$M_{v-FEM}(i)$: Vertical bending moment distribution, in kN.m, at station i due to local loads as given in [4.4.3]

$M_{lineload}(i)$: Vertical bending moment, in kN.m, at station i , due to the line load for the vertical shear force correction as required in [4.4.8].

To reach the horizontal hull girder target values at each frame and transverse bulkhead position as defined in [4.3.4], the horizontal bending moment adjustments, m_{hi} , are to be applied at web frames and transverse bulkhead positions of the finite element model, as shown in Fig 19. The horizontal bending moment adjustment at each longitudinal location, i , is to be calculated as follows:

$$f(i) = M_{h-targ}(i) - M_{h-FEM}(i)$$

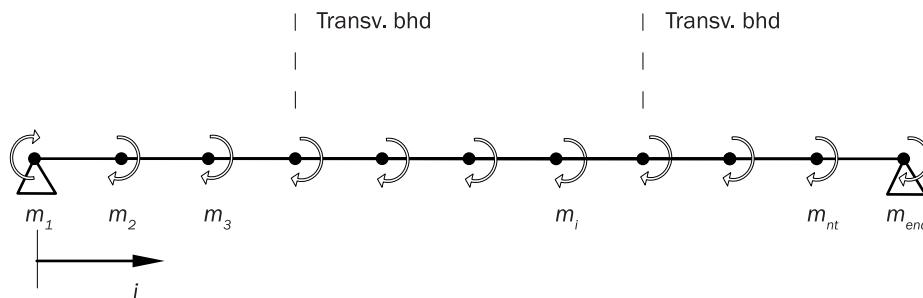
$$m_{hi} = \frac{f(i) + f(i+1)}{2} - \sum_{j=0}^{i-1} m_{hj}$$

$$m_{h_end} = - \sum_{j=0}^{n_t} m_{hj}$$

where:

- i : Longitudinal location for bending moment adjustments, m_{hi} .
- n_t : Total number of longitudinal stations where the horizontal bending moment adjustment, m_{hi} , is applied.
- m_{hi} : Horizontal bending moment adjustment, in kN.m, to be applied at transverse frame or bulkhead at station i .
- m_{h_end} : Horizontal bending moment adjustment, in kN.m, to be applied at the fore end section (n_t+1 station).
- m_{hj} : Argument of summation to be taken as:
 - $m_{h0} = 0$ when $j = 0$
 - $m_{hj} = m_{hi}$ when $j = i$

Figure 19 : Adjustments of bending moments outside midship cargo hold region.



m_{hi} can be substituted to m_{vi} in this figure and m_i is the positive bending moment in FE coordinate system.

$M_{h-targ}(i)$: Required target horizontal bending moment, in kN.m, at station i , calculated in accordance with [4.3.5].

$M_{H-FEM}(i)$: Horizontal bending moment distribution, in kN.m, at station i due to local loads as given in [4.4.3].

The vertical and horizontal bending moment adjustments, m_{vi} and m_{hi} , are to be applied at all web frames and bulkhead positions of the FE model. The adjustments are to be applied in FE model by distributing longitudinal axial nodal forces to all hull girder bending effective longitudinal elements in accordance with [4.4.10].

4.4.10 Application of bending moment adjustments on the FE model

The required vertical and horizontal bending moment adjustments are to be applied by distributing the longitudinal axial nodal forces among all the bending effective hull girder longitudinal elements of the considered FE model cross-section according to Ch 6, Sec 1, [1.2], as follows:

- for vertical bending moment:

$$(F_x)_i = \frac{M_v}{l_{y-n50}} \frac{A_{i-n50}}{n_i} Z_i$$

- for horizontal bending moment:

$$(F_x)_i = \frac{M_h}{l_{z-n50}} \frac{A_{i-n50}}{n_i} Y_i$$

where:

M_v : Vertical bending moment adjustment, in kN.m, to be applied to the considered cross-section of the model

M_h : Horizontal bending moment adjustment, in kN.m, to be applied to the considered cross-section of the model

$(F_x)_i$: Axial force, in kN, applied to a node of the i -th element

Z_i : Vertical distance, in m, from the neutral axis to the centre of the cross-sectional area of the i -th element

Y_i : Horizontal distance, in m, from the neutral axis to the centre of the cross-sectional area of the i -th element

A_{i-n50} : Cross-sectional area, in m^2 , of the i -th element

n_i : Number of nodal points of the i -th element on the cross-section:

- $n_i = 1$ for a beam element
- $n_i = 2$ for a 4-node shell element.

For cross-sections not located at the model ends, the average area of the corresponding i -th elements forward and aft of the considered cross-section is to be used.

4.5 Procedure to adjust hull girder torsional moments

4.5.1 General

The procedure in this sub-article describes how to adjust the hull girder torsional moment distribution on the cargo hold FE model to achieve the target torsional moment at the target location. The hull girder torsional moment target values are given in [4.3.6].

4.5.2 Torsional moment due to local loads

Torsional moment, in kN.m, at longitudinal station i due to local loads, M_{T-FEMi} in kN.m, is determined by the following formula (see Fig 20):

$$M_{T-FEMi} = \sum_k [f_{hik}(z_{ik} - z_T)] - \sum_k (f_{vik} y_{ik})$$

where:

M_{T-FEMi} : Lumped torsional moment, in kN.m, due to local load at longitudinal station i

z_T : Vertical coordinate from baseline, in m, of the horizontal shear centre at the transverse section under consideration, as defined in Ch 5, Sec 4, [3.5.1]

f_{hik} : Horizontal nodal force, in kN, of node k at longitudinal station i

f_{vik} : Vertical nodal force, in kN, of node k at longitudinal station i

y_{ik} : Y--coordinate, in m, of node k at longitudinal station i

z_{ik} : Z-coordinate, in m, of node k at longitudinal station i

M_{T-FEM0} : Lumped torsional moment, in kN.m, due to local load at aft end of the FE model (forward end for foremost cargo hold model), taken as:

- For the foremost cargo hold model:

$$M_{T-FEM0} = \sum_k [f_{hok}(z_{ok} - z_T)] - \sum_k (f_{vok} y_{ok}) + R_{H-fore} (z_{ind} - z_T)$$

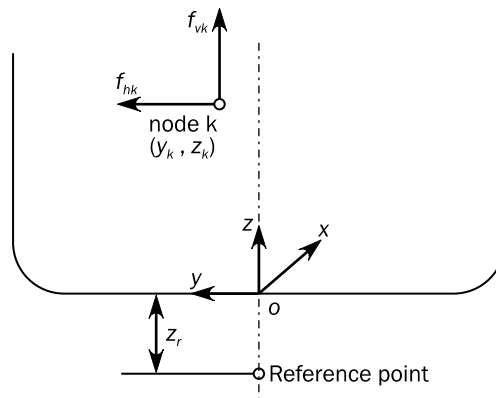
- For the other cargo hold models:

$$M_{T-FEM0} = \sum_k [f_{hok}(z_{ok} - z_T)] - \sum_k (f_{vok} y_{ok}) + R_{H-aft} (z_{ind} - z_T)$$

R_{H-fore} : Horizontal reaction forces, in kN, at the forward end, as defined in [4.4.3]

R_{FH_aft} : Horizontal reaction forces, in kN, at the aft end, as defined in [4.4.3]
 z_{ind} : Vertical coordinate, in m, of independent point as defined in [2.5.3].

Figure 20 : Station forces and acting location of torsional moment at section



4.5.3 Hull girder torsional moment

The hull girder torsional moment, $M_{T-FEM}(x_i)$, in kN.m, is obtained by accumulating the station torsional moment from the aft end section (forward end for foremost cargo hold model) as follows:

$$M_{T-FEM}(x_j) = \sum_i M_{T-FEMi}$$

- when $x_i \geq x_j$ for foremost cargo hold model,
- when $x_i < x_j$ otherwise.

where:

$M_{T-FEM}(x_j)$: Hull girder torsional moment, in kN.m, at longitudinal station x_j

x_j : X-coordinate, in m, of considered longitudinal station j.

The torsional moment distribution given in [4.5.2], has a step at each longitudinal station.

4.5.4 Procedure to adjust hull girder torsional moment to target value

The torsional moment is to be adjusted by applying a hull girder torsional moment M_{T-end} , in kN.m, at the independent point of the aft end section of the model (forward end for foremost cargo hold model), given as follows:

$$M_{T-end} = M_{wt-targ} - M_{T-FEM}(x_{targ})$$

where:

x_{targ} : X-coordinate, in m, of the target location for hull girder torsional moment, as defined in [4.3.6]

$M_{wt-targ}$: Target hull girder torsional moment, in kN.m, specified in [4.3.6], to be achieved at the target location

$M_{T-FEM}(x_{targ})$: Hull girder torsional moment, in kN.m, at target location due to local loads.

Due to the step of hull girder torsional moment at each longitudinal station, the hull girder torsional moment is to be selected from the values aft and forward of the target location as follows: Maximum value for positive torsional moment and minimum value for negative torsional moment.

4.6 Summary of hull girder load adjustments

4.6.1 The required methods of hull girder load adjustments for different cargo hold regions are given in Tab 8.

Table 8 : Overview of hull girder load adjustments in FE analyses

	Midship cargo hold region	After and Forward cargo hold region	Aft most cargo holds	Foremost cargo holds
Adjustment of Vertical Shear Forces	See [4.4.5]	See [4.4.5]	See [4.4.5]	See [4.4.5]
Adjustment of Bending Moments	See [4.4.8]	See [4.4.9]	See [4.4.9]	See [4.4.9]
Adjustment of Torsional Moment	See [4.5.4]	See [4.5.4]	See [4.5.4]	See [4.5.4]

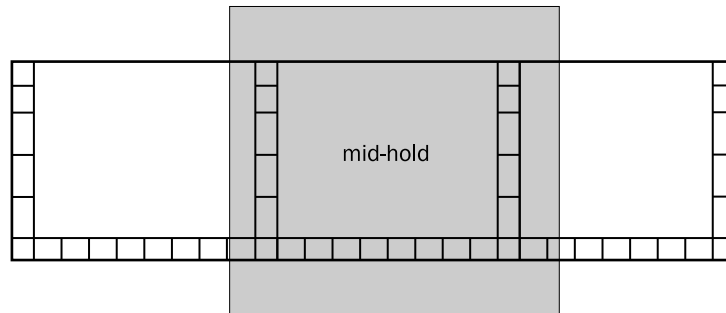
5 Analysis criteria

5.1 General

5.1.1 Evaluation areas

Verification of results against the acceptance criteria is to be carried out within the longitudinal extent of the mid-hold, as shown in Fig 21.

Figure 21 : Longitudinal extent of evaluation area



5.1.2 Structural members

The following structural elements within the evaluation area are to be verified with the criteria given in [5.2] and [5.3]:

- all the hull girder longitudinal structural members
- all the primary supporting structural members and bulkheads within the mid-hold
- all the structural members being part of the transverse bulkheads
- all structural members being part of the collision bulkhead and extending to one web frame spacing forward of the collision bulkhead
- all structural members being part of the forward transverse bulkhead of the machinery space and all hull girder longitudinal structural members aft of this transverse bulkhead within the extent of 15% of the aftmost cargo hold length excluding slop tanks if any.

5.2 Yield strength assessment

5.2.1 Von Mises stress

For all the plates of the structural members defined in [5.1.2], the Von Mises stress σ_{vm} , in N/mm², is to be calculated based on the membrane normal and shear stresses of the shell element. The stresses are to be evaluated at the element centroid of the mid-plane, as follows:

$$\sigma_{vm} = \sqrt{\sigma_x^2 - \sigma_x \sigma_y + \sigma_y^2 + 3 \tau_{xy}^2}$$

where:

- $\sigma_x \sigma_y$: Element normal membrane stresses, in N/mm²
 τ_{xy} : Element shear stress, in N/mm².

5.2.2 Axial stress in beams and rod elements

For beams and rod elements, the axial stress σ_{axial} , in N/mm², is to be calculated based on the axial force alone. The axial stress is to be evaluated at the middle of the element length.

5.2.3 Yield criteria

The structural elements given in [5.1.2] are to comply with the following criterion:

$$\lambda_y \leq \lambda_{yperm}$$

where:

λ_y : Yield utilisation factor:

$$\lambda_y = \frac{\sigma_{vm}}{R_Y} \text{ for shell elements}$$

$$\lambda_y = \frac{|\sigma_{axial}|}{R_Y} \text{ for rod or beam elements}$$

σ_{vm} : Von Mises stress, in N/mm²

σ_{axial} : Axial stress in rod or beam element, in N/mm²

λ_{yperm} : Standard mesh permissible yield utilisation factor defined in Tab 9.

5.2.4 Corrugation of corrugated bulkhead

The stress in corrugation of corrugated bulkheads is to be evaluated based on:

- a) the von Mises stress, σ_{vm} , in shell elements on the flange and web of the corrugation
- b) the axial stress, σ_{axial} , in dummy rod elements, modeled with unit cross sectional properties at the intersection between the flange and web of the corrugation.

5.3 Buckling strength assessment

5.3.1 All the structural elements in FE analysis carried out in accordance with this Section are to be assessed individually against the buckling requirements as defined in Ch 9, Sec 1.

Table 9 : Standard mesh permissible yield utilisation factor λ_{yperm}

Structural component	Acceptance criteria(1)	λ_{yperm}
Plating of all the longitudinal hull girder structural members, primary supporting structural members and bulkheads Face plate of the primary supporting members Dummy rod of corrugated bulkhead	AC-1	0,8
	AC-2	1,0
	AC-3	$1,0 \cdot R_{eH} / R_y$
Corrugation of vertically corrugated bulkheads with lower stool and horizontally corrugated bulkhead, under lateral pressure from liquid loads, for shell elements only Supporting structure in way of lower end of corrugated bulkheads without lower stool(2)	AC-1	0,72
	AC-2	0,9
	AC-3	$0,9 \cdot R_{eH} / R_y$
Corrugation of vertically corrugated bulkheads without lower stool under lateral pressure from liquid loads and without lower stool, for shell elements only	AC-1	0,65
	AC-2	0,81
	AC-3	$0,81 \cdot R_{eH} / R_y$
Supports and keys of independent cargo tanks	AC-1	0,8
	AC-2	0,9
	AC-3	$1,0 \cdot R_{eH} / R_y$
<p>(1) See Ch 8, Sec 1, [4] for the acceptance criteria definition.</p> <p>(2) Supporting structure for a transverse corrugated bulkhead refers to the structure in the longitudinal direction within half a web frame space forward and aft of the bulkhead, and within a vertical extent equal to the corrugation depth. Supporting structure for a longitudinal corrugated bulkhead refers to the structure in transverse direction within 3 longitudinal stiffener spacings from each side of the bulkhead, and within a vertical extent equal to the corrugation depth.</p>		

Appendix 2 Local Structural Strength Analysis

1 Objective and scope

1.1 General

1.1.1 The local strength analysis of structural details is to be in accordance with the requirements given in this Section.

1.1.2 Fine mesh analysis procedure

The details to be assessed by fine mesh analysis are to be modeled according to the requirements given in Article [2], under the FE load combinations defined in Article [3], and are to comply with the criteria given in Article [4].

1.2 Structural details to be assessed by fine mesh analysis

1.2.1 Mandatory structural details

Mandatory structural details subject to fine mesh analysis are listed in Ch 13, Sec 5, [2], as applicable depending on the assigned service notation.

For structural details having the same geometry and the same relative location inside the midship cargo region, one fine mesh model is required. The selection of the location of this fine mesh model is to be based on the detail which has the maximum yield utilisation factor λ_y as defined in Ch 8, App 1, [5.2.3].

Such analysis may also be considered for other details which are considered critical by the Society.

1.2.2 Structural details to be evaluated by screening

The following structural details and areas are to be evaluated by screening according to [1.2.3] in order to determine if a fine mesh analysis is required or not:

- manholes in all areas
- structural details listed in Ch 13, Sec 5, [2], as applicable depending on the assigned service notation

1.2.3 Screening criteria

Stresses in areas defined in [1.2.2], calculated for all the applicable FE load combinations given in Article [3], are to be checked against the following screening criterion:

$$\lambda_{sc} \leq \lambda_{scperm}$$

where:

λ_{sc} : Screening factor as defined in Tab 1 and in Part D and Part E for details specific to ship types, as applicable

λ_{scperm} : Permissible screening factor as defined in Tab 1 and in Part D and Part E for details specific to ship types, as applicable.

Where the screening criterion is not met, fine mesh analysis of the corresponding structural detail is required and to be performed according to [1.1.2].

Table 1 : Screening factors and permissible screening factors

Type of details	Screening factors λ_{sc}	Permissible screening factors λ_{scperm}	
		AC-2 (1)	AC-1 (1)
Manholes in all areas (2)	λ_y (3)	0,85 λ_{yperm} (4)	
(1) See Ch 8, Sec 1, [4] for acceptance criteria definition. (2) The representative element which has the maximum yield utilisation factor around the manhole and the large opening is to be verified against criteria. (3) λ_y : Standard mesh yield utilisation factor, as defined in Ch 8, App 1, [5.2.3] (4) λ_{yperm} : Standard mesh permissible yield utilisation factor, as defined in Ch 8, App 1, [5.2.3].			

2 Structural modeling

2.1 General

2.1.1 Evaluation of detailed stresses requires the use of refined finite element mesh in way of areas of high stress. This fine mesh analysis can be carried out by fine mesh zones incorporated into the cargo hold model. Alternatively, separate local FE model with fine mesh zones in conjunction with the boundary conditions obtained from the cargo hold model may be used.

2.2 Extent of model

2.2.1 If a separate local fine mesh model is used, its extent is to be such that the calculated stresses at the areas of interest are not significantly affected by the imposed boundary conditions. The boundary of the fine mesh model is to coincide with primary supporting members in the cargo hold model, such as web frame, girders, stringers and floors.

2.3 Mesh size

2.3.1 The mesh size in the fine mesh zones is not to be greater than 50 x 50 mm.

2.4 Elements

2.4.1 All plating within the fine mesh zone is to be represented by shell elements. The aspect ratio of elements within the fine mesh zone is to be kept as close to 1 as possible. Variation of mesh density within the fine mesh zone and the use of triangular elements are to be avoided. In all cases, the elements within the fine mesh model are to have an aspect ratio not exceeding 3. Distorted elements, with element corner angles less than 45° or greater than 135°, are to be avoided. Stiffeners inside the fine mesh zone are to be modeled using shell elements. Stiffeners outside the fine mesh zones may be modeled using beam elements.

2.4.2 The extent of the fine mesh zone is not to be less than 10 elements in all directions from the area under investigation. A smooth transition of mesh density from fine mesh zone to the boundary of the fine mesh model is to be maintained, see Fig 1 and Fig 2.

2.4.3 Where a fine mesh analysis is required for an opening, the first two layers of elements around the opening are to be modeled with mesh size not greater than 50 x 50 mm. A smooth transition from the fine mesh to the coarser mesh is to be maintained. Edge stiffeners which are welded directly to the edge of an opening are to be modeled with shell elements. Web stiffeners close to an opening may be modeled using rod or beam elements located at a distance of at least 50 mm from the edge of the opening. Example of fine mesh zone around an opening is shown in Fig 3.

Figure 1 : Fine mesh zone around bracket toes

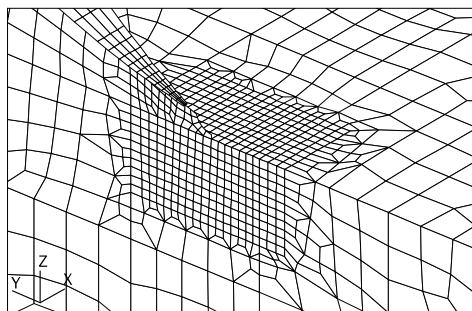
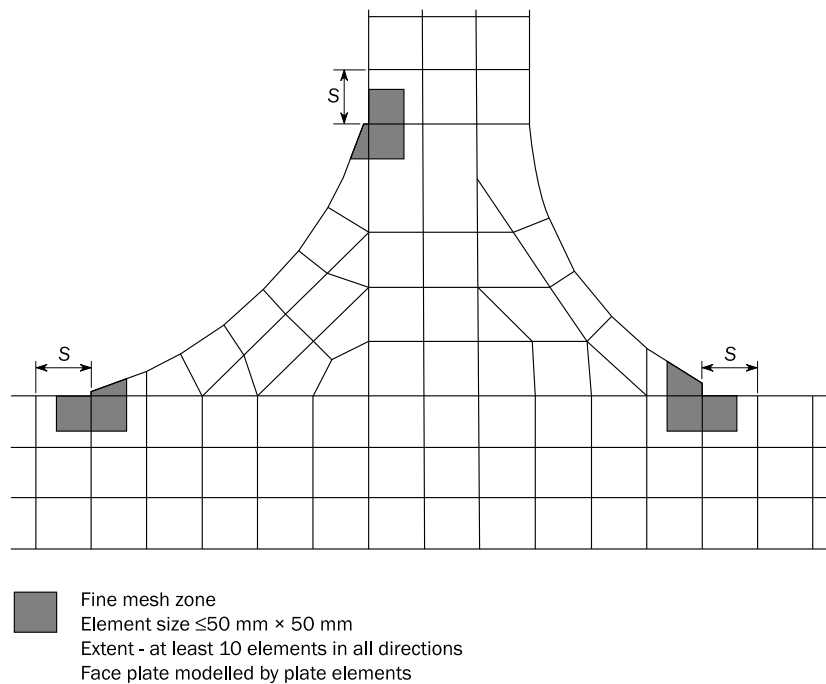


Figure 2 : Example of local model for the analysis of hatch opening structures

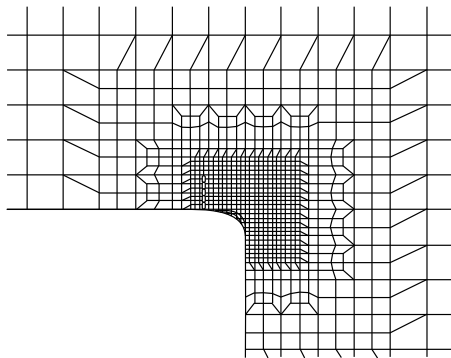
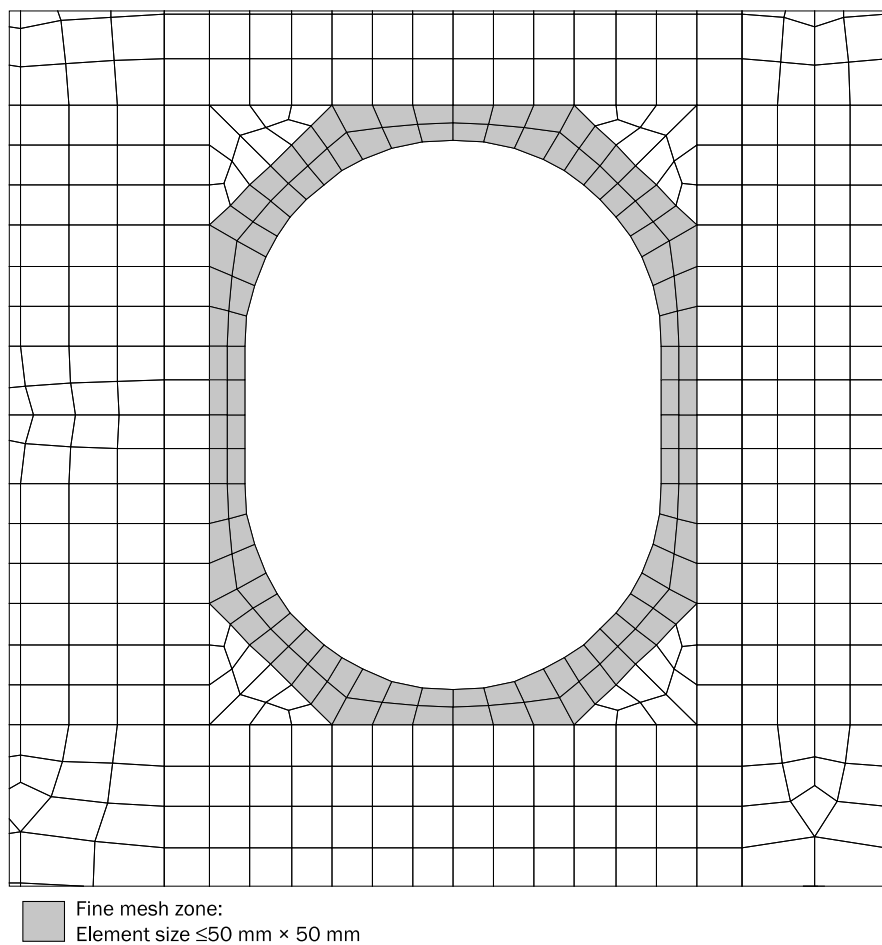


Figure 3 : Fine mesh zone around an opening



2.4.4 Face plates of openings, primary supporting members and associated brackets are to be modeled with at least two elements across their width on either side.

2.5 Transverse web frames

2.5.1 In addition to the requirements of [2.2] to [2.4], the modeling requirements in this sub-article are applicable to the analysis of a typical transverse web frame.

2.5.2 Where a FE sub-model is used, the model is to have an extent of at least 1+1 web frame spaces, i.e. one web frame space extending on either side of the transverse web frame under investigation. The transverse web frames forward and aft of the web frame under investigation need not be included in the sub-model.

2.5.3 The full depth and full breadth of the ship are to be modeled, see Fig 4.

Figure 4 : Example of extent of local model for fine mesh analysis of web frame bracket connections and openings

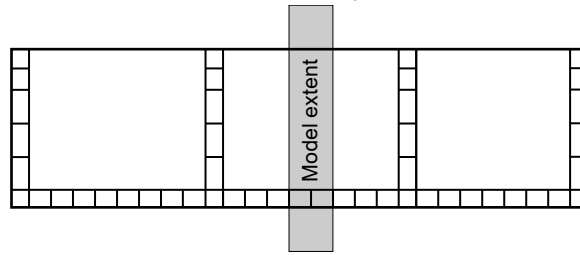
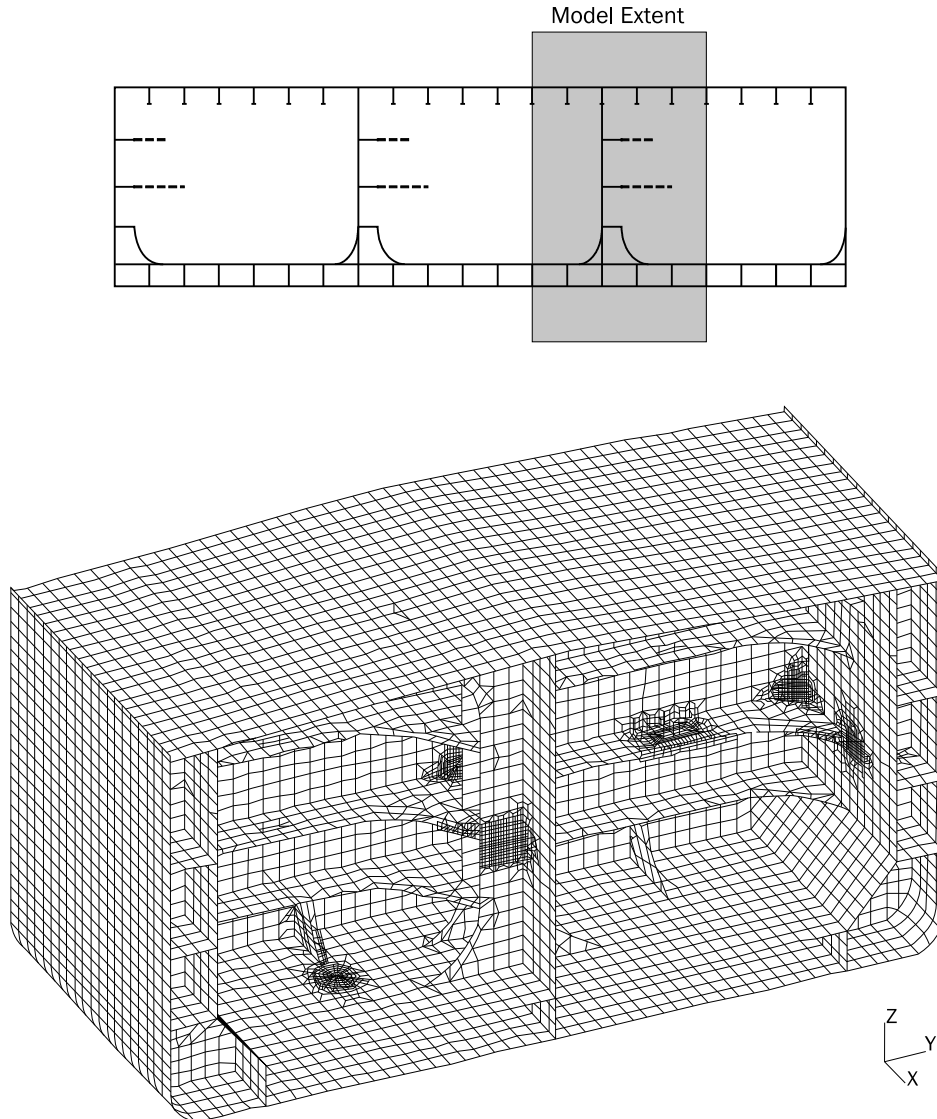


Figure 5 : Example of local model for fine mesh analysis of transverse bulkhead and adjacent structure



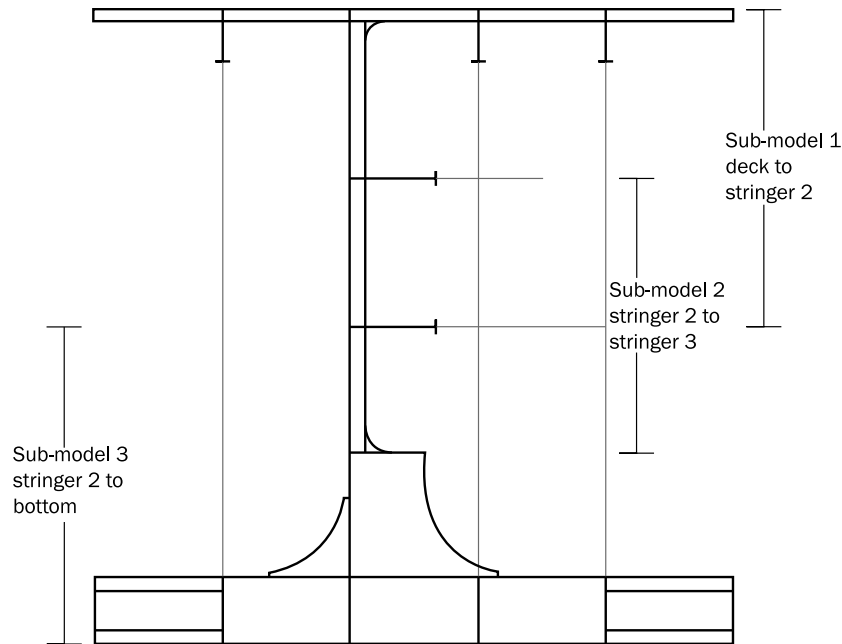
2.6 Transverse bulkhead stringers, buttress and adjacent web frame

2.6.1 In addition to the requirements of [2.2] to [2.4], the modeling requirements in this sub-section are applicable to the analysis of transverse bulkhead structures and adjacent web frame.

2.6.2 Due to the structural interaction among the transverse bulkhead, horizontal stringers, web frames, deck and double bottom, it is recommended that the FE local model represents a full section of the hull. Longitudinally, the ends of the model should extend over at least one web frame space beyond the areas that require investigation, see Fig 5.

2.6.3 Alternatively, it is acceptable to use a number of local models, as shown in Fig 6, to analyse different parts of the structure. For the analysis of the transverse bulkhead horizontal stringers the full breadth of the ship are to be modeled. For the analysis of buttress structure, the local model width should be at least 4+4 longitudinal spaces, i.e. four longitudinal spaces at each side of the buttress.

Figure 6 : Example of local analysis of transverse bulkhead structure using local models



2.7 Deck, double bottom longitudinal and adjoining transverse bulkhead vertical stiffeners

2.7.1 In addition to the requirements of [2.2] to [2.4], the modeling requirements in this sub-section are applicable specifically to the analysis of longitudinal and vertical stiffener end connections and attached web stiffeners.

2.7.2 Where a local FE model is used, its length is to be of at least 2 web frame spaces on each side of the area under investigation. The model width is to extend over at least 2 longitudinal stiffeners spaces on each side the area under investigation.

2.7.3 The web of the longitudinal stiffeners outside of the fine mesh zone should be represented by at least 3 shell elements across its depth. Similar size elements should be used to represent the plating of the bottom shell and inner bottom. The flange of the longitudinal stiffeners and face plate of brackets should be modeled with at least 2 shell elements across its width at one side.

2.7.4 The mesh size and extent of the fine mesh zone is to be in accordance with [2.3] and [2.4].

2.8 Corrugated bulkheads

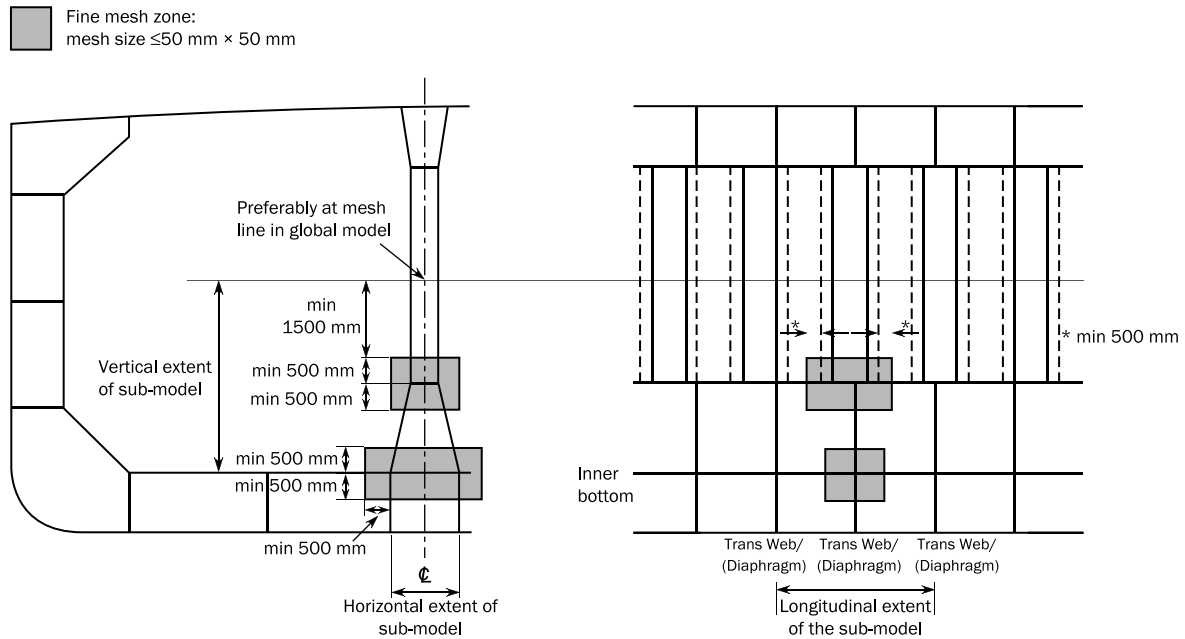
2.8.1 In addition to the requirements of [2.2] to [2.4], the modeling requirements in this sub-article are applicable to the analysis of connections of corrugated bulkheads to lower stool and the connection between lower stool and inner bottom.

2.8.2 The minimum extents of the local model are as follows, see also Fig 7:

- Vertically, the model is to extend from the bottom of the ship to a level of at least 2 m above the connection between the corrugation and the lower stool.
- For transverse corrugated bulkheads, the local model is to extend transversally to the nearest diaphragm web in the lower stool on each side of the fine mesh zone (i.e. the local model covers two lower stool transverse web/diaphragm spaces). The end diaphragms do not need to be modeled.
- For longitudinal corrugated bulkheads, the local model is to extend to the nearest web frame on each side of the fine mesh zone (i.e. the local model covers two frame spaces). The end web frames do not need to be modeled.
- For connection between the corrugation and the lower stool located close to the intersection of transverse and longitudinal corrugated bulkheads (such as for product tankers), the local model is to cover the structure between the diaphragms (in transverse direction) and web frames (in longitudinal direction) closest to the detail, whichever is relevant. In addition, the local model is to extend over at least one diaphragm/web frame outside the intersection between the transverse stool and the longitudinal stool.
- For lower stool to inner bottom connection, the connection between inner bottom, lower stool plate, diaphragm and double bottom girder, where applicable, is to be at the centre of the fine mesh zone.

2.8.3 The fine mesh zone is to cover at least the corrugation flange under investigation, the adjacent corrugation webs and at least 500 mm on each side of the corrugation webs (i.e. the fine mesh zone covers at least four corrugation knuckles, see Fig 7).

Figure 7 : Extent of local model and fine mesh zone for the analysis of corrugated bulkhead connection to lower stool and inner bottom



2.8.4 Diaphragm webs, brackets inside the lower stool and all stiffeners on the stool plate and diaphragm are to be modeled at their actual positions within the extent of the local model. Shell elements are to be used for the modeling of diaphragm, web and flange of vertically orientated stiffeners, and brackets in the fine mesh zone.

2.8.5 Horizontally orientated stiffeners within the fine mesh zone are to be represented by either shell or beam elements.

3 FE load combinations

3.1 General

3.1.1 The fine mesh detailed stress analysis is to be carried out for all the FE load combinations as defined in Ch 8, App 1, [3] required according to the applicable Part D or Part E chapter, except tank testing and flooding conditions, applied to the corresponding cargo hold analysis.

3.2 Application of loads and boundary conditions

3.2.1 General

Where a separate local model is used for the fine mesh detailed stress analysis, the nodal displacements from the global model are to be applied to the corresponding boundary nodes on the local model as prescribed displacements. Alternatively, equivalent nodal forces from the global model may be applied to the boundary nodes.

Where there are nodes on the local model boundaries which are not coincident with the nodal points on the global model, it is acceptable to impose prescribed displacements on these nodes using multi-point constraints. The use of linear multi-point constraint equations connecting two neighbouring coincident nodes is considered sufficient.

At the exception of flooding loads, all the local loads, including any loads applied for hull girder bending moment and/or shear force adjustments, in way of the structure represented by the separate local finite element model are to be applied to the model.

4 Analysis criteria

4.1 Yield strength assessment

4.1.1 Reference stress

Reference stress is Von Mises stress σ_{vm} as defined in Ch 8, App 1, [5.2.1], which is to be calculated based on the membrane normal and shear stresses of the shell element evaluated at the element centroid. The stresses are to be evaluated at the mid-plane of the element.

4.1.2 Permissible stress

The maximum permissible stresses are based on the mesh size of 50 x 50 mm, as specified in [2.1] to [2.4].

Where a smaller mesh size is used, an area weighted Von Mises stress σ_{vm-av} calculated over an area equal to the specified mesh size may be used to compare with the permissible stresses. The averaging is to be based only on elements with their entire boundary located within the desired area:

$$\sigma_{vm-av} = \frac{\sum_1^n A_i \sigma_{vm-i}}{\sum_1^n A_i}$$

The average stress is to be calculated based on stresses at the element centroid; stress values obtained by interpolation and/or extrapolation are not to be used.

Stress averaging is not to be carried across structural discontinuities and abutting structure.

4.1.3 Yield criteria

The structural assessment is to demonstrate that the stress complies with the following criterion: $\lambda_f \leq \lambda_{fperm}$

where:

λ_f : Fine mesh yield utilisation factor:

- for shell elements:

$$\lambda_f = \frac{\sigma_{vm}}{R_Y}$$

- for rod or beam elements:

$$\lambda_f = \frac{|\sigma_{axial}|}{R_Y}$$

σ_{vm} : Von Mises stress, in N/mm²

σ_{axial} : Axial stress in rod element, in N/mm²

λ_{fperm} : Fine mesh permissible yield utilisation factor as defined in Tab 2.

In addition, the average Von Mises stress over a standard mesh size as per Ch 8, App 1, [2.4.2] is not to exceed the permissible stress as defined in Ch 8, App 1, [5.2].

Table 2 : Fine mesh permissible yield utilisation factor λ_{fperm}

Structural component		Acceptance criteria (1)	λ_{fperm}
All components Supports and keys of independent cargo tanks	Elements not adjacent to welding	AC-1	1,36 f_f
		AC-2	1,70 f_f
		AC-3	1,70 $f_f \cdot R_{eH} / R_Y$
	Elements adjacent to welding	AC-1	1,20 f_f
		AC-2	1,50 f_f
		AC-3	1,50 $f_f \cdot R_{eH} / R_Y$
(1) See Ch 8, Sec 1, [4] for the acceptance criteria definition.			
Note 1: f_f : Fatigue factor, taken as:			
<ul style="list-style-type: none"> • $f_f = 1,0$ in general, including the free edge of base material • $f_f = 1,2$ for details assessed by very fine mesh analysis complying with the fatigue assessment criteria given in Ch 10, Sec 1. 			

Appendix 3 Full Length Structural Strength Analysis

1 Objective and scope

1.1 General

1.1.1 This Section gives the requirements for full length structural strength analysis to be used for the assessment of primary supporting members.

1.1.2 The structural analysis aims at calculating the stresses in the primary supporting members and in the hull plating, to be used for yielding and buckling checks.

1.2 Full length structural strength analysis procedure

1.2.1 Procedure description

The structural FE analysis is to be performed in accordance with the following:

- full length model with:
 - extent as given in [2.2]
 - finite element types as given in [2.3]
 - structural modeling as defined in [2.4]
- boundary conditions as defined in [2.5]
- loading conditions and load cases as defined in [3]
- load application as defined in [4]
- strength assessment as defined in [5].

2 Structural model

2.1 Model construction

2.1.1 Elements

The structural model is to represent the primary supporting members with the plating to which they are connected.

Ordinary stiffeners are also to be represented in the model in order to reproduce the stiffness and inertia of the actual hull girder structure.

2.1.2 Net scantlings

All the elements are to be modeled with their net scantlings according to Ch 4, Sec 3. Therefore, the hull girder stiffness and inertia to be reproduced by the model are also those obtained considering the net scantlings of the hull structures.

2.2 Extent of model

2.2.1 The complete ship is to be modeled so that the coupling between torsion and horizontal bending is properly taken into account in the structural analysis.

Superstructures are to be modeled in order to reproduce the correct lightweight distribution.

2.3 Finite element types

2.3.1 See Ch 8, App 1, [2.3].

2.4 Structural modeling

2.4.1 See Ch 8, App 1, [2.4].

Note 1: Openings modeling defined in Ch 8, App 1, Tab 1 are not applicable to complete ship models.

2.4.2 Lightweight and deadweight

The finite element model is to include both the lightweight and the deadweight mass and inertia distributions.

The lightweight can be adjusted using one of the following techniques:

- modification of the density properties of plate and beam elements
- additional nodal masses fitted on the structural model.

Massive items (main engine, hatch covers) are preferably be excluded of the lightweight distribution and modeled similarly to deadweight items.

Deadweight items (such as container stacks or liquids) are to be modeled as nodal masses linked to the model through additional elements designed in order to transfer loads without introducing artificial stiffness (interpolation elements). Nodal masses are also to include the inertia properties of the items they represent.

2.5 Boundary conditions of the model

2.5.1 General

All the boundary conditions described in this Section are in accordance with the global coordinate system defined in Ch 5, Sec 1.

2.5.2 Boundary conditions

In order to prevent the rigid body motions of the overall model, the constraints specified in Tab 1 are to be applied to full length finite element model analyses.

Table 1 : Boundary conditions to prevent rigid body motion of the model

Location	Translation			Rotation		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
One node on the fore end of the ship	free	fixed	fixed	free	free	free
One node on the port side shell at aft end of the ship (1)	fixed	free	fixed	free	free	free
One node on the starboard side shell at aft end of the ship (1)	free	fixed	fixed	free	free	free

(1) The nodes on the port side shell and that on the starboard side shell are to be symmetrical with respect to the ship’s longitudinal plane of symmetry.

3 Load combinations

3.1 General

3.1.1 The combination of loading conditions and load cases to be considered are given in Part D and Part E depending on the ship type.

4 Load application

4.1 General

4.1.1 Design wave method

The various load components which occur simultaneously may be combined by setting the characteristics of waves defined in [4.2.4] that maximise the dominant load effects given in [4.2.2].

Any other method may be used, provided relevant documentation is submitted to the Society for review.

4.1.2 Model loading

The loads are applied to the finite element model according to the following indications:

- a) Still water loads include:
 - The still water sea pressure, defined in Ch 5, Sec 5, [1]
 - The still water internal loads, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast
- b) Wave loads, determined by means of hydrodynamic calculations, include:
 - The wave pressure
 - The inertial loads
- c) The fluid pressure in tanks is affected by the change of direction of the total acceleration vector defined in Ch 5, Sec 3
- d) For dry unit cargoes, inertial forces are computed at the centre of mass, taking into account the mass moment of inertia
- e) Inertial loads for structure weight and dry uniform cargo are computed using local accelerations calculated at their location.

4.1.3 Equilibrium check

The convergence of the displacement, trim and vertical bending moment is deemed satisfactory within the following tolerances:

- 2% of the displacement
- 0,1 degree of the trim angle
- 10% of the still water bending moment.

4.2 Procedure for the selection of design waves

4.2.1 Summary of the loading procedure

The determination of the design wave characteristics for each load case includes the following steps:

- computation of the response operators (amplitude and phase) of the dominant load effect
- selection of the wave length and heading according to [3]
- determination of the wave phase such that the dominant load effect reaches its maximum
- computation of the wave amplitude corresponding to the design value of the dominant load effect.

4.2.2 Dominant load effects

Each load case maximises the value of one of the following load effects having a dominant influence on the strength of some parts of the structure:

- vertical wave bending moment in hogging and sagging condition amidships
- horizontal wave bending moment amidships
- wave torsional moment around 0,25L and 0,75L
- vertical acceleration at fore body sections
- roll motion
- wave pressure at the waterline amidships.

Additional loads might be investigated when deemed relevant by the Society.

4.2.3 Response Amplitude Operators

The Response Amplitude Operators (RAO's) and associated phase characteristics are to be computed for wave periods between 4 and 22 seconds, using a seakeeping program, for the following motions and load effects:

- heave, sway, pitch, roll and yaw motions
- vertical wave bending moment at 0,5L or at the longitudinal position where the bending moment RAO is maximum
- vertical wave shear force at 0,25L and 0,75L
- horizontal wave bending moment at 0,5L
- wave torsional moment at 0,25L and 0,75L.

The response amplitude operators are to be calculated for wave headings ranging from 0° (following seas) to 180° (head seas) by increment of 15°, using a ship speed of 5 knots.

The amplitude and phase of other dominant load effects may be computed at relevant wave period, using the RAO's listed above.

4.2.4 Design waves

For each load case, the ship is considered to encounter a Response Conditioned Wave (RCW). The RCW is an irregular wave train composed by at least 60 uni-directional waves. For each wave, the range of time is to be taken between $-\pi/\Delta\omega$ and $\pi/\Delta\omega$, where $\Delta\omega$ is the wave frequency step as defined in [4.2.6].

4.2.5 Design wave amplitude and phase

For each wave contributing to the RCW, the amplitude A_i and phase φ_i can be computed from the RAO and the wave spectrum, using the following relationships:

$$A_i = S(\omega_i) |RAO(\omega_i, \beta)| \frac{D}{m_0} \Delta\omega_i$$

$$\varphi_i = -RAO_\varphi(\omega_i, \beta)$$

where:

D : Design value of the dominant load effect

RAO : Response amplitude operator of the dominant load effect computed for the relevant wave heading and wave frequency

RAO_φ : Phase of the response amplitude operator of the dominant load effect for the relevant wave heading and wave frequency

ω_i : Wave frequency

β : Wave heading

S : Wave spectrum (Pierson-Moskowitz) with the peak period T_p

m₀ : Spectral moment of order 0, defined as:

$$m_0 = \int_0^\infty S(\omega) RAO(\omega, \beta)^2 d\omega$$

Δω_i : Wave frequency step.

The wave heading β, peak period T_p and design value D of the dominant load effect are given, for each load case, in [3].

When positioning the finite element model of the ship on the design wave, the amplitude of the wave is to be corrected to obtain the design value of the dominant load effect in order to take into account the non linear effects due to the hull shape and to the pressure distribution above the mean water line.

4.2.6 Seakeeping assumptions

When a direct seakeeping analysis is used to derive long-term values of hull girder loads, Response Amplitude Operators are to be computed, considering:

- a linear analysis
- a ship speed of 5 knots
- at least 36 headings (10° steps)
- frequencies in the range [0:2] rad/s
- a frequency step $\Delta\omega$ equal to:

$$\Delta\omega = 0,3 \sqrt{\frac{g}{L}}$$

5 Analysis criteria

5.1 Yield strength assessment

5.1.1 Von Mises stress

The Von Mises stress σ_{vm} , in N/mm², is to be calculated based on the membrane normal and shear stresses of the shell element. The stresses are to be evaluated at the element centroid of the mid plane, as follows:

$$\sigma_{vm} = \sqrt{\sigma_x^2 - \sigma_x \sigma_y + \sigma_y^2 + 3\tau_{xy}^2}$$

where:

- σ_x, σ_y : Element normal membrane stresses, in N/mm²
 τ_{xy} : Element shear stress, in N/mm².

5.1.2 Axial stress in beams and rod elements

For beams and rod elements, the axial stress σ_{axial} , in N/mm², is to be calculated based on the axial force alone. The axial stress is to be evaluated at mid-length of the element.

5.1.3 Yield criteria

The structural elements are to comply with the following criterion: $\lambda_y \leq \lambda_{yperm}$

where:

- λ_y : Yield utilisation factor:

$$\lambda_y = \frac{\sigma_{vm}}{R_Y} \text{ for shell elements}$$

$$\lambda_y = \frac{|\sigma_{axial}|}{R_Y} \text{ for rod or beam elements}$$

σ_{vm} : Von Mises stress, in N/mm²

σ_{axial} : Axial stress in rod or beam element, in N/mm²

λ_{yperm} : Permissible yield utilisation factor defined in Ch 8, App 1, Tab 9.

Where the Von Mises stress of the elements under investigation by fine mesh exceeds the yield criteria, the average Von Mises stress obtained from the fine mesh analysis, calculated over an area equivalent to the mesh size of the full length finite element model, is to satisfy the yield criterion above.

5.2 Buckling strength assessment

5.2.1 All the structural elements in FE analysis carried out in accordance with this Section are to be assessed individually against the buckling requirements as defined in Ch 9, Sec 1.

6 Refined analysis

6.1 Application

6.1.1 When a refined analysis is deemed necessary on a given detail, the requirements of this Article are to be applied.

6.2 Structural modeling

6.2.1 See Ch 8, App 2, [2].

6.3 Loading conditions and load cases

6.3.1 The loading conditions and load cases considered are to be similar to those applied for the full length model.

6.4 Load application

6.4.1 See Ch 8, App 2, [3.2].

6.5 Analysis criteria

6.5.1 See Ch 8, App 2, [4].

Part B

Hull and Stability

CHAPTER 9

BUCKLING

Section 1 Buckling

Section 1 Buckling

Symbols

For symbols not defined in this Section, refer to Ch 5, Sec 4.

1 General

1.1 Application

1.1.1 The buckling check of plating, stiffeners, primary supporting members and other structures such as pillars and brackets is to be performed according to the applicable requirements of NR615 Buckling Assessment of Plated Structures, taking into account, in addition, the requirements of this Section.

1.2 Allowable buckling utilisation factor

1.2.1 General structural elements

The allowable buckling utilisation factor η_{all} is defined in Tab 1.

Table 1 : Allowable buckling utilisation factor η_{all}

Structural component	Acceptance criteria	η_{all}
Plates and stiffeners	AC-1	0,80
Stiffened and unstiffened panels	AC-2	1,00
Vertically stiffened side shell plating of single side skin ship	AC-3	
Web plate in way of openings	AC-1	0,75
Pillars	AC-2	0,85
	AC-3	
Struts and cross ties	AC-1	0,65
	AC-2	0,75
	AC-3	
Corrugation of vertically corrugated bulkheads with lower stool and horizontally corrugated bulkhead, under lateral pressure from liquid loads, for shell elements only.	AC-1	0,72
	AC-2	0,90
Supporting structure in way of lower end of corrugated bulkheads without lower stool	AC-3	
Corrugation of vertically corrugated bulkheads without lower stool under lateral pressure from liquid loads, for shell elements only	AC-1	0,65
	AC-2	0,81
	AC-3	
<p>Note 1: Supporting structure for a transverse corrugated bulkhead refers to the structure in longitudinal direction within half a web frame space forward and aft of the bulkhead, and within a vertical extent equal to the corrugation depth.</p> <p>Note 2: Supporting structure for a longitudinal corrugated bulkhead refers to the structure in transverse direction within three longitudinal stiffener spacings from each side of the bulkhead, and within a vertical extent equal to the corrugation depth.</p>		

2 Slenderness requirements

2.1 Application

2.1.1 The slenderness requirements defined in NR615, Sec 2 are to be applied to all structural members including plating, web and face plate, if any, of stiffeners and tripping brackets, web plating and flange of primary supporting members.

Slenderness requirements are not to be applied to corrugations of bulkheads.

When the buckling capacity of a plate element is assessed according to NR615, Sec 5, its associated slenderness requirement may be disregarded.

3 Prescriptive buckling requirements

3.1 Application

3.1.1 The requirements in this Article are to be taken into account for application of NR615, Sec 3.

3.1.2 Partial safety factor

The partial safety factor S , defined in NR615, Sec 5, is to be replaced by:

$$\frac{S}{K_{\text{corr}}}$$

where:

K_{corr} : Coefficient to take into account the corrosion:

- In general: $K_{\text{corr}} = 1,0$
- For tank testing: $K_{\text{corr}} = 1,1$

3.2 Design load sets

3.2.1 General

Unless otherwise specified, the buckling checks are to be performed for all the design load sets defined in Ch 7, Sec 2, [2], with pressure combination defined in Ch 7, Sec 2, [1].

For each design load set defined in Ch 7, Sec 2, except the one associated to accidental design load scenario, the hull girder stress given in [3.3] is to be applied together with the lateral pressure determined according to Part B, Chapter 5, at the load calculation point defined in Ch 4, Sec 6.

Note 1: The still water loads Q_{sw} and M_{sw} need not be considered simultaneously but independently from each other when combined with wave loads, except in the following specific cases:

- where the minimum vertical still water bending moment $M_{\text{sw-min}}$ is positive, it is to be considered simultaneously with Q_{sw} when combined with the vertical wave bending moment in sagging condition $M_{\text{wv-s}}$
- where the minimum vertical still water shear force $Q_{\text{sw-min}}$ is positive, it is to be considered simultaneously with M_{sw} when combined with the negative vertical wave shear force $Q_{\text{wv-neg}}$
- where the maximum vertical still water shear force $Q_{\text{sw-max}}$ is negative, it is to be considered simultaneously with M_{sw} when combined with the positive vertical wave shear force $Q_{\text{wv-pos}}$.

3.2.2 Deckhouses side bulkheads

The buckling checks of structural members of deckhouses sides contributing to the longitudinal strength are to be performed for the design load set SEA-1 with a combined lateral pressure P_{ex} taken equal to 2,5 kN/m².

3.3 Hull girder stress

3.3.1 The hull girder bending stress σ_{hg} , in N/mm², is to be taken equal to σ_{L} as defined in Ch 6, Sec 1, [2.1.1] or Ch 6, Sec 1, [2.1.2] as applicable.

3.3.2 The hull girder shear stress τ_{hg} , in N/mm², is to be taken equal to τ_{L} as defined in Ch 6, Sec 1, [2.2.1] or Ch 6, Sec 1, [2.2.2] as applicable.

Part B

Hull and Stability

CHAPTER 10

FATIGUE

Section 1 Fatigue

Section 1 Fatigue

Symbols

- T_{DF} : Design fatigue life, in year, specified by the designer, but not to be taken less than 25 years.
For ships granted with additional class notation **FAT xx years**, T_{DF} is to be taken equal to xx years
- T_f : Calculated fatigue life, determined in accordance with NI611.

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships having a length equal to or greater than 150 m.

1.1.2 Fatigue assessment is performed on the applicable special structural details listed in Ch 13, Sec 5, [2] in order to prevent the following types of fatigue failure:

- fatigue cracks initiating from the weld toe and propagating into the base material
- fatigue cracks initiating from the free edge of non-welded details.

1.1.3 When the structural arrangement is such that some of the listed details listed are not relevant, specific requirements are defined by the Society on a case by case basis, depending on the arrangement adopted.

1.2 Reference

1.2.1 When reference is made to NI611 "Guidelines for Fatigue Assessment of Steel Ships and Offshore Units", the latest version of this Guidance Note is applicable.

1.3 Fatigue due to loading and unloading

1.3.1 The additional fatigue damage that may be induced by the loading and unloading cycles is to be considered for ships assigned with one of the following service notations:

- **hopper dredger**
- **hopper unit**
- **split hopper unit**
- **split hopper dredger.**

1.3.2 Wave loads associated to loading and unloading fatigue assessment are to be obtained using the specific f_p coefficient defined in Ch 5, Sec 3.

1.3.3 The detailed operational loading / unloading sequence is to be provided by the Designer (loading/unloading cycle period, loading conditions involved, number of loading / unloading cycles per year).

2 Loading conditions

2.1 Design loading conditions for fatigue assessment

2.1.1 General

Loading conditions representative of the intended operation and the fraction of time spent in each condition are to be considered for fatigue analysis.

Unless otherwise specified, the following loading conditions are to be considered:

- full load condition 50% of the time
- normal ballast condition 50% of the time

Tanks filling levels associated to each loading condition are detailed in Tab 1.

2.1.2 Ro-ro and passenger ships

For ships with the service notation **ro-ro cargo ship**, **PCT carrier**, **passenger ship** or **ro-ro passenger ship**, the full load condition is to be considered 100% of the time.

Table 1 : Tanks filling levels for fatigue loading conditions

Type of tank	Filling level	
	Full load condition	Normal ballast condition
Cargo holds(2)	100 %	0 %
Ballast tanks	0 %	100 %
Consumable tanks(1)	50 %	50 %
(1) Consumable tanks are to be filled at 100% in case of FE fatigue analysis		
(2) If applicable		

2.1.3 Container ships

For ships with the service notation **container ship**, the loading condition to be considered for fatigue is defined in Pt D, Ch 2, Sec 2, [11.2].

2.1.4 Bulk carriers, ore carriers and combination carriers

For ships with the service notation **bulk carrier**, **bulk carrier ESP**, **self-unloading bulk carrier ESP**, **ore carrier ESP** or **combination carrier ESP**, the following loading conditions are to be considered:

- full load homogeneous condition: 25% of the time
- partially filled alternate loading condition: 25% of the time if allowed by the loading manual. Otherwise, the full load homogeneous condition is to be increased to 50%.
- normal ballast condition: 25% of the time
- heavy ballast 25% of the time.

3 Corrosion model

3.1 General

3.1.1 Corrosion model

The fatigue assessment is to be performed based on net thicknesses according to Ch 4, Sec 2.

Unless otherwise specified in Part D or Part E, the following values of stress correction factor as defined in NI611 are to be considered:

- for analytical approach for longitudinal stiffeners:
 - $f_{c-a} = 0,95$
 - $f_{c-b} = 1,0$
- for FEA calculations:
 - $f_{c-FEA} = 0,95$

4 Fatigue assessment based on a deterministic approach

4.1 Longitudinal stiffener connections

4.1.1 Application

The fatigue strength of connections of longitudinal stiffeners with stiffeners of transverse primary supporting members is to be checked according to the methodology of NI611 as applicable to the “simplified rule based approach”.

For application of this methodology, requirements [4.1.2] to [4.1.6] are to be taken into account.

4.1.2 Loading conditions

The design fatigue loading conditions as defined in [2.1] are to be considered.

4.1.3 Hull girder loads

The vertical still water bending moment distribution defined in Ch 5, Sec 4, [2.1.3] is to be considered for the fatigue assessment. The torsional still water moment is to be taken equal to zero.

4.1.4 Load cases

The dynamic load cases to be considered are given in Ch 5, Sec 2, [3].

The design load scenario for fatigue assessment is defined in Ch 5, Sec 7, [3].

For the loading conditions defined in [4.1.2], all the fatigue load cases are to be considered for fatigue assessment in accordance with NI611.

4.1.5 Fatigue damage calculation

The fatigue damage is to be calculated according to NI611 as applicable, considering:

- a simplified rule based approach
- a single period design life pattern
- the corrosion protection.

4.1.6 Acceptance criteria

The acceptance criteria is defined in [6].

4.2 Other structural details

4.2.1 Application

When the structural details other than longitudinal connections to primary supporting members are assessed by deterministic fatigue analysis, they are to be checked according to the methodology of NI611 as applicable to the “rule based approach”, taking into account requirements [4.2.2] to [4.2.7].

4.2.2 Loading conditions

The design fatigue loading conditions as defined in [2.1] are to be considered.

4.2.3 Hull girders loads

The vertical still water bending moment and shear force distribution are to be taken as the maximum permissible value in seagoing operation.

The torsional still water moment is to be taken equal to zero.

4.2.4 Load cases

The dynamic load cases to be considered are given in Ch 5, Sec 2, [3].

The design load scenario for fatigue assessment is defined in Ch 5, Sec 7, [3].

For the loading conditions defined in [4.2.2], all the fatigue load cases are to be considered for fatigue assessment in accordance with NI611.

4.2.5 Hot spot stress calculation for welded details

For hot spot stress calculation of ordinary welded details as defined in NI611, the “hot spot stress without stress extrapolation” method is to be considered.

4.2.6 Fatigue damage calculation

The fatigue damage is to be calculated according to NI611 as applicable, considering:

- a simplified rule based approach
- a single period design life pattern
- the corrosion protection.

4.2.7 Acceptance criteria

The acceptance criterion is defined in [6].

5 Fatigue assessment based on spectral fatigue analysis

5.1 General

5.1.1 Fatigue strength of details subject to spectral fatigue analysis is to be assessed following the provisions of NI611 considering the assumptions given in [5.1.2] to [5.1.6].

5.1.2 Seakeeping assumptions

The seakeeping analysis necessary to the spectral fatigue assessment is to be based on:

- linear analysis
- ship speed, to be taken as 66% of the design speed
- at least 36 headings, 10° steps
- frequencies, to be taken in the range [0:2] rad/s
- frequency step, to be about $0,3 (g / L)^{0,5}$
- intermittent wetting, to be accounted for, where relevant.

5.1.3 Loading conditions

The design fatigue loading conditions as defined in [2.1] are to be considered.

5.1.4 Environmental conditions

The long term analysis of stress RAOs is to be carried out considering the North Atlantic scatter diagram.

5.1.5 Fatigue damage calculation

The fatigue damage is to be calculated according to NI611 as applicable, considering:

- a spectral analysis
- a single period design life pattern
- the corrosion protection.

5.1.6 Acceptance criteria

The acceptance criterion is defined in [6].

6 Acceptance criteria

6.1 Fatigue life and acceptance criteria

6.1.1 General

For each considered detail, the calculated fatigue life T_f is to be greater than T_{DF} .

Part B

Hull and Stability

CHAPTER 11

OTHER STRUCTURES

Section 1	Fore Part
Section 2	Machinery Space
Section 3	Aft Part
Section 4	Tanks Subject to Sloshing
Section 5	Superstructures and Deckhouses
Section 6	Bow Doors and Inner Doors
Section 7	Side Doors and Stern Doors
Section 8	Watertight and Weathertight Doors
Section 9	Large Hatch Covers
Section 10	Small Hatches
Section 11	Movable Decks, Inner Ramps and External Ramps
Section 12	Arrangement of Hull and Superstructure Openings
Section 13	Helicopter Decks and Platforms

Section 1 Fore Part

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

a_p : Correction factor for panel aspect ratio to be taken as:

$$\alpha_p = 1,2 - \frac{b}{2,1a}$$

but not to be taken greater than 1,0

b_1 : Breadth of impact area supported by primary supporting member, in m, as defined in Ch 7, Sec 6, [2.3.1]

c_E : Coefficient to be taken equal to:

$$c_E = 1 \quad \text{for } L \leq 65 \text{ m}$$

$$c_E = 3 - L / 32,5 \quad \text{for } 65 \text{ m} < L < 90 \text{ m}$$

$$c_E = 0 \quad \text{for } L \geq 90 \text{ m}$$

c_F : Coefficient to be taken equal to:

$$c_F = 0,9 \quad \text{for forecastle sides}$$

$$c_F = 1,0 \quad \text{in other cases}$$

f_{bdg} : Bending moment factor taken as:

$$f_{bdg} = 8 \left(1 + \frac{n_s}{2} \right)$$

n_s : End fixation factor taken as:

- for both ends with low end fixity (simply supported): $n_s = 0$
- for one end fixed and one end simply supported: $n_s = 1$
- for continuous members or members with brackets fitted at both ends: $n_s = 2$.

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the following structures of the fore part as defined in Ch 1, Sec 1, [2.1.2]:

- fore peak structures
- stem.

In addition, the requirements of this Section apply to structure subjected to impact loads:

- flat bottom forward, according to [3.2]
- bow area, according to [3.3].

2 Structural arrangement

2.1 Bottom Structure

2.1.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than the values specified in Tab 1.

Table 1 : Scantling of bottom plating and ordinary stiffeners

Element	Minimum value
Plating	Net minimum thickness, in mm: in general: $t = c_F (0,03 L_3 + 5,5) k^{1/2} - c_E$ for inner bottom: $t = 2 + 0,017 L_3 k^{1/2} + 4,5 s$
Ordinary stiffeners	Web net minimum thickness, in mm, to be not less than the lesser of: <ul style="list-style-type: none"> • $t = 1,5 L_0^{1/3} k^{1/6}$ • the net thickness of the attached plating.

2.1.2 Floors

In case of transverse framing, solid floors are to be fitted at each web frame location.

In case of longitudinal framing, the spacing of solid floors is not to be greater than 3,5 m or four transverse frame spaces, whichever is smaller.

The floors dimensions and scantlings are to be not less than those specified in Tab 2 and Tab 3.

Table 2 : Longitudinally framed bottom - Floors and girders dimensions and scantlings

Dimension or scantling	Specified value
Web height, in m	$h_M = 0,085 D + 0,15$
Web net thickness, in mm	$t = \min(10\text{mm}; 1,5L_0^{1/3}k^{1/6})$
Floor face plate net sectional area, in cm ²	$A_p = 3,15 D$
Floor face plate net thickness, in mm	$t_p = 0,4 D + 5$ may be assumed not greater than 14 mm

Table 3 : Transversely framed bottom - Floors dimensions and scantlings

Dimension or scantling	Specified value
Web height, in m	$h_M = 0,085 D + 0,15$
Web net thickness, in mm	$t = \min(10\text{mm}; 1,5L_0^{1/3}k^{1/6})$
Floor face plate net sectional area, in cm ²	$A_p = 1,67 D$

2.1.3 Bottom girders

A supporting structure is to be provided at the centreline, either by extending the centreline girder to the stem, or by providing a deep girder or a centreline bulkhead.

The centre bottom girder is to be connected to the collision bulkhead by means of a large end bracket.

The spacing of bottom girders is not to exceed:

- 2,5 m in case of transverse framing
- 3,5 m in case of longitudinal framing.

The bottom girders dimensions are to be not less than those specified in Tab 2.

2.1.4 Alternative design verification

The spacing of solid floors and bottom girders, defined in [2.1.2] and [2.1.3] respectively, may be increased, if the designer performs a verification of the bottom structure by means of grillage analysis or FE analysis and provides the full corresponding documentation.

The acceptance criteria to be applied are defined in Ch 7, Sec 6, [5.1.4]. A FE analysis is to be performed, considering the requirements provided in Part B, Chapter 8.

2.2 Centreline wash bulkheads

2.2.1 General

Except for dry peaks, a centreline longitudinal wash bulkhead may be required in liquid compartments for which there is a risk of resonance in the transverse direction.

2.2.2 Extension

In the case of a bulbous bow, such bulkhead is generally to extend for the whole length and depth of the fore peak.

Where hull structures are flared, such as those situated above the bulb and in the fore part of the peak, the bulkhead may be locally omitted.

Similarly, the extension of the bulkhead may be limited for bows without a bulb, depending on the shape of the hull. However, the bulkhead is to be fitted in the higher part of the peak.

2.2.3 Plating thickness

The net plating thickness of the lower part of the longitudinal bulkhead over a height at least equal to h_M defined in Tab 2 is to be not less than that required for the centre girder in [2.1.3].

Elsewhere, the net thickness of the longitudinal bulkhead plating is to be not less than the value obtained, in mm, from the following formula: $t = 6,5 + 0,013 L_1$

2.2.4 Ordinary stiffeners

The net section modulus of ordinary stiffeners is to be not less than the value obtained, in cm³, from the following formula:

$$w = 3,5 s \ell^2 k (z_{TOP} - z_M)$$

where:

- z_{TOP} : Z co-ordinate, in m, of the highest point of the tank
- z_M : Z co-ordinate, in m, of the stiffener mid-span.

2.2.5 Primary supporting members

Vertical and longitudinal primary supporting members, to be made preferably with symmetrical type sections, are to have a section modulus not less than 50% of that required for the corresponding side transverse or side girder.

The vertical and longitudinal webs are to be provided with adequate fairing end brackets and to be securely connected to the struts, if any.

2.2.6 Openings

Bulkhead openings are to be limited in the zone corresponding to the centre girder to approximately 2% of the total area of the bulkhead, and, in the zone above, to not less than 10% of the total area of the bulkhead. Openings are to be located such as to affect as little as possible the plating sections adjacent to primary supporting members.

2.3 Side shell structure

2.3.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than the values specified in Tab 4.

Table 4 : Scantling of side plating and ordinary stiffeners

Element	Minimum value
Plating	Net minimum thickness, in mm: $t = c_F (0,03 L_3 + 5,5) k^{1/2} - c_E$
Ordinary stiffeners	Web net minimum thickness, in mm, to be not less than the lesser of: <ul style="list-style-type: none"> • $t = 1,5 L_0^{1/3} k^{1/6}$ • the net thickness of the attached plating

2.3.2 Web frames

The spacing S of web frames, in m, as defined in Ch 1, Sec 3, Tab 4, is generally not to be taken greater than:

$$S = 2,6 + 0,005 L$$

2.3.3 Stringers

Stringers are to have an effective span not greater than 10 m and are to be adequately supported by web frame structures.

Moreover, the depth b_A , in mm, and the net thickness t_A , in mm, of the stringer webs of transversely framed side are generally to be not less than the values obtained from the following formulae:

$$b_A = 2,5 (180 + L)$$

$$t_A = (6 + 0,018 L) k^{1/2}$$

2.3.4 Alternative design verification

The spacing of web frames and stringers may be increased, if the designer performs a verification of the side shell supporting structure by means of beam analysis or FE analysis and provides the full corresponding documentation.

The acceptance criteria to be applied are defined in Ch 7, Sec 6, [5.1.4]. A FE analysis is to be performed, considering the requirements provided in Part B, Chapter 8.

2.3.5 Panting structures

In order to withstand the panting loads, horizontal structures are to be provided. These structures are to be fitted at a spacing generally not exceeding 2 m and consist of side girders supported by panting beams or side transverses whose ends are connected to deck transverses, located under the tank top, so as to form a strengthened ring structure.

Panting beams, which generally consist of sections having the greater side vertically arranged, are to be fitted every two frames. Each panting beam is to be connected to the side frames by means of brackets whose arms are generally to be not less than twice the panting beam depth.

Side frames not supporting panting beams are to be connected to side girders by means of brackets having the same thickness as that of the side girder and arms which are to be not less than one half of the depth of the side girder.

The net area A_B , in cm^2 , and the net inertia J_B , in cm^4 , of the panting beam section are to be not less than the values obtained from the following formulae:

$$A_B = 0,5 L - 18$$

$$J_B = 0,34 (0,5 L - 18) b_B^2$$

where:

b_B : Beam length, in m, measured between the internal edges of side girders or the internal edge of the side girder and any effective central or lateral support.

Where side girder spacing is other than 2 m, the values A_B and J_B are to be modified according to the relation between the actual spacing and 2 m.

Panting beams of considerable length are generally to be supported at the centreline by a wash bulkhead or pillars arranged both horizontally and vertically.

Non-tight platforms may be fitted in lieu of side girders and panting beams. Their openings and scantlings are to be in accordance with [2.6.1].

Their spacing is to be not greater than 2,5 m.

If the peak exceeds 10 m in depth, a non-tight platform is to be arranged at approximately mid-depth.

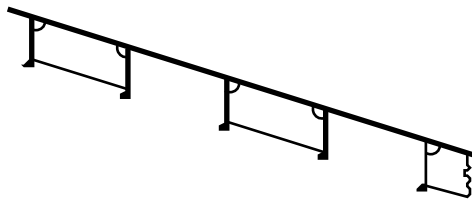
Where the peak exceeds 10 m in length and the frames are supported by panting beams or non-tight platforms, additional transverse wash bulkheads or side transverses are to be fitted.

2.4 Tripping brackets

2.4.1 For side shell and tank walls located forward of the collision bulkhead and vertically framed, tripping brackets spaced not more than 2,6 m are to be fitted, according to Fig 1, between primary supporting members, decks and/or platforms.

The as-built thickness of the tripping brackets is not to be less than the as-built thickness of the side frame webs to which they are connected.

Figure 1 : Tripping brackets



2.5 Decks

2.5.1 Plating and ordinary stiffeners

The net scantlings of deck plating and ordinary stiffeners, up to the bulkhead deck, are to be not less than the values obtained from the values specified in Tab 5.

Table 5 : Scantling of deck plating and ordinary stiffeners

Element	Minimum value
Plating	Net minimum thickness, in mm: $t = 2,1 + 0,013 L_3 k^{1/2} + 4,5 s$
Ordinary stiffeners	Web net minimum thickness, in mm, to be not less than the lesser of: <ul style="list-style-type: none"> $t = 1,5 L_0^{1/3} k^{1/6}$ the net thickness of the attached plating.

2.6 Platforms

2.6.1 Non-tight platforms

Non-tight platforms located inside the peak are to be provided with openings having a total area not less than 10% of that of the platforms. Moreover, the thickness of the plating and the section modulus of ordinary stiffeners are to be not less than those required in [2.2] for the non-tight central longitudinal bulkhead.

The number and depth of non-tight platforms within the peak is considered by the Society on a case by case basis.

The platforms may be replaced by equivalent horizontal structures whose scantlings are to be supported by direct calculations.

2.6.2 Platform transverses

The net sectional area of platform transverses, calculated considering a width of attached plating whose net sectional area is equal to that of the transverse flange, is to be not less than the value obtained, in cm^2 , from the following formula:

$$A = \frac{10P_{ex}d_s h_s}{C_p R_y}$$

where:

P_{ex} : Sea pressure, defined in Ch 5, Sec 5, [1], acting at the ends of the platform transverse in the direction of its axis.

- d_s : Half of the longitudinal distance between the two adjacent transverses, in m
 h_s : Half of the vertical distance between the two adjacent platforms, in m
 C_p : Coefficient, to be taken equal to:

$$C_p = 1 \quad \text{for} \quad \frac{d_p}{r_p} \leq 70$$

$$C_p = 1,7 - 0,01 \frac{d_p}{r_p} \quad \text{for} \quad 70 < \frac{d_p}{r_p} \leq 140$$

When $d_p/r_p > 140$, the scantlings of the struts are considered by the Society on a case by case basis

- d_p : Distance, in cm, from the face plate of the side transverse and that of the bulkhead vertical web, connected by the strut, measured at the level of the platform transverse
 r_p : Radius of gyration of the strut, to be obtained, in cm, from the following formula:

$$r_p = \sqrt{\frac{J}{A_E}}$$

- A_E : Actual net sectional area, in cm^2 , of the transverse section of the strut considered
 J : Minimum net moment of inertia, in cm^4 , of the strut considered

2.6.3 Breasthooks

Breasthooks are to have the same thickness of that required for platforms. They are to be arranged on the stem, in way of every side longitudinal, or at equivalent spacing in the case of transverse framing, extending aft for a length equal to approximately twice the breasthook spacing.

2.7 Bulbous bow

2.7.1 General

Where a bulbous bow is fitted, the structural arrangements are to be such that the bulb is adequately supported and integrated into the fore peak structure.

2.7.2 Diaphragm plates

At the forward end of the bulb, the structure is generally to be supported by horizontal diaphragm plates, spaced about 1 m apart, in conjunction with a deep centreline web.

In general, vertical transverse diaphragm plates are to be arranged in way of the transition from the peak framing to the bulb framing.

2.7.3 Special bulbous bow designs

In way of a wide bulb, additional strengthening in the form of a centreline wash bulkhead is generally to be fitted.

In way of a long bulb, additional strengthening in the form of transverse wash bulkheads or substantial web frames is to be fitted.

2.7.4 Strengthening for anchor and chain cable contact

The shell plating is to be increased in thickness at the forward end of the bulb and also in areas likely to be subjected to contact with anchors and chain cables during anchor handling. The increased plate thickness is to be the same as that required for plated stems given in [2.8.1].

2.8 Stems

2.8.1 Plate stem

The net thickness t_{sm} , in mm, is not to be less than: $t_{sm} = (0,6 + 0,4 S_B) (0,08 L + 2,7) k^{0,5}$

but need not be greater than: $22 k^{0,5} - 1$

where:

S_B : Spacing, in m, between horizontal stringers (partial or not), breasthooks, or equivalent horizontal stiffening members. Starting from 0,6 m above T_{SC} up to $(T_{SC} + C_w)$, the net thickness may gradually be reduced to $0,8 t_{sm}$.

The plating forming the stems is to be supported by horizontal diaphragms spaced not more than 1200 mm apart and connected, as far as practicable, to the adjacent frames and side stringers.

2.8.2 Bar stems

The gross area of bar stems constructed of forged or rolled steel is to be not less than the value obtained, in cm^2 , from the following formulae:

$$A_p = \left(0,40 + \frac{10T}{L}\right) (0,009L^2 + 20) \sqrt{k} \quad \text{for } L \leq 90$$

$$A_p = \left(0,40 + \frac{10T}{L}\right) (1,8L - 69) \sqrt{k} \quad \text{for } 90 < L \leq 200$$

where the ratio T/L in the above formulae is to be taken not less than 0,05 or greater than 0,075.

The gross thickness t_B of the bar stem is to be not less than the value obtained, in mm, from the following formula:

$$t_B = (0,4L + 13)\sqrt{k}$$

The cross-sectional area of the stem may be gradually tapered from the load waterline to the upper end, where it may be equal to the two thirds of the value as calculated above.

The lower part of the stem may be constructed of cast steel subject to the examination by the Society; where necessary, a vertical web is to be fitted for welding of the centre keelson.

Welding of the bar stem with the bar keel and the shell plating is to be in accordance with Ch 13, Sec 3, [5.6].

2.9 Thruster tunnel

2.9.1 General

The net thickness of the tunnel plating t_{tun} , in mm, is not to be less than the net thickness required for the shell plating in the vicinity of the bow thruster.

In addition, t_{tun} is not to be taken less than: $t_{\text{tun}} = 0,008 d_{\text{tun}} + 1,8$

where:

d_{tun} : Inside diameter of the tunnel, in mm, not to be taken less than 970 mm.

Where the outboard ends of the tunnel are provided with bars or grids, the bars or grids are to be effectively secured.

3 Structures subject to impact loads

3.1 General

3.1.1 Application

This Article covers the strengthening requirements for local impact loads that may occur on the forward structures.

3.1.2 General scantling requirements

Local scantling increase due to impact loads is to be made with due consideration given to the details, provide effective continuity of strength and avoid hard spots, notches and other harmful stress concentrations.

3.1.3 Design to resist impact loads

- a) The design of end connections of stiffeners in the impact regions is to provide end fixity, either by making the stiffeners continuous through supports, or by providing end brackets complying with Ch 4, Sec 5, [3.2]. Where it is not practical to comply with this requirement, the net plastic section modulus, $Z_{\text{pl-alt}}$, in cm^3 , for alternative end fixity arrangements is not to be less than:

$$Z_{\text{pl-alt}} = \frac{16Z_{\text{pl}}}{f_{\text{bdg}}}$$

where:

Z_{pl} : Net plastic section modulus, in cm^3 , as required by Ch 7, Sec 5, [1.3.1].

- b) Scantlings and arrangements of primary supporting members, including decks and bulkheads in way of the stiffeners, are to comply with Ch 7, Sec 6, [2.3]. In areas where impact load is maximum, the web stiffeners are to be arranged perpendicular to the hull envelope plating and double sided lug connections are to be provided.
- c) End brackets of primary supporting members are to be suitably stiffened along their edge. Consideration is to be given to the design of bracket toes to minimise abrupt changes of cross-section.
- d) Tripping arrangements are to comply with Part B, Chapter 9. In addition, tripping brackets are to be fitted at the toe of end brackets and at locations where the primary supporting member flange is knuckled or curved.

3.1.4 Shell plating

The net thickness t , in mm, of the hull envelope plating subjected to bottom slamming or bow impact according to [3.2] and [3.3] is to comply with the requirements in Ch 7, Sec 4, [4], considering the impact pressure P_{SLI} or P_{FI} as applicable, defined respectively in Ch 5, Sec 5, [4.2] and in Ch 5, Sec 5, [4.3].

3.1.5 Shell stiffeners

The shell stiffeners subjected to bottom slamming or bow impact according to [3.2] and [3.3] are to comply with the requirements in Ch 7, Sec 5, [1.3] considering the impact pressure P_{SLI} or P_{FI} as applicable, defined respectively in Ch 5, Sec 5, [4.2] and in Ch 5, Sec 5, [4.3].

3.1.6 Primary supporting members

The primary supporting members subjected to bottom slamming or bow impact according to [3.2] and [3.3] are to comply with the requirements in Ch 7, Sec 6, [2.3], considering the impact pressure P_{SLI} or P_{FI} as applicable, defined respectively in Ch 5, Sec 5, [4.2] and in Ch 5, Sec 5, [4.3].

3.2 Bottom slamming

3.2.1 Application

Where the minimum forward draught T_F , as specified in Ch 1, Sec 2, [1.6.1], is less than $0,04 L$, the bottom forward is to be additionally strengthened to resist bottom slamming pressures.

The draughts for which the bottom has been strengthened are to be indicated on the shell expansion plan and loading guidance information, as required in Ch 1, Sec 5.

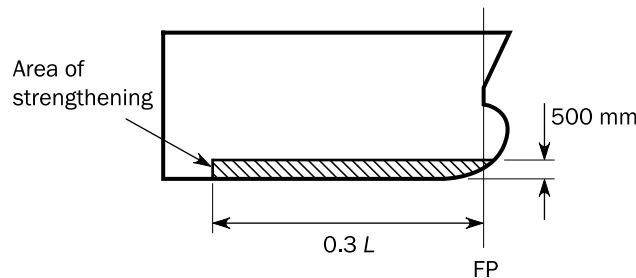
The load calculation point of the primary supporting members is specified in Ch 4, Sec 6, [4].

3.2.2 Extent of strengthening

The strengthening is to extend between $0,7L$ to the fore end, over the flat bottom and adjacent plating with attached stiffeners up to a height of 500 mm above the baseline, see Fig 2.

Outside the region strengthened to resist bottom slamming, the scantlings are to be tapered to maintain continuity of longitudinal and/or transverse strength.

Figure 2 : Extent of strengthening against bottom slamming



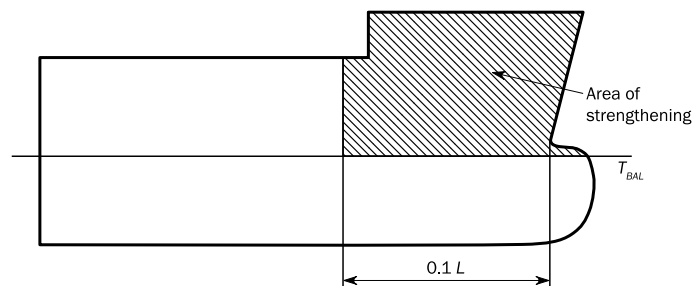
3.3 Bow impact

3.3.1 Application

The side structure in the ship forward area is to be strengthened against bow impact pressures. The strengthening is to extend forward of $0,1 L$ from the FP and, vertically, from the minimum design ballast draught T_{BAL} defined in Ch 1, Sec 3, [2.1.6] up to the forecastle deck, if any, or to the level at which a knuckle with an angle greater than 15° is located on the side shell. See Fig 3.

Outside the strengthening area, scantlings are to be tapered to maintain continuity of longitudinal and/or transverse strength.

Figure 3 : Extent of strengthening against bow impact



3.3.2 Decks bulkheads and webs of primary supporting members

The net web thickness t_w , in mm, of each primary supporting member, including decks and bulkheads in way of the side shell, is not to be less than:

$$t_w = \frac{P_{Fl} b_l}{\sin \varphi_w \sigma_{cr}}$$

where:

- φ_w : Angle, in deg, between the primary supporting member web and the shell plate, as shown in Fig 4
- σ_{cr} : Critical buckling stress in compression, in N/mm^2 , of the web of the primary supporting member or deck/bulkhead panel in way of the applied load, as given in Part B, Chapter 9. In the calculation, both σ'_{cx} and σ'_{cy} are to be considered and UP-B is to be applied.

3.3.3 Breasthooks and diaphragm plating

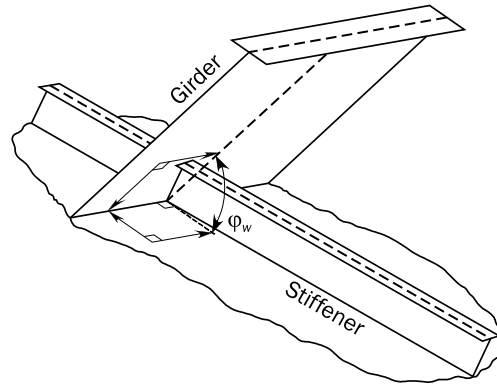
The net thickness of breasthooks/diaphragm plates in way of bow impact strengthening area defined in [3.3.1] t_w , in mm, is not to be less than:

$$t_w = \frac{s}{70} \sqrt{\frac{R_{eH}}{235}}$$

where:

- s : Spacing of stiffeners on the web, in mm, as defined in Ch 1, Sec 3, Tab 4. Where no stiffeners are fitted, s is to be taken as the depth of the web.

Figure 4 : Angle between shell primary member and shell plate



Section 2 Machinery Space

Symbols

P	: Maximum power, in kW, of the engine
n_r	: Number of revolutions per minute of the engine shaft at power equal to P
L_E	: Effective length, in m, of the engine foundation plate required for bolting the engine to the seating, as specified by the engine manufacturer.

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the scantlings and arrangement of structures located in the machinery space. It is the shipyard responsibility to design the ship in accordance with the machinery manufacturer's requirements.

2 Machinery space arrangement

2.1 Structural arrangement

2.1.1 All parts of the machinery, shafting, etc, are to be supported to properly transfer the loads to the ship structure. The adjacent structure is to be suitably stiffened.

2.1.2 Decks which are interrupted in the machinery space are to be tapered on the side by means of horizontal brackets.

2.1.3 In case of change of framing system between machinery space and adjacent hull areas, abrupt structural discontinuities are to be avoided.

2.1.4 The spacing of web frames in way of transversely framed machinery spaces is generally not to exceed five transverse frame spaces. Web frames are to be connected at the top and bottom to members of suitable stiffness.

Side transverses are to be aligned with floors.

For a longitudinally framed side, the side transverse spacing is to be not greater than 4-frame spacing.

2.1.5 Side shell longitudinal stiffeners are to be efficiently connected to transverse bulkheads to provide proper fixity and lateral support. When the stiffener is not continuous through the bulkhead, a soft-toe bracket is to be fitted. Brackets lapped onto the longitudinals are not satisfactory.

2.1.6 Where a transverse framing system is adopted, deck stiffeners are to be supported by a suitable arrangement of longitudinal girders in association with pillars or pillar bulkheads. Where fitted, deck transverses are to be arranged in line with web frames to provide end fixity and transverse continuity of strength.

Where a longitudinal framing system is adopted, deck longitudinals are to be supported by deck transverses in line with web frames in association with pillars or pillar bulkheads.

2.1.7 Machinery casing

Machinery casings are to be supported by a suitable arrangement of deck transverses and longitudinal girders in association with pillars or pillar bulkheads. In way of particularly large machinery casing openings, cross ties may be required. These are to be arranged in line with deck transverses.

The net thickness of bulkheads is to be not less than:

- 5,5 mm for bulkheads in way of cargo holds
- 4 mm for bulkheads in way of accommodation spaces.

2.1.8 The foundations of main propulsion units, reduction gears, shaft and thrust bearings, and the structure supporting those foundations are to maintain the required alignment and rigidity in all anticipated loading conditions. The following drawings are to be submitted to the machinery manufacturer for review:

- foundations of main propulsion units
- foundations of reduction gears
- foundations of thrust bearings
- structures supporting a), b) and c).

2.1.9 Platforms

The location and extension of platforms in machinery spaces are preferably to be arranged so as to be a continuation of the structure of side longitudinals, as well as of platforms and side girders located in the adjacent hull areas.

In general, platform transverses are to be arranged in way of side or longitudinal bulkhead transverses.

The net thickness of platforms is to be not less than that obtained, in mm, from the following formula:

$$t = 0,018 L_0 k^{1/2} + 4,5$$

2.2 Double bottom

2.2.1 General

Where the machinery space is immediately forward of the after peak, the double bottom is to be transversely framed. In all other cases it may be transversely or longitudinally framed.

2.2.2 Minimum thicknesses

The net thicknesses of inner bottom, floor and girder webs are to be not less than the values given in Tab 1.

Table 1 : Double bottom - Minimum net thicknesses of inner bottom, floor and girder webs

Element	Minimum net thickness, in mm	
	Machinery space within 0,4L amidships	Machinery space outside 0,4L amidships
Inner bottom	$3,0 + 0,024 L k^{1/2} + 0,0045b$ The Society may require the thickness of the inner bottom in way of the main machinery seatings and on the main thrust blocks to be increased, on a case by case basis.	
Margin plate	$L^{1/2} k^{1/4} + 1$	$0,9 L^{1/2} k^{1/4} + 1$
Centre girder	$1,8 L^{1/3} k^{1/6} + 4$	$1,55 L^{1/3} k^{1/6} + 3,5$
Floors and side girders	$1,7 L^{1/3} k^{1/6} + 1$	
Girder bounding a duct keel	$0,8 L^{1/2} k^{1/4} + 2,5$ to be taken not less than that required for the centre girder	

2.2.3 Lower net thickness values for floor and web girder web can be accepted, if based on direct calculations.

2.2.4 Double bottom height

The double bottom height at the centreline, irrespective of the location of the machinery space, is to be not less than the value defined in Ch 2, Sec 2, [3]. This depth may need to be considerably increased, depending on the type and depth of main machinery seatings.

Where the double bottom height in the machinery space differs from that in adjacent spaces, structural continuity of longitudinal members is to be provided by sloping the inner bottom over an adequate longitudinal extent. The knuckles in the sloped inner bottom are to be located in way of floors. A lesser double bottom height may be accepted in local areas provided that the overall strength of the double bottom structure is not thereby impaired.

2.2.5 Centreline girder

The double bottom is to be arranged with a centreline girder. Manholes in the centreline girder are only to be fitted where absolutely necessary for double bottom access and maintenance. Local strengthening in way of such manholes is to be provided.

2.2.6 Side bottom girders

In the machinery space, the number of side bottom girders is to be adequately increased, with respect to the adjacent areas, to provide adequate rigidity of the structure. The side bottom girders, in longitudinal stiffened double bottom, are to be in line with bottom longitudinals in adjacent areas. The spacing of such girders is generally not to be greater than 3 times that of the longitudinals and in no case greater than 3 m.

2.2.7 Girders in way of machinery seatings

Bottom girders are to be fitted in way of machinery seatings.

Bottom girders arranged in way of main machinery seatings are to be extended over the full length of the machinery space.

Where the machinery space is situated amidships, the bottom girders are to extend aft of the after bulkhead of such space for at least three frame spaces, and beyond to be connected to the hull structure by tapering.

Where the machinery space is situated aft, the bottom girders are to extend as far as practicable and be supported by floors and side primary supporting members at the ends.

Forward of the machinery space forward bulkhead, the bottom girders are to be tapered for at least three frame spaces and are to be effectively connected to the hull structure.

2.2.8 Floors in longitudinally stiffened double bottom

Where the double bottom is longitudinally stiffened, plate floors are to be fitted at every frame under the main engine and thrust bearing. Outboard of the engine and bearing seatings, the floors may be fitted at alternate frames.

2.2.9 Floors in transversely framed double bottom

Where the double bottom in the machinery space is transversely stiffened, floors are to be arranged at every frame. Boilers and other important machinery are to be supported by means of structural elements of adequate strength.

2.2.10 Manholes and wells

The number and size of manholes in floors located in way of seatings and adjacent areas are to be kept to the minimum necessary for double bottom access and maintenance.

The depth of manholes is generally to be not greater than 40% of the floor local depth.

In general, manhole edges are to be stiffened with flanges; failing this, the floor plate is to be adequately stiffened with flat bars at manhole sides.

Manholes with perforated portable plates are to be fitted in the inner bottom in the vicinity of wells arranged close to the aft bulkhead of the engine room.

Drainage of the tunnel is to be arranged through a well located at the aft end of the tunnel.

2.2.11 Inner bottom plating

Where main engines or thrust bearings are bolted directly to the inner bottom, the net thickness of the inner bottom plating is to be at least 19 mm. The hold-down bolts are to be arranged as close as possible to floors and longitudinal girders. Plating thickness and arrangements of hold-down bolts are also to consider the manufacturer's recommendations.

2.2.12 Heavy equipment

Where an heavy equipment is mounted directly on the inner bottom, the thickness of the floors and girders is to be suitably increased.

2.3 Single bottom

2.3.1 Floors in longitudinally framed single bottom

Where the single bottom is longitudinally framed, the floor spacing is to be not greater than:

- 1-frame spacing in way of the main engine and thrust bearing
- 2-frame spacing in other areas of the machinery spaces.

Boilers and other important machinery are to be supported by means of structural elements of adequate strength.

2.3.2 Floors in transversely framed single bottom

Where the single bottom is transversely framed, the floors are to be arranged at every frame.

Boilers and other important machinery are to be supported by means of structural elements of adequate strength.

2.3.3 Floor height

The height of floors in way of machinery spaces located amidships is to be not less than B/14,5. Where the top of the floors is recessed in way of main machinery, the height of the floors in way of this recess is generally to be not less than B/16. Lower values will be considered by the Society on a case by case basis.

Where the machinery space is situated aft or where there is considerable rise of floor, the depth of the floors will be considered by the Society on a case by case basis.

2.3.4 Floor flanging

Floors are to be fitted with welded face plates in way of:

- engine bed plates
- thrust blocks
- auxiliary seatings.

2.3.5 Minimum thicknesses

The net thicknesses of floor and girder webs are to be not less than the values given in Tab 2.

Table 2 : Single bottom - Minimum net thicknesses of floor and girder webs

Element	Minimum net thickness, in mm	
	Machinery space within 0,4L amidships	Machinery space outside 0,4L amidships
Centre girder	$7 + 0,05 L_0 k^{1/2}$	$6 + 0,05 L_0 k^{1/2}$
Floors and side girder	$6,5 + 0,05 L_0 k^{1/2}$	$5 + 0,05 L_0 k^{1/2}$

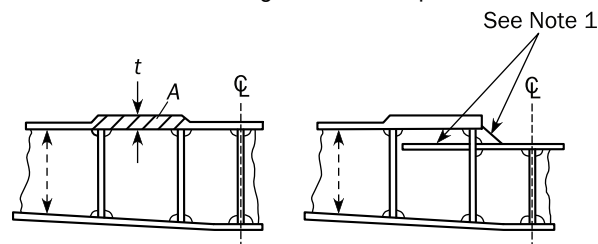
3 Machinery foundations

3.1 General

3.1.1 Main engines and thrust bearings are to be effectively secured to the hull structure by foundations having a strength sufficient to resist the various gravitational, thrust, torque, dynamic, and vibratory forces which may be imposed on them.

3.1.2 In the case of higher power internal combustion engines or turbine installations, the foundations are generally to be integrated within the double bottom structure. Consideration is to be given to substantial increase of the inner bottom plating thickness in way of the engine foundation plate or the turbine gear case and the thrust bearing, see Fig 1.

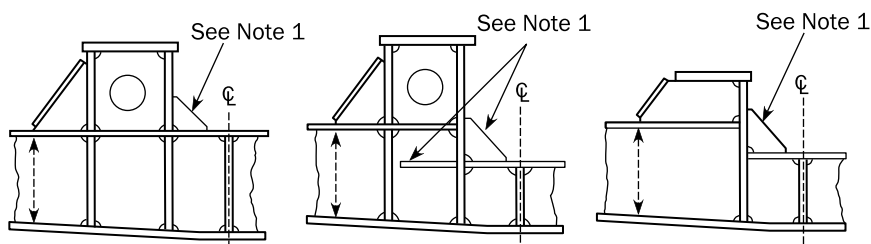
Figure 1 : Machinery foundations type 1
Seat integral with tank top



Note 1: Brackets are to be as large as possible. Brackets may be omitted to avoid interference with the girders of the engine foundation, in accordance with the recommendations of the engine manufacturer.

3.1.3 For main machinery supported on foundations of Type 2, as shown in Fig 2, the forces from the engine into the adjacent structure are to be distributed as uniformly as possible. Longitudinal members supporting the foundation are to be aligned with girders in the double bottom, and transverse stiffening is to be arranged in line with the floors, see Fig 2.

Figure 2 : Machinery foundations type 2
Built-up seat



Note 1: Brackets are to be as large as possible. Brackets may be omitted to avoid interference with the girders of the engine foundation, in accordance with the recommendations of the engine manufacturer.

3.1.4 Supporting structure above the double bottom plating

Girders in way of seatings are to be fitted with flanged brackets, generally located at each frame and extending towards both the centre of the ship and the sides.

The extension of the seatings above the double bottom plating is to be limited as far as practicable while ensuring adequate spaces for the fitting of bedplate bolts. Bolt holes are to be located such that they do not interfere with supporting structures.

3.1.5 Seatings in a single bottom structure

For ships having a single bottom structure within the machinery space, seatings are to be located above the floors and to be adequately connected to the latter and to the girders located below.

3.2 Scantlings

3.2.1 The net scantlings of the structural elements in way of the seatings of engines are to be determined by the engine manufacturer. They are to be checked on the basis of justificative calculations supplied by the engine manufacturer. If these calculations are not supplied, the net scantlings of the structural elements in way of the seatings of engines are to be not less than those obtained from the formulae in Tab 3.

3.3 Foundations for internal combustion engines and thrust bearings

3.3.1 The general rigidity of the engine is to be considered in the determination of the foundations scantlings, as it may have an incidence on the loads balance.

3.3.2 Generally, two girders are to be fitted in way of the foundation for internal combustion engines and thrust bearings.

3.3.3 Number of longitudinal members in way of seatings of engines

In general, at least two longitudinal members are to be fitted in way of seatings of main engines.

One longitudinal member may be fitted only where the following three formulae are complied with:

$$L < 150 \text{ m}$$

$$P < 7100 \text{ kW}$$

$$P < 2,3 n_R L_E$$

3.4 Auxiliary machinery foundations

3.4.1 Auxiliary machinery is to be secured on foundations that are of suitable size and arrangement to distribute the loads from the machinery evenly into the supporting structure.

Table 3 : Scantlings of the structural elements in way of seatings of engines

Scantling	Minimum value
Net cross-sectional area, in cm ² , of each bedplate of the seatings	$40 + 70 \frac{P}{n_r L_E}$
Net thickness, in mm, of each bedplate of the seatings	<ul style="list-style-type: none"> Bedplate supported by two or more longitudinal members: $\sqrt{240 + 175 \frac{P}{n_r L_E}}$ Bedplate supported by one longitudinal member: $5 + \sqrt{240 + 175 \frac{P}{n_r L_E}}$
Web net thickness, in mm, of girders fitted in way of each bedplate of the seatings	<ul style="list-style-type: none"> Bedplate supported by two or more longitudinal members: $\frac{1}{n_G} \sqrt{320 + 215 \frac{P}{n_r L_E}}$ where n_G is the number of longitudinal members in way of the bedplate considered Bedplate supported by one longitudinal member: $\sqrt{95 + 65 \frac{P}{n_r L_E}}$
Web net thickness, in mm, of transverse members fitted in way of bedplates of the seating(1)	$\sqrt{55 + 40 \frac{P}{n_r L_E}}$
(1) When intermediate transverse members welded to the bedplate are fitted, the web minimum net thickness may be reduced on a case-by-case basis.	

Section 3 Aft Part

Symbols

F_C : Force, in kN, taken equal to:

$$F_C = \left(\frac{2\pi N}{60}\right)^2 R_p P$$

P : Mass of a propeller blade, in t

N : Number of revolutions per minute of the propeller

R_p : Distance, in m, of the centre of gravity of a blade in relation to the rotation axis of the propeller

σ_{ALL} : Allowable stress, in N/mm²: $\sigma_{ALL} = 70 / k$

where:

k : Material factor, as defined in Ch 4, Sec 1, [2.2]

w_A : Section modulus, in cm³, of the arm at the level of the connection to the hull with respect to a transversal axis

w_B : Section modulus, in cm³, of the arm at the level of the connection to the hull with respect to a longitudinal axis

A : Sectional area, in cm², of the arm

A_s : Shear sectional area, in cm², of the arm

d_p : Propeller shaft diameter, in mm, measured inside the liner, if any

b : Breadth of the plate panel, in mm, as defined in Ch 4, Sec 6, [2.1.1].

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the scantlings and arrangement of structures located aft of the aft peak bulkhead.

2 Aft peak

2.1 Structural arrangement

2.1.1 Floors

Floors are to be fitted at each frame space in the aft peak. They are to extend at least above the stern tube. Where floors do not extend up to a platform or a deck, they are to be stiffened by flanges at their upper end.

Heavy plate floors are to be fitted in way of, and near, the rudder post, propeller post and rudder horn. They are to extend up to the peak tank top or platform. In this area, cut outs, scallops and other openings are to be kept to a minimum.

2.1.2 Platforms and side girders

Platforms and side girders within the peak are to be arranged in line with those located in the area immediately forward.

Where this arrangement is not possible due to the shape of the hull and access needs, structural continuity between the peak and the structures of the area immediately forward is to be ensured with wide tapering brackets.

Where the aft peak is adjacent to a longitudinally framed side machinery space, the side girders in the aft peak are to be fitted with tapering brackets.

2.1.3 Longitudinal bulkheads

A longitudinal non-tight bulkhead is to be fitted at the centreline of the ship, in general in the upper part of the peak, and stiffened at each frame spacing.

Where either the stern overhang is very large or the maximum breadth of the space divided by watertight and wash bulkheads is greater than 20 m, additional longitudinal wash bulkheads may be required.

2.1.4 Alternative design verification

Spacings and arrangements other than those required in [2.1.1], [2.1.2] and [2.1.3] may be agreed, provided the designer performs a verification by means of grillage analysis or FE analysis and provides the full corresponding documentation. The acceptance criteria to be applied are defined in Ch 7, Sec 6, [5.1.4]. A FE analysis is to be performed under consideration of the requirements provided in Part B, Chapter 8.

2.2 Stiffening of floors and girders

2.2.1 Stiffeners on the floors and girders in aft peak ballast or fresh water tanks above propeller are to be designed in accordance with [2.2.2] and [2.2.3]. This applies for stiffeners located in an area extending longitudinally between the forward edge of the rudder and the after end of the propeller boss and transversely within the diameter of the propeller.

2.2.2 The height of stiffeners h_{stf} , in mm, on the floors and girders in aft peak is not to be less than:

- for flat bar stiffeners: $h_{stf} = 80 l_{stf}$
- for bulb profiles and flanged stiffeners: $h_{stf} = 70 l_{stf}$

where:

l_{stf} : Stiffener length, in m, as shown in Fig 1. l_{stf} need not be taken greater than 5 m.

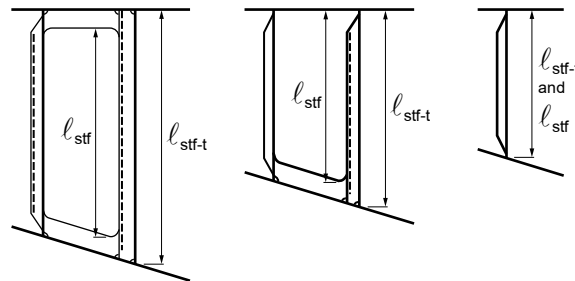
2.2.3 End brackets are to be provided as follows:

- at the lower and upper ends when l_{stf-t} exceeds 4 m
- at the lower end when l_{stf-t} exceeds 2,5 m

where:

l_{stf-t} : Total length of the stiffener, in m, as shown in Fig 1.

Figure 1 : Stiffening of floors and girders in the aft peak tank



$$l_{stf-t} > 4,0 \text{ m} \quad 4,0 \text{ m} \geq l_{stf-t} > 2,5 \text{ m} \quad l_{stf-t} \leq 2,5 \text{ m}$$

3 Connection of hull structures with the rudder horn

3.1 Connection of after peak structures with the rudder horn

3.1.1 General

The requirement of this sub-article apply to the connection between peak structure and rudder horn where the sternframe is of an open type and is fitted with the rudder horn.

3.1.2 Rudder horn

Horn design is to be such as to enable sufficient access for welding and inspection.

The scantlings of the rudder horn, which are to comply with Ch 12, Sec 1, [8.2], may be gradually tapered inside the hull. Connections by slot welds are not acceptable.

3.1.3 Hull structures

Direct calculations are to be performed to check the connection of the rudder horn to the structure of the vessel, taking account of the reactions induced by the rudder on the rudder horn.

The thickness of the structures adjacent to the rudder horn, such as shell plating, floors, platforms and side girders, the centreline bulkhead and any other structures, is to be adequately increased in relation to the horn scantlings.

3.2 Structural arrangement above the after peak

3.2.1 Side transverses

Where a rudder horn is fitted, side transverses, connected to deck beams, are to be arranged between the platform forming the peak tank top and the weather deck.

The side transverse spacing is to be not greater than:

- 2-frame spacing in way of the horn
- 4-frame spacing for and aft of the rudder horn
- 6-frame spacing in the area close to the after peak bulkhead.

The side transverses are to be fitted with end brackets and located within the poop.

3.2.2 Side girders

Where the depth from the peak tank top to the weather deck is greater than 2,6 m and the side is transversely framed, one or more side girders are to be fitted, preferably in line with similar structures existing forward.

4 Stern frames

4.1 General

4.1.1 Stern frames are to be fabricated from steel plates or made of cast steel with a hollow section. For applicable material specifications and steel grades, see Ch 4, Sec 1. Stern frames of other material or construction will be specially considered.

4.1.2 Cast steel and fabricated stern frames are to be strengthened by adequately spaced horizontal plates with gross thickness not less than 80% of the required thickness for stern frames. Abrupt changes of section are to be avoided in castings; all sections are to have adequate tapering radius.

4.1.3 In the upper part of the propeller aperture, where the hull form is full and centreline supports are provided, the thickness of stern frames may be reduced to 80% of the applicable requirement in [4.2.1].

4.2 Propeller posts

4.2.1 Gross scantlings of propeller posts

The gross scantlings of propeller posts are not to be less than those obtained from the formulae in Tab 1 for single screw ships and in Tab 2 for twin screw ships.

Scantlings and proportions of the propeller post which differ from those above may be considered acceptable, provided the section modulus of the propeller post section about its longitudinal axis is not less than the value calculated with the propeller post scantlings in Tab 1 or Tab 2, as applicable.

4.2.2 Propeller shaft bossing

In single screw ships, the thickness of the propeller shaft bossing, over the whole shaft bearing length and included in the propeller post, is not to be less than 60% of the thickness *b* required in [4.2.1] for bar propeller posts with a rectangular section.

4.3 Connections

4.3.1 Connections with hull structure

Stern frames are to be effectively attached to the aft structure and the required scantling for the lower part of the propeller post is to be extended from the aft end of propeller post, at the centerline of the propeller shaft, to a length not less than $(1500 + 6 L_3)$ mm, in order to provide an effective connection with the keel. However, the stern frame need not extend beyond the aft peak bulkhead.

Table 1 : Single screw ships - Gross scantlings of propeller posts

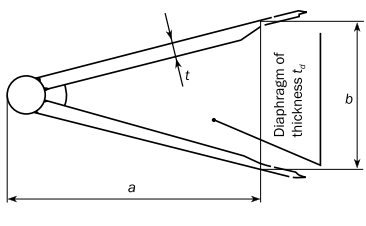
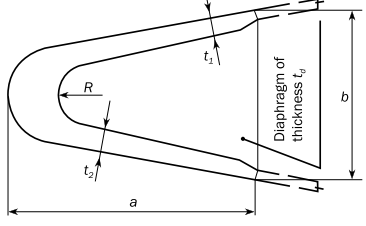
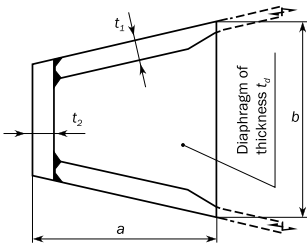
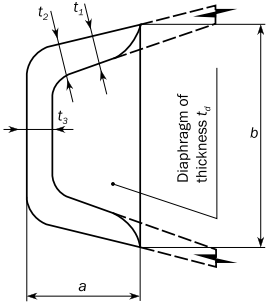
Gross scantlings of propeller posts, in mm	Fabricated propeller post	Cast propeller post	Bar propeller post, cast or forged, having a rectangular section
			
a	$50 L_2^{1/2}$	$33 L_2^{1/2}$	$10\sqrt{7, 2L - 256}$
b	$35 L_2^{1/2}$	$23 L_2^{1/2}$	$10\sqrt{4, 6L - 164}$
<i>t</i> ₁	$2,5 L_2^{1/2}$	$3,2 L_2^{1/2}$	–
<i>t</i> ₂	–	$4,4 L_2^{1/2}$	–
<i>t</i> _d	$1,3 L_2^{1/2}$	$2,0 L_2^{1/2}$	–
R	–	50 mm	–

Table 2 : Twin screw ships - Gross scantlings of propeller posts

Gross scantlings of propeller posts, in mm	Fabricated propeller post	Cast propeller post	Bar propeller post, cast or forged, having a rectangular section
			
a	$25 L_2^{1/2}$	$12,5 L_2^{1/2}$	$2,4 L + 6$
b	$25 L_2^{1/2}$	$25 L_2^{1/2}$	$0,8 L + 2$
t ₁	$2,5 L_2^{1/2}$	$2,5 L_2^{1/2}$	–
t ₂	$3,2 L_2^{1/2}$	$3,2 L_2^{1/2}$	–
t ₃	–	$4,4 L_2^{1/2}$	–
t _d	$1,3 L_2^{1/2}$	$2,0 L_2^{1/2}$	–

4.3.2 Connection with keel plate

The thickness of the lower part of the stern frames is to be gradually tapered to that of the solid bar keel or keel plate.

Where a keel plate is fitted, the lower part of the stern frame is to be designed to ensure an effective connection with the keel.

4.3.3 Connection with transom floors

Rudder posts and propeller posts are to be connected with transom floors having a height not less than the double bottom height and a net thickness not less than the value obtained, in mm, from the following formula:

$$t = 9 + 0,023 L_1$$

4.3.4 Connection with centre keelson

Where the stern frame is made of cast steel, the lower part of the stern frame is to be fitted, as far as practicable, with a longitudinal web for connection with the centre keelson.

4.4 Rudder gudgeons

4.4.1 In general, gudgeons are to be solidly forged or cast with the sternframe.

The height of the gudgeon is to be not greater than 1,2 times the pintle diameter. In any case, the height and diameter of the gudgeons are to be suitable to house the rudder pintle.

The thickness of the metal around the finished bore of the gudgeons is to be not less than half the diameter of the pintle.

4.5 Sterntubes

4.5.1 The sterntube thickness is considered by the Society on a case by case basis. In no case, however, may it be less than the thickness of the side plating adjacent to the sternframe.

Where the materials adopted for the sterntube and the plating adjacent to the sternframe are different, the sterntube thickness is to be at least equivalent to that of the plating.

5 Shell structure

5.1 Shell plating

5.1.1 Minimum net thickness

The minimum net thickness of plating are to be not less than values specified in Tab 3.

5.1.2 Shell plating connected with stern frame

The net thickness of shell plating connected with the stern frame is not to be less than the value obtained, in mm, from the following formula: $t = 0,094 (L_3 - 43) + 0,009 b$

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

$$t = 0,105 (L_3 - 47) + 0,011 b$$

5.1.3 Heavy shell plates

Heavy shell plates are to be fitted locally in way of the heavy plate floors as required in [2.1.1]. The net thickness of heavy shell plates is not to be less than the value given in [5.1.1]. Outboard of the heavy floors, the heavy shell plates may be reduced in thickness in as gradual a manner as practicable. Where the rudder horn plating is radiused into the shell plating, the radius *r* at the shell connection, in mm, is not to be less than: $r = 150 + 0,8 L_3$

5.1.4 Thruster tunnel plating

The net thickness t_{un} of the tunnel plating, in mm, is to comply with the requirements in Ch 11, Sec 1, [2.9].

Table 3 : Net thickness of plating

Plating location	Net minimum thickness, in mm
Bottom and side	$c_F (0,03 L_3 + 5,5) k^{1/2} - c_E$
Inner bottom	$2 + 0,017 L_3 k^{1/2} + 0,0045 b$
Deck	For strength deck: $2,1 + 0,013 L_3 k^{1/2} + 0,0045 b$
Platform and wash bulkhead	<ul style="list-style-type: none"> $1,3 + 0,004 L_3 k^{1/2} + 0,0045 b$ for $L < 120$ m $2,1 + 2,2 k^{1/2} + 0,001b$ for $L \geq 120$ m
Note 1: Where c_F and c_E are coefficient defined in Ch 11, Sec 1.	

5.2 Ordinary stiffeners

5.2.1 Web net minimum thicknesses

The web net minimum thickness of ordinary stiffeners are to be not less than values specified in Tab 3.

Table 4 : Net scantlings of ordinary stiffeners

Ordinary stiffener location	Minimum value
Bottom, side and deck Platform and wash bulkhead	Web net minimum thickness, in mm, to be not less than the lesser of: <ul style="list-style-type: none"> $t = 1,5 L_0^{1/3} k^{1/6}$ the net thickness of the attached plating.

6 Structure subject to stern impact loads

6.1 General

6.1.1 Application

This Article covers the strengthening requirements for local impact loads that may occur on the flat area of the bottom aft structure having a maximum deadrise angle of 30° and located at a distance not greater than h_{SL} from the design waterline, for ships having a length *L* at least equal to 170 m, where:

h_{SL} : Maximum relative wave elevation, in m, for stern impact pressure, as defined in Ch 5, Sec 5, [4.2.2].

6.1.2 General scantling requirements

Local scantling increase due to impact loads is to be made with due consideration given to the details, provide effective continuity of strength and avoid hard spots, notches and other harmful stress concentrations.

6.1.3 Design to resist impact loads

a) The design of end connections of stiffeners in the impact regions is to provide end fixity, either by making the stiffeners continuous through supports, or by providing end brackets complying with Ch 4, Sec 5, [3.2]. Where it is not practical to comply with this requirement, the net plastic section modulus, Z_{pl-alt} , in cm³, for alternative end fixity arrangements is not to be less than:

$$Z_{pl-alt} = \frac{16Z_{pl}}{f_{bdg}}$$

where:

Z_{pl} : Net plastic section modulus, in cm³, as required by Ch 7, Sec 5, [1.3.1].

- b) Scantlings and arrangements of primary supporting members, including decks and bulkheads in way of the stiffeners, are to comply with Ch 7, Sec 6, [2.3]. In areas where impact load is maximum, the web stiffeners are to be arranged perpendicular to the hull envelope plating and double sided lug connections are to be provided.
- c) End brackets of primary supporting members are to be suitably stiffened along their edge. Consideration is to be given to the design of bracket toes to minimise abrupt changes of cross-section.
- d) Tripping arrangements are to comply with Part B, Chapter 9. In addition, tripping brackets are to be fitted at the toe of end brackets and at locations where the primary supporting member flange is knuckled or curved.

6.1.4 Shell plating

The net thickness t , in mm, of the hull envelope plating subject to stern impact according to [6.1.1] is to comply with the requirements in Ch 7, Sec 4, [4], considering the impact pressure P_{SLI} defined in Ch 5, Sec 5, [4.2].

6.1.5 Shell stiffeners

The shell stiffeners subject to stern impact according to [6.1.1] are to comply with the requirements in Ch 7, Sec 5, [1.3] considering the impact pressure P_{SLI} defined in Ch 5, Sec 5, [4.2]

6.1.6 Primary supporting members

The primary supporting members subject to stern impact according to [6.1.1] are to comply with the requirements in Ch 7, Sec 6, [2.3], considering the impact pressure P_{SLI} defined in Ch 5, Sec 5, [4.2].

Section 4 Tanks Subject to Sloshing

Symbols

For symbols not defined in this Section, refer to Ch 1, Sec 3.

α_p : Correction factor for the panel aspect ratio to be taken as:

$$\alpha_p = 1,2 - \frac{b}{2,1 a}$$

but not to be taken greater than 1,0

a : Length of plate panel, in mm, as defined in Ch 4, Sec 6

b : Breadth of plate panel, in mm, as defined in Ch 4, Sec 6

l_{bdg} : Effective bending span, in m, as defined in Ch 4, Sec 6

l_{shr} : Effective shear span, in m, as defined in Ch 4, Sec 6

H : Height of a tank, in m, to be taken as the vertical distance from the bottom to the top of the tank, excluding any small hatchways

l_C : Longitudinal distance, in m, between transverse watertight bulkheads or transverse wash bulkheads, if any, or between a transverse watertight bulkhead and the adjacent transverse wash bulkhead

b_C : Transverse distance, in m, between longitudinal watertight bulkheads or longitudinal wash bulkheads, if any, or between a longitudinal watertight bulkhead and the adjacent longitudinal wash bulkhead

d_F : Filling level of a tank, in m, to be taken as the vertical distance, measured with the ship at rest, from the tank bottom to the free surface of the liquid

l_S : Length, in m, of the free surface of the liquid, measured horizontally with the ship at rest and depending on the filling level d_F , as shown in Fig 1. In this figure, wash bulkheads are those satisfying the requirements in Ch 4, Sec 5, [10.4.1]

b_S : Breadth, in m, of the free surface of the liquid, measured horizontally with the ship at rest and depending on the filling level d_F , as shown in Fig 2 for ships without longitudinal watertight or wash bulkheads.

For ships fitted with longitudinal watertight or wash bulkheads (see Fig 3), b_S is delimited by these bulkheads (to this end, wash bulkheads are those satisfying the requirements in Ch 4, Sec 5, [10.4.1])

σ_L : Hull girder normal stress, in N/mm², as defined in Ch 6, Sec 1, [2.1.2], calculated at the load calculation point as defined in Ch 4, Sec 6, [2.2] or Ch 4, Sec 6, [3.2].

1 Application

1.1 General

1.1.1 The requirements of this Section cover the strengthening requirements for localised loads that may occur in partly filled tanks intended for the carriage of liquid.

1.1.2 Sloshing and impact pressures are to be considered as applicable according to respectively [1.3] and [1.4].

1.1.3 Sloshing and impact pressures may be disregarded for filling levels lower than 0,50 H.

Figure 1 : Length l_S of the free surface of the liquid

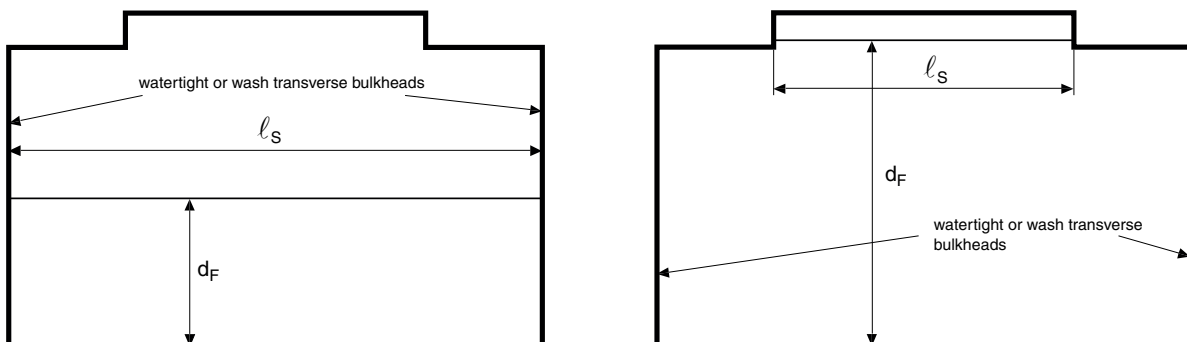


Figure 2 : Breadth b_s of the free surface of the liquid for ships without longitudinal bulkheads

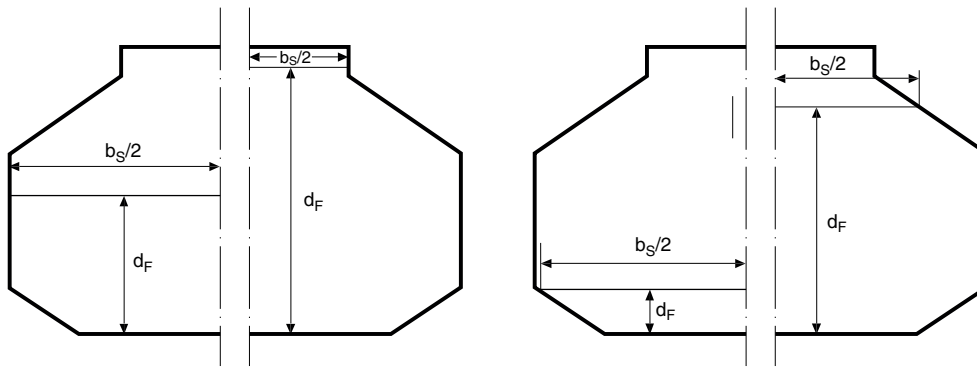
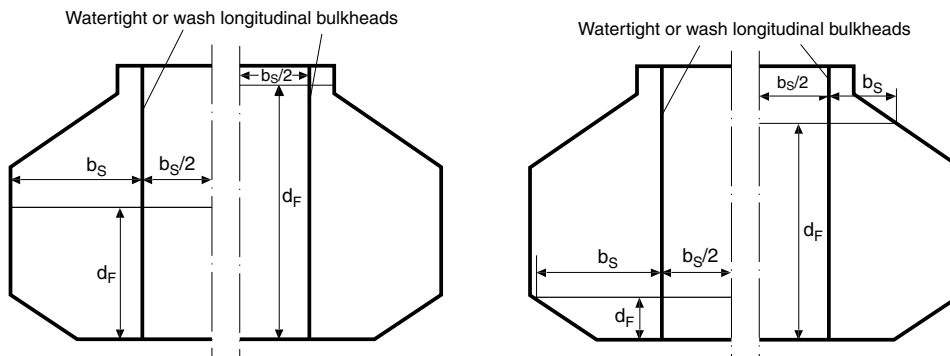


Figure 3 : Breadth b_s of the free surface of the liquid for ships with longitudinal bulkheads



1.2 Liquefied gas carriers

1.2.1 Sloshing in cargo containment tanks of liquefied gas carriers is to be checked according to:

- Pt D, Ch 9, Sec 4, or
- Pt D, Ch 9, Sec 20, or
- NR686 Sec 1,

as applicable.

1.3 Sloshing loads

1.3.1 Longitudinal motion

Where there is a risk of longitudinal resonance according to [1.5] for a filling level d_F , the sloshing pressure P_{sl} calculated according to Ch 5, Sec 6, [2.2.1] is to be considered as acting on transverse bulkheads which form tank boundaries, in the area extended vertically $0,2 d_F$ above and below d_F (see Ch 5, Sec 6, Fig 1).

Where tank bottom transverses or wash transverse bulkheads are fitted, the sloshing pressure calculated according to Ch 5, Sec 6, [2.4.2] is to be considered as acting on them.

The Society may also require the sloshing pressure to be considered when there is no risk of resonance, but the tank arrangement is such that $\ell_C / L > 0,15$.

1.3.2 Transverse motion

Where there is a risk of transverse resonance according to [1.5] for a filling level d_F , the sloshing pressure P_{st} calculated according to Ch 5, Sec 6, [2.2.1] is to be considered as acting on longitudinal bulkheads, inner sides or sides which, as the case may be, form tank boundaries, in the area extended vertically $0,2 d_F$ above and below d_F (see Ch 5, Sec 6, Fig 1).

If sloped longitudinal topsides are fitted, they are to be considered as subjected to the sloshing pressure if their height is less than $0,30 H$.

1.4 Impact loads

1.4.1 Longitudinal motion

Where there is a risk of longitudinal resonance in tanks with arrangements such that ℓ_s is greater than $0,13 L$ at any filling level d_F from $0,10 H$ to $0,95 H$, the dynamic impact pressure P_{W-I} due to liquid motions calculated according to Ch 5, Sec 6, [2.5.1] is to be considered as acting on:

- transverse bulkheads which form tank boundaries, in the area extended vertically $0,15 H$ from the tank top

- the tank top in the area extended longitudinally $0,3 \ell_c$ from the above transverse bulkheads.

Where the upper part of a transverse bulkhead is sloped, the impact pressure is to be considered as acting on the sloped part of the transverse bulkhead and the tank top (as the case may be) in the area extended longitudinally $0,3 \ell_c$ from the transverse bulkhead.

1.4.2 Transverse motion

Where there is a risk of transverse resonance in tanks with arrangements such that b_s is greater than $0,56 B$ at any filling level d_f from $0,10 H$ to $0,95 H$, the dynamic impact pressure P_{W-1} due to liquid motions calculated according to Ch 5, Sec 6, [2.5.1] is to be considered as acting on:

- longitudinal bulkheads, inner sides or sides which, as the case may be, form tank boundaries, in the area extended vertically $0,15 H$ from the tank top
- the tank top in the area extended transversely $0,3 b_c$ from the above longitudinal bulkheads, inner sides or sides.

Where the upper part of a longitudinal bulkhead, inner side or side is sloped, the impact pressure is to be considered as acting on this sloped part and the tank top (as the case may be) in the area extended transversely $0,3 b_c$ from the longitudinal bulkhead, inner side or side.

1.4.3 Static pressure

The static pressure P_{S-1} , acting on the full tank boundary and calculated according to Ch 5, Sec 6, [2.3.2], is to be combined with P_{W-1} according to Ch 5, Sec 6, [2.2.2].

1.5 Evaluation of the risk of resonance

1.5.1 Where tanks are partly filled at a level d_f such as $0,10 H \leq d_f \leq 0,95 H$, the risk of resonance between:

- the ship pitch motion and the longitudinal motion of the liquid inside the tank
- the ship roll motion and the transverse motion of the liquid inside the tank,

is to be evaluated on the basis of the criteria specified in Tab 1

where:

T_x : Natural period, in s, of the liquid motion in the longitudinal direction:

$$T_x = \sqrt{\frac{4\pi\ell_s}{g \tanh \frac{\pi d_f}{\ell_s}}}$$

T_y : Natural period, in s, of the liquid motion in the transverse direction:

$$T_y = \sqrt{\frac{4\pi b_s}{g \tanh \frac{\pi d_f}{b_s}}}$$

T_ϕ : Pitch period, in s, defined in Ch 5, Sec 3, [2.1.2]

T_θ : Roll period, in s, defined in Ch 5, Sec 3, [2.2.1].

1.5.2 The Society may accept that the risk of resonance is evaluated on the basis of dynamic calculation procedures, where deemed necessary in relation to the tank dimensions and the ship characteristics. The calculations are to be submitted to the Society for approval.

Table 1 : Criteria for the evaluation of the risk of resonance

Liquid motion direction	Risk of resonance when:	Resonance due to:
Longitudinal	$0,6 < \frac{T_x}{T_\phi} < 1,3$ and $\frac{d_f}{\ell_c} > 0,1$	Pitch
Transverse	$0,8 < \frac{T_y}{T_\theta} < 1,2$ and $\frac{d_f}{b_c} > 0,1$	Roll

2 Scantling of elements subject to sloshing loads

2.1 Plating

2.1.1 Net thickness

The net thickness of plating t , in mm, subject to sloshing pressures is not to be less than:

$$t = 0,0158 \alpha_p b \sqrt{\frac{P_{sl}}{C_s R_{eH}}}$$

where:

C_a : Permissible bending stress coefficient to be taken as:

$$C_a = \beta_a - \alpha_a \frac{|\sigma_L|}{R_{eH}}$$

without being taken greater than C_{a-max}

with β_a , α_a and C_{a-max} as defined in Tab 2

σ_L : Hull girder bending stress, in N/mm², corresponding to the greater of the still water sagging and hogging bending moments in absolute value

P_{sl} : Sloshing pressure, in kN/m², calculated according to Ch 5, Sec 6, [2.2.1].

Table 2 : Definition of β_a , α_a and C_{a-max}

Acceptance criteria set	Structural member	β_a	α_a	C_{a-max}
AC-1	Longitudinal strength members in the cargo hold region including, but not limited to:	0,9	0,5	0,8
	<ul style="list-style-type: none"> deck longitudinal bulkhead longitudinal girders and stringers 			
	<ul style="list-style-type: none"> transversely or vertically stiffened plating 	0,9	1,0	0,8
	Other strength members including:	0,8	0	0,8
	<ul style="list-style-type: none"> transverse bulkhead transverse stringers and web frames plating of tank boundaries and primary supporting members 			

2.2 Stiffeners

2.2.1 Net section modulus of horizontal stiffeners

The net section modulus Z, in cm³, of horizontal stiffeners subjected to sloshing pressures is not to be less than:

$$Z = \frac{P_{sl} S \ell_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

where:

f_{bdg} : Bending moment factor:

- $f_{bdg} = 12$
for stiffeners fixed against rotation at each end. This is generally to be applied for scantlings of all continuous stiffeners
- $f_{bdg} = 8$
for stiffeners with one or both ends not fixed against rotation. This is generally to be applied to discontinuous stiffeners

C_s : Permissible bending stress coefficient, to be taken as:

- For members subject to hull girder stress:
coefficient to be taken as defined in Tab 3
- $C_s = C_{s-max}$
for other cases

P_{sl} : Sloshing pressure, in kN/m², calculated according to Ch 5, Sec 6, [2.2.1].

C_{s-max} : Coefficient as defined in Tab 4.

2.2.2 Vertical stiffeners

Vertical stiffeners subject to sloshing loads are to be assessed by means of direct calculation according to Ch 7, Sec 5, [1.7] considering the permissible stress coefficient C_s as defined in [2.2.1].

2.3 Primary supporting members

2.3.1 Web plating

The web plating net thickness t of primary supporting members, in mm, is not to be less than:

$$t = 0,0158 \alpha_p b \sqrt{\frac{P_{sl}}{C_a R_{eH}}}$$

where:

- P_{sl} : Sloshing pressure, in kN/m², calculated according to Ch 5, Sec 6, [2.2.1]. The pressure is to be calculated at the load application point, defined in Ch 4, Sec 6, [4.1], taking into account the distribution over the height of the member
- C_a : Permissible plate bending stress coefficient, as given in [2.1.1].

2.3.2 Stiffeners on web plating

The net section modulus Z , in cm³, of each individual stiffener on the web plating of primary supporting members subjected to sloshing pressures is not to be less than:

$$Z = \frac{P_{sl} S l_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

where:

- P_{sl} : Sloshing pressure, in kN/m², calculated according to Ch 5, Sec 6, [2.2.1]. The pressure is to be calculated at the load application point, defined in Ch 4, Sec 6, [3.2], taking into account the distribution over the height of the member
- C_s : Permissible bending stress coefficient, as given in Tab 3
- f_{bdg} : Bending moment factor, as given in [2.2.1].

Table 3 : Permissible bending stress coefficient C_s

Sign of hull girder bending stress σ_L (1)	Lateral pressure acting on(2)	Stiffener boundary condition(3)	f_{bdg}	Coefficient C_s (4)
Tension (positive)	Stiffener side	F - F	12	$C_s = \beta_s - \alpha_s \frac{ \sigma_L }{R_{eH}}$ with $C_s \leq C_{s-max}$
		F - S	8	$C_s = \beta_s - \alpha_s \frac{ \sigma_L }{R_{eH}}$ with $C_s \leq C_{s-max}$
		S - S	8	$C_s = C_{s-max}$
	Plate side	F - F	12	$C_s = C_{s-max}$
		F - S	8	$C_s = C_{s-max}$
		S - S	8	$C_s = \beta_s - \alpha_s \frac{ \sigma_L }{R_{eH}}$ with $C_s \leq C_{s-max}$
Compression (negative)	Stiffener side	F - F	12	$C_s = C_{s-max}$
		F - S	8	$C_s = C_{s-max}$
		S - S	8	$C_s = \beta_s - \alpha_s \frac{ \sigma_L }{R_{eH}}$ with $C_s \leq C_{s-max}$
	Plate side	F - F	12	$C_s = \beta_s - \alpha_s \frac{ \sigma_L }{R_{eH}}$ with $C_s \leq C_{s-max}$
		F - S	8	$C_s = \beta_s - \alpha_s \frac{ \sigma_L }{R_{eH}}$ with $C_s \leq C_{s-max}$
		S - S	8	$C_s = C_{s-max}$

- (1) σ_L is to be considered for the hogging and sagging situations.
- (2) For primary supporting members located inside the considered tank and for wash bulkheads, the sloshing pressure is to be applied on both stiffener side and plate side.
- (3) F - F stands for both ends of the stiffener fixed against rotation
 F - S stands for one end of the stiffener fixed and the other not fixed against rotation
 S - S stands for both ends of the stiffener not fixed against rotation.
- (4) See Tab 4 for definition of β_s , α_s and C_{s-max} .

Table 4 : Definition of β_s , α_s and C_{s-max}

Acceptance criteria set	Structural member	β_s	α_s	C_{s-max}	
AC-1	Longitudinal strength members in the cargo hold region including, but not limited to: • deck stiffeners • stiffeners on longitudinal bulkheads • stiffeners on longitudinal girders and stringers	Longitudinal stiffeners	0,85	1,0	0,75
		Transverse or vertical stiffeners	0,70	0	0,70
	Other strength members including: • stiffeners on transverse bulkheads • stiffeners on transverse stringers and web frames • stiffeners on tank boundaries and primary supporting members		0,75	0	0,75

2.3.3 Tripping brackets supporting primary supporting members

The net section modulus Z , in cm^3 , in way of the base within the effective length d of tripping brackets, and the net shear sectional area A_{shr} , in cm^2 , after deduction of cut-outs and slots, of the tripping brackets supporting primary supporting members are not to be less than:

$$Z = \frac{1000P_{sl}s_{trip}h_2}{2C_sR_{eH}}$$

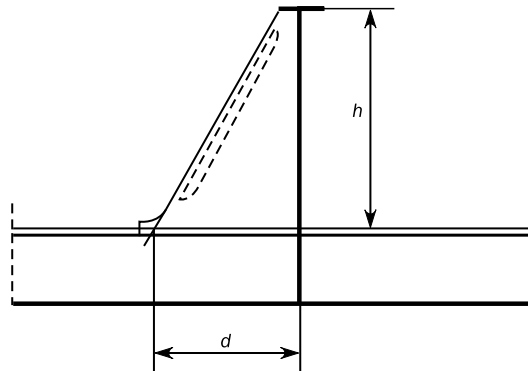
$$A_{shr} = 10\frac{P_{sl}s_{trip}h}{C_t\tau_{eH}}$$

where:

- P_{sl} : Sloshing pressure, in kN/m^2 , calculated according to Ch 5, Sec 6, [2.2.1]. The average pressure may be calculated at mid-point of the tripping bracket, taking into account the distribution over the height of the bracket
- s_{trip} : Mean spacing, in m, between tripping brackets or other primary supporting members or bulkheads
- h : Height of tripping bracket, in m (see Fig 4)
- C_s : Permissible bending stress coefficient for tripping brackets, to be taken as 0,75
- C_t : Permissible shear stress coefficient for tripping brackets, to be taken as 0,75.

The effective breadth of the attached plate to be used for the calculation of the section modulus of the tripping bracket is to be taken as $h/3$.

Figure 4 : Effective length d of tripping bracket



3 Scantling of elements subject to impact loads

3.1 Plating

3.1.1 Plate panels subject to impact loads according to [1.4] are to comply with the requirements of Ch 7, Sec 4, [4].

3.2 Ordinary stiffeners

3.2.1 Ordinary stiffeners subject to impact loads according to [1.4] are to comply with the requirements of Ch 7, Sec 5, [1.3].

3.2.2 Stiffeners partly located in the impact area

For stiffeners partly located within the application area defined in [1.4.1] and [1.4.2], the static pressure P_{S-1} and the dynamic impact pressure P_{W-1} are to be taken as follows:

- the static pressure P_{S-1} is to be considered as acting over the full span of the stiffener, and taken equal to $P_{S-1,eq}$
- the dynamic impact pressure P_{W-1} is to be considered as acting only on the portion of the stiffener span located within the application area, and taken equal to $P_{W-1,eq}$,

where

$$P_{S-1,eq} = \frac{(P_{S-1} + P_{S-2})}{2}$$

$$P_{W-1,eq} = \frac{\ell_1}{\ell} \cdot P_{W-1}$$

P_{S-1} , P_{S-2} : Static pressures, in kN/m^2 , calculated at both ends of the stiffener span.

ℓ_1 : Portion of the stiffener span, in m, located within the application area.

3.3 Primary supporting members

3.3.1 Primary supporting members subject to impact loads according to [1.4] are to comply with the requirements of Ch 7, Sec 6, [2.3].

Section 5 Superstructures and Deckhouses

Symbols

k	: Material factor, defined in Ch 4, Sec 1, [2.2] or Ch 4, Sec 1, [4.4] as applicable
P_{sd}	: Lateral pressure, in kN/m ² , defined in Ch 5, Sec 5, [5.4] calculated at midpoint of stiffener span, or at the middle of the plate field.
s	: Stiffener spacing, in mm
t_c	: Corrosion addition, defined in Ch 4, Sec 3

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the scantling of plating and associated structures of fore, side and aft bulkheads and decks of superstructures and deckhouses.

1.1.2 The requirements of this Section comply with the applicable regulations of the 1966 International Convention on Load Lines, as amended, with regard to the strength of enclosed superstructures.

1.1.3 In addition to the requirements of this Section, structural elements of superstructures and deckhouses forming tank boundaries are to comply with the applicable requirements of Part B, Chapter 7.

1.2 Net scantlings

1.2.1 Except for the stiffeners section modulus in [3.3.1], and as specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 3, [1.2].

1.3 Definitions

1.3.1 Superstructures

Superstructures are defined in Ch 1, Sec 3.

1.3.2 Deckhouses

Deckhouses are defined in Ch 1, Sec 3.

1.3.3 Tiers of superstructures and deckhouses

Tiers of superstructures and deckhouses are defined in Ch 1, Sec 3, [2.2.10].

The lowest tier is normally that tier which is directly situated above the uppermost continuous deck to which the moulded depth D is measured. However, when $(D - T_{sc})$ exceeds the minimum non-corrected tabular freeboard (according to ICLL as amended) by at least one standard superstructure height (as defined in Ch 1, Sec 3, Tab 5), then this tier may be defined as the 2nd tier and the tier above as the 3rd tier.

1.4 Connections of superstructures and deckhouses with the hull structure

1.4.1 Superstructure and deckhouse frames are to be fitted as far as practicable as extensions of those underlying and are to be effectively connected to both the latter and the deck beams above.

Fore and aft bulkheads of superstructures and deckhouses are to be efficiently supported by bulkheads, diaphragms, webs or pillars.

Where hatchways are fitted close to the ends of superstructures, additional strengthening may be required.

1.4.2 Connection to the deck of corners of superstructures and deckhouses is considered by the Society on a case by case basis. Where necessary, doublers or reinforced welding may be required.

1.4.3 As a rule, the frames of side bulkheads of superstructures and deckhouses are to have the same spacing as the beams of the supporting deck.

Web frames are to be arranged to support the side, fore and aft bulkheads of superstructures and deckhouses.

1.4.4 The side plating at fore and aft bulkheads of superstructures is to be tapered into the bulwark or sheerstrake of the strength deck.

Where a raised deck is fitted, this arrangement is to extend over at least a 3-frame spacing.

1.5 Structural arrangement of superstructures and deckhouses

1.5.1 Strengthening in way of superstructures and deckhouses

Web frames, transverse partial bulkheads or other equivalent strengthening are to be fitted inside deckhouses of at least 0,5 B in breadth extending more than 0,15 L in length within 0,4 L amidships. These transverse strengthening reinforcements are to be spaced approximately 9 m apart and are to be arranged, where practicable, in line with the transverse bulkheads below.

Web frames are also to be arranged in way of large openings, boats davits and other areas subjected to point loads.

Web frames, pillars, partial bulkheads and similar strengthening are to be arranged, in conjunction with deck transverses, at fore and aft bulkheads of superstructures and deckhouses.

1.5.2 Strengthening of the raised quarter deck stringer plate

When a superstructure is located above a raised quarter deck, the thickness of the raised quarter deck stringer plate is to be increased by 30% and is to be extended within the superstructure.

The increase above may be reduced when the raised quarter deck terminates outside 0,5 L amidships.

1.5.3 Openings

Openings are to be in accordance with Ch 6, Sec 1, [1].

Continuous coamings are to be fitted above and below doors or similar openings.

1.5.4 Access and doors

Access openings cut in sides of enclosed superstructures are to be fitted with doors made of steel or other equivalent material, and permanently attached.

Special consideration is to be given to the connection of doors to the surrounding structure.

Securing devices which ensure watertightness are to include tight gaskets, clamping dogs or other similar appliances, and are to be permanently attached to the bulkheads and doors. These doors are to be operable from both sides.

Unless otherwise permitted by the Society, doors open outwards to provide additional security against the impact of the sea.

1.5.5 Strengthening of deckhouses in way of lifeboats and rescue boats

Sides of deckhouses are to be strengthened in way of lifeboats and rescue boats and the top plating is to be reinforced in way of their lifting appliances.

1.5.6 Construction details

Lower tier stiffeners are to be welded to the decks at their ends.

Brackets are to be fitted at the upper and preferably also the lower ends of vertical stiffeners of exposed front bulkheads of engine casings and superstructures or deckhouses protecting pump room openings.

1.5.7 Use of aluminium alloys

Unprotected front bulkheads of first tier superstructures or deckhouses are generally to be built of steel and not of aluminium alloy.

Aluminium alloys may be adopted for front bulkheads of superstructures or deckhouses above the first tier.

2 Superstructures side bulkheads

2.1 Plating

2.1.1 The net thickness of plating of superstructures side bulkheads is to be determined in accordance with the applicable requirements of Ch 7, Sec 4, considering the lateral pressure defined in Ch 5, Sec 5, [5.3].

2.2 Stiffeners

2.2.1 The net scantlings of stiffeners of superstructures side bulkheads are to be determined in accordance with the applicable requirements of Ch 7, Sec 5, considering the lateral pressure defined in Ch 5, Sec 5, [5.3].

2.3 Primary supporting members

2.3.1 The net scantlings of primary supporting members of superstructures side bulkheads are to be determined in accordance with the applicable requirements of Ch 7, Sec 6, using the lateral pressure defined in Ch 5, Sec 5, [5.3].

3 Fore and aft bulkheads of superstructures and deckhouses, side bulkheads of deckhouses

3.1 Application

3.1.1 Buckling

In addition to the requirements in [3.2.1] to [3.4.1], the structural members of deckhouses side bulkheads contributing to the longitudinal strength are to be checked for buckling according to Ch 9, Sec 1, [3.2.2].

3.2 Plating

3.2.1 The net plating thickness of fore and aft bulkheads of superstructures and deckhouses, and of side bulkheads of deckhouses is to be not less than the value obtained, in mm, from the following formula:

$$t = 0,95s\sqrt{kP_{sd}} \cdot 10^{-3} - t_c$$

This net thickness is to be not less than:

- the values given in Tab 1 for steel superstructures,
- the following values for aluminium superstructures:
 - 4 mm for rolled products
 - 2,5 mm for extruded products.

Table 1 : Minimum thicknesses of superstructures and deckhouses

Location	Minimum thickness, in mm
Lowest tier(1)	$(5 + 0,01 L_3) k^{1/2} - t_c$
Second tier and above(2)	$(4 + 0,01 L_4) k^{1/2} - t_c$
(1) L_3 :	As defined in Ch 1, Sec 3, Tab 1
(2) L_4 :	Rule length L, but not less than 100 m and not greater than 300 m

3.3 Stiffeners

3.3.1 The gross section modulus of single span stiffeners of fore and aft bulkheads of superstructures and deckhouses, and of side bulkheads of deckhouses is to be not less than the value obtained, in cm³, from the following formula:

$$Z = k \frac{P_{sd} s \ell^2}{f_{bdg} 235}$$

where:

- ℓ : Span of the ordinary stiffener, in m.
For vertical stiffeners, ℓ is to be taken equal to the tweendeck height but not less than 2 m.
- f_{bdg} : Coefficient depending on the stiffener end connections, and taken equal to:
 - 12 for continuous horizontal stiffeners with at least one fixed end and for lower tier vertical stiffeners
 - 8 for horizontal stiffeners simply supported at both ends
 - value defined in Tab 2 for vertical stiffeners of upper tiers.

The section modulus of side ordinary stiffeners need not be greater than that of the side ordinary stiffeners of the tier situated directly below considering spacing and span.

Table 2 : Coefficient n for vertical stiffeners of fore and aft bulkheads of superstructures and deckhouses, and of side bulkheads of deckhouses

Coefficient f_{bdg}	Upper end welded to deck	Bracketed upper end	Sniped upper end
Lower end welded to deck	12	14	10
Bracketed lower end	14	14	12
Sniped lower end	10	12	10

3.4 Primary supporting members

3.4.1 It is to be checked that the stress values in primary supporting members of fore and aft bulkheads of superstructures and deckhouses, and of side bulkheads of deckhouses, calculated using the lateral pressure P_{sd} , in kN/m², defined in Ch 5, Sec 5, [5.4], comply with the following criterion:

$$\sigma_{\text{eq}} \leq \frac{235}{k}$$

where:

σ_{eq} : equivalent Von Mises stress, in N/mm²:

$$\sigma_{\text{eq}} = \sqrt{\sigma^2 + 3\tau^2}$$

4 Decks

4.1 Plating

4.1.1 The net thickness of decks plating is to be determined in accordance with the applicable requirements of Ch 7, Sec 4, considering the loads defined in Ch 5, Sec 5, [3] or in Ch 5, Sec 6, [6] as applicable.

4.1.2 For decks sheathed with wood, the net thickness obtained from [4.1.1] may be reduced by 10 percent.

4.2 Stiffeners

4.2.1 The net scantlings of decks ordinary stiffeners are to be determined in accordance with the applicable requirements of Ch 7, Sec 5, considering the loads defined in Ch 5, Sec 5, [3] or in Ch 5, Sec 6, [6] as applicable.

4.3 Primary supporting members

4.3.1 The net scantlings of decks primary supporting members are to be determined in accordance with the applicable requirements of Ch 7, Sec 6, considering the loads defined in Ch 5, Sec 5, [3] or in Ch 5, Sec 6, [6] as applicable.

5 Additional requirements applicable to movable wheelhouses

5.1 General

5.1.1 The requirements of this Article apply in addition of those in [1] to [4].

5.1.2 The structures of movable wheelhouses are to be checked in low and in high position.

5.1.3 Mechanical locking devices are to be fitted in addition to hydraulic systems.

5.2 Supports and guides, connections with the deck, under deck reinforcements, locking devices

5.2.1 Still water and inertial forces

The supports or guides of movable wheelhouses, connections with the deck, under deck reinforcements and locking devices are to be checked considering the sum of the following forces:

- still water and inertial forces, determined according to Ch 5, Sec 6, [6.2]
- wind forces, corresponding to a lateral pressure of 1,2kN/m².

5.2.2 Checking criteria

It is to be checked that the calculated stress values comply with the following criterion:

$$\sigma_{\text{eq}} \leq \frac{235}{k\gamma_R\gamma_m}$$

where:

σ_{eq} : equivalent Von Mises stress, in N/mm²:

$$\sigma_{\text{eq}} = \sqrt{\sigma^2 + 3\tau^2}$$

γ_R : Partial safety factor covering uncertainties regarding resistance, to be taken equal to:

- 1,10 in general
- 1,40 for checking locking devices

γ_m : Partial safety factor covering uncertainties regarding material, to be taken equal to 1,02.

Section 6 Bow Doors and Inner Doors

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the arrangement, strength and securing of bow doors and inner doors leading to a complete or long forward enclosed superstructure or to a long non-enclosed superstructure, where fitted to attain minimum bow height equivalence.

The requirements apply to ships engaged on international voyages and also to ships engaged only in domestic (non international) voyages, except where specifically indicated otherwise in this Section.

1.1.2 Two types of bow door are provided for:

- visor doors opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary supporting members of the door by longitudinally arranged lifting arms
- side-opening doors opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the ship. It is anticipated that side-opening bow doors are arranged in pairs.

Other types of bow door are considered by the Society on a case by case basis in association with the applicable requirements of this Section.

1.2 Gross scantlings

1.2.1 With reference to Ch 4, Sec 2, [1.1.2], all scantlings and dimensions referred to in this Section are gross, i.e. they include the margins for corrosion.

1.3 Arrangement

1.3.1 Bow doors are to be situated above the freeboard deck. A watertight recess in the freeboard deck located forward of the collision bulkhead and above the deepest waterline fitted for arrangement of ramps or other related mechanical devices may be regarded as a part of the freeboard deck for the purpose of this requirement.

1.3.2 An inner door is to be fitted as part of the collision bulkhead. The inner door need not be fitted directly above the bulkhead below, provided it is located within the limits specified for the position of the collision bulkhead, as per.

A vehicle ramp may be arranged for this purpose, provided its position complies with Ch 2, Sec 1, [3.1].

If this is not possible, a separate inner weathertight door is to be installed, as far as practicable within the limits specified for the position of the collision bulkhead.

1.3.3 Bow doors are to be so fitted as to ensure tightness consistent with operational conditions and to give effective protection to inner doors.

Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the cargo space and arranged with fixed sealing supports on the aft side of the doors.

1.3.4 Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a separate inner weathertight door is to be installed, as indicated in [1.3.2].

1.3.5 The requirements for inner doors are based on the assumption that vehicles are effectively lashed and secured against movement in stowed position.

1.4 Definitions

1.4.1 Securing device

A securing device is a device used to keep the door closed by preventing it from rotating about its hinges.

1.4.2 Supporting device

A supporting device is a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, which transmits loads from the door to the ship's structure.

1.4.3 Locking device

A locking device is a device that locks a securing device in the closed position.

2 Design loads

2.1 Bow doors

2.1.1 The design loads to be considered for the scantlings of bow doors are defined in Ch 5, Sec 5, [7.1].

2.2 Inner doors

2.2.1 Design external pressure

The design external pressure to be considered for the scantlings of primary supporting members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of the values obtained, in kN/m², from the following formulae:

$$p_E = 0,45 L_1$$

$$p_E = 10 h$$

where:

h : Distance, in m, from the calculation point to the top of the cargo space.

2.2.2 Design internal pressure

The design internal pressure p_i to be considered for the scantlings of securing devices of inner doors is to be not less than 25 kN/m².

3 Scantlings of bow doors

3.1 General

3.1.1 The strength of bow doors is to be commensurate with that of the surrounding structure.

3.1.2 Bow doors are to be adequately stiffened and means are to be provided to prevent lateral or vertical movement of the doors when closed.

For visor doors, adequate strength for opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the ship's structure.

3.2 Plating and ordinary stiffeners

3.2.1 Plating

The thickness of the bow door plating is to be not less than that obtained according to the requirements in Ch 11, Sec 1 for the fore part, using the bow door stiffener spacing. In no case may it be less than the minimum required thickness of fore part shell plating.

3.2.2 Ordinary stiffeners

The section modulus of bow door ordinary stiffeners is to be not less than that obtained according to the requirements in Ch 11, Sec 1 for the fore part, using the bow door stiffener spacing.

Consideration is to be given, where necessary, to differences in conditions of fixity between the ends of ordinary stiffeners of bow doors and those of the fore part shell.

3.3 Primary supporting members

3.3.1 Bow door ordinary stiffeners are to be supported by primary supporting members constituting the main stiffening of the door.

3.3.2 The primary supporting members of the bow door and the hull structure in way are to have sufficient stiffness to ensure integrity of the boundary support of the door.

3.3.3 Scantlings of primary supporting members are generally to be verified through direct calculations on the basis of the external pressure p_E in Ch 5, Sec 5, [7.1.1] and the strength criteria in [6.1.1] and [6.1.2].

In general, isolated beam models may be used to calculate the loads and stresses in primary supporting members.

Members are to be considered to have simply supported end connections.

4 Scantlings of inner doors

4.1 General

4.1.1 The gross scantlings of the primary supporting members are generally to be verified through direct strength calculations on the basis of the external pressure p_E in [2.1.1] and the strength criteria in [6.1.1] and [6.1.2].

In general, isolated beam models may be used to calculate the loads and stresses in primary supporting members.

4.1.2 Where inner doors also serve as vehicle ramps, their scantlings are to be not less than those obtained according to Ch 11, Sec 11.

4.1.3 The distribution of the forces acting on the securing and supporting devices is generally to be supported by direct calculations taking into account the flexibility of the structure and the actual position and stiffness of the supports.

5 Securing and supporting of bow doors

5.1 General

5.1.1 Bow doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure.

The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.

Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered by the Society on a case by case basis.

The maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

A means is to be provided for mechanically fixing the door in the open position.

5.1.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide local compression of the packing material may generally not be included in the calculation in [5.2.5].

The number of securing and supporting devices is generally to be the minimum practical while taking into account the requirements for redundant provision given in [5.2.6] and [5.2.7] and the available space for adequate support in the hull structure.

5.1.3 For visor doors which open outwards, the pivot arrangement is generally to be such that the visor is self-closing under external loads, i.e. it is to be checked that the closing moment M_V , defined in Ch 5, Sec 5, [7.1.3], is in compliance with the following formula:

$$M_V > 0$$

Moreover, the closing moment M_V is to be not less than the value M_{V0} , in kN.m, obtained from the following formula:

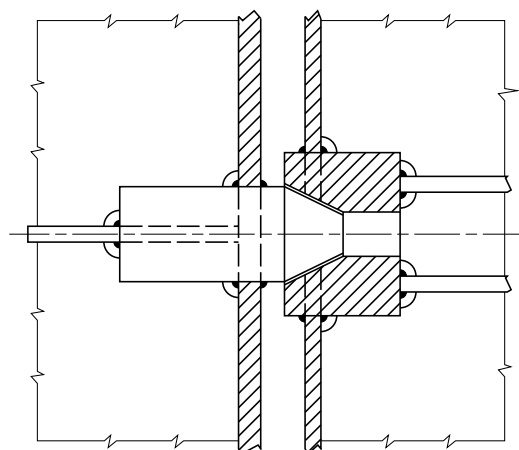
$$M_{V0} = 10Wc + 0,1\sqrt{a^2 + b^2}\sqrt{F_x^2 + F_z^2}$$

5.1.4 For side-opening doors, a thrust bearing is to be provided in way of girder ends at the closing of the two leaves to prevent one leaf from shifting towards the other under the effect of unsymmetrical pressure (see example in Fig 1).

The parts of the thrust bearing are to be kept secured to each other by means of securing devices.

The Society may consider any other arrangement serving the same purpose.

Figure 1 : Thrust bearing



5.2 Scantlings

5.2.1 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the allowable stresses defined in [6.1.1].

5.2.2 For visor doors, the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

- Case 1: F_x and F_z
- Case 2: $0,7F_y$ acting on each side separately together with $0,7F_x$ and $0,7F_z$,

where F_x , F_y and F_z are to be calculated as indicated in Ch 5, Sec 5, [7.1.2] and applied at the centroid of projected areas.

5.2.3 For side-opening doors, the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

- Case 1: F_x , F_y and F_z acting on both doors
- Case 2: $0,7F_x$ and $0,7F_z$ acting on both doors and $0,7F_y$ acting on each door separately,

where F_x , F_y and F_z are to be calculated as indicated in Ch 5, Sec 5, [7.1.2] and applied at the centroid of projected areas.

5.2.4 The support forces as calculated according to Case 1 in [5.2.2] and Case 1 in [5.2.3] are to generally give rise to a zero moment about the transverse axis through the centroid of the area A_x .

For visor doors, longitudinal reaction forces of pin and/or wedge supports at the door base contributing to this moment are not to be in the forward direction.

5.2.5 The distribution of the reaction forces acting on the securing and supporting devices may need to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.

5.2.6 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that, in the event of failure of any single securing or supporting device, the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20% the allowable stresses defined in [6.1.1].

5.2.7 For visor doors, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the allowable stresses defined in [6.1.1].

The opening moment M_0 to be balanced by this reaction force is to be taken not less than that obtained, in kN.m, from the following formula: $M_0 = 10 W d + 5 A_x a$

where:

- d : Vertical distance, in m, from the hinge axis to the centre of gravity of the door, as shown in Ch 5, Sec 5, Fig 6
- a : Vertical distance, in m, defined in Ch 5, Sec 5, [7.1.3].

5.2.8 For visor doors, the securing and supporting devices excluding the hinges are to be capable of resisting the vertical design force ($F_z - 10 W$), in kN, within the allowable stresses defined in [6.1.1].

5.2.9 All load transmitting elements in the design load path, from the door through securing and supporting devices into the ship's structure, including welded connections, are to be of the same strength standard as required for the securing and supporting devices. These elements include pins, supporting brackets and back-up brackets.

6 Strength criteria

6.1 Primary supporting members and securing and supporting devices

6.1.1 Yielding check

It is to be checked that the normal stresses σ , the shear stress τ and the equivalent stress σ_{VM} , induced in the primary supporting members and in the securing and supporting devices of bow doors by the design load defined in [2], are in compliance with the following formulae:

$$\sigma \leq \sigma_{ALL}$$

$$\tau \leq \tau_{ALL}$$

$$\sigma_{VM} = (\sigma^2 + 3 \tau^2)^{0,5} \leq \sigma_{VM,ALL}$$

where:

σ_{ALL} : Allowable normal stress, in N/mm², equal to: $\sigma_{ALL} = 120/k$

τ_{ALL} : Allowable shear stress, in N/mm², equal to: $\tau_{ALL} = 80/k$

$\sigma_{VM,ALL}$: Allowable equivalent stress, in N/mm², equal to: $\sigma_{VM,ALL} = 150/k$

k : Material factor, defined in Ch 4, Sec 1, [2.2], but to be taken not less than 0,72 unless a fatigue analysis is carried out.

6.1.2 Buckling check

The buckling check of primary supporting members is to be carried out according to Ch 9, Sec 1.

6.1.3 Bearings

For steel to steel bearings in securing and supporting devices, it is to be checked that the nominal bearing pressure σ_B , in N/mm², is in compliance with the following formula: $\sigma_B \leq 0,8 R_{e,HB}$

where:

$$\sigma_B = 10 \frac{F}{A_B}$$

F : Design force, in kN, defined in Ch 5, Sec 5, [7.1.2]

A_B : Projected bearing area, in cm²

R_{e,HB} : Yield stress, in N/mm², of the bearing material.

For other bearing materials, the allowable bearing pressure is to be determined according to the manufacturer's specification.

6.1.4 Bolts

The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces.

It is to be checked that the tension σ_T in way of threads of bolts not carrying support forces is in compliance with the following formula: $\sigma_T \leq \sigma_{T,ALL}$

where:

$\sigma_{T,ALL}$: Allowable tension in way of threads of bolts, in N/mm², equal to: $\sigma_{T,ALL} = 125/k$

k : Material coefficient defined in [6.1.1].

7 Securing and locking arrangement

7.1 Systems for operation

7.1.1 Securing devices are to be simple to operate and easily accessible.

Securing devices are to be equipped with mechanical locking arrangement (self-locking or separate arrangement), or to be of the gravity type.

The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

7.1.2 Bow doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control, from a position above the freeboard deck, of:

- the closing and opening of the doors, and
- associated securing and locking devices for every door.

Indication of the open/closed position of every door and every securing and locking device is to be provided at the remote control stations.

The operating panels for operation of doors are to be inaccessible to unauthorised persons.

A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

7.1.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position. This means that, in the event of loss of hydraulic fluid, the securing devices remain locked.

The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when in closed position.

7.2 Systems for indication/monitoring

7.2.1 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on the operating panel to show that the bow door and inner door are closed and that their securing and locking devices are properly positioned.

The indication panel is to be provided with a lamp test function. It is not to be possible to turn off the indicator light.

7.2.2 The indicator system is to be designed on the fail safe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured.

The power supply for the indicator system for operating and closing doors is to be independent of the power supply for operating and closing the doors and is to be provided with a back-up power supply from the emergency source of power or other secure power supply, e.g. UPS.

The sensors of the indicator system are to be protected from water, ice formation and mechanical damage.

Note 1: The indicator system is considered designed on the fail-safe principal when:

- the indication panel is provided with:
 - a power failure alarm
 - an earth failure alarm
 - a lamp test
 - separate indication for door closed, door locked, door not closed and door not locked
- limit switches electrically closed when the door is closed (when more limit switches are provided they may be connected in series)
- limit switches electrically closed when securing arrangements are in place (when more limit switches are provided they may be connected in series)
- two electrical circuits (also in one multicore cable), one for the indication of door closed/not closed and the other for door locked/not locked
- in case of dislocation of limit switches, indication to show: not closed/not locked/securing arrangement not in place - as appropriate.

7.2.3 The indication panel on the navigation bridge is to be equipped with a mode selection function “harbour/sea voyage”, so arranged that an audible alarm is given on the navigation bridge if the ship leaves harbour with the bow door or the inner door not closed or with any of the securing devices not in the correct position.

7.2.4 A water leakage detection system with an audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the inner door.

Note 1: The indicator system is considered designed on the fail-safe principal when:

- the indication panel is provided with:
 - a power failure alarm
 - an earth failure alarm
 - a lamp test
 - separate indication for door closed, door locked, door not closed and door not locked
- limit switches electrically closed when the door is closed (when more limit switches are provided they may be connected in series)
- limit switches electrically closed when securing arrangements are in place (when more limit switches are provided they may be connected in series)
- two electrical circuits (also in one multicore cable), one for the indication of door closed/not closed and the other for door locked/not locked
- in case of dislocation of limit switches, indication to show: not closed/not locked/securing arrangement not in place - as appropriate.

7.2.5 Between the bow door and the inner door a television surveillance system is to be fitted with a monitor on the navigation bridge and in the engine control room.

The system is to monitor the position of the doors and a sufficient number of their securing devices.

Special consideration is to be given for the lighting and contrasting colour of the objects under surveillance.

Note 1: The indicator system is considered designed on the fail-safe principal when:

- the indication panel is provided with:
 - a power failure alarm
 - an earth failure alarm
 - a lamp test
 - separate indication for door closed, door locked, door not closed and door not locked
- limit switches electrically closed when the door is closed (when more limit switches are provided they may be connected in series)
- limit switches electrically closed when securing arrangements are in place (when more limit switches are provided they may be connected in series)
- two electrical circuits (also in one multicore cable), one for the indication of door closed/not closed and the other for door locked/not locked
- in case of dislocation of limit switches, indication to show: not closed/not locked/securing arrangement not in place - as appropriate.

7.2.6 The indicator system for the closure of the doors and the television surveillance systems for the doors and water leakage detection, and for special category and ro-ro spaces are to be suitable to operate correctly in the ambient conditions on board and to be type approved on the basis of the applicable tests required in Part D, Chapter 1 and/or Part D, Chapter 12.

7.2.7 A drainage system is to be arranged in the area between bow door and ramp or, where no ramp is fitted, between the bow door and the inner door.

The system is to be equipped with an audible alarm function to the navigation bridge being set off when the water levels in these areas exceed 0,5 m or the high water level alarm, whichever is lesser.

Note 1: The indicator system is considered designed on the fail-safe principal when:

- the indication panel is provided with:
 - a power failure alarm
 - an earth failure alarm
 - a lamp test
 - separate indication for door closed, door locked, door not closed and door not locked
- limit switches electrically closed when the door is closed (when more limit switches are provided they may be connected in series)
- limit switches electrically closed when securing arrangements are in place (when more limit switches are provided they may be connected in series)

- two electrical circuits (also in one multicore cable), one for the indication of door closed/not closed and the other for door locked/not locked
- in case of dislocation of limit switches, indication to show: not closed/not locked/securing arrangement not in place - as appropriate.

7.2.8 For ro-ro passenger ships on international voyages, the special category spaces and ro-ro spaces are to be continuously patrolled or monitored by effective means, such as television surveillance, so that any movement of vehicles in adverse weather conditions or unauthorized access by passengers thereto, can be detected whilst the ship is underway.

8 Operating and Maintenance Manual

8.1 General

8.1.1 An Operating and Maintenance Manual for the bow door and inner door is to be provided on board and is to contain the necessary information on:

- a) Main particulars and design drawings:
 - special safety precautions
 - details of ship
 - equipment and design loading (for ramps)
 - key plan of equipment (doors and ramps)
 - manufacturer's recommended testing for equipment
 - description of equipment:
 - bow doors
 - inner bow doors
 - bow ramp/doors
 - central power pack
 - bridge panel
 - engine control room panel
- b) Service conditions:
 - limiting heel and trim of ship for loading/unloading
 - limiting heel and trim for door operations
 - doors/ramps operating instructions
 - doors/ramps emergency operating instructions
- c) Maintenance:
 - schedule and extent of maintenance
 - trouble shooting and acceptable clearances
 - manufacturer's maintenance procedures
- d) Register of inspections, including inspection of locking, securing and supporting devices, repairs and renewals.

This manual is to be submitted to the Society for approval that the above mentioned items are contained in the OMM and that the maintenance part includes the necessary information with regard to inspections, trouble-shooting and acceptance/rejection criteria.

Note 1: It is recommended that inspections of the doors and supporting and securing devices be carried out by ship's personnel at monthly intervals or following any incidents which could result in damage, including heavy weather or contact in the region of the shell doors. A record is to be kept and any damage found during such inspections is to be reported to the Society.

8.1.2 Documented operating procedures for closing and securing the bow door and inner door are to be kept on board and posted at an appropriate place.

Section 7 Side Doors and Stern Doors

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the arrangement, strength and securing of side doors located abaft the collision bulkhead, and of stern doors leading to enclosed spaces.

The requirements apply to ships assigned with the service notation **ro-ro passenger ship** or **ro-ro cargo ship** engaged on international voyages and also in domestic (non-international) voyages, except where specifically indicated otherwise in this section.

Shell doors not covered by this Section are dealt with in Ch 11, Sec 8.

1.2 Gross scantlings

1.2.1 With reference to Ch 4, Sec 2, [1.1.2], all scantlings and dimensions referred to in this Section are gross, i.e. they include the margins for corrosion.

1.3 Arrangement

1.3.1 Side doors and stern doors are to be so fitted as to ensure tightness and structural integrity commensurate with their location and the surrounding structure.

1.3.2 Where the sill of any side door is below the uppermost load line, the arrangement is considered by the Society on a case by case basis.

1.3.3 Doors are preferably to open outwards.

1.4 Definitions

1.4.1 Securing device

A securing device is a device used to keep the door closed by preventing it from rotating about its hinges or about pivoted attachments to the ship.

1.4.2 Supporting device

A supporting device is a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, which transmits loads from the door to the ship's structure.

1.4.3 Locking device

A locking device is a device that locks a securing device in the closed position.

2 Design loads

2.1 Side and stern doors

2.1.1 The design loads to be considered for the scantlings of side and stern doors are defined in Ch 5, Sec 5, [7.2].

3 Scantlings of side doors and stern doors

3.1 General

3.1.1 The strength of side doors and stern doors is to be commensurate with that of the surrounding structure.

3.1.2 Side doors and stern doors are to be adequately stiffened and means are to be provided to prevent any lateral or vertical movement of the doors when closed.

Adequate strength is to be provided in the connections of the lifting/manoeuvring arms and hinges to the door structure and to the ship's structure.

3.1.3 Where doors also serve as vehicle ramps, the design of the hinges is to take into account the ship angle of trim and heel which may result in uneven loading on the hinges.

3.1.4 Shell door openings are to have well rounded corners and adequate compensation is to be arranged with web frames at sides and stringers or equivalent above and below.

3.2 Plating and ordinary stiffeners

3.2.1 Plating

The thickness of the door plating is to be not less than that obtained according to the requirements in Ch 7, Sec 4, for side plating, using the door stiffener spacing. It is in no case to be less than the minimum required thickness of side plating.

Where doors also serve as vehicle ramps, the thickness of the door plating is to be not less than that obtained according to Ch 11, Sec 11.

3.2.2 Ordinary stiffeners

The scantling of door ordinary stiffeners is to be not less than that obtained according to the requirements in Ch 7, Sec 5, for the side, using the door stiffener spacing.

Consideration is to be given, where necessary, to differences in conditions of fixity between the ends of ordinary stiffeners of doors and those of the side.

Where doors also serve as vehicle ramps, the scantling of ordinary stiffeners is to be not less than that obtained according to Ch 11, Sec 11.

3.3 Primary supporting members

3.3.1 The door ordinary stiffeners are to be supported by primary supporting members constituting the main stiffening of the door.

3.3.2 The primary supporting members and the hull structure in way are to have sufficient stiffness to ensure structural integrity of the boundary of the door.

3.3.3 Scantlings of primary supporting members are generally to be verified through direct strength calculations on the basis of the design forces in [2] and the strength criteria in Ch 11, Sec 6, [6.1.1] and Ch 11, Sec 6, [6.1.2].

In general, isolated beam models may be used to calculate the loads and stresses in primary supporting members.

Members are to be considered to have simply supported end connections.

4 Securing and supporting of doors

4.1 General

4.1.1 Side doors and stern doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure.

The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.

Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered by the Society on a case by case basis.

The maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

A means is to be provided for mechanically fixing the door in the open position.

4.1.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide local compression of the packing material may generally not be included in the calculation in [4.2.2].

The number of securing and supporting devices is generally to be the minimum practical while taking into account the requirements for redundant provision given in [4.2.3] and the available space for adequate support in the hull structure.

4.2 Scantlings

4.2.1 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the allowable stresses defined in [5.1.1].

4.2.2 The distribution of the reaction forces acting on the securing and supporting devices may need to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position of the supports.

4.2.3 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that, in the event of failure of any single securing or supporting device, the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20% the allowable stresses defined in [5.1.1] for normal or damaged conditions.

4.2.4 All load transmitting elements in the design load path, from the door through securing and supporting devices into the ship's structure, including welded connections, are to be of the same strength standard as required for the securing and supporting devices. These elements include pins, support brackets and back-up brackets.

5 Strength criteria

5.1 Primary supporting members and securing and supporting devices

5.1.1 Yielding check

It is to be checked that the normal stress σ , the shear stress τ and the equivalent stress σ_{VM} , induced in the primary supporting members and in the securing and supporting devices of doors by the design load defined in [2], are in compliance with the following formulae:

$$\sigma \leq \sigma_{ALL}$$

$$\tau \leq \tau_{ALL}$$

$$\sigma_{VM} = (\sigma^2 + 3 \tau^2)^{0.5} \leq \sigma_{VM,ALL}$$

where:

σ_{ALL} : Allowable normal stress, in N/mm²: $\sigma_{ALL} = 120 / k$

τ_{ALL} : Allowable shear stress, in N/mm²: $\tau_{ALL} = 80 / k$

$\sigma_{VM,ALL}$: Allowable equivalent stress, in N/mm²: $\sigma_{VM,ALL} = 150 / k$

k : Material factor, defined in Ch 4, Sec 1, [2.2], but to be taken not less than 0,72 unless a fatigue analysis is carried out. In case of damaged ship conditions assessment, the above allowable stresses are to be increased by 20%.

5.1.2 Buckling check

The buckling check of primary supporting members is to be carried out according to Ch 9, Sec 1.

5.1.3 Bearings

For steel to steel bearings in securing and supporting devices, it is to be checked that the nominal bearing pressure σ_B , in N/mm², is in compliance with the following formula: $\sigma_B \leq 0,8 R_{eH,B}$

where:

$$\sigma_B = 10 \frac{F}{A_B}$$

with:

F : Design force, in KN, defined in Ch 5, Sec 5, [7.2.1]

A_B : Projected bearing area, in cm²

$R_{eH,B}$: Yield stress, in N/mm², of the bearing material.

For other bearing materials, the allowable bearing pressure is to be determined according to the manufacturer's specification.

5.1.4 Bolts

The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces.

It is to be checked that the tension σ_T in way of threads of bolts not carrying support forces is in compliance with the following formula: $\sigma_T \leq \sigma_{T,ALL}$

where:

$\sigma_{T,ALL}$: Allowable tension in way of threads of bolts, in N/mm²: $\sigma_{T,ALL} = 125 / k$

k : Material factor, defined in Ch 11, Sec 6, [6.1.1].

6 Securing and locking arrangement

6.1 Systems for operation

6.1.1 Securing devices are to be simple to operate and easily accessible.

Securing devices are to be equipped with mechanical locking arrangement (self-locking or separate arrangement), or to be of the gravity type.

The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

6.1.2 Doors which are located partly or totally below the freeboard deck with a clear opening area greater than 6 m² are to be provided with an arrangement for remote control, from a position above the freeboard deck, of:

- the closing and opening of the doors
- associated securing and locking devices.

For doors which are required to be equipped with a remote control arrangement, indication of the open/closed position of the door and the securing and locking device is to be provided at the remote control stations.

The operating panels for operation of doors are to be inaccessible to unauthorised persons.

A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

6.1.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position. This means that, in the event of loss of hydraulic fluid, the securing devices remain locked.

The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when in closed position.

6.2 Systems for indication / monitoring

6.2.1 The following requirements apply to doors in the boundary of special category spaces or ro-ro spaces, as defined in Pt D, Ch 12, Sec 2, [1.1], through which such spaces may be flooded.

For cargo ships, where no part of the door is below the uppermost waterline and the area of the door opening is not greater than 6m², then the requirements of this sub-article need not be applied.

6.2.2 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on each operating panel to indicate that the doors are closed and that their securing and locking devices are properly positioned.

The indication panel is to be provided with a lamp test function. It shall not be possible to turn off the indicator light.

6.2.3 The indicator system is to be designed on the fail safe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors and is to be provided with a backup power supply from the emergency source of power or secure power supply, e.g. UPS.

The sensors of the indicator system are to be protected from water, ice formation and mechanical damages.

Note 1: See Ch 11, Sec 6, [7.2.2] for fail safe principal design.

6.2.4 The indication panel on the navigation bridge is to be equipped with a mode selection function "harbour/sea voyage", so arranged that audible alarm is given on the navigation bridge if the ship leaves harbour with any side shell or stern door not closed or with any of the securing devices not in the correct position.

6.2.5 For passenger ships, a water leakage detection system with audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of any leakage through the doors.

For cargo ships, a water leakage detection system with audible alarm is to be arranged to provide an indication to the navigation bridge.

6.2.6 For ro-ro passenger ships, on international voyages, the special category spaces and ro-ro spaces are to be continuously patrolled or monitored by effective means, such as television surveillance, so that any movement of vehicles in adverse weather conditions and unauthorized access by passengers thereto, can be detected whilst the ship is underway.

7 Operating and Maintenance Manual

7.1 General

7.1.1 An Operating and Maintenance Manual for the side doors and stern doors is to be provided on board and is to contain the necessary information on:

- a) main particulars and design drawings:
 - special safety precautions
 - details of ship
 - equipment and design loading (for ramps)
 - key plan of equipment (doors and ramps)
 - manufacturer's recommended testing for equipment
 - description of equipment:
 - side doors
 - stern doors
 - central power pack
 - bridge panel
 - engine control room panel

b) service conditions:

- limiting heel and trim of ship for loading / unloading
- limiting heel and trim for door operations
- doors / ramps operating instructions
- doors / ramps emergency operating instructions

c) maintenance:

- schedule and extend of maintenance
- trouble shooting and acceptable clearances
- manufacturer's maintenance procedures

d) register of inspections, including inspection of locking, securing and supporting devices, repairs and renewals.

This manual is to be submitted in duplicate to the Society for approval that the above mentioned items are contained in the OMM and that the maintenance part includes the necessary information with regard to inspections, trouble-shooting and acceptance / rejection criteria.

Note 1: It is recommended that inspections of the door and supporting and securing devices be carried out by ship's personnel at monthly intervals or following any incidents which could result in damage, including heavy weather or contact in the region of the shell doors. A record is to be kept and any damage recorded during such inspections is to be reported to the Society.

7.1.2 Documented operating procedures for closing and securing the side and stern doors are to be kept on board and posted at an appropriate place.

Section 8 Watertight and Weathertight Doors

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the scantling of shell doors not covered by Ch 11, Sec 7 and doors in bulkheads that are required to be watertight or weathertight.

1.2 Definitions

1.2.1 Watertightness

The various degrees of watertightness are defined in NR 467 Ch 3, Sec 3, [3.3.2].

1.2.2 Securing device

A securing device is a device used to keep the door closed by preventing it from rotating about its hinges, or from sliding open.

1.2.3 Supporting device

A supporting device is a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, which transmits loads from the door to the ship's structure.

1.2.4 Locking device

A locking device is a device locking the securing device in the closed position.

2 Design loads

2.1 General

2.1.1 Doors are to be designed to offer equivalent strength compared to the adjacent bulkhead in which they are fitted. Therefore, they are to be assessed considering the same design loads, as per the examples given in the following requirements.

2.2 Side shell doors

2.2.1 Doors fitted in side shell are to be checked with the outside sea pressures defined in Ch 5, Sec 5, and whenever relevant, with the internal flooding pressure defined in Ch 5, Sec 6, [1.4].

2.3 Internal bulkheads doors

2.3.1 Doors fitted in watertight bulkheads are to be checked with the flooding pressures defined in Ch 5, Sec 6, [1.4], for spaces on both sides of the bulkhead.

2.4 Superstructure doors

2.4.1 Doors fitted in superstructure walls are to be checked with the loads defined in Ch 5, Sec 5, [5].

3 Door leaf scantling

3.1 Plating

3.1.1 The net thickness of watertight and weathertight doors is to be not less than that calculated according to Ch 7, Sec 4 or to Ch 11, Sec 5, [2.1] or Ch 11, Sec 5, [3.2], as relevant.

3.2 Stiffeners

3.2.1 The net scantling of doors stiffeners is to be not less than that calculated according to Ch 7, Sec 5 or to Ch 11, Sec 5, [2.2] or Ch 11, Sec 5, [3.3], as relevant, considering that doors stiffeners are generally to be considered as simply supported at ends instead of clamped.

3.3 Glass

3.3.1 If permitted, when glazing is fitted in the door leaf, its thickness is to be in line with the requirements of Ch 11, Sec 12, [3.3].

4 Securing and supporting

4.1 General

4.1.1 Doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure.

The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.

Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered by the Society on a case by case basis.

In order to prevent damage to the packing material, the edges of the part of the door frame in contact with the seal should be rounded or chamfered.

The maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

4.1.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide local compression of the packing material may generally not be included in the calculation in [4.2].

The number and distribution of securing and supporting devices is to be set to achieve the scantling criteria in [4.2] and the required degree of watertightness.

4.2 Scantlings

4.2.1 Securing and supporting devices are to be adequately designed so that they can comply with the checking criteria defined in Ch 7, Sec 6, [5.1.4] for primary members, using AC-2 or AC-3 acceptance criteria as relevant.

4.2.2 In addition to the requirements in [4.2.1], every element transmitting loads by means of direct contact must be checked against bearing. In that respect, the maximum normal compressive stress σ_c distributed over the contact area between the two elements is not to be higher than R_{eH} .

4.2.3 The distribution of the reaction forces acting on the securing and supporting devices is generally to be supported by direct calculations taking into account the flexibility of the hull structure, the actual position of the supports and the design load pattern. In case of homogeneously distributed supports and uniform design pressure, the total force acting on the door may be considered as evenly divided amongst the supports.

4.2.4 All load transmitting elements in the design load path, from the door through securing and supporting devices into the ship's structure, including welded connections, are to be of the same strength standard as required for the securing and supporting devices. These elements include pins, support brackets and back-up brackets.

5 Inspection and testing

5.1 General

5.1.1 Watertight and semi-watertight doors which become immersed by an equilibrium or intermediate waterplane are to be subjected to a hydrostatic pressure test.

5.1.2 For large doors of more than 6 m² intended for use in the watertight subdivision boundaries of cargo spaces, structural analysis may be accepted in lieu of pressure testing. Where such doors utilize gasket seals, a prototype pressure test to confirm that the compression of the gasket material is capable of accommodating any deflection, revealed by the structural analysis, is to be carried out.

5.1.3 Watertight doors above the freeboard or bulkhead deck which are not immersed by an equilibrium or intermediate waterplane but become intermittently immersed at angles of heel in the required range of positive stability beyond the equilibrium position may be only hose tested (required only to be weathertight according to Ch 3, Sec 3, [3.3.2]).

5.2 Hydrostatic pressure testing

5.2.1 The head of water used for the pressure test shall correspond at least to the head measured from the lower edge of the door opening, at the location in which the door is to be fitted in the vessel, to the bulkhead deck or freeboard deck, as applicable, or to the most unfavourable damage waterplane, if that be greater. Testing may be carried out at the factory or other shore based testing facility prior to installation in the ship. The duration of the test is to be at least 30 min.

5.2.2 For cargo ships not covered by damage stability requirements, watertight doors are to be tested by water pressure to a head of water measured from the lower edge of the opening to one meter above the freeboard deck.

5.2.3 Leakage criteria for watertight doors

The following acceptable leakage criteria should apply:

- doors with gaskets: no leakage
- doors with metallic sealing: max leakage 1 litre/min.

Limited leakage may be accepted for pressure tests on large doors located in cargo spaces employing gasket seals or guillotine doors located in conveyor tunnels, in accordance with the following value, in litre/min:

$$\frac{(P + 4.572) \times h^3}{6568}$$

where:

P : Perimeter of door opening (m)

h : Test head of water (m).

However, in the case of doors where the water head taken for the determination of the scantling does not exceed 6,10 m, the leakage rate may be taken equal to 0,375 litre/min if this value is greater than that calculated by the above-mentioned formula.

5.2.4 Leakage criteria for semi-watertight doors

A leakage quantity of approximately 100 l/hour is to be considered as being acceptable for a 1,35 m² opening.

5.2.5 For doors on passenger ships which are used at sea or which become submerged by the equilibrium or intermediate waterplane, a prototype test shall be conducted, on each side of the door, to check the satisfactory closing of the door against a force equivalent to a water height of at least 1m above the sill on the centre line of the door.

5.3 Hose testing

5.3.1 All watertight, semi-watertight and weathertight doors shall be subject to a hose test after installation in a ship. Hose testing is to be carried out:

- from both sides of a watertight or semi-watertight door unless, for a specific application, exposure to floodwater is anticipated only from one side
- from both sides of internal bulkheads weathertight doors (fitted above bulkhead deck)
- from the exposed side of external weathertight doors (superstructures).

Where a hose test is not practicable because of possible damage to machinery, electrical equipment insulation or outfitting items, it may be replaced by means such as an ultrasonic leak test or an equivalent test.

6 Type approval procedure

6.1 General

6.1.1 Type approval certificates of doors may be issued to applicant manufacturers to certify that the design of the door has been assessed against a given strength level.

6.1.2 The documents and information listed in [6.2.1] must allow for the door strength to be checked against the applied design load.

6.1.3 In case a type approved door is fitted onboard a vessel, the hull supporting structure in way of the door is to be checked to have adequate strength according to [4].

6.1.4 A type approved door fitted onboard a vessel is to be selected to have a design load at least equivalent to the adjacent bulkhead in which it is fitted.

6.2 Documents and information to be submitted

6.2.1 Prior to issuance of type approval certificate, the following documents and information must be submitted to the Society for review, for each door model and variant:

- maximum considered design load
- tightness level (weathertight, semi-watertight or watertight)
- door dimensions
- structural drawings of the door, including securing devices
- material and mechanical properties of each part of the door
- test and inspection procedure (if relevant, see [6.3]).

6.3 Prototype test

6.3.1 *Where testing of individual doors is not carried out because of possible damage to insulation or outfitting items, testing of individual doors may be replaced by a prototype pressure test of each type and size of door with a test pressure corresponding at least to the head required for the individual location. The prototype test is to be carried out before the door is fitted. The installation method and procedure for fitting the door on board is to correspond to that of the prototype test. When fitted on board, each door is to be checked for proper seating between the bulkhead, the frame and the door.*

The corresponding test reports are to be annexed to the type approval certificate.

6.3.2 In such a case, the test procedure is to be submitted to the Society for review and is to be in line with the relevant requirements in [5].

Section 9 Large Hatch Covers

Symbols

For symbols not defined in this section, refer to Ch 1, Sec 3.

- P_S : Still water pressure, in kN/m^2 , as defined in [4.1]
 P_W : Wave pressure, in kN/m^2 , as defined in [4.1]
 P_C : Pressure acting on the hatch coaming, in kN/m^2 , as defined in [6.2]
 F_S, F_W : Coefficients taken equal to:
 $F_S = 0$ and $F_W = 0,9$ for ballast water loads on hatch covers of the ballast hold
 $F_S = 1.0$ and $F_W = 1,0$ in other cases
 b_p : Effective breadth, in mm, of the plating attached to the stiffener or primary supporting member, as defined in [3]
 A_{shr} : Net shear sectional area, in cm^2 , of the stiffener or primary supporting member
 f_{bc} : Boundary coefficient for stiffeners and primary supporting members, taken equal to:
 $f_{bc} = 8$, in the case of stiffeners and primary supporting members simply supported at both ends or supported at one end and clamped at the other end
 $f_{bc} = 12$, in the case of stiffeners and primary supporting members clamped at both ends
 t_c : Total corrosion addition, in mm, as defined in [1.5]
 σ_a, τ_a : Allowable stresses, in N/mm^2 , as defined in [1.6].

1 General

1.1 Application

1.1.1 The requirements of this Section apply to large cargo hatch covers and coamings on weather decks, as defined in Ch 1, Sec 3, [2.4].

1.2 Definitions

1.2.1 Large hatches

Large hatches are hatches with openings greater than $2,5 \text{ m}^2$.

1.2.2 ICLL

Where ICLL is referred to in the text, this is to be taken as the International Convention on Load Lines, 1966 as amended by the 1988 protocol, as amended in 2003.

1.2.3 Single skin cover

A hatch cover made of steel or equivalent material which has continuous top and side plating, but is open underneath with the stiffening structure exposed. The cover is weathertight and fitted with gaskets and clamping devices unless such fittings are specifically excluded.

1.2.4 Double skin cover

A hatch cover as above but with continuous bottom plating such that all the stiffening structure and internals are protected from the environment.

1.2.5 Pontoon type cover

A special type of portable cover, secured weathertight by tarpaulins and battening devices.

1.3 Materials

1.3.1 Steel

The formulae for scantlings given in [5] are applicable to steel hatch covers.

The materials used for construction of the steel large hatch covers, stoppers, securing devices and their weldings are to comply with the applicable requirements of Ch 4, Sec 1 and Part B, Chapter 13 respectively.

Specifications of the materials are to be shown in the drawings of the hatch covers.

1.3.2 Other materials

The use of materials other than steel is to be considered by the Society on a case-by-case basis, by checking that criteria adopted for scantlings are such as to ensure strength and stiffness equivalent to those of steel hatch covers.

1.4 Net scantlings

1.4.1 Corrosion additions for steel other than stainless steel

All scantlings referred to in this section are net, i.e. they do not include any margin for corrosion.

When calculating the stresses σ and τ in [5.3] and [5.4], the net scantlings are to be used.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

The corrosion additions are given in [1.5].

1.4.2 Corrosion additions for aluminium alloys

For structural members made of aluminium alloys, the corrosion addition t_c is to be taken equal to 0.

1.5 Corrosion additions

1.5.1 The total corrosion addition for both sides to be considered for the plating and internal members of hatch covers is equal to the value specified in Tab 1.

The corrosion addition for hatch coamings and coaming stays is defined according to Ch 4, Sec 3.

1.6 Allowable stresses

1.6.1 The allowable stresses σ_a and τ_{ar} in N/mm², are to be obtained from Tab 2.

The allowable buckling utilisation factors are given in Tab 3:

Table 1 : Corrosion additions t_c for hatch covers and hatch coamings

Application	Structure	t_c , in mm
Weather deck hatches of container ships, car carriers, paper carriers, passenger ships	Hatch covers	1,0
	Hatch coamings	1,5
Hatch covers of ships having the service notation bulk carrier, self-unloading bulk carrier ESP, ore carrier ESP or combination carrier ESP	Plating and stiffeners of single skin hatch cover	2,0
	Top and bottom plating of double skin hatch cover	2,0
	Internal structures of double skin hatch cover	1,5
Weather deck hatches of all other ship types covered by this Section	Hatch covers in general	2,0
	Weather exposed plating and bottom plating of double skin hatch covers	1,5
	Internal structure of double skin hatch covers and closed box girders	1,0
	Hatch coamings	1,5
	Coaming stays and stiffeners	1,5

Table 2 : Allowable stresses

Members of	Subjected to	σ_{ar} in N/mm ²	τ_{ar} in N/mm ²
Watertight hatch cover	External pressure, as defined in [4.1.2]	0,80 R_{eH}	0,46 R_{eH}
Watertight hatch cover	Other loads, as defined in [4.1.4] to [4.1.8]	0,90 R_{eH} for load categories: S+D 0,72 R_{eH} for load categories: S	0,51 R_{eH}

Table 3 : Allowable buckling utilisation factors

Structural component	Subject to	η_{all} , Allowable buckling utilisation factor
Plates and stiffeners Web of PSM	External pressure, as defined in [4.1.2]	0,80 for load categories: S+D
	Other loads, as defined in [4.1.4] to [4.1.8]	0,90 for load categories: S+D 0,72 for load categories: S

2 Arrangements

2.1 Height of hatch coamings

2.1.1 The height of hatch coamings is not to be less than:

- 600 mm in position 1
- 450 mm in position 2.

2.1.2 The height of hatch coamings in positions 1 and 2 closed by steel covers provided with gaskets and securing devices may be reduced with respect to the above values or the coamings may be omitted entirely, on condition that the Administration is satisfied that the safety of the ship is not thereby impaired in any sea conditions.

In such cases the scantlings of the covers, their gasketing, their securing arrangements and the drainage of recesses in the deck are considered by the Society on a case-by-case basis.

2.2 Hatch covers

2.2.1 The stiffeners and primary supporting members of the hatch covers are to be continuous over the breadth and length of the hatch covers, as far as practical. When this is impractical, sniped end connections are not to be used and appropriate arrangements are to be adopted to ensure sufficient load carrying capacity.

2.2.2 The spacing of primary supporting members parallel to the direction of stiffeners is not to be greater than 1/3 of the span of primary supporting members.

2.2.3 The breadth of the primary supporting member face plate is not to be less than 40% of their depth for laterally unsupported spans greater than 3 m. Tripping brackets attached to the face plate may be considered as a lateral support for primary supporting members.

The face plate outstand is not to exceed 15 times the gross face plate thickness.

2.2.4 Efficient retaining arrangements are to be provided to prevent translation of the hatch cover under the action of the longitudinal and transverse forces exerted by cargoes on the cover, if any. These retaining arrangements are to be located in way of the hatch coaming side brackets.

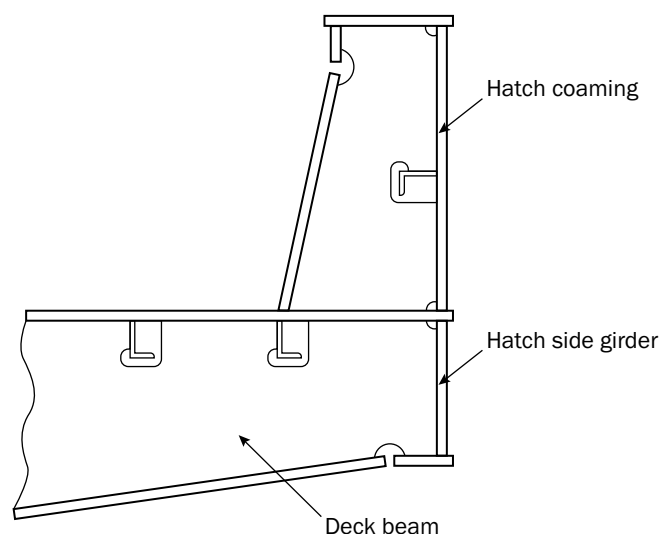
2.2.5 The width of each bearing surface for hatch covers is to be at least 65 mm.

2.3 Hatch coamings

2.3.1 Coamings, stiffeners and brackets are to be capable of withstanding the local forces in way of the clamping devices and handling facilities necessary for securing and moving the hatch covers as well as those due to cargo stowed on the latter.

2.3.2 Special attention is to be paid to the strength of the fore transverse coaming of the forward hatch and to the scantlings of the closing devices of the hatch cover on this coaming.

Figure 1 : Example of extension to lower edge of deck beams of longitudinal coaming by fitting a hatch side girder



2.3.3 Longitudinal coamings are to be vertically extended at least to the lower edge of deck beams or hatch side girders below deck are to be fitted in line with longitudinal coamings. Extended coaming plates are to be flanged or fitted with face bars or half-round bars at the level of lower edge of the deck beams (see Fig 1).

- where they are not part of continuous deck girders, the lower edge of longitudinal coamings including below deck structure as an extension measure above are to extend for at least two frame spaces beyond the end of the hatch openings.
- where they are part of continuous deck girders, their scantlings are to be as required in Ch 7, Sec 6 and Ch 9, Sec 1.

2.3.4 A web frame or a similar structure is to be provided below the deck in line with the transverse coaming. Transverse coamings are to extend below the deck and to be connected with the web frames.

3 Width of Attached Plating

3.1 Stiffeners

3.1.1 The width of the attached plating b_p , in mm, to be considered for the check of stiffeners is to be taken as:

- where the attached plating extends on both sides of the stiffener:

$$b_p = s$$

- where the attached plating extends on one side of the stiffener:

$$b_p = 0.5 s$$

3.2 Primary supporting members

3.2.1 The effective breadth, in mm, of the attached plating to be considered for the yielding and buckling checks of primary supporting members analysed through isolated beam or grillage model is to be taken as:

- where the plating extends on both sides of the primary supporting member:

$$b_p = b_{eff}$$

- where the plating extends on one side of the primary supporting member:

$$b_p = 0.5b_{eff}$$

where:

b_{eff} : Effective breadth of attached plating, in m, as defined in Ch 4, Sec 6, [1.3.2].

For structural evaluations based on isolated beam or grillage models, the areas of stiffeners are not to be included in the idealisation of the attached plating of the primary members.

4 Load Model

4.1 Lateral pressures and forces

4.1.1 General

The lateral pressures and forces to be considered as acting on hatch covers are given in [4.1.2] to [4.1.8]. When two or more panels are connected by hinges, each individual panel is to be considered separately.

In any case, the green sea loads defined in [4.1.2] and [4.1.3] are to be considered for hatch covers located on exposed decks.

Additionally, when the hatch cover is intended to carry uniform cargoes, special cargoes or containers, the pressures and forces defined in [4.1.4] to [4.1.8] are to be considered independently from the sea pressures.

4.1.2 Vertical weather design load

The vertical weather design load acting on exposed hatch covers is to be considered and is defined in Ch 5, Sec 5, [6.2.1].

4.1.3 Horizontal weather design load

The horizontal weather design load acting on coamings of exposed hatches is to be considered and taken as given in Tab 4.

Table 4 : Horizontal weather loads

Application		P_A in kN/m ²
Ships having the service notation bulk carrier, self-unloading bulk carrier ESP, ore carrier ESP or combination carrier ESP	Most forward transverse coaming of ships not fitted with a forecastle according to Pt D, Ch 4, Sec 2, [2]; Pt D, Ch 5, Sec 2, [3] and Pt D, Ch 6, Sec 2, [1] depending on the service notation.	290
	All other coamings	220
All other ship types covered by this Section		as defined in Ch 5, Sec 5, [6.2.2]

4.1.4 Internal pressures due to ballast water

If applicable, the internal static and dynamic lateral pressures due to ballast water are to be considered and are defined in Ch 5, Sec 6, [1].

4.1.5 Pressures due to uniform or unit cargoes

If applicable, the static and dynamic pressures or forces due to uniform or unit cargoes are to be considered and are defined in Ch 5, Sec 6, [6].

4.1.6 Pressures and forces due to wheel loads

If applicable, the static and dynamic pressures or forces due to uniform or unit cargoes are to be considered and are defined in Ch 5, Sec 6, [7].

4.1.7 Pressures or forces due to special cargoes

In the case of carriage of special cargoes (e.g. pipes, etc) on the hatch covers which may temporarily retain water during navigation, the lateral pressures or forces to be applied are considered by the Society on a case-by-case basis.

4.1.8 Forces due to containers

In the case of carriage of containers on the hatch covers, the concentrated forces under the containers corners are to be considered and are defined in Ch 5, Sec 6, [8].

4.1.9 Self weight

The effect of the hatch cover structure weight is to be included in the static loads but not in the dynamic loads.

4.2 Load point

4.2.1 Wave lateral pressure for hatch covers on exposed decks

The wave lateral pressure to be considered as acting on each hatch cover is to be calculated at a point located:

- Longitudinally, at the hatch cover mid-length.
- Transversely, on the longitudinal plane of symmetry of the ship.
- Vertically, at the top of the hatch cover.

4.2.2 Lateral pressures other than the wave pressure

The lateral pressure is to be calculated at the level of the tight boundary of the cover:

- In way of the geometrical centre of gravity of the plate panel, for plating.
- At mid-span, for stiffeners and primary supporting members.

5 Strength Check

5.1 General

5.1.1 Application

The strength check is applicable to rectangular hatch covers subjected to a lateral pressure and/or concentrated loads, designed with primary supporting members arranged in one direction or as a grillage of longitudinal and transverse primary supporting members.

In the latter case, i.e. when the hatch cover is arranged as a grillage of longitudinal and transverse primary supporting members, or when the Society deems it necessary, the stresses in the primary supporting members are to be determined by a grillage or a finite element analysis.

It is to be checked that stresses induced by concentrated loads are in accordance with the criteria in [5.4.5].

When FE analysis is carried out, the buckling assessment as described in [5.2.4], [5.3.4] and [5.4.7] can be made considering only the stresses given by the FE analysis.

The hatch covers fitted with U type stiffeners as shown in Fig 2 are to be checked by means of FE analysis. In transverse section of the stiffener, nodes are to be located at the connection between the web of the U type stiffener and the hatch cover plate as well as at the connection between the web and the flange of the U type stiffener. The buckling assessment as described in [5.2.4], [5.3.4] and [5.4.7] can be made considering only the stresses given by the FE analysis.

5.1.2 Hatch covers supporting containers

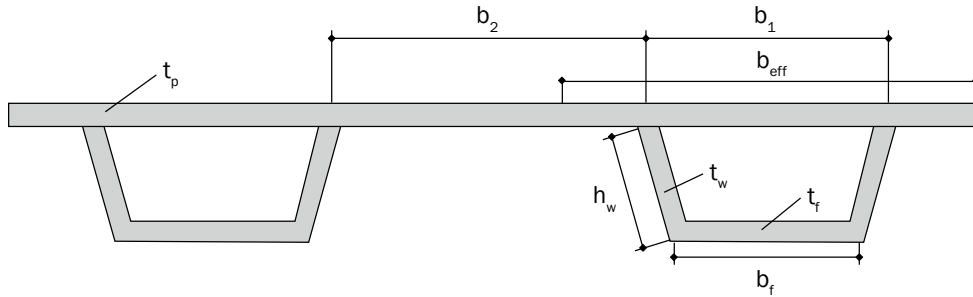
The scantlings of hatch covers supporting containers are to comply with the applicable requirements of the Society.

5.1.3 Hatch covers supporting wheel loads

The scantlings of hatch covers supporting wheeled loads are to be obtained in accordance with the applicable requirements of:

- Ch 7, Sec 4, for plating
- Ch 7, Sec 5, or by direct calculations under consideration of the permissible stresses given in [5.4.5], for ordinary stiffeners
- Ch 7, Sec 6, for primary supporting members.

Figure 2 : Example of hatch cover fitted with U type stiffener



5.1.4 Hatch covers subjected to special cargoes

For hatch covers supporting special cargoes, stiffeners and primary supporting members are generally to be checked by direct calculations, taking into account the stiffener arrangements and their relative inertia. It is to be checked that stresses induced by special cargoes are in accordance with the criteria in [5.4.5].

5.2 Plating

5.2.1 Net thickness

The net thickness, in mm, of steel hatch cover top plating is not to be taken less than:

$$t = 0,0158 F_p b \sqrt{\frac{F_s P_s + F_w P_w}{0,95 R_{eH}}}$$

where:

F_p : Factor for combined membrane and bending response, equal to:

- $F_p = 1,5$ in general
- $F_p = 1,9 \sigma / \sigma_a$ for the attached plating of primary supporting members and for $\sigma \geq 0,8 \sigma_a$

σ : Normal stress, in N/mm², in the attached plating of primary supporting members, calculated according to [5.4.3] or determined through a grillage analysis or a finite element analysis.

5.2.2 Minimum net thickness

In addition to [5.2.1], the net thickness, in mm, of the plating forming the top of the hatch cover is not to be taken less than the greater of the following values:

$$t = \frac{b}{100}$$

$$t = 6$$

5.2.3 Lower plating of double skin hatch covers and box girders

The thickness to fulfil the strength requirements is to be obtained from the calculations according to [5.4].

When the lower plating is taken into account as a strength member of the hatch cover, its net thickness, in mm, is not to be less than 5 mm.

When project cargo is intended to be carried on a hatch cover, the net thickness must not be less than: $t = 6,5 s$

When the lower plating is not considered as a strength member of the hatch cover, the thickness of the lower plating is to be determined according to Ch 7, Sec 4.

Note 1: Project cargo means especially large or bulky cargo lashed to the hatch cover. Examples are parts of cranes or wind power stations, turbines, etc. Cargoes that can be considered as uniformly distributed over the hatch cover, e.g., timber, pipes or steel coils need not to be considered as project cargo.

5.2.4 Buckling strength

The buckling strength of the hatch cover plating subjected to loading conditions as defined in [4.1] is to comply with the requirements in Ch 9, Sec 1, considering the following stresses:

- a) For beam theory calculation, i.e. not calculated by means of finite element analysis:
 - σ_x or σ_y is selected for the uniaxial check of the plate in the direction parallel to the primary supporting member,
 - $\tau = 0$.
- b) For finite element analysis: σ_x , σ_y , τ obtained from FE analysis.

For hatch covers fitted with U type stiffeners, the buckling panels b_1 , b_2 and c (see Fig 2) are to be assessed separately.

5.3 Stiffeners

5.3.1 Stiffeners are to comply with the applicable slenderness and proportion requirements given in Ch 9, Sec 1.

5.3.2 Minimum net thickness of web

The net thickness, in mm, of the stiffener web is to be taken not less than 4 mm.

5.3.3 Net section modulus and net shear sectional area

The net section modulus Z , in cm^3 , and the net shear sectional area A_{shr} , in cm^2 , of a stiffener subject to lateral pressure are to be taken not less than given by the following formulae:

$$Z = \frac{(F_s P_s + F_w P_w) s \cdot \ell_s^2}{f_{bc} \sigma_a}$$

$$A_{shr} = \frac{5(F_s P_s + F_w P_w) s \ell_s}{\tau_a} 10^{-3}$$

where:

ℓ_s : Stiffener span, in m, to be taken as the spacing, in m, of primary supporting members or the distance between a primary supporting member and the edge support, as applicable. When brackets are fitted at both ends of all stiffener spans, the stiffener span may be reduced by an amount equal to 2/3 of the minimum brackets arm length, but not greater than 10% of the gross span, for each bracket.

5.3.4 Buckling strength

The buckling strength of the hatch cover stiffeners subjected to loading conditions as defined in [4.1] is to comply with the requirements in Ch 9, Sec 1, considering the following stresses:

- a) For uniaxial stresses obtained by beam theory, i.e. not calculated by means of finite element analysis:
 - σ_x : stiffener axial stress
 - $\sigma_y = 0$
 - $\tau = 0$.
- b) For stresses calculated by means of finite element analysis:
 - σ_x : stiffener axial stress from FE analysis
 - σ_y : stress perpendicular to the stiffener
 - τ : shear stress in the attached plate.

The buckling strength of the hatch cover fitted with U type stiffeners subjected to loading conditions as defined in [4.1] is to be checked as detailed above, considering the U type as an equivalent T-bar profile as follows:

- web height taken equal to d as defined in Ch 4, Sec 5, Fig 27
- web thickness equal to $2 t_w$
- flange breadth taken as b_3 , as shown on Fig 2
- flange thickness taken as t_f , as shown on Fig 2
- effective width of the attached plating, b_{eff} , taken as:

$$b_{eff} = C_{x1} b_1 + C_{x2} b_2$$

where:

C_{x1}, C_{x2} : Reduction factor defined in NR615, calculated for the EPP b_1 and b_2 according to case 1.

5.4 Primary supporting members

5.4.1 Application

The requirements in [5.4.3] to [5.4.6] apply to primary supporting members which may be analysed through isolated beam models. Primary supporting members whose arrangement is of a grillage type and which cannot be analysed through isolated beam models are to be checked by direct calculations, using the checking criteria in [5.4.5].

5.4.2 Minimum net thickness of web

The web net thickness of primary supporting members, in mm, is not to be less than 6 mm.

5.4.3 Normal and shear stress for isolated beam

In case that grillage analysis or finite element analysis are not carried out, according to the requirements in [5.1.1], the maximum normal stress σ and shear stress τ , in N/mm^2 , in the primary supporting members are to be taken as given by the following formulae:

$$\sigma = \frac{S(F_s P_s + F_w P_w) \ell_m^2}{f_{bc} Z}$$

$$\tau = \frac{5 S(F_s P_s + F_w P_w) \ell_m}{A_{shr}}$$

where:

ℓ_m : Bending span, in m, of the primary supporting member.

5.4.4 Edge girders (skirt plates)

Scantlings of edge girders are obtained from the calculations according to [5.4] under consideration of the permissible stresses defined in [1.6].

The net thickness, in mm, of the outer edge girders exposed to wash of sea is not to be less than the greatest of:

- $t = 15,8 b \sqrt{\frac{p_A}{0,95 R_{eH}}}$
- $t = 8,5 \beta$
- $t_{min} = 5 \text{ mm},$

where:

p_A : Horizontal pressure, in kN/m^2 , as defined in Ch 5, Sec 5, [6.2.2].

The stiffness of edge girders is to be sufficient to maintain adequate sealing pressure between securing devices. The moment of inertia I , in cm^4 , of edge girders is not to be less than:

$$I = 6 \theta \sigma_{SD}^4$$

where:

q : Packing line pressure, in N/mm , to be taken not less than 5 N/mm

s_{SD} : Spacing, in m , of securing devices.

5.4.5 Checking criteria

The normal stress σ and the shear stress τ , calculated according to [5.4.3] or determined through a grillage analysis or finite element analysis, as the case may be, are to comply with the following formulae:

$$\sigma \leq \sigma_a$$

$$\tau \leq \tau_a$$

5.4.6 Deflection limit

The net moment of inertia of a primary supporting member, when loaded by sea pressure, excluding the self-weight of the structure, is to be such that the deflection does not exceed $\mu \ell_{max}$.

where:

μ : Coefficient taken equal to: $\mu = 0,0056$ for weathertight hatch covers.

ℓ_{max} : Greatest span, in m , of primary supporting members.

5.4.7 Buckling strength of the web panels of the primary supporting members

The buckling strength of the web of primary supporting members subjected to loading conditions as defined in [4.1] is to comply with the requirements in Ch 9, Sec 1, considering the following stresses:

- Shear stress obtained by beam theory (i.e. calculated according to [5.4.3] or determined through a grillage analysis), or
- σ_x, σ_y, τ obtained by FE analysis.

5.4.8 Slenderness criteria

For buckling stiffeners on webs of primary supporting members, the ratio h_w/t_w is to comply with the following formula:

$$\frac{h_w}{t_w} \leq 15 \sqrt{\frac{235}{R_{eH}}}$$

5.5 Stiffeners and primary supporting members of variable cross section

5.5.1 The net section modulus Z , in cm^3 , of stiffeners and primary supporting members with a variable cross section is to be taken not less than the greater of the values given by the following formulae:

$$Z = Z_{CS}$$

$$Z = \left(1 + \frac{3,2\alpha - \psi - 0,8}{7\psi + 0,4} \right) Z_{CS}$$

where:

Z_{CS} : Net section modulus, in cm^3 , for a constant cross section, complying with the checking criteria in [5.4.5]

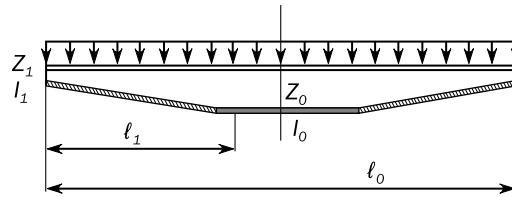
a : Coefficient taken equal to:

$$\alpha = \frac{\ell_1}{\ell_0}$$

ψ : Coefficient taken equal to:

$$\psi = \frac{Z_1}{Z_0}$$

Figure 3 : Variable cross section stiffener



- l_1 : Length of the variable section part, in m, as shown in Fig 3
- l_0 : Span measured, in m, between end supports, as shown in Fig 3
- Z_1 : Net section modulus at end, in cm^3 , as shown in Fig 3
- Z_0 : Net section modulus at mid-span, in cm^3 , as shown in Fig 3.

Moreover, the net moment of inertia, in cm^4 , of stiffeners and primary supporting members with a variable cross section is to be taken not less than the greater of the values given by the following formulae:

$$I = I_{CS}$$

$$I = \left[1 + 8\alpha^3 \left(\frac{1-\varphi}{0.2 + 3\sqrt{\varphi}} \right) \right] I_{CS}$$

where:

- I_{CS} : Net moment of inertia, in cm^4 , with a constant cross section complying with [5.4.6]
- φ : Coefficient taken equal to:

$$\varphi = \frac{I_1}{I_0}$$

- I_1 : Net moment of inertia at end, in cm^4 Fig 3
- I_0 : Net moment of inertia at mid-span, in cm^4 , as shown in Fig 3.

The use of these formulae is limited to the determination of the strength of stiffeners and primary supporting members in which abrupt changes in the cross section do not occur along their length.

6 Hatch Coamings

6.1 Stiffening

- 6.1.1** The stiffeners of the hatch coamings are to be continuous over the breadth and length of the hatch coamings.
- 6.1.2** Coamings are to be stiffened on their upper edges with a stiffener suitably shaped to fit the hatch cover closing appliances.
- 6.1.3** Where the height of the coaming exceeds 900 mm, additional strengthening may be required. However, reductions may be granted for transverse coamings in protected areas.
- 6.1.4** When two hatches are close to each other, under deck stiffeners are to be fitted to connect the longitudinal coamings in order to maintaining the continuity of their strength. Similar stiffening is to be provided over 2 frame spacings at ends of hatches exceeding 9 frame spacings in length. In some cases, the Society may require the continuity of coamings to be maintained above the deck.
- 6.1.5** Where watertight metallic hatch covers are fitted, other arrangements of equivalent strength may be adopted.

6.2 Load model

- 6.2.1** The wave lateral pressure, P_A in kN/m^2 , to be considered as acting on the hatch coamings is defined in [4.1.3].
- 6.2.2** For cargo holds intended for the carriage of ballast water, the liquid internal pressures applied on hatch coaming is also to be determined according to Ch 5, Sec 6.

6.3 Scantlings

6.3.1 Plating

The net thickness, in mm, of the hatch coaming plate is not to be taken less than the greater value given by the following formulae:

$$t = 0,016b \sqrt{\frac{P_A}{0,95R_{eH}}}$$

$$t = 9,5$$

6.3.2 Stiffeners

The net section modulus, Z , in cm^3 , of longitudinal or transverse stiffeners fitted on hatch coamings is not to be taken less than:

$$Z = 1,21 \frac{P_A s \ell^2}{f_{bc} c_p R_{eH}}$$

where:

f_{bc} : Coefficient taken equal to:

$f_{bc} = 16$ in general

$f_{bc} = 12$ for the end span of stiffeners sniped at the coaming corners

c_p : Ratio of the plastic section modulus to the elastic section modulus of the stiffeners with an attached plate breadth, in mm, equal to $40t$, where t is the plate net thickness.

$c_p = 1,16$ in the absence of more precise evaluation.

6.3.3 Coaming stays

At the connection with deck, the net section modulus Z , in cm^3 , and the net thickness t_w , in mm, of the coaming stays designed as beams with flange connected to the deck or sniped and fitted with a bracket (examples shown in Fig 4 and Fig 5) are to be taken not less than:

$$Z = \frac{s_c P_A H_C^2}{1,9 R_{eH}}$$

$$t_w = \frac{s_c P_A H_C}{0,5h R_{eH}}$$

where:

H_C : Stay height, in m

s_c : Stay spacing, in mm

h : Stay depth, in mm, at the connection with deck.

For calculating of offered section modulus of coaming stays, the face plate area may be taken into account only when it is welded with full penetration welds to the deck plating and provided with adequate under deck structure supporting the coaming stay in the deck structure.

Figure 4 : Coaming stay (example 1)

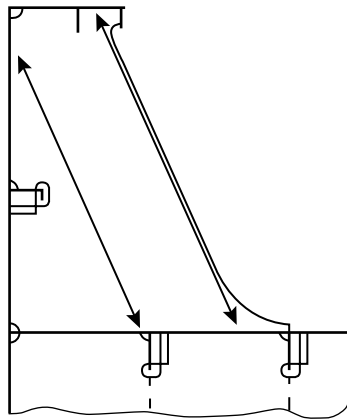
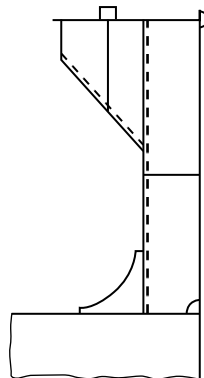


Figure 5 : Coaming stay (example 2)



For other designs of coaming stays, such as those shown in Fig 6 and Fig 7, the stress levels determined through a grillage analysis or finite element analysis, as the case may be, apply and are to be checked at the highest stressed locations. The stress levels are to comply with the following formulae:

$$\sigma \leq 0,95 R_{eH}$$

$$\tau \leq 0,5 R_{eH}$$

Figure 6 : Coaming stay (example 3)

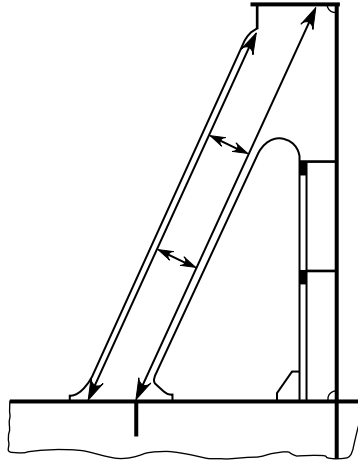
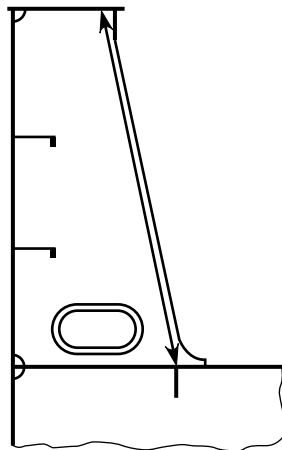


Figure 7 : Coaming stay (example 4)



6.3.4 Local details

The design of local details is to comply with the requirements in this section ensuring adequate structural continuity from the hatch covers into the supporting deck structure.

Hatch coamings and supporting structures are to be adequately stiffened to accommodate the loading from hatch covers, in longitudinal, transverse and vertical directions.

The normal stress σ and the shear stress τ , in N/mm^2 , induced in the under deck structures by the loads transmitted by stays are to comply with the following formulae:

$$\sigma \leq 0,95 R_{eH}$$

$$\tau \leq 0,5 R_{eH}$$

Unless otherwise stated, weld connections and materials are to be dimensioned and selected in accordance with the requirements of the Society.

Double continuous fillet welding is to be adopted for the connections of stay webs with deck plating and the weld leg length is not to be less than $0,62 t_w$ where t_w is the gross thickness of the stay web.

Toes of stay webs are to be connected to the deck plating with partial penetration double bevel welds extending over a distance not less than 15% of the stay width.

7 Container foundations on hatch covers

7.1 Strength requirements

7.1.1 The substructures of container foundations are to be designed for cargo and container loads according to Ch 5, Sec 6, [9.2], applying the permissible stresses according to [5.4.5].

8 Weathertightness, closing arrangement, securing devices, stoppers and supports

8.1 Weathertightness

8.1.1 Where the hatchway is exposed, the weathertightness is to be ensured by gaskets and clamping devices sufficient in number and quality.

Weathertightness may also be ensured by means of tarpaulins.

8.1.2 In general, a minimum of two securing devices or equivalent is to be provided on each side of the hatch cover.

8.2 Gaskets

8.2.1 The weight of hatch covers and any cargo stowed thereon, together with inertia forces generated by ship motions, are to be transmitted to the ship's structure.

8.2.2 The sealing is to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary weathertightness. Similar sealing is to be arranged between cross-joint elements.

Where fitted, compression flat bars or angles are to be well rounded where in contact with the gasket and to be made of a corrosion-resistant material.

8.2.3 The gasket and the securing arrangements are to maintain their efficiency when subjected to large relative movements between the hatch cover and the ship's structure or between hatch cover elements.

If necessary, suitable devices are to be fitted to limit such movements.

8.2.4 The gasket material is to be of a quality suitable for all environmental conditions likely to be encountered by the ship, and is to be compatible with the cargoes transported.

The material and form of gasket selected are to be considered in conjunction with the type of hatch cover, the securing arrangement and the expected relative movement between the hatch cover and the ship's structure.

The gasket is to be effectively secured to the hatch cover.

8.2.5 Coamings and steel parts of hatch covers in contact with gaskets are to have no sharp edges.

8.2.6 Metallic contact is required to ensure earthing connection between the hatch cover and the hull structures.

8.2.7 Dispensation of weathertight gaskets

For hatch covers of cargo holds solely for the transport of containers, upon request by the Owner and subject to compliance with the following conditions, the fitting of weathertight gaskets according to [8.2.1] to [8.2.6] may be dispensed:

- the hatchway coamings are to be not less than 600 mm in height
- the exposed deck on which the hatch covers are located is situated above a depth $H(x)$. $H(x)$, in m, is to be shown to comply with the following criterion:

$$H(x) \geq T + f_b + h$$

where:

f_b : Minimum required freeboard, in m, determined according to ICLL Reg.28, as amended

h : Distance, in m, taken equal to:

- for $x / L_{LL} \leq 0,75$: $h = 2 h_s$

- for $x / L_{LL} > 0,75$: $h = 3 h_s$

h_s : Standard height of superstructure, defined in Ch 1, Sec 3, Tab 5

- labyrinths, gutter bars or equivalent are to be fitted near the edges of each panel in way of the gaps to minimise the amount of water that can enter the container hold from the top surface of each panel
- the labyrinths and gaps between hatch cover panels are to be considered as unprotected openings with respect to the requirements of intact and damage stability calculations
- the non-weathertight gaps between hatch cover panels are to be as small as possible commensurate with the capacity of the bilge system and expected water ingress, and the capacity and operational effectiveness of the fire-fighting system and, in general, not greater than 50 mm
- with regard to drainage of cargo holds and the necessary fire-fighting system, reference is made to applicable requirements in Part C, Chapter 1 and Part C, Chapter 4

- bilge alarms are to be provided in each hold fitted with non-weathertight covers
- scantlings of the hatch cover panels are to be equivalent to those for weathertight covers and in accordance with the applicable requirements of the present Section.

8.3 Closing arrangement, securing devices and stoppers

8.3.1 General

Panel hatch covers are to be secured by appropriate devices (bolts, wedges or similar) suitably spaced along the coamings and between cover elements.

Hatch covers provided with special sealing devices, insulated hatch covers, flush hatch covers and those having coamings of a reduced height according to [2.1.2] are to be considered by the Society on a case-by-case basis.

8.3.2 Arrangements

The securing and stopping devices are to be arranged so as to ensure sufficient compression on gaskets between hatch covers and coamings and between adjacent hatch covers.

Arrangement and spacing are to be determined with due attention to the effectiveness for weathertightness, depending on the type and the size of the hatch cover, as well as on the stiffness of the hatch cover edges between the securing devices.

At cross-joints of multi-panel covers, (male/female) vertical guides are to be fitted to prevent excessive relative vertical deflections between loaded/unloaded panels.

The location of stoppers is to be compatible with the relative movements between hatch covers and the ship's structure in order to prevent damage to them. The number of stoppers is to be as small as possible.

Towards the ends of the ship, vertical acceleration forces may exceed the gravity force. The resulting lifting forces are to be considered when dimensioning the securing devices according to [8.3.5]. Lifting forces from cargo secured on the hatch cover during rolling are also to be taken into account.

Hatch covers provided with special sealing devices, insulated hatch covers, flush hatch covers and those having coamings of a reduced height (see [2.1]) are considered by the Society on a case by case basis.

In the case of hatch covers carrying containers, the scantlings of the closing devices are to take into account the possible upward vertical forces transmitted by the containers.

8.3.3 Spacing

The spacing of the securing arrangements is not to be greater than 6 m.

8.3.4 Construction

Securing arrangements with reduced scantlings may be accepted provided it can be demonstrated that the possibility of water reaching the deck is negligible.

Securing devices are to be of reliable construction and securely attached to the hatchway coamings, decks or hatch covers.

Individual securing devices on each hatch cover are to have approximately the same stiffness characteristics.

8.3.5 Area of securing devices

The gross cross area of each securing device is not to be less than the value obtained, in cm², from the following formula:

$$A = 1,4 S_s \left(\frac{235}{R_{eH}} \right)^\alpha$$

where:

S_s : Spacing, in m, of securing devices.

α : Coefficient taken equal to:

$$\alpha = 0,75 \text{ for } R_{eH} > 235 \text{ N/mm}^2$$

$$\alpha = 1,0 \text{ for } R_{eH} \leq 235 \text{ N/mm}^2.$$

In the above calculations, R_{eH} may not be taken greater than $0,7 R_m$.

Between hatch cover and coaming and at cross-joints, a packing line pressure sufficient to obtain weathertightness is to be maintained by securing devices. For packing line pressures exceeding 5 N/mm, the net cross area A is to be increased in direct proportion. The packing line pressure is to be specified.

In the case of securing arrangements which are particularly stressed due to the unusual width of the hatchway, the net cross area A of the above securing arrangements is to be determined through direct calculations.

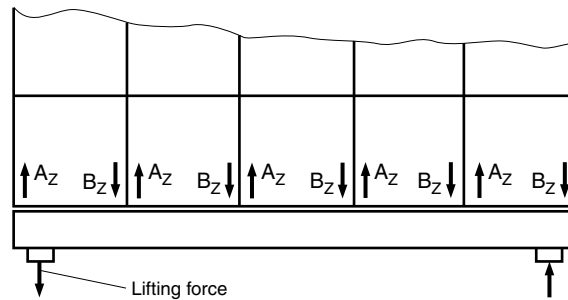
8.3.6 Anti lifting devices

The securing devices of hatch covers, on which cargo is to be lashed, are to be designed for the lifting forces resulting from loads according to Ch 5, Sec 6, [9.2.4] (see Fig 8). Unsymmetrical loadings, which may occur in practice, are to be considered. Under these loadings, the equivalent stress, in N/mm², in the securing devices is not to exceed:

$$\sigma_v = 150/k_r$$

Note 1: The partial load cases given in Ch 5, Sec 6, Tab 15 may not cover all unsymmetrical loadings, critical for hatch cover lifting.

Figure 8 : Lifting forces at a hatch cover



8.3.7 Inertia of edges elements

The hatch cover edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices.

The moment of inertia of edge elements is not to be less than the value obtained, in cm^4 , from the following formula:

$$I = 6 P_L S_S^4$$

where:

P_L : Packing line pressure, in N/mm, to be taken not less than 5

S_S : Spacing, in m, of securing devices.

8.3.8 Diameter of rods or bolts

Rods or bolts are to have a gross diameter not less than 19 mm for hatchways exceeding 5 m^2 in area.

8.3.9 Stoppers

Hatch covers are to be effectively secured, by means of stoppers, against the transverse forces arising from a pressure of 175 kN/m^2 .

With the exclusion of No. 1 hatch cover, hatch covers are to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 175 kN/m^2 .

No. 1 hatch cover is to be effectively secured, by means of stoppers, against the longitudinal forces acting on the forward end arising from a pressure of 230 kN/m^2 . This pressure may be reduced to 175 kN/m^2 if a forecastle is fitted in accordance with Ch 4, Sec 2, [3], Ch 5, Sec 2, [3] and Ch 6, Sec 2, [2] depending on the service notation.

The equivalent stress in stoppers, their supporting structures and calculated in the throat of the stopper welds is to be equal to or less than the allowable value, equal to $0,8 R_{eH}$.

8.4 Cleats

8.4.1 Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

8.4.2 Where hydraulic cleating is adopted, a positive means is to be provided to ensure that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

8.5 Tarpaulins

8.5.1 Where weathertightness of hatch covers is ensured by means of tarpaulins, at least two layers of tarpaulins are to be fitted.

Tarpaulins are to be free from jute and waterproof and are to have adequate characteristics of strength and resistance to atmospheric agents and high and low temperatures.

The mass per unit surface of tarpaulins made of vegetable fibres, before the waterproofing treatment, is to be not less than:

- $0,65 \text{ kg/m}^2$ for waterproofing by tarring
- $0,60 \text{ kg/m}^2$ for waterproofing by chemical dressing
- $0,55 \text{ kg/m}^2$ for waterproofing by dressing with black oil.

In addition to tarpaulins made of vegetable fibres, those of synthetic fabrics or plastic laminates may be accepted by the Society provided their qualities, as regards strength, waterproofing and resistance to high and low temperatures, are equivalent to those of tarpaulins made of vegetable fibres.

8.6 Wedges, battens and locking bars

8.6.1 Wedges

Wedges are to be of tough wood, generally not more than 200 mm in length and 50 mm in width.

They are generally to be tapered not more than 1 in 6 and their thickness is to be not less than 13 mm.

8.6.2 Battens and locking bars

For all hatchways in exposed positions, battens or transverse bars in steel or other equivalent means are to be provided in order to efficiently secure the portable covers after the tarpaulins are battened down.

Portable covers of more than 1,5 m in length are to be secured by at least two such securing appliances.

8.7 Hatch covers supports

8.7.1 Horizontal forces

For the design of hatch cover supports, the horizontal force F_h , in kN, to be considered is given by the following formula:

$$F_h = m \alpha$$

where:

α : Acceleration taken equal to:

- in longitudinal direction: $\alpha_x = 0,2 \text{ g}$
- in transverse direction: $\alpha_y = 0,5 \text{ g}$

m : Sum of mass of cargo lashed on the hatch cover and mass of hatch cover, in t.

The accelerations in longitudinal and transverse direction do not need to be considered as acting simultaneously.

8.7.2 Allowable pressure

For the transmission of the support forces resulting from the load cases specified in [4] and of the horizontal mass forces specified in [8.7.1], supports are to be provided which are to be designed such that the nominal surface pressures, in N/mm^2 , do not exceed in general the following values:

$$p_{n \max} = d p_n$$

where:

d : Parameter taken equal to:

$$d = 3,75 - 0,015 L,$$

to be taken not greater than $d_{\max} = 3,0$ and not less than d_{\min}

$\delta_{\mu IV}$: Parameter defined as follows:

- $d_{\min} = 1,0$ in general
- $d_{\min} = 2,0$ for partial loading conditions, see Ch 5, Sec 6, [9.2.5]

p_n : Permissible nominal surface pressure, in N/mm^2 , as defined in Tab 5.

For metallic supporting surfaces not subjected to relative displacements, the nominal surface pressure, in N/mm^2 , is to be taken equal to:

$$p_{n \max} = 3 \pi_n$$

Note 1: When the vertical hatch cover support material manufacturer can provide proof that the material is sufficient for the increased surface pressure, not only statically but under dynamic conditions including relative motion for adequate number of cycles, permissible nominal surface pressure may be relaxed on a case-by-case basis, pending realistic long term distribution of spectra for vertical loads and relative horizontal motion.

Drawings of the supports are to be submitted, specifying the permitted maximum pressure given by the material manufacturer related to long time stress.

Where large relative displacements of the supporting surfaces are to be expected, the use of material having low wear and frictional properties is recommended.

The substructures of the supports are to be of such a design, that a uniform pressure distribution is achieved.

Irrespective of the arrangement of stoppers, the supports are to be able to transmit the following force P_h , in kN, in the longitudinal and transverse directions:

$$P_h = \mu_1 \frac{P_v}{\sqrt{d}}$$

where:

P_v : Vertical supporting force, in kN.

μ_1 : Frictional coefficient, taken equal generally to 0,5

For non-metallic, low-friction support materials on steel, μ_1 may be reduced, without being taken less than 0,35.

Supports as well as the adjacent structures and substructures are to be designed such that the permissible stresses according to [5.4.5] are not exceeded.

For substructures and adjacent structures of supports subjected to horizontal forces P_h , fatigue strength may be checked.

Table 5 : Permissible nominal surface pressure p_n

Support material	p_n , in N/mm ² , when loaded by:	
	vertical force	horizontal force (on stoppers)
Hull structural steel	25	40
Hardened steel	35	50
Plastic materials on steel	50	–

9 Drainage

9.1 Arrangement

9.1.1 Drainage is to be arranged inside the line of gaskets by means of a gutter bar or vertical extension of the hatch side and end coaming.

9.1.2 Drain openings are to be arranged at the ends of drain channels and are to be provided with efficient means for preventing ingress of water from outside, such as non-return valves or equivalent.

9.1.3 Cross-joints of multi-panel hatch covers are to be arranged with drainage of water from the space above the gasket and a drainage channel below the gasket.

9.1.4 If a continuous outer steel contact is arranged between the cover and the ship's structure, drainage from the space between the steel contact and the gasket is also to be provided.

10 Testing

10.1 Initial test of watertight hatches

10.1.1 Watertight hatches are to be tested by water pressure to the maximum head of water they might sustain in a final or intermediate stage of flooding.

For cargo ships not covered by damage stability requirements, watertight hatches are to be tested by water pressure to a head of water measured from the lower edge of the opening to one metre above the freeboard deck.

10.2 Prototype test

10.2.1 *Where testing of individual hatches is not carried out because of possible damage to insulation or outfitting items, testing of individual hatches may be replaced by a prototype pressure test of each type and size of hatch with a test pressure corresponding at least to the head required for the individual location. The prototype test is to be carried out before the hatch is fitted. The installation method and procedure for fitting the hatch on board is to correspond to that of the prototype test. When fitted on board, each door is to be checked for proper seating between the deck, the coaming and the hatch.*

Section 10 Small Hatches

1 General

1.1 Definition

1.1.1 Small hatches are hatches designed for access to spaces below the deck and are capable to be closed weathertight or watertight, as applicable. Their opening is generally equal to or less than 2,5 m².

1.2 Application

1.2.1 The requirements in Article [2] apply to small hatch covers fitted on exposed decks.

1.2.2 The requirements in Article [3] apply to small hatch covers fitted on the exposed fore deck over the forward 0,25 L, for ships equal to or greater than 80 m in length, where the height of the exposed deck in way of the hatch is less than 0,1 L or 22 m above the summer load waterline, whichever is the lesser.

1.2.3 The requirements in Article [4] apply to small hatch covers fitted on non-exposed decks.

1.3 Materials

1.3.1 Steel

Materials used for the construction of steel small hatch covers are to comply with the applicable requirements of NR216 Materials and Welding, Chapter 3 or Chapter 5, as applicable.

1.3.2 Other materials

The use of materials other than steel is considered by the Society on a case-by-case basis, by checking that criteria adopted for scantlings are such as to ensure strength and stiffness equivalent to those of steel hatch covers.

2 Small hatches fitted on exposed decks

2.1 General

2.1.1 Hatch covers on exposed decks are to be weathertight.

2.1.2 The height of small hatch coamings is to be not less than 600 mm if located in position 1, and 450 mm if located in position 2. Where the closing appliances are secured weathertight by gaskets and swing bolts, the height of the coamings may be reduced or the coamings may be omitted altogether.

2.1.3 In any case the gross thickness of covers is to be not less than that of the adjacent plating, based on the same spacing and the same steel.

2.1.4 Securing arrangements and stiffening of hatch cover edges are to be such that weathertightness can be maintained in any sea condition.

At least one securing device is to be fitted at each side. Circular hole hinges are considered equivalent to securing devices.

2.1.5 Hatches of special design are considered by the Society on a case-by-case basis.

2.1.6 Hold access points located on the weather deck are to be provided with watertight metallic hatch covers, unless they are protected by a closed superstructure. The same applies to access points located on the forecastle deck and leading directly to a dry cargo hold through a trunk.

2.1.7 Access points to cofferdams and ballast tanks are to be manholes-fitted with watertight covers fixed with bolts sufficiently closely spaced.

2.2 Gaskets

2.2.1 The sealing is to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary weathertightness.

2.2.2 Coamings and steel parts of hatch covers in contact with gaskets are to have no sharp edges.

2.2.3 For non-bolted hatch covers, metal-to-metal contacts are to be provided in order to prevent over compression of the gasket. They are to be designed in order to withstand the bearing force induced by any relevant lateral load on the hatch cover.

3 Small hatches fitted on the exposed fore deck

3.1 Application

3.1.1 Small hatches designed for emergency escape need not comply with the requirements in [3.4.1], items a) and b), [3.4.3] and [3.5.1].

Securing devices of hatches designed for emergency escape are to be of a quick-acting type (e.g. one action wheel handles are provided as central locking devices for latching/unlatching of hatch cover) operable from both sides of the hatch cover.

3.2 Strength

3.2.1 The gross thickness of covers is to be not less than that of the adjacent plating based on the same spacing and the same steel.

3.2.2 For small rectangular steel hatch covers, the gross plate thickness, stiffener arrangement and scantlings are to be not less than those obtained, in mm, from Tab 1 and Fig 1.

Ordinary stiffeners, where fitted, are to be aligned with the metal-to-metal contact points, required in [3.3.1] (see also Fig 1).

Primary stiffeners are to be continuous.

All stiffeners are to be welded to the inner edge stiffener (see Fig 2).

3.2.3 The upper edge of the hatch coamings is to be suitably reinforced by an horizontal section, generally not more than 170 to 190 mm from the upper edge of the coamings.

3.2.4 For small hatch covers of circular or similar shape, the cover plate thickness and reinforcement are to comply with Ch 11, Sec 9, [5].

3.2.5 For small hatch covers constructed of materials other than steel, the required scantlings are to provide equivalent strength.

3.3 Weathertightness

3.3.1 The hatch cover is to be fitted with a gasket of elastic material. This is to be designed to allow a metal-to-metal contact at a designed compression and to prevent over compression of the gasket by green sea forces that may cause the securing devices to be loosened or dislodged. The metal-to-metal contacts are to be arranged close to each securing device in accordance with Fig 1 and of a sufficient capacity to withstand the bearing force.

3.4 Primary securing devices

3.4.1 Small hatches located on exposed fore deck are to be fitted with primary securing devices such that their hatch covers can be secured in place and made weathertight by means of a mechanism employing any one of the following methods:

- a) butterfly nuts tightening onto forks (clamps)
- b) quick acting cleats
- c) central locking device.

Dogs (twist tightening handles) with wedges are not acceptable.

3.4.2 The primary securing method is to be designed and manufactured such that the designed compression pressure is achieved by one person without the need of any tools.

3.4.3 For a primary securing method using butterfly nuts, the forks (clamps) are to be of robust design. They are to be designed to minimize the risk of butterfly nuts being dislodged while in use by means of curving the forks upwards, a raised surface on the free end, or a similar method. The plate thickness of unstiffened steel forks is to be not less than 16 mm. An example arrangement is shown in Fig 2.

Table 1 : Gross scantlings for small steel hatch covers on the fore deck

Nominal size (mm x mm)	Cover plate thickness (mm)	Primary stiffeners	Ordinary stiffeners
		Flat bar (mm x mm) ; number	
630 x 630	8	–	–
630 x 830	8	100 x 8 ; 1	–
830 x 630	8	100 x 8 ; 1	–
830 x 830	8	100 x 10 ; 1	–
1030 x 1030	8	120 x 12 ; 1	80 x 8 ; 2
1330 x 1330	8	150 x 12 ; 2	100 x 10 ; 2

3.4.4 For small hatch covers located on the exposed deck forward of the foremost cargo hatch, the hinges are to be fitted such that the predominant direction of green seas is to cause the cover to close, which means that the hinges are normally to be located on the fore edge.

3.4.5 On small hatches located between the main hatches, for example between Nos. 1 and 2, the hinges are to be placed on the fore edge or outboard edge, whichever is practicable for protection from green water in beam sea and bow quartering conditions.

Figure 1 : Arrangement of stiffeners

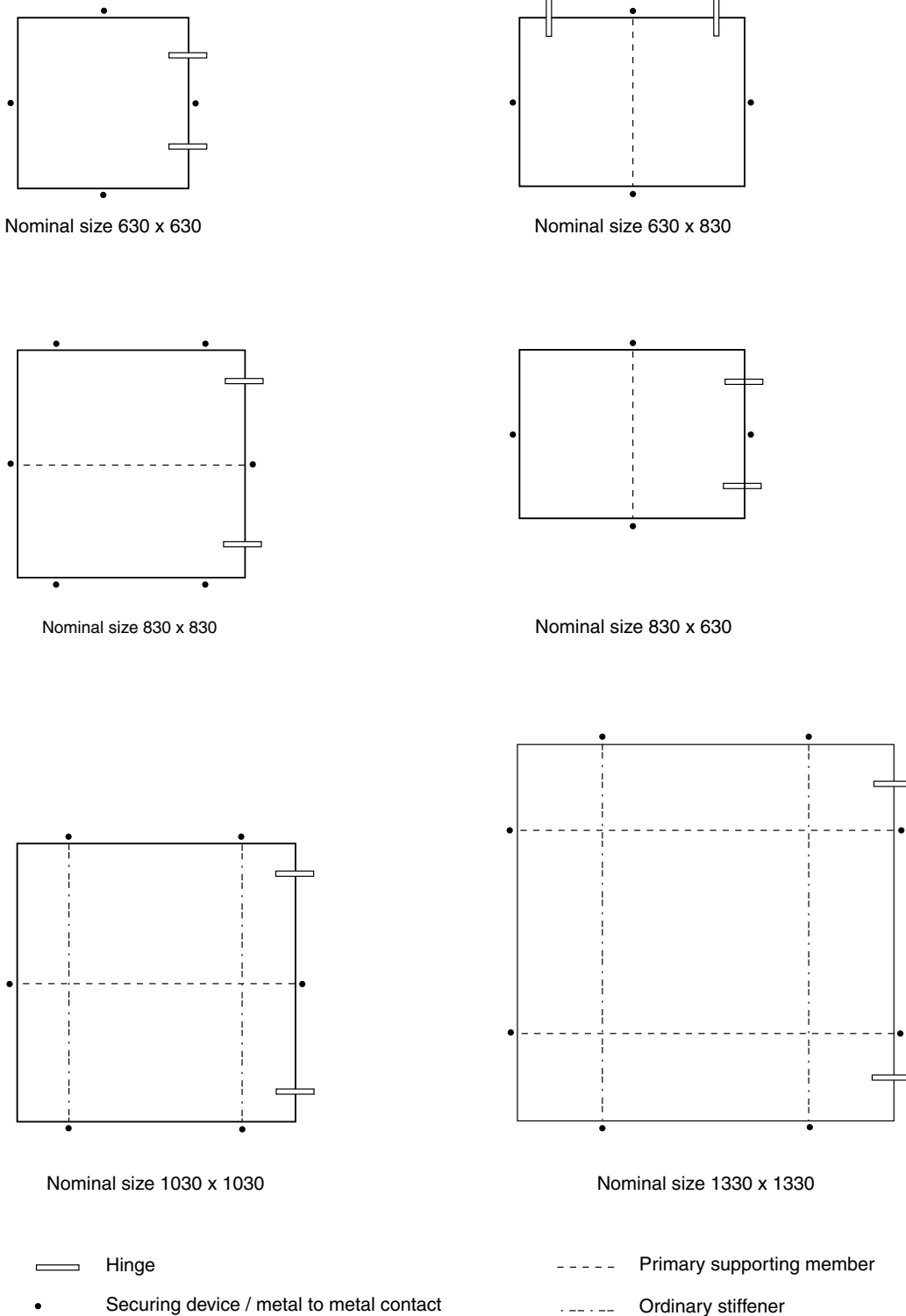
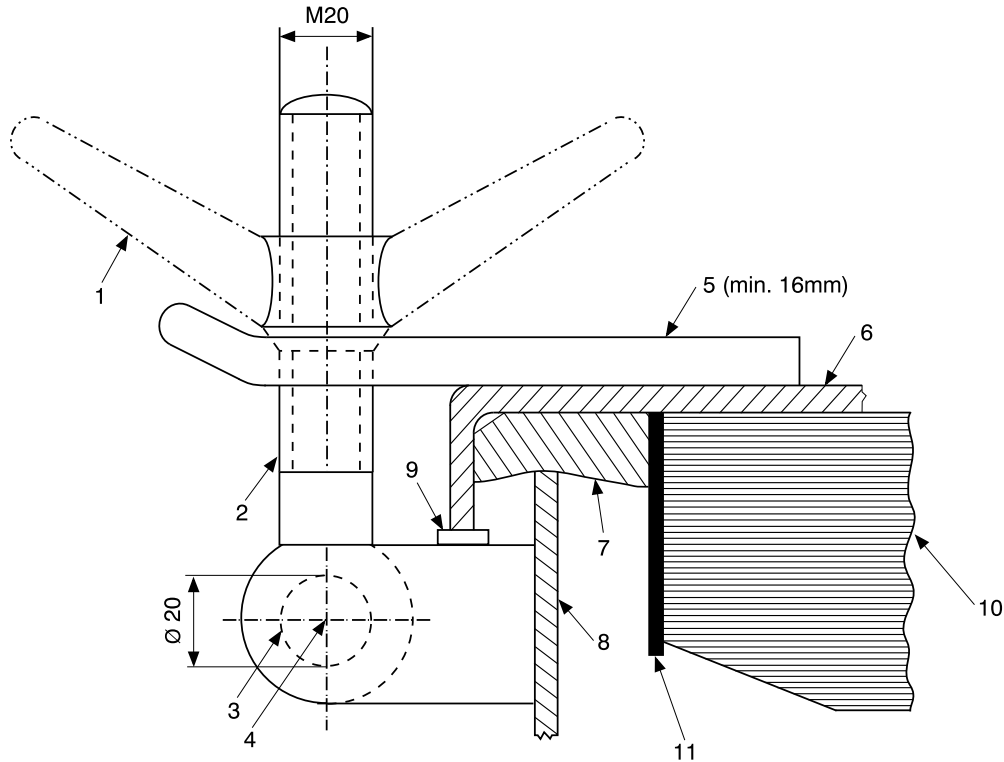


Figure 2 : Example of a primary securing method



- 1 : Butterfly nut
- 2 : Bolt
- 3 : Pin
- 4 : Centre of pin
- 5 : Fork (clamp) plate
- 6 : Hatch cover
- 7 : Gasket
- 8 : Hatch coaming
- 9 : Bearing pad welded on the bracket of a toggle bolt for metal to metal contact
- 10 : Stiffener
- 11 : Inner edge stiffener.

3.5 Secondary securing devices

3.5.1 Small hatches on the fore deck are to be fitted with an independent secondary securing device, e.g. by means of a sliding bolt, a hasp or a backing bar of slack fit, which is capable of keeping the hatch cover in place, even in the event that the primary securing device became loosened or dislodged. It is to be fitted on the side opposite to the hatch cover hinges.

4 Small hatch covers fitted on non-exposed decks

4.1 General

4.1.1 Hatch covers on non-exposed decks may not be weathertight.

4.1.2 Small hatch covers fitted on non-exposed decks are to have strength equivalent to that required for the adjacent deck (see Part B, Chapter 7).

4.1.3 Small hatch covers fitted on non-exposed decks are to have a level of tightness equivalent to that required for adjacent compartment(s).

4.1.4 If the hatch cover is weathertight or watertight and non-bolted, metal-to-metal contacts are to be provided in order to prevent over compression of the gasket. They are to be designed in order to withstand the bearing force induced by any relevant lateral load on the hatch cover.

5 Testing

5.1 Initial test of watertight hatches

5.1.1 Watertight hatches are to be tested by water pressure to the maximum head of water they might sustain in a final or intermediate stage of flooding.

For cargo ships not covered by damage stability requirements, watertight hatches are to be tested by water pressure to a head of water measured from the lower edge of the opening to one metre above the freeboard deck.

5.2 Prototype test

5.2.1 *Where testing of individual hatches is not carried out because of possible damage to insulation or outfitting items, testing of individual hatches may be replaced by a prototype pressure test of each type and size of hatch with a test pressure corresponding at least to the head required for the individual location. The prototype test is to be carried out before the hatch is fitted. The installation method and procedure for fitting the hatch on board is to correspond to that of the prototype test. When fitted on board, each door is to be checked for proper seating between the deck, the coaming and the hatch.*

Section 11 Movable Decks, Inner Ramps and External Ramps

1 Movable decks and inner ramps

1.1 Application

1.1.1 The requirements of this Section apply to movable decks and inner ramps when the additional class notation **ALP** is not granted and when no cargo gear register is issued.

1.1.2 On special request of the owner the movable inner ramps under load may be examined by the Society in the scope of application of additional class notation **ALP** (see Pt A, Ch 1, Sec 2, [6.12.1]).

1.2 Materials

1.2.1 The decks and inner ramps are to be made of steel or aluminium alloys complying with the requirements of NR216 Materials. Other materials of equivalent strength may be used, subject to a case by case examination by the Society.

1.3 Plating

1.3.1 The net thickness of plate panels subjected to wheeled loads is to be not less than the value obtained from Ch 7, Sec 4, [3.3], where nP_0 is not to be taken less than 5 kN.

1.4 Ordinary stiffeners

1.4.1 The net section modulus and the net shear sectional area of ordinary stiffeners subjected to wheeled loads is to be not less than the value obtained from Ch 7, Sec 5, [1.2].

1.5 Primary supporting members

1.5.1 General

The supporting structure of movable decks and inner ramps is to be verified through direct calculation, considering the following cases:

- movable deck stowed in upper position, empty and locked, at sea
- movable deck in service, loaded, in lower position, resting on supports or supporting legs and locked, at sea
- movable inner ramp in sloped position, supported by hinges at one end and by a deck at the other, with possible intermediate supports, loaded, at harbour
- movable inner ramp in horizontal position, loaded and locked, at sea.

1.5.2 Loading cases

The scantlings of the supporting structure are to be verified for the design load sets DL-1 and DL-2, considering the following cases:

- loaded movable deck or inner ramp under loads according to the load distribution indicated by the Designer
- loaded movable deck or inner ramp under uniformly distributed loads corresponding to a pressure, in kN/m^2 , equal to $P_1 + P_2$
- empty movable deck under uniformly distributed masses corresponding to a pressure, in kN/m^2 , equal to P_1

where:

$$P_1 = \frac{P_p}{A_p}$$

$$P_2 = n_v \frac{P_v}{A_p}$$

P_p : Mass of the movable deck, in kN

P_v : Mass of a vehicle, in kN

n_v : Maximum number of vehicles loaded on the movable deck

A_p : Effective area of the movable deck, in m^2 .

1.5.3 Lateral pressure

The total pressure P , in kN/m^2 , for both the static and the static + dynamic design load scenarios is to be derived for each dynamic load case and is to be taken as: $P = P_s + P_w$

where:

P_s, P_d : Still water and inertial pressures transmitted to the movable deck or inner ramp structures, obtained, in kN/m^2 , from Tab 1.

1.5.4 Checking criteria

Combined stress σ_{VM} is to be checked in accordance with the criteria defined in Ch 7, Sec 6, [5.1.4].

1.5.5 Allowable deflection

The scantlings of main stiffeners and the distribution of supports are to be such that the deflection of the loaded movable deck or loaded inner ramp does not exceed 5 mm/m.

1.6 Supports, suspensions and locking devices

1.6.1 Scantlings of wire suspensions are to be determined by direct calculation on the basis of the loads in [1.5.2] and [1.5.3], taking account of a safety factor at least equal to 5.

1.6.2 Combined stress σ_{VM} in rigid supports and locking devices is to be checked in accordance with the criteria defined in Ch 7, Sec 6, [5.1.4].

1.7 Tests and trials

1.7.1 Tests and trials defined in [1.7.2] to [1.7.4] are to be carried out in the presence of the Surveyor. Upon special request, these conditions of tests and trials may be modified to comply with any relevant national regulations in use.

1.7.2 The wire ropes are to be submitted to a tensile test on test-piece.

1.7.3 The loose gears used for the platform and ramp handling (chain, shackles, removable blocks, etc.) are to be indicated with a safe working load (SWL) compatible with the loads to be supported. The loose gears are to be individually tested before lifting onboard.

The test of these loose gears are to be in accordance with the applicable requirements of Rule Note NR 526, Rules for the classification of lifting appliances onboard ships and offshore units.

1.7.4 A trial to verify the correct operation of lowering and lifting devices of the platform is to be carried out before going into service.

This trial is made without overload unless special requirement of National Authorities.

2 External ramps

2.1 General

2.1.1 The external ramps are to be examined for their watertightness, if applicable.

2.1.2 The locking of external ramps in stowage position at sea is examined by the Society on a case by case basis.

2.1.3 The ship's structure under the reactions due to the ramp is examined by the Society on a case by case basis.

2.2 Plating

2.2.1 The net thickness of plate panels subjected to wheeled loads is to be not less than the value obtained from Ch 7, Sec 4, [3.3], where nP_0 is not to be taken less than 5 kN, and considering only the design load set DL-2 (harbour condition).

2.3 Ordinary stiffeners

2.3.1 The net section modulus and the net shear sectional area of ordinary stiffeners subjected to wheeled loads is to be not less than the value obtained from Ch 7, Sec 5, [1.2] considering only the design load set DL-2 (harbour condition).

2.4 Primary supporting members

2.4.1 The scantlings of ordinary stiffeners and primary supporting members are to be determined under vehicle loads in harbour condition at rest, as defined in Tab 1.

Table 1 : Still water pressure P_s and inertial pressure P_w for primary supporting members of movable decks and ramps

Ship condition	Item	Design load set	Acceptance criteria	P_s and P_w , in kN/m ²
Seagoing conditions	<ul style="list-style-type: none"> Movable decks Inner ramps 	DL-1	AC-2	$P_s = P_1 + P_2$ $P_{w,x} = \frac{a_x}{g}(P_1 + P_2)$ for x direction $P_{w,y} = \frac{a_y}{g}(P_1 + P_2)$ for y direction $P_{w,z} = \frac{a_z}{g}(P_1 + \alpha P_2)$ for z direction
Harbour condition during lifting(1)	<ul style="list-style-type: none"> Movable decks Inner ramps 	DL-2	AC-1	$P_s = P_1$
Harbour condition at rest(1)	<ul style="list-style-type: none"> Movable decks Inner ramps External ramps 	DL-2	AC-1	$P_s = P_1 + P_2$

(1) For harbour conditions, a heel angle of 5° and a trim angle of 2° are taken into account. In case the designer is proposing a heel angle of less than 5° based on specific operational conditions, the used angle is to be clearly specified on the loading manual.

Note 1:

P_1, P_2 : Pressures, in kN/m², to be calculated according to [1.5.2] for the condition considered.

α : Coefficient taken equal to 0,5

a_x : Longitudinal acceleration, in m/s², at the load position being considered, for the considered load case, to be obtained according to Ch 5, Sec 3, [3]

a_y : Transverse acceleration, in m/s², at the load position being considered, for the considered load case, to be obtained according to Ch 5, Sec 3, [3]

a_z : Vertical acceleration, in m/s², at the load position being considered, for the considered load case, to be obtained according to Ch 5, Sec 3, [3]

Section 12 Arrangement of Hull and Superstructure Openings

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the arrangement of hull and superstructure openings excluding hatchways, for which the requirements in Ch 11, Sec 9 and Ch 11, Sec 10 apply.

1.2 Definitions

1.2.1 Standard height of superstructure

The standard height of superstructure is that defined in Ch 1, Sec 3, Tab 5.

1.2.2 Standard sheer

The standard sheer is that defined according to regulation 38 of the International Load Line Convention 1966, as amended.

1.2.3 Exposed zones

Exposed zones are the boundaries of superstructures or deckhouses set in from the ship's side at a distance equal to or less than 0,04 B.

1.2.4 Unexposed zones

Unexposed zones are the boundaries of deckhouses set in from the ship's side at a distance greater than 0,04 B.

2 External openings

2.1 General

2.1.1 *All external openings leading to compartments assumed intact in the damage analysis, which are below the final damage waterline, are required to be watertight.*

2.1.2 *External openings required to be watertight in accordance with [2.1.1] are to be of sufficient strength and, except for cargo hatch covers, are to be fitted with indicators on the bridge.*

2.1.3 *No openings, be they permanent openings, recessed promenades or temporary openings such as shell doors, windows or ports, are allowed on the side shell between the embarkation station of the marine evacuation system and the waterline in the lightest seagoing condition. Windows and sidescuttles of the non-opening type are allowed if complying with Pt C, Ch 4, Sec 5, [3.2.3], item c).*

2.1.4 *Openings in the shell plating below the deck limiting the vertical extent of damage shall be fitted with a device that prevents unauthorized opening if they are accessible during the voyage.*

2.1.5 *Other closing appliances which are kept permanently closed at sea to ensure the watertight integrity of external openings are to be provided with a notice affixed to each appliance to the effect that it is to be kept closed. Manholes fitted with closely bolted covers need not be so marked.*

3 Sidescuttles, windows and skylights

3.1 General

3.1.1 Application

The requirements in [3.1] to [3.4] apply to sidescuttles and rectangular windows providing light and air, located in positions which are exposed to the action of sea and/or bad weather.

3.1.2 Sidescuttle definition

Sidescuttles are round or oval openings with an area not exceeding 0,16 m². Round or oval openings having areas exceeding 0,16 m² are to be treated as windows.

3.1.3 Window definition

Windows are rectangular openings generally, having a radius at each corner relative to the window size in accordance with recognised national or international standards, and round or oval openings with an area exceeding 0,16 m².

3.1.4 Number of openings in the shell plating

The number of openings in the shell plating are to be reduced to the minimum compatible with the design and proper working of the ship.

3.1.5 Material and scantlings

Sidescuttles and windows together with their glasses, deadlights and storm covers, if fitted, are to be of approved design and substantial construction in accordance with, or equivalent to, recognised national or international standards.

Non-metallic frames are not acceptable. The use of ordinary cast iron is prohibited for sidescuttles below the freeboard deck.

3.1.6 Means of closing and opening

The arrangement and efficiency of the means for closing any opening in the shell plating are to be consistent with its intended purpose and the position in which it is fitted is to be generally to the satisfaction of the Society.

3.1.7 Opening of sidescuttles

All sidescuttles, the sills of which are below the bulkhead deck for passenger ships or the freeboard deck for cargo ships, are to be of such construction as to prevent effectively any person opening them without the consent of the Master of the ship.

3.2 Opening arrangement

3.2.1 General

Sidescuttles are not to be fitted in such a position that their sills are below a line drawn parallel to the freeboard deck at side and having its lowest point 0,025B or 0,5 m, whichever is the greater distance, above the summer load waterline (or timber summer load waterline if assigned).

3.2.2 Sidescuttles below (1,4 + 0,025 B) m above the water

Where in 'tweendecks the sills of any of the sidescuttles are below a line drawn parallel to the bulkhead deck at side of passenger ships and the freeboard deck at side of cargo ships, and having its lowest point 1,4+0,025B m above the water when the voyage commences, all the sidescuttles in that 'tweendecks are to be closed watertight and locked before the voyage commences, and they may not be opened before the ship arrives at the next port. In the application of this requirement, the appropriate allowance for fresh water may be made when applicable.

For any ship that has one or more sidescuttles so placed that the above requirements apply when it is floating at its deepest subdivision load line, the Society may indicate the limiting mean draught at which these sidescuttles are to have their sills above the line drawn parallel to the bulkhead deck at side of passenger ships and the freeboard deck at side of cargo ships, and having its lowest point 1,4+0,025B above the waterline corresponding to the limiting mean draught, and at which it is therefore permissible for the voyage to commence without them being closed and locked and to be opened during navigation on the responsibility of the master. In tropical zones as defined in the International Convention on Load Lines in force, this limiting draught may be increased by 0,3 m.

3.2.3 Cargo spaces

No sidescuttles may be fitted in any spaces which are appropriated exclusively for the carriage of cargo.

Sidescuttles may, however, be fitted in spaces appropriated alternatively for the carriage of cargo or passengers, but they are to be of such construction as to prevent effectively any person opening them or their deadlights without the consent of the Master.

3.2.4 Non-opening type sidescuttles

Sidescuttles are to be of the non-opening type in the following cases:

- where they become immersed by any intermediate stage of flooding or the final equilibrium waterplane in any required damage case for ships subject to damage stability regulations
- where they are fitted outside the space considered flooded and are below the final waterline for those ships where the freeboard is reduced on account of subdivision characteristics.

3.2.5 Manholes and flush scuttles

Manholes and flush scuttles in positions 1 or 2, or within superstructures other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

3.2.6 Ships with several decks

In ships having several decks above the bulkhead deck, such as passenger ships, the arrangement of sidescuttles and rectangular windows is considered by the Society on a case by case basis.

Particular consideration is to be given to the ship side up to the upper deck and the front bulkhead of the superstructure.

3.2.7 Automatic ventilating scuttles

Automatic ventilating sidescuttles are not to be fitted in the shell plating below the bulkhead deck of passenger ships and the freeboard deck of cargo ships without the special agreement of the Society.

3.2.8 Window arrangement

Windows may not be fitted below the freeboard deck, in first tier end bulkheads or sides of enclosed superstructures and in first tier deckhouses considered as being buoyant in the stability calculations or protecting openings leading below.

3.2.9 Skylights

Fixed or opening skylights are to have glass thickness appropriate to their size and position as required for sidescuttles and windows. Skylight glasses in any position are to be protected from mechanical damage and, where fitted in positions 1 or 2, to be provided with permanently attached robust deadlights or storm covers.

3.2.10 Gangway, cargo and coaling ports

Gangway, cargo and fuelling ports fitted below the bulkhead deck of passenger ships and the freeboard deck of cargo ships are to be watertight and in no case they are to be so fitted as to have their lowest point below the summer load line.

3.3 Glasses

3.3.1 General

In general, toughened glasses with frames of special type are to be used in compliance with, or equivalent to, recognised national or international standards.

Direct metal to glass contact is to be avoided.

The use of clear plate glasses is considered by the Society on a case by case basis.

3.3.2 Design loads

Design loads are to be determined in accordance with the applicable requirements of Ch 5, Sec 5, [5].

In damaged ship conditions, where windows or sidescuttles are located below the deepest equilibrium waterline, the design pressure p , in kN/m^2 , is to be taken equal to:

$$p = p_s$$

where:

p_s : Still water pressure, taken equal to: $p_s = r g d_f$

d_f : Distance, in m, from the calculation point to the deepest equilibrium waterline.

The deepest equilibrium waterlines are to be provided by the Designer under his own responsibility.

3.3.3 Scantling

The windows and sidescuttles assessment methodology defined in this Article is equivalent to Standard ISO 11336-1:2012.

The scantling of windows and sidescuttle defined in this sub-article are provided for the following types of window or sidescuttle:

- monolithic window or sidescuttle (see [3.3.4])
- laminated window or sidescuttle (see [3.3.5])
- double windows unit with gap (see [3.3.6]).

All the window and sidescuttle edges are considered as simply supported.

3.3.4 Thickness of monolithic window

The thicknesses, in mm, of monolithic windows and sidescuttles are to be obtained from the following formula:

- rectangular window or sidescuttle:

$$t = 31,6s \sqrt{\frac{\beta p S_f}{R_m}}$$

- circular window or sidescuttle:

$$t = 17,4d \sqrt{\frac{\beta p S_f}{R_m}}$$

where:

s : Shorter side, in m, of rectangular window or sidescuttle

Where the window is supported only on 2 edges, s is to be taken as the unsupported side

ℓ : Longer side, in m, of rectangular window or sidescuttle

d : Diameter, in m, of circular window or sidescuttle

- R_m : Guaranteed minimum flexural strength, in N/mm², of material used. For guidance only, the guaranteed minimum flexural strength R_m for glass window is:
- for thermally or chemically toughened glass: $R_m = 120$ N/mm²
 - for polymethylmethacrylate (PMMA) glass: $R_m = 100$ N/mm²
 - for polycarbonate (PC) glass: $R_m = 90$ N/mm²
- S_f : Safety factor taken equal to:
- 3,0 for thermally or chemically toughened glass:
 - 3,5 for polymethylmethacrylate (PMMA) or polycarbonate (PC) glass:
- β : Aspect ratio coefficient of the rectangular window or sidescuttle, obtained in Tab 2
Where the window is supported only by 2 edges, β is to be taken equal to 1,0.

The thickness of windows or sidescuttles having other shapes may be obtained by considering rectangles or circles of equivalent dimensions s_{eq} , l_{eq} or d_{eq} as defined in Tab 1.

Table 1 : Equivalent dimensions for windows having other shapes

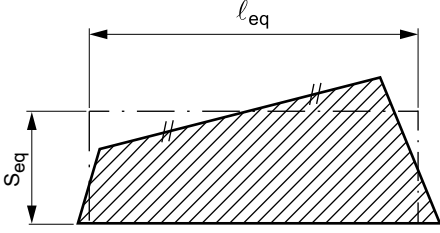
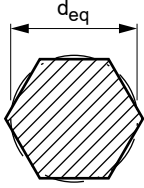
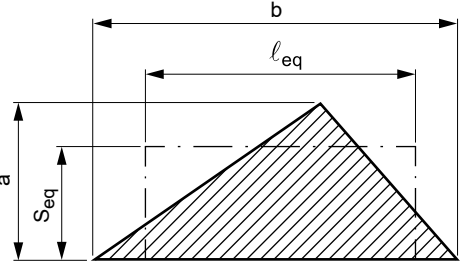
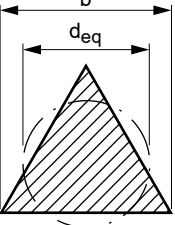
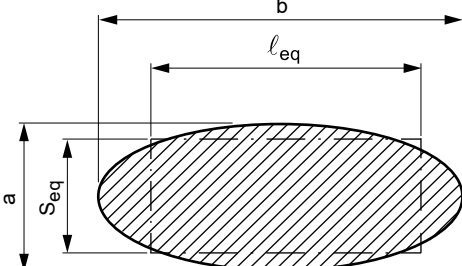
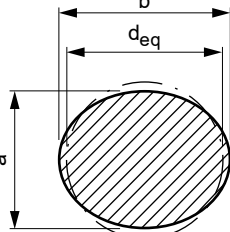
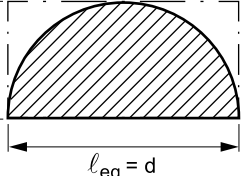
<p>a) Quadrangle</p>  <p>The equivalent rectangle has the same area</p>	<p>b) Polygon</p>  <p>The equivalent circle has the same area</p>	<p>c) Triangle</p>  <p>$s_{eq} = 2a/3$ $l_{eq} = 3b/4$</p>	
<p>d) Equilateral triangle</p>  <p>$d_{eq} = 3b/4$</p>	<p>e) Flat ellipse</p>  <p>$s_{eq} = 0,87a$ $l_{eq} = 0,87b$</p>	<p>f) Round ellipse</p>  <p>$d_{eq} = \sqrt{ab}$</p>	<p>g) Semi circle</p>  <p>$s_{eq} = d/2$ $l_{eq} = d$</p>

Table 2 : Coefficient β

l/s	β
1,0	0,284
1,5	0,475
2,0	0,608
2,5	0,684
3,0	0,716
3,5	0,734
$\geq 4,0$	0,750

3.3.5 Laminated window

Laminated windows are windows realized by placing an interlayer of resin (polyvinyl butyral as a general rule) between plies of same or different materials.

For laminated windows made with plies of the same material:

- When the mechanical properties of the interlayer material (the laminating adhesive material) are not known, the plies of the laminated window are considered as mechanically independent, and the equivalent thickness is to be calculated as defined in [3.3.6].
- When the mechanical properties of the interlayer material are known in terms of shear modulus, G , in N/mm^2 , the plies of the laminated window are considered as mechanically collaborating, and the equivalent thickness is to be calculated as defined in [3.3.7].

When the laminated window is made with plies of different materials, they are considered as mechanically independent, and the equivalent thickness is to be calculated as defined in [3.3.8].

3.3.6 Thickness of laminated window with independent plies

The equivalent thickness t_{eq} , in mm, of laminates made of n independent plies of thicknesses $t_{p,1}, t_{p,2}, \dots, t_{p,n}$ is to comply with the following formula:

$$t_{eq} \geq t$$

where:

$$t_{eq} = \min[t_{eq,j}]$$

$$t_{eq,j} = \sqrt[n]{\frac{\sum_{j=1}^n t_{p,j}^3}{t_{p,j}}}$$

j : Ply index, ranging from 1 to n

t : Thickness, in mm, of a monolithic window, calculated according to [3.3.4].

3.3.7 Thickness of laminated window with collaborating plies

The equivalent thickness t_{eq} , in mm, of laminates made of two collaborating plies of the same material, and of thicknesses t_1 and t_2 separated by an interlayer of thickness t_i is to comply with the following formula:

$$t_{eq} \geq t$$

where:

$$t_{eq} = \min[t_{1eq,s}, t_{2eq,s}]$$

$t_{1eq,s}, t_{2eq,s}$: Equivalent thickness for strength as obtained from the following formulae:

$$t_{1eq,s} = \sqrt{\frac{t_{eq,d}^3}{t_1 + 2\Gamma t_{s2}}}$$

$$t_{2eq,s} = \sqrt{\frac{t_{eq,d}^3}{t_2 + 2\Gamma t_{s1}}}$$

$t_{eq,d}$: Equivalent thickness for deflection as obtained from the following formula:

$$t_{1eq,d} = \sqrt[3]{t_1^3 + t_2^3 + 12\Gamma I_s}$$

Γ : Shear transfer coefficient as obtained from the following formula, without being taken less than 0 (independent plies behaviour) and more than 1,0 (monolithic behaviour):

$$\Gamma = \frac{1}{1 + 9,6 \frac{E \cdot I_s \cdot t_i}{G \cdot h \cdot s^2 \cdot 10^6}}$$

$$t_{s1} = \frac{hs \cdot t_1}{t_1 + t_2}$$

$$t_{s2} = \frac{hs \cdot t_2}{t_1 + t_2}$$

$$I_s = t_1 t_{s2}^2 + t_2 t_{s1}^2$$

$$hs = 0,5(t_1 + t_2) + t_i$$

G : Shear modulus of the interlayer at 25 °C, in N/mm^2 , generally taken equal to 1,6 N/mm^2 for polyvinyl butyral (PVB). For other interlayer materials the shear modulus value at 25 °C for short time duration load (60 s) shall be declared by the interlayer material manufacturer

E : Young's modulus of the plies, in N/mm^2

s : Shorter side, in m, of rectangular window or sidescuttle.

In case of multiple (more than two plies) laminates the calculation is to be iterated. The iteration is to start from the outer ply (the one directly loaded by water pressure) and end with the inner ply.

3.3.8 Thickness of laminated window with plies of different materials

The equivalent thickness t_{eq} , in mm, of laminates made of n plies of different materials, of thicknesses $t_{p,1}, t_{p,2}, \dots, t_{p,n}$ and of Young's modulus $E_{p,1}, E_{p,2}, \dots, E_{p,n}$ is to comply with the following formula:

$$t_{eq} \geq t$$

where:

$$t_{eq} = \min[t_{eq,j}]$$

$$t_{eq,j} = \sqrt[n]{\frac{\sum_{j=1}^n E_{p,j} t_{p,j}^3}{E_{p,j} t_{p,j}}}$$

j : Ply index, ranging from 1 to n

t : Thickness, in mm, of a monolithic window, calculated according to [3.3.4] for the same material than the ply giving the minimum value of $t_{eq,j}$.

3.3.9 Thickness of double windows

Double windows are glass windows made of two plies of glass separated by an hermetically sealed spacebar.

The thickness of the ply exposed to the loads defined in [3.3.2] is to be calculated as per monolithic windows according to [3.3.4].

3.3.10 Thickness of glasses forming screen bulkheads or internal boundaries of deckhouses

The thickness of glasses forming screen bulkheads on the side of enclosed promenade spaces and that for rectangular windows in the internal boundaries of deckhouses which are protected by such screen bulkheads are considered by the Society on a case by case basis.

The Society may require both limitations on the size of rectangular windows and the use of glasses of increased thickness in way of front bulkheads which are particularly exposed to heavy sea.

3.4 Deadlight arrangement

3.4.1 General

Sidescuttles to the following spaces are to be fitted with efficient, hinged inside deadlights:

- spaces below the freeboard deck
- spaces within the first tier of enclosed superstructures
- first tier deckhouses on the freeboard deck protecting openings leading below or considered buoyant in stability calculations.

Deadlights are to be capable of being closed and secured watertight if fitted below the freeboard deck and weathertight if fitted above.

3.4.2 Watertight deadlights

Efficient hinged inside deadlights, so arranged that they can be easily and effectively closed and secured watertight, are to be fitted to all sidescuttles except that, abaft one eighth of the ship's length from the forward perpendicular and above a line drawn parallel to the bulkhead deck at side and having its lowest point at a height of $(3,7+0,025B)$ m above the deepest subdivision summer load line, the deadlights may be portable in passenger accommodation other than that for steerage passengers, unless the deadlights are required by the International Convention on Load Lines in force to be permanently attached in their proper positions. Such portable deadlights are to be stowed adjacent to the sidescuttles they serve.

3.4.3 Openings at the side shell in the second tier

Sidescuttles and windows at the side shell in the second tier, protecting direct access below or considered buoyant in the stability calculations, are to be provided with efficient, hinged inside deadlights capable of being effectively closed and secured weathertight.

3.4.4 Openings set inboard in the second tier

Sidescuttles and windows set inboard from the side shell in the second tier, protecting direct access below to spaces listed in [3.4.1], are to be provided with either efficient, hinged inside deadlights or, where they are accessible, permanently attached external storm covers of approved design and substantial construction capable of being effectively closed and secured weathertight.

Cabin bulkheads and doors in the second tier separating sidescuttles and windows from a direct access leading below may be accepted in place of fitted deadlights or storm covers.

Note 1: Deadlights in accordance with recognised standards are fitted to the inside of windows and sidescuttles, while storm covers of comparable specifications to deadlights are fitted to the outside of windows, where accessible, and may be hinged or portable.

3.4.5 Deckhouses on superstructures of less than standard height

Deckhouses situated on a raised quarterdeck or on a superstructure of less than standard height may be treated as being on the second tier as far as the provision of deadlights is concerned, provided the height of the raised quarterdeck or superstructure is not less than the standard quarterdeck height.

3.4.6 Openings protected by a deckhouse

Where an opening in a superstructure deck or in the top of a deckhouse on the freeboard deck which gives access to a space below the freeboard deck or to a space within an enclosed superstructure is protected by a deckhouse, then it is considered that only those sidescuttles fitted in spaces which give direct access to an open stairway need to be fitted with deadlights.

4 Discharges

4.1 Arrangement of discharges

4.1.1 Inlets and discharges

All inlets and discharges in the shell plating are to be fitted with efficient and accessible arrangements for preventing the accidental admission of water into the ship.

4.1.2 Inboard opening of ash-chute, rubbish-chute

The inboard opening of each ash-chute, rubbish-chute, etc. is to be fitted with an efficient cover.

If the inboard opening is situated below the bulkhead deck for passenger ships or the freeboard deck for cargo ships, the cover is to be watertight, and in addition an automatic non-return valve is to be fitted in the chute in an easily accessible position above the deepest subdivision summer load line. When the chute is not in use, both the cover and the valve are to be kept closed and secured.

4.2 Arrangement of garbage chutes

4.2.1 Inboard end above the waterline

The inboard end is to be located above the waterline formed by an 8,5° heel, to port or starboard, at a draught corresponding to the assigned summer freeboard, but not less than 1000 mm above the summer load waterline.

Where the inboard end of the garbage chute exceeds 0,01L above the summer load waterline, valve control from the freeboard deck is not required, provided the inboard gate valve is always accessible under service conditions.

4.2.2 Inboard end below the waterline

Where the inboard end of a garbage chute is below the freeboard deck of a passenger ship, or the waterline corresponding to the deepest draught after damage in a cargo ship of more than 100 m in length, then:

- *the inboard end hinged cover/valve is to be watertight*
- *the valve is to be a screw-down non-return valve fitted in an easily accessible position above the deepest subdivision load line*
- *the screw-down non-return valve is to be controlled from a position above the bulkhead deck and provided with open/shut indicators. The valve control is to be clearly marked: "Keep closed when not in use".*

4.2.3 Gate valves

For garbage chutes, two gate valves controlled from the working deck of the chute may be accepted instead of a non-return valve with a positive means of closing it from a position above the freeboard deck. In addition, the lower gate valve is to be controlled from a position above the freeboard deck. An interlock system between the two valves is to be arranged.

The distance between the two gate valves is to be adequate to allow the smooth operation of the interlock system.

4.2.4 Hinged cover and discharge flap

The upper gate valve, as required in [4.2.3], may be replaced by a hinged weathertight cover at the inboard end of the chute together with a discharge flap which replaces the lower gate valve.

The cover and discharge flap are to be arranged with an interlock so that the flap cannot be operated until the hopper cover is closed.

4.2.5 Marking of valve and hinged cover

The gate valve controls and/or hinged cover are to be clearly marked: "Keep closed when not in use".

4.3 Scantlings of garbage chutes

4.3.1 Material

The chute is to be constructed of steel. Other equivalent materials are considered by the Society on a case by case basis.

4.3.2 Wall thickness

The wall thickness of the chute up to and including the cover is to be not less than that obtained, in mm, from Tab 3.

Table 3 : Wall thickness of garbage chutes

External diameter d, in mm	Thickness, in mm
$d \leq 80$	7,0
$80 < d < 180$	$7,0 + 0,03 (d - 80)$
$180 \leq d \leq 220$	$10,0 + 0,063 (d - 180)$
$d > 220$	12,5

5 Transducers

5.1 General

5.1.1 Transducers are not to be fitted inside compartments intended for fuel and hydrocarbons. They may only be fitted in adjacent cofferdams.

If transducers are fitted in hazardous areas, they are to be fitted inside a watertight box. In this case, transducers are to be sealed and the connecting cables are to be specially protected.

5.2 Protection of transducers in ballast and main compartment

5.2.1 Transducers may be fitted in compartments intended for ballast (double bottoms, deep tank, peak). In such a case, the instrument and its power cable are to be mechanically protected and the watertightness of the protecting device is to be such that the material and its cable may be considered as protected against external agents.

5.2.2 Where transducers are not fitted inside a small box or a little separate compartment within a double bottom but directly within a main compartment, it is necessary to provide for inspection of materials of every part which ensures structural and watertight integrity and to test them at works after completion. Besides, the complete set is to be tested under a hydraulic pressure at least equal to 1,5 times the service pressure, the latter being considered as equal to the depth of the ship.

If a transducer is fitted inside a single bottom ship, the tank of the transducer itself is to be considered as ensuring the structural integrity. Special attention is to be paid to welding and testing of the transducer bell.

5.3 Fitting of hull boss and transducer receiver

5.3.1 The hull boss is to be made of steel with the same grade and yield stress as the bottom plates to which it is fitted. Full penetration welding is to be performed with suitable electrodes.

When the transducer receiver, owing to the fitting arrangement, slightly projects beyond the external surface of the shell plates, the precise position of the installation is to be supplied to the Owner to enable him to take the necessary precautions in case of docking.

5.4 Fitting of transducer in heavily stressed areas

5.4.1 Where the transducer is fitted in the midship region or in heavily stressed areas, the openings are to be either elliptical (ratio 2/1, the major axis being parallel to the longitudinal axis of the ship) or truncated ellipse shaped at least for large ships. Moreover, a possible compensation is to be provided on the location of the cut.

6 Freeing ports

6.1 General provisions

6.1.1 General

Where bulwarks on the weather portions of freeboard or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of water and for draining them.

A well is any area on the deck exposed to the weather, where water may be entrapped. Wells are considered to be deck areas bounded on four sides by deck structures; however, depending on their configuration, deck areas bounded on three or even two sides by deck structures may be deemed wells.

6.1.2 Freeing port areas

The minimum required freeing port areas in bulwarks on the freeboard deck, on each side of the ship, are specified in Tab 4.

6.1.3 Freeing port arrangement

Where a sheer is provided, two thirds of the freeing port area required is to be provided in the half of the well nearer the lowest point of the sheer curve.

Where the exposed freeboard deck or an exposed superstructure deck has little or no sheer, the freeing port area is to be spread along the length of the well.

However, bulwarks may not have substantial openings or accesses near the breaks of superstructures, unless they are effectively detached from the superstructure sides.

Table 4 : Freeing port area in bulwark located on freeboard deck

Ship types or ship particulars	Area A of freeing ports, in m ²	Applicable requirement
Type A	$0,33 \ell_B h_B$	[6.5.2]
Type B-100	$0,33 \ell_B h_B$	[6.5.2]
Type B-60	$0,25 \ell_B h_B$	[6.5.1]
Ships fitted with a trunk included in freeboard calculation and/ or breadth $\geq 0,6 B$	$0,33 \ell_B h_B$	[6.3.1]
Ships fitted with a trunk not included in freeboard calculation and/ or continuous or substantially continuous hatch coamings	A_2	[6.3.1]
Ships fitted with non-continuous trunk and/ or hatch coamings	A_3	[6.3.2]
Ships fitted with open superstructure	A_S for superstructures	[6.4.2]
	A_W for wells	[6.4.3]
Other ships	A_1	[6.2.1]
Note 1:		
ℓ_B	: Length, in m, of bulwark in a well at one side of the ship	
h_B	: Mean height, in m, of bulwark in a well of length ℓ_B .	

6.1.4 Freeing port positioning

The lower edge of freeing ports is to be as near the deck as practicable.

All the openings in the bulwark are to be protected by rails or bars spaced approximately 230 mm apart.

6.1.5 Freeing port closures

If shutters or closures are fitted to freeing ports, ample clearance is to be provided to prevent jamming. Hinges are to have pins or bearings of non-corrodible material. If shutters are fitted with securing appliances, these appliances are to be of approved construction.

In ships operating in areas where icing is likely to occur, no shutters are to be fitted in the freeing ports.

6.1.6 Gutter bars

Gutter bars greater than 300 mm in height fitted around the weather decks of tankers, in way of cargo manifolds and cargo piping, are to be treated as bulwarks. The freeing port area is to be calculated in accordance with the applicable requirements of this Section.

6.2 Freeing port area in a well not adjacent to a trunk or hatchways

6.2.1 Freeing port area

Where the sheer in way of the well is standard or greater than the standard, the freeing port area on each side of the ship for each well is to be not less than that obtained, in m², in Tab 5.

In ships with no sheer, the above area is to be increased by 50%. Where the sheer is less than the standard, the percentage of increase is to be obtained by linear interpolation.

6.2.2 Minimum freeing port area for a deckhouse having breadth not less than 0,8 B

Where a flush deck ship is fitted amidships with a deckhouse having breadth not less than 0,8 B and the width of the passageways along the side of the ship less than 1,5 m, the freeing port area is to be calculated for two separate wells, before and abaft the deckhouse. For each of these wells, the freeing port area is to be obtained from Tab 5, where ℓ_B is to be taken equal to the actual length of the well considered.

6.2.3 Minimum freeing port area for screen bulkhead

Where a screen bulkhead is fitted across the full breadth of the ship at the fore end of a midship deckhouse, the weather deck is to be considered as divided into two wells, irrespective of the width of the deckhouse, and the freeing port area is to be obtained in accordance with [6.1.2].

6.3 Freeing port area in a well contiguous to a trunk or hatchways

6.3.1 Freeing port area for continuous trunk or continuous hatchway coaming

The freeing port area in the well contiguous to substantially continuous trunk/hatchway coaming is to be not less than:

- that obtained from Tab 6, where the trunk / hatchway coaming is not included in the freeboard calculation
- 33% of the bulwark area where the trunk / hatchway coaming meets the conditions of the International Convention on Load Lines in force and is included in the freeboard calculation.

6.3.2 Freeing area for non-continuous trunk or hatchway coaming

Where the free flow of water across the deck of the ship is impeded due to the presence of a non-continuous trunk, hatchway coaming or deckhouse in the whole length of the well considered, the freeing port area in the bulwark of this well is to be not less than that obtained, in m², from Tab 7.

Table 5 : Freeing port area in a well not adjacent to a trunk or hatchways

Location	Area A ₁ of freeing ports, in m ²	
	$\ell_B \leq 20$	$\ell_B > 20$
Freeboard deck and raised quarterdecks	$0,7 + 0,035 \ell_B + A_C$	$0,07 \ell_B + A_C$
Superstructure decks	$0,35 + 0,0175 \ell_B + 0,5 A_C$	$0,035 \ell_B + 0,5 A_C$

Note 1:
 ℓ_B : Length, in m, of bulwark in the well, to be taken not greater than 0,7 L_{LL}
 A_C : Area, in m², to be taken, with its sign, equal to:

$$A_C = \frac{\ell_B}{25}(h_B - 1,2) \text{ for } h_B > 1,2$$

$$A_C = 0 \text{ for } 0,9 \leq h_B \leq 1,2$$

$$A_C = \frac{\ell_B}{25}(h_B - 0,9) \text{ for } h_B < 0,9$$
 h_B : Mean height, in m, of the bulwark in a well of length ℓ_B .

Table 6 : Freeing port area in a well contiguous to a continuous trunk or hatchway

Breadth B _H , in m, of hatchway or trunk	Area A ₂ , in m ² , of freeing ports
$B_H \leq 0,4 B$	$0,2 \ell_B h_B \left(\frac{h_S}{2 h_W} \right)$
$0,4 B < B_H < 0,75 B$	$\left[0,2 - 0,286 \left(\frac{B_H}{B} - 0,4 \right) \right] \ell_B h_B \left(\frac{h_S}{2 h_W} \right)$
$B_H \geq 0,75 B$	$0,1 \ell_B h_B \left(\frac{h_S}{2 h_W} \right)$

Note 1:
 ℓ_B : Length, in m, of bulwark in a well at one side of the ship
 h_B : Mean height, in m, of bulwark in a well of length ℓ_B
 h_S : Standard superstructure height, in m, defined in [1.2.1]
 h_W : Distance, in m, of the well deck above the freeboard deck, to be taken not less than 0,5 h_S.

Table 7 : Freeing port area in a well contiguous to a non-continuous trunk or hatchway

Free flow area f _p , in m ²	Freeing port area A ₃ , in m ²
$f_p \leq A_1$	A ₂
$A_1 < f_p < A_2$	A ₁ + A ₂ - f _p
$f_p \geq A_2$	A ₁

Note 1:
 f_p : Free flow area on deck, equal to the net area of gaps between hatchways, and between hatchways and superstructures and deckhouses up to the actual height of the bulwark
 A_1 : Area of freeing ports, in m², to be obtained from Tab 5
 A_2 : Area of freeing ports, in m², to be obtained from Tab 6.

6.4 Freeing port area in an open space within superstructures

6.4.1 General

In ships having superstructures on the freeboard or superstructure decks, which are open at either or both ends to wells formed by bulwarks on the open decks, adequate provision for freeing the open spaces within the superstructures is to be provided.

6.4.2 Freeing port area for open superstructures

The freeing port area on each side of the ship for the open superstructure is to be not less than that obtained, in m², from the following formula:

$$A_s = A_1 c_{SH} \left[1 - \left(\frac{\ell_W}{\ell_T} \right)^2 \right] \left(\frac{b_0 h_s}{2 \ell_T h_W} \right)$$

where:

- ℓ_T : Total well length, in m, to be taken equal to: $\ell_T = \ell_W + \ell_s$
- ℓ_W : Length, in m, of the open deck enclosed by bulwarks
- ℓ_s : Length, in m, of the common space within the open superstructures
- A_1 : Freeing port area, in m², required for an open well of length ℓ_T , in accordance with Tab 5, where A_C is to be taken equal to zero
- c_{SH} : Coefficient which accounts for the absence of sheer, if applicable, to be taken equal to:
 - $c_{SH} = 1,0$ in the case of standard sheer or sheer greater than standard sheer
 - $c_{SH} = 1,5$ in the case of no sheer
- b_0 : Breadth, in m, of the openings in the end bulkhead of enclosed superstructures
- h_s, h_W : As defined in Tab 6.

6.4.3 Freeing port area for open well

The freeing port area on each side of the ship for the open well is to be not less than that obtained, in m², from the following formula:

$$A_W = A_1 c_{SH} \left(\frac{h_s}{2 h_W} \right)$$

- A_1 : Freeing port area, in m², required for an open well of length ℓ_W , in accordance with Tab 5
- ℓ_W : Defined in [6.4.2].

The resulting freeing port areas for the open superstructure A_s and for the open well A_W are to be provided along each side of the open space covered by the open superstructure and each side of the open well, respectively.

6.5 Freeing port area in bulwarks of the freeboard deck for ships of types A, B-100 and B-60

6.5.1 Freeing arrangement for type B-60

For type B-60 ships, the freeing port area in the lower part of the bulwarks of the freeboard deck is to be not less than 25% of the total area of the bulwarks in the well considered.

The upper edge of the sheer strake is to be kept as low as possible.

6.5.2 Freeing arrangement for type A and type B-100 ships with trunks

For type A and type B-100 ships, open rails are to be fitted on the weather parts of the freeboard deck in way of the trunk for at least half the length of these exposed parts.

Alternatively, if a continuous bulwark is fitted, the freeing port area in the lower part of the bulwarks of the freeboard deck is to be not less than 33% of the total area of the bulwarks in the well considered.

7 Machinery space openings

7.1 Engine room skylights

7.1.1 Engine room skylights in positions 1 or 2 are to be properly framed, securely attached to the deck and efficiently enclosed by steel casings of suitable strength. Where the casings are not protected by other structures, their strength will be considered by the Society on a case by case basis.

7.1.2 Skylights, where fitted with openings for light and air, are to have coamings of a height not less than:

- 900 mm, if in position 1
- 760 mm, if in position 2.

7.2 Closing devices

7.2.1 Machinery casings

Openings in machinery space casings in positions 1 or 2 are to be fitted with doors of steel or other equivalent materials, permanently and strongly attached to the bulkhead, and framed, stiffened and fitted so that the whole structure is of equivalent strength to the unpierced bulkhead and weathertight when closed. The doors are to be capable of being operated from both sides and generally to open outwards to give additional protection against wave impact.

Other openings in such casings are to be fitted with equivalent covers, permanently attached in their proper position.

7.2.2 Machinery casings on Type A ships

Machinery casings on Type A ships are to be protected by an enclosed poop or bridge of at least standard height, or by a deckhouse of equal height and equivalent strength.

Machinery casings may, however, be exposed if there are no openings giving direct access from the freeboard deck to the machinery spaces.

However, a weathertight door is permitted in the machinery casing, provided that it leads to a space or passageway which is as strongly constructed as the casing and is separated from the stairway to the engine room by a second weathertight door of steel or other equivalent material.

7.2.3 Height of the sill of the door

The height of the sill of the door is to be not less than:

- 600 mm above the deck if in position 1
- 380 mm above the deck if in position 2
- 230 mm in all other cases.

7.2.4 Double doors

Where casings are not protected by other structures, double doors (i.e. inner and outer doors) are required for ships assigned freeboard less than that based on Table B of regulation 28 of the International Load Line Convention 1966, as amended. An inner sill of 230 mm in conjunction with the outer sill of 600 mm is to be provided.

7.2.5 Fiddly openings

Fiddly openings are to be fitted with strong covers of steel or other equivalent material permanently attached in their proper positions and capable of being secured weathertight.

7.3 Coamings

7.3.1 Coamings of any fiddly, funnel or machinery space ventilator in an exposed position on the freeboard deck or superstructure deck are to be as high above the deck as is reasonable and practicable.

In general, ventilators necessary to continuously supply the machinery space and, on demand, the emergency generator room are to have coamings whose height is in compliance with [9.1.2], but need not be fitted with weathertight closing appliances.

Where, due to the ship's size and arrangement, this is not practicable, lesser heights for machinery space and emergency generator room ventilator coamings, fitted with weathertight closing appliances in accordance with [9.1.2], may be permitted by the Society in combination with other suitable arrangements to ensure an uninterrupted, adequate supply of ventilation to these spaces.

8 Companionway

8.1 General

8.1.1 Openings in freeboard deck

Openings in freeboard deck other than hatchways, machinery space openings, manholes and flush scuttles are to be protected by an enclosed superstructure or by a deckhouse or companionway of equivalent strength and weathertightness.

8.1.2 Openings in superstructures

Openings in an exposed superstructure deck or in the top of a deckhouse on the freeboard deck which give access to a space below the freeboard deck or a space within an enclosed superstructure are to be protected by an efficient deckhouse or companionway.

8.1.3 Openings in superstructures having height less than standard height

Openings in the top of a deckhouse on a raised quarterdeck or superstructure of less than standard height, having a height equal to or greater than the standard quarterdeck height are to be provided with an acceptable means of closing but need not be protected by an efficient deckhouse or companionway provided the height of the deckhouse is at least the standard height of a superstructure.

8.2 Scantlings

8.2.1 Companionways on exposed decks protecting openings leading into enclosed spaces are to be of steel and strongly attached to the deck and are to have adequate scantlings.

8.3 Closing devices

8.3.1 Doors

Doorways in deckhouses or companionways leading to or giving access to spaces below the freeboard deck or to enclosed superstructures are to be fitted with weathertight doors. The doors are to be made of steel, to be capable of being operated from both sides and generally to open outwards to give additional protection against wave impact.

Alternatively, if stairways within a deckhouse are enclosed within properly constructed companionways fitted with weathertight doors, the external door need not be watertight.

Where the closing appliances of access openings in superstructures and deckhouses are not weathertight, interior deck openings are to be considered exposed, i.e. situated in the open deck.

8.3.2 Height of sills

The height above the deck of sills to the doorways in companionways is to be not less than:

- 600 mm in position 1
- 380 mm in position 2.

Where access is not provided from above, the height of the sills to doorways in a poop bridge or deckhouse on the freeboard deck is to be 600 mm.

Where access is provided to spaces inside a bridge or poop from the deck above as an alternative to access from the freeboard deck, the height of the sills into the bridge or poop is to be at least 380 mm. This also applies to deckhouses on the freeboard deck.

9 Ventilators

9.1 Closing appliances

9.1.1 General

Ventilator openings are to be provided with efficient weathertight closing appliances of steel or other equivalent material, designed to offer equivalent strength compared to the adjacent bulkhead or coaming in which they are fitted.

9.1.2 Closing appliance exemption

Ventilators need not be fitted with closing appliances, unless specifically required by the Society, if the coamings extend for more than:

- 4,5 m above the deck in position 1
- 2,3 m above the deck in position 2.

9.1.3 Closing appliances for ships of not more than 100 m in length

In ships of not more than 100 m in length, the closing appliances are to be permanently attached to the ventilator coamings.

9.1.4 Closing appliances for ships of more than 100 m in length

Where, in ships of more than 100 m in length, the closing appliances are not permanently attached, they are to be conveniently stowed near the ventilators to which they are to be fitted.

9.1.5 Ventilation of machinery spaces and emergency generator room

In order to satisfactorily ensure, in all weather conditions:

- the continuous ventilation of machinery spaces,
- and, when necessary, the immediate ventilation of the emergency generator room,

the ventilators serving such spaces are to comply with [9.1.2], i.e. their openings are to be so located that they do not require closing appliances.

Note 1: See also Pt C, Ch 4, Sec 2, [2.1] regarding closing appliances for ventilation systems.

9.1.6 Reduced height of ventilator coamings for machinery spaces and emergency generator room

Where, due to the ship's size and arrangement, the requirements in [9.1.5] are not practicable, lesser heights may be accepted for machinery space and emergency generator room ventilator coamings fitted with weathertight closing appliances in accordance with [9.1.1], [9.1.3] and [9.1.4] in combination with other suitable arrangements, such as separators fitted with drains, to ensure an uninterrupted, adequate supply of ventilation to these spaces.

9.1.7 Closing arrangements of ventilators led overboard or through enclosed superstructures

Closing arrangements of ventilators led overboard to the ship side or through enclosed superstructures are considered by the Society on a case by case basis. If such ventilators are led overboard more than 4,5 m above the freeboard deck, closing appliances may be omitted provided that satisfactory baffles and drainage arrangements are fitted.

9.2 Coamings

9.2.1 General

Ventilators in positions 1 or 2 to spaces below freeboard decks or decks of enclosed superstructures are to have coamings of steel or other equivalent material, substantially constructed and efficiently connected to the deck.

Ventilators passing through superstructures other than enclosed superstructures are to have substantially constructed coamings of steel or other equivalent material at the freeboard deck.

9.2.2 Scantlings

The scantlings of ventilator coamings exposed to the weather are to be not less than those obtained from Tab 8.

In exposed locations or for the purpose of compliance with buoyancy calculations, the height of coamings may be required to be increased to the satisfaction of the Society.

Table 8 : Scantlings of ventilator coamings

Feature	Scantlings
Height of the coaming, in mm, above the deck	h = 900 in position 1 h = 760 in position 2
Thickness of the coaming, in mm (1)	$t = 5,5 + 0,01 d_v$ with $7,5 \leq t \leq 10,0$
Support	If $h > 900$ mm, the coaming is to be suitably stiffened or supported by stays
(1) Where the height of the ventilator exceeds the height h, the thickness of the coaming may be gradually reduced, above that height, to a minimum of 6,5 mm.	
Note 1: d_v : Internal diameter of the ventilator, in mm.	

10 Tank cleaning openings

10.1 General

10.1.1 Ullage plugs, sighting ports and tank cleaning openings may not be arranged in enclosed spaces.

Section 13 Helicopter Decks and Platforms

Symbols

W_H : Maximum weight of the helicopter, in t.

1 Application

1.1 General

1.1.1 The requirements of this Section apply to areas equipped for the landing and take-off of helicopters with landing gears or landing skids, and located on a deck or on a platform permanently connected to the hull structure.

1.1.2 Helicopter deck or platform intended for the landing of helicopters having landing devices other than wheels or skids are to be examined by the Society on a case-by-case basis.

2 Definition

2.1 Landing gear

2.1.1 A landing gear may consist of a single wheel or a group of wheels.

3 General arrangement

3.1 Landing area and approach sector

3.1.1 The main dimensions of the landing area, its location on board, the approach sector for landing and take-off are to comply with the applicable requirements from National or other Authorities.

3.1.2 The landing area and the approach sector are to be free of obstructions above the level of the helicopter deck or platform.

Note 1: The following items may exceed the height of the landing area, but not more than 100 mm:

- guttering or slightly raised kerb
- lightning equipment
- outboard edge of the safety net
- foam monitors
- those handrails and other items associated with the landing area which are incapable of complete retraction or lowering for helicopter operations.

3.2 Sheathing of the landing area

3.2.1 Within the landing area, a non-skid deck covering is recommended.

Where the helicopter deck or platform is wood sheathed, special attention is to be paid to the fire protection.

3.3 Safety net

3.3.1 It is recommended to provide a safety net at the sides of the helicopter deck or platform.

3.4 Drainage system

3.4.1 Gutterways of adequate height and a drainage system are recommended on the periphery of the helicopter deck or platform.

4 Design principle

4.1 General

4.1.1 Local deck strengthening is to be fitted at the connection of diagonals and pillars supporting platform.

5 Design loads

5.1 Emergency landing load

5.1.1 The emergency landing force F_{EL} transmitted through one landing gear or one extremity of skid to the helicopter deck or platform is to be obtained for the static + dynamic design load scenario (design load set DL-1), in kN, from the following formula:

$$F_{EL} = 1,25 g W_H$$

The point of application of the force F_{EL} is to be taken so as to produce the most severe stresses on the supporting structure.

5.2 Garage load

5.2.1 Where a garage zone is fitted in addition to the landing area, the static and dynamic forces F_{W-S} and F_{W-D} transmitted through each landing gear or each landing skid to the helicopter deck or platform are to be obtained for both the static and the static + dynamic design load scenarios (design load sets DL-1 and DL-2), in kN, as specified in Ch 5, Sec 6, [7], where M is to be taken equal to:

- for helicopter with landing gears:

M is the landing gear load, in t, to be specified by the Designer. If the landing gear load is not known, M is to be taken equal to:

$$M = \frac{1,25}{n} W_H$$

where n is the total number of landing gears

- for helicopter with landing skids: $M = 0,5 W_H$

5.2.2 When helicopters are parked in an unprotected area, sea pressures on deck, as per Ch 5, Sec 5, [3], are to be considered independently of the loads defined in [5.2.1].

5.3 Specific loads for helicopter platforms

5.3.1 The total force F , in kN/m², for both the static and the static + dynamic design load scenarios (design load sets DL-1 and DL-2) is to be derived for each dynamic load case and is to be taken as:

- for static design load scenario: $F = F_S$
- for static + dynamic design load scenario: $F = F_S + F_W$

where:

F_S, F_W : Still water and inertial forces transmitted to the hull structure, obtained, in kN, from Tab 1.

Table 1 : Helicopter platforms - Still water and inertial forces

Ship condition	Design load set	Still water force F_S and inertial force F_W , in kN
Seagoing condition	DL-1	$F_S = (W_H + W_p) g$
		$F_{W,X} = (W_H + W_p) a_x + 1,2 A_{HX}$ in x direction
		$F_{W,Y} = (W_H + W_p) a_y + 1,2 A_{HY}$ in y direction
Harbour condition	DL-2	$F_S = (W_H + W_p) g$ in z direction

Note 1:

W_p : Structural weight of the helicopter platform, in t, to be evenly distributed, and to be taken not less than the value obtained from the following formula:

$$W_p = 0,2 A_H$$

A_H : Area, in m², of the entire landing area

a_x, a_y, a_z : Accelerations, in m/s², determined at the helicopter centre of gravity, and defined in Ch 5, Sec 3, [3]

A_{HX}, A_{HY} : Vertical areas, in m², of the helicopter platform in x and y directions respectively. Unless otherwise specified, A_{HX} and A_{HY} may be taken equal to $A_H/3$

6 Scantlings

6.1 General

6.1.1 The scantlings of the structure of an helicopter deck or platform are to be obtained according to [6.2], [6.3] and [6.4]. They are to be considered in addition to scantlings obtained from other applicable loads, in particular from sea pressures.

6.2 Plating

6.2.1 Load model

The following forces P_0 , in kN, are to be considered independently:

- Emergency landing load: $P_0 = F_{EL}$
where F_{EL} is the force corresponding to the emergency landing load, as defined in [5.1]
- Garage load:
 - for static design load scenario: $P_0 = F_{W-S}$
 - for static + dynamic design load scenario: $P_0 = F_{W-S} + F_{W-D}$
 where F_{W-S} and F_{W-D} are the forces corresponding to the garage load, as defined in [5.2].

6.2.2 Net thickness of plating

The net thickness of an helicopter deck or platform subjected to forces defined in [6.2.1] is not to be less than the value obtained according to Ch 7, Sec 4, [3.3], with:

A_T : Tyre or skid print area, in m^2 .

For helicopter with skids in emergency landing case, only the extremity of skid of 0,3 m x 0,01 m is to be considered.

For other cases, where the print area A_T is not specified by the Designer, the following values are to be taken into account:

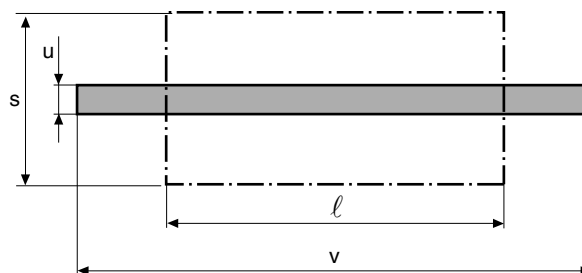
- for one tyre: 0,3 m x 0,3 m
- for one skid: 1 m x 0,01 m.

C_a : Coefficient defined in Ch 7, Sec 4, [1.1.1] and taken equal to C_{a-max} in the particular case of a platform.

6.2.3 Helicopter with skids

For helicopters with skids, in the particular case where $v > \ell$, v being equal to the skid length, the skid print outside of the plate panel is to be disregarded. The load and the print area to be considered are to be reduced accordingly. (see Fig 1).

Figure 1 : Skid print with $v > \ell$



6.3 Ordinary stiffeners

6.3.1 Load model

The following forces P_0 , in kN, are to be considered independently:

- Emergency landing load: $P_0 = F_{EL}$
where F_{EL} is the force corresponding to the emergency landing load, as defined in [5.1]
- Garage load:
 - for static design load scenario: $P_0 = F_{W-S}$
 - for static + dynamic design load scenario: $P_0 = F_{W-S} + F_{W-D}$
 where F_{W-S} and F_{W-D} are the forces corresponding to the garage load, as defined in [5.2].
- Helicopter platform:
 - for static design load scenario: $F = F_S$
 - for static + dynamic design load scenario: $F = F_S + F_W$
 where F_S and F_W are the forces defined in [5.3].

6.3.2 Scantlings

Scantlings of stiffeners induced by loads defined in [6.3.1] are to be calculated according to Ch 7, Sec 5, [1.2] where:

$$w = \frac{\alpha_W K_S P_0 \ell_{bdg}}{6 \chi C_s R_{eH}} 10^3$$

in case of helicopter with wheels, or

$$w = \frac{\alpha_w P_0 \ell_{bdg}}{10 \chi C_s R_{eH}} 10^3$$

in case of helicopter with landing skids.

6.4 Primary supporting members

6.4.1 Load model

The following loads are to be considered independently:

- emergency landing load, as defined in [5.1]
- garage load, as defined in [5.2], if applicable
- for an helicopter platform, specific loads as defined in [5.3].

The most unfavourable case, i.e. where the maximum number of landing gears is located on the same primary supporting members, is to be considered.

6.4.2 Checking criteria

In both cases of helicopter with wheels and helicopter with landing skids, the calculated stress values are to comply with the requirements defined in Ch 7, Sec 6, [5.1.4].

In addition, the hull girder stresses are to be taken equal to 0 in the particular case of an helicopter platform.

Part B

Hull and Stability

CHAPTER 12

HULL OUTFITTING

Section 1	Rudders
Section 2	Bulwarks and Guard Rails
Section 3	Propeller shaft brackets
Section 4	Equipment
Appendix 1	Criteria for Direct Calculation of Rudder Loads
Appendix 2	Towing and Mooring Arrangement

Section 1 Rudders

Symbols

- V_{AV} : Maximum ahead service speed, in knots, with the ship on summer load waterline; if V_{AV} is less than 10 knots, the maximum service speed is to be taken not less than the value obtained from the following formula:
- $$V_{MIN} = \frac{V_{AV} + 20}{3}$$
- V_{AD} : Maximum astern speed, in knots, to be taken not less than 0,5 V_{AV}
- A : Total area of the rudder blade, in m^2 , bounded by the blade external contour, including the mainpiece and the part forward of the centreline of the rudder pintles, if any
- k_1 : Material factor, defined in [1.4.3]
- k : Material factor, defined in Ch 4, Sec 1, [2.2] (see also [1.4.5])
- C_R : Rudder force, in N, acting on the rudder blade, defined in [2.1.2]
- M_{TR} : Rudder torque, in N.m, acting on the rudder blade, defined in [2.1.3] and [2.2.3]
- M_B : Bending moment, in N.m, in the rudder stock, to be calculated according to Ch 12, App 1, [1.4], for each type of rudder listed in Tab 4.

1 General

1.1 Application

1.1.1 Ordinary profile rudders

The requirements of this Section apply to ordinary profile rudders, without any special arrangement for increasing the rudder force, whose maximum orientation at maximum ship speed is limited to 35° on each side.

In general, an orientation greater than 35° is accepted for manoeuvres or navigation at very low speed.

1.1.2 High efficiency rudders

The requirements of this Section also apply to rudders fitted with flaps to increase rudder efficiency. For these rudder types, an orientation at maximum speed different from 35° may be accepted. In these cases, the rudder forces are to be calculated by the Designer for the most severe combinations between orientation angle and ship speed. These calculations are to be considered by the Society on a case-by-case basis.

The rudder scantlings are to be designed so as to be able to sustain possible failures of the orientation control system, or, alternatively, redundancy of the system itself may be required.

1.1.3 Steering nozzles

The requirements for steering nozzles are given in Article [10].

1.1.4 Special rudder types

Rudders others than those in [1.1.1], [1.1.2] and [1.1.3] are to be considered by the Society on a case-by-case basis.

1.2 Gross scantlings

1.2.1 With reference to Ch 4, Sec 2, [1.1.2], all scantlings and dimensions referred to in this Section are gross, i.e. they include the margins for corrosion.

1.3 Arrangements

1.3.1 Effective means are to be provided for supporting the weight of the rudder without excessive bearing pressure, e.g. by means of a rudder carrier attached to the upper part of the rudder stock. The hull structure in way of the rudder carrier is to be suitably strengthened.

1.3.2 Suitable arrangements are to be provided to prevent the rudder from lifting.

In addition, structural rudder stops of suitable strength are to be provided, except where the steering gear is provided with its own rudder stopping devices, as detailed in Pt C, Ch 1, Sec 13.

1.3.3 In rudder trunks which are open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline two separate stuffing boxes are to be provided.

1.4 Materials

1.4.1 Rudder stocks, pintles, coupling bolts, keys and cast parts of rudders are to be made of rolled steel, steel forgings or steel castings according to the applicable requirements in:

- NR216 Materials and Welding, Chapter 3 (steel plate)
- NR216 Materials and Welding, Chapter 5 (steel forgings)
- NR216 Materials and Welding, Chapter 6 (steel castings).

1.4.2 The material used for rudder stocks, pintles, keys and bolts is to have a specified minimum yield stress not less than 200 N/mm².

1.4.3 The requirements relevant to the determination of scantlings contained in this Section apply to steels having a specified minimum yield stress equal to 235 N/mm².

Where the material used for rudder stocks, pintles, coupling bolts, keys and cast parts of rudders has a specified minimum yield stress different from 235 N/mm², the scantlings calculated with the formulae contained in the requirements of this Section are to be modified, as indicated, depending on the material factor k_1 , to be obtained from the following formula:

$$k_1 = \left(\frac{235}{R_{eH}} \right)^n$$

where:

- R_{eH} : Specified minimum yield stress, in N/mm², of the specified steel, and not exceeding the lower of 0,7 R_m and 450 N/mm²
- R_m : Tensile strength, in N/mm², of the steel used
- n : Coefficient to be taken equal to:
- $n = 0,75$ for $R_{eH} > 235$ N/mm²
 - $n = 1,00$ for $R_{eH} \leq 235$ N/mm².

1.4.4 Significant reductions in rudder stock diameter due to the application of steels with specified minimum yield stresses greater than 235 N/mm² may be accepted by the Society subject to the results of a check calculation of the rudder stock deformations (refer to [4.2.1]).

1.4.5 Welded parts of rudders are to be made of approved rolled hull materials. For these members, the material factor k defined in Ch 4, Sec 1, [2.2] is to be used.

2 Force and torque acting on the rudder

2.1 Rudder blade without cut-outs

2.1.1 Rudder blade description

A rudder blade without cut-outs may have trapezoidal or rectangular contour.

2.1.2 Rudder force

The rudder force C_R is to be obtained, in N, from the following formula: $C_R = 132 n_R A V^2 r_1 r_2 r_3$

where:

- n_R : Navigation coefficient, defined in Tab 1
- V : V_{AV} or V_{AD} , depending on the condition under consideration (for high lift profiles see [1.1.2])
- r_1 : Shape factor, to be taken equal to:
- $$r_1 = \frac{\lambda + 2}{3}$$
- λ : Coefficient, to be taken equal to:
- $$\lambda = \frac{h^2}{A_T}$$
- and not greater than 2
- h : Mean height, in m, of the rudder area to be taken equal to (see Fig 1):
- $$h = \frac{z_3 + z_4 - z_2}{2}$$
- A_T : Area, in m², to be calculated by adding the rudder blade area A to the area of the rudder post or rudder horn, if any, up to the height h
- r_2 : Coefficient to be obtained from Tab 2

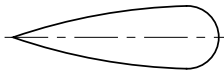
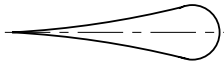
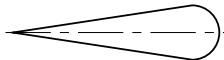

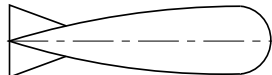
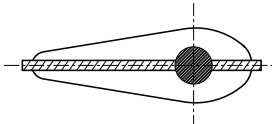
r_3 : Coefficient to be taken equal to:

- $r_3 = 0,8$ for rudders outside the propeller jet (centre rudders on twin screw ships, or similar cases)
- $r_3 = 1,15$ for rudders behind a fixed propeller nozzle
- $r_3 = 1,0$ in other cases.

Table 1 : Navigation coefficient

Navigation notation	Navigation coefficient n_R
unrestricted navigation	1,00
summer zone	0,95
tropical zone	0,85
coastal area	0,85
sheltered area	0,75

Table 2 : Values of coefficient r_2

Rudder profile type	r_2 for ahead condition	r_2 for astern condition
NACA 00 - Goettingen 	1,10	0,80
Hollow 	1,35	0,90
Flat side 	1,10	0,90
High lift 	1,70	1,30
Fish tail 	1,40	0,80
Single plate 	1,00	1,00
Mixed profiles (e.g. HSVA)	1,21	0,90

2.1.3 Rudder torque

The rudder torque M_{TR} , for both ahead and astern conditions, is to be obtained, in N.m, from the following formula:

$$M_{TR} = C_R r$$

where:

r : Lever of the force C_R , in m, equal to:

$$r = b \left(\alpha - \frac{A_F}{A} \right)$$

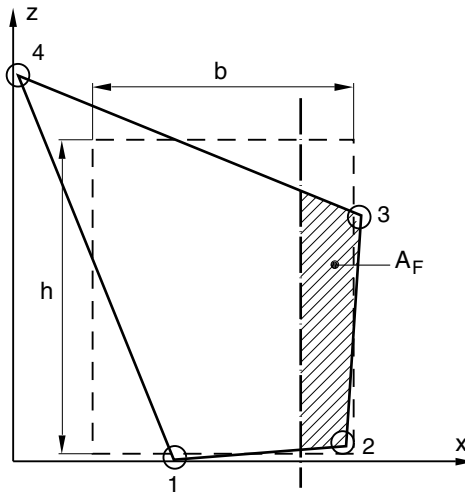
and to be taken not less than 0,1 b for the ahead condition

b : Mean breadth, in m, of rudder area to be taken equal to (see Fig 1):

$$b = \frac{x_2 + x_3 - x_1}{2}$$

- α : Coefficient to be taken equal to:
 - $\alpha = 0,33$ for ahead condition
 - $\alpha = 0,66$ for astern condition
- A_F : Area, in m^2 , of the rudder blade portion afore the centreline of rudder stock (see Fig 1).

Figure 1 : Geometry of rudder blade without cut-outs

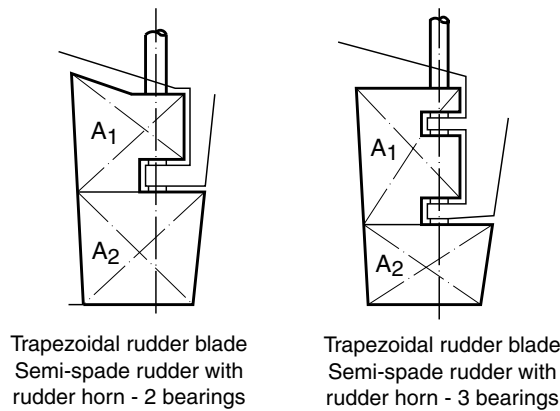


2.2 Rudder blade with cut-outs (semi-spade rudders)

2.2.1 Rudder blade description

A rudder blade with cut-outs may have trapezoidal or rectangular contour, as indicated in Fig 2.

Figure 2 : Rudder blades with cut-outs



2.2.2 Rudder force

The rudder force C_R , in N, acting on the blade is to be calculated in accordance with [2.1.2].

2.2.3 Rudder torque

The rudder torque M_{TR} , in N.m, is to be calculated in accordance with the following procedure.

The rudder blade area A is to be divided into two rectangular or trapezoidal parts having areas A_1 and A_2 , defined in Fig 2, so that:

$$A = A_1 + A_2$$

The rudder forces C_{R1} and C_{R2} , acting on each part A_1 and A_2 of the rudder blade, respectively, are to be obtained, in N, from the following formulae:

$$C_{R1} = C_R \frac{A_1}{A}$$

$$C_{R2} = C_R \frac{A_2}{A}$$

The levers r_1 and r_2 of the forces C_{R1} and C_{R2} , respectively, are to be obtained, in m, from the following formulae:

$$r_1 = b_1 \left(\alpha - \frac{A_{1F}}{A_1} \right)$$

$$r_2 = b_2 \left(\alpha - \frac{A_{2F}}{A_2} \right)$$

where:

b_1, b_2 : Mean breadths of the rudder blade parts having areas A_1 and A_2 , respectively, to be determined according to [2.1.3]

A_{1F}, A_{2F} : Areas, in m^2 , of the rudder blade parts, defined in Fig 3

α : Coefficient to be taken equal to:

- $\alpha = 0,33$ for ahead condition
- $\alpha = 0,66$ for astern condition

For rudder parts located behind a fixed structure such as a rudder horn, α is to be taken equal to:

- $\alpha = 0,25$ for ahead condition
- $\alpha = 0,55$ for astern condition.

The torques M_{TR1} and M_{TR2} , relevant to the rudder blade parts A_1 and A_2 respectively, are to be obtained, in N.m, from the following formulae:

$$M_{TR1} = C_{R1} r_1$$

$$M_{TR2} = C_{R2} r_2$$

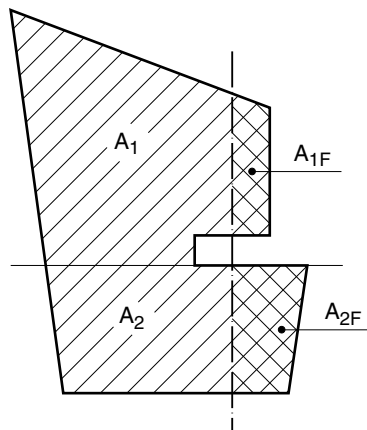
The total torque M_{TR} acting on the rudder stock, for both ahead and astern conditions, is to be obtained, in N.m, from the following formula:

$$M_{TR} = M_{TR1} + M_{TR2}$$

For the ahead condition only, M_{TR} is to be taken not less than the value obtained, in N.m, from the following formula:

$$M_{TR,MIN} = 0,1 C_R \frac{A_1 b_1 + A_2 b_2}{A}$$

Figure 3 : Geometry of rudder blade with cut-outs



3 Rudder types and relevant loads acting on the rudder structure

3.1 General

3.1.1 Loads per rudder category - basic assumptions

Depending on the shape of the rudder blade and arrangement of the rudder, twelve types of rudders are considered. Tab 4 summarizes these rudder types.

The force and torque acting on the rudder, defined in [2], may induce in the rudder structure the following loads:

- bending moment and torque in the rudder stock
- support forces at pintle and rudder stock bearings
- bending moment, shear force and torque in the rudder body
- bending moment, shear force and torque in rudder horns and solepieces.

Support forces, bending moments and shear forces are to be obtained according to Ch 12, App 1, [1.4], depending on the rudder type.

3.1.2 Loads for the scantlings and assembling of rudder parts

The loads to be considered for the scantlings of rudder parts and some assembling parts are indicated in Tab 3.

Table 3 : Scantling of parts, rudder stock couplings and relevant loads

Item identification	Relevant loads
Rudder stock scantlings	<ul style="list-style-type: none"> • either torque only, or • both, torque and bending moment See [4]
Rudder stock couplings	<ul style="list-style-type: none"> • either torque only, or • both, torque and bending moment See [5]
Rudder stock bearings	Horizontal reaction forces, F_{Air} See [6.2]
Pintle bearings	Horizontal reaction forces, F_{Air} See [6.3]
Scantling of pintles	Horizontal reaction forces, F_{Air} See [6.4]
Rudder blade scantlings	Bending moment and shear force See [7]
Rudder horn scantlings	Bending moment, shear force and torque See [8.1] and [8.2]
Solepiece scantlings	Bending moment and shear force See [8.4]

4 Rudder stock scantlings

4.1 Rudder stock diameter

4.1.1 Basic formulation

The scantling of the rudder stock diameter is based on the Von Mises equivalent stress criterion, written for a state of stress induced by a combined torque, M_{TR} , and a bending moment, M_B , acting on the rudder stock. The Von Mises equivalent stress, σ_E , calculated for this state of stress, has to be in compliance with the following formula: $\sigma_E \leq \sigma_{E,ALL}$

where:

σ_E : Equivalent stress, in N/mm², to be obtained from the following formula:

$$\sigma_E = \sqrt{\sigma_B^2 + 3\tau_T^2}$$

σ_B : Bending stress, in N/mm², to be obtained from the following formula:

$$\sigma_B = \frac{10,2M_B}{d_S^3} \cdot 10^3$$

τ_T : Torsional stress, in N/mm², to be obtained from the following formula:

$$\tau_T = \frac{5,1M_{TR}}{d_S^3} \cdot 10^3$$

d_S : Stock diameter, in mm

$\sigma_{E,ALL}$: Allowable equivalent stress, in N/mm², equal to: $\sigma_{E,ALL} = 118 / k_1$

For this purpose, the rudder stock diameter is to be not less than the value obtained, in mm, from the following formula:

$$d_{TFi} = 4,2(M_{TR} k_1)^{1/3} \left[1 + \frac{4}{3} \left(\frac{M_{Bi}}{M_{TR}} \right)^2 \right]^{1/6}$$

where M_{Bi} is to be obtained according to Ch 12, App 1, [1.1.1], for each type of rudder listed in Tab 4.

4.1.2 Rule rudder stock diameter

The rudder stock diameter, at the lower part, is to be not less than the value obtained, in mm, from the following formula:

$$d_{TF} = 4,2(M_{TR} k_1)^{1/3} \left[1 + \frac{4}{3} \left(\frac{M_B}{M_{TR}} \right)^2 \right]^{1/6}$$

with:

M_B : Maximum absolute value of bending moment M_{Bi} over the rudder stock length, to be obtained according to Ch 12, App 1, [1.4], for each type of rudder listed in Tab 4.

If not otherwise specified, the notation d_i used in this Section is equivalent to d_{TF} .

4.1.3 Rudder stock cross sections with null bending moment

The diameter, in mm, of a rudder stock cross section subjected to torque only is not to be less than the diameter d_T obtained from [4.1.2], taking M_B equal to zero: $d_T = 4,2 (M_{TR} k_1)^{1/3}$

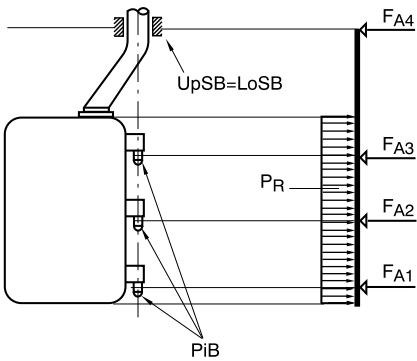
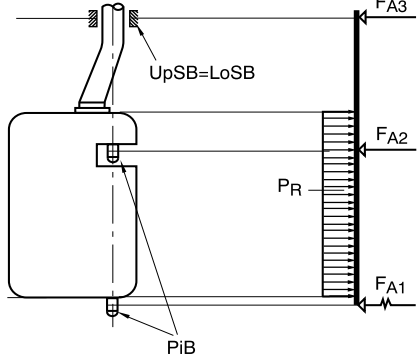
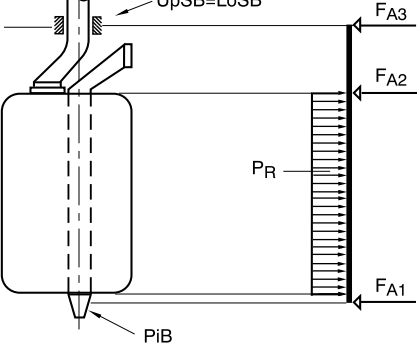
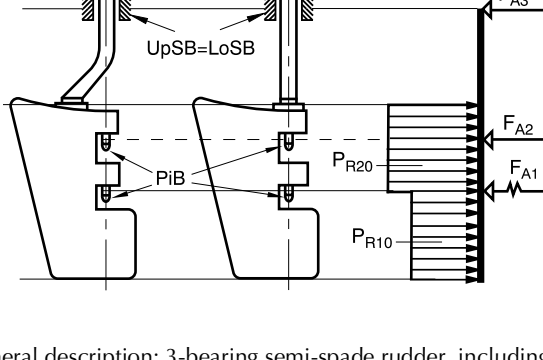
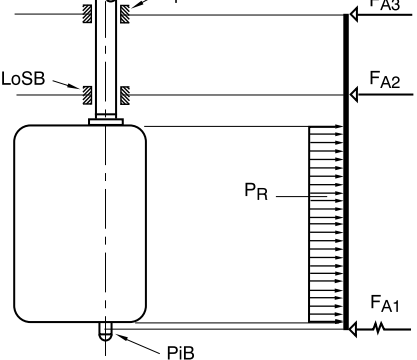
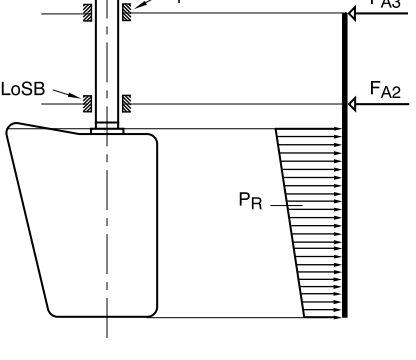
This is equivalent to check that the torsional shear stress τ_T , in N/mm², induced by the torque only, is in compliance with the following formula: $\tau_T \leq \tau_{ALL}$

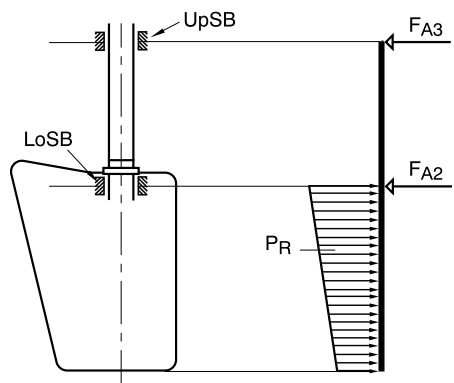
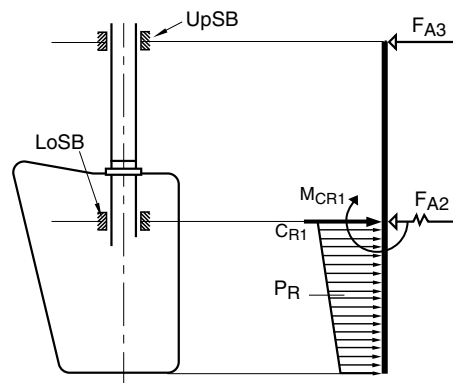
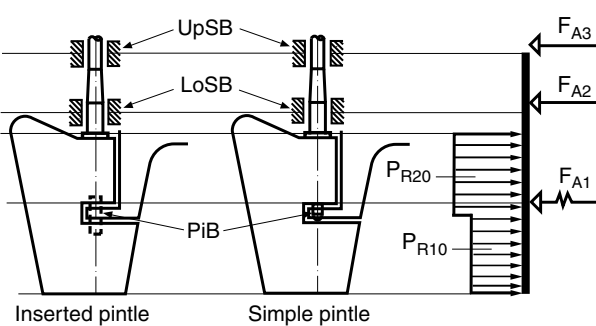
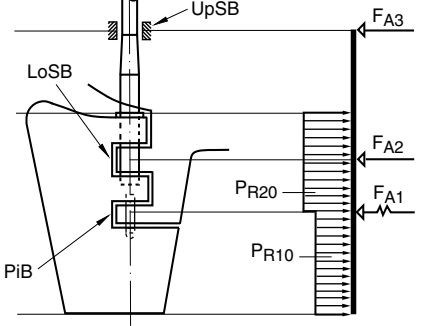
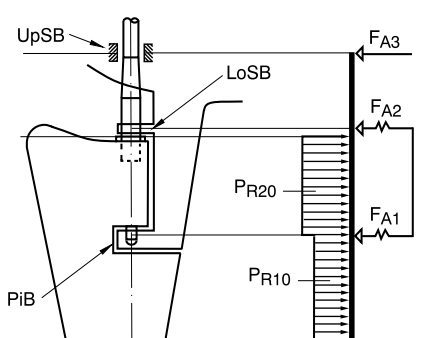
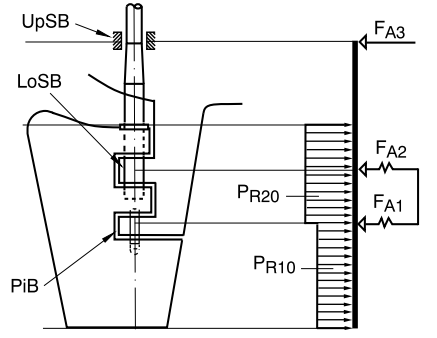
where:

τ_{ALL} : Allowable torsional shear stress, in N/mm²: $\tau_{ALL} = 68 / k_1$

τ_T : Torsional stress, in N/mm², defined in [4.1.1].

Table 4 : Types of rudders and load diagram

<p>Type 1</p>  <p>General description: 4-bearing rudder, including 3 pintle bearings and 1 rudder-stock bearing. See Ch 12, App 1, [1.4.1].</p>	<p>Type 2</p>  <p>General description: 3-bearing rudder, including 2 pintle bearings and 1 rudder-stock bearing (the lower pintle bearing is represented by 1-elastic support). See Ch 12, App 1, [1.4.2].</p>
<p>Type 3</p>  <p>General description: 3-bearing rudder, including 2 bearings associated to the simplex rudder shaft and 1 rudder-stock bearing. See Ch 12, App 1, [1.4.3].</p>	<p>Type 4</p>  <p>General description: 3-bearing semi-spade rudder, including 2 pintle bearings and 1 rudder-stock bearing (the lower pintle bearing is represented by 1-elastic support). See Ch 12, App 1, [1.4.4].</p>
<p>Type 5</p>  <p>General description: 3-bearing rudder, including 1-elastic pintle bearing and 2 rudder-stock bearings. See Ch 12, App 1, [1.4.5].</p>	<p>Type 6a</p>  <p>General description: 2-bearing spade rudder, including 2 rudder-stock bearings, both of them located out of the rudder blade area. See Ch 12, App 1, [1.4.6].</p>

<p>Type 6b</p>  <p>General description: 2-bearing spade rudder, including 2 rudder-stock bearings, the lowest one located inside of the rudder blade area and close to its upper edge. See Ch 12, App 1, [1.4.7].</p>	<p>Type 6c</p>  <p>General description: 2-bearing spade rudder, including 2 rudder-stock bearings, the lowest one located inside of the rudder blade area. See Ch 12, App 1, [1.4.8].</p>
<p>Type 7</p>  <p>General description: 3-bearing semi-spade rudder, including 1-elastic pintle bearing and 2 rudder-stock bearings. See Ch 12, App 1, [1.4.9].</p>	<p>Type 8</p>  <p>General description: 3-bearing semi-spade rudder, including 1-elastic pintle bearing and 2 rudder-stock bearings (with 1 rudder-stock bearing inside of the rudder blade area). See Ch 12, App 1, [1.4.10].</p>
<p>Type 9</p>  <p>General description: 3-bearing semi-spade rudder, including 1 pintle bearing and 2 rudder-stock bearings (lower pintle and stock bearings represented by 2-conjugate elastic supports). See Ch 12, App 1, [1.4.11].</p>	<p>Type 10</p>  <p>General description: 3-bearing semi-spade rudder, including 1 pintle bearing and 2 rudder-stock bearings (lower pintle and stock bearings represented by 2-conjugate elastic supports, located inside of the rudder blade area). See Ch 12, App 1, [1.4.12].</p>
<p>Note 1: Bending moment and shear forces need to be calculated at any generic horizontal section of the rudder blade, to make possible strength checks prescribed under [7.2].</p> <p>Note 2:</p> <ul style="list-style-type: none"> UpSB : Upper rudder-stock bearing LoSB : Lower rudder-stock bearing PiB : Position of pintle bearing(s). <p>Note 3: Steering nozzle rudders are not included in this table (refer to [10] for more details).</p>	

4.1.4 Rule rudder stock diameter in way of the tiller

In general, the diameter of a rudder stock subjected to torque and bending may be gradually tapered above the lower stock bearing so as to reach, from d_{TF} value, the value of d_T in way of the quadrant or the tiller.

4.2 Deformation criterion

4.2.1 Rudder stock slope in way of bearings

Large rudder stock deformations are to be avoided in order to avoid excessive edge pressures in way of bearings.

The Society may require an additional check of the rudder stock diameter to make sure that the rudder stock slopes in way of bearings are acceptable, by relating them to bearing lengths (see [6.2.3]) and bearing clearances (see [6.2.4]).

4.3 Service notations - Navigation in ice

4.3.1 Service notations

For specific service notations, increase in rudder stock diameter is required according to the relevant requirements in Part D or Part E.

4.3.2 Navigation in ice

For ships having an additional **ICE CLASS** notation, refer to applicable requirements in Pt F, Ch 8, Sec 2.

5 Rudder stock couplings

5.1 Horizontal flange couplings

5.1.1 General

In general, the coupling flange and the rudder stock are to be forged from a solid piece. A shoulder radius as large as practicable is to be provided for between the rudder stock and the coupling flange. This radius is to be not less than $0,15 d_1$, where d_1 is defined in [4.1.2].

5.1.2 Welding

Where the rudder stock diameter does not exceed 350 mm, the coupling flange may be welded onto the stock, provided that its thickness is increased by 10% and that the weld extends through the full thickness of the coupling flange and that the assembly obtained is subjected to heat treatment. This heat treatment is not required if the diameter of the rudder stock is less than 75 mm.

Where the coupling flange is welded, the grade of the steel used is to be of weldable quality, with a carbon content not exceeding 0,23% on ladle analysis and a carbon equivalent CEQ not exceeding 0,41. The welding conditions (preparation before welding, choice of electrodes, pre- and post-heating, inspection after welding) are to be defined to the satisfaction of the Society. The throat weld at the top of the flange is to be concave shaped to give a fillet shoulder radius as large as practicable. This radius:

- is to be not less than $0,15d_1$, where d_1 is defined in [4.1.2]
- may be obtained by grinding. If disk grinding is carried out, score marks are to be avoided in the direction of the weld
- is to be checked with a template for accuracy. Four profiles at least are to be checked. A report is to be submitted to the Surveyor.

The inspection is to include full non destructive tests at weld location (dye penetrant or magnetic particle test and ultrasonic test).

5.1.3 Bolts

Horizontal flange couplings are to be connected by fitted bolts having a diameter not less than the value obtained, in mm, from the following formula:

$$d_B = 0,62 \sqrt{\frac{d_1^3 k_{1B}}{n_B e_M k_{1S}}}$$

where:

- d_1 : Rudder stock diameter, in mm, defined in [4.1.2]
- k_{1S} : Material factor k_1 for the steel used for the rudder stock
- k_{1B} : Material factor k_1 for the steel used for the bolts
- e_M : Mean distance, in mm, of the bolt axes from the centre of the bolt system
- n_B : Total number of bolts, which is to be not less than 6.

Non-fitted bolts may be used provided that, in way of the mating plane of the coupling flanges, a key is fitted having a section of $(0,25d_T \times 0,10d_T)$ mm² and keyways in both the coupling flanges, and provided that at least two of the coupling bolts are fitted bolts.

The distance from the bolt axes to the external edge of the coupling flange is to be not less than $1,2 d_B$.

5.1.4 Coupling flange

The thickness of the coupling flange is to be not less than the value obtained, in mm, from the following formulae, whichever is the greater:

- $t_p = d_B \sqrt{\frac{k_{1F}}{k_{1B}}}$
- $t_p = 0,9 d_B$

where:

- d_B : Bolt diameter, in mm, calculated in accordance with [5.1.3], where the number of bolts n_B is to be taken not greater than 8
- k_{1F} : Material factor k_1 for the steel used for the flange
- k_{1B} : Material factor k_1 for the steel used for the bolts.

5.1.5 Locking device

A suitable locking device is to be provided to prevent the accidental loosening of nuts.

5.2 Couplings between rudder stocks and tillers

5.2.1 Application

The requirements of this sub-article apply in addition to those specified in Pt C, Ch 1, Sec 13.

The requirements specified in [5.2.3] and [5.2.4] apply to solid rudder stocks in steel and to tiller bosses, either in steel or in SG iron, with constant external diameter. Solid rudder stocks others than those above will be considered by the Society on a case-by-case basis, provided that the relevant calculations, to be based on the following criteria, are submitted to the Society:

- Young's modulus:
 - $E = 2,06 \cdot 10^5$ N/mm² for steel
 - $E = 1,67 \cdot 10^5$ N/mm² for SG iron
- Poisson's ratio:
 - $\nu = 0,30$ for steel
 - $\nu = 0,28$ for SG iron
- Frictional coefficient:
 - $\mu = 0,15$ for contact steel/steel
 - $\mu = 0,13$ for contact steel/SG iron
- Torque C_T transmissible through friction: $C_T \geq \eta M_{TR}$
 where η is defined in [5.2.3]
- Combined stress in the boss:

$$\sqrt{\sigma_R^2 + \sigma_T^2 - \sigma_R \sigma_T} \leq (0,5 + 0,2 \eta) R_{eH}$$

where:

- σ_R, σ_T : Algebraic values of, respectively, the radial compression stress and the tangent tensile stress, in N/mm², induced by the grip pressure and calculated at the bore surface ($\sigma_R = p_F$, where p_F is the grip pressure in the considered horizontal cross-section of the boss)

- Where the rudder stock is hollow, the following strength criterion is to be complied with, at any point of the rudder stock cross-section:

$$\sqrt{\sigma_R^2 + \sigma_T^2 - \sigma_R \sigma_T + 3 \tau^2} \leq 0,7 R_{eH}$$

where:

- σ_R, σ_T : Algebraic values of, respectively, the radial and the tangent compressive stresses, in N/mm², induced by the grip pressure
- τ : Shear stress, in N/mm², induced by the torque M_{TR} .

5.2.2 General

The entrance edge of the tiller bore and that of the rudder stock cone are to be rounded or bevelled.

The right fit of the tapered bearing is to be checked before final fit up, to ascertain that the actual bearing is evenly distributed and at least equal to 80% of the theoretical bearing area; push-up length is measured from the relative positioning of the two parts corresponding to this case.

The required push-up length is to be checked after releasing of hydraulic pressures applied in the hydraulic nut and in the assembly.

5.2.3 Push-up length of cone couplings with hydraulic arrangements for assembling and disassembling the coupling

It is to be checked that the push-up length Δ_E , in mm, of the rudder stock tapered part into the tiller boss is in compliance with the following formula:

$$\Delta_0 \leq \Delta_E \leq \Delta_1$$

where:

$$\Delta_0 = 6,2 \frac{M_{TR} \eta \gamma}{c d_M t_i \mu_A \beta} 10^{-3}$$

$$\Delta_1 = \frac{2\eta + 5}{1,8} \cdot \frac{\gamma d_0 R_{eH}}{c} 10^{-6}$$

η : Coefficient to be taken equal to:

- $\eta = 1$ for keyed connections
- $\eta = 2$ for keyless connections

c : Taper of conical coupling measured on diameter, to be obtained from the following formula:

$$c = (d_U - d_0) / \ell_c$$

t_i, ℓ_c, d_U, d_0 : Geometrical parameters of the coupling, defined in Fig 4

β : Coefficient to be taken equal to:

$$\beta = 1 - \left(\frac{d_M}{d_E}\right)^2$$

d_M : Mean diameter, in mm, of the conical bore, to be obtained from the following formula:

$$d_M = d_U - 0,5 c \ell_c$$

d_E : External boss diameter, in mm

μ_A : Coefficient to be taken equal to:

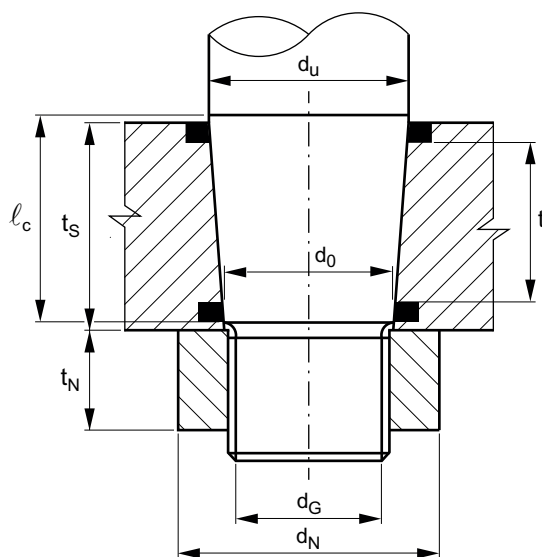
$$\mu_A = \sqrt{\mu^2 - 0,25 c^2}$$

μ, γ : Coefficients to be taken equal to:

- for rudder stocks and bosses made of steel:
 - $\mu = 0,15$
 - $\gamma = 1$
- for rudder stocks made of steel and bosses made of SG iron:
 - $\mu = 0,13$
 - $\gamma = 1,24 - 0,1 \beta$

R_{eH} : Defined in [1.4.3].

Figure 4 : Geometry of cone coupling



5.2.4 Boss of cone couplings with hydraulic arrangements for assembling and disassembling the coupling

The scantlings of the boss are to comply with the following formula:

$$\frac{1,8}{2\eta + 5} \cdot \frac{\Delta_E c}{\gamma d_0} 10^6 \leq R_{eH}$$

where:

- Δ_E : Push-up length adopted, in mm
- c, η, γ : Defined in [5.2.3]
- d_0 : Defined in Fig 4
- R_{eH} : Defined in [1.4.3].

5.2.5 Cylindrical couplings by shrink fit

It is to be checked that the diametral shrinkage allowance δ_E , in mm, is in compliance with the following formula:

$$\delta_0 \leq \delta_E \leq \delta_1$$

where:

$$\delta_0 = 6,2 \cdot \frac{M_{TR} \eta \gamma}{d_U t_i \mu \beta_1} 10^{-3}$$

$$\delta_1 = \frac{2\eta + 5}{1,8} \cdot \gamma d_U R_{eH} 10^{-6}$$

- η, μ, γ, c : Defined in [5.2.3]
- d_U : Defined in Fig 4
- β_1 : Coefficient to be taken equal to:

$$\beta_1 = 1 - \left(\frac{d_U}{d_E}\right)^2$$

- R_{eH} : Defined in [1.4.3].

5.2.6 Keyless couplings through special devices

The use of special devices for frictional connections, such as expansible rings, may be accepted by the Society on a case-by-case basis provided that the following conditions are complied with:

- evidence that the device is efficient (theoretical calculations and results of experimental tests, references of behaviour during service, etc.) are to be submitted to the Society
- the torque transmissible by friction is to be not less than 2 M_{TR}
- design conditions and strength criteria are to comply with [5.2.1]
- instructions provided by the manufacturer are to be complied with, notably concerning the pre-stressing of the tightening screws.

5.3 Cone couplings between rudder stocks and rudder blades

5.3.1 Taper on diameter

The taper on diameter of the cone couplings is to be in compliance with the following formulae:

- for cone couplings without hydraulic arrangements for assembling and disassembling the coupling:

$$\frac{1}{12} \leq \frac{d_U - d_0}{l_c} \leq \frac{1}{8}$$

- for cone couplings with hydraulic arrangements for assembling and disassembling the coupling (assembling with oil injection and hydraulic nut):

$$\frac{1}{20} \leq \frac{d_U - d_0}{l_c} \leq \frac{1}{12}$$

where:

- d_U, l_c, d_0 : Geometrical parameters of the coupling, defined in Fig 4.

5.3.2 Push-up pressure of cone coupling with hydraulic arrangements for assembling and disassembling the coupling

The push-up pressure, in N/mm², is not to be less than the greater of the two following values:

$$p_{req1} = \frac{2Q_F}{d_M^2 t_i \pi \mu_0} 10^3$$

$$p_{req2} = \frac{6M_{BC}}{t_i^2 d_M} 10^3$$

where:

- Q_F : Design yield moment of rudder stock, in N.m, defined in [5.3.6]
 d_M : Mean diameter, in mm, of the conical bore defined in [5.2.3]
 t_i : Geometrical parameter of the coupling defined in Fig 4
 μ_0 : Frictional coefficient, taken equal to 0,15
 M_{Bc} : Bending moment at mid-height of the cone coupling, in N.m, to be deduced from the calculation of the bending moment in the rudder stock, M_B , as defined in Ch 12, App 1.

It has to be demonstrated by the designer that the push-up pressure does not exceed the permissible surface pressure in the cone. The permissible surface pressure, in N/mm², is to be determined by the following formula:

$$p_{perm} = \frac{0.8R_{eH}(1 - \alpha^2)}{\sqrt{3 + \alpha^4}}$$

where:

- R_{eH} : Minimum yield stress for the steel used for the gudgeon
 α : d_M/d_E
 d_E : Minimum outer dimension (diameter or width) of the solid part in way of any horizontal cross section.

5.3.3 Push-up length of cone coupling with hydraulic arrangements for assembling and disassembling the coupling

It is to be checked that the push-up length Δ_E , in mm, of the rudder stock tapered part into the boss is in compliance with the following formula:

$$\Delta_0 \leq \Delta_E \leq \Delta_1$$

where:

$$\Delta_0 = \frac{p_{req}d_M}{E\left(\frac{1 - \alpha^2}{2}\right)c} + \frac{0.8R_{tm}}{c}$$

$$\Delta_1 = \frac{1.6R_{eH}d_M}{Ec\sqrt{3 + \alpha^4}} + \frac{0.8R_{tm}}{c}$$

- R_{tm} : Mean roughness, in mm, taken equal to 0,01
 c : Taper on conical coupling defined in [5.2.3].

Note 1: In case of hydraulic pressure connections, the required push-up force P_e , in N, may be determined by the following formula:

$$P_e = p_{req}d_M\pi t_i\left(\frac{c}{2} + 0,02\right)$$

5.3.4 Lower rudder stock end

The lower rudder stock end is to be fitted with a threaded part having a core diameter, d_G , in mm, not less than (see Fig 4):

$$d_G = 0,65 d_U$$

where:

- d_U : Rudder stock diameter, in mm, as defined in Fig 4.

This threaded part is to be fitted with an adequate slogging nut efficiently locked in rotation.

The contact length t_i , in mm, of the rudder stock coupling cone inserted in the massive part (see Fig 4), deduction made of the chamfers and sealing ring grooves (oil grooves may be disregarded), is to be such that:

$$t_i \geq 1,5 d_U \sqrt{k_1}$$

where:

- k_1 : Material factor of the massive part.

When the foreseen contact surface ratio between the rudder stock and the massive part is greater than 70%, a lower t_i/d_U ratio may be accepted, on a case-by-case basis, provided that the contact percentage is proportionally higher, without however being taken less than 1,2.

The dimensions of the slogging nut are recommended to be as follows (see Fig 4):

- outer diameter: $d_N \geq \text{Max}(1,2 d_0 ; 1,5 d_G)$
- thickness: $t_N \geq 0,60 d_G$

where:

- d_0 : As defined in Fig 4.

These dimensions and the core diameter d_G of the lower rudder stock end are given for guidance only, the determination of the adequate scantlings being left to the Designer.

5.3.5 Washer

For cone couplings with hydraulic arrangements for assembling and disassembling the coupling, a washer is to be fitted between the nut and the rudder gudgeon, having a thickness not less than $0,09 d_G$ and an outer diameter not less than $1,3 d_0$ or $1,6 d_G$, whichever is the greater.

The washer is not needed if the seat-surface of the nut is flat and, at least, identical to the contact surface calculated for a washer with the required diameter.

5.3.6 Couplings with key

For cone couplings without hydraulic arrangements for assembling and disassembling the coupling, a key is to be fitted and keyways in both the tapered part and the rudder gudgeon.

The key is to be machined and located on the fore or aft part of the rudder. The key is to be inserted at half-thickness into stock and into the solid part of the rudder.

The key shear area a_s , in cm^2 , is to be not less than:

$$a_s = \frac{17,55 Q_F}{d_k R_{eH1}}$$

where:

Q_F : Design yield moment of rudder stock, in N.m, obtained from the following formula:

$$Q_F = 0,02664 \frac{d_1^3}{k_{1S}}$$

Where the actual stock diameter is greater than the calculated diameter d_1 , the actual diameter is to be used, without being taken greater than $1,145 d_1$.

d_1 : Rudder stock diameter, in mm, taken equal to d_T , as defined in [4.1.3]

k_{1S} : Material factor k_1 for the steel used for the rudder stock

d_k : Mean diameter of the conical part of the rudder stock at the key, in mm

R_{eH1} : Specified minimum yield stress R_{eH} for the steel used for key.

The effective surface area a_k , in cm^2 , of the key (without rounded edges) between key and rudder stock or cone coupling is not to be less than:

$$a_k = \frac{5 Q_F}{d_k R_{eH2}}$$

where:

R_{eH2} : Specified minimum yield stress R_{eH} of the key, stock or coupling material, whichever is less.

It is to be proved that 50% of the design yield moment Q_F is solely transmitted by friction in the cone couplings. This can be done by calculating the required push-up pressure p_{req} and push-up length Δ_E according to [5.3.2] and [5.3.3] for a torsional moment Q'_F equal to $0,5 Q_F$.

In the specific case where the key is considered to transmit the entire rudder torque to the couplings, the scantlings of the key, as well as the push-up force and push-up length, are to be at the discretion of the Society.

5.3.7 Instructions

All necessary instructions for hydraulic assembly and disassembly of the nut, including indication of the values of all relevant parameters, are to be available on board.

5.4 Vertical flange couplings

5.4.1 Vertical flange couplings are to be connected by fitted bolts having a diameter, in mm, not less than the value obtained, in mm, from the following formula:

$$d_B = \frac{0,81 d_1}{\sqrt{n_B}} \sqrt{\frac{k_{1B}}{k_{1S}}}$$

where:

d_1 : Rudder stock diameter, in mm, defined in [4.1.2]

k_{1S}, k_{1B} : Material factors, defined in [5.1.3]

n_B : Total number of bolts, which is to be not less than 8.

5.4.2 The first moment of area of the sectional area of bolts about the vertical axis through the centre of the coupling is to be not less than the value obtained, in cm^3 , from the following formula:

$$M_S = 0,00043 d_1^3$$

where:

d_1 : Rudder stock diameter, in mm, defined in [4.1.2].

5.4.3 The thickness of the coupling flange, in mm, is to be not less than d_B , defined in [5.4.1].

5.4.4 The distance, in mm, from the bolt axes to the external edge of the coupling flange is to be not less than $1,2 d_B$, where d_B is defined in [5.4.1].

5.4.5 A suitable locking device is to be provided to prevent the accidental loosening of nuts.

5.5 Couplings by continuous rudder stock welded to the rudder blade

5.5.1 When the rudder stock extends through the upper plate of the rudder blade and is welded to it, the thickness of this plate in the vicinity of the rudder stock is to be not less than $0,20 d_1$, where d_1 is defined in [4.1.2].

5.5.2 The welding of the upper plate of the rudder blade with the rudder stock is to be made with a full penetration weld and is to be subjected to non-destructive inspection through dye penetrant or magnetic particle test and ultrasonic test.

The throat weld at the top of the rudder upper plate is to be concave shaped to give a fillet shoulder radius as large as practicable. This radius:

- is to be not less than $0,15 d_1$, where d_1 is defined in [4.1.2]
- may be obtained by grinding. If disk grinding is carried out, score marks are to be avoided in the direction of the weld
- is to be checked with a template for accuracy. Four profiles, at least, are to be checked. A report is to be submitted to the Surveyor.

5.6 Rudder trunks

5.6.1 The requirements [5.6.2] to [5.6.8] apply to trunk configurations which are extended below stern frame and arranged in such a way that the trunk is stressed by forces due to rudder action.

5.6.2 The bending and shear stresses in the rudder trunk, in N/mm^2 , are to be in compliance with the following formulae:

$$\sigma \leq 80 / k$$

$$\tau \leq 48 / \kappa$$

where k is not to be taken less than 0,7.

For the calculation of the bending and shear stresses, refer to Ch 12, App 1, [1.8].

5.6.3 The steel grade used for the rudder trunk is to be of weldable quality, with a carbon content not exceeding 0,23% on ladle analysis or a carbon equivalent CEQ not exceeding 0,41.

5.6.4 The weld at the connection between the rudder trunk and the shell or the bottom of the skeg is to be full penetration.

The fillet shoulder radius r is to be as large as practicable and to comply with the following formulae: $r = 0,1 d_1$

where d_1 is defined in [4.1.2],

without being less than:

$$r = 60 \text{ mm when } \sigma \geq 40 / k \text{ N/mm}^2$$

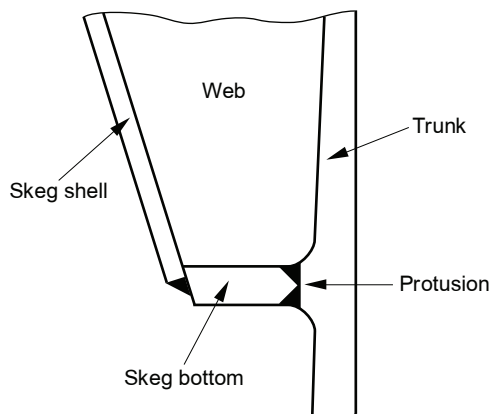
$$r = 30 \text{ mm when } \sigma < 40 / k \text{ N/mm}^2.$$

The radius may be obtained by grinding. If disk grinding is carried out, score marks are to be avoided in the direction of the weld.

The radius is to be checked with a template for accuracy. Four profiles at least are to be checked. A report is to be submitted to the Surveyor.

5.6.5 In case of type 6c rudders, the trunk tube is to be made with a protrusion at connection with skeg bottom, and scallops in webs are to be avoided at connection between the bottom of the skeg and the trunk or the shell, as shown in Fig 5.

Figure 5 : Typical trunk/skeg connection on type 6c rudders



5.6.6 Before welding is started, a detailed welding procedure specification is to be submitted to the Society covering the weld preparation, welding positions, welding parameters, welding consumables, preheating, post weld heat treatment and inspection procedures. This welding procedure is to be supported by approval tests in accordance with the applicable requirements of NR216 Materials and Welding, Ch 12, Sec 3.

The manufacturer is to maintain records of welding, subsequent heat treatment and inspections traceable to the welds. These records are to be submitted to the Surveyor.

Non destructive tests are to be conducted at least 24 hours after completion of the welding. The welds are to be 100% magnetic particle tested and 100% ultrasonic tested. The welds are to be free from cracks, lack of fusion and incomplete penetration. The non destructive tests reports are to be handed over to the Surveyor.

5.6.7 Rudder trunks in materials other than steel are to be specially considered by the Society.

5.6.8 The thickness of the shell or of the bottom plate is to be compatible with the trunk thickness.

6 Rudder stock and pintle bearings

6.1 Forces on rudder stock and pintle bearings

6.1.1 Support forces F_{Ai} , for $i = 1, 2, 3, 4$, as described in Tab 4, are to be obtained according to Ch 12, App 1, depending on the rudder type.

6.2 Rudder stock bearing

6.2.1 The mean bearing pressure acting on the rudder stock bearing is to be in compliance with the following formula:

$$p_F \leq p_{F,ALL}$$

where:

p_F : Mean bearing pressure acting on the rudder stock bearings, in N/mm², equal to:

$$p_F = \frac{F_{Ai}}{d_m h_m}$$

F_{Ai} : Support force acting on the rudder stock bearing, in N

d_m : Actual inner diameter, in mm, of the rudder stock bearings (contact diameter)

h_m : Bearing length, in mm (see [6.2.3])

$p_{F,ALL}$: Allowable bearing pressure, in N/mm², defined in Tab 5.

Values greater than those given in Tab 5 may be accepted by the Society on the basis of specific tests.

6.2.2 An adequate lubrication of the bearing surface is to be ensured.

6.2.3 The length/diameter ratio of the bearing surface is not to be greater than 1,2.

6.2.4 The manufacturing clearance t_0 on the diameter of metallic supports is to be not less than the value obtained, in mm, from the following formula:

$$t_0 = \frac{d_m}{1000} + 1$$

In the case of non-metallic supports, the clearances are to be carefully evaluated on the basis of the thermal and distortion properties of the materials employed. In any case, for non metallic supports, the clearance on support diameter is to be not less than 1,5 mm unless a smaller clearance is supported by the manufacturer's recommendation and there is documented evidence of satisfactory service history with a reduced clearance.

6.2.5 Liners and bushes are to be fitted in way of the bearings. Their minimum thickness is to be equal to:

- 8 mm for metallic and synthetic materials
- 22 mm for lignum vitae material.

Table 5 : Allowable bearing pressure

Bearing material	$p_{F,ALL}$, in N/mm ²
Lignum vitae	2,5
White metal, oil lubricated	4,5
Synthetic material with hardness greater than 60 Shore D (1)	5,5
Steel, bronze and hot-pressed bronze-graphite materials (2)	7,0
(1) Indentation hardness test at 23°C and with 50% moisture to be performed according to a recognised standard. Type of synthetic bearing materials is to be approved by the Society.	
(2) Stainless and wear-resistant steel in combination with stock liner approved by the Society.	

6.3 Pintle bearings

6.3.1 The mean bearing pressure acting on the gudgeons is to be in compliance with the following formula: $p_F \leq p_{F,ALL}$ where:

p_F : Mean bearing pressure acting on the gudgeons, in N/mm², equal to:

$$p_F = \frac{F_{Ai}}{d_{AC} h_L}$$

F_{Ai} : Support force acting on the pintle, in N

d_{AC} : Actual diameter, in mm, of the rudder pintles (contact diameter)

h_L : Bearing length, in mm (see [6.3.3])

$p_{F,ALL}$: Allowable bearing pressure, in N/mm², defined in Tab 5.

Values greater than those given in Tab 5 may be accepted by the Society on the basis of specific tests.

6.3.2 An adequate lubrication of the bearing surface is to be ensured.

6.3.3 The length/diameter ratio of the bearing surface is not to be less than 1 and not to be greater than 1,2.

6.3.4 The manufacturing clearance t_0 on the diameter of metallic supports is to be not less than the value obtained, in mm, from the following formula:

$$t_0 = \frac{d_{AC}}{1000} + 1$$

In the case of non-metallic supports, the clearances are to be carefully evaluated on the basis of the thermal and distortion properties of the materials employed. In any case, for non-metallic supports, the clearance on support diameter is to be not less than 1,5 mm.

6.3.5 The thickness of any liner or bush, in mm, is to be not less than the greater of:

- $0,01\sqrt{F_{Ai}}$
- the minimum thickness defined in [6.2.5].

6.4 Pintles

6.4.1 Rudder pintles are to have a diameter not less than the value obtained, in mm, from the following formula:

$$d_A = \frac{0,38V_{AV}}{V_{AV} + 3} \sqrt{F_{Ai} k_1} + f_C$$

where:

d_A : corresponds to d_U value shown in Fig 4

F_{Ai} : Force, in N, acting on the pintle, as specified in Tab 4

f_C : Coefficient depending on corrosion, whose value may generally be obtained from the following formula:

$$f_C = 30\sqrt{k_1}$$

The Society may accept lower values of f_C , considering the ship's dimensions and satisfactory service experience of corrosion control systems adopted.

6.4.2 Provision is to be made for a suitable locking device to prevent the accidental loosening of pintles.

6.4.3 The pintles are to have a conical coupling with a taper on diameter in accordance with [5.3.1].

The conical coupling is to be secured by a nut. The dimensions of the massive part and slogging nut are to be in accordance with the following formulae:

$$d_E \geq d_M + 0,6 d_A$$

$$t_N \geq 0,60 d_G$$

$$d_N \geq 1,2 d_0 \text{ and, in any case, } d_N \geq 1,5 d_G$$

where:

d_A : Pintle diameter defined in [6.4.1]

d_E : External diameter, in mm, of the massive part of Fig 4, having the thickness t_s

d_M : Mean diameter, in mm, of the conical bore, as defined in [5.2.3]

t_s, d_G, t_N, d_N, d_0 : Geometrical parameters of the coupling, defined in Fig 4.

The above minimum dimensions of the locking nut are only given for guidance, the determination of adequate scantlings being left to the Designer.

6.4.4 The length of the pintle housing in the gudgeon, which corresponds to t_i in Fig 4, is to be not less than the greater of the values obtained, in mm, from the following formulae:

$$h_L = 0,35\sqrt{F_{Ai}k_i}$$

$$h_L = d_A$$

where:

F_{Ai} : Force, in N, acting on the pintle, as specified in Tab 4.

The thickness of pintle housing in the gudgeon, in mm, is to be not less than $0,25 d_A$, where d_A is defined in [6.4.1].

6.4.5 The required push-up pressure for pintle bearings, in N/mm^2 , is to be determined by the following formula:

$$p_{req} = 0,4 \frac{F_{Ai}d_A}{d_M^2 t_i}$$

where:

d_M : Mean diameter, in mm, of the conical bore defined in [5.2.3]

t_i : Geometrical parameter of the coupling defined in Fig 4.

The push-up length is to be calculated according to [5.3.3] using required push-up pressure and pintle bearing properties.

7 Rudder blade scantlings

7.1 General

7.1.1 Application

The requirements in [7.1] to [7.6] apply to streamlined rudders and, when applicable, to rudder blades of single plate rudders.

7.1.2 Rudder blade structure

The structure of the rudder blade is to be such that stresses are correctly transmitted to the rudder stock and pintles. To this end, horizontal and vertical web plates are to be provided.

Horizontal and vertical webs acting as main bending girders of the rudder blade are to be suitably reinforced.

7.1.3 Access openings

Streamlined rudders, including those filled with pitch, cork or foam, are to be fitted with plug-holes and the necessary devices to allow their mounting and dismounting.

Access openings to the pintles are to be provided. If necessary, the rudder blade plating is to be strengthened in way of these openings.

The corners of openings intended for the dismantling of pintles or stock nuts are to be rounded off with a radius as large as practicable.

Where the access to the rudder stock nut is closed with a welded plate, a full penetration weld is to be provided.

7.1.4 Connection of the rudder blade to the trailing edge for rudder blade area greater than 6 m²

Where the rudder blade area is greater than 6 m², the connection of the rudder blade plating to the trailing edge is to be made by means of a forged or cast steel fashion piece, a flat or a round bar.

7.1.5 Rudder horn recess

Except in way of solid parts in cast steel, the corners of the recess intended for the passage of the rudder horn heel are to be designed with a radius at least equal to 5 times the plate thickness, but in no case smaller than 100 mm.

Welding in side plate is to be avoided in or at the end of these radii.

Edges of side plate and weld adjacent to radii are to be ground smooth.

7.2 Strength checks

7.2.1 Bending stresses

For the generic horizontal section of the rudder blade it is to be checked that the bending stress σ , in N/mm^2 , induced by the loads defined in [3.1], is in compliance with the following formula: $\sigma \leq \sigma_{ALL}$

where:

σ_{ALL} : Allowable bending stress, in N/mm^2 , specified in Tab 6.

7.2.2 Shear stresses

For the generic horizontal section of the rudder blade it is to be checked that the shear stress τ , in N/mm^2 , induced by the loads defined in [3.1], is in compliance with the following formula: $\tau \leq \tau_{ALL}$

where:

τ_{ALL} : Allowable shear stress, in N/mm^2 , specified in Tab 6.

7.2.3 Combined bending and shear stresses

For the generic horizontal section of the rudder blade it is to be checked that the equivalent stress σ_E is in compliance with the following formula: $\sigma_E \leq \sigma_{E,ALL}$

where:

σ_E : Equivalent stress induced by the loads defined in [3.1], to be obtained, in N/mm², from the following formula:

$$\sigma_E = \sqrt{\sigma^2 + 3\tau^2}$$

σ : Bending stress, in N/mm²

τ : Shear stress, in N/mm²

$\sigma_{E,ALL}$: Allowable equivalent stress, in N/mm², specified in Tab 6.

Table 6 : Allowable stresses for rudder blade scantlings

Type of rudder blade	Allowable bending stress σ_{ALL} in N/mm ²	Allowable shear stress τ_{ALL} in N/mm ²	Allowable equivalent stress $\sigma_{E,ALL}$ in N/mm ²
General	110 / k	50 / k	120 / k
In way of the recess for rudder horn pintle on semi-spade rudders(1)	75	50	100
(1) No benefit is given for high tensile steel in this case.			

7.3 Rudder blade plating

7.3.1 Plate thickness

The thickness of each rudder blade plate panel is to be not less than the value obtained, in mm, from the following formula:

$$t_F = 5,5s\beta \sqrt{k\left(T + \frac{C_R 10^{-4}}{A}\right) + 2,5}$$

where:

β : Coefficient equal to:

$$\beta = \sqrt{1,1 - 0,5\left(\frac{s}{b_L}\right)^2}$$

to be taken not greater than 1,0 if $b_L/s > 2,5$

s : Length, in m, of the shorter side of the plate panel

b_L : Length, in m, of the longer side of the plate panel.

7.3.2 Thickness of the top and bottom plates of the rudder blade

The thickness of the top and bottom plates of the rudder blade is to be taken as the maximum of:

- the thickness t_F defined in [7.3.1], by considering the relevant values of s and b_L , for both the top and bottom plates
- 1,2 times the thicknesses obtained for the attached side platings around the top and bottom plates, respectively, calculated according to [7.3.1], by considering the relevant values of s and b_L

Where the rudder is connected to the rudder stock with a coupling flange, the thickness of the top plate which is welded in extension of the rudder coupling flange is to be not less than 1,1 times the thickness calculated above.

7.3.3 Web thickness

Web thickness is to be at least 70% of that required for rudder plating and in no case is it to be less than 8 mm, except for the upper and lower horizontal webs. The thickness of each of these webs is to be uniform and not less than that of the web panel having the greatest thickness t_F , as calculated in [7.3.1]. In any case it is not required that the thickness is increased by more than 20% in respect of normal webs.

When the design of the rudder does not incorporate a mainpiece, this is to be replaced by two vertical webs closely spaced, having thickness not less than that obtained from Tab 7. In rudders having area less than 6 m², one vertical web only may be accepted provided its thickness is at least twice that of normal webs.

7.3.4 Thickness of side plating and vertical web plates welded to solid part or to rudder coupling flange

The thickness, in mm, of the vertical web plates welded to the solid part where the rudder stock is housed, or welded to the rudder coupling flange, as well as the thickness of the rudder side plating under this solid part, or under the rudder coupling flange, is to be not less than the value obtained, in mm, from Tab 7.

7.3.5 Reinforced strake of semi-spade rudders

A reinforced strake is to be provided in the lower pintle zone of semi-spade rudders. Its thickness is to be not less than 1,6 t_F , where t_F is defined in [7.3.1]. This strake is to be extended forward of the main vertical web plate (see Fig 6).

7.3.6 Main vertical webs of semi-spade rudders

The thickness of the main vertical web plate in the area between the rudder blade upper part and the pintle housing of semi-spade rudders is to be not less than $2,6 t_F$, where t_F is defined in [7.3.1].

Under the pintle housing the thickness of this web is to be not less than the value obtained from Tab 7.

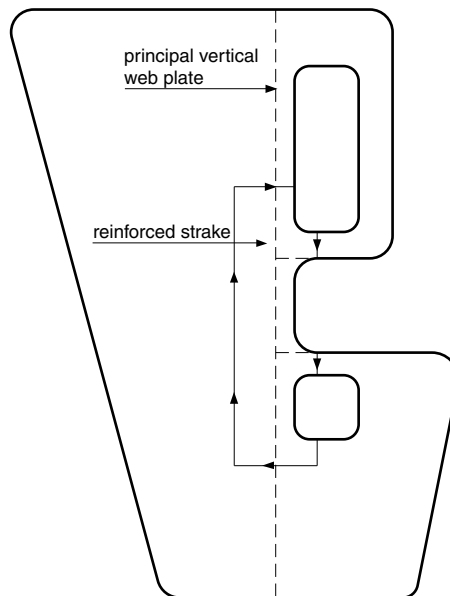
Where two main vertical webs are fitted, the thicknesses of these webs are to be not less than the values obtained from Tab 7 depending on whether the web is fitted in a rudder blade area without opening or if the web is along the recess cut in the rudder for the passage of the rudder horn heel.

Table 7 : Thickness of the vertical webs and rudder side plating welded to solid part or to rudder coupling flange

Type of rudder	Thickness of vertical web plates, in mm		Thickness of rudder plating, in mm	
	Rudder blade without opening	At opening boundary	Rudder blade without opening	Area with opening
Rudder types 1, 2, 3 and 4 (see Tab 4)	t_F	$1,3 t_F$	t_F	$1,2 t_F$
Rudder type 5 (see Tab 4)	$1,2 t_F$	$1,6 t_F$	$1,2 t_F$	$1,4 t_F$
Rudder types 6, 7, 8, 9 and 10 (see Tab 4)	$1,4 t_F$	$2,0 t_F$	$1,3 t_F$	$1,6 t_F$

Note 1: t_F as defined in [7.3.1].

Figure 6 : Reinforced strake extension for semi-spade rudders



7.3.7 Welding

The welded connections of blade plating to vertical and horizontal webs are to be in compliance with the applicable requirements of NR216 Materials and Welding.

Where the welds of the rudder blade are accessible only from outside of the rudder, slots on a flat bar welded to the webs are to be provided to support the weld root, to be cut on one side of the rudder only.

Slot-welding is to be limited as far as possible. Slot welding is not to be used in areas with large in-plane stresses transverse to the slots or in way of cut-out areas of semi-spade rudders.

When slot welding is applied, the length of the slots is to be at least 75 mm with a breadth of 2 times the rudder plate thickness t_F , in mm. The distance between ends of slots is not to be greater than 125 mm. The slots are to be fillet welded around the edges and filled with a suitable compound, e.g. epoxy putty. Slots are not to be filled with weld.

7.3.8 Rudder nose plate thickness

Rudder nose plates are to have a thickness not less than:

- $1,25 t_F$ without exceeding 22 mm, for $t_F < 22$ mm
- t_F , for $t_F \geq 22$ mm

where t_F is defined in [7.3.1].

The rudder nose plate thickness may be increased on a case by case basis to be considered by the Society.

7.4 Connections of rudder blade structure with solid parts in forged or cast steel

7.4.1 General

Solid parts in forged or cast steel which ensure the housing of the rudder stock or of the pintle are in general to be connected to the rudder structure by means of two horizontal web plates and two vertical web plates.

7.4.2 Minimum section modulus of the connection with the rudder stock housing

The section modulus of the cross-section of the structure of the rudder blade which is connected with the solid part where the rudder stock is housed, which is made by vertical web plates and rudder plating, is to be not less than that obtained, in cm^3 , from the following formula:

$$w_s = c_s d_1^3 \left(\frac{H_E - H_X}{H_E} \right) \frac{k}{k_1} 10^{-4}$$

where:

c_s : Coefficient, to be taken equal to:

- $c_s = 1,0$ if there is no opening in the rudder plating or if such openings are closed by a full penetration welded plate
- $c_s = 1,5$ if there is an opening in the considered cross-section of the rudder

d_1 : Rudder stock diameter, in mm, defined in [4.1.2]

H_E : Vertical distance, in m, between the lower edge of the rudder blade and the upper edge of the solid part

H_X : Vertical distance, in m, between the considered cross-section and the upper edge of the solid part

k, k_1 : Material factors, defined in [1.4], for the rudder blade plating and the rudder stock, respectively.

7.4.3 Calculation of the actual section modulus of the connection with the rudder stock housing

The actual section modulus of the cross-section of the structure of the rudder blade which is connected with the solid part where the rudder stock is housed is to be calculated with respect to the symmetrical axis of the rudder.

The breadth of the rudder plating to be considered for the calculation of this actual section modulus is to be not greater than that obtained, in m, from the following formula:

$$b = s_v + 2 \frac{H_X}{m}$$

where:

s_v : Spacing, in m, between the two vertical webs (see Fig 7)

H_X : Distance defined in [7.4.2]

m : Coefficient to be taken, in general, equal to 3.

Where openings for access to the rudder stock nut are not closed by a full penetration welded plate according to [7.1.3], they are to be deducted (see Fig 7).

7.4.4 Thickness of horizontal web plates

The thickness of the horizontal web plates connected to the upper and lower ends of the solid part, as well as that of the rudder blade plating between these webs, is to be not less than the greater of the values obtained, in mm, from the following formulae:

$$t_H = 1,2 t_F$$

$$t_H = 0,045 \frac{d_s^2}{s_H}$$

where:

t_F : Defined in [7.3.1]

d_s : Diameter, in mm, to be taken equal to:

- d_1 for the solid part connected to the rudder stock
- d_A for the solid part connected to the pintle

d_1 : Rudder stock diameter, in mm, defined in [4.1.2]

d_A : Pintle diameter, in mm, defined in [6.4.1]

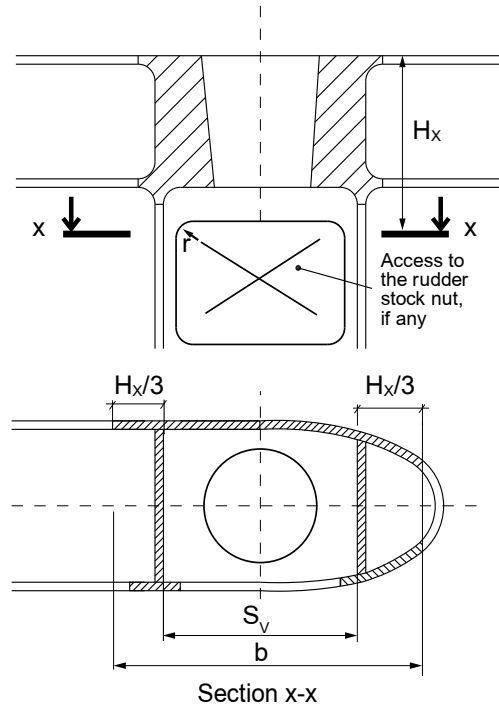
s_H : Spacing, in mm, between the two horizontal web plates.

Different thickness may be accepted when justified on the basis of direct calculations submitted to the Society for approval.

7.4.5 Thickness of side plating and vertical web plates welded to the solid part

The thickness of the vertical web plates welded to the solid part where the rudder stock is housed as well as the thickness of the rudder side plating under this solid part is to be not less than the values obtained, in mm, from Tab 7.

Figure 7 : Cross-section of the connection between rudder blade structure and rudder stock housing



7.4.6 Solid part protrusions

The solid parts are to be provided with protrusions. Vertical and horizontal web plates of the rudder are to be butt welded to these protrusions.

These protrusions are not required when the web plate thickness is less than:

- 10 mm for web plates welded to the solid part on which the lower pintle of a semi-spade rudder is housed and for vertical web plates welded to the solid part of the rudder stock coupling of spade rudders
- 20 mm for the other web plates.

7.5 Connection of the rudder blade with the rudder stock by means of horizontal flanges

7.5.1 Minimum section modulus of the connection

The section modulus of the cross-section of the structure of the rudder blade which is directly connected with the flange, which is made by vertical web plates and rudder blade plating, is to be not less than the value obtained, in cm^3 , from the following formula:

$$w_s = 1,3 d_1^3 10^{-4}$$

where d_1 is the rudder stock diameter d_{TF} , in mm, to be calculated in compliance with [4.1.2], taking k_1 equal to 1.

7.5.2 Actual section modulus of the connection

The section modulus of the cross-section of the structure of the rudder blade which is directly connected with the flange is to be calculated with respect to the symmetrical axis of the rudder.

For the calculation of this actual section modulus, the length of the rudder cross-section equal to the length of the rudder coupling flange is to be considered.

Where the rudder plating is provided with an opening under the rudder coupling flange, the actual section modulus of the rudder blade is to be calculated in compliance with [7.4.3].

7.5.3 Welding of the rudder blade structure to the rudder blade flange

The welds between the rudder blade structure and the rudder blade flange are to be full penetrated (or of equivalent strength) and are to be 100% inspected by means of non-destructive tests.

Where the full penetration welds of the rudder blade are accessible only from outside of the rudder, a backing flat bar is to be provided to support the weld root.

The external fillet welds between the rudder blade plating and the rudder coupling flange are to be of concave shape and their throat thickness is to be at least equal to 0,5 times the rudder blade thickness.

Moreover, the rudder coupling flange is to be checked before welding by non-destructive inspection for lamination and inclusion detection in order to reduce the risk of lamellar tearing.

7.5.4 Thickness of side plating and vertical web plates welded to the rudder coupling flange

The thickness of the vertical web plates directly welded to the rudder coupling flange as well as the plating thickness of the rudder blade upper strake in the area of the connection with the rudder coupling flange are to be not less than the values obtained, in mm, from Tab 7.

7.6 Single plate rudders

7.6.1 Mainpiece diameter

The mainpiece diameter is to be obtained from the formulae in [4.1.2] or [4.1.3].

In any case, the mainpiece diameter is to be not less than the stock diameter.

For spade rudders the lower third may taper down to 0,75 times the stock diameter.

7.6.2 Blade thickness

The blade thickness is to be not less than the value obtained, in mm, from the following formula:

$$t_b = 1,5sV_{AV}\sqrt{k} + 2,5$$

where:

s : Spacing of stiffening arms, in m, to be taken not greater than 1 m (see Fig 8).

7.6.3 Arms

The thickness of the arms is to be not less than the blade thickness.

The section modulus of the generic section is to be not less than the value obtained, in cm³, from the following formula:

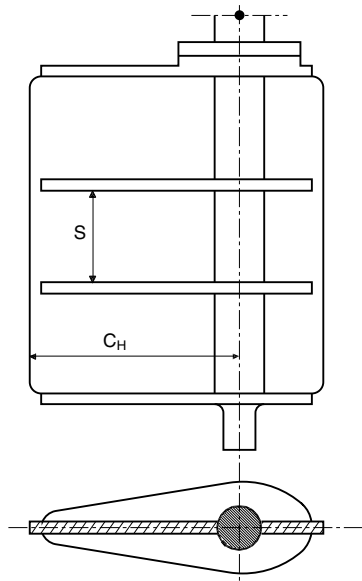
$$Z_A = 0,5 s C_H^2 V_{AV}^2 k$$

where:

C_H : Horizontal distance, in m, from the aft edge of the rudder to the centreline of the rudder stock (see Fig 8)

s : Defined in [7.6.2].

Figure 8 : Single plate rudder



8 Rudder horn and solepiece scantlings

8.1 General

8.1.1 The weight of the rudder is normally supported by a carrier bearing inside the rudder trunk.

In the case of unbalanced rudders having more than one pintle, the weight of the rudder may be supported by a suitable disc fitted in the solepiece gudgeon.

Robust and effective structural rudder stops are to be fitted, except where adequate positive stopping arrangements are provided in the steering gear, in compliance with the applicable requirements of Pt C, Ch 1, Sec 13.

8.2 Rudder horn**8.2.1 General**

When the connection between the rudder horn and the hull structure is designed as a curved transition into the hull plating, special consideration is to be paid to the effectiveness of the rudder horn plate in bending and to the stresses in the transverse web plates.

8.2.2 Loads

The following loads acting on the generic section of the rudder horn are to be considered:

- bending moment
- shear force
- torque.

Bending moment, shear forces and torque are to be calculated according to Ch 12, App 1, [1.6], or Ch 12, App 1, [1.7], depending on the relevant type of rudder.

8.2.3 Shear stress check

For the generic section of the rudder horn, it is to be checked that:

$$\tau_S \leq \tau_{ALL}$$

where:

τ_S : Shear stress, in N/mm², to be obtained according to, either Ch 12, App 1, [1.6] or Ch 12, App 1, [1.7]

τ_{ALL} : Allowable shear stress, in N/mm²:

$$\tau_{ALL} = 48 / k_1$$

8.2.4 Combined stress strength check

For the generic section of the rudder horn, it is to be checked that:

$$\sigma_E \leq \sigma_{E,ALL}$$

$$\sigma_B \leq \sigma_{B,ALL}$$

where:

σ_E : Equivalent stress to be obtained, in N/mm², from the following formula:

$$\sigma_E = \sqrt{\sigma_B^2 + 3(\tau_S^2 + \tau_T^2)}$$

σ_B : Bending stress, in N/mm², to be obtained from, either Ch 12, App 1, [1.6] or Ch 12, App 1, [1.7], depending on the rudder type

τ_S, τ_T : Shear and torsional stresses, in N/mm², to be obtained according to, either Ch 12, App 1, [1.6] or Ch 12, App 1, [1.7]

$\sigma_{E,ALL}$: Allowable equivalent stress, in N/mm², equal to:

$$\sigma_{E,ALL} = 120 / k_1$$

$\sigma_{B,ALL}$: Allowable bending stress, in N/mm², equal to:

$$\sigma_{B,ALL} = 67 / k_1.$$

8.2.5 Rudder horn plating

The thickness, in mm, of the rudder horn side plating is not to be less than:

$$t = 2,4\sqrt{(Lk)}$$

where

L : Rule length as defined in Ch 1, Sec 2, [3.1]

k : Material factor as given in [1.4].

8.3 Connection of after peak structures with the rudder horn**8.3.1 General**

The requirement in Ch 11, Sec 3, [3] apply to the connection between peak structure and rudder horn where the sternframe is of an open type and is fitted with the rudder horn.

8.4 Solepieces**8.4.1 Strength checks**

For the generic section of the solepiece, it is to be checked that:

$$\sigma_B \leq \sigma_{B,ALL}$$

$$\tau \leq \tau_{ALL}$$

where:

- σ_B : Bending stress, in N/mm², to be obtained according to Ch 12, App 1, [1.5.2]
 τ : Shear stress, in N/mm², to be obtained according to Ch 12, App 1, [1.5.2]
 $\sigma_{B,ALL}$: Allowable bending stress, in N/mm², equal to:
 $\sigma_{B,ALL} = 80 / k_1$
 τ_{ALL} : Allowable shear stress, in N/mm², equal to:
 $\tau_{ALL} = 48 / k_1$.

8.4.2 Minimum section modulus around the horizontal axis

The section modulus around the horizontal axis Y (see Ch 12, App 1, Fig 11) is to be not less than the value obtained, in cm³, from the following formula:

$$W_Y = 0,5 W_Z$$

where:

W_Z : Section modulus, in cm³, around the vertical axis Z (see Ch 12, App 1, Fig 11).

9 Simplex rudder shaft**9.1 Scantlings****9.1.1 Diameter of the rudder shaft**

The rudder shaft diameter is to be not less than the value obtained, in mm, from the following formula:

$$d = 17,9 \left(\frac{\alpha A (V_{AV} + 2)^2}{\ell} \right)^{1/3}$$

where:

- α : Coefficient equal to:
- $\alpha = b (\ell - b + a)$ if $a \leq b$
 - $\alpha = a (\ell - a + b)$ if $a > b$

a, b, ℓ : Geometrical parameters, in m, defined in Fig 9.

9.1.2 Sectional area of rudder shaft

The overall sectional area of the rudder shaft is to be not less than the greater of the following values:

- 70% of the sectional area for the propeller post defined in Ch 11, Sec 3, [4.2]
- value of the sectional area of the pintle supporting half the rudder blade, whose diameter is to be calculated from the formula in [6.4.1].

If the latter value is the greater, it is to be applied only where the rudder bears on the rudder shaft; in such case, it is recommended that an overthickness or a bush is provided in way of the bearing areas.

9.1.3 Bearings

The bearing length of the rudder shaft is to be not less than 1,2 d, where d is the shaft diameter defined in [9.1.1].

The mean pressure acting on the bearings is not to exceed the relevant allowable values, defined in Tab 5.

9.1.4 The manufacturing clearance t_0 on the diameter of metallic supports is to be not less than the value obtained, in mm, from the following formula:

$$t_0 = \frac{d_A}{1000} + 1$$

where:

d_A : Actual inner diameter, in mm, of the rudder shaft bearing (contact diameter).

In the case of non-metallic supports, the clearances are to be carefully evaluated on the basis of the thermal and distortion properties of the materials employed.

In any case, for non-metallic supports, the clearance on support diameter is to be not less than 1,5 mm.

9.2 Connections**9.2.1 Connection with the hull**

The shaft is to be connected with the hull by means of a vertical coupling flange having thickness at least equal to $d/4$, where d is the shaft diameter, obtained from the formula in [9.1.1] (see Fig 9).

The coupling flange is to be secured by means of six fitted bolts. The shank diameter of the bolts is to be not less than the coupling flange thickness defined above.

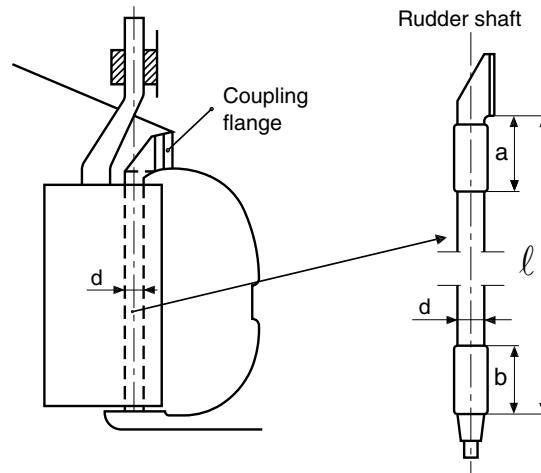
The distance from the bolt centre lines to the coupling flange edge is to be not less than 1,17 times the bolt diameter defined above.

9.2.2 Connection with the solepiece

The rudder shaft is to be connected with the solepiece by means of a cone coupling, having a taper on the radius equal to about 1/10 and housing length not less than 1,1 d, where d is obtained from the formula in [9.1.1] (See Fig 9).

The mean pressure exerted by the rudder shaft on the bearing is to be not greater than the relevant allowable bearing pressure, defined in Tab 5 assuming a rudder with two pintles.

Figure 9 : Simplex rudder shaft geometry



10 Nozzles

10.1 General

10.1.1 The requirements of this Article apply to the scantlings of steering and fixed nozzles for which the power transmitted to the propeller is less than the value obtained, in kW, from the following formula:

$$P = \frac{16900}{d_M}$$

where:

d_M : Inner diameter of the nozzle, in m.

Nozzles for which the power transmitted is greater than the value obtained from the above formula are considered on a case-by-case basis.

10.1.2 Nozzles normally consist of a double skin cylindrical structure stiffened by ring webs and other longitudinal webs placed perpendicular to the nozzle.

One of the ring webs is to be fitted in way of the axis of rotation of the nozzle.

10.1.3

The section modulus W_N , in cm^3 , of the nozzle double skin profile (half nozzle cross section) around its neutral axis parallel to the center line, is not to be less than:

$$W_N = n d^2 b V_{AV}^2$$

where:

d : Inner diameter of nozzle, in m

b : Length of nozzle, in m

n : Coefficient taken equal to:

- 1,0 for steering nozzles
- 0,7 for fixed nozzles.

10.1.4 Care is to be taken in the manufacture of the nozzle to ensure the welded connection between plating and webs.

10.1.5 The internal part of the nozzle is to be adequately protected against corrosion.

10.2 Nozzle plating and internal diaphragms

10.2.1 The thickness of the inner plating of the nozzle is to be not less than the value obtained, in mm, from the following formulae:

$$t_F = (0,085\sqrt{Pd_M} + 9,65)\sqrt{k} \quad \text{for } P \leq \frac{6100}{d_M}$$

$$t_F = (0,085\sqrt{Pd_M} + 11,65)\sqrt{k} \quad \text{for } P > \frac{6100}{d_M}$$

where:

P, d_M : Defined in [10.1.1].

The thickness t_F is to be extended to a length, across the transverse section containing the propeller blade tips, equal to one fourth of the total nozzle length.

Outside this length, the thickness of the inner plating is to be not less than $(t_F - 7)$ mm and, in any case, not less than 7 mm.

10.2.2 The thickness of the outer plating of the nozzle is to be not less than $(t_F - 9)$ mm, where t_F is defined in [10.2.1] and, in any case, not less than 7 mm.

10.2.3 The thicknesses of ring webs and longitudinal webs are to be not less than $(t_F - 7)$ mm, where t_F is defined in [10.2.1], and, in any case, not less than 7 mm.

However, the thickness of the ring web, in way of the headbox and pintle support structure, is to be not less than t_F .

The Society may consider reduced thicknesses where an approved stainless steel is used, in relation to its type.

10.3 Nozzle stock

10.3.1 The diameter of the nozzle stock is to be not less than the value obtained, in mm, from the following formula:

$$d_{NTF} = 6,42 (M_T k_1)^{1/3}$$

where:

M_T : Torque, to be taken as the greater of those obtained, in N.m, from the following formulae:

- $M_{TAV} = 0,3 S_{AV} a$
- $M_{TAD} = S_{AD} b$

S_{AV} : Force, in N, equal to: $S_{AV} = 150 V_{AV}^2 A_N$

S_{AD} : Force, in N, equal to: $S_{AD} = 200 V_{AD}^2 A_N$

A_N : Area, in m^2 , equal to: $A_N = 1,35 A_{1N} + A_{2N}$

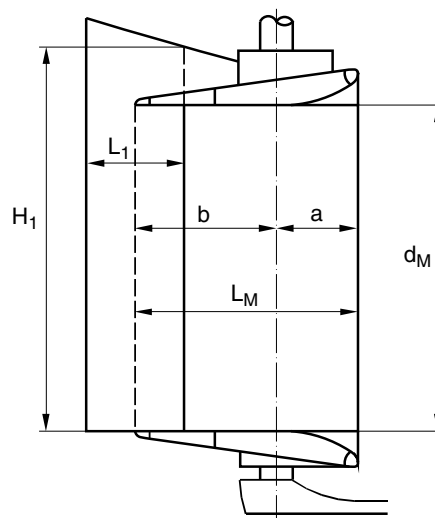
A_{1N} : Area, in m^2 , equal to: $A_{1N} = L_M d_M$

A_{2N} : Area, in m^2 , equal to: $A_{2N} = L_1 H_1$

a, b, L_M, d_M, L_1, H_1 : Geometrical parameters of the nozzle, in m, defined in Fig 10.

The diameter of the nozzle stock may be gradually tapered above the upper stock bearing so as to reach, in way of the tiller or quadrant, the value obtained, in mm, from the following formula: $d_{NT} = 0,75 d_{NTF}$

Figure 10 : Geometrical parameters of the nozzle



10.4 Pintles

10.4.1 The diameter of the pintles is to be not less than the value obtained, in mm, from the following formula:

$$d_A = \left(\frac{0,35V_{AV}}{V_{AV} + 3} \sqrt{S_{AV} + 30} \right) \sqrt{k_1}$$

where:

S_{AV} : Defined in [10.3.1].

10.4.2 The length/diameter ratio of the pintle is not to be less than 1 and not to be greater than 1,2.

Smaller values of h_A may be accepted provided that the pressure on the gudgeon bearing p_F is in compliance with the following formula: $p_F \leq p_{F,ALL}$

where:

p_F : Mean bearing pressure acting on the gudgeon, to be obtained in N/mm², from the following formula:

$$p_F = \frac{0,6S'}{d'_A h'_A}$$

S' : The greater of the values S_{AV} and S_{AD} , in N, defined in [10.3.1]

d'_A : Actual pintle diameter, in mm

h'_A : Actual bearing length of pintle, in mm

$p_{F,ALL}$: Allowable bearing pressure, in N/mm², defined in Tab 5.

10.5 Nozzle coupling

10.5.1 Diameter of coupling bolts

The diameter of the coupling bolts is to be not less than the value obtained, in mm, from the following formula:

$$d_B = 0,62 \sqrt{\frac{d_{NTF}^3 k_{1B}}{n_B e_M k_{1S}}}$$

where:

d_{NTF} : Diameter of the nozzle stock, in mm, defined in [10.3.1]

k_{1S} : Material factor k_1 for the steel used for the stock

k_{1B} : Material factor k_1 for the steel used for the bolts

e_M : Mean distance, in mm, from the bolt axes to the longitudinal axis through the coupling centre (i.e. the centre of the bolt system)

n_B : Total number of bolts, which is to be not less than:

- 4 if $d_{NTF} \leq 75$ mm
- 6 if $d_{NTF} > 75$ mm.

Non-fitted bolts may be used provided that, in way of the mating plane of the coupling flanges, a key is fitted having a section of $(0,25d_{NT} \times 0,10d_{NT})$ mm², where d_{NT} is defined in [10.3.1], and keyways in both the coupling flanges, and provided that at least two of the coupling bolts are fitted bolts.

The distance from the bolt axes to the external edge of the coupling flange is to be not less than 1,2 d_B .

10.5.2 Thickness of coupling flange

The thickness of the coupling flange is to be not less than the value obtained, in mm, from the following formula:

$$t_P = d_B \sqrt{\frac{k_{1F}}{k_{1B}}}$$

where:

d_B : Diameter of the coupling bolts, in mm, defined in [10.5.1]

k_{1B} : Material factor k_1 for the steel used for the bolts

k_{1F} : Material factor k_1 for the steel used for the coupling flange.

10.5.3 Push-up length of cone couplings with hydraulic arrangements for assembling and disassembling the coupling

It is to be checked that the push-up length Δ_E of the nozzle stock tapered part into the boss is in compliance with the following formula: $\Delta_0 \leq \Delta_E \leq \Delta_1$

where:

Δ_0 : The greater of:

- $6,2 \cdot \frac{M_{TR} \eta \gamma}{c d_M t_i \mu_A \beta}$

$$\bullet 16 \cdot \frac{M_{TR} \eta \gamma}{c t_i^2 \beta} \cdot \sqrt{\frac{d_{NTF}^{\xi} - d_{NT}^{\xi}}{d_{NT}^{\xi}}}$$

$$\Delta_1 = \frac{2\eta + 5}{1,8} \cdot \frac{\gamma d_0 R_{eH}}{10^6 c (1 + \rho_1)}$$

$$\rho_1 = \frac{80 \sqrt{d_{NTF}^{\xi} - d_{NT}^{\xi}}}{R_{eH} d_M t_i^2 \left[1 - \left(\frac{d_0}{d_E} \right)^2 \right]}$$

d_{NTF}, d_{NT} : Nozzle stock diameters, in mm, to be obtained from [10.3.1], considering $k_1 = 1$

$\eta, c, \beta, d_M, d_E, \mu_A, \mu, \gamma$: Defined in [5.2.3]

t_i, d_0 : Defined in Fig 4

R_{eH} : Defined in [1.4.3].

10.5.4 Locking device

A suitable locking device is to be provided to prevent the accidental loosening of nuts.

11 Azimuth propulsion system

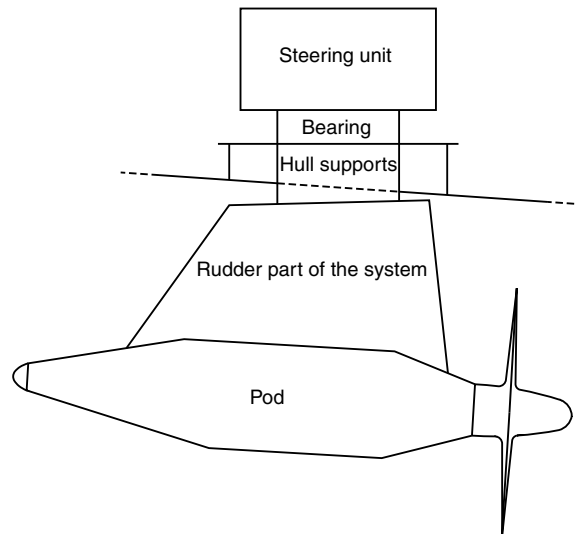
11.1 General

11.1.1 Arrangement

The azimuth propulsion system is constituted by the following sub-systems (see Fig 11):

- the steering unit
- the bearing
- the hull supports
- the rudder part of the system
- the pod, which contains the electric motor in the case of a podded propulsion system.

Figure 11 : Azimuth propulsion system



11.1.2 Application

The requirements of this Article apply to the scantlings of the hull supports, the rudder part and the pod.

The steering unit and the bearing are to comply with the requirements in Pt C, Ch 1, Sec 11 and Pt C, Ch 1, Sec 12 respectively.

11.1.3 Operating conditions

The maximum angle at which the azimuth propulsion system can be oriented on each side when the ship navigates at its maximum speed is to be specified by the Designer. Such maximum angle is generally to be less than 35° on each side.

In general, orientations greater than this maximum angle may be considered by the Society for azimuth propulsion systems during manoeuvres, provided that the orientation values together with the relevant speed values are submitted to the Society for approval.

11.2 Arrangement

11.2.1 Plans to be submitted

In addition to the plans showing the structural arrangement of the pod and the rudder part of the system, the plans showing the arrangement of the azimuth propulsion system supports are to be submitted to the Society for approval. The scantlings of the supports and the maximum loads which act on the supports are to be specified in these drawings.

11.2.2 Locking device

The azimuth propulsion system is to be mechanically lockable in a fixed position, in order to avoid rotations of the system and propulsion in undesirable directions in the event of damage.

11.3 Design loads

11.3.1 The lateral pressure to be considered for scantling of plating and ordinary stiffeners of the azimuth propulsion system is to be determined for an orientation of the system equal to the maximum angle at which the azimuth propulsion system can be oriented on each side when the ship navigates at its maximum speed.

The total force which acts on the azimuth propulsion system is to be obtained by integrating the lateral pressure on the external surface of the system.

The calculations of lateral pressure and total force are to be submitted to the Society for information.

11.4 Plating

11.4.1 Plating of the rudder part of the azimuth propulsion system

The thickness of plating of the rudder part of the azimuth propulsion system is to be not less than that obtained, in mm, from the formulae in [7.3.1], in which the term C_R/A is to be replaced by the lateral pressure calculated according to [11.3].

11.4.2 Plating of the pod

The thickness of plating of the pod is to be not less than that obtained, in mm, from the formulae in Ch 7, Sec 4, where the lateral pressure is to be calculated according to [11.3].

11.4.3 Webs

The thickness of webs of the rudder part of the azimuth propulsion system is to be determined according to [7.3.3], where the lateral pressure is to be calculated according to [11.3].

11.5 Ordinary stiffeners

11.5.1 Ordinary stiffeners of the pod

The scantlings of ordinary stiffeners of the pod are to be not less than those obtained from the formulae in Ch 7, Sec 5, where the lateral pressure is to be calculated according to [11.3].

11.6 Primary supporting members

11.6.1 Analysis criteria

The scantlings of primary supporting members of the azimuth propulsion system are to be obtained by the Designer through direct calculations, to be carried out according to the following requirements:

- the structural model is to include the pod, the rudder part of the azimuth propulsion system, the bearing and the hull supports
- the boundary conditions are to represent the connections of the azimuth propulsion system to the hull structures
- the loads to be applied are those defined in [11.6.2].

The direct calculation analyses (structural model, load and stress calculation, strength checks) carried out by the Designer are to be submitted to the Society for information.

11.6.2 Loads

The following loads are to be considered by the Designer in the direct calculation of the primary supporting members of the azimuth propulsion system:

- gravity loads
- buoyancy
- maximum loads calculated for an orientation of the system equal to the maximum angle at which the azimuth propulsion system can be oriented on each side when the ship navigates at its maximum speed
- maximum loads calculated for the possible orientations of the system greater than the maximum angle at the relevant speed (see [11.1.3])
- maximum loads calculated for the crash stop of the ship obtained through inversion of the propeller rotation
- maximum loads calculated for the crash stop of the ship obtained through a 180° rotation of the pod.

11.6.3 Strength check

It is to be checked that the Von Mises equivalent stress σ_{VM} in primary supporting members, calculated, in N/mm², for the load cases defined in [11.6.2], is in compliance with the following criteria: $\sigma_{VM} \leq \sigma_{ALL}$

where:

σ_{ALL} : Allowable stress, in N/mm², to be taken equal to 0,55 R_{eH}

R_{eH} : Minimum yield stress, in N/mm², of the specified steel. R_{eH} is not to exceed the lower of 0,7 R_m and 450 N/mm²

R_m : Minimum ultimate tensile strength, in N/mm², of the steel used.

When the loads are calculated for crash stop of the ship, the criteria given in [11.6.4] are to be complied with.

When fine mesh finite element analysis is used for the calculation of stresses, the criteria in Ch 8, App 2, [4] is to be applied using the permissible yield utilisation factors for the AC-2 criteria multiplied by σ_{ALL} / R_{eH} .

11.6.4 Strength check for crash stop of the ship

When the loads are calculated for crash stop of the ship, the Von Mises equivalent stress σ_{VM} in primary supporting members, calculated, in N/mm², is to be checked with the following criteria: $\sigma_{VM} \leq \sigma_{CRASH}$

where:

$$\sigma_{CRASH} = 1,25 \sigma_{ALL}$$

σ_{ALL} : Allowable stress as defined in [11.6.3].

When fine mesh finite element analysis is used for the calculation of stresses, the criteria in Ch 8, App 2, [4] is to be applied using the permissible yield utilisation factors for the AC-2 criteria multiplied by σ_{CRASH} / R_{eH} .

11.7 Hull supports of the azimuth propulsion system**11.7.1 Analysis criteria**

The scantlings of hull supports of the azimuth propulsion system are to be obtained by the Designer through direct calculations, to be carried out in accordance with the requirements in [11.6.1].

11.7.2 Loads

The loads to be considered in the direct calculation of the hull supports of the azimuth propulsion system are those specified in [11.6.2].

11.7.3 Strength check

It is to be checked that the Von Mises equivalent stress σ_{VM} in hull supports, in N/mm², calculated for the load cases defined in [11.6.2], is in compliance with the following criteria: $\sigma_{VM} \leq \sigma_{ALL}$

where:

σ_{ALL} : Allowable stress, in N/mm², equal to: $\sigma_{ALL} = 65 / k$

k : Material factor, defined in Ch 4, Sec 1, [2.2].

When the loads are calculated for crash stop of the ship, the criteria given in [11.7.4] is to be complied with.

Values of σ_{VM} greater than σ_{ALL} may be accepted by the Society on a case-by-case basis, depending on the localisation of σ_{VM} and on the type of direct calculation analysis.

When fine mesh finite element analysis is used for the calculation of stresses, the criteria in Ch 8, App 2, [4] is to be applied using the permissible yield utilisation factors for the AC-2 criteria multiplied by σ_{ALL} / R_{eH} .

11.7.4 Strength check for crash stop of the ship

When the loads are calculated for crash stop of the ship, the Von Mises equivalent stress σ_{VM} in primary supporting members, calculated, in N/mm², is to be checked with the following criteria: $\sigma_{VM} \leq \sigma_{CRASH}$

where:

$$\sigma_{CRASH} = 1,25 \sigma_{ALL}$$

σ_{ALL} : Allowable stress as defined in [11.7.3].

When fine mesh finite element analysis is used for the calculation of stresses, the criteria in Ch 8, App 2, [4] is to be applied using the permissible yield utilisation factors for the AC-2 criteria multiplied by σ_{CRASH} / R_{eH} .

11.7.5 Buckling check

A local buckling check is to be carried out, for plate panels which constitute hull supports of the azimuth propulsion system, according to Ch 9, Sec 1 calculating the stresses in the plate panels according to [11.7.1] and [11.7.2].

Section 2 Bulwarks and Guard Rails

1 General

1.1 Application

1.1.1 Bulwarks or guard rails are to be provided at the boundaries of exposed freeboard and superstructure decks.

1.2 General requirements

1.2.1 Minimum height

Bulwarks or guard rails, are to be of 1,0 m in height as a minimum, measured above sheathing, and are to be constructed as required in [2.2] and [3.2]. Where this height would interfere with the normal operation of the ship, a lesser height may be accepted by the Society on a case-by-case basis.

1.2.2 Where superstructures are connected by trunks, open rails are to be fitted for the whole length of the exposed parts of the freeboard deck.

1.2.3 In type A and B-100 ships, open rails on the weather parts of the freeboard deck for at least half the length of the exposed parts are to be fitted.

Alternatively, freeing ports complying with Ch 11, Sec 12, [6.5.2] are to be fitted.

1.2.4 In ships with bulwarks and trunks of breadth not less than 0,6 B, which are included in the calculation of freeboard, open rails on the weather parts of the freeboard deck in way of the trunk for at least half the length of the exposed parts are to be fitted. Alternatively, freeing ports complying with Ch 11, Sec 12, [6.3.1] are to be fitted.

1.2.5 The freeing port area in the lower part of the bulwarks is to be in compliance with the applicable requirements of Ch 11, Sec 12, [6].

2 Bulwarks

2.1 Construction of bulwarks

2.1.1 Bulwark plating is to be stiffened at the upper edge by a suitable rail and supported either by stays or brackets spaced not more than 2,0 m apart.

The free edge of the stay or bracket is to be stiffened.

Bulwarks are to be aligned with the beams located below or are to be connected to them by means of local transverse stiffeners. As an alternative, the lower end of the stay may be supported by a longitudinal stiffener.

In type A, B-60 and B-100 ships, the spacing forward of 0,07 L from the fore end of brackets and stays is to be not greater than 1,2 m.

2.1.2 Bulwarks are to be arranged to ensure that they do not contribute to hull girder strength.

As a rule, bulwarks are not to be connected either to the upper edge of the sheerstrake plate or to the stringer plate.

Failing this, the detail of the connection will be examined by the Society on a case-by-case basis.

2.1.3 Bulwark plating and stays are to be adequately strengthened in way of eye plates used for shrouds or other tackles used for cargo gear operation, as well as in way of hawser holes or fairleads provided for mooring or towing.

2.1.4 Openings in bulwarks are to be arranged so that the protection of the crew is to be at least equivalent to that provided by the horizontal courses in [3.2.3].

For this purpose, vertical rails or bars spaced approximately 230 mm apart may be accepted in lieu of rails or bars arranged horizontally.

Cut-outs in bulwarks for gangways or other openings are to be kept clear of superstructures discontinuities.

Where bulwarks are cut completely, the scantlings of stays or brackets are to be increased with respect to those given in [2.2].

2.1.5 In the case of ships intended for the carriage of timber deck cargoes, the specific provisions of the freeboard regulations are to be complied with.

2.2 Scantlings

2.2.1 Thickness

The thickness of bulwarks on the freeboard deck not exceeding 1100 mm in height is to be not less than:

- 5,5 mm for $L \leq 30$ m
- 6,0 mm for $30 \text{ m} < L \leq 120$ m
- 6,5 mm for $L > 120$ m.

Where the height of the bulwark is equal to or greater than 1800 mm, its thickness is to be equal to that calculated for the side of a superstructure situated in the same location as the bulwark, as obtained from Ch 11, Sec 5, [2.1.1], without being taken less than the minimum thicknesses specified above.

For bulwarks between 1100 mm and 1800 mm in height, their thickness is to be calculated by linear interpolation.

2.2.2 Stays

The gross section modulus of stays in way of the lower part of the bulwark is to be not less than the value $Z_{\text{stay-gr}}$ in cm^3 , obtained from the following formula:

$$Z_{\text{stay-gr}} = 40 s_{\text{stay}} (1 + 0,01 L) h_{\text{blwk}}^2$$

where:

- s_{stay} : Spacing of the stays, in m
 L : Length of ship, in m, to be assumed not greater than 100 m
 h_{blwk} : Height of bulwark from the top of the deck plating to the top of the rail, in m.

The Society may accept scantlings determined by direct calculations as an alternative to the above value of $Z_{\text{stay-gr}}$.

The actual section of the connection between stays and deck structures is to be taken into account when calculating the above section modulus.

To this end, the bulb or face plate of the stay may be taken into account only where welded to the deck; in this case the beam located below is to be connected by double continuous welding.

For stays with strengthening members not connected to the deck, the calculation of the required minimum section modulus is considered by the Society on a case-by-case basis.

At the ends of the ship, where the bulwark is connected to the sheerstrake, an attached plating having width not exceeding 600 mm may also be included in the calculation of the actual section modulus of stays.

2.2.3 At the ends of partial superstructures and for the distance over which their side plating is tapered into the bulwark, the latter is to have the same thickness as the side plating; where openings are cut in the bulwark at these positions, adequate compensation is to be provided either by increasing the thickness of the plating or by other suitable means.

2.2.4 Bulwarks located in the bow flare area as defined in Ch 11, Sec 1, [3.3] are to be reinforced according to Ch 11, Sec 1, [3], considering the stays as cantilever primary supporting members.

3 Guard rails

3.1 General

3.1.1 Where guard rails are provided, the upper edge of sheerstrake is to be kept as low as possible.

3.1.2 Where superstructures are connected by trunks, open rails are to be fitted along the whole length of the exposed parts of the freeboard deck.

3.1.3 Guard rails fitted on superstructure and freeboard decks shall have at least three courses. In other locations, guard rails with at least two courses shall be fitted.

3.2 Construction of guard rails

3.2.1 Stanchions of guard rails are to comply with the following requirements:

- fixed, removable or hinged stanchions are to be fitted approximately 1,5 m apart
- at least every third stanchion is to be supported by a bracket or stay (other alternatives may be accepted under the requirements of [3.2.2])
- removable or hinged stanchions are to be capable of being locked in the upright position
- in the case of ships with rounded gunwales or sheerstrake, the stanchions are to be placed on the flat part of the deck
- in the case of ships with welded sheerstrake, the stanchions are not to be attached to the sheerstrake, an upstand or a continuous gutter bar.

3.2.2 In lieu of at least every third stanchion supported by a stay, three other alternatives may be accepted:

- at least every third stanchion is of increased breadth: $k b_s = 2,9 b_s$
- at least every second stanchion is of increased breadth: $k b_s = 2,4 b_s$
- every stanchion is of increased breadth: $k b_s = 1,9 b_s$

where:

b_s : breadth of normal stanchion according to the design standard

Flat steel stanchions of increased breadth (see Fig 1) are to be aligned with member below deck. A minimum flat bar 100 x 12 is to be welded to deck by double continuous fillet welds with leg size of minimum 7 mm or as specified by the design standard.

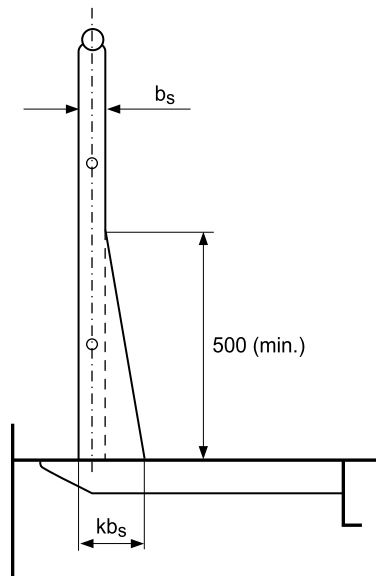
The stanchions with increased breadth need not be aligned with under deck structure for deck plating exceeding 20 mm. This minimum plate thickness may be achieved by doubling plates.

3.2.3 The size of openings, below the lowest course of rails and the deck or upstand, is to be a maximum of 230 mm. The distance between other courses is not to be greater than 380 mm.

3.2.4 Wire ropes may be accepted, in lieu of guard rails, only in special circumstances and then only in limited lengths. In such cases, they are to be made taut by means of turnbuckles.

3.2.5 Chains may be accepted, in lieu of guard rails, only where they are fitted between two fixed stanchions and/or bulwarks. If the opening is wide, the chains are to be fitted with vertical courses to prevent the horizontal courses from spreading apart.

Figure 1 : Guard rail stanchion of increased breadth



Section 3 Propeller shaft brackets

Symbols

F_C : Force, in kN, taken equal to:

$$F_C = \left(\frac{2\pi N}{60}\right)^2 R_p P$$

P : Mass of a propeller blade, in t

N : Number of revolutions per minute of the propeller

R_p : Distance, in m, of the centre of gravity of a blade in relation to the rotation axis of the propeller

σ_{ALL} : Allowable stress, in N/mm²:

$$\sigma_{ALL} = 70 / k$$

k : Material factor, as defined in Ch 4, Sec 1, [2.2]

w_A : Section modulus, in cm³, of the arm at the level of the connection to the hull with respect to a transversal axis

w_B : Section modulus, in cm³, of the arm at the level of the connection to the hull with respect to a longitudinal axis

A : Sectional area, in cm², of the arm

A_s : Shear sectional area, in cm², of the arm

d_p : Propeller shaft diameter, in mm, measured inside the liner, if any.

1 Propeller shaft brackets

1.1 General

1.1.1 Propeller shafting is either enclosed in bossing or independent of the main hull and supported by shaft brackets.

1.2 Double arm propeller shaft brackets

1.2.1 General

This type of propeller shaft bracket consists of two arms arranged, as far as practicable, at right angles and converging in the propeller shaft bossing.

Exceptions to this will be considered by the Society on a case by case basis.

1.2.2 Scantlings of arms

The moment in the arm, in kN.m, is to be obtained from the following formula:

$$M = \frac{F_C}{\sin \alpha} \left(\frac{L}{\ell} d_1 \cos \beta + L - \ell \right)$$

where:

α : Angle between the two arms

β : Angle defined in Fig 1

d_1 : Distance, in m, defined in Fig 1

L, ℓ : Lengths, in m, defined in Fig 2.

It is to be checked that the bending stress σ_F , the compressive stress σ_N and the shear stress τ are in compliance with the following formula:

$$\sqrt{(\sigma_F + \sigma_N)^2 + 3\tau^2} \leq \sigma_{ALL}$$

where:

$$\sigma_F = \frac{M}{w_A} 10^3$$

$$\sigma_N = 10F_C \frac{L \sin \beta}{A \ell \sin \alpha}$$

$$\tau = 10F_C \frac{L \cos \beta}{A_s \ell \sin \alpha}$$

Figure 1 : Angle β and length d_1

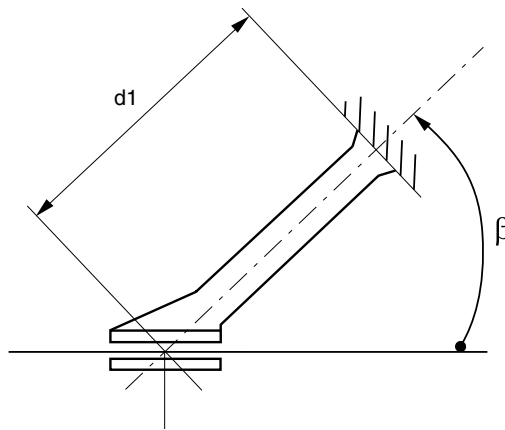
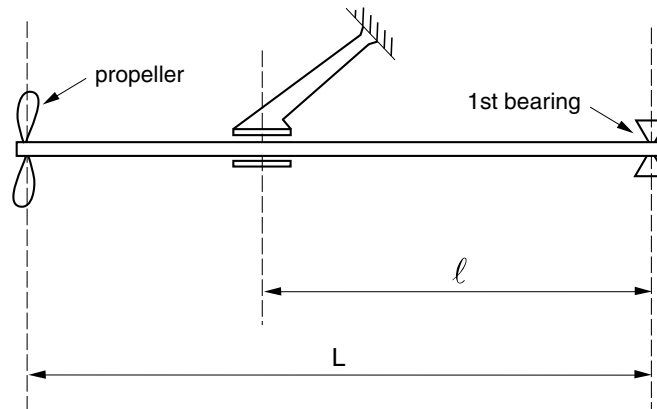


Figure 2 : Lengths L and ℓ



1.2.3 Scantlings of propeller shaft bossing

The length of the propeller shaft bossing is to be not less than the length of the aft sterntube bearing bushes (see Pt C, Ch 1, Sec 7, [2.4]).

The thickness of the propeller shaft bossing is to be not less than $0,33 d_p$.

1.2.4 Bracket arm attachments

In way of bracket arms attachments, the thickness of deep floors or girders is to be suitably increased. Moreover, the shell plating is to be increased in thickness and suitably stiffened.

The securing of the arms to the hull structure is to prevent any displacement of the brackets with respect to the hull.

1.3 Single arm propeller shaft brackets

1.3.1 General

This type of propeller shaft bracket consists of one arm and may be used only on ships less than 65 m in length.

1.3.2 Scantlings of arms

The moment in case of a single arm, in kN.m, is to be obtained from the following formula:

$$M = d_2 0,75 F_c \frac{L}{\ell}$$

where:

d_2 : Length of the arm, in m, measured between the propeller shaft axis and the hull

L, ℓ : Lengths, in m, defined in Fig 2.

It is to be checked that the bending stress σ_f and the shear stress τ are in compliance with the following formula:

$$\sqrt{\sigma_f^2 + 3\tau^2} \leq \sigma_{ALL}$$

where:

$$\sigma_f = \frac{M}{w_B} 10^3$$

$$\tau = 10 F_c \frac{L}{A_s \ell}$$

1.3.3 Scantlings of propeller shaft bossing

The length of the propeller shaft bossing is to be not less than the length of the aft sterntube bearing bushes (see Pt C, Ch 1, Sec 7, [2.4]).

The thickness of the propeller shaft bossing is to be not less than $0,33 d_p$.

1.3.4 Bracket arm attachments

In way of bracket arms attachments, the thickness of deep floors or girders is to be suitably increased. Moreover, the shell plating is to be increased in thickness and suitably stiffened.

The securing of the arm to the hull structure is to prevent any displacement of the bracket with respect to the hull.

1.4 Bossed propeller shaft brackets

1.4.1 General

Where bossed propeller shaft brackets are fitted, their scantlings are to be considered by the Society on a case by case basis.

1.4.2 Scantling of the boss

The length of the boss is to be not less than the length of the aft sterntube bearing bushes (see Pt C, Ch 1, Sec 7, [2.4]).

The thickness of the boss, in mm, is to be not less than $0,33 d_p$.

The aft end of the bossing is to be adequately supported.

1.4.3 Scantling of the end supports

The scantlings of end supports are to be specially considered. Supports are to be adequately designed to transmit the loads to the main structure.

End supports are to be connected to at least two deep floors of increased thickness or connected to each other within the ship.

1.4.4 Stiffening of the boss plating

Stiffening of the boss plating is to be specially considered. At the aft end, transverse diaphragms are to be fitted at every frame and connected to floors of increased scantlings.

At the fore end, web frames spaced not more than four frames apart are to be fitted.

Section 4 Equipment

Symbols

- EN : Equipment Number defined in [1.2]
- σ_{ALL} : Allowable stress, in N/mm², used for the yielding check in [3.9.7], [3.10.7], [3.11.2] and [3.11.3], to be taken as the lesser of:
- $\sigma_{ALL} = 0,67 R_{eH}$
 - $\sigma_{ALL} = 0,40 R_m$
- R_{eH} : Minimum yield stress, in N/mm², of the material, defined in Ch 1, Sec 3, Tab 2
- R_m : Tensile strength, in N/mm², of the material, defined in Ch 1, Sec 3, Tab 2.

1 General

1.1 Application

1.1.1 The requirements of the present Article and Article [2] apply to temporary mooring of a ship within a harbour or sheltered area when the ship is awaiting a berth, the tide, etc.

Therefore, the equipment complying with these requirements:

- is not intended for holding a ship off fully exposed coasts in rough weather or for stopping a ship which is moving or drifting.
- is intended for holding a ship in good holding ground, where the conditions are such as to avoid dragging of the anchor. In poor holding ground the holding power of the anchors is to be significantly reduced.

1.1.2 The required anchoring equipment in [1.2] is given considering the following environmental conditions:

- maximum current speed of 5 knots (2,5 m/s)
- maximum wind speed of 50 knots (25 m/s)
- no waves
- minimum scope of chain cable of 6, the scope being the ratio between length of chain paid out and water depth.

1.1.3 As guidance for the limitations of the anchoring equipment used in semi-sheltered anchorages, the required anchoring equipment as defined in [1.2] can also be considered applicable for ships with the length L_E as defined in [1.2.2] greater than 135 m to the following environmental conditions including waves:

- maximum current speed of 3 knots (1,54 m/s)
- maximum wind speed of 21 knots (11 m/s)
- waves with maximum significant height of 2 m
- minimum scope of chain cable of 6, the scope being the ratio between length of chain paid out and water depth.

1.1.4 For ships intended to anchor in deep and unsheltered water and assigned with the additional class notation **UNSHelterED ANCHORING** refer to additional applicable requirements in Pt F, Ch 11, Sec 4.

1.1.5 It is assumed that under normal circumstances a ship uses only one bow anchor and chain cable at a time.

1.2 Equipment number

1.2.1 General

All ships are to be provided with equipment in anchors and chain cables, to be obtained from Tab 1, based on their Equipment Number EN.

For ships having the navigation notation **coastal area** or **sheltered area**, the equipment in anchors and chain cables may be reduced. The reduction consists of entering in Tab 1 one line higher for ships having the navigation notation **coastal area** and two lines higher for ships having the navigation notation **sheltered area**, based on their Equipment Number EN.

1.2.2 Equipment Number formulae

The Equipment Number EN is to be obtained from the following formula:

$$EN = \Delta^{2/3} + 2 (h B + S_{iun}) + 0,1 A$$

where:

Δ : Moulded displacement of the ship, in t, to the summer load waterline

- h** : Effective height, in m, from the summer load waterline to the top of the uppermost house, to be obtained in accordance with the following formula:

$$h = a + \sum h_n$$
 When calculating h , sheer and trim are to be disregarded
- a** : Vertical distance at hull side, in m, from the Summer Load waterline amidships to the upper deck
- h_n** : Height, in m, at the centreline of tier “n” of superstructures or deckhouses having a breadth greater than B/4. Where a house having a breadth greater than B/4 is above a house with a breadth of B/4 or less, the upper house is to be included and the lower ignored.
 For the lowest tier, h_1 is to be measured at centreline from the upper deck or from a notional deck line where there is local discontinuity in the upper deck, see Fig 1.
- S_{fun}** : Effective front projected area of the funnel, in m^2 , defined as:

$$S_{fun} = A_{FS} - S_{shield}$$
- A_{FS}** : In case a single funnel is fitted on the ship, front projected area of the funnel, in m^2 , calculated between the upper deck at centreline, or notional deck line where there is local discontinuity in the upper deck, and the effective height h_f . A_{FS} is taken equal to zero if the funnel breadth is less than or equal to B/4 at all elevations along the funnel height.
 In case several funnels are fitted on the ship, sum of the front projected area of each funnel, in m^2 , calculated between the upper deck, or notional deck line where there is local discontinuity in the upper deck, and the effective height h_f . A_{FS} is to be taken equal to zero if the sum of each funnel breadth is less or equal to B/4 at all elevations along the funnels height.
- h_f** : In case a single funnel is fitted on the ship, effective height of the funnel, in m, measured from the upper deck at centreline, or notional deck line where there is local discontinuity in the upper deck, to the top of the funnel. The top of the funnel may be taken at the level where the funnel breadth reaches B/4.
 In case several funnels are fitted on the ship, effective height of the funnel, in m, measured from the upper deck, or notional deck line where there is local discontinuity in the upper deck, to the top of the highest funnel. The top of the highest funnel may be taken at the level where the sum of each funnel breadth reaches B/4.
- S_{shield}** : The section of front projected area A_{FS} , in m^2 , which is shielded by all deck houses having breadth greater than B/4. If there are more than one shielded section, the individual shielded sections i.e. $S_{shield1}$, $S_{shield2}$, etc., as shown in Fig 2 are to be added together.
 To determine S_{shield} , the deckhouse breadth is assumed B for all deck houses having breadth greater than B/4 as shown for $S_{shield1}$, $S_{shield2}$ in Fig 2.
- A** : Side projected area, in m^2 , of the hull, superstructures houses and funnels above the summer load waterline which are within the length L_E and also have a breadth greater than B/4.
 In case a single funnel is fitted on the ship, the side projected area is considered in A when A_{FS} is greater than zero. In this case, the side projected area of the funnel should be calculated between the upper deck, or notional deck line where there is local discontinuity in the upper deck, and the effective height h_f .
 In case several funnels are fitted on the ship, the total side projected area of the funnels is to be considered in the side projected area A when A_{FS} is greater than zero.
 In case of several funnels, the shielding effect of funnels in transverse direction may be considered in the total side projected area, i.e., when the side projected areas of two or more funnels fully or partially overlap, the overlapped area needs only to be counted once.
- L_E** : Equipment length, in m, equal to L without being taken neither less than 96% nor greater than 97% of the total length of the summer load waterline.

Fixed screens, fixed picture windows or bulwarks 1,5 m or more in height are to be regarded as parts of houses when determining h and A. In particular, the hatched area shown in Fig 3 is to be included. In case of non butt-jointed picture windows, only the efficient closed areas are to be included.

The height of hatch coamings and that of any deck cargo, such as containers, may be disregarded when determining h and A.

1.2.3 Specific cases

For ships of special design or ships engaged in special services or on special voyages, the Society may consider equipment other than that in Tab 1 on a case-by-case basis.

The Society may accept ships with low equipment number ($30 \leq EN < 50$) or with high equipment number ($EN \geq 16000$). The determination of the equipment will be considered on a case-by-case basis.

For $30 \leq EN < 50$, anchors and stud link chain cables are to be fitted according to the values in Tab 2.

However, the design of such equipment is to comply with the present Section and the requirements in NR216 Materials and Welding, Chapter 10.

Figure 1 : Effective height h

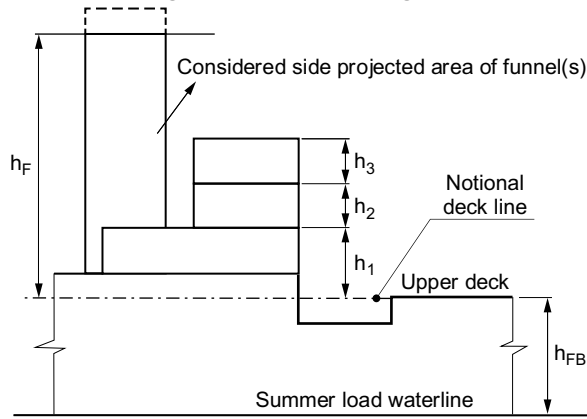


Figure 2 : Shielded sections

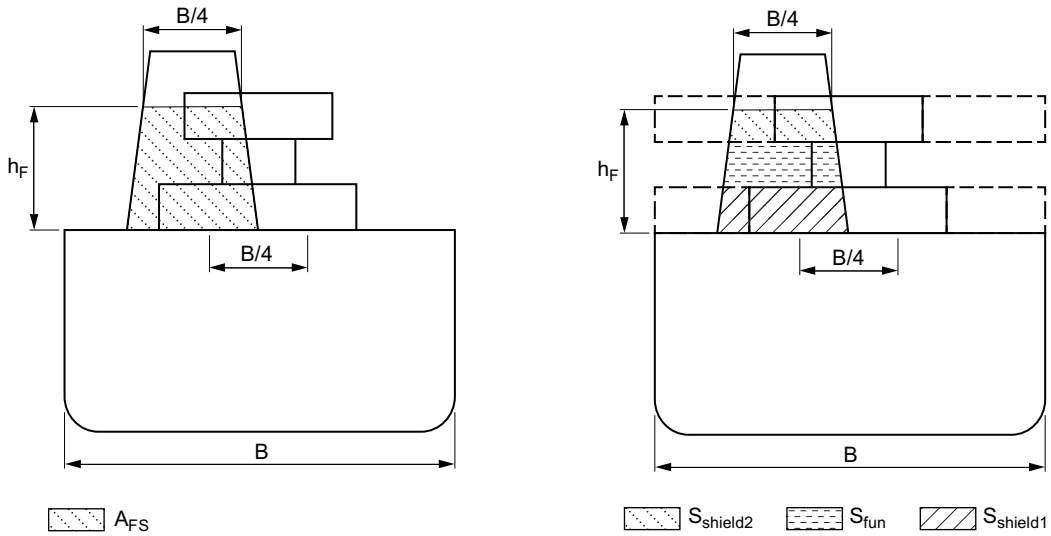


Figure 3 : Effective area of bulwarks or fixed screen to be included in the Equipment Number

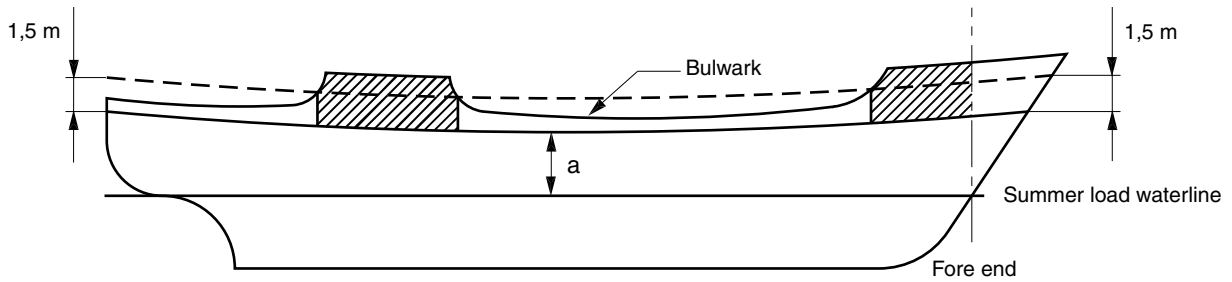


Table 1 : Equipment

Equipment number EN $A \leq EN < B$		Stockless bower anchors		Stud link chain cables for bower anchors			
		Number of anchors	Mass per anchor, in kg	Total length in m	Diameter, in mm		
A	B				Q1	Q2	Q3
50	70	2	180	220,0	14,0	12,5	
70	90	2	240	220,0	16,0	14,0	
90	110	2	300	247,5	17,5	16,0	
110	130	2	360	247,5	19,0	17,5	
130	150	2	420	275,0	20,5	17,5	
150	175	2	480	275,0	22,0	19,0	
175	205	2	570	302,5	24,0	20,5	

Equipment number EN A ≤ EN < B		Stockless bower anchors		Stud link chain cables for bower anchors			
		Number of anchors	Mass per anchor, in kg	Total length in m	Diameter, in mm		
A	B				Q1	Q2	Q3
205	240	2	660	302,5	26,0	22,0	20,5
240	280	2	780	330,0	28,0	24,0	22,0
280	320	2	900	357,5	30,0	26,0	24,0
320	360	2	1020	357,5	32,0	28,0	24,0
360	400	2	1140	385,0	34,0	30,0	26,0
400	450	2	1290	385,0	36,0	32,0	28,0
450	500	2	1440	412,5	38,0	34,0	30,0
500	550	2	1590	412,5	40,0	34,0	30,0
550	600	2	1740	440,0	42,0	36,0	32,0
600	660	2	1920	440,0	44,0	38,0	34,0
660	720	2	2100	440,0	46,0	40,0	36,0
720	780	2	2280	467,5	48,0	42,0	36,0
780	840	2	2460	467,5	50,0	44,0	38,0
840	910	2	2640	467,5	52,0	46,0	40,0
910	980	2	2850	495,0	54,0	48,0	42,0
980	1060	2	3060	495,0	56,0	50,0	44,0
1060	1140	2	3300	495,0	58,0	50,0	46,0
1140	1220	2	3540	522,5	60,0	52,0	46,0
1220	1300	2	3780	522,5	62,0	54,0	48,0
1300	1390	2	4050	522,5	64,0	56,0	50,0
1390	1480	2	4320	550,0	66,0	58,0	50,0
1480	1570	2	4590	550,0	68,0	60,0	52,0
1570	1670	2	4890	550,0	70,0	62,0	54,0
1670	1790	2	5250	577,5	73,0	64,0	56,0
1790	1930	2	5610	577,5	76,0	66,0	58,0
1930	2080	2	6000	577,5	78,0	68,0	60,0
2080	2230	2	6450	605,0	81,0	70,0	62,0
2230	2380	2	6900	605,0	84,0	73,0	64,0
2380	2530	2	7350	605,0	87,0	76,0	66,0
2530	2700	2	7800	632,5	90,0	78,0	68,0
2700	2870	2	8300	632,5	92,0	81,0	70,0
2870	3040	2	8700	632,5	95,0	84,0	73,0
3040	3210	2	9300	660,0	97,0	84,0	76,0
3210	3400	2	9900	660,0	100,0	87,0	78,0
3400	3600	2	10500	660,0	102,0	90,0	78,0
3600	3800	2	11100	687,5	105,0	92,0	81,0
3800	4000	2	11700	687,5	107,0	95,0	84,0
4000	4200	2	12300	687,5	111,0	97,0	87,0
4200	4400	2	12900	715,0	114,0	100,0	87,0
4400	4600	2	13500	715,0	117,0	102,0	90,0
4600	4800	2	14100	715,0	120,0	105,0	92,0
4800	5000	2	14700	742,5	122,0	107,0	95,0
5000	5200	2	15400	742,5	124,0	111,0	97,0
5200	5500	2	16100	742,5	127,0	111,0	97,0
5500	5800	2	16900	742,5	130,0	114,0	100,0
5800	6100	2	17800	742,5	132,0	117,0	102,0

Equipment number EN A ≤ EN < B		Stockless bower anchors		Stud link chain cables for bower anchors			
		Number of anchors	Mass per anchor, in kg	Total length in m	Diameter, in mm		
A	B				Q1	Q2	Q3
6100	6500	2	18800	742,5		120,0	107,0
6500	6900	2	20000	770,0		124,0	111,0
6900	7400	2	21500	770,0		127,0	114,0
7400	7900	2	23000	770,0		132,0	117,0
7900	8400	2	24500	770,0		137,0	122,0
8400	8900	2	26000	770,0		142,0	127,0
8900	9400	2	27500	770,0		147,0	132,0
9400	10000	2	29000	770,0		152,0	132,0
10000	10700	2	31000	770,0			137,0
10700	11500	2	33000	770,0			142,0
11500	12400	2	35500	770,0			147,0
12400	13400	2	38500	770,0			152,0
13400	14600	2	42000	770,0			157,0
14600	16000	2	46000	770,0			162,0

Table 2 : Equipment for 30 ≤ EN < 50

Stockless bower anchors		Stud link chain cables for bower anchors		
N	Mass per anchor, in kg	Total length, in m	Diameter, in mm	
			Q1	Q2
2	120	192,5	12,5	11

2 Anchoring equipment

2.1 Anchors

2.1.1 General

The anchors are to be of an approved type and satisfy the testing conditions laid down in NR216 Rules for Materials and Welding. The scantlings of anchors are to be in compliance with [2.1.2] to [2.1.7].

In general, stockless anchors are to be adopted.

Anchors are to be constructed and tested in compliance with approved plans.

2.1.2 Ordinary anchors

The required mass for each bower anchor is to be obtained from Tab 1.

The individual mass of a main anchor may differ by ±7% from the mass required for each anchor, provided that the total mass of anchors is not less than the total mass required in Tab 1.

The mass of the head of an ordinary stockless anchor, including pins and accessories, is to be not less than 60% of the total mass of the anchor.

Where a stock anchor is provided, the mass of the anchor, excluding the stock, is to be not less than 80% of the mass required in Tab 1 for a stockless anchor. The mass of the stock is to be not less than 25% of the mass of the anchor without the stock but including the connecting shackle.

2.1.3 High and very high holding power anchors

High holding power (HHP) and very high holding power (VHHP) anchors, i.e. anchors for which a holding power higher than that of ordinary anchors has been proved according to NR216 Materials and Welding, Ch 10, Sec 1, do not require prior adjustment or special placement on the sea bottom.

Where HHP or VHHP anchors are used as bower anchors, the mass of each anchor is to be not less than 75% or 50%, respectively, of that required for ordinary stockless bower anchors in Tab 1.

The mass of VHHP anchors is to be, in general, less than or equal to 1500 kg.

2.1.4 Installation of chain cables and anchors on board

The bower anchors are to be connected to their own chain cables and positioned on board ready for use.

To hold the anchor tight in against the hull or the anchor pocket, respectively, it is recommended to fit anchor lashings, e.g., a 'devil's claw'.

Anchor lashings should be designed to resist a load at least corresponding to twice the anchor mass plus 10 m of cable without exceeding 40% of the yield strength of the material.

2.1.5 Tests for high holding power anchors approval

For approval of a HHP anchor, comparative full scale tests are to be performed to show that the holding power of the HHP anchor is at least twice the holding power of an ordinary stockless anchor of the same mass.

For approval as HHP anchors of a whole range of mass, such tests are to be carried out on anchors whose sizes are, as far as possible, representative of the full range of masses proposed. In this case, at least two anchors of different sizes are to be tested. The mass of the maximum size to be approved is to be not greater than 10 times the maximum size tested. The mass of the smallest is to be not less than 0,1 times the minimum size tested.

2.1.6 Tests for very high holding power anchors approval

For approval of a VHHP anchor, comparative full scale tests are to be performed to show that the holding power of the VHHP anchor is to be at least four times the holding power of an ordinary stockless anchor of the same mass or at least twice the holding power of a previously approved HHP anchor of the same mass.

For approval as VHHP anchors of a whole range of mass, such tests are to be carried out on anchors whose sizes are, as far as possible, representative of the full range of masses proposed. In this case, at least three anchors of different sizes are to be tested, indicative of the bottom, middle and top of the mass range.

2.1.7 Specification for tests on high holding power and very high holding power anchors

Full scale tests are to be performed on various types of sea bottom: soft mud or silt, sand or gravel and hard clay or similar compounded material.

Tests are generally to be carried out from a tug. Shore based tests may be accepted by the Society on a case-by-case basis.

The holding power test load is to be less than or equal to the proof load of the anchor, specified in NR216 Materials and Welding, Ch 10, Sec 1.

For each series of sizes, the two anchors selected for testing (ordinary stockless and HHP anchors for testing HHP anchors, ordinary stockless and VHHP anchors or, when ordinary stockless anchors are not available, HHP and VHHP anchors for testing VHHP anchors) are to have the same mass.

The length of chain cable connected to each anchor, having a diameter appropriate to its mass, is to be such that the pull on the shank remains horizontal. For this purpose a value of the ratio between the length of the chain cable paid out and the water depth equal to 10 is considered normal. A lower value of this ratio may be accepted by the Society on a case-by-case basis, without being less than 6.

Three tests are to be carried out for each anchor and type of sea bottom.

The pull is to be measured by dynamometer; measurements based on the RPM/bollard pull curve of tug may, however, be accepted instead of dynamometer readings.

Note is to be taken where possible of the stability of the anchor and its ease of breaking out.

2.2 Chain cables for bower anchors

2.2.1 Material

The anchor chain cables are classified as grade Q1, Q2 or Q3 depending on the type of steel used and its manufacture.

The characteristics of the steel used and the method of manufacture of chain cables are to be approved by the Society for each manufacturer. The material from which chain cables are manufactured and the completed chain cables themselves are to be tested in accordance with the applicable requirements of:

- NR216 Materials and Welding, Ch 10, Sec 2
- NR216 Materials and Welding, Ch 10, Sec 3.

Chain cables made of grade Q1 may not be used with high holding power and very high holding power anchors.

2.2.2 Scantlings of stud link chain cables

The mass and geometry of stud link chain cables, including the links, are to be in compliance with the requirements in NR216 Materials and Welding, Ch 10, Sec 2.

The diameter of stud link chain cables is to be not less than the value in Tab 1.

2.2.3 Studless link chain cables

For ships with EN less than 90, studless short link chain cables may be accepted by the Society as an alternative to stud link chain cables, provided that the equivalence in strength is based on proof load, defined in NR216 Materials and Welding, Ch 10, Sec 3, and that the steel grade of the studless chain is equivalent to the steel grade of the stud chains it replaces, as defined in [2.2.1].

2.2.4 Anchor chain cable arrangement

Anchor chain cables are to be made by lengths of 27,5 m each, joined together by Dee or lugless shackles.

The total length of chain cable, required in Tab 1, is to be divided in approximately equal parts between the two anchors ready for use.

Where different arrangements are provided, they are considered by the Society on a case-by-case basis.

2.3 Attachment pieces

2.3.1 General

Where the lengths of chain cable are joined to each other by means of shackles of the ordinary Dee type, the anchor may be attached directly to the end link of the first length of chain cable by a Dee type end shackle.

A detachable open link in two parts riveted together may be used in lieu of the ordinary Dee type end shackle; in such case the open end link with increased diameter, defined in [2.3.2], is to be omitted.

Where the various lengths of chain cable are joined by means of lugless shackles and therefore no special end and increased diameter links are provided, the anchor may be attached to the first length of chain cable by a special pear-shaped lugless end shackle or by fitting an attachment piece.

2.3.2 Scantlings

The diameters of the attachment pieces, in mm, are to be not less than the values indicated in Tab 3.

Attachment pieces may incorporate the following items between the increased diameter stud link and the open end link:

- swivel, having diameter = 1,2 d
- increased stud link, having diameter = 1,1 d.

Where different compositions are provided, they will be considered by the Society on a case-by-case basis.

Table 3 : Diameters of attachment pieces

Attachment piece	Diameter, in mm
End shackle	1,4 d
Open end link	1,2 d
Increased stud link	1,1 d
Common stud link	d
Lugless shackle	d
Note 1:	
d : Diameter, in mm, of the common link.	

2.3.3 Material

Attachment pieces, joining shackles and end shackles are to be of such material and design as to provide strength equivalent to that of the attached chain cable, and are to be tested in accordance with the applicable requirements of NR216 Materials and Welding, Chapter 10.

2.4 Hawse pipes

2.4.1 Hawse pipes are to be of substantial construction. Their position and slope are to be arranged so as to facilitate housing and dropping of the anchors and avoid damage to the hull during these operations. The parts on which the chains bear are to be rounded to a suitable radius.

2.4.2 All mooring units and accessories, such as tumbler, riding and trip stoppers are to be securely fastened, to the Surveyor's satisfaction.

2.5 Windlass

2.5.1 General

The Rule Note NR626 Anchor Windlass is to be applied, considering the windlass brake capacity defined in [2.5.2].

2.5.2 Brake capacity

Based on mooring line arrangements with brakes engaged and cable lifter disengaged, the capacity HL (Holding Load), in kN, of the windlass brake is to be sufficient to withstand the following design loads without any permanent deformation of the stressed parts and without brake slip:

- 0,8 times the breaking load BL of the chain, if not combined with a chain stopper
- 0,45 times the breaking load BL of the chain, if combined with a chain stopper.

2.6 Chain stopper

2.6.1 A chain stopper is generally to be fitted between the windlass and the hawse pipe in order to relieve the windlass of the pull of the chain cable when the ship is at anchor. The chain stopper is to comply with applicable requirements given in the Rule Note NR626 Anchor Windlass.

For the same purpose, a piece of chain cable may be used with a rigging screw capable of supporting the weight of the anchor when housed in the hawse pipe or a chain tensioner. Such arrangements are not to be considered as chain stoppers.

2.6.2 Where the windlass is at a distance from the hawse pipes and no chain stoppers are fitted, suitable arrangements are to be provided to lead the chain cables to the windlass.

2.7 Chain locker

2.7.1 The capacity of the chain locker is to be adequate to stow all chain cable equipment and provide an easy direct lead to the windlass.

2.7.2 Where two chains are used, the chain lockers are to be divided into two compartments, each capable of housing the full length of one line.

2.7.3 The inboard ends of chain cables are to be secured to suitably reinforced attachments in the structure by means of end shackles, whether or not associated with attachment pieces.

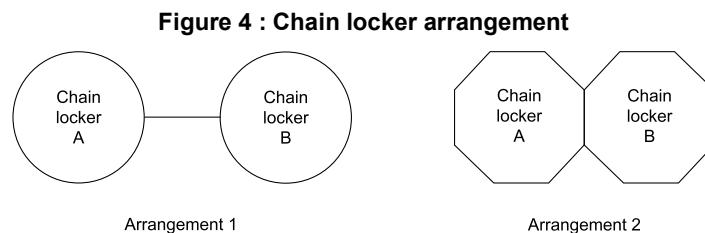
Generally, such attachments are to be able to withstand a force not less than 15% of the breaking load of the chain cable.

In an emergency, the attachments are to be easily released from outside the chain locker.

2.7.4 The chain locker boundaries and access openings are to be watertight. Provisions are to be made to minimise the probability of the chain locker being flooded in bad weather. Adequate drainage facilities for the chain locker are to be provided.

2.7.5 Spurling pipes and chain lockers are to be watertight up to the weather deck.

Bulkheads between separate chain lockers (see Fig 4, Arrangement 1) or which form a common boundary of chain lockers (see Fig 4, Arrangement 2), need not however be watertight.



2.7.6 Where means of access is provided, it is to be closed by a substantial cover and secured by closely spaced bolts.

2.7.7 Where a means of access to spurling pipes or cable lockers is located below the weather deck, the access cover and its securing arrangements are to be in accordance with recognized standards or equivalent for watertight manhole covers. Butterfly nuts and/or hinged bolts are prohibited as the securing mechanism for the access cover.

2.7.8 Spurling pipes through which anchor cables are led are to be provided with permanently attached closing appliances, to minimize water ingress.

Examples of arrangements for permanently attached closing appliances are such as steel plates with cut-outs to accommodate chain links or canvas hoods with a lashing arrangement that maintains the cover in the secured position.

3 Emergency towing arrangement

3.1 Definitions

3.1.1 Deadweight

Deadweight is the difference, in t, between the displacement of a ship in water of a specific gravity of 1,025 t/m³ at the summer load line corresponding to the assigned summer freeboard and the lightweight of the ship.

3.2 Application

3.2.1 The requirements of this Article apply to equipment arrangement for towing ships out of danger in emergencies such as complete mechanical breakdowns, loss of power or loss of steering capability.

The concerned ships are:

- the ships as defined in [3.2.2]
- all ships when the additional class notation **ETA** is assigned.

3.2.2 An emergency towing arrangement is to be fitted at both ends on board of ships of 20000 t deadweight and above with one of the following service notations:

- combination carrier ESP
- oil tanker ESP
- FLS tanker
- chemical tanker ESP
- liquefied gas carrier
- LNG bunkering ship.

3.3 Documentation

3.3.1 Documentation for approval

In addition to the documents in Ch 1, Sec 4, the following documentation is to be submitted to the Society for approval:

- general layout of the bow and stern towing arrangements and associated equipment
- operation manual for the bow and stern towing arrangements
- construction drawings of the bow and stern strongpoints (towing brackets or chain cable stoppers) and fairleads (towing chocks), together with material specifications and relevant calculations
- drawings of the local ship structures supporting the loads applied by strongpoints, fairleads and roller pedestals.

3.3.2 Documentation for information

The following documentation is to be submitted to the Society for information (see Ch 1, Sec 4):

- specifications of chafing gears, towing pennants, pick-up gears and roller fairleads
- height, in m, of the lightest seagoing ballast freeboard measured at stern towing fairlead
- deadweight, in t, of the ship at summer load line.

3.4 General

3.4.1 Scope

The emergency towing arrangements are to be so designed as to facilitate salvage and emergency towing operations on the concerned ship, primarily to reduce the risk of pollution.

3.4.2 Main characteristics

The emergency towing arrangements are, at all times, to be capable of rapid deployment in the absence of main power on the ship to be towed and easy connection to the towing ship.

To demonstrate such rapid and easy deployment, the emergency towing arrangements are to comply with the requirements in [3.12].

3.4.3 Typical layout

Fig 5 shows an emergency towing arrangement which may be used as reference.

3.4.4 List of major components

The major components of the towing arrangements, their position on board and the requirements of this Article which they are to comply with are defined in Tab 4.

3.4.5 Inspection and maintenance

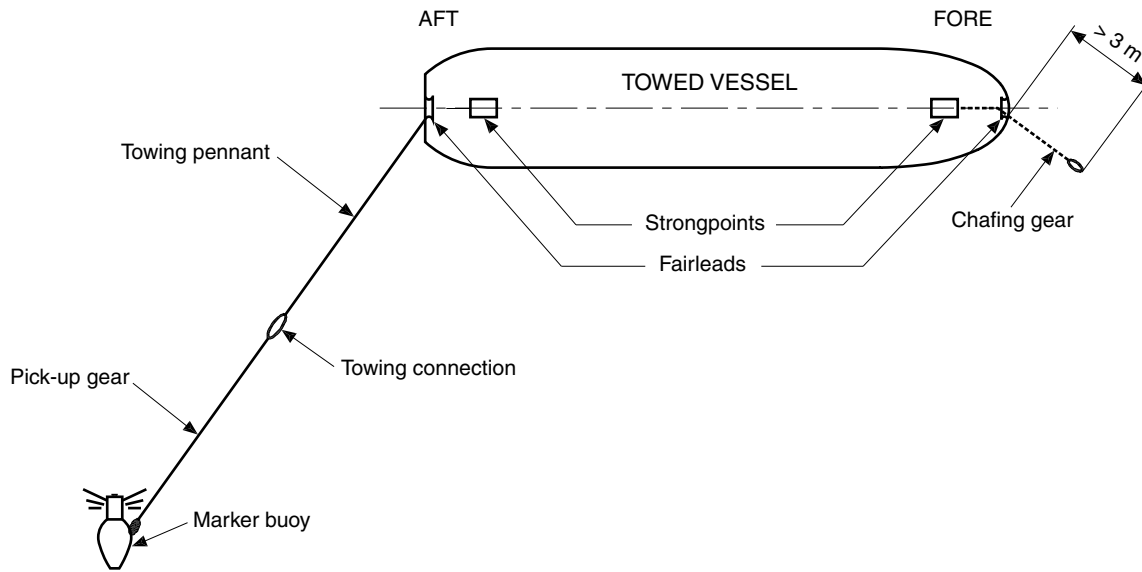
All the emergency towing arrangement components are to be inspected by ship personnel at regular intervals and maintained in good working order.

Table 4 : Major components of the emergency towing arrangement

Towing component	Non pre-rigged	Pre-rigged	Reference of applicable requirements
Towing pennant	Optional	Required	[3.7]
Fairlead	Required	Required	[3.9]
Strongpoint (inboard end fastening of the towing gear)	Required	Required	[3.10]
Pick-up gear	Optional	Required	No requirement
Pedestal roller fairlead	Required	Depending on design	No requirement

Towing component	Forward	Afterward	Reference of applicable requirements
Chafing gear	Required	Depending on design	[3.8]

Figure 5 : Typical emergency towing arrangement



3.5 Emergency towing arrangement approval

3.5.1 General

Emergency towing arrangements of ships are to comply with the following requirements:

- they are to comply with the requirements of this item
- they are to be type approved according to the requirements in [3.13]
- Certificates of inspection of materials and equipment are to be provided according to [3.13.2]
- fitting on board of the emergency towing arrangements is to be witnessed by a Surveyor of the Society and a relevant Certificate is to be issued
- demonstration of the rapid deployment according to the criteria in [3.12] is to be effected for each ship and this is to be reported in the above Certificate.

3.5.2 Alternative to testing the rapid deployment for each ship

At the request of the Owner, the testing of the rapid deployment for each ship according to [3.5.1] may be waived provided that:

- the design of emergency towing arrangements of the considered ship is identical to the type approved arrangements and this is confirmed by the on board inspection required in [3.5.1]
- the strongpoints (chain stoppers, towing brackets or equivalent fittings) are type approved (prototype tested).

In this case, an exemption certificate is to be issued.

In general, such dispensation may be granted to subsequent ships of a series of identical new buildings fitted with identical arrangements.

3.6 Safe working load (SWL) of towing pennants, chafing gears, fairleads and strongpoints

3.6.1 Safe working load

The safe working load (defined as one half of the ultimate strength) of towing pennants, chafing gear, fairleads and strongpoints is to be not less than that obtained, in kN, from Tab 5.

The strength of towing pennants, chafing gear, fairleads and strongpoints is to be sufficient for all pulling angles of the towline, i.e. up to 90° from the ship's centreline to port and starboard and 30° vertical downwards.

The safe working load of other components is to be sufficient to withstand the load to which such components may be subjected during the towing operation.

Table 5 : Safe working load

Ship deadweight DWT, in t	Safe working load, in kN
20000 ≤ DWT < 50000	1000
DWT ≥ 50000	2000

3.7 Towing pennant

3.7.1 Material

The towing pennant may be made of steel wire rope or synthetic fibre rope, which is to comply with the applicable requirements in NR216 Materials and Welding, Ch 10, Sec 5.

3.7.2 Length of towing pennant

The length ℓ_p of the towing pennant is to be not less than that obtained, in m, from the following formula:

$$\ell_p = 2H + 50$$

where:

H : Lightest seagoing ballast freeboard measured, in m, at the fairlead.

3.7.3 Minimum breaking strength of towing pennants when separate chafing gear is used

Where a separate chafing gear is used, the minimum breaking strength MBS_p of towing pennants, including their terminations, is to be not less than that obtained from the following formula:

$$MBS_p = 2 \Sigma \Omega \Lambda$$

where:

SWL : Safe working load of the towing pennants, defined in [2.6.1].

3.7.4 Minimum breaking strength of towing pennants when no separate chafing gear is used

Where no separate chafing gear is used (i.e. where the towing pennant may chafe against the fairlead during towing operation), the minimum breaking strength of the towing pennants MBS_{PC} is to be not less than that obtained, in kN, from the following formula:

$$MBS_{PC} = \varphi MBS_p$$

where:

MBS_p : Minimum breaking strength, in kN, defined in [3.7.3]

φ : Coefficient to be taken equal to:

$$\varphi = \frac{2\sqrt{\rho}}{2\sqrt{\rho} - 1}$$

φ may be taken equal to 1,0 if tests carried out under a test load equal to twice the safe working load defined in [3.6.1] demonstrate that the strength of the towing pennants is satisfactory

ρ : Bending ratio (ratio between the minimum bearing surface diameter of the fairlead and the towing pennant diameter), to be taken not less than 7.

3.7.5 Towing pennant termination

For towing connection, the towing pennant is to have a hard eye-formed termination allowing connection to a standard shackle.

Socketed or ferrule-secured eye terminations of the towing pennant are to be type tested in order to demonstrate that their minimum breaking strength is not less than twice the safe working load defined in [3.6.1].

3.8 Chafing gear

3.8.1 General

Different solutions for the design of chafing gear may be used.

If a chafing chain is to be used, it is to have the characteristics defined in the following requirements.

3.8.2 Type

Chafing chains are to be stud link chains.

3.8.3 Material

In general, grade Q3 chain cables and associated accessories complying with the applicable requirements in:

- NR216 Materials and Welding, Ch 10, Sec 2
- NR216 Materials and Welding, Ch 10, Sec 3

are to be used.

3.8.4 Chafing chain length

The chafing chain is to be long enough to ensure that the towing pennant, or the towline, remains outside the fairlead during the towing operation. A chain extending from the strongpoint to a point at least 3 m beyond the fairlead complies with this requirement.

3.8.5 Minimum breaking strength

The minimum breaking strength of the stud link chafing chain and the associated links is to be not less than twice the safe working load defined in [3.6.1].

3.8.6 Diameter of the common links

The diameter of the common links of stud link chain cables is to be not less than:

- 52 mm for a safe working load, defined in [3.6.1], equal to 1000 kN
- 76 mm for a safe working load, defined in [3.6.1], equal to 2000 kN.

3.8.7 Chafing chain ends

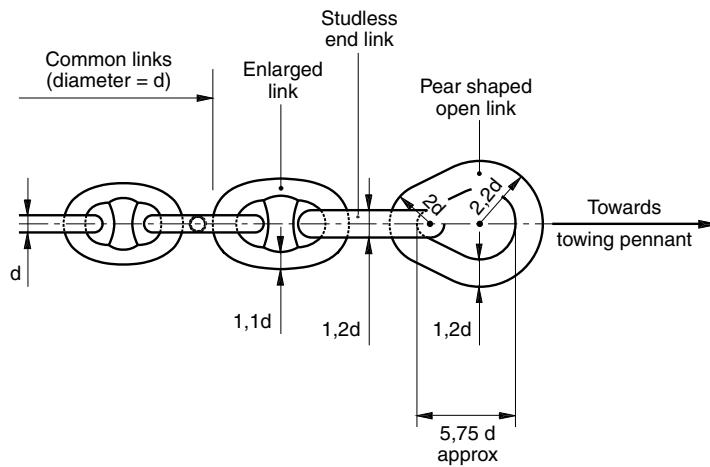
One end of the chafing chain is to be suitable for connection to the strongpoint. Where a chain stopper is used, the inboard end of the chafing chain is to be efficiently secured in order to prevent any inadvertent loss of the chafing chain when operating the stopping device. Where the chafing chain is connected to a towing bracket, the corresponding chain end may be constructed as shown in Fig 6, but the inner dimension of the pear link may be taken as 5,30 d (instead of 5,75 d).

The other end of the chafing chain is to be fitted with a standard pear-shaped open link allowing connection to a standard bow shackle. A typical arrangement of this chain end is shown in Fig 6. Arrangements different than that shown in Fig 6 are considered by the Society on a case-by-case basis.

3.8.8 Storing

The chafing chain is to be stored and stowed in such a way that it can be rapidly connected to the strongpoint.

Figure 6 : Typical outboard chafing chain end



3.9 Fairleads

3.9.1 General

Fairleads are normally to be of a closed type (such as Panama chocks).

Fairleads are to have an opening large enough to pass the largest portion of the chafing gear, towing pennant or towline. The corners of the opening are to be suitably rounded.

Where the fairleads are designed to pass chafing chains, the openings are to be not less than 600mm in width and 450mm in height.

3.9.2 Material

Fairleads are to be made of fabricated steel plates or other ductile materials such as weldable forged or cast steel complying with the applicable requirements of:

- NR216 Materials and Welding, Chapter 3 (steel plate)
- NR216 Materials and Welding, Chapter 5 (steel forgings)
- NR216 Materials and Welding, Chapter 6 (steel castings).

3.9.3 Operating condition

The fairleads are to give adequate support for the towing pennant during towing operation, which means bending 90° to port and starboard side and 30° vertical downwards.

3.9.4 Positioning

The fairleads are to be located so as to facilitate towing from either side of the bow or stern and minimise the stress on the towing system.

The fairleads are to be located as close as possible to the deck and, in any case, in such a position that the chafing chain is approximately parallel to the deck when it is under strain between the strongpoint and the fairlead.

Furthermore, the bow and stern fairleads are normally to be located on the ship's centreline. Where it is practically impossible to fit the towing fairleads exactly on the ship's centreline, it may be acceptable to have them slightly shifted from the centreline.

3.9.5 Bending ratio

The bending ratio (ratio between the towing pennant bearing surface diameter and the towing pennant diameter) is to be not less than 7.

3.9.6 Fairlead lips

The lips of the fairlead are to be suitably faired in order to prevent the chafing chain from fouling on the lower lip when deployed or during towing.

3.9.7 Yielding check

The equivalent Von Mises stress σ_E , in N/mm², induced in the fairlead by a load equal to the safe working load defined in [3.6.1], is to comply with the following formula:

$$\sigma_E \leq \sigma_{ALL}$$

Areas subjected to stress concentrations are considered by the Society on a case-by-case basis.

Where the fairleads are analysed through standard mesh finite element models, the allowable stress may be taken as 1,1 σ_{ALL} .

3.9.8 Alternative to the yielding check

The above yielding check may be waived provided that fairleads are tested with a test load equal to twice the safe working load defined in [3.6.1] and this test is witnessed by a Surveyor of the Society. In this case, the Designer is responsible for ensuring that the fairlead scantlings are sufficient to withstand such a test load.

Unless otherwise agreed by the Society, components subjected to this test load are considered as prototype items and are to be discarded.

3.10 Strongpoint

3.10.1 General

The strongpoint (inboard end fastening of the towing gear) is to be a chain cable stopper or a towing bracket or other fitting of equivalent strength and ease of connection. The strongpoint can be designed integral with the fairlead.

The strongpoint is to be type approved according to [3.13] and is to be clearly marked with its SWL.

3.10.2 Materials

The strongpoint is to be made of fabricated steel or other ductile materials such as forged or cast steel complying with the applicable requirements of:

- NR216 Materials and Welding, Chapter 3 (steel plate)
- NR216 Materials and Welding, Chapter 5 (steel forgings)
- NR216 Materials and Welding, Chapter 6 (steel castings).

Use of spheroidal graphite cast iron (SG iron) may be accepted for the main framing of the strongpoint provided that:

- the part concerned is not intended to be a component part of a welded assembly
- the SG iron is of ferritic structure with an elongation not less than 12%
- the yield stress at 0,2% is measured and certified
- the internal structure of the component is inspected by suitable non-destructive means.

The material used for the stopping device (pawl or hinged bar) of chain stoppers and for the connecting pin of towing brackets is to have mechanical properties not less than those of grade Q3 chain cables, defined in NR216 Materials and Welding, Chapter 10.

3.10.3 Typical strongpoint arrangement

Typical arrangements of chain stoppers and towing brackets are shown in Fig 7, which may be used as reference.

Chain stoppers may be of the hinged bar type or pawl (tongue) type or of other equivalent design.

3.10.4 Position and operating condition

The operating conditions and the positions of the strongpoints are to comply with those defined in [3.9.3] and [3.9.4], respectively, for the fairleads.

3.10.5 Stopping device

The stopping device (chain engaging pawl or bar) is to be arranged, when in closed position, to prevent the chain stopper from working in the open position, in order to avoid chain cable release and allow it to pay out.

Stopping devices are to be easy and safe to operate and, in the open position, are to be properly secured.

3.10.6 Connecting pin of the towing bracket

The scantlings of the connecting pin of the towing bracket are to be not less than those of a pin of a grade Q3 end shackle, as shown in Fig 7, provided that clearance between the two side lugs of the bracket does not exceed 2,0d, where d is the chain diameter specified in [3.8.6] (see also Fig 6).

3.10.7 Yielding check

The equivalent Von Mises stress σ_E , in N/mm², induced in the strongpoint by a load equal to the safe working load defined in [3.6.1], is to comply with the following formula:

$$\sigma_E \leq \sigma_{ALL}$$

Areas subjected to stress concentrations are considered by the Society on a case-by-case basis.

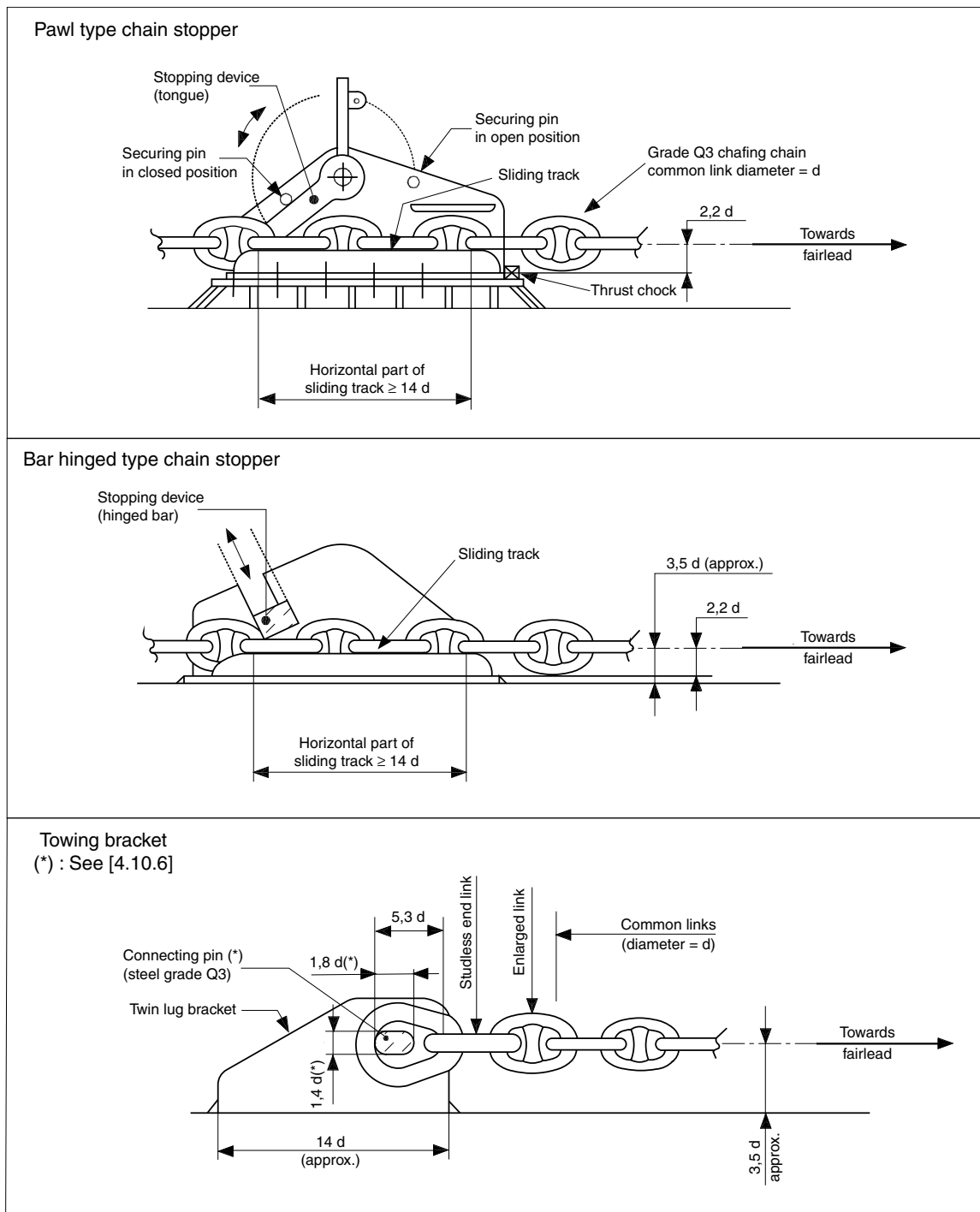
Where the strongpoints are analysed through standard mesh finite element models, the allowable stress may be taken as 1,1 σ_{ALL} .

3.10.8 Alternative to the yielding check

The above yielding check may be waived provided that strongpoints are tested with a test load equal to twice the safe working load defined in [3.6.1] and this test is witnessed by a Surveyor. In this case, the Designer is responsible for ensuring that the fairlead scantlings are sufficient to withstand such a test load.

Unless otherwise agreed by the Society, components subjected to this test load are considered as prototype items and are to be discarded.

Figure 7 : Typical strongpoint arrangement



3.10.9 Bolted connection

Where a chain stopper or a towing bracket is bolted to a seating welded to the deck, the bolts are to be relieved from shear force by means of efficient thrust chocks capable of withstanding a horizontal force equal to 1,3 times the safe working load defined in [3.6.1] within the allowable stress defined in [3.10.7].

The steel quality of bolts is to be not less than grade 8.8 as defined by ISO standard No. 898/1.

Bolts are to be pre-stressed in compliance with appropriate standards and their tightening is to be suitably checked.

3.11 Hull structures in way of fairleads or strongpoints

3.11.1 Materials and welding

The materials used for the reinforcement of the hull structure in way of the fairleads or the strongpoints are to comply with the applicable requirements of NR216 Materials and Welding.

Main welds of the strongpoints with the hull structure are to be 100% inspected by adequate non-destructive tests.

3.11.2 Yielding check of bulwark and stays

The equivalent Von Mises stress σ_E , in N/mm², induced in the bulwark plating and stays in way of the fairleads by a load equal to the safe working load defined in [3.6.1], for the operating condition of the fairleads defined in [3.9.3], is to comply with the following formula:

$$\sigma_E \leq \sigma_{ALL}$$

3.11.3 Yielding check of deck structures

The equivalent Von Mises stress σ_E , in N/mm², induced in the deck structures in way of chain stoppers or towing brackets, including deck seatings and deck connections, by a horizontal load equal to 1,3 times the safe working load defined in [3.6.1], is to comply with the following formula:

$$\sigma_E \leq \sigma_{ALL}$$

3.11.4 Minimum gross thickness of deck plating

The gross thickness of the deck is to be not less than:

- 12 mm for a safe working load, defined in [3.6.1], equal to 1000 kN
- 15 mm for a safe working load, defined in [3.6.1], equal to 2000 kN.

3.12 Rapid deployment of towing arrangement

3.12.1 General

To facilitate approval of towing arrangements and to ensure rapid deployment, emergency towing arrangements are to comply with the requirements of this item.

3.12.2 Marking

All components, including control devices, of the emergency towing arrangements are to be clearly marked to facilitate safe and effective use even in darkness and poor visibility.

3.12.3 Aft arrangement

The aft emergency towing arrangement is to be pre-rigged and be capable of being deployed in a controlled manner in harbour conditions in not more than 15 minutes.

The pick-up gear for the aft towing pennant is to be designed at least for manual operation by one person taking into account the absence of power and the potential for adverse environmental conditions that may prevail during such emergency towing operations.

The pick-up gear is to be protected against the weather and other adverse conditions that may prevail.

3.12.4 Forward

The forward emergency towing arrangement is to be capable of being deployed in harbour conditions in not more than 1 hour.

The forward emergency towing arrangement is to be designed at least with a means of securing a tow line to the chafing gear using a suitably positioned pedestal roller to facilitate connection of the towing pennant.

Forward emergency towing arrangements which comply with the requirements for aft emergency towing arrangements may be accepted.

3.13 Type approval

3.13.1 Type approval procedure

Emergency towing arrangements are to be type approved according to the following procedure:

- the arrangement design is to comply with the requirements of this Section

- each component of the towing arrangement is to be tested and its manufacturing is to be witnessed and certified by a Surveyor according to [3.13.2]
- prototype tests are to be carried out in compliance with [3.13.3].

3.13.2 Inspection and certification

The materials and equipment are to be inspected and certified as specified in Tab 6.

3.13.3 Prototype tests

Prototype tests are to be witnessed by a Surveyor and are to include the following:

- demonstration of the rapid deployment according to the criteria in [3.12]
- load test of the strongpoints (chain stoppers, towing brackets or equivalent fittings) under a proof load equal to 1,3 times the safe working load defined in [3.6.1].

A comprehensive test report duly endorsed by the Surveyor is to be submitted to the Society for review.

Table 6 : Material and equipment certification status

Component	Material		Equipment	
	Certificate	Reference of applicable requirements	Certificate	Reference of applicable requirements
Towing pennant	Not applicable	[3.7.1]	COI (1)	[3.7]
Chafing chain and associated accessories	COI (2)	[3.8.3]	COI (1)	[3.8]
Fairleads	CW	[3.9.2]	COI	[3.9]
Strongpoint:			COI (3)	[3.10]
• main framing	COI (2)	[3.10.2]		
• stopping device	COI (2)	[3.10.2]		
Pick-up gear:				No requirement
• rope	Not applicable	–	CW	
• buoy	Not applicable	–	Not required (4)	
• line-throwing appliance	Not applicable	–	Not required (4)	
Pedestal roller fairlead	CW	–	Not required (4)	No requirement
<p>(1) According to NR216 Materials and Welding, Ch 10, Sec 2 (2) According to NR216 Materials and Welding, Ch 1, Sec 1, [4.2]. (3) To be type approved. (4) May be type approved.</p> <p>Note 1: COI : Certificate of inspection, CW : Works' certificate 3.1.B according to EN 10204.</p>				

4 Towing and mooring arrangement

4.1 General

4.1.1 Condition of classification

The towing and mooring arrangement as defined in Ch 12, App 2, [1] and the towing and mooring lines as defined in Ch 12, App 2, [2] are given as a guidance but are not required as a condition of classification.

4.2 Shipboard fittings and supporting hull structures associated with towing and mooring

4.2.1 Definitions

“Normal towing” means towing operations necessary for manoeuvring in ports and sheltered waters associated with the normal operations of the ship.

“Escort towing” means towing operations required in specific estuaries, in particular, for laden oil tankers or LNG carriers. Its main purpose is to control the ship in case of failures of the propulsion or steering system.

“Other towing” means towing operations necessary for towing the ship by another ship or a tug, e.g. such as to assist the ship in case of emergency, for ships not assigned with the additional class notation **ETA**.

“Emergency towing” means towing operations to assist the ship in case of emergency, for ships assigned with the additional class notation **ETA**.

“Canal transit towing” means towing operations for ships transiting canals, e.g. the Panama Canal.

“Shipboard fittings” means the components limited to the following: bollards and bits, fairleads, stand rollers, chocks used for mooring and similar components used for normal, escort and other towing operations. Other components such as capstans, winches, etc. are not covered by the present sub-article. Any weld or bolt or equivalent device connecting the shipboard fitting to the supporting structure is part of the shipboard fitting and if selected from an recognised standard subject to that standard.

“Supporting hull structure” means the part of the ship structure on/in which the shipboard fitting is placed and which is directly submitted to the forces exerted on the shipboard fitting. The supporting hull structure of capstans, winches, etc. used for mooring and for normal, escort and other towing operations is also subject to the present sub-article.

The “nominal capacity condition” is defined as the theoretical condition where the maximum possible deck cargoes are included in the ship arrangement in their respective positions. For ships carrying containers, the nominal capacity condition represents the theoretical condition where the maximum possible number of containers is included in the ship arrangement in their respective positions.

“Ship Design Minimum Breaking Load” (MBL_{SD}) means the minimum breaking load of new, dry mooring lines or tow line for which shipboard fittings and supporting hull structures are designed in order to meet mooring restraint requirements or the towing requirements of other towing service.

“Line Design Break Force” (LDBF) means the minimum force that a new, dry, spliced, mooring line will break at. This is for all synthetic cordage materials.

4.2.2 Application

Requirements under the present sub-article apply to:

- conventional ships, i.e. displacement-type ships of 500 GT and above, excluding special purpose ships as defined in the IMO resolution MSC.266(84)
- shipboard fittings used for mooring and for normal, escort and other towing operations
- supporting hull structure under shipboard fittings used for mooring and for normal, escort and other towing operations
- supporting hull structure under winches and capstans used for mooring operations.

Requirements under the present sub-article do not apply for following towing operations:

- emergency towing: refer to Article [3]
- canal transit towing: reference is to be made to local canal transit requirements.

4.2.3 Arrangement

The strength of shipboard fittings used for mooring and for normal, escort and other towing operations at bow, sides and stern, and of their supporting hull structures are to comply with the present sub-article.

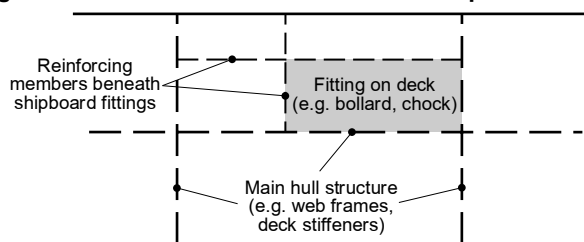
The strength of supporting hull structures of winches and capstans used for mooring are to comply with the present sub-article as well.

Shipboard fittings, winches and capstans are to be located on stiffeners and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the towing and mooring loads.

The reinforced members beneath shipboard fittings are to be effectively arranged for any variation of direction (horizontally and vertically) of the mooring and towing forces acting upon the shipboard fittings, see Fig 8 for a sample arrangement. Proper alignment of fitting and supporting hull structure is to be ensured.

Other arrangements may be accepted (for chocks in bulwarks, etc.) provided the strength is confirmed adequate for the intended service.

Figure 8 : Reinforced members beneath shipboard fittings



4.2.4 Selection of shipboard fittings

Shipboard fittings may be selected from a recognised standard accepted by the Society (ISO standard for example) and at least based on the following loads:

- a) Normal towing operations: the intended maximum towing load (e.g. static bollard pull) as indicated on the towing and mooring arrangements plan
- b) Escort or other towing operations: the MBL_{SD} of the tow line according to Ch 12, App 2
- c) For fittings intended to be used for, both, normal and escort or other towing operations, the greater of the loads according to a) and b)
- d) Mooring operations: the MBL_{SD} of the mooring line according to Ch 12, App 2.

Towing bitts (double bollards) may be chosen for the towing line attached with eye splice if the recognised standard distinguishes between different methods to attach the line, i.e. figure-of-eight or eye splice attachment, see Fig 10.

Mooring bitts (double bollards) are to be chosen for the mooring line attached in figure-of-eight fashion if the recognised standard distinguishes between different methods to attach the line, i.e. figure-of-eight or eye splice attachment, see Fig 11.

When the shipboard fitting is not selected from an accepted standard:

- The design load used to assess its strength and its attachment to the ship is to be in accordance with [4.2.5].
- Towing bitts (double bollards) are required to resist the loads caused by the towing line attached with eye splice
- Mooring bitts (double bollards) are required to resist the loads caused by the mooring line attached in figure-of-eight fashion.
- At the discretion of the Society, load tests may be accepted as alternative to strength assessment by calculations.

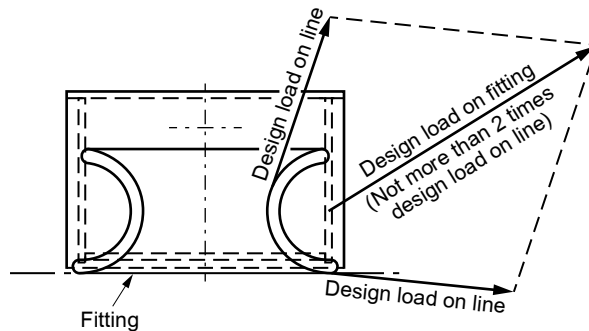
Note 1: With the line attached to a mooring bitt in the usual way (figure-of-eight fashion), either of the two posts of the mooring bitt can be subjected to a force twice as large as that acting on the mooring line.

4.2.5 Design load

The design load is to be applied to fittings in all directions that may occur by taking into account the arrangement shown on the mooring and towing arrangements plan. Where the mooring or towing line takes a turn at a fitting the total design load applied to the fitting is equal to the resultant of the design loads acting on the line, see Fig 9.

However, in no case does the design load applied to the fitting need to be greater than twice the design load on the line.

Figure 9 : Design load on fitting



The acting point of the force on shipboard fittings is to be taken at the attachment point of the mooring or towing line or at a change in its direction. For bollards and bitts the attachment point of the line is to be taken not less than 4/5 of the tube height above the base, see Fig 10 and Fig 11.

However, if fins are fitted to the bollard tubes to keep the mooring line as low as possible, the attachment point of the mooring line may be taken at the location of the fins, see b) in Fig 11.

The design load to be applied to supporting hull structures and to shipboard fittings not selected from a recognised standard, in kN, is to be taken equal to:

- Normal towing operations:
1,25 times the greater of the intended maximum towing load (e.g. static bollard pull) and the safe towing load TOW requested by the applicant, see [4.2.8]
- Escort or other towing operations:
the greater of the ship design minimum breaking load according to Ch 12, App 2 and 1,25 times the safe towing load TOW requested by the applicant, see [4.2.8]
- For fittings intended to be used for, both, normal and escort or other towing operations:
the greater of the design loads according to a) and b).
- Mooring operations:
1,15 times the greater of the MBL_{SD} of the mooring line according to Ch 12, App 2 and the SWL of the shipboard fitting requested by the applicant, see [4.2.9].

The design load to be applied to supporting hull structure of winches and capstans used for mooring operations, in kN, is to be taken equal to:

- Supporting hull structure of winches:
1,25 times the intended maximum brake holding load, see notes below.
- Supporting hull structure of capstans:
1,25 times the maximum hauling-in force.

Note 1: The maximum brake holding load of winches used for mooring operations is to be assumed not less than 80% of the MBL_{SD} of the mooring line according to Ch 12, App 2, [2].

Note 2: The MBL_{SD} of tow and mooring lines taken in Ch 12, App 2, Tab 1 are to be based on an Equipment Number calculated according to [1.2.2] with a side projected area A including deck cargoes as given by the ship nominal capacity condition defined in [4.2.1].

Note 3: The increase of the LDBF of tow and mooring lines for synthetic ropes as required in Ch 12, App 2, [2.5] needs not to be taken into account for the loads applied to shipboard fittings and supporting hull structure.

Note 4: For fittings intended to be used for both towing and mooring operations, the corresponding design loads are to be considered independently.

Figure 10 : Attachment point of the towing line on bollard and bitts

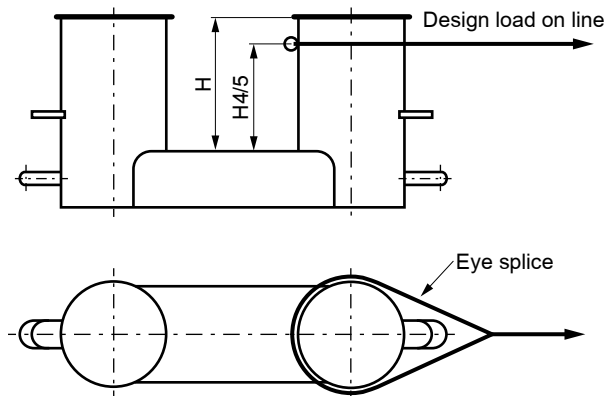
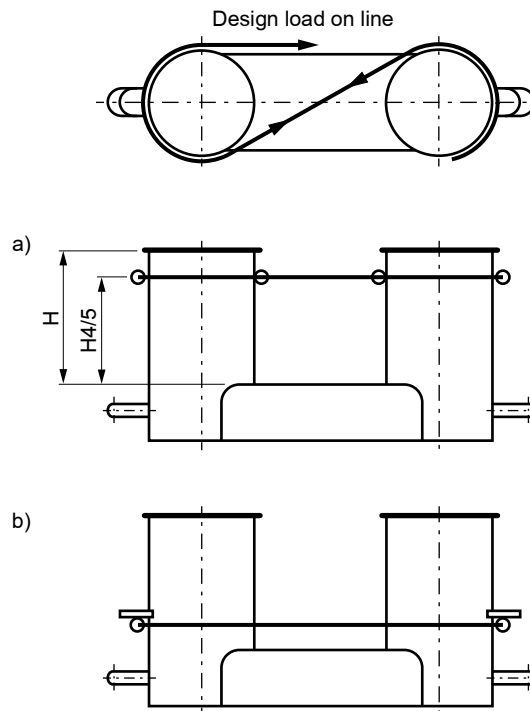


Figure 11 : Attachment point of the mooring line on bollard and bitts



4.2.6 Allowable stresses

Allowable stresses under the design load conditions as specified in [4.2.5] are as follows:

- a) For strength assessment by means of beam theory or grillage analysis:
 - normal stress: $1,0 R_{eH}$
 - shear stress: $0,6 R_{eH}$
- b) For strength assessment by means of finite element analysis:
 - Von Mises stress: $1,0 R_{eH}$

Note 1: Normal stress is to be considered as the sum of bending stress and axial stress, with the corresponding shearing stress acting perpendicular to the normal stress. No stress concentration factors are to be taken into account.

Note 2: For strength assessment by means of finite element analysis the mesh is to be fine enough to represent the geometry as realistically as possible. The aspect ratios of elements are not to exceed 3. Girders are to be modelled using shell or plane stress elements. Symmetric girder flanges may be modelled by beam or truss elements. The element height of girder webs is not to exceed one-third of the web height. In way of small openings in girder webs the web thickness is to be reduced to a mean thickness over the web height. Large openings are to be modelled. Stiffeners may be modelled by using shell, plane stress, or beam elements. The mesh size of stiffeners is to be fine enough to obtain proper

bending stress. If flat bars are modelled using shell or plane stress elements, dummy rod elements are to be modelled at the free edge of the flat bars and the stresses of the dummy elements are to be evaluated. Stresses are to be read from the centre of the individual element. For shell elements the stresses are to be evaluated at the mid plane of the element.

4.2.7 Corrosion additions

The scantlings obtained by applying the allowable stresses as specified in [4.2.6] are net scantlings excluding any addition for corrosion.

The total corrosion addition t_c is not to be less than the following values:

- for the supporting hull structure, according to Ch 4, Sec 3 for the surrounding structure (e.g. deck structures, bulwark structures).
- for pedestals and foundations on deck which are not part of a fitting according to a recognised standard, 2.0 mm.
- for shipboard fittings not selected from a recognised standard, 2.0 mm.

Note 1: In addition to the corrosion addition t_c given above, a wear down allowance t_w not less than 1.0 mm is to be included for shipboard fittings not selected from an recognised standard. This wear allowance is to be added to surfaces which are intended to regularly contact the line.

4.2.8 Safe Towing Load (TOW)

The safe towing load (TOW) is the safe load limit of shipboard fittings used for towing purpose.

Unless a greater TOW is requested by the applicant, the TOW is not to exceed:

- a) Normal towing operations: the intended maximum towing load (e.g. static bollard pull)
- b) Escort or other towing operations: 80% of the MBL_{SD} of the tow line according to Ch 12, App 2
- c) For fittings intended to be used for, both, normal and escort or other towing operations: the greater of the design loads according to a) and b).

TOW, in t, of each shipboard fitting is to be marked (by weld bead or equivalent) on the deck fittings used for towing.

For fittings intended to be used for, both, towing and mooring, SWL, in t, according to [4.2.9] is to be marked in addition to TOW.

Note 1: The above requirements on TOW apply for the use with no more than one line. If not otherwise chosen, for towing bits (double bollards) TOW is the load limit for a towing line attached with eye-splice.

4.2.9 Safe Working Load (SWL)

The safe working load (SWL) is the safe load limit of shipboard fittings used for mooring purpose.

Unless a greater SWL is requested by the applicant, the SWL is not to exceed the MBL_{SD} of the mooring line as given in Ch 12, App 2, Tab 1.

SWL, in t, of each shipboard fitting is to be marked (by weld bead or equivalent) on the deck fittings used for mooring.

For fittings intended to be used for, both, mooring and towing, TOW, in t, according to [4.2.8] is to be marked in addition to SWL.

Note 1: The above requirements on SWL apply for the use with no more than one mooring line.

4.2.10 Towing and mooring arrangements plan

A plan showing the towing and mooring arrangement is to be submitted to the Society for information. This plan is to define the method of using the towing and mooring lines and is to include the following information for each shipboard fitting:

- a) Location on the ship
- b) Fitting type
- c) SWL/TOW
- d) Purpose (mooring, harbour towing, escort towing, other towing)
- e) Manner of applying towing and mooring lines including limiting fleet angle i.e. angle of change in direction of a line at the fitting.

Item c) with respect to items d) and e), is subject to approval by the Society.

Furthermore, following information is to be clearly indicated on the plan:

- the arrangement of mooring lines showing the number of lines
- the MBL_{SD} of each mooring line
- the acceptable environmental conditions as given in Ch 12, App 2, [2.7.3] for the MBL_{SD} of mooring lines for ships with Equipment Number EN > 2000:
 - 30 second mean wind speed from any direction (v_w or v_w^* according to Ch 12, App 2, [2.7.3])
 - maximum current speed acting on bow or stern ($\pm 10^\circ$)

Note 1: The SWL and TOW for the intended use for each shipboard fitting is to be noted in the towing and mooring arrangements plan available on board for the guidance of the Master. It is to be noted that TOW is the load limit for towing purpose and SWL that for mooring purpose. If not otherwise chosen, for towing bits it is to be noted that TOW is the load limit for a towing line attached with eye-splice.

Note 2: The information as listed above is to be incorporated into the pilot card in order to provide the pilot proper information on harbour, escort and other towing operations.

Appendix 1 Criteria for Direct Calculation of Rudder Loads

Symbols

- $l_{10}, l_{20}, l_{30}, l_{40}$: Lengths, in m, of the individual girders of the rudder system
- l_{50} : Length, in m, of the solepiece
- l_{TRU} : Length, in m, of the trunk
- $J_{10}, J_{20}, J_{30}, J_{40}$: Moments of inertia about the x axis, in cm⁴, of the individual girders of the rudder system having lengths $l_{10}, l_{20}, l_{30}, l_{40}$. For rudders supported by a solepiece only, J_{20} indicates the moment of inertia of the pintle in the sole piece
- J_{50} : Moment of inertia about the z axis, in cm⁴, of the solepiece
- J_{TRU} : Moment of inertia about the x axis, in cm⁴, of the trunk
- C_R : Rudder force, in N, acting on the rudder blade, defined in Ch 12, Sec 1, [2.1.1]
- C_{R1}, C_{R2} : Rudder forces, in N, defined in Ch 12, Sec 1, [2.2.3]
- E : Young's modulus, in N/m²: $E = 2,06 \cdot 10^{11}$ N/m²
- G : Shear elasticity modulus, in N/m²: $G = 7,85 \cdot 10^{10}$ N/m².

1 Criteria for direct calculation of the loads acting on the rudder structure

1.1 General

1.1.1 Application

The requirements of this Appendix apply to all types of rudders listed under Ch 12, Sec 1, Tab 4.

The requirements of this Appendix provide the criteria for calculating the following forces and moments:

- bending moment M_{Bi} in the rudder stock (defined as the maximum of absolute values of bending moment M_{Bi} over the rudder stock length)
- support forces F_{Ai}
- bending moment M_R and shear force Q_R in the rudder body.

1.1.2 Calculation of forces and moments

The forces and moments in [1.1.1] are to be calculated according to [1.4], for each type of rudder.

They are to be used for the stress analysis required in:

- Ch 12, Sec 1, [4], for the rudder stock
- Ch 12, Sec 1, [6], for the rudder stock and the pintle bearings
- Ch 12, Sec 1, [7] for the rudder blade
- Ch 12, Sec 1, [8] for the rudder horn and the solepiece.

1.2 Required data

1.2.1 Forces per unit length

The forces per unit length are to be calculated, in N/m, for each type of rudder, according to requirements given under [1.4].

1.2.2 Support stiffness properties

Three general cases are considered:

- all supports are completely rigid. This is assumed for the rudder types 1 and 3.
- Combination of one elastic support with several rigid supports.
The elastic support is represented by a spring, with its constant calculated in N/m, according to [1.3.1] and [1.3.2]:
 - Z_C for rudders with solepiece (rudder type 2 as in Fig 1, and rudder type 5 as in Fig 3)
 - Z_p for semi-spade rudders with one elastic support provided by a rudder horn (rudder type 4 as in Fig 2, rudder type 7 as in Fig 7, and rudder type 8 as in Fig 8)
 - Z_{TRU} for spade rudders with rudder trunk (rudder type 6c, as shown in Fig 6).
- Combination of 2-conjugate elastic supports and one rigid support (rudder type 9 as in Fig 9, and rudder type 10 as in Fig 10).
The 2-conjugate elastic supports are defined by using two additional equations, according to [1.3.3].

1.3 Calculation of support stiffness properties

1.3.1 Sole piece

The spring constant Z_C for the support in the solepiece (see Fig 11) is to be obtained, in N/m, from the following formula:

$$Z_C = \frac{3EJ_{50}}{\ell_{50}^3} \cdot 10^{-8}$$

1.3.2 Rudder horn with 1-elastic support

The spring constant Z_P for the support in the rudder horn (see Fig 12 and Fig 13) is to be obtained, in N/m, from the following formula:

$$Z_P = \frac{1}{f_B + f_T}$$

where:

f_B : Unit displacement of rudder horn due to a unit force of 1 N acting in the centroid of the rudder horn, to be obtained, in m/N, from the following formula:

$$f_B = 1,3 \frac{d^3}{3EJ_N} \cdot 10^8$$

f_T : Unit displacement due to torsion, in m/N, to be obtained, in case of a rudder horn with a hollow cross section, from the following formula:

$$f_T = \frac{de^2}{4GF_T^2} \sum_i \frac{u_i}{t_i}$$

with:

d : Height, in m, of the rudder horn as defined in Fig 12 and Fig 13. This value is measured downwards from the upper rudder horn end, at the point of curvature transition, till the mid-line of the lower rudder horn pintle

J_N : Moment of inertia of rudder horn about the x axis, in cm^4

e : Rudder-horn torsion lever, in m, as defined in Fig 12 and Fig 13 (value taken at $z = d/2$)

F_T : Mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn, in m^2

u_i : Length, in mm, of the individual plates forming the mean horn sectional area

t_i : Thickness of the individual plates mentioned above, in mm.

1.3.3 Rudder horn with 2-conjugate elastic supports

The 2-conjugate elastic supports are defined by the following equations:

- at the lower rudder horn bearing: $y_1 = -K_{12} F_{A2} - K_{22} F_{A1}$
- at the upper rudder horn bearing: $y_2 = -K_{11} F_{A2} - K_{12} F_{A1}$

where:

y_1, y_2 : Horizontal displacements, in m, at the lower and upper rudder horn bearings, respectively

F_{A1}, F_{A2} : Horizontal support forces, in N, at the lower and upper rudder horn bearings, respectively

K_{11}, K_{22}, K_{12} : Rudder horn compliance constants obtained, in m/N, from the following formulae:

$$K_{11} = 1,3 \cdot \frac{\lambda^3}{3EJ_{1h}} + \frac{e^2 \cdot \lambda}{GJ_{th}}$$

$$K_{12} = 1,3 \cdot \left[\frac{\lambda^3}{3EJ_{1h}} + \frac{\lambda^2 \cdot (d-\lambda)}{2EJ_{1h}} \right] + \frac{e^2 \cdot \lambda}{GJ_{th}}$$

$$K_{22} = 1,3 \cdot \left[\frac{\lambda^3}{3EJ_{1h}} + \frac{\lambda^2 \cdot (d-\lambda)}{EJ_{1h}} + \frac{\lambda \cdot (d-\lambda)^2}{EJ_{1h}} + \frac{(d-\lambda)^3}{3EJ_{2h}} \right] + \frac{e^2 \cdot d}{GJ_{th}}$$

where:

d : Height of the rudder horn, in m, defined in Fig 14 and Fig 15. This value is measured downwards from the upper rudder horn end, at the point of curvature transition, till the mid-line of the lower rudder horn pintle

λ : Length, in m, as defined in Fig 14 and Fig 15. This length is measured downwards from the upper rudder horn end, at the point of curvature transition, till the mid-line of the upper rudder horn bearing. For $\lambda = 0$, the above formulae converge to those given in [1.3.2], in case of a rudder horn with a hollow cross-section

e : Rudder-horn torsion lever, in m, as defined in Fig 14 and Fig 15 (value taken at $z = d/2$)

J_{1h} : Moment of inertia of rudder horn about the x axis, in m^4 , for the region above the upper rudder horn bearing. Note that J_{1h} is an average value over the length λ (see Fig 15)

J_{2h} : Moment of inertia of rudder horn about the x axis, in m^4 , for the region between the upper and lower rudder horn bearings. Note that J_{2h} is an average value over the length $d - \lambda$ (see Fig 15)

J_{th} : Torsional stiffness factor of the rudder horn, in m^4 .

For any thin wall closed section:

$$J_{th} = \frac{4F_T^2}{\sum_i \frac{u_i}{t_i}}$$

F_T : Mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn, in m^2

u_i : Length, in mm, of the individual plates forming the mean horn sectional area

t_i : Thickness, in mm, of the individual plates mentioned above

Note that the J_{th} value is taken as an average value, valid over the rudder horn height.

1.3.4 Rudder trunk

The spring constant Z_{TRU} for the support in the trunk (lower rudder stock bearing as shown in Fig 16) is to be obtained, in N/m, from the following formula:

$$Z_{TRU} = \frac{3EJ_{TRU}}{\ell_{TRU}^3} \cdot 10^{-8}$$

1.4 Calculation of the main structure of the rudder system

1.4.1 Rudder type 1

The force per unit length p_R acting on the rudder body is to be obtained, in N/m, from the following formula:

$$p_R = \frac{C_R}{\ell}$$

with:

ℓ : Height of the rudder blade, in m.

The rudder structure is to be calculated according to approximate formulae given here below:

- maximum bending moment in the rudder stock, in N·m: $M_B = 0$
- support forces, in N:
 - $F_{A1} = F_{A2} = F_{A3} = C_R / 3$
 - $F_{A4} = 0$
- bending moment in the rudder blade of streamlined rudders, in N·m: $M_R = C_R \ell / 24$

1.4.2 Rudder type 2

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 1.

The force per unit length p_R acting on the rudder body is to be obtained, in N/m, from the following formula:

$$p_R = \frac{C_R}{\ell}$$

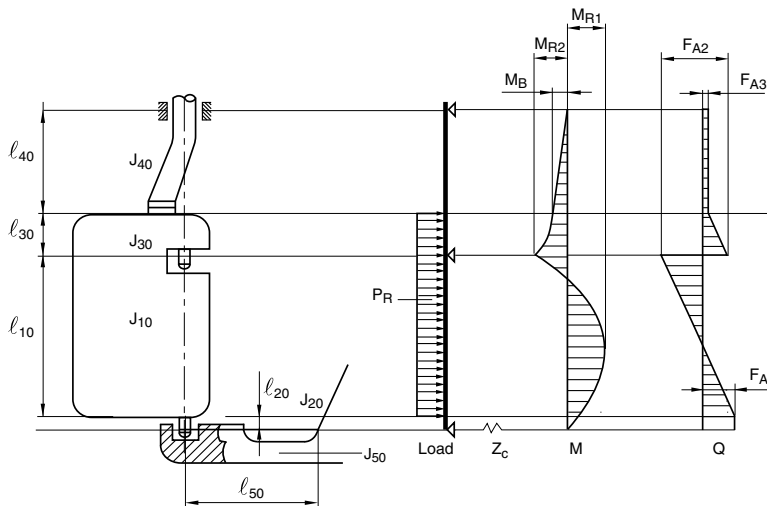
with:

ℓ : Height of the rudder blade, in m, as follows:

$$\ell = \ell_{10} + \ell_{30}$$

The spring constant Z_c is to be calculated according to [1.3.1].

Figure 1 : Rudder type 2



1.4.3 Rudder type 3

The force per unit length p_R acting on the rudder body is to be obtained, in N/m, from the following formula:

$$p_R = \frac{C_R}{l}$$

with:

l : Height of the rudder blade, in m.

The rudder structure is to be calculated according to approximate formulae given here below:

- maximum bending moment in the rudder stock, in N·m: $M_B = 0$
- support forces, in N:

$$F_{A1} = F_{A2} = C_R/2$$

$$F_{A3} = 0$$

1.4.4 Rudder type 4

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 2.

The forces per unit length p_{R10} and p_{R20} acting on the rudder body are to be obtained, in N/m, from the following formulae:

$$p_{R10} = \frac{C_{R2}}{l_{10}}$$

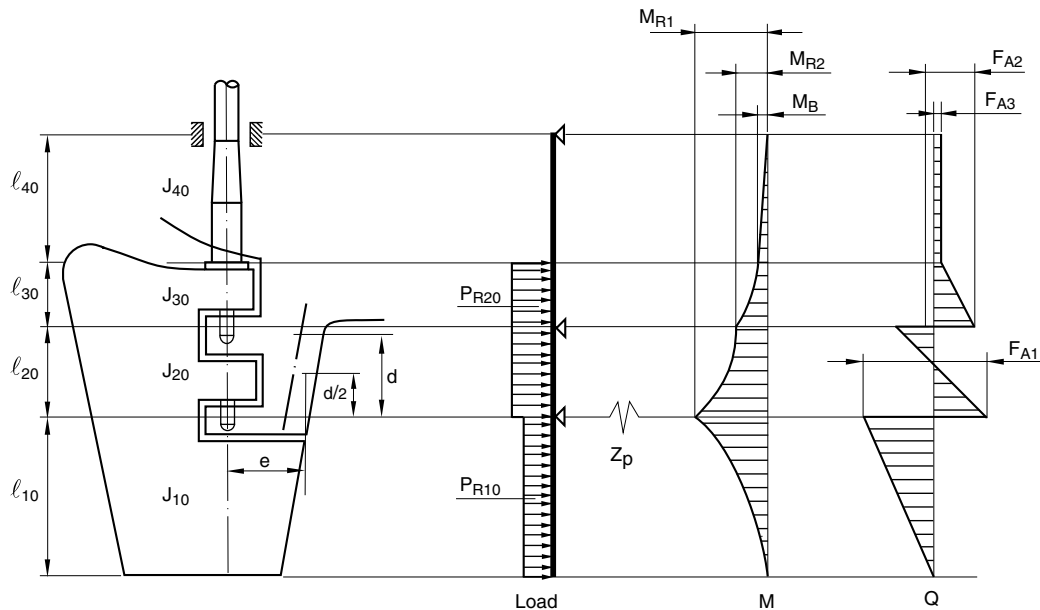
$$p_{R20} = \frac{C_{R1}}{l}$$

with:

$$l = l_{20} + l_{30}$$

The spring constant Z_p is to be calculated according to [1.3.2].

Figure 2 : Rudder type 4



1.4.5 Rudder type 5

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 3.

The force per unit length p_R acting on the rudder body is to be obtained, in N/m, from the following formula:

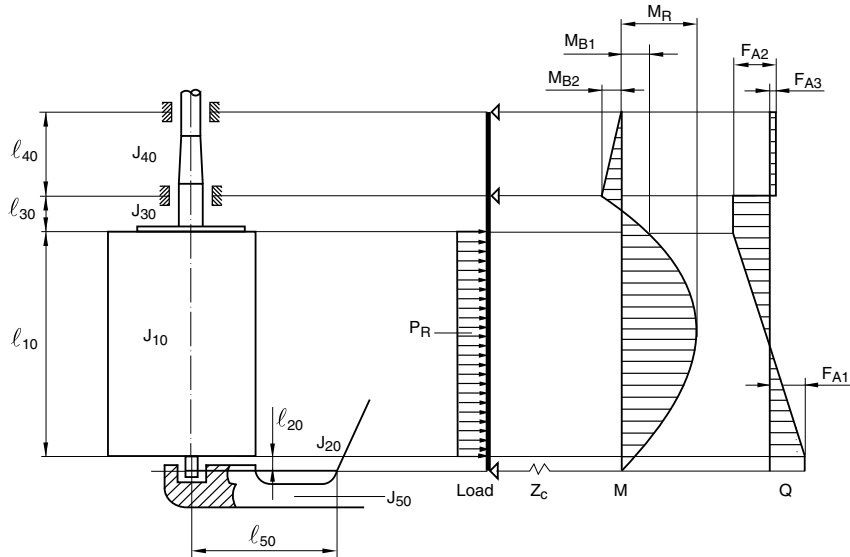
$$p_R = \frac{C_R}{l}$$

with:

l : Height of the rudder blade, in m.

The spring constant Z_c is to be calculated according to [1.3.1].

Figure 3 : Rudder type 5



1.4.6 Rudder type 6a

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 4. The force per unit length p_R acting on the rudder body is to be obtained, in N/m, from the following formula:

$$p_{Rz} = p_{R10} + \left(\frac{p_{R20} - p_{R10}}{l_{10}} \right) \cdot z$$

where:

- z : Position of rudder blade section, in m, taken over l_{10} length
- p_{Rz} : Force per unit length, in N/m, obtained at the z position
- p_{R10} : Force per unit length, in N/m, obtained for z equal to zero
- p_{R20} : Force per unit length, in N/m, obtained for z equal to l_{10} .

For this type of rudder, the results of calculations performed according to diagrams shown in Fig 4 may also be obtained from the following formulae:

- maximum bending moment in the rudder stock, in N-m:

$$M_B = C_R \left(l_{20} + \frac{l_{10}(2C_1 + C_2)}{3(C_1 + C_2)} \right)$$

where C_1 and C_2 are the lengths, in m, defined in Fig 4

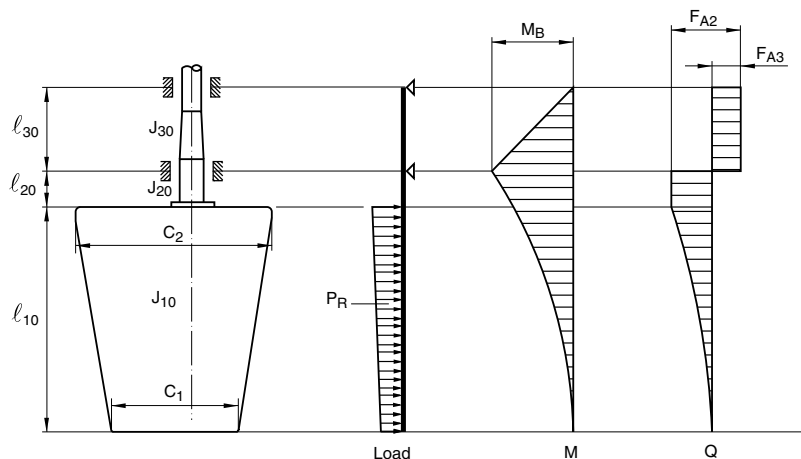
- support forces, in N:

$$F_{A3} = \frac{M_B}{l_{30}}$$

$$F_{A2} = C_R + F_{A3}$$

- maximum shear force in the rudder body, in N: $Q_R = C_R$.

Figure 4 : Rudder type 6a



1.4.7 Rudder type 6b

This type of rudder is regarding spade rudders with rudder trunks continued into the rudder blade, through a quite short length, in such way the centre of gravity of the rudder blade is located below the lower rudder stock bearing. The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 5.

The force per unit length p_R acting on the lower part of the rudder body is to be obtained, in N/m, from the following formula:

$$p_{Rz} = p_{R10} + \left(\frac{p_{R20} - p_{R10}}{\ell_{10}} \right) \cdot z$$

where:

- z : Position of rudder blade section, in m, taken over ℓ_{10} length
- p_{Rz} : Force per unit length, in N/m, obtained at the z position
- p_{R10} : Force per unit length, in N/m, obtained for z equal to zero
- p_{R20} : Force per unit length, in N/m, obtained for z equal to ℓ_{10} .

The values of p_{R10} and p_{R20} are obtained from the following two equations:

$$p_{R10} = \frac{2C_R(2\ell_{10} - 3\ell_{CG})}{\ell_{10}^2}$$

$$p_{R20} = \frac{2C_R(3\ell_{CG} - \ell_{10})}{\ell_{10}^2}$$

where:

- C_R : Force, in N, acting on the total rudder blade area A , to be calculated in accordance with Ch 12, Sec 1, [2.1.2]
- A : Total rudder blade area, in m^2
- ℓ_{CG} : Vertical position, in m, of the centre of gravity of the total rudder blade area A , to be taken from the bottom of the rudder blade.

The bending moments M_R and M_B , in N·m, for the scantling of both the rudder blade and the lower rudder stock diameter, respectively, are identical and shall be taken as follows:

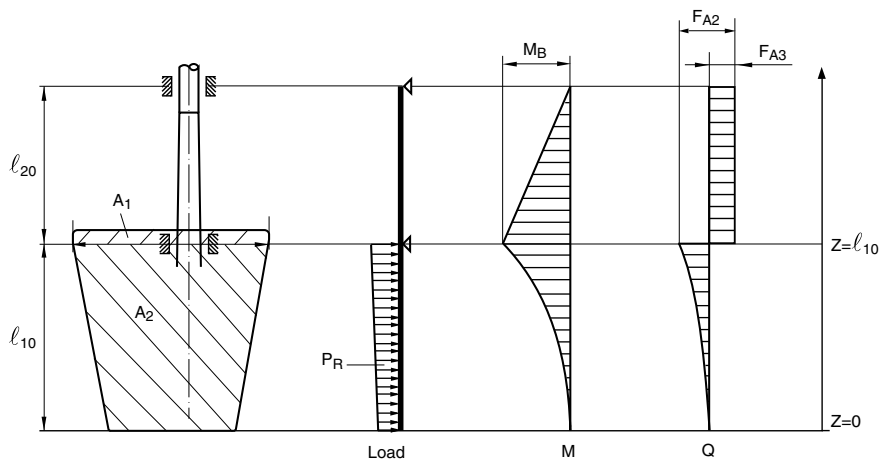
$$M_R = M_B = C_R \cdot (\ell_{10} - \ell_{CG})$$

The reaction forces F_{A2} and F_{A3} , in N, may be determined as follows:

$$F_{A3} = M_B / \ell_{20}$$

$$F_{A2} = -(C_R + F_{A3})$$

Figure 5 : Rudder type 6b



1.4.8 Rudder type 6c

This type of rudder provides a more general solution for the scantling of spade rudders with rudder trunks continued into the rudder blade. There is no limitation on the location of the centre of gravity of the total rudder blade area, which may be located either below the lower rudder stock bearing or slightly above it. The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 6.

The force per unit length p_R acting on the lower part of the rudder body is to be obtained, in N/m, from the following formula:

$$p_{Rz} = p_{R10} + \left(\frac{p_{R20} - p_{R10}}{\ell_{10}} \right) \cdot z$$

where:

- z : Position of rudder blade section, in m, taken over ℓ_{10} length

- p_{Rz} : Force per unit length, in N/m, obtained at the z position
- p_{R10} : Force per unit length, in N/m, obtained for z equal to zero
- p_{R20} : Force per unit length, in N/m, obtained for z equal to l_{10} .

The values of p_{R10} and p_{R20} are obtained from the following two equations:

$$p_{R10} = \frac{2C_{R2}(2l_{10} - 3l_{CG2})}{l_{10}^2}$$

$$p_{R20} = \frac{2C_{R2}(3l_{CG2} - l_{10})}{l_{10}^2}$$

where:

- C_{R2} : Force, in N, acting on the rudder blade area A_2 , to be calculated in accordance with Ch 12, Sec 1, [2.2.3]
- A_2 : Rudder blade area, in m^2 , located below the lower rudder stock bearing
- l_{CG2} : Vertical position, in m, of the centre of gravity of the rudder blade area A_2 , to be taken from the bottom of the rudder blade.

The bending moment M_R , in N-m, for the scantling of the rudder blade, shall be taken as the greatest of the following values:

- $M_{C_{R2}} = C_{R2} \cdot (l_{10} - l_{CG2})$
- $M_{C_{R1}} = C_{R1} \cdot (l_{CG1} - l_{10})$

where:

- $M_{C_{R2}}$: Bending moment, in N-m, induced by the rudder force C_{R2} ($M_{C_{R2}}$ is assumed to be of a negative sign)
- $M_{C_{R1}}$: Bending moment, in N-m, induced by the rudder force C_{R1} ($M_{C_{R1}}$ is assumed to be of a positive sign)
- C_{R1} : Force, in N, acting on the rudder blade area A_1 , to be calculated in accordance with Ch 12, Sec 1, [2.2.3]
- A_1 : Rudder blade area, in m^2 , located above the lower rudder stock bearing
- l_{CG1} : Vertical position, in m, of the centre of gravity of the rudder blade area A_1 , to be taken from the bottom of the rudder blade.

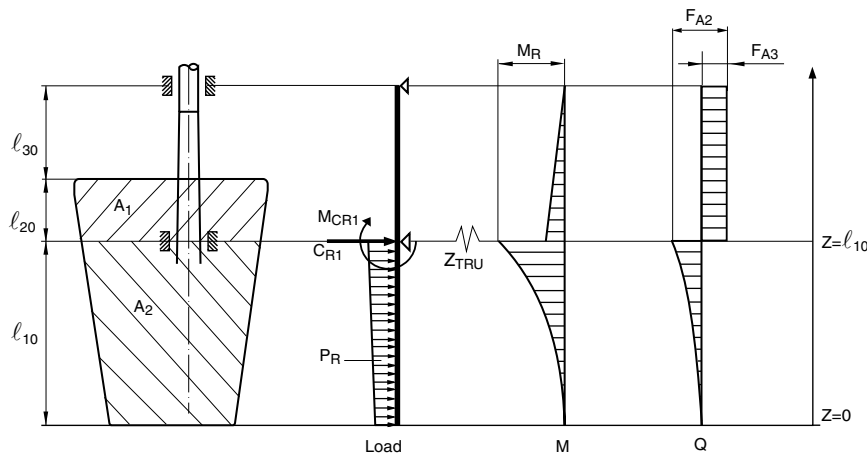
The bending moment M_B , in N-m, for the scantling of the lower rudder stock diameter, is given by the algebraic sum of $M_{C_{R2}}$ and $M_{C_{R1}}$, as follows: $M_B = M_{C_{R2}} + M_{C_{R1}}$

The reaction forces F_{A2} and F_{A3} , in N, may be determined as follows:

$$F_{A3} = M_B / (l_{20} + l_{30})$$

$$F_{A2} = -(C_{R1} + C_{R2} + F_{A3})$$

Figure 6 : Rudder type 6c



1.4.9 Rudder type 7

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 7.

The forces per unit length p_{R10} and p_{R20} acting on the rudder body are to be obtained, in N/m, from the following formulae:

$$p_{R10} = \frac{C_{R2}}{l_{10}}$$

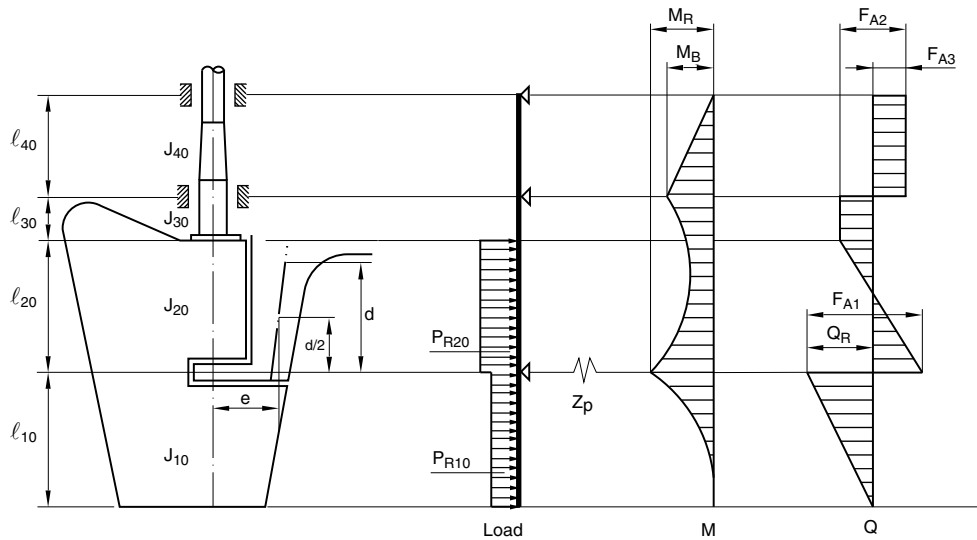
$$p_{R20} = \frac{C_{R1}}{l}$$

where:

- l : Value equal to: $l = l_{20}$

The spring constant Z_p is to be calculated according to [1.3.2].

Figure 7 : Rudder type 7



1.4.10 Rudder type 8

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 8.

The forces per unit length p_{R10} and p_{R20} acting on the rudder body are to be obtained, in N/m, from the following formulae:

$$p_{R10} = \frac{C_{R2}}{l_{10}}$$

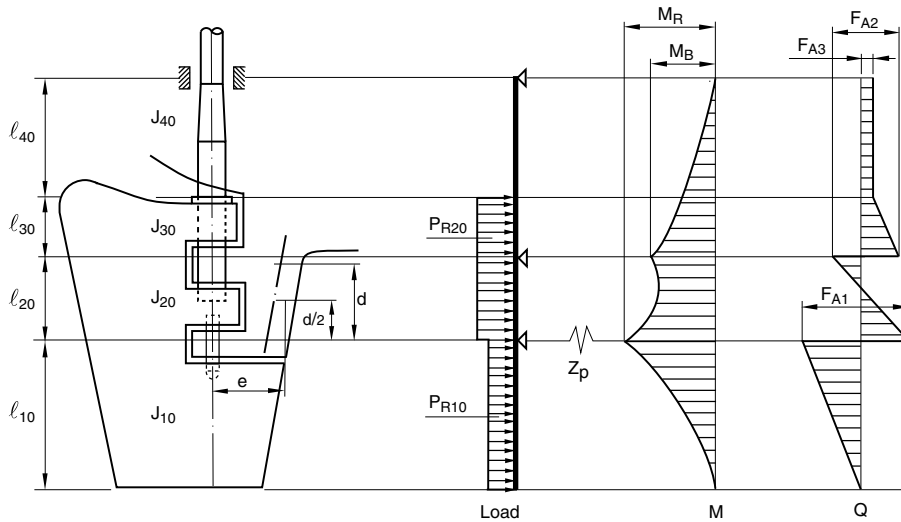
$$p_{R20} = \frac{C_{R1}}{l}$$

with:

$$l = l_{20} + l_{30}$$

The spring constant Z_p is to be calculated according to [1.3.2].

Figure 8 : Rudder type 8



1.4.11 Rudder type 9

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 9.

The forces per unit length p_{R10} and p_{R20} acting on the rudder body are to be obtained, in N/m, from the following formulae:

$$p_{R10} = \frac{C_{R2}}{l_{10}}$$

$$p_{R20} = \frac{C_{R1}}{l}$$

with:

$$l = l_{20}$$

The stiffness properties of the 2-conjugate elastic supports are to be calculated according to [1.3.3].

Figure 9 : Rudder type 9

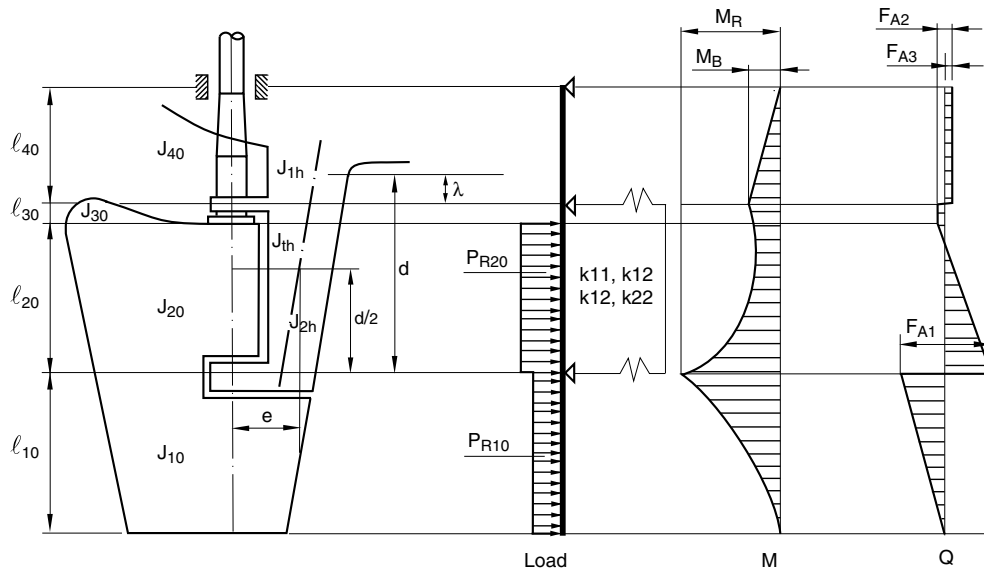
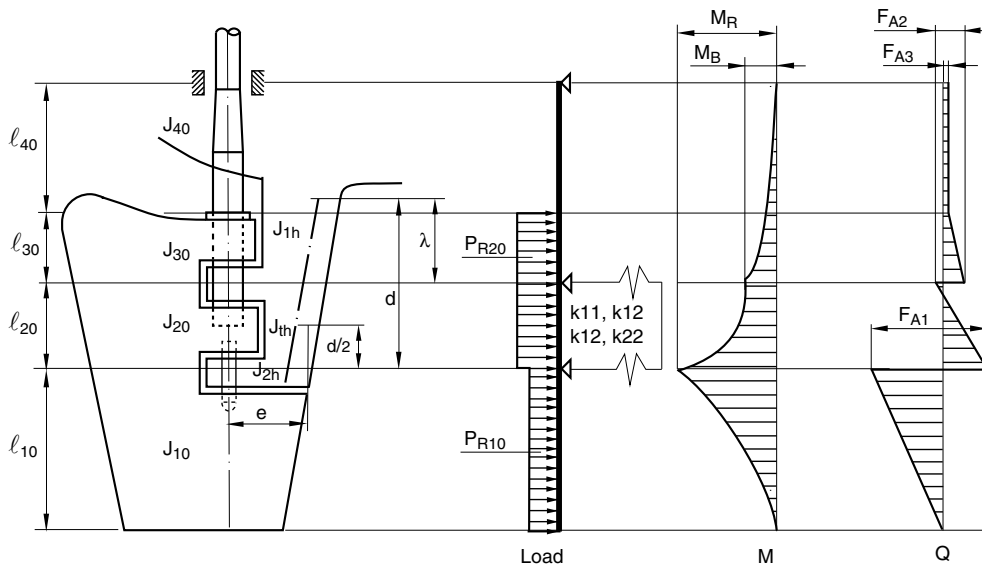


Figure 10 : Rudder type 10



1.4.12 Rudder type 10

The rudder structure is to be calculated according to load, shear force and bending moment diagrams shown in Fig 10. The forces per unit length p_{R10} and p_{R20} acting on the rudder body are to be obtained, in N/m, from the following formulae:

$$p_{R10} = \frac{C_{R2}}{l_{10}}$$

$$p_{R20} = \frac{C_{R1}}{l}$$

with:

$$l = l_{20} + l_{30}$$

The stiffness properties of the 2-conjugate elastic supports are to be calculated according to [1.3.3].

1.5 Calculation of the solepiece

1.5.1 Bending moment

The bending moment acting on the generic section of the solepiece is to be obtained, in N-m, from the following formula:

$$M_S = F_{A1} \times x$$

where:

F_{A1} : Supporting force, in N, in the pintle bearing, to be determined according to [1.4], for the relevant type of rudder

x : Distance, in m, defined in Fig 11.

1.5.2 Stress calculations

For the generic section of the solepiece within the length ℓ_{50} , defined in Fig 11, the following stresses are to be calculated:

σ_B : Bending stress to be obtained, in N/mm², from the following formula:

$$\sigma_B = \frac{M_S}{W_Z}$$

τ : Shear stress to be obtained, in N/mm², from the following formula:

$$\tau = \frac{F_{A1}}{A_S}$$

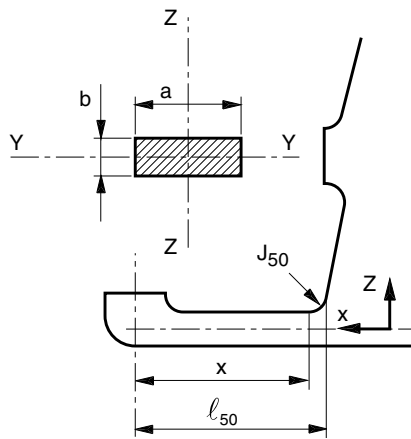
M_S : Bending moment, in N·m, at the section considered, as defined in [1.5.1]

F_{A1} : Force, in N, defined in [1.5.1]

W_Z : Section modulus, in cm³, around the vertical axis Z (see Fig 11)

A_S : Shear sectional area, in mm², in a plane perpendicular to the X axis of the solepiece.

Figure 11 : Solepiece geometry



1.6 Rudder horn calculation (case of 1-elastic support)

1.6.1 Bending moment

The bending moment acting on the generic section of the rudder horn is to be obtained, in N·m, from the following formula:

$$M_H = F_{A1} z$$

where:

F_{A1} : Support force at the rudder horn lower-pintle, in N, to be obtained according to [1.4], for the relevant type of rudder

z : Distance, in m, defined in Fig 13, to be taken less than the distance d , in m, defined in the same figure.

1.6.2 Shear force

The shear force Q_H acting on the generic section of the rudder horn is to be obtained, in N, from the following formula:

$$Q_H = F_{A1}$$

where:

F_{A1} : Force, in N, defined in [1.6.1].

1.6.3 Torque

The torque acting on the generic section of the rudder horn is to be obtained, in N·m, from the following formula:

$$M_T = F_{A1} e_{(z)}$$

where:

F_{A1} : Force, in N, defined in [1.6.1]

$e_{(z)}$: Torsion lever, in m, defined in Fig 13.

1.6.4 Stress calculations

For the generic section of the rudder horn within the length d , defined in Fig 13, the following stresses are to be calculated:

σ_B : Bending stress to be obtained, in N/mm², from the following formula:

$$\sigma_B = \frac{M_H}{W_X}$$

M_H : Bending moment at the section considered, in N·m, defined in [1.6.1]

W_X : Section modulus, in cm³, around the horizontal axis X (see Fig 13)

τ_s : Shear stress to be obtained, in N/mm², from the following formula:

$$\tau_s = \frac{F_{A1}}{A_H}$$

F_{A1} : Force, in N, defined in [1.6.1]

A_H : Effective shear sectional area of the rudder horn, in mm², in y-direction

τ_T : Torsional stress to be obtained for hollow rudder horn, in N/mm², from the following formula:

$$\tau_T = \frac{M_T 10^3}{2 F_T t_H}$$

For solid rudder horn, τ_T is to be considered by the Society on a case-by-case basis

M_T : Torque, in N·m, defined in [1.6.3]

F_T : Mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn, in m²

t_H : Plate thickness of rudder horn, in mm. For a given cross section of the rudder horn, the maximum value of τ_T , is obtained at the minimum value of t_H .

Figure 12 : Rudder and rudder horn geometries (1-elastic support)

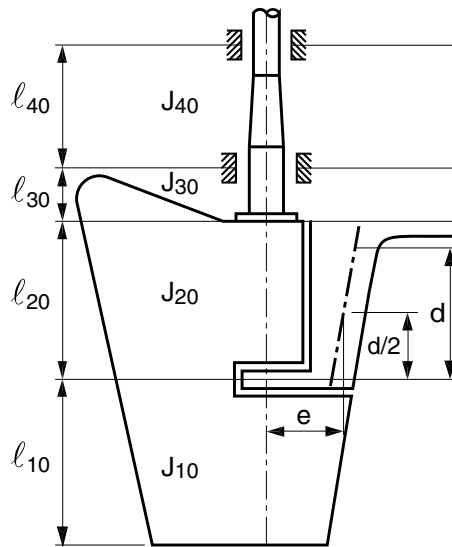
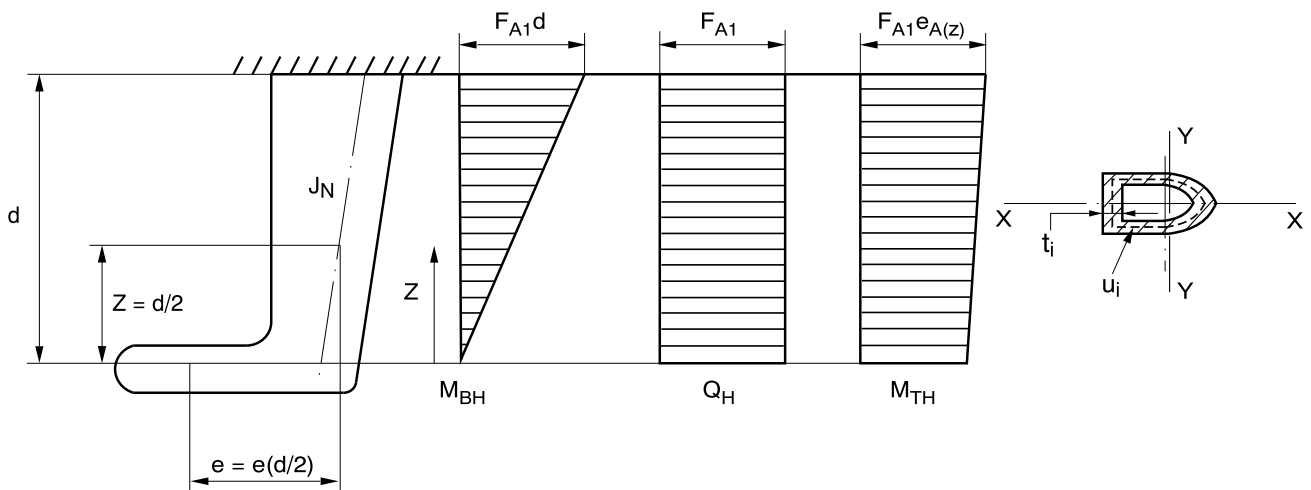


Figure 13 : Rudder horn geometry (1-elastic support)



1.7 Rudder horn calculation (case of 2-conjugate elastic supports)

1.7.1 Bending moment

The bending moment acting on the generic section of the rudder horn is to be obtained, in N·m, from the following formulae:

- between the lower and upper supports provided by the rudder horn: $M_H = F_{A1} z$
- above the rudder horn upper-support: $M_H = F_{A1} z + F_{A2} (z - d_{iw})$

where:

- F_{A1} : Support force at the rudder horn lower-support, in N, to be obtained according to [1.4], for the relevant type of rudder
 F_{A2} : Support force at the rudder horn upper-support, in N, to be obtained according to [1.4], for the relevant type of rudder
 z : Distance, in m, defined in Fig 15, to be taken less than the distance d , in m, defined in the same figure
 d_{lu} : Distance, in m, between the rudder-horn lower and upper bearings (according to Fig 14, $d_{lu} = d - \lambda$).

1.7.2 Shear force

The shear force Q_H acting on the generic section of the rudder horn is to be obtained, in N, from the following formulae:

- between the lower and upper rudder horn bearings: $Q_H = F_{A1}$
- above the rudder horn upper-bearing: $Q_H = F_{A1} + F_{A2}$

where:

F_{A1}, F_{A2} : Support forces, in N, defined in [1.7.1].

1.7.3 Torque

The torque acting on the generic section of the rudder horn is to be obtained, in N·m, from the following formulae:

- between the lower and upper rudder horn bearings: $M_T = F_{A1} e_{(z)}$
- above the rudder horn upper-bearing: $M_T = F_{A1} e_{(z)} + F_{A2} e_{(z)}$

where:

F_{A1}, F_{A2} : Support forces, in N, defined in [1.7.1]

$e_{(z)}$: Torsion lever, in m, defined in Fig 15.

1.7.4 Shear stress calculation

a) For a generic section of the rudder horn, located between its lower and upper bearings, the following stresses are to be calculated:

τ_s : Shear stress, in N/mm², to be obtained from the following formula:

$$\tau_s = \frac{F_{A1}}{A_H}$$

τ_T : Torsional stress, in N/mm², to be obtained for hollow rudder horn from the following formula:

$$\tau_T = \frac{M_T 10^3}{2 F_T t_H}$$

For solid rudder horn, τ_T is to be considered by the Society on a case-by-case basis

b) For a generic section of the rudder horn, located in the region above its upper bearing, the following stresses are to be calculated:

τ_s : Shear stress, in N/mm², to be obtained from the following formula:

$$\tau_s = \frac{F_{A1} + F_{A2}}{A_H}$$

τ_T : Torsional stress, in N/mm², to be obtained for hollow rudder horn from the following formula:

$$\tau_T = \frac{M_T 10^3}{2 F_T t_H}$$

For solid rudder horn, τ_T is to be considered by the Society on a case-by-case basis

where:

F_{A1}, F_{A2} : Support forces, in N, defined in [1.7.1]

A_H : Effective shear sectional area of the rudder horn, in mm², in y-direction

M_T : Torque, in N·m, defined in [1.7.3]

F_T : Mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn, in m²

t_H : Plate thickness of rudder horn, in mm. For a given cross section of the rudder horn, the maximum value of τ_T , is obtained at the minimum value of t_H .

1.7.5 Bending stress calculation

For the generic section of the rudder horn within the length d , defined in Fig 15, the following stresses are to be calculated:

σ_B : Bending stress, in N/mm², to be obtained from the following formula:

$$\sigma_B = \frac{M_H}{W_X}$$

M_H : Bending moment at the section considered, in N·m, defined in [1.7.1]

W_X : Section modulus, in cm³, around the horizontal axis X (see Fig 15).

Figure 14 : Rudder and rudder horn geometries (2-conjugate elastic supports)

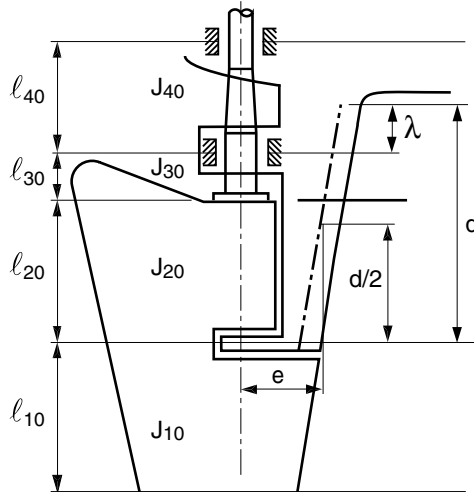
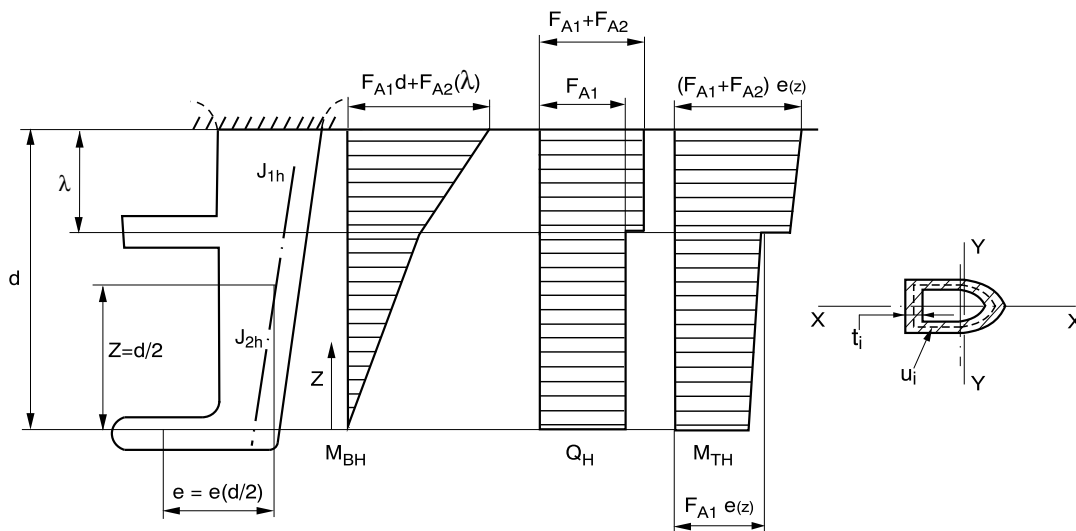


Figure 15 : Rudder horn geometry (2-conjugate elastic supports)



1.8 Calculation of the rudder trunk

1.8.1 Bending moment

The bending moment acting on the generic section of the trunk is to be obtained, in N·m, from the following formula:

$$M_{TRU} = F_{A2} z$$

where:

- F_{A2} : Support force, in N, at the lower rudder stock bearing, as defined in [1.4]
- z : Distance, in m, defined in Fig 16.

1.8.2 Stress calculations

For the generic section of the trunk within the length l_{TRU} , defined in Fig 16, the following stresses are to be calculated:

- σ_B : Bending stress to be obtained, in N/mm², from the following formula:

$$\sigma_B = \frac{M_{TRU}}{W_{TRU}}$$

- τ : Shear stress to be obtained, in N/mm², from the following formula:

$$\tau = \frac{F_{A2}}{A_{TRU}}$$

M_{TRU} : Bending moment, in N·m, at the section considered, as defined in [1.8.1]

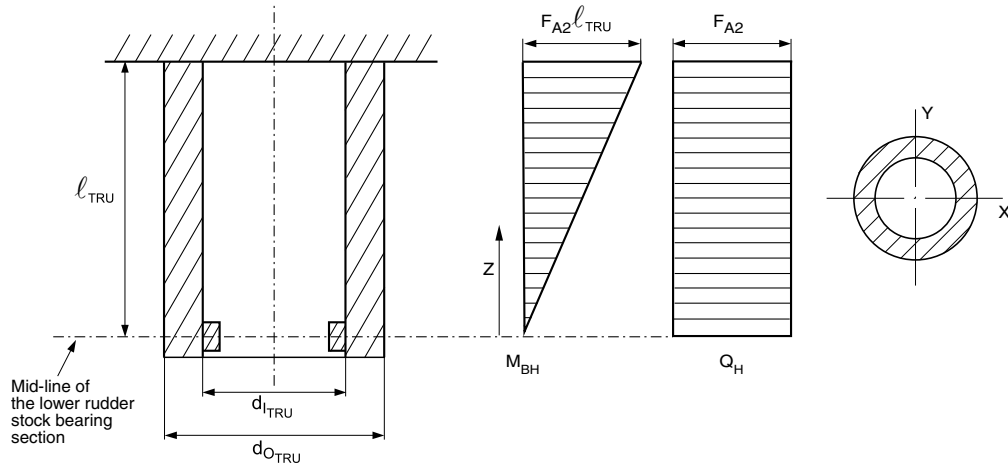
F_{A2} : Support force, in N, at the lower rudder stock bearing, as defined in [1.4]

W_{TRU} : Section modulus, in cm³, around the horizontal axis X (see Fig 16)

A_{TRU} : Shear sectional area, in mm^2 , in a plane perpendicular to the Z axis of the trunk.

The length l_{TRU} is the distance in m, taken between the mid-line of the lower rudder stock bearing and the “top line” of the trunk. This “top line” is defined either where the trunk is clamped into the shell or at the bottom of the skeg, as shown in the diagram Fig 16.

Figure 16 : Rudder trunk geometry



Appendix 2 Towing and Mooring Arrangement

1 General

1.1 Application

1.1.1 The towing and mooring arrangement as defined in the present article and the towing and mooring lines as defined in Article [2] are given as a guidance but are not required as a condition of classification.

1.2 Definition

1.2.1 For symbols and definitions not defined in this Section, refer to Ch 12, Sec 4.

1.3 Mooring arrangement

1.3.1 Attention is to be given to the arrangement of the equipment for towing and mooring operations in order to prevent interference of mooring and towing lines as far as practicable. It is beneficial to provide dedicated towing arrangements separate from the mooring equipment.

1.3.2 Mooring lines in the same service (e.g. breast lines as defined in [2.7.1]) are to be of the same characteristic in terms of strength and elasticity.

1.3.3 As far as possible, sufficient number of mooring winches are to be fitted to allow for all mooring lines to be belayed on winches. This allows for an efficient distribution of the load to all mooring lines in the same service and for the mooring lines to shed load before they break. If the mooring arrangement is designed such that mooring lines are partly to be belayed on bitts or bollards, it should be considered that these lines may not be as effective as the mooring lines belayed on winches.

1.3.4 Mooring lines are to have as straight a lead as is practicable from the mooring drum to the fairlead.

1.3.5 At points of change in direction sufficiently large radii of the contact surface of a rope on a fitting are to be provided to minimize the wear experienced by mooring lines and as recommended by the rope manufacturer for the rope type intended to be used.

1.4 Towing arrangement

1.4.1 As far as possible, towing lines is to be led through a closed chock. The use of open fairleads with rollers or closed roller fairleads is to be avoided.

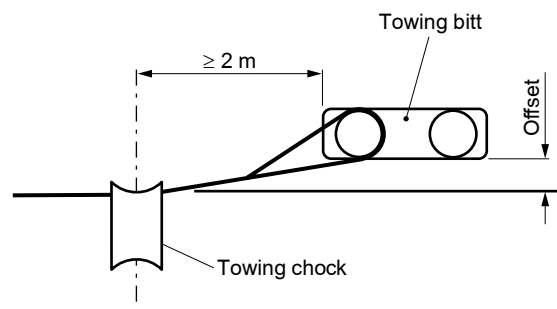
1.4.2 For towing purpose it is recommended to provide at least one chock close to centreline of the ship forward and aft. It is also beneficial to provide additional chocks on port and starboard side at the transom and at the bow.

1.4.3 Towing lines are to have a straight lead from the towing bitt or bollard to the chock.

1.4.4 For the purpose of towing, bitts or bollards serving a chock are to be located slightly offset and in a distance of at least 2 m away from the chock, see Fig 1.

1.4.5 Warping drums are to be preferably positioned not more than 20 m away from the chock, measured along the path of the line.

Figure 1 : Bitts or bollards serving a chock for towing purpose



2 Tow lines and mooring lines

2.1 General

2.1.1 The equipment in tow line and mooring lines (length, MBL_{SD} and number of lines) is obtained from Tab 1 and Tab 2 based on an Equipment Number EN calculated according to Ch 12, Sec 4, [1.2.2] with a side projected area A including deck cargoes at ship nominal capacity, as defined in Ch 12, Sec 4, [4.2.1].

2.1.2 For mooring lines for ships with $EN > 2000$, length, breaking load and number of lines are defined in [2.7].

2.1.3 The breaking load given in Tab 1, Tab 2 or in [2.7.4] is used to determine the maximum design load applied to shipboard fittings as defined in Ch 12, Sec 4, [4.2.5].

2.1.4 The tow lines having the characteristics defined in Tab 1, Tab 2 and [2.7] are intended as those belonging to the ship to be towed by a tug or another ship under normal towing conditions (calm water / harbour).

2.1.5 The Designer is to verify the adequacy of towing lines based on assessments carried out for the individual towing arrangement.

2.1.6 The designer is to verify the adequacy of mooring lines based on assessments carried out for the individual mooring arrangement, expected shore-side mooring facilities and design environmental conditions for the berth.

2.2 Materials

2.2.1 Tow lines and mooring lines may be of wire or synthetic fibre or a mixture of wire and fibre.

2.2.2 The breaking loads defined in Tab 1, Tab 2 and [2.7.4] refer to steel wires.

2.2.3 As a guidance, all requirements about manufacturing, sampling and testing for steel wires and fibre ropes are available in NR216 Materials and Welding, Ch 10, Sec 5.

2.3 Steel wires

2.3.1 Steel wires are to be made of flexible galvanised steel and are to be of types defined in Tab 3.

2.3.2 Where the wire is wound on the winch drum, steel wires to be used with mooring winches may be constructed with an independent metal core instead of a fibre core. In general such wires are to have not less than 186 threads in addition to the metallic core.

2.4 Length of mooring lines

2.4.1 The length of individual mooring lines may be reduced by up to 7% of the length defined in Tab 1 and [2.7.5] provided that the total length of mooring lines is greater than that obtained by adding the lengths of the individual lines defined in Tab 1 and [2.7.5].

2.4.2 For ships with the service notation **supply**, the length of mooring lines may be reduced. The reduced length ℓ is to be not less than that obtained, in m, from the following formula:

$$\ell = L + 20$$

2.5 Synthetic fibre ropes

2.5.1 Where synthetic fibre ropes are adopted, their size is to be determined taking into account the type of material used and the manufacturing characteristics of the rope, as well as the different properties of such ropes.

2.5.2 It is recommended to use lines with reduced risk of recoil (snap-back) to mitigate the risk of injuries or fatalities in the case of breaking mooring lines.

2.5.3 The line design break force of synthetic fibre ropes B_{LS} is to be not less than that obtained, in kN, from the following formula:

$$B_{LS} = K B_{L0}$$

where:

B_{L0} : MBL_{SD} , in kN, for the line, defined in Tab 1, Tab 2 and [2.7.4]

K : Coefficient to be taken equal to:

- for polyamide lines: $K = 1,2$
- for lines made in other synthetic material: $K = 1,1$

2.5.4 Fibre rope diameters are to be not less than 20 mm.

Table 1 : Tow line and mooring lines for EN ≤ 2000

Equipment number EN A < EN ≤ B		Tow line		Mooring lines		
A	B	Minimum length, in m	MBL _{SDr} in kN(1)	N(2)	Length of each line, in m	MBL _{SDr} in kN(1)
50	70	180	98	3	80	37
70	90	180	98	3	100	40
90	110	180	98	3	110	42
110	130	180	98	3	110	48
130	150	180	98	3	120	53
150	175	180	98	3	120	59
175	205	180	112	3	120	64
205	240	180	129	4	120	69
240	280	180	150	4	120	75
280	320	180	174	4	140	80
320	360	180	207	4	140	85
360	400	180	224	4	140	96
400	450	180	250	4	140	107
450	500	180	277	4	140	117
500	550	190	306	4	160	134
550	600	190	338	4	160	143
600	660	190	370	4	160	160
660	720	190	406	4	160	171
720	780	190	441	4	170	187
780	840	190	479	4	170	202
840	910	190	518	4	170	218
910	980	190	559	4	170	235
980	1060	200	603	4	180	250
1060	1140	200	647	4	180	272
1140	1220	200	691	4	180	293
1220	1300	200	738	4	180	309
1300	1390	200	786	4	180	336
1390	1480	200	836	4	180	352
1480	1570	220	888	5	190	352
1570	1670	220	941	5	190	362
1670	1790	220	1024	5	190	384
1790	1930	220	1109	5	190	411
1930	2000	220	1168	5	190	437

(1) Refer to Ch 12, Sec 4, [4.2.1]
(2) Refer to [2.6].

Table 2 : Tow line for EN > 2000

Equipment number EN A < EN ≤ B		Tow line	
A	B	Minimum length, in m	MBL _{SD} , in kN(1)
2000	2080	220	1168
2080	2230	240	1259
2230	2380	240	1356
2380	2530	240	1453
2530	2700	260	1471
2700	2870	260	1471
2870	3040	260	1471
3040	3210	280	1471
3210	3400	280	1471
3400	3600	280	1471
3600	3800	300	1471
3800	4000	300	1471
4000	4200	300	1471
4200	4400	300	1471
4400	4600	300	1471
4600	4800	300	1471
4800	5000	300	1471
5000	5200	300	1471
5200	5500	300	1471
5500	5800	300	1471
5800	6100	300	1471
6100	6500	300	1471
6500	6900	300	1471
6900	7400	300	1471
7400	7900	300	1471
7900	8400	300	1471
8400	8900	300	1471
8900	9400	300	1471
9400	10000	300	1471
10000	10700	300	1471
10700	11500	300	1471
11500	12400	300	1471
12400	13400	300	1471
13400	14600	300	1471
14600	16000	300	1471

(1) Refer to Ch 12, Sec 4, [4.2.1]

Table 3 : Steel wire composition

Breaking load B _L , in kN	Steel wire components		
	Number of threads	Range of ultimate tensile strength of threads, in N/mm ²	Composition of wire
B _L < 216	72	1420 – 1570	6 strands with 7-fibre core
216 < B _L < 490	144	1570 – 1770	6 strands with 7-fibre core
B _L > 490	216 or 222	1770 – 1960	6 strands with 1-fibre core

2.6 Additional mooring lines

2.6.1 For ships having the ration $A/EN > 0,9$, additional mooring lines are defined in Tab 4, in addition to the number of mooring lines defined in Tab 1.

Table 4 : Additional mooring lines

A / EN	Number of additional mooring lines
$0,9 < A / EN \leq 1,1$	1
$1,1 < A / EN \leq 1,2$	2
$1,2 < A / EN$	3

Note 1: A and EN are defined in Ch 12, Sec 4, [1.2.2].

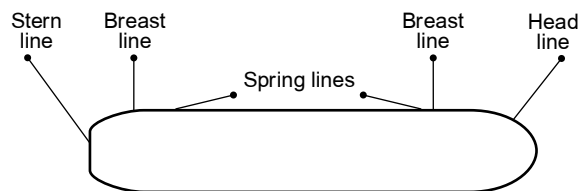
2.7 Mooring lines for ships with EN > 2000

2.7.1 Definitions

The following is defined with respect to the purpose of mooring lines, see also Fig 2:

- breast line: mooring line that is deployed perpendicular to the ship, restraining the ship in the off-berth direction.
- spring line: mooring line that is deployed almost parallel to the ship, restraining the ship in fore or aft direction.
- head/Stern line: mooring line that is oriented between longitudinal and transverse direction, restraining the ship in the off-berth and in fore or aft direction. The amount of restraint in fore or aft and off-berth direction depends on the line angle relative to these directions.

Figure 2 : Breast, spring and head/stern mooring lines



2.7.2 Side projected area A_1

The strength of mooring lines and the number of head, stern, and breast lines for ships with an Equipment Number EN > 2000 are based on the side-projected area A_1 .

Side projected area A_1 is to be calculated similar to the side-projected area A according to Ch 12, Sec 4, [1.2.2] but considering the following conditions:

- the ballast draft is to be considered for the calculation of the side projected area A_1 . For ship types having small variation in the draft, like e.g. passenger and RO/RO ships, the side projected area A_1 may be calculated using the summer load waterline.
- deck cargoes at ship nominal capacity condition as defined in Ch 12, Sec 4, [4.2.1] are to be included for the determination of side-projected area A_1 . For the condition with cargo on deck, the summer load waterline may be considered.

Note 1: Wind shielding of the pier can be considered for the calculation of the side-projected area A_1 unless the ship is intended to be regularly moored to jetty type piers. A height of the pier surface of 3 m over waterline may be assumed, i.e. the lower part of the side-projected area with a height of 3 m above the waterline for the considered loading condition may be disregarded for the calculation of the side-projected area A_1 .

Note 2: Deck cargoes may not need to be considered if ballast draft condition generates a larger side-projected area A_1 than the full load condition with cargoes on deck. The larger of both side-projected areas is to be chosen as side-projected area A_1 .

2.7.3 Environmental conditions

The mooring lines are based on a maximum current speed of 2 knots (1,0 m/s) and the following maximum wind speed v_w , in m/s:

- for ships with one of the service notations **passenger ship**, **ro-ro passenger ship** or **ro-ro cargo ship**:
 - with $2000 \text{ m}^2 < A_1 \leq 4000 \text{ m}^2$: $v_w = 25,0 - 0,002 (A_1 - 2000)$
 - with $A_1 > 4000 \text{ m}^2$: $v_w = 21,0$
- for other ships: $v_w = 25,0$

The wind speed is considered representative of a 30 second mean speed from any direction and at a height of 10 m above the ground. The current speed is considered representative of the maximum current speed acting on bow or stern ($\pm 10^\circ$) and at a depth of one-half of the mean draft. Furthermore, it is considered that ships are moored to solid piers that provide shielding against cross current.

Additional loads caused by, e.g., higher wind or current speeds, cross currents, additional wave loads, or reduced shielding from non-solid piers may need to be particularly considered. Furthermore, it should be observed that unbeneficial mooring layouts can considerably increase the loads on single mooring lines.

2.7.4 Ship design minimum breaking load

The ship design minimum breaking load MBL_{SD} , in kN, of the mooring lines is to be taken as: $MBL_{SD} = 0,1 A_1 + 350$

The ship design minimum breaking load MBL_{SD} may be limited to 1275 kN (130 t).

However, in this case the moorings are to be considered as not sufficient for environmental conditions given in [2.7.3].

For these ships, the acceptable wind speed v_w^* , in m/s, can be estimated as follows:

$$v_w^* = v_w \sqrt{\frac{MBL_{SD}^*}{MBL_{SD}}}$$

where v_w as defined in [2.7.3], MBL_{SD} as defined above and MBL_{SD}^* the ship design minimum breaking load of the mooring lines intended to be supplied.

However, the ship design minimum breaking load is not to be taken less than corresponding to an acceptable wind speed of 21 m/s:

$$MBL_{SD}^* \geq \left(\frac{21}{v_w}\right)^2 MBL_{SD}$$

If lines are intended to be supplied for an acceptable wind speed v_w^* higher than v_w as defined in [2.7.3], the ship design minimum breaking load MBL_{SD}^* is to be taken as:

$$MLB_{SD}^* = \left(\frac{v_w^*}{v_w}\right)^2 MBL_{SD}$$

2.7.5 Length of mooring lines

For ships with $EN > 2000$, the length of mooring lines may be taken as 200 m.

2.7.6 Head, stern and breast lines

The total number of head, stern and breast lines is to be taken as:

- for ships with one of the service notations **oil tanker, oil tanker ESP, chemical tanker ESP, bulk carrier, bulk carrier ESP, self-unloading bulk carrier ESP, ore carrier ESP or combination carrier ESP:**

$$n = 8,3 \cdot 10^{-4} A_1 + 4$$

- for other ships:

$$n = 8,3 \cdot 10^{-4} A_1 + 6$$

This number n is to be rounded to the nearest whole number and may be increased or decreased in conjunction with an adjustment to the strength of the lines. The adjusted ship design minimum breaking load MBL_{SD}^{**} , should be taken as:

- for increased number of lines:

$$MBL_{SD}^{**} = 1,2 \cdot MBL_{SD} \cdot \frac{n}{n^{**}} \leq MBL_{SD}$$

- for reduced number of lines:

$$MBL_{SD}^{**} = MBL_{SD} \cdot \frac{n}{n^{**}}$$

where MBL_{SD} is MBL_{SD} or MBL_{SD}^* specified in [2.7.4], n^{**} is the increased or decreased total number of head, stern and breast lines and n the number of lines for the considered ship type as calculated by the above formulas without rounding.

Vice versa, the ship design minimum breaking load of head, stern and breast lines may be increased or decreased in conjunction with an adjustment to the number of lines.

2.7.7 Spring lines

The total number of spring lines is to be taken not less than:

- for ship with $EN < 5000$: two lines
- for ships with $EN \geq 5000$: four lines.

The ship design minimum breaking load of spring lines is to be the same as that of the head, stern and breast lines. If the number of head, stern and breast lines is increased in conjunction with an adjustment to the ship design minimum breaking load of the lines, the number of spring lines should be taken as follows, but rounded up to the nearest even number:

$$n_s^* = \frac{MBL_{SD}}{MBL_{SD}^{**}} \cdot n_s$$

where MBL_{SD} is MBL_{SD} or MBL_{SD}^* specified in [2.7.4], n_s is the number of spring lines as given above and n_s^* is the increased number of spring lines.

Part B

Hull and Stability

CHAPTER 13

CONSTRUCTION AND TESTING

Section 1	Construction and Fabrication
Section 2	Fabrication by Welding
Section 3	Design of Weld Joints
Section 4	Non-Destructive Testing
Section 5	Special Structural Details
Section 6	Testing
Appendix 1	Welding Details
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Section 1 Construction and Fabrication

1 General

1.1 Workmanship

1.1.1 All workmanship is to be of standard marine quality and acceptable to the Surveyor. Welding is to be in accordance with the requirements of Ch 13, Sec 2. Any defect is to be rectified to the satisfaction of the Surveyor before the material is covered with paint, cement or any other composition.

1.2 Fabrication standard

1.2.1 Structural fabrication is to be carried out in accordance with IACS Recommendation No. 47 or with a recognised fabrication standard which has been accepted by the Society prior to the commencement of fabrication/construction.

1.2.2 The fabrication standard to be used during fabrication/construction is to be made available to the attending representative of the Society prior to the commencement of the fabrication/construction.

1.2.3 The fabrication standard is to include information, to establish the range and the tolerance limits, for the items specified as follows:

- a) Cut edges:
The slope of the cut edge and the roughness of the cut edges.
- b) Flanged stiffeners and brackets and built-up sections:
The breadth of flange and depth of web, angle between flange and web, and straightness in plane of flange or at the top of face plate.
- c) Pillars:
The straightness between decks and cylindrical structure diameter.
- d) Brackets and flat bar stiffeners:
The distortion at the free edge line of tripping brackets and flat bar stiffeners.
- e) Sub-assembly stiffeners:
Details of sniped end of face plates and webs.
- f) Plate assembly:
For flat and curved blocks, the dimensions (length and breadth), distortion and squareness, and the deviation of interior members from the plate.
- g) Cubic assembly:
In addition to the criteria for plate assembly, twisting deviation between upper and lower plates, for flat and curved cubic blocks.
- h) Special assembly:
The distance between upper and lower gudgeons, distance between aft edge of propeller boss and aft peak bulkhead, twist of stern frame assembly, breadth and length of top plate of main engine bed. Where boring out of the propeller boss and stern frame, skeg or solepiece are to be carried out after completing the major part of the welding of the aft part of the ship. Where block boring is used, the shaft alignment is to be carried out using a method and sequence submitted to and recognised by the Society. The fit-up and alignment of the rudder, pintles and axles are to be carried out after completing the major parts of the welding of the aft part of the ship. The contacts between the conical surfaces of pintles, rudder stocks and rudder axles are to be checked before the final mounting.
- i) Butt joints in plating:
Alignment of butt joint in plating.
- j) Cruciform joints:
Alignment measured on the median line and measured on the heel line of cruciform joints.
- k) Alignment of interior members:
Alignments of flange of T profiles, alignment of panel stiffeners, gaps in T joints and lap joints, and distance between scallop and cut-outs for continuous stiffeners in assembly and in erection joints.
- l) Keel and bottom sighting:
Deflections for whole length of the ship, and for the distance between two adjacent bulkheads, cocking-up of fore body and of aft body, and rise of floor amidships.

m) Dimensions:

Length between perpendiculars, moulded breadth and depth at midship, and length between aft edge of propeller boss and main engine.

n) Fairness of plating between frames:

Deflections between frames of shell, tank top, bulkhead, upper deck, superstructure deck, deckhouse deck and wall plating.

o) Fairness of plating in way of frames:

Deflections of shell, tank top, bulkhead, strength deck plating and other structures measured in way of frames.

2 Cut-outs, plate edges

2.1 General

2.1.1 The free edges (cut surfaces) of cut-outs, hatch corners, etc are to be properly prepared and are to be free from notches. As a general rule, cutting draglines, etc are to be smoothly ground. All edges are to be broken or in cases of highly stressed parts, be rounded off.

Free edges on flame or machine cut plates or flanges are not to be sharp cornered and are to be finished off as specified above. This also applies to cutting drag lines, etc, in particular to the upper edge of sheer strake and analogously to weld joints, changes in sectional areas or similar discontinuities.

2.1.2 Corners in hatch opening are to be machine cut.

3 Cold forming

3.1 Special structural members

3.1.1 For highly stressed components of the hull girder where notch toughness is of particular concern (e.g. items required to be Class III in Ch 4, Sec 1, Tab 3, such as radius gunwales (bent sheer plates) and bilge strakes), the inside bending radius, in cold formed plating, is not to be less than 10 times the as-built plate thickness for carbon-manganese steels (see Ch 4, Sec 1). The allowable inside bending radius may be reduced provided the requirements stated in [3.3] are complied with.

3.2 Corrugated bulkheads and hopper knuckles

3.2.1 For corrugated bulkheads and hopper knuckles, the inside bending radius R , as defined in Ch 4, Sec 5, Fig 27, in cold formed plating, is not to be less than 4.5 times the as-built plate thickness for carbon-manganese steels (see Ch 4, Sec 1). The allowable inside bending radius may be reduced provided the requirements stated in [3.3] are complied with.

3.3 Low bending radius

3.3.1 When the inside bending radius is reduced below the limits defined [3.1], supporting data is to be provided. The bending radius is in no case to be less than 2 times the as-built plate thickness. As a minimum, the following additional requirements are to be complied with:

a) For all bent plates:

- 100% visual inspection of the bent area is to be carried out
- random checks by magnetic particle testing are to be carried out.

b) In addition to item a), for bent plates at boundaries to tanks or ballast holds:

- the steel is to be of grade D/DH or higher
- the material is impact tested in the strain-aged condition and satisfies the requirements stated herein. The deformation is to be equal to the maximum deformation to be applied during production, calculated by the formula $t_{as-built} / (2r_{bdg} + t_{as-built})$, where $t_{as-built}$ is the as-built thickness of the plate material and r_{bdg} is the bending radius. One sample is to be plastically strained at the calculated deformation or 5%, whichever is greater and then artificially aged at 250°C for one hour then subject to Charpy V-notch testing. The average impact energy after strain ageing is to meet the impact requirements specified for the grade of steel used.

4 Hot forming

4.1 Temperature requirements

4.1.1 Steel is not to be formed between the upper and lower critical temperatures. If the forming temperature exceeds 650°C for as-rolled, controlled rolled, thermo-mechanical controlled rolled or normalised steels, or is not at least 30°C lower than the tempering temperature for quenched and tempered steels, mechanical tests are to be made to assure that these temperatures have not adversely affected both the tensile and impact properties of the steel. Where curve forming or fairing, by line or spot heating, is carried out in accordance with [4.2.1], these mechanical tests are not required.

4.1.2 After further heating, other than specified in [4.1.1], of thermo-mechanically controlled steels (TMCP plates) for forming and stress relieving, it is to be demonstrated that the mechanical properties meet the requirements specified by a procedure test using representative material.

4.2 Line or spot heating

4.2.1 Curve forming or fairing, by linear or spot heating, is to be carried out using approved procedures in order to ensure that the properties of the material are not adversely affected. Heating temperature on the surface is to be controlled so as not to exceed the maximum allowable limit applicable to the plate grade.

5 Modifications and repairs during construction

5.1 General

5.1.1 Deviations in the joint preparation and other specified requirements, in excess of the permitted tolerances and found during construction, are to be repaired as agreed with the Society on a case by case basis.

5.2 Gap and weld deformations

5.2.1 Welding by building up of gaps exceeding the required values and repairs of weld deformations may be accepted by the Society upon special examination.

5.3 Defects

5.3.1 Defects and imperfections on the materials and welded connections found during construction are to be evaluated for possible acceptance on the basis of the applicable requirements of the Society.

Where the limits of acceptance are exceeded, the defective material and welds are to be discarded or repaired, as deemed appropriate by the Surveyor on a case by case basis.

When any serious or systematic defect is detected either in the welded connections or in the base material, the manufacturer is required to promptly inform the Surveyor and submit the repair proposal.

The Surveyor may require destructive or non-destructive examinations to be carried out for initial identification of the defects found and, in the event that repairs are undertaken, for verification of their satisfactory completion.

5.4 Repairs on structures already welded

5.4.1 In the case of repairs involving the replacement of material already welded on the hull, the procedures to be adopted are to be agreed with the Society on a case by case basis.

Section 2 Fabrication by Welding

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the preparation, execution and inspection of welded connections in hull structures.

They are to be complemented by the criteria given in Ch 13, App 1, to which reference is made. These criteria being given as recommendations, minor departures may be accepted by the Society, on a case by case basis.

The general requirements relevant to fabrication by welding and qualification of welding procedures are given in NR216 Materials and Welding, Chapter 12.

1.1.2 Weld connections are to be executed according to the approved plans. A detail not specifically represented in the plans is, if any, to comply with the applicable requirements.

1.1.3 It is understood that welding of the various types of steel is to be carried out by means of welding procedures approved for the purpose, even though an explicit indication to this effect may not appear on the approved plans.

1.1.4 The quality standard adopted by the shipyard is to be submitted to the Society and applies to all constructions unless otherwise specified on a case by case basis.

1.2 Base material

1.2.1 The requirements of this Section apply for the welding of hull structural steels or aluminium alloys of the types considered in NR216 Materials and Welding or other types accepted as equivalent by the Society.

1.2.2 The service temperature is intended to be the ambient temperature, unless otherwise stated.

1.3 Documentation to be submitted

1.3.1 The structural plans to be submitted for approval, according to Ch 1, Sec 4, are to contain the necessary data relevant to the fabrication by welding of the structures and items represented as far as class is concerned.

For important structures, the main sequences of prefabrication, assembly and welding and non-destructive examination planned are also to be represented in the plans.

Plans relevant to the special details specified in Ch 13, Sec 5 are to be submitted.

1.3.2 A plan showing the location of the various steel types is to be submitted at least for outer shell, deck and bulkhead structures.

1.4 Personnel and equipment

1.4.1 Welders and welding operators

Welders for manual welding and for semi-automatic welding processes are to be properly trained and are to be certified by the Society, as required in the individual applications, unless otherwise agreed.

Welders are to be certified according to the procedures given in Rule Note NR476 Approval Testing of Welders.

The certification is to be in due course of validity.

Personnel manning the automatic welding machines are to be competent and sufficiently trained.

1.4.2 Automatic welding operators

Personnel manning automatic welding machines and equipment are to be competent and sufficiently trained.

1.4.3 Organisation

The internal organisation of the shipyard is to be such as to ensure compliance with the requirements in [1.4.1] and [1.4.2] and to provide for assistance and inspection of welding personnel, as necessary, by means of a suitable number of competent supervisors.

1.4.4 Non-destructive testing operators

Requirements for NDT personnel are given in Ch 13, Sec 4, [3].

1.4.5 Technical equipment and facilities

The welding equipment is to be appropriate to the adopted welding procedures, of adequate output power and such as to provide for stability of the arc in the different welding positions.

In particular, the welding equipment for special welding procedures is to be provided with adequate and duly calibrated measuring instruments, enabling easy and accurate reading, and adequate devices for easy regulation and regular feed.

Manual electrodes, wires and fluxes are to be stored in suitable locations so as to ensure their preservation in proper condition. Especially, where consumables with hydrogen-controlled grade are to be used, proper precautions are to be taken to ensure that manufacturer’s instructions are followed to obtain (drying) and maintain (storage, maximum time exposed, re-backing, ...) hydrogen-controlled grade.

2 Welding

2.1 General

2.1.1 All welding is to be carried out by approved welders, in accordance with approved welding procedures, using approved welding consumables, in compliance with NR216 Materials and welding.

2.2 Welding consumables and procedures

2.2.1 Approval of welding consumables and procedures

Welding consumables and welding procedures adopted are to be approved by the Society.

The requirements for the approval of welding consumables are given in NR216 Materials and Welding, Chapter 11.

The requirements for the approval of welding procedures are given in NR216 Materials and Welding, Chapter 12.

2.2.2 Consumables

For welding of hull structural steels, the minimum consumable grades to be adopted, as defined in NR216 Materials and welding, are specified in Tab 1 depending on the steel grade.

Consumables used for manual or semi-automatic welding (covered electrodes, flux-cored and flux-coated wires) of higher strength hull structural steels are to be at least of hydrogen-controlled grade H15 (H). Where the carbon equivalent C_{eq} is not more than 0,41% and the thickness is below 30 mm, any type of approved higher strength consumables may be used at the discretion of the Society.

Especially, welding consumables with hydrogen-controlled grade H15 (H) and H10 (HH) shall be used for welding hull steel forgings and castings of respectively ordinary strength level and higher strength level.

Where quality control systems are in place which ensure that the grade of welding consumable used is higher than the minimum required for the particular strength steel being welded, the welding consumables that are used may have a weld deposit material yield strength that is greater than R_{eH_weld} specified in Ch 13, Sec 3 and the size of the weld may be determined based on the yield strength of the higher grade welding consumable.

Table 1 : Consumable grades

Steel grade	Consumable minimum grade	
	Butt welding, partial and full T penetration welding	Fillet welding
A	1	1
B - D	2	
E	3	
AH32 - AH36 - DH32 - DH36	2Y	2Y
EH32 - EH36 - EH36CAS	3Y	
FH32 - FH36 - FH36CAS	4Y	
AH40	2Y40	2Y40
DH40 - EH40 - EH40CAS	3Y40	
FH40 - FH40CAS	4Y40	
EH47 - EH47CAS	3Y47	3Y47

Note 1: Welding consumables approved for welding higher strength steels (Y) may be used in lieu of those approved for welding normal strength steels having the same or a lower grade; welding consumables approved in grade Y40 may be used in lieu of those approved in grade Y having the same or a lower grade.

Note 2: In the case of welded connections between two hull structural steels of different grades, as regards strength or notch toughness, welding consumables appropriate to one or the other steel are to be adopted.

2.3 Welding operations

2.3.1 Weather protection

Adequate protection from the weather is to be provided to parts being welded; in any event, such parts are to be dry.

In welding procedures using bare, cored or coated wires with gas shielding, the welding is to be carried out in weather protected conditions, so as to ensure that the gas outflow from the nozzle is not disturbed by winds and draughts.

2.3.2 Butt connection edge preparation

The edge preparation is to be of the required geometry and correctly performed. In particular, if edge preparation is carried out by flame, it is to be free from cracks or other detrimental notches.

2.3.3 Surface condition

The surfaces to be welded are to be free from rust, moisture and other substances, such as mill scale, slag caused by oxygen cutting, grease or paint, which may produce defects in the welds.

Effective means of cleaning are to be adopted particularly in connections with special welding procedures; flame or mechanical cleaning may be required.

The presence of a shop primer may be accepted, provided it has been approved by the Society.

Shop primers are to be approved by the Society for a specific type and thickness according to NR216 Materials and Welding, Ch 13, Sec 1.

2.3.4 Assembling and gap

The setting appliances and system to be used for positioning are to ensure adequate tightening adjustment and an appropriate gap of the parts to be welded, while allowing maximum freedom for shrinkage to prevent cracks or other defects due to excessive restraint.

The gap between the edges is to comply with the required tolerances or, when not specified, it is to be in accordance with normal good practice.

Completed welded joints are to be to the satisfaction of the attending Surveyor. Edge preparations and root gaps are to be in accordance with the approved welding procedure. The gap between the members being joined should not exceed the maximum values given in IACS Recommendation No. 47 or as specified in recognised fabrication standard approved by the Society. Where the gap between members being joined exceeds the specified values, corrective measures are to be taken in accordance with an approved welding procedure specification.

2.3.5 Gap in fillet weld tee connections

In fillet weld tee connections, a gap g , as shown in Fig 1, not greater than 2 mm may be accepted without increasing the throat thickness calculated according to Ch 13, Sec 3, [3.2.7] or Ch 4, Sec 5, [5.2.8], as applicable.

In the case of a gap greater than 2 mm, the above throat thickness is to be increased accordingly as specified in Ch 13, Sec 5 for some special connections of various ship types.

In any event, the gap g may not exceed 4 mm.

2.3.6 Plate misalignment in butt connections

The misalignment m , measured as shown in Fig 2, between plates with the same as-built thickness $t_{as-built}$ is to be less than $0,15 t_{as-built}$ without being greater than 3 mm.

2.3.7 Misalignment in cruciform connections

The misalignment m in cruciform connections, measured on the median lines as shown in Fig 3, is to be less than:

- $t_{as-built}/2$, in general, where $t_{as-built}$ is the thickness of the thinner abutting plate
- the values specified in Ch 13, Sec 5 for some special connections of various ship types.

The Society may require lower misalignment to be adopted for cruciform connections subjected to high stresses.

Figure 1 : Gap in fillet weld tee connections

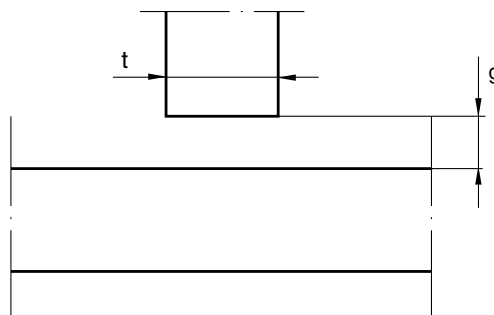


Figure 2 : Plate misalignment in butt connections

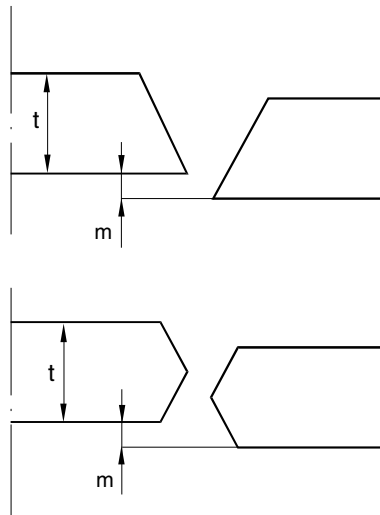
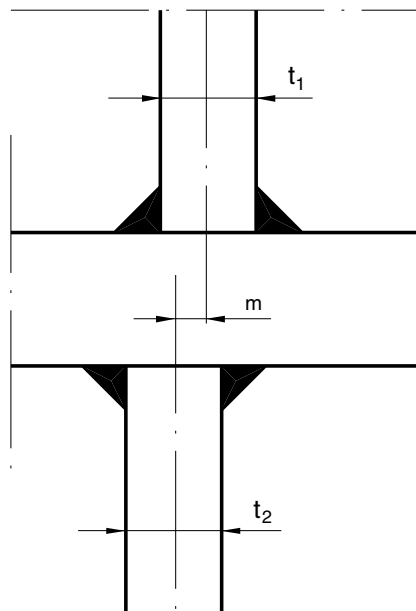


Figure 3 : Misalignment in cruciform connections



2.3.8 Assembling of aluminium alloy parts

When welding aluminium alloy parts, particular care is to be taken so as to:

- reduce as far as possible restraint from welding shrinkage, by adopting assembling and tack welding procedures suitable for this purpose
- keep possible deformations within the allowable limits.

2.3.9 Preheating and interpass temperatures

Suitable preheating, to be maintained during welding, and slow cooling may be required by the Society on a case by case basis.

2.3.10 Welding sequences

Consideration is to be given to the assembly sequence and the effect of the overall shrinkage of plate panels, assemblies, etc, resulting from the welding processes employed. Welding is to proceed systematically, with each welded joint being completed in correct sequence, without undue interruption. When practicable, welding is to commence at the centre of a joint and proceed outwards, or at the centre of assembly and progress outwards towards the perimeter so that each part has freedom to move in one or more directions.

Welding sequences and direction of welding are to be determined so as to minimise deformations and prevent defects in the welded connection.

All main connections are generally to be completed before the ship is afloat.

Departures from the above provision may be accepted by the Society on a case by case basis, taking into account any detailed information on the size and position of welds and the stresses of the zones concerned, both during ship launching and with the ship afloat.

Moreover, during the welding operation afloat, loading conditions are to be adjusted in order to have an acceptable level of longitudinal stress.

Note 1: As a general guidance, the level of longitudinal stress during the welding operation is to be below 50 MPa in the concerned area; however, lower limits may be requested by the surveyor depending on the specificities of the ship and/or welding.

In general, butt joints are to be welded from both sides. Before welding is carried out on the second side, unsound metal is to be removed at the root by a suitable method. Butt welding from one side will only be permitted for specific applications with an approved welding procedure specification.

2.3.11 Interpass cleaning

After each run, the slag is to be removed by means of a chipping hammer and a metal brush; the same precaution is to be taken when an interrupted weld is resumed or two welds are to be connected.

2.3.12 Stress relieving

It is recommended and in some cases it may be required that special structures subject to high stresses, having complex shapes and involving welding of elements of considerable thickness (such as rudder spades and stern frames), are prefabricated in parts of adequate size and stress-relieved in the furnace, before final assembly, at a temperature within the range $550^{\circ}\text{C} \div 620^{\circ}\text{C}$, as appropriate for the type of steel.

2.3.13 Arrangements at junctions of welds

Welds are to be made flush in way of the faying surface where stiffening members, attached by continuous fillet welds, cross the completely finished butt or seam welds. Similarly, butt welds in webs of stiffening members are to be completed and made flush with the stiffening member before the fillet weld is made. The ends of the flush portion are to run out smoothly without notches or sudden changes of section. Where these conditions can not be complied with, a scallop is to be arranged in the web of the stiffening member. Scallops are to be of the size, and in a position, that a satisfactory return weld can be made.

2.4 Crossing of structural elements

2.4.1 In the case of T crossing of structural elements (one element continuous, the other physically interrupted at the crossing) when it is essential to achieve structural continuity through the continuous element (continuity obtained by means of the welded connections at the crossing), particular care is to be devoted to obtaining the correspondence of the interrupted elements on both sides of the continuous element. Suitable systems for checking such correspondence are to be adopted.

2.5 Hatch coaming

2.5.1 Application

This sub-article applies to welding of plates having a minimum specified yield stress R_{eH} equal to 460 N/mm² and a thickness equal to or greater than 50 mm but not greater than 100 mm, used for longitudinal structural members in the upper deck region (such as hatch side coaming, hatch coaming top and attached longitudinal stiffeners).

Specific procedures are to be submitted to the Society for plates having a thickness greater than 100 mm.

Special care is to be paid to the final welding so that harmful defects do not remain.

2.5.2 Short bead

Short bead length for tack and repairs of welds by welding is not to be less than 50 mm. In the case where the cold cracking susceptibility index P_{cm} , as defined in NR216 Materials and Welding, is less than or equal to 0,19, short bead length of 25 mm may be considered by the Society on a case-by-case basis.

2.5.3 Preheating

Preheating is to be at least 50°C when air temperature is 5°C and under. In the case where the cold cracking susceptibility index P_{cm} , as defined in NR216 Materials and Welding, is less than or equal to 0,19, air temperature of 0°C and under may be considered by the Society on a case-by-case basis.

3 Inspections and checks

3.1 General

3.1.1 Materials, workmanship, structures and welded connections are to be subjected, at the beginning of the work, during construction and after completion, to inspections by the Shipbuilder suitable to check compliance with the applicable requirements, approved plans and standards.

3.1.2 The Shipbuilder is to make available to the Surveyor a list of the manual welders and welding operators and their respective qualifications.

The Shipbuilder's internal organisation is responsible for ensuring that welders and operators are not employed under improper conditions or beyond the limits of their respective valid qualifications and that welding procedures are adopted within the approved limits and under the appropriate operating conditions.

3.1.3 The Shipbuilder is responsible for ensuring that the operating conditions, welding procedures and work schedule are in accordance with the applicable requirements, approved plans and recognised good welding practice.

3.1.4 The Shipbuilder is responsible for ensuring that non-destructive testing are planned, carried out and reported in accordance with Ch 13, Sec 4.

3.2 Hatch coaming

3.2.1 Application

This sub-article applies to ships with hatch side coaming plate thickness t such that:

- $85 \text{ mm} \leq t \leq 100 \text{ mm}$ for steel with $R_{eH} = 355 \text{ N/mm}^2$
- $50 \text{ mm} \leq t \leq 100 \text{ mm}$ for steel with $R_{eH} = 390 \text{ N/mm}^2$ or $R_{eH} = 460 \text{ N/mm}^2$.

Special consideration is to be given to hatch side coaming plate thickness greater than 100 mm.

3.2.2 Ultrasonic testing

Ultrasonic testing is to be performed on all block-to-block butt welds of upper longitudinal members along central part over their full lengths.

Upper longitudinal members are defined as follows:

- uppermost strakes of inner hull and longitudinal bulkheads
- sheerstrake
- main deck
- coaming side plate
- coaming top plate

and all their attached longitudinal stiffeners.

Section 3 Design of Weld Joints

Symbols

A_{weld}	: Effective fillet weld area, in cm^2 , weld throat multiplied by weld length
f	: Root face, in mm
w_F	: Weld factor
l_{dep}	: Total length of deposit of weld metal, in mm
l_{leg}	: Leg length of continuous, lapped or intermittent fillet weld, in mm
p	: Distance between successive fillet welds, in mm
d	: Length of the welded connection in mm
R_{eH_weld}	: Minimum yield stress of weld deposit, in N/mm^2
$t_{\text{as-built}}$: As-built thickness of the plating abutting on another plating, in mm
t_{gap}	: Allowance for fillet weld gap, is to be taken equal to 2,0 mm
t_{throat}	: Throat thickness of fillet weld in mm, as defined in [3.2.7]
f_{yd}	: Coefficient not to be taken less than:

$$f_{yd} = \left(\frac{1}{k}\right)^{0,50} \left(\frac{235}{R_{eH_weld}}\right)^{0,75}$$

nor less than 0,71

k	: Material factor of the abutting member
R_{eH_weld}	: Specified minimum yield stress for the weld deposit, in N/mm^2 , not to be less than: <ul style="list-style-type: none"> • 305 N/mm^2 for welding of normal strength steel with $R_{eH} = 235 \text{ N/mm}^2$ • 375 N/mm^2 for welding of higher strength steel with R_{eH} from 265 to 355 N/mm^2 • 400 N/mm^2 for welding of higher strength steel with $R_{eH} = 390 \text{ N/mm}^2$ • 460 N/mm^2 for welding of higher strength steel with $R_{eH} = 460 \text{ N/mm}^2$.

1 General

1.1 Application

1.1.1 General

For the various structural details typical of welded construction in shipbuilding and not dealt with in this Section, the rules of good practice, recognised standards and past experience are to apply as agreed by the Society.

1.1.2 Weld type, size and materials

The requirements of this Section apply to the design of welded connections in hull structures and are based on the following considerations:

- joint type
- criticality of the joint
- magnitude, type and direction of the stress in the joint
- material properties of the parent and weld material
- weld gap size.

1.1.3 The requirements given in this Section are considered minimum for electric-arc welding in hull construction, but alternative methods, arrangements and details will be specially considered for approval.

1.1.4 Plans and/or specifications showing weld sizes and weld details are to be submitted for approval.

1.1.5 Minimum leg length

Whether the welds are continuous or intermittent, the leg length thickness of the fillet welds is not to be less than:

- 4,0 mm, for plating as built thickness of less than 6 mm
- 5,0 mm, otherwise.

1.2 Arrangement

1.2.1 Plate orientation

The plates of the shell and strength deck are generally to be arranged with their length in the fore-aft direction. Possible exceptions to the above will be considered by the Society on a case-by-case basis; tests as deemed necessary (for example, transverse impact tests) may be required by the Society.

1.2.2 Overall arrangement

Particular consideration is to be given to the overall arrangement and structural details of highly stressed parts of the hull.

1.2.3 Prefabrication sequences

Prefabrication sequences are to be arranged so as to facilitate positioning and assembling as far as possible.

The amount of welding to be performed on board is to be limited to a minimum and restricted to easily accessible connections.

1.2.4 Distance between welds

In general, the distance between two adjacent butts in the same strake of shell or deck plating is to be greater than two frame spaces.

2 Butt joint

2.1 General

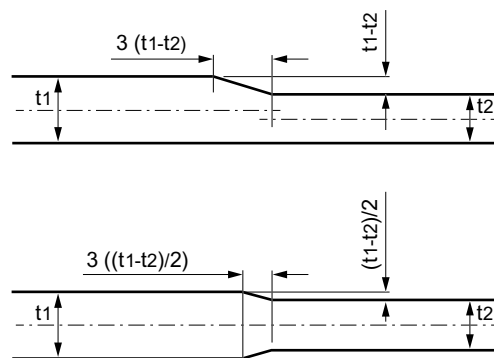
2.1.1 In general, butt connections of plating are to be full penetration, welded on both sides except where special procedures or specific techniques, considered equivalent by the Society, are adopted.

Connections different from the above may be accepted by the Society on a case by case basis; in such cases, the relevant detail and workmanship specifications are to be approved.

2.1.2 Welding of plates with different thicknesses

In the case of welding of plates with difference in as-built thickness greater than 4 mm on one side, the thicker plate is normally to be tapered. The taper length is to be not less than 3 times the difference in as-built thickness on the considered side (see Fig 1).

Figure 1 : Taper length



2.1.3 Edge preparation, root gap

Typical edge preparations and gaps are indicated in Ch 13, App 1, [1.2].

The acceptable root gap is to be in accordance with the adopted welding procedure and relevant bevel preparation.

2.1.4 Butt welding on permanent backing

Butt welding on permanent backing, i.e. butt welding assembly of two plates backed by the flange or the face plate of a stiffener, may be accepted where back welding is not feasible or in specific cases deemed acceptable by the Society.

The type of bevel and the gap between the members to be assembled are to be such as to ensure a proper penetration of the weld on its backing and an adequate connection to the stiffener as required.

2.1.5 Section, bulbs and flat bars

When lengths of longitudinals of the shell plating and strength deck within 0,6 L amidships, or elements in general subject to high stresses, are to be connected together by butt joints, these are to be full penetration. Other solutions may be adopted if deemed acceptable by the Society on a case by case basis.

The work is to be done in accordance with an approved procedure; in particular, this requirement applies to work done on board or in conditions of difficult access to the welded connection. Special measures may be required by the Society.

Welding of bulbs without a doubler is to be performed by welders specifically certified by the Society for such type of welding.

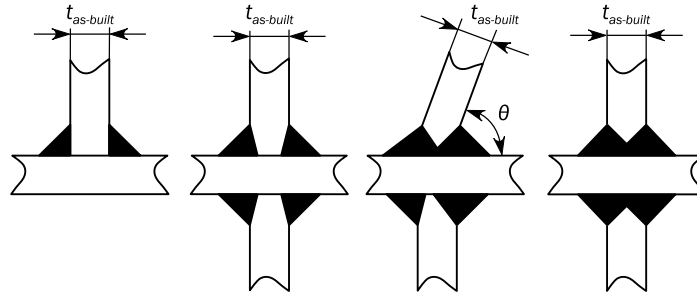
3 Tee or cross joint

3.1 Application

3.1.1 The connection of primary supporting members, stiffener webs to plating as well as the plating abutting on another plating, are to be made by fillet or penetration welding, as shown in Fig 2.

3.1.2 Where the connection is highly stressed or otherwise considered critical, a partial or full penetration weld is to be achieved by bevelling the edge of the abutting plate.

Figure 2 : Tee or cross joints



$t_{as-built}$: As-built thickness of the member being attached, in mm
 θ : Connecting angle, in deg.

3.2 Fillet welding

3.2.1 General

Ordinary fillet welding may be adopted for tee connections of the various simple and composite structural elements, where they are subjected to low tensile stress or where they are not critical for fatigue.

Where this is not the case, partial or full tee penetration welding according to [3.3] is to be adopted.

3.2.2 The required weld sizes are to be rounded to the nearest half millimetre.

3.2.3 Fillet welding types

Fillet welding may be of the following types:

- continuous fillet welding, where the weld is constituted by a continuous fillet on each side of the abutting plate (see [3.2.4])
- intermittent fillet welding, which may be subdivided (see [3.2.5]) into:
 - chain welding
 - scallop welding
 - staggered welding.

3.2.4 Continuous fillet welding

Continuous fillet welding is to be adopted in general:

- for watertight connections
- for connections of brackets, lugs and scallops
- at the ends of connections for a length of at least 75mm
- where intermittent welding is not allowed, according to [3.2.5]
- for connections of stiffeners subject to wheeled loads.

Continuous fillet welding may also be adopted in lieu of intermittent welding wherever deemed suitable, and it is recommended where the spacing p , calculated according to [3.2.5], is low.

Continuous welding is to be adopted in the following locations:

- a) connection of the web to the face plate for all members
- b) all fillet welds where higher strength steel is used
- c) boundaries of weathertight decks and erections, including hatch coamings, companionways and other openings
- d) boundaries of tanks and watertight compartments
- e) all structures inside tanks and cargo holds
- f) stiffeners and primary supporting members at tank boundaries
- g) all structures in the aft peak and stiffeners and primary supporting members of the aft peak bulkhead
- h) all structures in the fore peak

- i) welding in way of all end connections of stiffeners and primary supporting members, including end brackets, lugs, scallops, and at orthogonal connections with other members
- j) all lap welds in the main hull
- k) primary supporting members and stiffener members to bottom shell in the 0,3 L forward region
- l) flat bar longitudinals to plating
- m) the attachment of minor fittings to higher strength steel plating and other connections or attachments
- n) pillars to heads and heels
- o) hatch coaming stay webs to deck plating, see [3.3.5].

3.2.5 Intermittent welding

Where continuous welding is not required, intermittent welding may be applied.

Where beams, stiffeners, frames, etc, are intermittently welded and pass through slotted girders, shelves or stringers, there is to be a pair of matched intermittent welds (double continuous welds having the length of an intermittent fillet weld) on each side of every intersection. In addition, the beams, stiffeners and frames are to be efficiently attached to the girders, shelves and stringers.

Where intermittent welding or one side continuous welding is permitted, double continuous welds are to be applied for one-tenth of their shear span at each end, in accordance with [3.2.6] and [3.2.7].

One side continuous welding may be accepted instead of chain and staggered intermittent welding for connections of stiffeners in the dry spaces of deckhouses and superstructures, where not affected by sea pressure, tank pressure or concentrated loads.

The size for one side continuous weld is to be of fillet required by [3.2.6] for intermittent welding, where f_3 factor is to be taken as 2,0.

The spacing p and the length d , in mm, of an intermittent weld, shown in:

- Fig 3, for chain welding
- Fig 4, for scallop welding
- Fig 5, for staggered welding

are to be such that:

$$\frac{p}{d} \leq \varphi$$

where the coefficient φ is defined in Tab 1 and Tab 3 for the different types of intermittent welding, depending on the type and location of the connection.

In general, staggered welding is not allowed for connections subjected to high alternate stresses.

In addition, the following limitations are to be complied with:

- chain welding (see Fig 3):
 - $d \geq 75$ mm
 - $p - d \leq 200$ mm
- scallop welding (see Fig 4):
 - $d \geq 75$ mm
 - $p - d \leq 150$ mm
 - $v \leq 0,25 b$ without being greater than 75 mm
- staggered welding (see Fig 5):
 - $d \geq 75$ mm
 - $p - 2d \leq 300$ mm
 - $p \leq 2d$ for connections subjected to high alternate stresses.

Figure 3 : Intermittent chain welding

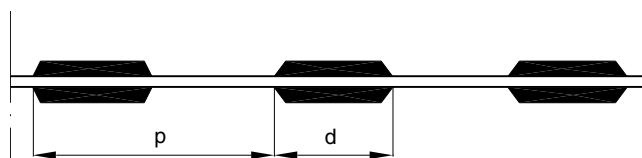


Figure 4 : Intermittent scallop welding

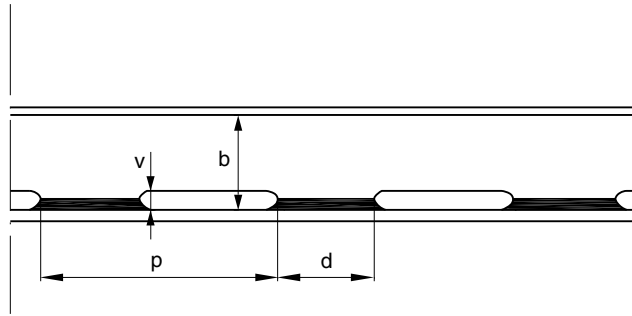
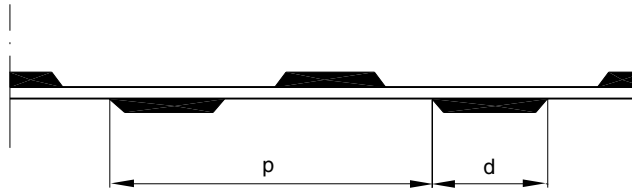


Figure 5 : Intermittent staggered welding



3.2.6 Leg length

The leg length, l_{leg} in mm, of continuous, lapped or intermittent fillet welds is not to be taken less than the greater of the following values:

$$l_{leg} = f_1 f_2 t_{as-built}$$

$$l_{leg} = f_{yd} w_F f_2 f_3 t_{as-built} + t_{gap}$$

nor less than the minimum values given in [1.1.5],

where:

f_1 : Coefficient depending on the welding type:

- $f_1 = 0,30$ for double continuous welding
- $f_1 = 0,38$ for intermittent welding

f_2 : Coefficient depending on the edge preparation:

- $f_2 = 1,0$ for welds without bevelling
- $f_2 = 0,7$ for welds with one/both side bevelling and $f = t_{as-built} / 3$ (see Ch 13, App 1)

w_F : Weld factor, defined in Tab 1 for various hull structural connections and Tab 2; for connections of primary supporting members belonging to single skin structures and not mentioned in Tab 1 or Tab 2, w_F is defined in Tab 3; for some connections of specific ship types, the values of w_F specified in Part D or Part E for these ship types are to be used in lieu of the corresponding values in Tab 1, Tab 2 or Tab 3

f_3 : Correction factor for the type of weld:

- $f_3 = 1,0$ for double continuous weld
- $f_3 = p / d$ for intermittent welding

Table 1 : Weld factors w_F and coefficient ϕ for the various hull structural connections

Hull area	Connection		$w_F(1)$	$\phi(2)(3)$			p_1 , in mm (see [3.2.9])(3)	
	of	to		CH	SC	ST		
General, unless otherwise specified in the table	watertight plates	boundaries	0,48					
	oil-tight plates	boundaries	0,51					
	brackets at ends of members		0,48					
	ordinary stiffener and collar plates	deep tank bulkheads	0,24					
		web of primary supporting members and collar plates	see Ch 4, Sec 5, [5.2.8]					
	webs of ordinary stiffeners	plating (except deep tank bulkhead)	at ends (4)	0,20				
			elsewhere	0,20	3,5	3,0	4,6	ST 260
face plate of fabricated stiffeners		at ends (15% span) (4)	0,38					
	elsewhere	0,20	3,5	3,0	4,6	ST 260		

Hull area	Connection		$w_F(1)$	$\varphi(2)(3)$			p_1 , in mm (see [3.2.9])(3)	
	of	to		CH	SC	ST		
Bottom and double bottom	longitudinal ordinary stiffeners	bottom and inner bottom plating	0,24	3,5	3,0	4,6	ST 260	
	centre girder	shell plating	0,38	1,8	1,8		CH/SC 130	
		inner bottom plating	0,38	2,2	2,2		CH/SC 160	
	side girders	bottom and inner bottom plating	0,24	3,5	3,0	4,6	ST 260	
		floors (interrupted girders)	0,28	2,2			CH 160	
	floors	bottom and inner bottom plating	in general	0,18	3,5	3,0	4,6	ST 260
			at ends (20% of span) for longitudinally framed double bottom	0,38	1,8			CH 130
		inner bottom plating in way of brackets of primary supporting members		0,35	1,8			CH 130
		girders (interrupted floors)		0,28	2,2			CH 160
	centre girder and side girders in way of hopper tanks		0,38					
	partial side girders	floors	0,35	1,8			CH 130	
	bracket on centre girder	Centre girder, inner bottom, floors and shell plates	0,38					
web stiffeners	floor and girder webs	0,20	3,5	3,0	4,6	ST 260		
Side and inner side	ordinary stiffeners	side and inner side plating	0,18	3,5	3,0	4,6	ST 260	
	girders and web frames in double side skin ships	side plating	0,30					
		inner side plating and web of primary supporting members	in way of deck transverse and end connections	0,43				
			in way of cross tie	0,36				
			elsewhere	0,30				
Deck	strength deck $t_{as-built} \geq 13$ mm	side plating within 0,6 L amidships	Partial penetration welding					
		elsewhere	0,48					
	strength deck $t_{as-built} < 13$ mm	side plating	0,48					
	non-watertight decks	side plating	0,38	2,2			CH 160	
	ordinary stiffeners and intercostal girders	deck plating	0,20	3,5	3,0	4,6	ST 260	
	hatch coamings	deck plating	in general	0,38				
			at corners of hatchways for 15% of the hatch length	Full penetration welding (7)				
web stiffeners	coaming webs	0,20 (8)	3,5	3,0	4,6	ST 260		

Hull area	Connection			w _F (1)	φ(2)(3)			p ₁ , in mm (see [3.2.9])(3)
	of	to			CH	SC	ST	
Bulkheads	tank bulkhead structures	tank bottom	plating and ordinary stiffeners (plane bulkheads)	0,63				
			vertical corrugations (corrugated bulkheads)	Full penetration welding, in general				
		boundaries other than tank bottom		0,50				
	watertight bulkhead structures	boundaries		0,50				
	non-watertight bulkhead structures	boundaries	wash bulkheads	0,24	2,2	2,2		CH/SC 160
			others	0,18	3,5	3,0	4,6	ST 260
ordinary stiffeners	bulkhead plating	in general	0,18	3,5	3,0	4,6	ST 260	
		at ends (25% of span), where no end brackets are fitted	0,48					
Structures located forward of 0,75 L from the AE(5)	bottom longitudinal ordinary stiffeners	bottom plating		0,28	2,2			CH 160
	floors and girders	bottom and inner bottom plating		0,35	1,8			CH 130
	side frames in panting area	side plating		0,28	2,2			CH 160
	webs of side girders in single side skin structures	side plating and face plate	A < 65 cm ² (6)	0,35	1,8	1,8		CH/SC 130
			A ≥ 65 cm ² (6)	See Tab 3				
After peak(5)	internal structures	boundaries and each other: below waterline		0,38				
		above waterline		0,20				
	side ordinary stiffeners	side plating		0,28				
	floors	bottom and inner bottom plating		0,28				
Machinery space(5)	centre girder	keel and inner bottom plating	in way of main engine foundations	0,63				
			in way of seating of auxiliary machinery and boilers	0,50				
			elsewhere	0,48	1,8	1,8		CH/SC 130
	side girders	bottom and inner bottom plating	in way of main engine foundations	Partial penetration welding				
			in way of seating of auxiliary machinery and boilers	0,50				
			elsewhere	0,28	2,2	2,2		CH/SC 160
	floors (except in way of main engine foundations)	bottom and inner bottom plating	in way of seating of auxiliary machinery and boilers	0,50				
			elsewhere	0,38	2,2	2,2		CH/SC 160
	floors in way of main engine foundations	bottom plating		0,50				
		foundation plates		0,63				
floors	centre girder	single bottom	0,63					
		double bottom	0,48	1,8	1,8		CH/SC 130	

Hull area	Connection		w_F (1)	φ (2)(3)			p_1 , in mm (see [3.2.9])(3)	
	of	to		CH	SC	ST		
Superstructures and deckhouses	external bulkheads	deck	in general	0,48				
			engine and boiler casings at corners of openings (15% of opening length)	0,63				
	internal bulkheads	deck		0,20	3,5	3,0	4,6	ST 260
	ordinary stiffeners	external and internal bulkhead plating		0,18	3,5	3,0	4,6	ST 260
Hatch covers	ordinary stiffener	plating		0,24	3,5	3,0	4,6	ST 260
Pillars	elements composing the pillar section	each other (fabricated pillars)		0,18				
	pillars	deck	pillars in compression	0,50				
			pillars in tension	See [5.2]				
Rudders	horizontal and vertical webs directly connected to solid parts	solid parts or rudder stock		According to Ch 12, Sec 1, [7.4] or Ch 12, Sec 1, [7.5]				
		elsewhere	for shear force greater than or equal to 45% of the maximum rudder body value	0,63				
			for shear force lower than 45% of the maximum rudder body value	0,28				
	other webs	each other		0,28		2,2		SC 160
		plating	in general		0,28		2,2	
	top and bottom plates of rudder plating			0,50				

- (1) In connections for which $w_F \geq 0,50$, continuous fillet welding is to be adopted
- (2) For coefficient φ , see [3.2.5]. In connections for which no φ value is specified for a certain type of intermittent welding, such type is not permitted and continuous welding is to be adopted
- (3) CH = chain welding, SC = scallop welding, ST = staggered welding
- (4) The web at the end of intermittently welded girders or stiffeners is to be continuously welded to the plating or the flange plate, as applicable, over a distance d at least equal to the depth h of the girder or stiffeners, with $300 \text{ mm} \geq d \geq 75 \text{ mm}$. Where end brackets are fitted, ends means the area extended in way of brackets and at least 50 mm beyond the bracket toes
- (5) For connections not mentioned, the requirements for the central part apply
- (6) A is the face plate sectional area of the side girders, in cm^2
- (7) $w_F = 0,43$ for hatch coaming other than in cargo holds
- (8) Continuous welding

Table 2 : Weld factors w_F for miscellaneous fittings and equipment

Item	Connection to		w_F
Hatch cover	Primary supporting members	at ends (10% of span) of PSM	0,48
		elsewhere	0,24
	Stiffeners	at ends	0,38
		elsewhere	0,20
Mast, derrick post, crane pedestal, etc.	deck / underdeck reinforced structure		0,43
Deck machinery seat	deck		0,24
Mooring equipment seat	deck		0,43
Ring for access hole type cover	anywhere		0,43
Stiffening of side shell doors and weathertight doors	anywhere		0,24
Frames of shell and weathertight doors	anywhere		0,43
Coaming of ventilator and air pipe	deck		0,43
Ventilators, etc., fittings	anywhere		0,24
Scupper and discharge	deck		0,55
Bulwark stay	deck		0,24
Bulwark plating	deck		0,43
Guard rail, stanchion	deck		0,43
Cleats and fittings	hatch coaming and hatch cover		0,24 (1)

(1) Minimum value of the weld factor. Where $t_{as-built} > 11,5\text{mm}$, l_{leg} need not exceed $0,62 t_{as-built}$. Penetration welding may be required depending on the design.

Table 3 : Welding factors w_F and coefficient ϕ for connections of primary supporting members

Primary supporting member	Connection			w_F (1)	ϕ (2) (3)			p_{11} , in mm (see [3.2.9])(3)	
	of	to			CH	SC	ST		
General (4)	web, where $A < 65 \text{ cm}^2$	plating	at ends (15% of shear span)	0,48					
			elsewhere	0,38	3,0	3,0		CH/SC 210	
		face plate			0,24				
		web, where $A \geq 65 \text{ cm}^2$	plating	at ends (15% of shear span)	0,48				
	elsewhere			0,38					
		face plate	at ends	0,50					
elsewhere			0,38	1,8	1,8		CH/SC 130		
	end brackets	face plate		0,38					
In tanks, where $A < 65 \text{ cm}^2$ (5)	web	plating	at ends (15% of shear span)	0,48					
			elsewhere	0,38	2,2	2,2		CH/SC 160	
		face plate	at ends	0,28					
			elsewhere	0,24	3,0	3,0		CH/SC 210	
	end brackets	face plate		0,48					
In tanks, where $A \geq 65 \text{ cm}^2$	web	plating	at ends (15% of shear span)	0,48					
			elsewhere	0,38					
		face plate			0,38				
			end brackets	face plate		0,48			

(1) In connections for which $w_F \geq 0,50$ continuous fillet welding is to be adopted.
(2) For coefficient ϕ , see [3.2.5]. In connections for which no ϕ value is specified for a certain type of intermittent welding, such type is not permitted.
(3) CH = chain welding, SC = scallop welding, ST = staggered welding.
(4) For cantilever deck beams, continuous welding is to be adopted.
(5) For primary supporting members in tanks intended for the carriage of ballast or fresh water, continuous welding is to be adopted.
Note 1: A is the face plate sectional area of the primary supporting member, in cm^2 .
Note 2: Ends of primary supporting members means the area extended 20% of the span from the span ends. Where end brackets are fitted, ends means the area extended in way of brackets and at least 100 mm beyond the bracket toes.

3.2.7 Throat size

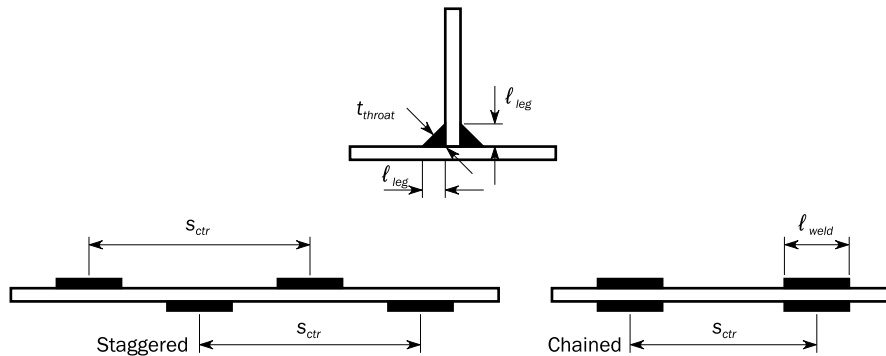
The throat size, in mm, as shown in Fig 6, is not to be less than:

$$t_{throat} = \frac{l_{leg}}{\sqrt{2}}$$

In the case of automatic or semi-automatic deep penetration weld, the throat thickness (the minimum values included) may be reduced according to [3.2.13].

The throat thickness may be required by the Society to be increased, depending on the results of structural analyses.

Figure 6 : Weld scantlings definitions



3.2.8 Longitudinal stiffeners

Welding of longitudinal stiffeners to plating is to be double continuous at the ends of the longitudinal stiffeners over 15% of their shear span as defined in Ch 4, Sec 6, [1.1.3].

In way of primary supporting members, the length of the double continuous weld is to be equal to the depth of the longitudinal or the end bracket, whichever is greater.

Where the as-built web thickness of the abutting longitudinal stiffener is greater than 15 mm and exceeds the thickness of the attached plating, the welding is to be double continuous and the leg length of the weld is not to be less than the greatest of the following values:

- a) 0,30 t_{as-built}, where t_{as-built} is the as-built thickness of the attached plating without being taken greater than 30 mm
- b) 0,27 t_{as-built} + 1, where t_{as-built} is the as-built thickness of the abutting member. The leg size resulting of this formula need not be taken greater than 8,0 mm
- c) the minimum leg length given in [1.1.5].

3.2.9 Weld dimensions in a specific case

Where intermittent fillet welding is adopted with:

- length d = 75 mm
- throat thickness t_{throat} specified in Tab 4 depending on the thickness t_{as-built}

the weld spacing may be taken equal to the value p₁ defined in Tab 1. The values of p₁ in Tab 1 may be used when:

$$8 \leq t_{as-built} \leq 16 \text{ mm.}$$

Table 4 : Required throat thickness

t _{as-built} in mm	t _{throat} in mm	t _{as-built} in mm	t _{throat} in mm
6	3,0	17	7,0
8	3,5	18	7,0
9	4,0	19	7,5
10	4,5	20	7,5
11	5,0	21	8,5
12	5,5	22	8,5
13	6,0	23	9,0
14	6,0	24	9,0
15	6,5	25	10,0
16	6,5	26	10,0

For thickness $t_{as-built}$ less than 8 mm, the values of p_1 may be increased, with respect to those in Tab 1, by:

- 10 mm for chain or scallop welding
- 20 mm for staggered welding,

without exceeding the limits in [3.2.5].

For thickness $t_{as-built}$ greater than 16 mm, the values of p_1 are to be reduced, with respect to those in Tab 1, by:

- 10 mm for chain or scallop welding
- 20 mm for staggered welding.

3.2.10 Throat thickness of welds between cut-outs

The throat thickness of the welds between the cut-outs in primary supporting member webs for the passage of ordinary stiffeners is to be not less than the value obtained, in mm, from the following formula:

$$t_{TC} = t_{throat} \frac{\epsilon}{\lambda}$$

where:

- t_{throat} : Throat thickness defined in [3.2.7]
- ϵ, λ : Dimensions, in mm, to be taken as shown in:
 - Fig 7 for continuous welding
 - Fig 8 for intermittent scallop welding.

Figure 7 : Continuous fillet welding between cut-outs

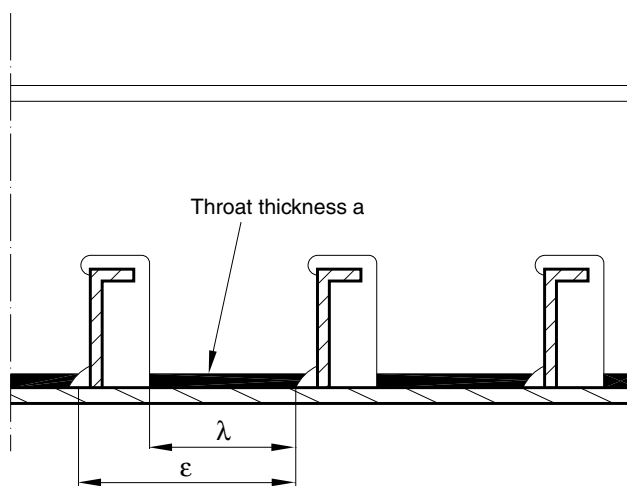
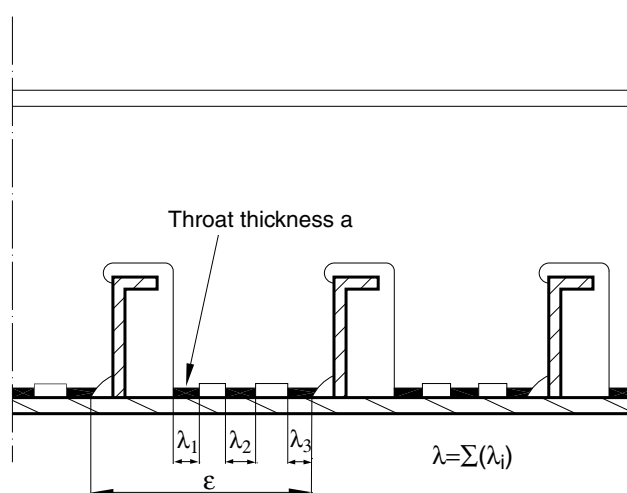


Figure 8 : Intermittent scallop fillet welding between cut-outs



3.2.11 Shear area of primary supporting member end connections

Welding of the end connections of primary supporting members is to be such that the weld area is to be equivalent to the gross cross-sectional area of the member. The weld leg length l_{leg} , in mm, is to be taken as:

$$l_{leg} = 1,41 f_{yd} \frac{h_w t_{gr-req}}{l_{dep}}$$

where:

- h_w : Web height of primary supporting members, in mm
- t_{gr-req} : Required gross thickness, in mm, of the web in way of the end connection, including 10% of shear span, based on the highest average usage factor for yield from cargo hold FE analysis or the shear area requirement for PSM outside central part
- l_{dep} : Total length of deposit of weld metal, in mm, taken as (see Fig 9): $l_{dep} = 2 l_{weld}$
- l_{weld} : Length of the welded connection in mm, as shown in Fig 9

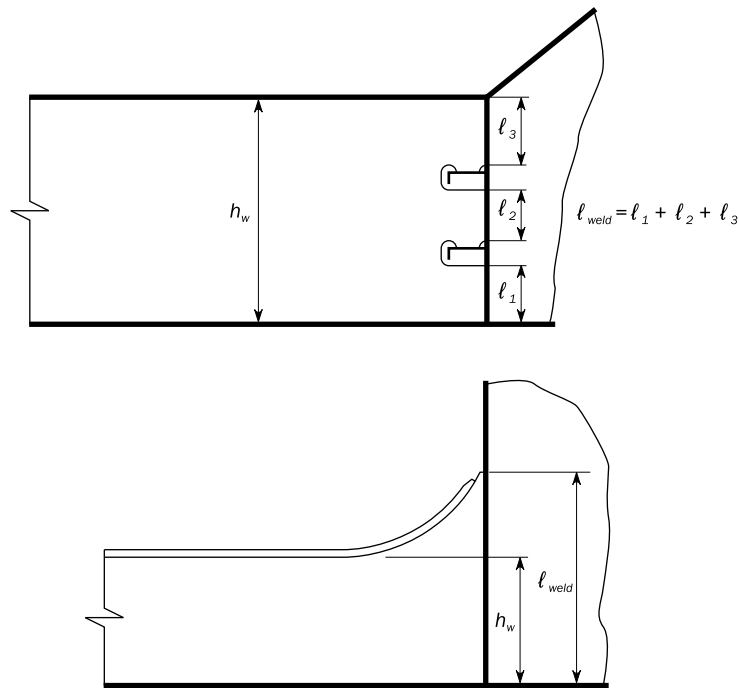
The size of weld is not to be less than the value calculated in accordance with [3.2.6].

3.2.12 Longitudinal continuity provided by brackets

Where the longitudinal continuity of a member contributing to the longitudinal strength of the ship is provided by brackets, the weld area A_{weld} is not to be less than the gross cross-sectional area of the member. The weld area A_{weld} , in cm^2 , is to be determined by the following formula:

$$A_{weld} = \frac{f_{yd} t_{throat} l_{dep}}{100}$$

Figure 9 : Shear area of primary supporting member



Note: The length l_{weld} is the length of the welded connection. The total length of the weld deposit l_{dep} if welded with double continuous fillet welds is twice the length of the welded connection l_{weld} .

3.2.13 Reduced weld size of deep penetration fillet welding

Where an approved automatic deep penetration procedure is used and where the gap between the assembled members can be controlled to be not more than 1 mm, the weld factors given in Tab 2 may be reduced by 15%, without leading to leg size reduction of more than 1,5 mm. Reductions of up to 20%, without leading to leg size reduction of more than 1,5 mm, will be accepted provided that the shipyard is able to demonstrate that the following requirements are consistently met:

- a) The welding is performed in accordance with welding procedure tests covering both minimum and maximum root gaps.
- b) The weld penetration at the root is at least equivalent to the granted leg size reduction.
- c) An established quality control system is in place.

The same reduction applies also for semi-automatic procedures where the welding is carried out in the downhand position.

3.2.14 Reduced weld size justification

Where any of the methods for reduction of the weld size are adopted, the specific requirements allowing the reduction are to be indicated on the drawings. The drawings are to document the weld design and dimensioning requirements for the reduced weld length and the required weld leg length given by [3.2.6] without the leg length reduction. Also, notes are to be added to the drawings to describe the difference in the two leg lengths and the requirements for their application.

3.3 Partial or full penetration welds

3.3.1 Partial or full penetration welding

In areas with high tensile stresses or areas considered critical, full or partial penetration welds are to be used.

Partial or full tee penetration welding is required, in any event, where indicated for the connections specified in Part D or Part E depending on the ship type. Further requirements are specified in Ch 13, Sec 5.

Examples of partial or full penetration welds with typical edge preparation are given in Ch 13, App 1.

3.3.2 One side partial penetration weld

For partial penetration welds with one side bevelling the fillet weld at the opposite side of the bevel is to satisfy the requirements given in [3.2].

3.3.3 Extent of full or partial penetration welding

The extent of full or partial penetration welding in each particular location listed in [3.3.5] and [3.3.6] is to be approved by the Society. However, the minimum extent of full/partial penetration welding from the reference point (i.e. intersection point of structural members, end of bracket toe, etc.) is not to be taken less than 300 mm, unless otherwise specially stated.

3.3.4 Lamellar tearing

Precautions are to be taken in order to avoid lamellar tears, which may be associated with:

- cold cracking when performing tee connections between plates of considerable thickness or high restraint
- large fillet welding and full penetration welding on higher strength steels.

3.3.5 Locations required for full penetration welding

Full penetration welds are to be used in the following locations and elsewhere as required by these rules:

- a) floors to hopper/inner bottom plating in way of radiused hopper knuckle
- b) radiused hatch coaming plate at corners to deck
- c) connection of vertical corrugated bulkhead to the lower hopper plate and to the inner bottom plate within the cargo hold region, when the vertical corrugated bulkhead is arranged without a lower stool
- d) connection of structural elements in the double bottom in line with corrugated bulkhead flanges to the inner bottom plate, when the vertical corrugated bulkhead is arranged without a lower stool
- e) connection of vertical corrugated bulkhead to the lower hopper plate, and connection of structural elements in the lower hopper area in line with corrugated bulkhead flanges to the lower hopper plate, where connections are clear of lower stools
- f) connection of vertical corrugated bulkhead to top plating of lower stool.
- g) corrugated bulkhead lower stool side plating to lower stool top plate.
- h) corrugated bulkhead lower stool side plating to inner bottom
- i) connection of structural elements in double bottom to the inner bottom plate in holds intended for the carriage of liquid at sea with a distance of 300 mm from the side plating of the lower stool
- j) edge reinforcement or pipe penetration both to strength deck, sheer strake and bottom plating within 0,6 L amidships, when the dimensions of the opening exceeds 300 mm
- k) abutting plate panels with as-built thickness less than or equal to 12 mm, forming outer shell boundaries below the scantling draught, including but not limited to: sea chests, rudder trunks, and portions of transom. For as-built thickness greater than 12 mm, partial penetration in accordance with [3.3.1]
- l) crane pedestals and associated bracketing and support structure
- m) for toe connections of longitudinal hatch coaming end bracket to the deck plating, full penetration weld for a distance of $0,15 H_c$ from toe of side coaming termination bracket is required, where H_c is the hatch coaming height
- n) rudder horns and shaft brackets to shell structure
- o) thick flanges of long transverse web frames to side web frames. Thick flanges of long longitudinal girder to bulkhead web frames
- p) brackets connecting face plates of cross decks and deck girders
- q) cross deck structures to transverse web frames (recommendation).

3.3.6 Locations required for partial penetration welding

Partial penetration welding as defined in [3.3.1], is to be used in the following locations:

- a) Connection of hopper sloping plate to longitudinal bulkhead (inner hull) or horizontal girder in double side space.
- b) End connection of longitudinal/transverse bulkhead primary supporting member, including buttress structure, to the double bottom and both end connections of backing bracket, where it is fitted
- c) Corrugated bulkhead lower stool supporting floors to inner bottom
- d) Corrugated bulkhead gusset and shedder plates
- e) Lower 15% of the length of built-up corrugation of vertical corrugated bulkheads
- f) structural elements in double bottom below bulkhead primary supporting members and stool plates, except in way of [3.3.5] item i)
- g) Lower hopper plate to inner bottom
- h) horizontal stringers on bulkheads in way of their bracket toe and the heel.

3.3.7 Fine mesh finite element analysis

High stress area means an area where fine mesh finite element analysis is to be carried out and the fine mesh yield utilisation factor in elements adjacent to the weld is more than 90% of the fine mesh permissible utilisation factor, as defined in Ch 8, App 2, [4.1.3]

In high stress area, at least partial penetration welds as defined in [3.3.1] are to be used. The minimum extent of full or partial penetration welding in that case is to be the greater of the following:

- 150 mm in either direction from the element with the highest yield utilisation factor
- the extent covering all elements that exceed the above mentioned yield utilisation factor criteria.

4 Other types of joints

4.1 Lapped joints

4.1.1 General

Lap joint welds may be adopted in very specific cases subject to the approval of the Society. Lap joint welds may be adopted for the following:

- peripheral connections of doubler plates
- internal structural elements subject to very low stress.

Elsewhere, lap-joint welding may be allowed by the Society on a case by case basis, if deemed necessary under specific conditions.

Continuous welding is generally to be adopted.

4.1.2 Dimensions

The dimensions of the lap-joint are to be specified and are considered on a case by case basis. Typical details are given in Ch 13, App 1, [1.4].

4.1.3 Gap

The surfaces of lap-joints are to be in sufficiently close contact.

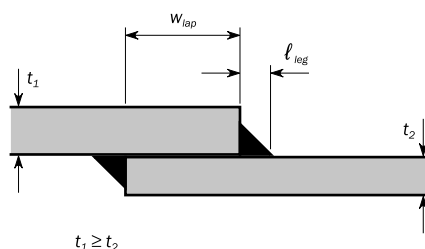
4.1.4 Overlaps for lugs

The overlaps for lugs and collars in way of cut-outs for the passage of stiffeners through webs and bulkhead plating are not to be less than three times the thickness of the lug and not be greater than 50 mm.

4.1.5 Lapped end connections

Lapped end connections are to have continuous welds on each edge with leg length l_{leg} , in mm, as shown on Fig 10 such that the sum of the two leg lengths is not less than 1,5 times the as-built thickness of the thinner plate.

Figure 10 : Fillet weld in lapped joint



4.1.6 Overlapped seams

Overlapped seams are to have continuous welds on both edges, of the sizes required by [3.2.6] for the boundaries of tank/hold or watertight bulkheads. Seams for plates with as-built thickness of 12,5 mm or less, which are clear of tanks/holds, may have one edge with intermittent welds in accordance with [3.2.6] for watertight bulkhead boundaries.

4.2 Slot welds

4.2.1 General

Slot welds may be adopted in very specific cases subject to the approval of the Society. However, slot welds of doublers on the outer shell and strength deck are not permitted within 0,6 L amidships.

4.2.2 Dimensions

Slot welds are to be of appropriate shape (in general oval) and dimensions, depending on the plate thickness, and may not be completely filled by the weld.

Typical dimensions of the slot weld and the throat thickness of the fillet weld are given in Ch 13, App 1, [1.4].

The distance between two consecutive slot welds is to be not greater than a value which is defined on a case by case basis taking into account:

- the transverse spacing between adjacent slot weld lines
- the stresses acting in the connected plates
- the structural arrangement below the connected plates.

4.2.3 Closing plates

For the connection of plating to internal webs, where access for welding is not practicable, the closing plating may be attached by slot welds to face plates fitted to the webs.

Slots are to be well-rounded and have a minimum slot length ℓ of 90 mm and a minimum width G of twice the as-built plate thickness. Slots cut in plating are to have smooth, clean and square edges and are in general to be spaced a distance L not greater than 140 mm. Slots are not to be filled with welding.

4.3 Stud and lifting lug welds

4.3.1 Where permanent or temporary studs or lifting lugs are to be attached by welding to main structural parts in areas subject to high stress, the proposed locations are to be submitted for approval.

4.4 Plug welding

4.4.1 Plug welding may be adopted only when accepted by the Society on a case by case basis, according to specifically defined criteria. Typical details are given in Ch 13, App 1, [1.4].

5 Specific weld connections

5.1 Bilge keels

5.1.1 The ground bar is to be connected to the shell with a continuous fillet weld, and the bilge keel to the ground bar with a continuous fillet weld in accordance with Tab 5.

5.1.2 Butt welds, in the bilge keel and ground bar, are to be well clear of each other and of butts in the shell plating as shown in Fig 11. In general, shell butts are to be flush in way of the ground bar and ground bar butts are to be flush in way of the bilge keel. Direct connection between ground bar butt welds and shell plating is not permitted. This may be obtained by use of removable backing.

5.1.3 At the ends of the ground bar, the leg length is to be increased as given in Tab 5, without exceeding the as-built thickness of the ground bar as shown in Fig 11. The welded transition at the ends of the ground bar to the plating connection should be formed with the weld flank angle of 45° or less.

Table 5 : Connections of bilge keels

Structural items being joined	Leg length of weld, in mm	
	At ends(1)	Elsewhere
Ground bar to the shell	0,62 $t_{1as-built}$	0,48 $t_{1as-built}$
Bilge keel web to ground bar	0,48 $t_{2as-built}$	0,30 $t_{2as-built}$
$t_{1as-built}$: As-built thickness of ground bar, in mm $t_{2as-built}$: As-built thickness of web of bilge keel, in mm. (1) Zone "b" in Ch 4, Sec 5, Fig 25 and Ch 4, Sec 5, Fig 26 for definition of "ends"		

5.1.4 In general, scallops and cut-outs are not to be used. Crack arresting holes are to be drilled in the bilge keel butt welds as close as practicable to the ground bar. The diameter of the hole is to be greater than the width W of the butt weld and is to be a minimum of 25 mm. Where the butt weld has been subject to non-destructive examination, the crack arresting hole may be omitted.

5.2 End connections of pillars

5.2.1 The end connections of pillars are to have an effective fillet weld area, in cm^2 , (weld throat multiplied by weld length) not less than:

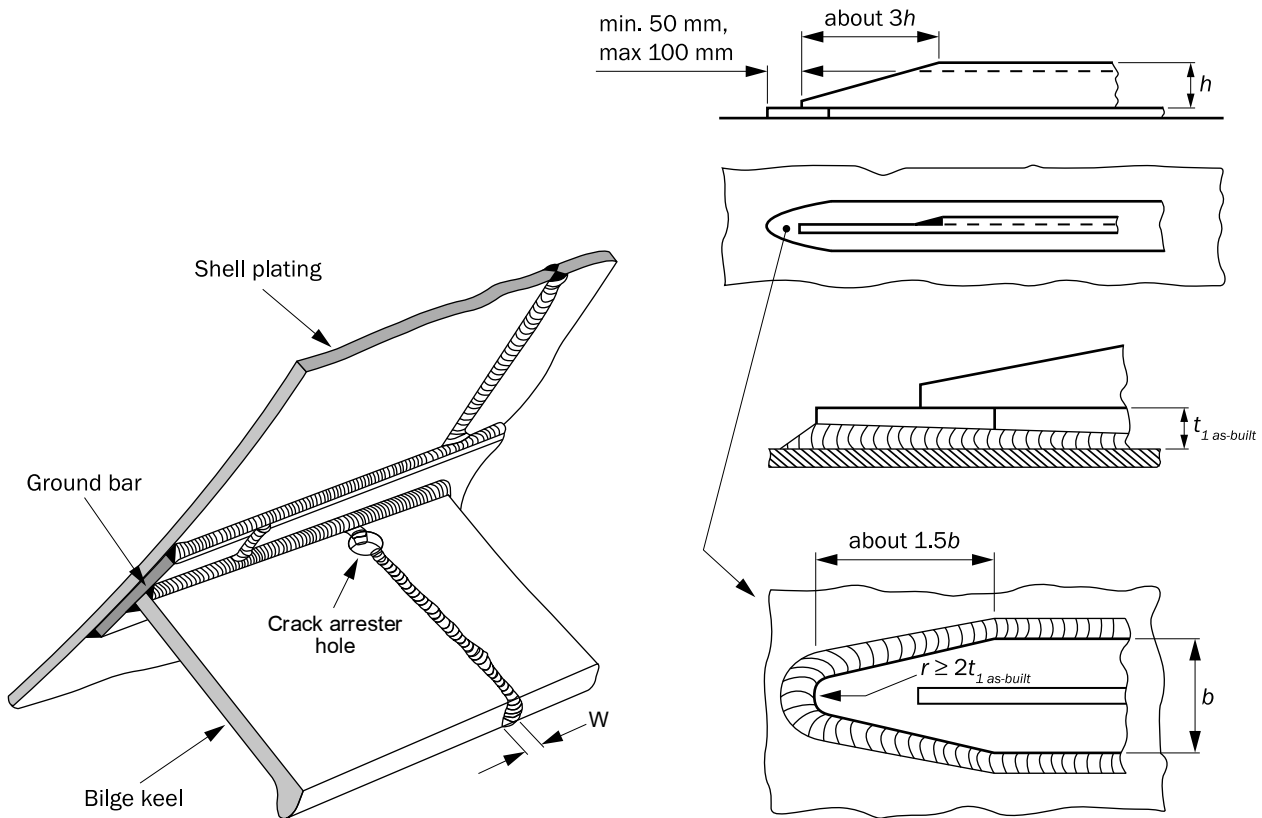
$$A_{\text{weld}} = f_3 \left(\frac{235}{R_{eH_weld}} \right)^{0.75} F$$

where:

- F : Design load, for the structure under consideration, in kN
- f_3 : Coefficient equal to:
 - 0,05 when pillar is in compression only
 - 0,14 when pillar is in tension.

When A_{weld} cannot practically be achieved by fillet welding for pillars in tension, full penetration welding is to be adopted.

Figure 11 : Bilge keel



5.3 Abutting plates with small angles

5.3.1 Where angle θ between the abutting plate and the connected plate is less than 75° as shown in Fig 12, the size of fillet welds l_θ , in mm, for the side of larger angle is to be increased in accordance with:

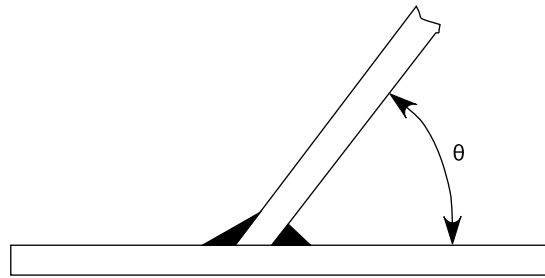
$$l_\theta = \frac{l_{\text{leg}}}{\sqrt{2} \sin \frac{\theta}{2}}$$

where:

- l_{leg} : Leg length of fillet weld, in mm, as defined in [3.2.6]
- θ : Connecting angle, in deg, as shown in Fig 12.

5.3.2 Connections of main strength members where θ is less than 45° , see Fig 12, may be applied only in dry spaces and voids.

Figure 12 : Connecting angle



5.4 Struts connecting ordinary stiffeners

5.4.1 In case of a strut connected by lap joint to the ordinary stiffener, the throat thickness of the weld is to be obtained, in mm, from the following formula:

$$t_{\text{throat}} = \frac{\eta F}{n \ell_w \tau} 10^3$$

where:

- F : Maximum force transmitted by the strut, in kN
- η : Safety factor, to be taken equal to 2
- n : Number of welds in way of the strut axis
- ℓ_w : Length of the weld in way of the strut axis, in mm
- τ : Permissible shear stress, to be taken equal to 100 N/mm².

5.5 Connection between propeller post and propeller shaft bossing

5.5.1 Fabricated propeller posts are to be welded with full penetration welding to the propeller shaft bossing.

5.6 Bar stem connections

5.6.1 The bar stem is to be welded to the bar keel generally with butt welding. The shell plating is also to be welded directly to the bar stem with butt welding.

5.7 Deck subjected to wheeled loads

5.7.1 Double continuous fillet welding is to be adopted for the connections of ordinary stiffeners with deck plating.

Section 4 Non-Destructive Testing

1 General

1.1 Scope

1.1.1 This Section gives requirements on the methods and quality levels that are to be adopted for the non-destructive testing (NDT) of ship hull structure steel welds during new building.

1.1.2 For the purpose of this Section, the hull structure is defined as follows:

- a) hull envelope including all internal and external structures
- b) superstructures, deckhouses and casings
- c) welded foundations, e.g. main engine seatings
- d) hatch coamings, bulwarks
- e) all penetrations fitted and welded into bulkheads, decks and shell
- f) the fittings of all connections to decks, bulkheads and shell, such as air pipes and ship side valves – all ILLC 1966, as amended, items
- g) welded attachments to shell, decks and primary members, e.g. crane
- h) pedestals, bits and bollards, but only as regards their interaction on the hull structure.

1.1.3 The quality levels given in this Section refer to production quality and not to fitness for-purpose of the welds examined.

1.1.4 The NDT is normally to be performed by the Shipbuilder or its subcontractors in accordance with the requirements of this Section. The Surveyor may require witnessing of the testing.

1.1.5 It is the Shipbuilder's responsibility to assure that testing specifications and procedures are adhered to during the construction and the reports are made available to the Society on the findings made by the NDT.

1.1.6 The extent of testing and the number of checkpoints are to be agreed between the Shipbuilder and the Society. For criticality of structure reference is to be made to Ch 4, Sec 1, Tab 3, Ch 4, Sec 1, Tab 8, Ch 4, Sec 1, Tab 10 and, as applicable, NR606 Common Structural Rules for Bulk Carriers and Oil Tankers.

1.1.7 This Section covers conventional NDT methods. As far as advanced non-destructive testing (ANDT) methods are concerned, reference is made to NR216 Materials and Welding, Chapter 14. ANDT methods are typically phased array ultrasonic testing (PAUT), time of flight diffraction (TOFD), digital radiography (RT-D), radiosopic testing (RT-S), and computed radiography (RT-CR).

1.1.8 Terms and definitions

The following terms and definitions apply:

- NDT : Non-Destructive Testing: the development and application of technical methods to examine materials or components in ways that do not impair their future usefulness and serviceability, in order to measure geometrical characteristics and to detect, locate, measure and evaluate flaws. NDT is also known as non-destructive examination (NDE), non-destructive inspection (NDI) and non-destructive evaluation (NDE).
- RT : Radiographic Testing
- UT : Ultrasonic Testing
- MT : Magnetic Particle Testing
- PT : Dye or Liquid Penetrant Testing
- PWHT : Post Weld Heat Treatment
- VT : Visual Testing.

2 Application

2.1 Base metals

2.1.1 This Section applies to fusion welds made in normal and higher strength hull structural steels, extra high strength steels for welded structure, connection welds with hull steel forgings and castings in accordance with NR216 Materials and Welding. Base metal other than the above may be considered by the Society.

2.2 Welding processes

2.2.1 This Section applies to fusion welds made using manual metal arc welding (shielded metal arc welding, 111), gas-shielded metal arc welding (gas metal arc welding, including flux cored arc welding, 13x), gas-shielded arc welding with non-consumable tungsten electrode (gas tungsten arc welding, 14x), submerged arc welding (12x), electro-slag welding (72x) and electro-gas welding processes (73).

Note 1: Terms and numbers according to ISO 4063:2009 ("x" indicates that relevant subgroups are included).

This Section may also be applied to welding processes other than the above at the discretion of the Society.

2.3 Weld joints

2.3.1 This Section applies to butt welds with full penetration, tee, corner and cruciform joints with or without full penetration, and fillet welds.

2.4 Timing of NDT

2.4.1 NDT is to be conducted after welds have cooled to ambient temperature and after post weld heat treatment where applicable.

2.4.2 For high strength steels for welded structure with specified minimum yield stress in the range of 420 N/mm² to 690 N/mm², NDT is not to be carried out before 48 hours after completion of welding. For steel with specified minimum yield greater than 690 N/mm², NDT is not to be carried out before 72 hours after completion of welding. Regardless of yield strength, consideration is to be given to requiring a delayed inspection where evidence of delayed cracking has been observed in production welds. At the discretion of the Surveyor, a longer interval and/or additional random inspection at a later period may be required, (for example in case of high thickness welds).

At the discretion of the Surveyor, the 72 hour interval may be reduced to 48 hours for RT or UT inspection, provided there is no indication of delayed cracking, and a complete visual and random MT or PT inspection to the satisfaction of the Surveyor is conducted 72 hours after welds have been completed and cooled to ambient temperature.

Where PWHT is carried out the requirement for testing after a delay period may be relaxed, at the discretion of the Surveyor.

2.5 Applicable methods for testing of weld joints

2.5.1 The methods mentioned in this Section for detection of surface imperfections are VT, PT and MT. The methods mentioned for detection of internal imperfections are UT and RT.

2.5.2 Applicable methods for testing of the different types of weld joints are given in Tab 1.

Table 1 : Applicable methods for testing of weld joints

Weld joints	Parent material thickness	Applicable test methods
Butt welds with full penetration	thickness < 8mm (1)	VT, PT, MT, RT
	thickness ≥ 8mm	VT, PT, MT, UT, RT
Tee joints, corner joints and cruciform joints with full penetration	thickness < 8mm (1)	VT, PT, MT, RT (3)
	thickness ≥ 8mm	VT, PT, MT, UT, RT (3)
Tee joints, corner joints and cruciform joints without full penetration and fillet welds	All	VT, PT, MT, UT (2) , RT (3)
(1) In cases of thickness below 8mm the Society may consider application of an appropriate advanced UT method (2) UT may be used to check the extent of penetration in tee, corner and cruciform joints. This requirement is to be agreed with the Society (3) RT may be applied however there will be limitations		

3 Qualification of personnel involved in NDT

3.1 General

3.1.1 The Shipbuilder or its subcontractors is responsible for the qualification and preferably 3rd party certification of its supervisors and operators to a recognised certification scheme based on ISO 9712:2012.

Personnel qualification to an employer based qualification scheme as e.g. SNT-TC-1A, 2016 or ANSI/ASNT CP-189, 2016 may be accepted if the Shipbuilder or its subcontractors written practice is reviewed and found acceptable by the Society. The Shipbuilder or its subcontractors written practice is to, as a minimum, except for the impartiality requirements of a certification body and/or authorised body, comply with ISO 9712:2012.

The supervisors and operators certificates and competence are to comprise all industrial sectors and techniques being applied by the Shipbuilder or its subcontractors.

Level 3 personnel is to be certified by an accredited certification body.

3.1.2 The Shipbuilder or its subcontractors are to have a supervisor or supervisors, responsible for the appropriate execution of NDT operations and for the professional standard of the operators and their equipment, including the professional administration of the working procedures. The Shipbuilder or its subcontractors are to employ, on a full-time basis, at least one supervisor independently certified to Level 3 in the method(s) concerned as per the requirements of [3.1.1]. It is not permissible to appoint Level 3 personnel; they must be certified by an accredited certification body. It is recognised that a Shipbuilder or its subcontractors may not directly employ a Level 3 in all the stated methods practiced. In such cases, it is permissible to employ an external, independently certified, Level 3 in those methods not held by the full-time Level 3(s) of the Shipbuilder or its subcontractors.

The supervisor is to be directly involved in review and acceptance of NDT procedures, NDT reports, calibration of NDT equipment and tools. The supervisor is to, on behalf of the Shipbuilder or its subcontractors, re-evaluate the qualification of the operators annually.

3.1.3 The operator carrying out the NDT and interpreting indications, is to be, as a minimum, qualified and certified to Level 2 in the NDT method(s) concerned and as described in [3.1.1].

However, operators only undertaking the gathering of data using any NDT method and not performing data interpretation or data analysis may be qualified and certified as appropriate, at level 1.

The operator is to have adequate knowledge of materials, welding, structures or components, NDT equipment and limitations that are sufficient to apply the relevant NDT method for each application appropriately.

3.1.4 In case of non-destructive testing carried out by an independent company from the manufacturer or shipyard, qualification of operators is to comply with the requirements set out in NR669 Recognition of non-destructive testing suppliers.

4 Surface condition

4.1 General

4.1.1 Areas to be examined are to be free from scale, slag, loose rust, weld spatter, oil, grease, dirt or paint that might affect the sensitivity of the testing method.

Preparation and cleaning of welds for subsequent NDT are to be in accordance with the accepted NDT procedures, and are to be to the satisfaction of the Surveyor. Surface conditions that prevent proper interpretation may be cause for rejection of the weld area of interest.

5 General plan of testing

5.1 NDT method selection

5.1.1 The extent of testing and the associated quality levels are to be planned by the Shipbuilder according to the ship design, ship type and welding processes used. For new construction survey, reference is to be made to the NDT requirements of Pt A, Ch 3, Sec 7 and applicable parts of NR540 Kick-Off Meeting Templates for Newbuilding.

5.1.2 For each construction, the Shipbuilder is to submit a plan for review by the Society, specifying the areas to be examined, the extent of testing and the quality levels, with reference to the NDT procedures to be used. Particular attention is to be paid to inspecting welds in highly stressed areas and welds in primary and special category structural members indicated in Ch 4, Sec 1. The NDT procedure(s) are to meet the requirement stated in Article [6]. The plan is only to be released to the personnel in charge of the NDT and its supervision.

5.1.3 In selecting checkpoints, emphasis is to be given to the following inspection locations:

- welds in high stressed areas
- fatigue sensitive areas
- other important structural elements
- welds which are inaccessible or very difficult to inspect in service
- field erected welds
- suspected problem areas.

Block construction welds performed in the yards, or at subcontracted yards/facilities, are to be considered in selecting checkpoints.

If an unacceptable level of indications is found the NDT extent is to be increased.

5.1.4 The NDT requirements given in Ch 13, Sec 6 are to be taken into consideration in the NDT plan.

5.1.5 The identification system is to identify the exact locations of the lengths of weld examined.

5.1.6 All welds over their full length are to be subject to VT by personnel designated by the Shipbuilder, who may be exempted from the qualification requirements defined in [3].

5.1.7 As far as practicable, PT or MT are to be used when investigating the outer surface of welds, checking the intermediate weld passes and back-gouged joints prior to subsequent passes deposition. MT is to be performed in ferromagnetic materials welds unless otherwise agreed with the Society. Surface inspection of important tee or corner joints, using an approved MT or PT method, is to be conducted to the satisfaction of the Surveyor.

5.1.8 Welded connections of large cast or forged components (e.g. stern frame, stern boss, rudder parts, shaft brackets...) are to be tested over their full length using MT (MT is the preferred method) or PT, (PT is to be applied for non-ferrous metals) and at agreed locations using RT or UT.

5.1.9 As given in Tab 1, UT or RT or a combination of UT and RT may be used for testing of butt welds with full penetration of 8 mm or greater. Methods to be used are to be agreed with the Society. The method used is to be suited for the detection of particular types and orientations of discontinuities. RT and UT are used for detection of internal discontinuities, and in essence they supplement and complement each other. RT is generally most effective in detecting volumetric discontinuities (e.g. porosity and slag) whilst UT is more effective for detecting planar discontinuities (e.g. laminations, lack of fusion and cracks).

5.1.10 In general start/stop points in welds made using automatic (mechanized) welding processes are to be examined using RT or UT, except for internal members where the extent of testing is to be agreed with the attending Surveyor. Panel butt welds made using automatic welding at pre-manufacturing stage are to be tested at random by RT or UT.

5.1.11 Where the Surveyor becomes aware that an NDT location has been repaired without a record of the original defect, the shipyard is to carry out additional examinations on adjacent areas to the repaired area to the satisfaction of the attending Surveyor.

6 Testing

6.1 General

6.1.1 The testing method, equipment and conditions are to comply with recognized National or International standards, or other documents to the satisfaction of the Society.

6.1.2 Sufficient details are to be given in a written procedure for each NDT technique submitted to the Society for acceptance.

6.1.3 The testing volume is to be the zone which include the weld and parent material for at least 10mm each side of the weld, or the width of the heat affected zone (HAZ), whichever is greater. In all cases inspection is to cover the whole testing volume.

6.1.4 Provision is to be made for the Surveyor to verify the inspection, reports and records (e.g. radiographs) on request.

6.2 Visual testing (VT)

6.2.1 The personnel in charge of VT is to confirm that the surface condition is acceptable prior to carrying out the inspection. VT is to be carried out in accordance with standards agreed between the Shipbuilder and the Society.

6.3 Liquid penetrant testing (PT)

6.3.1 PT is to be carried out in accordance to ISO 3452-1:2013 or a recognized standard accepted by the Society.

6.3.2 The extent of PT is to be in accordance to the plans agreed with the attending Surveyor and to the satisfaction of the Surveyor.

6.3.3 The surface to be examined is to be clean and free from scale, oil, grease, dirt or paint so there are not contaminants and entrapped material that may impede penetration of the inspection media.

6.3.4 The temperature of parts examined is to be typically between 5°C and 50°C. Outside this temperature range special low/high temperature penetrant and reference comparator blocks are to be used.

6.4 Magnetic particle testing (MT)

6.4.1 MT is to be carried out in accordance to ISO 17638:2016 or a recognized standard accepted by the Society.

6.4.2 The extent of MT is to be in accordance to the plans agreed with the attending Surveyor and to the satisfaction of the Surveyor.

6.4.3 The surface to be examined is to be free from scale, weld spatter, oil, grease, dirt or paint and is to be clean and dry. In general, the inside and outside of the welds to be inspected need to be sufficiently free from irregularities that may mask or interfere with interpretation.

6.5 Radiographic testing (RT)

6.5.1 RT is to be carried out in accordance to ISO 17636-1:2013 or a recognized standard accepted by the Society.

6.5.2 The minimum inspected weld length for each checkpoint is to be specified in the approved NDT plan (see [5.1.2]). For hull welds the minimum length inspected by RT is typically 300 mm.

The extent of RT is to be in accordance to the approved plans and the requirements of this paragraph, to the satisfaction of the Surveyor.

The number of checkpoints is to be increased if the proportion of non-conforming indications is abnormally high.

6.5.3 The inside and outside surfaces of the welds to be radiographed are to be sufficiently free from irregularities that may mask or interfere with interpretation. Surface conditions that prevent proper interpretation of radiographs may be cause for rejection of the weld area of interest.

6.5.4 RT is to be carried out on the welded butts of shell plating, strength deck plating as well as of members contributing to the longitudinal strength.

RT may also be required for the joints of members subject to heavy stresses.

6.5.5 The requirements given in [6.5.6] and Article [6] are to be considered as general rules. Reduction of the number of RT checkpoints may be accepted by the Society when consistent satisfactory quality is justified by the Shipbuilder. In such case, the extent of NDT is to remain equivalent to that given in [6.5.6] and Article [6].

6.5.6 In the midship area, RT checkpoints are to be selected at the joining of panels.

Each RT checkpoint is to be located at a crossing of butt joints.

In a given ship cross-section bounded by the panels, one RT checkpoint is to be selected for each butt of sheerstrake, stringer, bilge and keel plate. In addition, the following RT checkpoints are to be selected:

- bottom plating: two RT checkpoints
- deck plating: two RT checkpoints
- side shell plating: two RT checkpoints at each side.

For ships where $B + D \leq 15$ m, only one RT checkpoint is to be selected for each of the above items.

This requirement remains applicable where panel butts are shifted or where some strakes are built independently from the panels. It is recommended to select most of these RT checkpoints at the crossing of butt and panel seams.

Still in the midship area, RT checkpoints are to be selected, at random, for the following main structural members:

- butts of continuous longitudinal bulkheads
- butts of longitudinal stiffeners, deck and bottom girders contributing to the overall strength
- assembly joints of insert plates at the corners of the openings.

Additionally, RT checkpoints are to be selected, at random, for the butt welds of the bilge keel and of intermediate flat.

6.5.7 Apart from the midship area, RT checkpoints are to be selected at random by the Shipbuilder in agreement with the Surveyor for the major location points. It is further recommended:

- to select a number of RT checkpoints for the very thick parts and those comprising restrained joint, such as sternframes, shaft brackets, stabiliser recesses, masts
- to check the full length or to increase the number of RT checkpoints for the first joint of a series of identical joints. This recommendation is applicable not only to the assembly joints of prefabricated members completed on the slip, but also to joints completed in the workshop to prepare such prefabricated members.

6.5.8 Consideration may be given for reduction of inspection frequency for automated welds where quality assurance techniques indicate consistent satisfactory quality.

6.6 Ultrasonic testing (UT)

6.6.1 UT is to be carried out according to procedure based on ISO 17640:2018 (testing procedure), ISO 23279:2017 (characterization) and ISO 11666:2018 (acceptance levels) or recognized standards accepted by the Society.

6.6.2 The minimum inspected weld length for each checkpoint is to be specified in the approved NDT plan (see [5.1.2]).

The extent of UT is to be in accordance to the approved plans and to the satisfaction of the Surveyor.

A checkpoint is to consist of the entire weld length or a length agreed with the Society.

7 Acceptance Levels (criteria)

7.1 General

7.1.1 This Article details the acceptance levels (criteria) followed for the assessment of the NDT results. Techniques include but are not limited to: VT, MT, PT, RT and UT.

7.1.2 As far as necessary, testing techniques are to be combined to facilitate the assessment of indications against the acceptance criteria.

7.1.3 The assessment of indications not covered by this Article is to be made in accordance with a standard agreed with the Society. Alternative acceptance criteria can be agreed with the Society, provided equivalency is established.

The general accepted methods for testing of welds are provided in Tab 2 and Tab 3 for surface and embedded discontinuities respectively (Refer to ISO 17635:2016).

Table 2 : Method for detection of surface discontinuities (All type of welds including fillet welds)

Materials	Testing method
Ferritic steel	VT
	VT, MT
	VT, PT

Table 3 : NDT for detection of embedded discontinuities (for butt and T joints with full penetration)

Materials and type of joint	Nominal thickness (t) of the parent material to be welded (mm)		
	t < 8	8 ≤ t ≤ 40	t > 40
Ferritic butt-joints	RT or UT(1)	RT or UT	UT or RT(2)
Ferritic T-joints	UT(1) or RT(2)	UT or RT(2)	UT or RT(2)

(1) Below 8mm the Society may consider application of an appropriate advanced UT method.
 (2) RT may be applied however there will be limitations.

7.2 Quality Levels

7.2.1 Testing requirements follow the designation of a particular quality level of imperfections in fusion-welded joints in accordance with ISO 5817:2014. Three quality levels (B, C and D) are specified.

In general Quality level C is to be applied for hull structure.

Quality level B corresponds to the highest requirement on the finished weld, and may be applied on critical welds.

This standard applies to steel materials with thickness above 0,5 mm.

Note 1: ISO 5817:2014 Table 1 provides the requirements on the limits of imperfections for each quality level. ISO 5817:2014 Annex A also provides examples for the determination of percentage of imperfections (number of pores in surface percent).

All levels (B, C and D) refer to production quality and not to the fitness for purpose (ability of product, process or service to serve a defined purpose under specific conditions). The correlation between the quality levels defined in ISO 5817:2014, testing levels/ techniques and acceptance levels (for each NDT technique) will serve to define the purpose under specific conditions. The acceptance level required for examination shall be agreed with the Society. This will determine the quality level required in accordance with the non-destructive technique selected. Refer to Tab 4 to Tab 9.

7.3 Testing Levels

7.3.1 The testing coverage and thus the probability of detection increases from testing level A to testing level C. The testing level is to be agreed with the Society. Testing level D is intended for special applications, this can only be used when defined by the Shipbuilder specification.

Note 1: ISO 17640:2018 Annex A tables A.1 to A.7 provide guidance on the selection of testing levels for all type of joints in relation to the thickness of parent material and inspection requirements.

7.3.2 The testing technique used for the assessment of indications is also to be specified.

7.4 Acceptance Levels

7.4.1 The acceptance levels are specified for each testing technique used for performing the inspection. The criteria applied is to comply with each standard identified in Tab 4 to Tab 9 (or any recognized acceptable standard agreed with the Society).

7.4.2 Probability of detection (POD) indicates the probability that a testing technique will detect a given flaw.

7.5 Visual testing (VT)

7.5.1 The acceptance levels and required quality levels for VT are provided in IACS Recommendation 47, “Shipbuilding and Repair Quality Standard” and Tab 4.

7.6 Penetrant testing (PT)

7.6.1 The acceptance levels and required quality levels for PT are provided in Tab 5.

Table 4 : Visual testing

Quality levels (ISO 5817:2014 applies)(1)	Testing techniques/ levels (ISO 17637:2016 applies)(1)	Acceptance levels(2)
B	Level not specified	B
C		C
D		D
(1) Or any recognized standard agreed with the Society and demonstrated to be acceptable		
(2) The acceptance levels for VT are the same to the quality levels requirements of ISO 5817:2014		

Table 5 : Penetrant testing

Quality levels (ISO 5817:2014 applies)(1)	Testing techniques/ levels (ISO 3452-1:2013 applies)(1)	Acceptance levels (ISO 23277:2015 applies)(1)
B	Level not specified	2X
C		2X
D		3X
(1) Or any recognized standard agreed with the Society and demonstrated to be acceptable		

Table 6 : Magnetic Particle Testing

Quality levels (ISO 5817:2014 applies)(1)	Testing techniques/ levels (ISO 17638:2016 applies)(1)	Acceptance levels (ISO 23278:2015 applies)(1)
B	Level not specified	2X
C		2X
D		3X
(1) Or any recognized standard agreed with the Society and demonstrated to be acceptable		

Table 7 : Radiographic Testing

Quality levels (ISO 5817:2014 applies)(1)	Testing techniques/ levels (ISO 17636-1:2013 applies)(1)	Acceptance levels (ISO 10675-1:2016 applies)(1)
B	B (class)	1
C	B(2) (class)	2
D	at least A (class)	3
(1) Or any recognized standard agreed with the Society and demonstrated to be acceptable		
(2) For circumferential weld testing, the minimum number of exposures may correspond to the requirements of ISO 17636-1:2013, class A		

7.7 Magnetic Particle testing (MT)

7.7.1 The acceptance levels and required quality levels for MT is provided in Tab 6.

7.8 Radiographic testing (RT)

7.8.1 The acceptance levels and required quality levels for RT are provided in Tab 7.

Reference radiographs for the assessment of weld imperfections are to be provided in accordance to ISO 5817:2014 or acceptable recognized standard agreed with the Society.

7.9 Ultrasonic testing (UT)

7.9.1 The acceptance levels and required quality levels for UT are provided in Tab 8 and Tab 9.

7.9.2 UT Acceptance Levels apply to the examination of full penetration ferritic steel welds, with thickness from 8 mm to 100 mm. The nominal frequency of probes used is to be between 2MHz and 5MHz. Examination procedures for other type of welds, material, thicknesses above 100 mm and examination conditions are to be submitted to the consideration of the Society.

7.9.3 The acceptance levels for UT of welds are to be defined in accordance to ISO 11666:2018 requirements or any recognized acceptable standard agreed with the Society. The standard specifies acceptance level 2 and 3 for full penetration welded joints in ferritic steels, corresponding to quality levels B and C (Refer to table 8).

Table 8 : Ultrasonic Testing

Quality levels (ISO 5817:2014 applies)(1)(2)	Testing techniques/ levels (ISO 17640:2018 applies)(1)(2)	Acceptance levels (ISO 11666:2018 applies)(1)(2)
B	at least B	2
C	at least A	3
D	at least A	3(3)

(1) Or any recognized standard agreed with the Society and demonstrated to be acceptable
 (2) When characterization of indications is required, ISO 23279:2017 is to be applied
 (3) UT is not recommended but can be defined in a specification with same requirement as Quality Level C

Table 9 : Recommended Testing and Quality Levels (ISO 17640)

Testing level(1)(2)(3) (ISO 17640:2018 applies)	Quality level (ISO 5817:2014 applies)
A	C, D
B	B
C	By agreement
D	Special application

(1) POD increases from testing level A to C as testing coverage increases
 (2) Testing Level D for special application is to be agreed with the Society
 (3) Specific requirements for testing levels A to C, are provided for various types of joints in ISO 17460:2018 Annex A

7.9.4 Sensitivity settings and levels. The sensitivity levels are set by the following techniques:

- Technique 1: based on 3 mm diameter side-drilled holes
- Technique 2: based on distance gain size (DGS) curves for flat bottom holes (diskshaped reflectors)
- Technique 3: using a distance-amplitude-corrected (DAC) curve of a rectangular notch of 1 mm depth and 1 mm width
- Technique 4: using the tandem technique with reference to a 6 mm diameter flatbottom hole (disk shaped reflector)

The evaluation levels (reference, evaluative, recording and acceptance) are specified in ISO 11666:2018 Annex A.

8 Reporting

8.1 General

8.1.1 Reports of NDT required are to be prepared by the Shipbuilder and are to be made available to the Society.

8.1.2 Reports of NDT are to include the following generic items:

- date of testing
- hull number, location and length of weld inspected
- names, qualification level and signature of personnel that have performed the testing
- identification of the component examined
- identification of the welds examined
- steel grade, type of joint, thickness of parent material, welding process
- acceptance criteria
- testing standards used
- testing equipment and arrangement used
- any test limitations, viewing conditions and temperature

- results of testing with reference to acceptance criteria, location and size of reportable indications
- statement of acceptance / non-acceptance, evaluation date, name and signature of evaluator
- number of repairs if specific area repaired more than twice.

8.1.3 In addition to generic items, reports of PT are to include the following specific items:

- type of penetrant, cleaner and developer used
- penetration time and development time.

8.1.4 In addition to generic items, reports of MT are to include the following specific items:

- type of magnetization
- magnetic field strength
- detection media
- viewing conditions
- demagnetization, if required.

8.1.5 In addition to generic items, reports of RT are to include the following specific items:

- type and size of radiation source (width of radiation source), X-ray voltage
- type of film/designation and number of film in each film holder/cassette
- number of radiographs (exposures)
- type of intensifying screens
- exposure technique, time of exposure and source-to-film distance as per below:
- distance from radiation source to weld
- distance from source side of the weld to radiographic film
- angle of radiation beam through the weld (from normal)
- sensitivity, type and position of IQI (source side or film side)
- density
- geometric un-sharpness
- specific acceptance class criteria for RT.

Examinations used for acceptance or rejection of welds are to be recorded in an acceptable medium. A written record providing following information: identification and description of welds, procedures and equipment used, location within recorded medium and results are to be included. The control of documentation unprocessed original images and digitally processes images is to be to the satisfaction of the Surveyor.

8.1.6 In addition to generic items, reports of UT are to include the following specific items:

- type and identification of ultrasonic equipment used (instrument maker, model, series number), probes (instrument maker, serial number), transducer type (angle, serial number and frequency) and type of couplant (brand)
- sensitivity levels calibrated and applied for each probe
- transfer loss correction applied Type of reference blocks
- signal response used for defect detection
- reflections interpreted as failing to meet acceptance criteria.

The method for review and evaluation of UT reports is required for adequate quality control and is to be to the satisfaction of the Surveyor.

8.1.7 The shipyard is to keep the inspection records specified in [8.1.2] to [8.1.6] for at least for 5 years.

9 Unacceptable indications and repairs

9.1 General

9.1.1 Unacceptable indications are to be eliminated and repaired where necessary. The repair welds are to be examined on their full length using appropriate NDT method at the discretion of the Surveyor.

9.1.2 When unacceptable indications are found, additional areas of the same weld length are to be examined unless it is agreed with the Surveyor and fabricator that the indication is isolated without any doubt. In case of automatic welded joints, additional NDT are to be extended to all areas of the same weld length.

All radiographs exhibiting non-conforming indications are to be brought to the attention of the Surveyor. Such welds are to be repaired and inspected as required by the Surveyor. When non-conforming indications are observed at the end of a radiograph, additional RT is generally required to determine their extent. As an alternative, the extent of non-conforming welds may be ascertained by excavation, when approved by the Surveyor.

9.1.3 The extent of testing may be extended at the Surveyor's discretion when repeated non-acceptable discontinuities are found, specially for butts of sheerstrake, stringer plate, bilge strake or keel plate.

9.1.4 The inspection records specified in Article [8] are to include the records of repaired welds.

9.1.5 The Shipbuilder is to take appropriate actions to monitor and improve the quality of welds to the required level. The repair rate is to be recorded by the shipyard and any necessary corrective actions are to be identified in the builder's Quality Assurance system.

Section 5 Special Structural Details

1 General

1.1 Application

1.1.1 Special structural details are those characterised by complex geometry, possibly associated with high or alternate stresses.

1.1.2 For special structural details, specific requirements are to be fulfilled during:

- design
- construction
- selection of materials
- welding
- survey.

The purpose of these requirements is specified in [1.2] to [1.6].

1.1.3 Special structural details are those listed in Article [2] together with the specific requirements which are to be fulfilled. Other structural details may be considered by the Society as special details, when deemed necessary on the basis of the criteria in [1.1.1]. The criteria to be fulfilled in such cases are defined by the Society on a case by case basis.

1.1.4 As regards matters not explicitly specified in Article [2], the Rule requirements are to be complied with in any event; in particular:

- Part B, Chapter 4 for design principles and structural arrangements
- Part B, Chapter 7, for structural scantling
- Part B, Chapter 13 for construction and welding requirements
- the applicable requirements of Part D, Part E and Part F.

1.2 Design requirements

1.2.1 General requirements

Design requirements specify:

- the local geometry, dimensions and scantlings of the structural elements which constitute the detail
- any local strengthening
- the cases where a fatigue check is to be carried out according to Part B, Chapter 10.

1.2.2 Fatigue check requirements

Where a fatigue check is to be carried out, the design requirements specify (see Ch 10, Sec 1, [2]):

- the locations (hot spots) where the stresses are to be calculated and the fatigue check performed
- the direction in which the normal stresses are to be calculated

1.3 Constructional requirements

1.3.1 Constructional requirements specify the allowable misalignment and tolerances, depending on the detail arrangement and any local strengthening.

1.4 Material requirements

1.4.1 Material requirements specify the material quality to be used for specific elements which constitute the detail, depending on their manufacturing procedure, the type of stresses they are subjected to, and the importance of the detail with respect to the ship operation and overall safety.

In addition, these requirements specify where material inspections are to be carried out.

1.5 Welding requirements

1.5.1 Welding requirements specify where partial or full T penetration welding (see Ch 13, Sec 3, [3.3]) or any particular welding type or sequence is to be adopted. In addition, these requirements specify when welding procedures are to be approved.

Since weld shape and undercuts are influencing factors on fatigue behaviour, fillet welds are to be elongated in the direction of the highest stresses and care is to be taken to avoid undercuts, in particular at the hot spots.

1.6 Survey requirements

1.6.1 Survey requirements specify where non-destructive examinations of welds are to be carried out and, where this is the case, which type is to be adopted.

2 List and characteristics of special structural details

2.1 General

2.1.1 This Article specifies the requirements which are to be fulfilled for the different ship types and related special structural details:

- a description of the hull areas where the details are located (see Tab 1)
- the structural detail description
- the requirements for the fine mesh yielding analysis
- the requirements for the fatigue check
- a reference to a table in Ch 13, App 2 where a sketch of the detail is shown together with the specific requirements which are to be fulfilled.

Table 1 : List of special structural detail areas

Area ref. No.	Area description	Ship type					
		All ships (1)	Ships carrying liquid cargo in bulk (2)	Liquefied gas carriers	Container ships	Bulk, ore and combination carriers	Ro-ro ships
		see [2.2]	see [2.3]	see [2.4]	see [2.5]	see [2.6]	see [2.7]
1	Part of side extended: <ul style="list-style-type: none"> • longitudinally, between the after peak bulkhead and the collision bulkhead • vertically, between 0,7T_{BAL} and 1,15T_{SC} from the baseline 	X	(3)				
2	Part of inner side and longitudinal bulkheads in the cargo area extended vertically above half tank height, where the tank breadth exceeds 0,55B		X				
3	Double bottom in way of longitudinal and / or transverse bulkheads		X	X	X	X	
4	Double bottom in way of hopper tanks		X	X		X	
5	Lower part of transverse bulkheads with lower stools		X			X	
6	Lower part of inner side		X	X	X	X	
7	Side frames			X		X	
8	Topside tanks			X		X	
9	Upper deck			X	X	X	X
10	Primary supporting members		X	X		X	
11	Upper part of inner side		X	X	X	X	
12	Longitudinal and transverse bulkheads				X		X
13	Racking frames						X
14	Side and stern doors				X		X
15	Supports and keys			X			
16	Foundation deck			X			
17	Double side in way of transverse bulkheads			X	X		
18	Engine room				X		
19	Deep fuel tanks				X		
(1) All types of ships with longitudinally framed sides							
(2) Except liquefied gas carriers							
(3) See [2.2]							

2.2 All types of ships with longitudinally framed sides

2.2.1 The special structural details relevant to all types of longitudinally framed ships, including those mentioned in [2.3] to [2.7], are listed and described in Tab 2.

2.3 Ships carrying liquid cargo in bulk, except liquefied gas carriers

2.3.1 The special structural details for various hull areas relevant to ships with the service notation **oil tanker ESP, chemical tanker ESP, FLS tanker, asphalt carrier** or **tanker** are listed and described in Tab 3.

When the structural arrangement in a certain area is such that the details considered in Tab 3 can not comply with corresponding requirements, specific requirements are defined by the Society on a case by case basis, depending on the arrangement adopted.

2.4 Liquefied gas carriers

2.4.1 The special structural details for various hull areas relevant to ships with the service notation **liquefied gas carrier** or **LNG bunkering ship** are listed and described in:

- Tab 4 for structural details common to all liquefied gas carriers
- Tab 5 for additional structural details for type A gas carriers
- Tab 6 for additional structural details for type B gas carriers
- Tab 7 and NR686, Sec 1, [18.3.11] for additional structural details for membrane type gas carriers

When the structural arrangement in a certain area is such that the details considered in the above specified tables can not comply with corresponding requirements, specific requirements are defined by the Society on a case by case basis, depending on the arrangement adopted.

2.5 Container ships

2.5.1 The special structural details for various hull areas relevant to ships with the service notation **container ship** are listed and described in Tab 8.

When the structural arrangement in a certain area is such that the details considered in Tab 8 can not comply with corresponding requirements, specific requirements are defined by the Society on a case by case basis, depending on the arrangement adopted.

2.6 Bulk, ore and combination carriers

2.6.1 The special structural details for various hull areas relevant to ships with the service notation **bulk carrier** or **bulk carrier ESP, self-unloading bulk carrier ESP, ore carrier ESP** and **combination carrier ESP** are listed and described in Tab 9.

When the structural arrangement in a certain area is such that the details considered in Tab 9 can not comply with corresponding requirements, specific requirements are defined by the Society on a case by case basis, depending on the arrangement adopted.

2.7 Ro-ro ships

2.7.1 The special structural details for various hull areas relevant to ships with the service notation **Ro-Ro cargo ship, Ro-Ro passenger ship** or **PCT carrier** are listed and described in Tab 10.

When the structural arrangement in a certain area is such that the details considered in Tab 10 can not comply with corresponding requirements, specific requirements are defined by the Society on a case by case basis, depending on the arrangement adopted.

Table 2 : Ships with longitudinally framed sides - Special structural details

Area	Area description	Structural detail description	Yielding check		Fatigue check		Reference tables in Ch 13, App 2
			Screening	Fine mesh	Simplified stress analysis	Very fine mesh	
1	Part of side extended: <ul style="list-style-type: none"> • longitudinally, between the after peak bulkhead and the collision bulkhead • vertically, between $0,7T_{BAL}$ and $1,15T_{SC}$ from the baseline(1) 	End connections of side longitudinal stiffeners to transverse bulkheads or web frames					Ch 13, App 2, Tab 1 to Ch 13, App 2, Tab 6
		End connections of side longitudinal stiffeners to stiffeners of transverse bulkheads or web frames			X		Ch 13, App 2, Tab 7 to Ch 13, App 2, Tab 13
(1) where T_{BAL} is the ship's draft in light ballast condition and T_{SC} is the scantling draught, as defined in Ch 1, Sec 3, Tab 1							

Table 3 : Ships carrying liquid cargo in bulk, except liquefied gas carriers - Special structural details

Area	Area description	Structural detail description	Yielding check		Fatigue check		Reference tables in Ch 13, App 2
			Screening (1)	Fine mesh	Simplified stress analysis	Very fine mesh	
2	Part of inner side and longitudinal bulkheads in the cargo area extended vertically above half tank height, where the tank breadth exceeds 0,55B	Connection of bulkhead longitudinal stiffeners with transverse primary supporting members					Ch 13, App 2, Tab 14 to Ch 13, App 2, Tab 19
		Connection of bulkhead longitudinal stiffeners with stiffeners of transverse primary supporting members			X		Ch 13, App 2, Tab 20 to Ch 13, App 2, Tab 26
3	Double bottom in way of longitudinal and/or transverse bulkheads	Connection of bottom and inner bottom longitudinal stiffeners with floors			X(2)		Ch 13, App 2, Tab 27 to Ch 13, App 2, Tab 29
		Connection of inner bottom with transverse bulkheads or lower stools		X(3)		X(3)	Ch 13, App 2, Tab 30
4	Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates		X		X	Ch 13, App 2, Tab 32 to Ch 13, App 2, Tab 35
5	Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads		X		X	Ch 13, App 2, Tab 39 to Ch 13, App 2, Tab 45
		Connection of lower stools with corrugated bulkheads		X		X(4)	Ch 13, App 2, Tab 46 to Ch 13, App 2, Tab 53
6	Lower part of inner side	Connection of hopper tank sloping plates with inner side		X		X	Ch 13, App 2, Tab 54 to Ch 13, App 2, Tab 60
10	Primary supporting members	Transverse web frame bracket toe		X		X	–
		Horizontal stringer toe		X		X	–
		Large openings	X(5)				–
11	Upper part of inner side	Intersection of upper hopper sloping plates with inner side		X		X(6)	–

(1) see screening criteria in Ch 8, App 2, [1.2.3]
 (2) Only where longitudinal stiffeners are connected to floors vertical web stiffeners
 (3) In way of double bottom girders
 (4) Not for Ch 13, App 2, Tab 49 and Ch 13, App 2, Tab 53
 (5) For which their geometry is required to be represented in the cargo hold model in accordance with Ch 8, App 1
 (6) Where the angle between hopper plate and inner hull longitudinal bulkhead is less than 130 deg, at the most critical frame location

Table 4 : Liquefied gas carriers (All types) - Special structural details

Area	Area description	Structural detail description	Yielding check		Fatigue check		Reference tables in Ch 13, App 2
			Screening (1)	Fine mesh	Simplified stress analysis	Very fine mesh	
3	Double bottom in way of longitudinal and/or transverse bulkheads	Connection of bottom and inner bottom longitudinal stiffeners with floors			X(2)		Ch 13, App 2, Tab 27 to Ch 13, App 2, Tab 29
		Connection of inner bottom with transverse bulkheads or lower stools(3)		X(4)		X(4)	Ch 13, App 2, Tab 31
4	Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank slopping plates		X		X	Ch 13, App 2, Tab 36 to Ch 13, App 2, Tab 38
6	Lower part of inner side	Connection of hopper tank sloping plates with inner side(5)		X		X	Ch 13, App 2, Tab 61 to Ch 13, App 2, Tab 62
8	Topside tanks	Intersection of upper hopper sloping plates with tween'deck		X		X	–
10	Primary supporting members	Large openings	X(6)				–
11	Upper part of inner side	Intersection of upper hopper sloping plates with inner side		X		X	–

(1) see screening criteria in Ch 8, App 2, [1.2.3]
 (2) Only where longitudinal stiffeners are connected to floors vertical web stiffeners
 (3) Including swash bulkheads
 (4) In way of double bottom girders
 (5) Where there is no prolonging bracket in way of knuckle joints, the connection of transverse webs to the inner hull and longitudinal girder plating is to be made with partial penetration welds over a length not less than 300 mm
 (6) For which their geometry is required to be represented in the cargo hold model in accordance with Ch 8, App 1

Table 5 : Liquefied gas carriers (Type A) - Additional special structural details

Area	Area description	Structural detail description	Yielding check		Fatigue check		Reference tables in Ch 13, App 2
			Screening	Fine mesh	Simplified stress analysis	Very fine mesh	
7	Side frames	Connection of side frames with hopper and topside tanks		X		X	–
9	Upper deck	Liquid dome opening		X		X	–
15	Support and keys	Vertical supports of cargo(1)		X		X	–
		Anti-rolling keys(2)		X		X	–
		Anti-pitching keys(3)		X		X	–

(1) For the fatigue calculation of this detail, longitudinal and transverse forces due to friction are to be considered in addition to vertical reaction forces
 (2) For the fatigue calculation of this detail, longitudinal forces due to friction are to be considered in addition to transverse forces. Initial construction gap is also to be taken into account
 (3) For the fatigue calculation of this detail, transverse forces due to friction are to be considered in addition to longitudinal forces. Initial construction gap is also to be taken taken into account

Table 6 : Liquefied gas carriers (Type B) - Additional special structural details

Area	Area description	Structural detail description	Yielding check		Fatigue check		Reference tables in Ch 13, App 2
			Screening	Fine mesh	Simplified stress analysis	Very fine mesh	
9	Upper deck	Connection between tank cover and main deck(1)		X		X	–
16	Foundation deck	Connection between inner side bulkhead and foundation deck(2)		X		X	–
		Connection between skirt and foundation deck(3)		X		X	–
<p>(1) Hot spots to be checked are located in inner bottom plating, transverse bulkhead plating and girders plating. If an additional longitudinal bracket is fitted above inner bottom in line with girder in way of connection, hot spots in this bracket are also to be checked</p> <p>(2) Hot spots to be checked are located in inner side plating, scarfing bracket and transverse web frames both below and above foundation deck. If an additional transverse bracket is fitted above foundation deck in way of connection, hot spots in this bracket are also to be checked</p> <p>(3) Hot spots to be checked are located in skirt plating, in scarfing brackets and in transverse web frame below foundation deck on both sides of connection</p>							

Table 7 : Liquefied gas carriers (Membrane type) - Additional special structural details

Area	Area description	Structural detail description	Yielding check		Fatigue check		Reference tables in Ch 13, App 2
			Screening	Fine mesh	Simplified stress analysis	Very fine mesh	
9	Upper deck	Connection between fore end of trunk deck and main deck		X		X	–
		Connection between aft end of trunk deck and superstructures		X		X	–
17	Double side in way of transverse bulkheads	Connection between cofferdam bulkheads and side stringers		X		X	–

Table 8 : Container ships - Special structural details

Area	Area description	Structural detail description	Yielding check		Fatigue check		Reference tables in Ch 13, App 2
			Screening (1)	Fine mesh	Simplified stress analysis	Very fine mesh	
3	Double bottom in way of longitudinal and/or transverse bulkheads	Typical openings in double bottom girders located in way of transverse watertight bulkheads	X				-
		Typical connection of double bottom girders and vertical girders of transverse watertight bulkheads	X				-
		Connections of inner bottom girders with deep fuel tank longitudinal and transverse bulkheads				X	-
		Connection of bottom and inner bottom longitudinal stiffeners with floors			X		-
6	Lower part of inner side	Typical corners of web frame bilge area in way of connection of inner hull and lowermost stringer	X				-
9	Upper deck	Ends of hatch coamings, if any in this region				X	Ch 13, App 2, Tab 67 Ch 13, App 2, Tab 68
		Connection of superstructures with strength deck				X	-
		Representative hatch corners in way of cargo holds (2), in particular in way of: -connection between engine room area and cargo hold areas -connections between fuel tanks and adjacent cargo holds -watertight bulkheads -support bulkheads -any area with significant scantling discontinuities.				X	Ch 13, App 2, Tab 66
11	Upper part of inner side	Large openings in the upper part of inner hull				X	-
12	Longitudinal and transverse bulkheads	Typical uppermost openings in vertical girders of transverse watertight bulkhead in way of cross deck	X				-
		Connection of inner bottom and longitudinal step bulkhead	X				-
		Typical lowest openings in vertical girders of transverse watertight bulkhead in way of double bottom	X				-
14	Side and stern doors	Large openings in the upper part of the side shell (e.g. pilot doors, accommodation ladder)				X	-
17	Double side in way of transverse bulkheads	Typical connection of horizontal stringers of double side in way of transverse watertight bulkheads	X				-
18	Engine room	Openings in way of engine room platforms (3)				X (4)	-
19	Deep Fuel tanks	Large brackets toes of primary members in fuel tanks	X				-
		Openings in way of deep fuel tank platforms, when deep fuel tanks are located in the cargo hold area (3)				X (4)	-

(1) See screening criteria in Ch 8, App 2, [1.2.3]

(2) From the second deck to the top of hatch coaming, where second deck means the first complete deck below the main deck

(3) From the second deck to the upper deck

(4) Applicable for ships of length L greater than 250 m

Table 9 : Bulk, ore and combination carriers - Special structural details

Area	Area description	Structural detail description	Yielding check		Fatigue check		Reference tables in Ch 13, App 2
			Screening (1)	Fine mesh	Simplified stress analysis	Very fine mesh	
3	Double bottom in way of longitudinal and/or transverse bulkheads	Connection of bottom and inner bottom longitudinal stiffeners with floors			X(2)		Ch 13, App 2, Tab 27 to Ch 13, App 2, Tab 29
		Connection of inner bottom with transverse bulkheads or lower stools		X		X(3)(4)	Ch 13, App 2, Tab 30
4	Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates		X(5)		X(4)	Ch 13, App 2, Tab 32 to Ch 13, App 2, Tab 35
5	Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads		X		X	Ch 13, App 2, Tab 39 to Ch 13, App 2, Tab 45
		Connection of lower stools with corrugated bulkheads		X		X(6)	Ch 13, App 2, Tab 46 to Ch 13, App 2, Tab 53
6	Lower part of inner side	Connection of hopper tank sloping plates with inner side		X		X	Ch 13, App 2, Tab 54 to Ch 13, App 2, Tab 60
7	Side frames	Connection of side frames with hopper and topside tanks		X(5)		X(7)	Ch 13, App 2, Tab 63 Ch 13, App 2, Tab 64
8	Topside tanks	Connection of transverse corrugated bulkheads with topside tanks					Ch 13, App 2, Tab 65
9	Upper deck	Deck plating in way of hatch corners				X	Ch 13, App 2, Tab 66
		Ends of longitudinal hatch coamings				X	Ch 13, App 2, Tab 67 Ch 13, App 2, Tab 68
10	Primary supporting members	Large openings	X(8)				–
11	Upper part of inner side	Intersection of upper hopper sloping plates with inner side		X		X(9)	–

(1) See screening criteria in Ch 8, App 2, [1.2.3]
(2) Only where longitudinal stiffeners are connected to floors vertical web stiffeners
(3) In way of double bottom girders
(4) Full or empty hold in alternate condition not assigned as a ballast hold (cargo hold closest to the midship)
(5) For single side skin ships
(6) Not for Ch 13, App 2, Tab 49 and Ch 13, App 2, Tab 53
(7) Full or empty hold in alternate condition and ballast hold of single skin ships (cargo hold closest to the midship)
(8) For which their geometry is required to be represented in the cargo hold model in accordance with Ch 8, App 1.
(9) Where the angle between hopper plate and inner hull longitudinal bulkhead is less than 130 deg, at the most critical frame location

Table 10 : Ro-Ro cargo and Ro-Ro passenger ships - Special structural details

Area	Area description	Structural detail description	Yielding check		Fatigue check		Reference tables in Ch 13, App 2
			Screening	Fine mesh	Simplified stress analysis	Very fine mesh	
9	Upper deck	Connection with funnel		X		X	–
		Corners of ramp openings		X		X	–
12	Longitudinal and transverse bulkheads	Corners of doors openings		X		X	–
13	Racking frames	Connection to transverse bulkhead or bottom structure		X		X(1)	–
		Corners of openings		X		X	–
14	Side and stern doors	Corners of openings		X		X(1)	–

(1) Very fine mesh fatigue assessment is mandatory for these details only for Ro-Ro cargo ships

Section 6 Testing

1 Testing procedures of watertight compartments

1.1 Application

1.1.1 These test procedures are to confirm the watertightness of tanks and watertight boundaries, and the structural adequacy of tanks forming a part of the watertight subdivisions of ships. These procedures may also be applied to verify the weathertightness of structures and shipboard outfitting.

The tightness of all tanks and watertight boundaries of ships during new construction and ships relevant to major conversions or major repairs is to be confirmed by these test procedures prior to the delivery of the ships.

Note 1: Watertight subdivision means the transverse and longitudinal subdivisions of the ship required to satisfy the subdivision requirements of SOLAS Chapter II-1.

Note 2: Major repair means a repair affecting structural integrity.

1.1.2 Testing procedures of watertight compartments for SOLAS Ships are to be carried out in accordance with requirements [1.4.1] to [1.9.1], unless:

- the shipyard provides documentary evidence of the shipowner's agreement to a request to the Flag Administration for an exemption from the application of SOLAS Chapter II-1, Regulation 11, or for an equivalency agreeing that the content of [1.10] is equivalent to SOLAS Chapter II-1, Regulation 11; and
- the above-mentioned exemption/equivalency has been granted by the responsible Flag Administration.

1.1.3 All gravity tanks and other boundaries required to be watertight or weathertight are to be tested in accordance with these procedures and proven tight and structurally adequate as follows:

- gravity tanks for their tightness and structural adequacy
- watertight boundaries other than tank boundaries for their watertightness
- weathertight boundaries for their weathertightness.

Note 1: Gravity tank means a tank that is subject to vapour pressure not greater than 70 kPa.

1.1.4 Testing of structures not listed in Tab 2 or Tab 3 is to be specially considered by the Society.

1.2 General

1.2.1 Tests are to be carried out in the presence of a Surveyor at a stage sufficiently close to the completion of work, with all the hatches, doors, windows, etc., installed and all the penetrations including pipe connections fitted, and before any ceiling and cement work is applied over the joints. Specific test requirements are given in [1.6] and Tab 2. For the timing of the application of coating and the provision of safe access to joints, see [1.7], [1.8] and Tab 4.

1.3 Definitions

1.3.1 Structural test

A structural test is a test to verify the structural adequacy of tank construction. This may be a hydrostatic test or, where the situation warrants, a hydropneumatic test.

1.3.2 Leak test

A leak test is a test to verify the tightness of a boundary. Unless a specific test is indicated, this may be a hydrostatic/hydropneumatic test or an air test. A hose test may be considered to be an acceptable form of leak test for certain boundaries, as indicated by footnote (3) of Tab 2.

1.3.3 Each type of structural and leak test is defined in Tab 1.

1.4 Structural test procedures

1.4.1 Type and time of test

Where a structural test is specified in Tab 1 and Tab 3, a hydrostatic test in accordance with [1.6.1] is acceptable. Where practical limitations (strength of building berth, light density of liquid, etc.) prevent the performance of a hydrostatic test, a hydropneumatic test in accordance with [1.6.2] may be accepted instead.

A hydrostatic or hydropneumatic test for the confirmation of structural adequacy may be carried out while the ship is afloat, provided the results of a leak test are confirmed to be satisfactory before the ship is set afloat.

Table 1 : Types of test

Test types	Procedure
Hydrostatic test (leak and structural)	The space to be tested is filled with a liquid to a specified head
Hydropneumatic test (leak and structural)	Combination of a hydrostatic test and an air test, the space to be tested being partially filled with liquid and pressurized with air
Hose test (leak)	Tightness check of the joint to be tested by means of a jet of water, the joint being visible from the opposite side
Air test (leak)	Tightness check by means of an air pressure differential and a leak-indicating solution. It includes tank air tests and joint air tests, such as compressed air fillet weld tests and vacuum box tests
Compressed air fillet weld test (leak)	Air test of fillet welded tee joints, by means of a leak indicating solution applied on fillet welds
Vacuum box test (leak)	A box over a joint with a leak indicating solution applied on the welds. A vacuum is created inside the box to detect any leaks
Ultrasonic test (leak)	Tightness check of the sealing of closing devices such as hatch covers, by means of ultrasonic detection techniques
Penetration test (leak)	Check, by means of low surface tension liquids (i.e. dye penetrant test), that no visual dye penetrant indications of potential continuous leakages exist in the boundaries of a compartment

1.4.2 Testing schedule for new construction and major structural conversion or repair

- tanks which are intended to hold liquids, and which form part of the watertight subdivision of the ship, shall be tested for tightness and structural strength as indicated in Tab 2 and Tab 3
- tank boundaries are to be tested from at least one side. The tanks for the structural test are to be selected so that all the representative structural members are tested for the expected tension and compression
- watertight boundaries of spaces other than tanks may be exempted from the structural test, provided that the boundary watertightness of the exempted spaces is verified by leak tests and inspections. The tank structural test is to be carried out and the requirements from item a) to item b) are to be applied for ballast holds, chain lockers, and for a representative cargo hold in case of cargo holds intended for in-port ballasting
- tanks which do not form part of the watertight subdivision of the ship, may be exempted from structural testing provided that the boundary watertightness of the exempted spaces is verified by leak tests and inspections.

1.5 Leak test procedures

1.5.1 For the leak tests specified in Tab 2, tank air tests, compressed air fillet weld tests and vacuum box tests, in accordance respectively with [1.6.3], [1.6.5] and [1.6.6], or their combinations, are acceptable. Hydrostatic or hydropneumatic tests may be also accepted as leak tests, provided [1.7], [1.8] and [1.9] are complied with. Hose tests, in accordance with [1.6.3], are also acceptable for items 14 to 17 referred to in Tab 2, taking footnote (3) into account.

1.5.2 Air tests of joints may be carried out at the block stage, provided that all work on the block that may affect the tightness of a joint is completed before the test. The application of the leak test for each type of welded joint is specified in Tab 4. See also [1.7.1] for the application of final coatings, [1.8] for the safe access to joints, and Tab 4 for the summary.

1.6 Test methods

1.6.1 Hydrostatic test

Unless another liquid is approved, hydrostatic tests are to consist in filling the space with fresh water or sea water, whichever is appropriate for testing, to the level specified in Tab 2 or Tab 3. See also [1.9].

In case where a tank is intended for cargoes having a density higher than the density of the liquid used for the test, the testing pressure height is to be adjusted is to simulate the actual loading as far as practicable.

All the external surfaces of the tested space are to be examined for structural distortion, bulging and buckling, any other related damage, and leaks.

1.6.2 Hydropneumatic test

Hydropneumatic tests, where approved, are to be such that the test condition, in conjunction with the approved liquid level and supplemental air pressure, simulates the actual loading as far as practicable. The requirements and recommendations in [1.6.4] for tank air tests apply also to hydropneumatic tests. See also [1.9].

All the external surfaces of the tested space are to be examined for structural distortion, bulging and buckling, any other related damage, and leaks.

1.6.3 Hose test

Hose tests are to be carried out with the pressure in the hose nozzle maintained at least at $2 \cdot 10^5$ Pa during the test. The nozzle is to have a minimum inside diameter of 12 mm and to be at a perpendicular distance from the joint not exceeding 1,5 m. The water jet is to impinge upon the weld.

Where a hose test is not practical because of possible damage to machinery, electrical equipment insulation, or outfitting items, it may be replaced by a careful visual examination of the welded connections, supported where necessary by means such as a dye penetrant test or an ultrasonic leak test, or equivalent.

1.6.4 Tank air test

All boundary welds, erection joints and penetrations including pipe connections are to be examined in accordance with approved procedures and under a stabilized pressure differential above atmospheric pressure not less than $0,15 \cdot 10^5$ Pa, with a leak-indicating solution (such as soapy water/detergent or a proprietary solution) applied.

A U-tube having a height sufficient to hold a head of water corresponding to the required test pressure is to be arranged. The cross-sectional area of the U-tube is not to be less than that of the pipe supplying air to the tank. Arrangements involving the use of two calibrated pressure gauges to verify the required test pressure may be accepted taking into account the provisions in F5.1 and F7.4 of IACS Recommendation 140, "Recommendation for Safe Precautions during Survey and Testing of Pressurized Systems".

A double inspection of the tested welds is to be carried out. The first inspection is to be made immediately upon application of the leak indication solution; the second one is to be made approximately four or five minutes after, in order to detect those smaller leaks which may take time to appear.

Table 2 : Test requirements for tanks and boundaries

No.	Tank or boundaries to be tested	Test type	Test head or pressure	Remarks
1	Double bottom tanks(4)	leak and structural (1)	The greater of: • top of the overflow(9) • 2,4 m above top of tank(2) • bulkhead deck	
2	Double bottom voids(5)	leak	See [1.6.4] to [1.6.6], as applicable	Including pump room double bottom and bunker tank protection double hull required by MARPOL Annex I
3	Double side tanks	leak and structural (1)	The greater of: • top of the overflow(9) • 2,4 m above top of tank(2) • bulkhead deck	
4	Double side voids	leak	See [1.6.4] to [1.6.6], as applicable	
5	Deep tanks other than those listed elsewhere in this Table	leak and structural (1)	The greater of: • top of the overflow(9) • 2,4 m above top of tank(2)	
6	Cargo oil tanks	leak and structural (1)	The greater of: • top of the overflow • 2,4 m above top of tank(2) • top of tank plus setting of any pressure relief valve(2)	
7	Ballast holds of bulk carriers	leak and structural (1)	The greater of: • top of the overflow • top of cargo hatch coaming	
8	Peak tanks	leak and structural (1)	The greater of: • top of the overflow(9) • 2,4 m above top of tank(2)	After peak to be tested after installation of stern tube
9	a) Fore peak spaces with equipment	leak	See [1.6.3] to [1.6.6], as applicable	
	b) Fore peak voids	leak	See [1.6.3] to [1.6.6], as applicable	
	c) Aft peak spaces with equipment	leak	See [1.6.3] to [1.6.6], as applicable	
	d) Aft peak voids	leak	See [1.6.4] to [1.6.6], as applicable	After peak to be tested after installation of stern tube
10	Cofferdams	leak	See [1.6.4] to [1.6.6], as applicable	

No.	Tank or boundaries to be tested	Test type	Test head or pressure	Remarks
11	a) Watertight bulkheads	leak (8)	See [1.6.3] to [1.6.6], as applicable (7)	
	b) Superstructure end bulkheads	leak	See [1.6.3] to [1.6.6], as applicable	
12	Watertight doors below freeboard or bulkhead deck	leak (6)(7)	See [1.6.3] to [1.6.6], as applicable	
13	Double plate rudder blades	leak	See [1.6.4] to [1.6.6], as applicable	
14	Shaft tunnels clear of deep tanks	leak (3)	See [1.6.3] to [1.6.6], as applicable	
15	Shell doors	leak (3)	See [1.6.3] to [1.6.6], as applicable	
16	Weather-tight hatch covers and closing appliances	leak (3)(7)	See [1.6.3] to [1.6.6], as applicable	Hatch covers closed by tarpaulins and battens excluded
17	Watertight hatch covers and closing appliances	leak and structural	Damage equilibrium waterline (10)(11)	
18	Dual purpose tank/dry cargo hatch covers	leak (3)(7)	See [1.6.3] to [1.6.6], as applicable	In addition to the structural test in item 6 or item 7
19	Chain lockers	leak and structural	Head of water up to top of chain pipe	
20	L.O. sump tanks and other similar tanks/spaces under main engines	leak (12)	See [1.6.3] to [1.6.6], as applicable	
21	Ballast ducts	leak and structural (1)	The greater of: <ul style="list-style-type: none"> ballast pump maximum pressure setting of any pressure relief valve 	
22	Fuel oil tanks	leak and structural (1)	The greater of: <ul style="list-style-type: none"> top of the overflow 2,4 m above top of tank(2) top of tank plus setting of any pressure relief valve(2) bulkhead deck 	
23	Fuel oil overflow tanks not intended to hold fuel	leak and structural (1)	The greater of: <ul style="list-style-type: none"> top of the overflow(9) 2,4 m above top of tank(2) bulkhead deck 	

- (1)** See [1.4.2]
- (2)** The top of a tank is the deck forming the top of the tank, excluding any hatchways.
- (3)** Hose test may be also considered as a medium of the leak test. See [1.3.2].
- (4)** Including the duct keels and dry compartments arranged in accordance with the provisions of Ch 2, Sec 2, [3.1.4].
- (5)** Including the duct keels and dry compartments arranged in accordance with the provisions of SOLAS, Regulations II-1/11.2 and II-1/9.4 respectively, and/or the oil fuel tank protection and pump room bottom protection arranged in accordance with the provisions of MARPOL Annex I, Chapter 3, Part A, Regulation 12A and Chapter 4, Part A, Regulation 22, respectively.
- (6)** Where watertightness of watertight doors has not been confirmed by a prototype test, a hydrostatic test (filling of the watertight spaces with water) is to be carried out. See SOLAS Regulation II-1/16.2 and MSC/Circ.1176.
- (7)** As an alternative to the hose test, other testing methods listed in [1.6.7] to [1.6.9] may be acceptable, subject to adequacy of such testing methods being verified. See SOLAS Regulation II-1/11.1. For watertight bulkheads (item 11 a)), alternatives to the hose test may be used only where the hose test is not practicable.
- (8)** A structural test (see [1.4.2]) is also to be carried out for a representative cargo hold in case of cargo holds intended for in-port ballasting. The filling level required for the structural test of such cargo holds is to be the maximum loading that will occur in-port, as indicated in the loading manual.
- (9)** Test head to the top of overflow does not apply to:
 - Tanks filled by gravity (i.e. sewage, grey water and similar tanks, not filled with pumps). In that case the top of overflow is replaced by the highest point of the filling line
 - Fuel oil overflow tanks not intended to hold fuel and arranged with level alarm.
- (10)** For cargo ships not covered by damage stability requirements, watertight hatches are to be tested by water pressure to a head of water measured from the lower edge of the opening to one metre above the freeboard deck. (see SOLAS II-1 Part B-2 Reg 16)
- (11)** A prototype pressure test of each type and size of hatch may be carried out instead of individual hatches tests.
- (12)** Where L.O. sump tanks and other similar spaces under main engines intended to hold liquid form part of the watertight subdivision of the ship, they are to be tested as per the requirements of Item 5, Deep tanks other than those listed elsewhere in this table.

Table 3 : Additional test requirements for special service ships/tanks

Item	Type of ship/tank	Structure to be tested	Type of test	Test head or pressure	Remarks
1	Liquefied gas carriers	Integral tanks	leak and structural	See Pt D, Ch 9, Sec 4	
		Hull structure supporting membrane or semi-membrane tanks	See Pt D, Ch 9, Sec 4		
		Independent tanks type A			
		Independent tanks type B			
		Independent tanks type C			
2	Edible liquid tanks	Independent tanks	leak and structural (1)	The greater of: <ul style="list-style-type: none"> • top of the overflow • 0,9 m above top of tank (2) 	
3	Chemical carriers	Integral or independent cargo tanks	leak and structural (1)	The greater of: <ul style="list-style-type: none"> • 2,4 m above top of tank (2) • top of tank plus setting of any pressure relief valve (2) 	An appropriate additional head is to be considered where a cargo tank is designed for the carriage of cargoes with specific gravities greater than 1,0
4	Chemical fuel tanks	Integral or independent tanks	leak and structural (1)	The greater of: <ul style="list-style-type: none"> • 2,4 m above top of tank (2) • top of tank plus setting of any pressure relief valve (2) 	An appropriate additional head is to be considered where a cargo tank is designed for the carriage of cargoes with specific gravities greater than 1,0
(1) See [1.4.2]					
(2) Top of tank is deck forming the top of the tank excluding any hatchways.					

1.6.5 Compressed air fillet weld test

In this air test, compressed air is injected from one end of a fillet welded joint, and the pressure verified at the other end of the joint by a pressure gauge. Pressure gauges are to be arranged so that an air pressure of at least $0,15 \cdot 10^5$ Pa can be verified at each end of any passage within the portion being tested.

Note 1: Where a leak test is required for fabrication involving partial penetration welds, a compressed air test is also to be carried out in the same manner as to fillet weld where the root face is large, i.e. 6-8 mm.

1.6.6 Vacuum box test

A box (vacuum testing box) with air connections, gauges and an inspection window is placed over the joint with a leak-indicating solution applied to the weld cap vicinity. The air within the box is removed by an ejector to create a vacuum of $0,20 \cdot 10^5$ to $0,26 \cdot 10^5$ Pa inside the box.

1.6.7 Ultrasonic test

An ultrasonic echo transmitter is to be arranged on the inside of a compartment, and a receiver on the outside. The watertight/ weathertight boundaries of the compartment are scanned with the receiver, in order to detect an ultrasonic leak indication. Any leakage in the sealing of the compartment is indicated at a location where sound is detectable by the receiver.

1.6.8 Penetration test

For the test of butt welds or other weld joints, a low surface tension liquid is applied on one side of a compartment boundary or a structural arrangement. If no liquid is detected on the opposite sides of the boundaries after the expiration of a defined period of time, this indicates tightness of the boundaries. In certain cases, a developer solution may be painted or sprayed on the other side of the weld to aid leak detection.

1.6.9 Other test

Other methods of testing may be considered by the Society upon submission of full particulars prior to the commencement of the tests.

1.7 Application of coating

1.7.1 Final coating

For butt joints welded by means of an automatic process, the final coating may be applied at any time before completion of a leak test of the spaces bounded by the joints, provided that the welds have been visually inspected with care, to the satisfaction of the Surveyor.

The Surveyors reserve the right to require a leak test prior to the application of a final coating over automatic erection butt welds. For all the other joints, the final coating is to be applied after the completion of the joint leak test. See also Tab 4.

Table 4 : Application of leak test, coating, and provision of safe access for the different types of welded joints

Type of welded joints		Leak test	Coating (1)		Safe access (2)	
			Before leak test	After leak test but before structural test	Leak test	Structural test
Butt	Automatic	not required	allowed (3)	not applicable	not required	not required
	Manual or semi-automatic (4)	required	not allowed	allowed	required	not required
Fillet	Boundary including penetrations	required	not allowed	allowed	required	not required

(1) Coating refers to internal (tank/hold) coating, where applied, and external (shell/deck) painting. It does not refer to shop primer.
 (2) Temporary means of access for verification of the leak test.
 (3) The condition applies provided that the welds have been visually inspected with care, to the satisfaction of the Surveyor.
 (4) Flux Core Arc Welding (FCAW) semi-automatic butt welds need not be tested, provided careful visual inspections show continuous and uniform weld profile shape, free from repairs, and the results of NDT show no significant defects.

1.7.2 Temporary coating

Any temporary coating which may conceal defects or leaks is to be applied at the same time as for a final coating (see [1.7.1]). This requirement does not apply to shop primers.

1.8 Safe access to joints

1.8.1 For leak tests, a safe access to all joints under examination is to be provided. See also Tab 4.

1.9 Hydrostatic or hydropneumatic tightness test

1.9.1 In cases where the hydrostatic or hydropneumatic tests are applied instead of a specific leak test, the examined boundaries are to be dew-free, otherwise small leaks are not visible.

1.10 Non-SOLAS ships and SOLAS Exemption / Equivalent Ships

1.10.1 Testing procedures are to be carried out in accordance with the requirements [1.4.1] to [1.9.1] in association with the following alternative procedures for [1.4.2] and alternative test requirements for Tab 2.

1.10.2 The tank boundaries are to be tested from at least one side. The tanks for structural test are to be selected so that all representative structural members are tested for the expected tension and compression.

1.10.3 Structural tests are to be carried out for at least one tank of a group of tanks having structural similarity (i.e. same design conditions, alike structural configurations with only minor localised differences determined to be acceptable by the attending Surveyor) on each vessel provided all other tanks are tested for leaks by an air test. The acceptance of leak testing using an air test instead of a structural test does not apply to cargo space boundaries adjacent to other compartments in tankers and combination carriers or to the boundaries of tanks for segregated cargoes or pollutant cargoes in other types of ships.

1.10.4 Additional tanks may require structural testing if found necessary after the structural testing of the first tank.

1.10.5 Where the structural adequacy of the tanks of a vessel were verified by the structural testing required in Tab 2, subsequent vessels in the series (i.e. sister ships built from the same plans at the same shipyard) may be exempted from structural testing of tanks, provided that:

- a) water-tightness of boundaries of all tanks is verified by leak tests and thorough inspections are carried out.
- b) structural testing is carried out for at least one tank of each type among all tanks of each sister vessel.
- c) additional tanks may require structural testing if found necessary after the structural testing of the first tank or if deemed necessary by the attending Surveyor.

For cargo space boundaries adjacent to other compartments in tankers and combination carriers or boundaries of tanks for segregated cargoes or pollutant cargoes in other types of ships, the provisions of [1.10.3] shall apply in lieu of item b).

1.10.6 Sister ships built (i.e. keel laid) two years or more after the delivery of the last ship of the series, may be tested in accordance with [1.10.5] at the discretion of the Classification Society, provided that:

- a) general workmanship has been maintained (i.e. there has been no discontinuity of shipbuilding or significant changes in the construction methodology or technology at the yard, shipyard personnel are appropriately qualified and demonstrate an adequate level of workmanship as determined by the Classification Society); and

- b) an NDT plan is implemented and evaluated by the Classification Society for the tanks not subject to structural tests. Shipbuilding quality standards for the hull structure during new construction are to be reviewed and agreed during the kick-off meeting. Structural fabrication is to be carried out in accordance with IACS Recommendation 47, "Shipbuilding and Repair Quality Standard", or a recognised fabrication standard which has been accepted by the Classification Society prior to the commencement of fabrication/construction. The work is to be carried out in accordance with the Rules and under survey of the Classification Society.

2 Miscellaneous

2.1 Watertight decks, trunks, etc.

2.1.1 *After completion, a hose or flooding test is to be applied to watertight decks and a hose test to watertight trunks, tunnels and ventilators.*

2.2 Steering nozzles

2.2.1 Upon completion of manufacture, the nozzle is to be subjected to a leak test.

Appendix 1 Welding Details

Symbols

f : Root face, in mm.

1 Contents

1.1 General

1.1.1 Types and edge plate preparation of the manual welds carried out on the various parts of the hull are dealt with in this Appendix.

Other types and tolerances may be used after special examination of the Society.

1.1.2 The method used to prepare the parts to be welded is left to the discretion of each shipyard, according to its own technology and experience. It is approved at the same time as the approval of the welding procedures referred to in Ch 13, Sec 2, [2.2.1].

1.2 Butt welding edge preparation

1.2.1 Typical butt weld plate edge preparation for manual welding is specified in Tab 1 and Tab 2.

Table 1 : Typical butt weld plate edge preparation (manual welding) - See Note 1

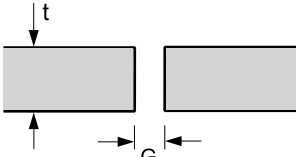
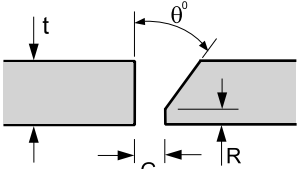
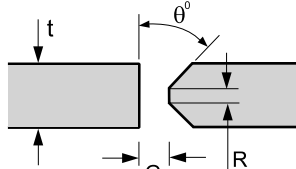
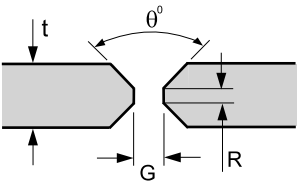
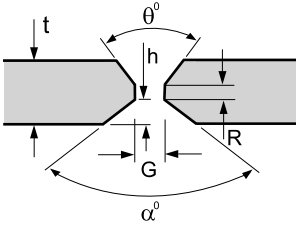
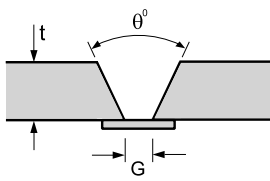
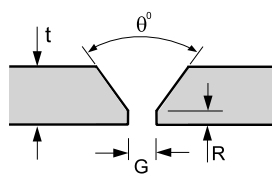
Detail	Dimensions	Detail	Dimensions
<p>Square butt</p> 	$t \leq 5 \text{ mm}$ $G = 3 \text{ mm}$		
<p>Single bevel butt</p> 	$t > 5 \text{ mm}$ $G \leq 3 \text{ mm}$ $R \leq 3 \text{ mm}$ $50^\circ \leq \theta \leq 70^\circ$	<p>Double bevel butt</p> 	$t > 19 \text{ mm}$ $G \leq 3 \text{ mm}$ $R \leq 3 \text{ mm}$ $50^\circ \leq \theta \leq 70^\circ$
<p>Double vee butt, uniform bevels</p> 	$G \leq 3 \text{ mm}$ $R \leq 3 \text{ mm}$ $50^\circ \leq \theta \leq 70^\circ$	<p>Double vee butt, non-uniform bevels</p> 	$G \leq 3 \text{ mm}$ $R \leq 3 \text{ mm}$ $6 \leq h \leq t/3 \text{ mm}$ $\theta = 50^\circ$ $\alpha = 90^\circ$
<p>Note 1: Different plate edge preparation may be accepted by the Society on the basis of an appropriate welding procedure specification.</p>			

Table 2 : Typical butt weld plate edge preparation (manual welding) - See Note 1

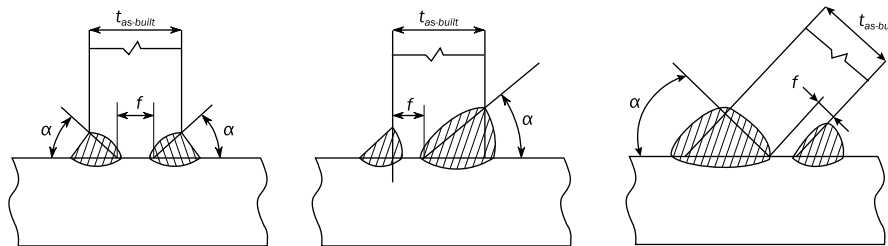
Detail	Dimensions	Detail	Dimensions
<p>Single vee butt, one side welding with backing strip (temporary or permanent)</p> 	$3 \leq G \leq 9 \text{ mm}$ $30^\circ \leq \theta \leq 45^\circ$	<p>Single vee butt</p> 	$G \leq 3 \text{ mm}$ $50^\circ \leq \theta \leq 70^\circ$ $R \leq 3 \text{ mm}$
<p>Note 1: Different plate edge preparation may be accepted by the Society on the basis of an appropriate welding procedure specification.</p>			

1.3 Partial of full penetration edge preparation

1.3.1 Typical edge preparations for partial or full penetration welding are indicated in:

- for partial penetration welds: Fig 1, in which f , in mm, is to be taken between 3 mm and $t_{as-built}/3$, and α between 40° and 60°

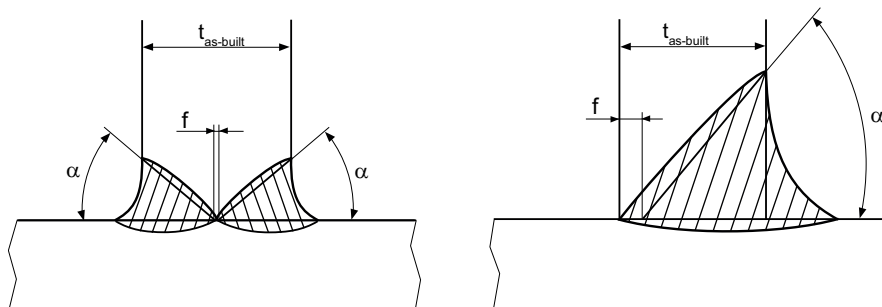
Figure 1 : Partial penetration weld



- for full penetration welds: Fig 2, in which f , in mm, is to be taken between 0 and 3 mm, and α between 40° and 60°
 Back gouging is generally required for full penetration welds.

In case of full penetration welding, the root face is to be removed, e.g. by gouging before welding of the back side.

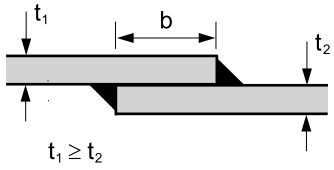
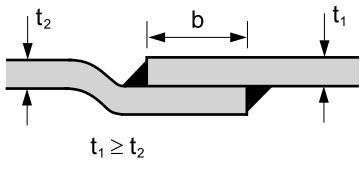
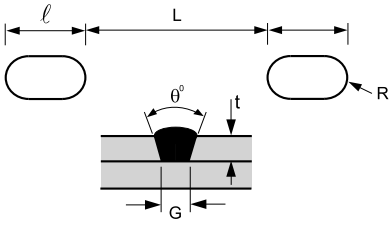
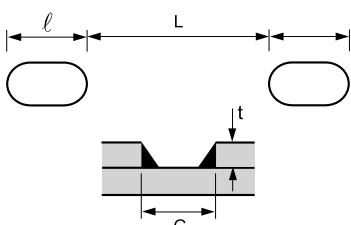
Figure 2 : Full penetration weld



1.4 Lap-joint, slot and plug welding

1.4.1 Welding details of lap-joint, slot and plug welds are specified in Tab 3.

Table 3 : Typical lap joint, plug and slot welding (manual welding)

<p>Fillet weld in lap joint</p>  <p>$t_1 \geq t_2$</p> <p>$b = 2 t_2 + 25 \text{ mm}$</p> <p>Remark: location of lap joint to be approved by the Society</p>	<p>Fillet weld in joggled lap joint</p>  <p>$t_1 \geq t_2$</p> <p>$b \geq 2 t_2 + 25 \text{ mm}$</p> <p>Remark: location of lap joint to be approved by the Society</p>
<p>Plug welding</p>  <ul style="list-style-type: none"> • $t \leq 12 \text{ mm}$ • $12 \text{ mm} < t \leq 25 \text{ mm}$ $l = 60 \text{ mm}$ $l = 80 \text{ mm}$ $R = 6 \text{ mm}$ $R = 0,5 t \text{ mm}$ $40^\circ \leq \theta \leq 50^\circ$ $\theta = 30^\circ$ $G = 12 \text{ mm}$ $G = t \text{ mm}$ $L > 2 l$ $L > 2 l$ 	<p>Slot welding</p>  <ul style="list-style-type: none"> • $t_{\text{as-built}} \leq 12 \text{ mm}$ • $t > 12 \text{ mm}$ $G = 20 \text{ mm}$ $G = 2 t$ $l = 80 \text{ mm}$ $l = 100 \text{ mm}$ $2 l \leq L \leq 3 l, \text{ max } 250 \text{ mm}$ $2 l \leq L \leq 3 l, \text{ max } 250 \text{ mm}$

Appendix 2 Reference Sheets for Special Structural Details

1 Contents

1.1 General

1.1.1 This Appendix includes the reference sheets for special structural details, as referred to in Ch 13, Sec 5.

Table 1 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

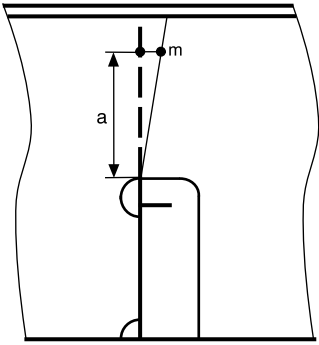
AREA 1: Side between $0,7T_{BAL}$ and $1,15T$ from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - No collar plate	Sheet 1.1
 <p data-bbox="884 779 1394 835">t_w = web thickness of transverse primary supporting member</p>		
SCANTLINGS:	FATIGUE:	
Net sectional area of the web stiffener according to Ch 4, Sec 5, [5.2].	Fatigue check not required.	
CONSTRUCTION:	NDE:	
<ul style="list-style-type: none"> • Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal $\leq a / 50$. • Cut-outs in the web free of sharps notches. • Gap between web and side longitudinal to be not greater than 4 mm. 	Visual examination 100%.	
WELDING AND MATERIALS:		
<p>Welding requirements:</p> <ul style="list-style-type: none"> - continuous fillet welding along the connection of web with side longitudinal, - throat thickness according to Ch 4, Sec 5, [5.2]; in case of gap g greater than 2 mm, increase the throat thickness by: $0,7(g - 2)$ mm, - weld around the cuts in the web at the connection with the longitudinal and the side shell, - avoid burned notches on web. 		

Table 2 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

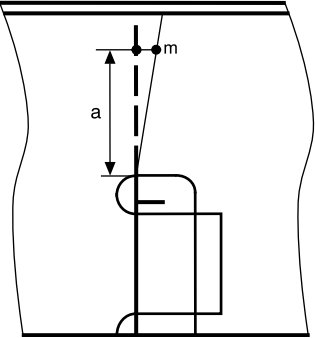
<p>AREA 1: Side between $0,7T_{BAL}$ and $1,15T$ from the baseline</p>	<p>Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - One collar plate</p>	<p>Sheet 1.2</p>
<div style="display: flex; justify-content: space-between; align-items: flex-start;"> <div style="text-align: center;">  </div> <div style="margin-left: 20px;"> <p>t_w = web thickness of transverse primary supporting member t_{CP} = collar plate thickness</p> </div> </div>		
<p>SCANTLINGS:</p>		<p>FATIGUE:</p>
<p>Net sectional area of the web stiffener according to Ch 4, Sec 5, [5.2].</p>		<p>Fatigue check not required.</p>
<p>CONSTRUCTION:</p>		<p>NDE:</p>
<ul style="list-style-type: none"> • Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal $\leq a / 50$. • Misalignment between web and collar plate $\leq t_{CP}$. • Cut-outs in the web free of sharps notches. • Gap between web and side longitudinal and between collar plate and side longitudinal to be not greater than 4 mm. 		<p>Visual examination 100%.</p>
<p>WELDING AND MATERIALS:</p>		
<ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - continuous fillet welding along the connection of web and collar plate with side longitudinal and at the lap joint between web and collar plate, - throat thickness according to Ch 4, Sec 5, [5.2]; in case of gap g greater than 2 mm, increase the throat thickness by: $0,7(g - 2)$ mm, - weld around the cuts in the web at the connection with the longitudinal and the side shell, - avoid burned notches on web. • Fillet welding of overlapped joint to be done all around. 		

Table 3 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

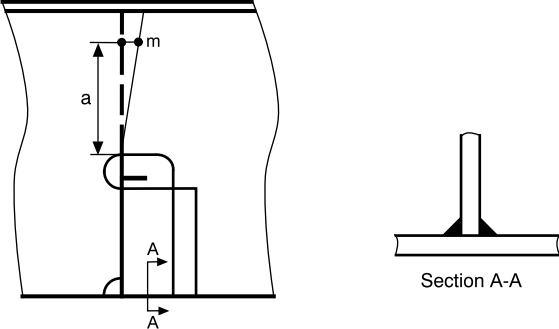
<p>AREA 1: Side between $0,7T_{BAL}$ and $1,15T$ from the baseline</p>	<p>Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - One large collar plate</p>	<p>Sheet 1.3</p>
<div style="text-align: center;">  <p>t_w = web thickness of transverse primary supporting member t_{CP} = collar plate thickness</p> </div>		
<p>SCANTLINGS:</p>	<p>FATIGUE:</p>	
<p>Net sectional area of the web stiffener according to Ch 4, Sec 5, [5.2].</p>	<p>Fatigue check not required.</p>	
<p>CONSTRUCTION:</p>	<p>NDE:</p>	
<ul style="list-style-type: none"> • Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal $\leq a / 50$. • Misalignment between web and collar plate $\leq t_{CP}$. • Cut-outs in the web free of sharps notches. • Gap between web and side longitudinal and between collar plate and side longitudinal to be not greater than 4 mm. 	<p>Visual examination 100%.</p>	
<p>WELDING AND MATERIALS:</p>		
<ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - continuous fillet welding along the connection of web and collar plate with side longitudinal and at the lap joint between web and collar plate, - throat thickness according to Ch 4, Sec 5, [5.2]; in case of gap g greater than 2 mm, increase the throat thickness by: $0,7(g - 2)$ mm, - T joint connection of collar plate with side shell: see section A-A, - weld around the cuts in the web at the connection with the longitudinal and the side shell, - avoid burned notches on web. • Fillet welding of overlapped joint to be done all around. 		

Table 4 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

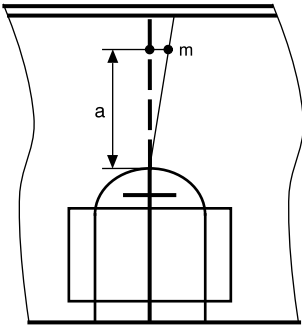
<p>AREA 1: Side between $0,7T_{BAL}$ and $1,15T$ from the baseline</p>	<p>Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - Two collar plates</p>	<p>Sheet 1.4</p>
<div style="display: flex; justify-content: space-between; align-items: flex-start;"> <div style="text-align: center;">  </div> <div style="margin-left: 20px;"> <p>t_w = web thickness of transverse primary supporting member t_{CP} = collar plate thickness</p> </div> </div>		
<p>SCANTLINGS:</p>		<p>FATIGUE:</p>
<p>Net sectional area of the web stiffener according to Ch 4, Sec 5, [5.2].</p>		<p>Fatigue check not required.</p>
<p>CONSTRUCTION:</p>		<p>NDE:</p>
<ul style="list-style-type: none"> • Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal $\leq a / 50$. • Misalignment between collar plates across the side longitudinal $\leq t_{CP} / 2$. • Cut-outs in the web free of sharps notches. • Gap between collar plates and side longitudinal to be not greater than 4 mm. 		<p>Visual examination 100%.</p>
<p>WELDING AND MATERIALS:</p>		
<ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - continuous fillet welding along the connection of collar plates with side longitudinal and at the lap joint between web and collar plates, - throat thickness according to Ch 4, Sec 5, [5.2]; in case of gap g greater than 2 mm, increase the throat thickness by: $0,7 (g - 2)$ mm, - avoid burned notches on web. • Fillet welding of overlapped joint to be done all around. 		

Table 5 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

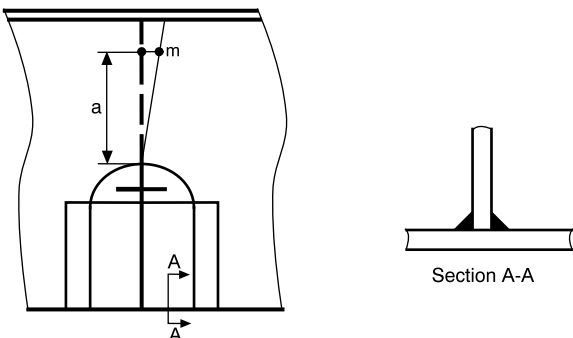
<p>AREA 1: Side between $0,7T_{BAL}$ and $1,15T$ from the baseline</p>	<p>Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - Two large collar plates</p>	<p>Sheet 1.5</p>
<div style="text-align: center;">  <p>t_w = web thickness of transverse primary supporting member t_{CP} = collar plate thickness</p> </div>		
<p>SCANTLINGS:</p>		<p>FATIGUE:</p>
<p>Net sectional area of the web stiffener according to Ch 4, Sec 5, [5.2].</p>		<p>Fatigue check not required.</p>
<p>CONSTRUCTION:</p>		<p>NDE:</p>
<ul style="list-style-type: none"> • Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal $\leq a / 50$. • Misalignment between collar plates across the side longitudinal $\leq t_{CP} / 2$. • Cut-outs in the web free of sharps notches. • Gap between collar plates and side longitudinal to be not greater than 4 mm. 		<p>Visual examination 100%.</p>
<p>WELDING AND MATERIALS:</p>		
<ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - continuous fillet welding along the connection of collar plates with side longitudinal and at the lap joint between web and collar plates, - throat thickness according to Ch 4, Sec 5, [5.2]; in case of gap g greater than 2 mm, increase the throat thickness by: $0,7(g - 2)$ mm, - T joint connection of collar plates with side shell: see section A-A, - avoid burned notches on web. • Fillet welding of overlapped joint to be done all around. 		

Table 6 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

<p>AREA 1: Side between $0,7T_{BAL}$ and $1,15T$ from the baseline</p>	<p>Watertight connection of side longitudinal ordinary stiffeners with watertight side diaphragms or transverse bulkheads – Example of connection with lugs</p>	<p>Sheet 1.6</p>
<p>t_w = transverse bulkhead web thickness t_l = lug thickness</p>		
<p>SCANTLINGS:</p>	<p>FATIGUE:</p>	
<ul style="list-style-type: none"> $d = 30 \div 60$ mm. $t_l \geq t_w$. 	<p>Fatigue check not required.</p>	
<p>CONSTRUCTION:</p>	<p>NDE:</p>	
<ul style="list-style-type: none"> Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal $\leq a / 50$. Misalignment between lugs across the side longitudinal $\leq t_l / 2$. Misalignment at the butts within lug parts $\leq t_l / 5$. Gap between bulkhead plating and lugs to be not greater than 4 mm. 	<ul style="list-style-type: none"> Visual examination 100%. Magnetic particle or dye penetrant examination: when deemed necessary depending on the quality of the lap joint weld. 	
<p>WELDING AND MATERIALS:</p>		
<p>Welding requirements:</p> <ul style="list-style-type: none"> - continuous fillet welding along the connection of lugs with the side longitudinal and at the lap joints between web and lugs, - throat thickness according to Ch 4, Sec 5, [5.2]; in case of gap g greater than 2 mm, increase the throat thickness by: $0,7(g - 2)$ mm, - T joint connection of collar plates with side shell: see section A-A, - welding sequence: 1 to 5 (see sketch). 		

Table 7 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

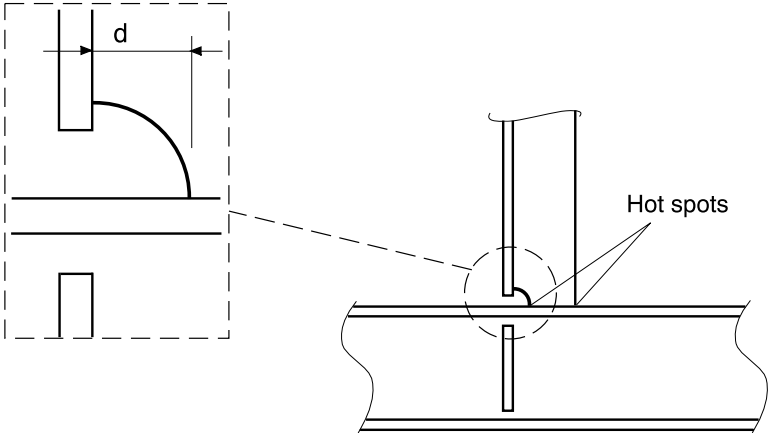
<p>AREA 1: Side between $0,7T_{BAL}$ and $1,15T$ from the baseline</p>	<p>Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - No bracket</p>	<p>Sheet 1.7</p>
<div style="display: flex; align-items: center;">  <div style="margin-left: 20px;"> <p>t = minimum thickness between those of:</p> <ul style="list-style-type: none"> - web of side longitudinal, - stiffener of transverse primary supporting member. </div> </div>		
<p>SCANTLINGS:</p>		<p>FATIGUE:</p>
<p>d to be as small as possible, maximum 35 mm recommended.</p>		<p>Fatigue check to be carried out according to NI611.</p>
<p>CONSTRUCTION:</p>		<p>NDE:</p>
<ul style="list-style-type: none"> • Misalignment between side longitudinal and web stiffener $\leq t / 3$. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but $\leq t / 2$. For bulbs, a misalignment of 6 mm may be accepted. 		<p>Visual examination 100%.</p>
<p>WELDING AND MATERIALS:</p>		
<p>Welding requirements:</p> <ul style="list-style-type: none"> - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction. 		

Table 8 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

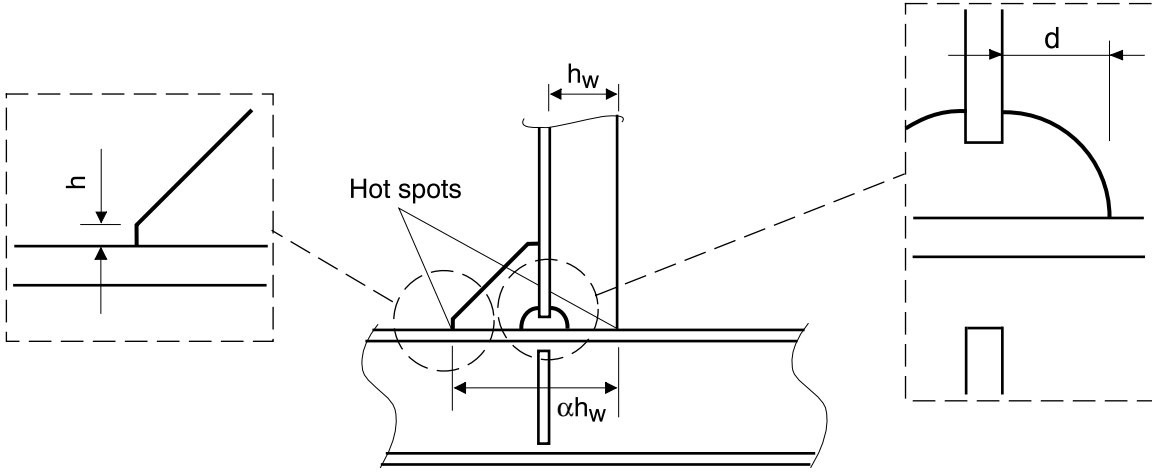
<p>AREA 1: Side between $0,7T_{BAL}$ and $1,15T$ from the baseline</p>	<p>Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One bracket</p>	<p>Sheet 1.8</p>
 <p style="text-align: center;">$t = \text{minimum thickness among those of the connected elements}$</p>		
<p>SCANTLING:</p>	<p>FATIGUE:</p>	
<ul style="list-style-type: none"> • $\alpha \geq 2$. • Bracket to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener. 	<p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p>	<p>NDE:</p>	
<ul style="list-style-type: none"> • Misalignment between side longitudinal, web stiffener and bracket $\leq t / 3$. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but $\leq t / 2$. For bulbs, a misalignment of 6 mm may be accepted. 	<p>Visual examination 100%.</p>	
<p>WELDING AND MATERIALS:</p>		
<p>Welding requirements:</p> <ul style="list-style-type: none"> - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction. 		

Table 9 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

<p>AREA 1: Side between $0,7T_{BAL}$ and $1,15T$ from the baseline</p>	<p>Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One radiused bracket</p>	<p>Sheet 1.9</p>
<p style="text-align: center;">$t = \text{minimum thickness among those of the connected elements}$</p>		
<p>SCANTLINGS:</p>		<p>FATIGUE:</p>
<ul style="list-style-type: none"> • $\alpha \geq 2$. • Bracket to be symmetric. • $R \geq 1,5 (\alpha - 1) h_w$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener. 		<p>Fatigue check to be carried out according to NI611.</p>
<p>CONSTRUCTION:</p>		<p>NDE:</p>
<ul style="list-style-type: none"> • Misalignment between side longitudinal, web stiffener and bracket $\leq t / 3$. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but $\leq t / 2$. For bulbs, a misalignment of 6 mm may be accepted. 		<p>Visual examination 100%.</p>
<p>WELDING AND MATERIALS:</p>		
<p>Welding requirements:</p> <ul style="list-style-type: none"> - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction. 		

Table 10 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

<p>AREA 1: Side between $0,7T_{BAL}$ and $1,15T$ from the baseline</p>	<p>Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One bracket</p>	<p>Sheet 1.10</p>
<p style="text-align: center;">$t = \text{minimum thickness among those of the connected elements}$</p>		
<p>SCANTLINGS:</p>		<p>FATIGUE:</p>
<ul style="list-style-type: none"> • $\alpha \geq 2$. • Bracket to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener. 		<p>Fatigue check to be carried out according to NI611.</p>
<p>CONSTRUCTION:</p>		<p>NDE:</p>
<ul style="list-style-type: none"> • Misalignment between side longitudinal, web stiffener and bracket $\leq t / 3$. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but $\leq t / 2$. For bulbs, a misalignment of 6 mm may be accepted. 		<p>Visual examination 100%.</p>
<p>WELDING AND MATERIALS:</p>		
<p>Welding requirements:</p> <ul style="list-style-type: none"> - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction. 		

Table 11 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

<p>AREA 1: Side between $0,7T_{BAL}$ and $1,15T$ from the baseline</p>	<p>Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One radiused bracket</p>	<p>Sheet 1.11</p>
<p style="text-align: center;">$t = \text{minimum thickness among those of the connected elements}$</p>		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • $\alpha \geq 2$. • Bracket to be symmetric. • $R \geq 1,5 (\alpha - 1) h_w$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment between side longitudinal, web stiffener and bracket $\leq t / 3$. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but $\leq t / 2$. For bulbs, a misalignment of 6 mm may be accepted. 	<p>NDE:</p> <p>Visual examination 100%.</p>	
<p>WELDING AND MATERIALS:</p> <p>Welding requirements:</p> <ul style="list-style-type: none"> - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction. 		

Table 12 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

<p>AREA 1: Side between $0,7T_{BAL}$ and $1,15T$ from the baseline</p>	<p>Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - Two brackets</p>	<p>Sheet 1.12</p>
<p style="text-align: center;">$t = \text{minimum thickness among those of the connected elements}$</p>		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • $\alpha \geq 2$. • $\beta \geq 1$. • Brackets to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the brackets to be not less than that of web stiffener. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment between side longitudinal, web stiffener and brackets $\leq t / 3$. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but $\leq t / 2$. For bulbs, a misalignment of 6 mm may be accepted. 	<p>NDE:</p> <p>Visual examination 100%.</p>	
<p>WELDING AND MATERIALS:</p> <ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction. • Material requirements: <ul style="list-style-type: none"> - material of brackets to be the same of longitudinals. 		

Table 13 : ALL LONGITUDINALLY FRAMED SIDE SHIPS

<p>AREA 1: Side between $0,7T_{BAL}$ and $1,15T$ from the baseline</p>	<p>Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - Two radiused brackets</p>	<p>Sheet 1.13</p>
<p style="text-align: center;">t = minimum thickness among those of the connected elements</p>		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • $\alpha \geq 2$. • $\beta \geq 1$. • Brackets to be symmetric. • $R_1 \geq 1,5 (\alpha - 1) h_w$ • $R_2 \geq 1,5 \beta h_w$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the brackets to be not less than that of web stiffener. 		<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment between side longitudinal, web stiffener and brackets $\leq t/3$. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but $\leq t/2$. For bulbs, a misalignment of 6 mm may be accepted. 		<p>NDE:</p> <p>Visual examination 100%.</p>
<p>WELDING AND MATERIALS:</p> <ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction. • Material requirements: <ul style="list-style-type: none"> - material of brackets to be the same of longitudinals. 		

Table 14 : OIL TANKERS, CHEMICAL TANKERS

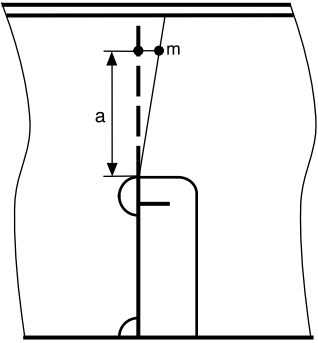
AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with transverse primary supporting members - No collar plate	Sheet 2.1
<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="text-align: center;">  </div> <div> t_w = web thickness of transverse primary supporting member </div> </div>		
SCANTLINGS:		FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 5, [5.2].		Fatigue check not required.
CONSTRUCTION:		NDE:
<ul style="list-style-type: none"> • Web stiffener not compulsory. When fitted, its misalignment m with the web of the longitudinal $\leq a / 50$. • Cut-outs in the web free of sharps notches. • Gap between web and longitudinal to be not greater than 4 mm. 		Visual examination 100%.
WELDING AND MATERIALS:		
Welding requirements: <ul style="list-style-type: none"> - continuous fillet welding along the connection of web with longitudinal, - throat thickness according to Ch 4, Sec 5, [5.2]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm, - weld around the cuts in the web at the connection with the longitudinal and the plating, - avoid burned notches on web. 		

Table 15 : OIL TANKERS, CHEMICAL TANKERS

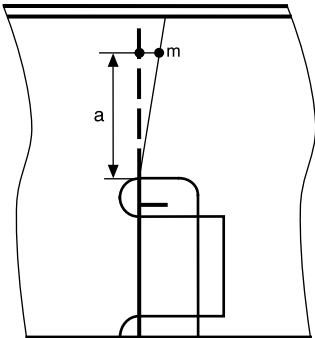
AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with transverse primary supporting members - One collar plate	Sheet 2.2
<div style="display: flex; align-items: center;">  <div style="margin-left: 20px;"> <p>t_w = web thickness of transverse primary supporting member t_{CP} = collar plate thickness</p> </div> </div>		
SCANTLINGS:		FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 5, [5.2].		Fatigue check not required.
CONSTRUCTION:		NDE:
<ul style="list-style-type: none"> • Web stiffener not compulsory. When fitted, its misalignment m with the web of the longitudinal $\leq a / 50$. • Misalignment between web and collar plate $\leq t_{CP}$. • Cut-outs in the web free of sharps notches. • Gap between web and longitudinal and between collar plate and longitudinal to be not greater than 4 mm. 		Visual examination 100%.
WELDING AND MATERIALS:		
<ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - continuous fillet welding along the connection of web and collar plate with longitudinal and at the lap joint between web and collar plate, - throat thickness according to Ch 4, Sec 5, [5.2]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm, - weld around the cuts in the web at the connection with the longitudinal and the plating, - avoid burned notches on web. • Fillet welding of overlapped joint to be done all around. 		

Table 16 : OIL TANKERS, CHEMICAL TANKERS

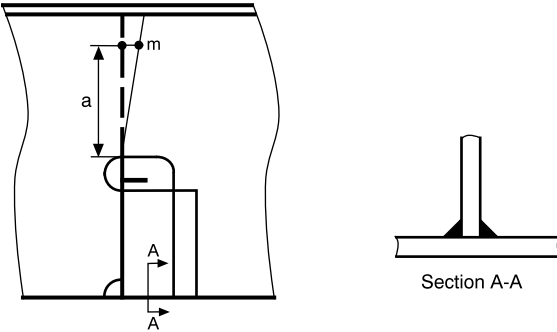
<p>AREA 2: Inner side and longitudinal bulkheads above 0,5H</p>	<p>Connection of inner side or bulkhead longitudinal ordinary stiffeners with transverse primary supporting members - One large collar plate</p>	<p>Sheet 2.3</p>
<div style="text-align: center;">  <p>t_w = web thickness of transverse primary supporting member t_{CP} = collar plate thickness</p> </div>		
<p>SCANTLINGS:</p>		<p>FATIGUE:</p>
<p>Net sectional area of the web stiffener according to Ch 4, Sec 5, [5.2].</p>		<p>Fatigue check not required.</p>
<p>CONSTRUCTION:</p>		<p>NDE:</p>
<ul style="list-style-type: none"> • Web stiffener not compulsory. When fitted, its misalignment m with the web of the longitudinal $\leq a / 50$. • Misalignment between web and collar plate $\leq t_{CP}$. • Cut-outs in the web free of sharps notches. • Gap between web and longitudinal and between collar plate and longitudinal to be not greater than 4 mm. 		<p>Visual examination 100%.</p>
<p>WELDING AND MATERIALS:</p>		
<ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - continuous fillet welding along the connection of web and collar plate with longitudinal and at the lap joint between web and collar plate, - throat thickness according to Ch 4, Sec 5, [5.2]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm, - T joint connection of collar plate with the plating: see section A-A, - weld around the cuts in the web at the connection with the longitudinal and the plating, - avoid burned notches on web. • Fillet welding of overlapped joint to be done all around. 		

Table 17 : OIL TANKERS, CHEMICAL TANKERS

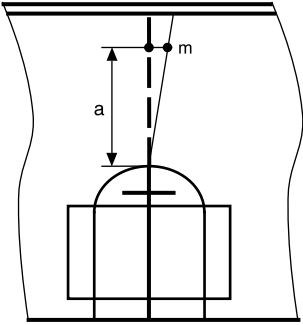
AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with transverse primary supporting members - Two collar plates	Sheet 2.4
<div style="display: flex; justify-content: space-between; align-items: flex-start;"> <div style="text-align: center;">  </div> <div style="margin-left: 20px;"> <p>t_w = web thickness of transverse primary supporting member t_{CP} = collar plate thickness</p> </div> </div>		
SCANTLINGS:		FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 5, [5.2].		Fatigue check not required.
CONSTRUCTION:		NDE:
<ul style="list-style-type: none"> • Web stiffener not compulsory. When fitted, its misalignment m with the web of the longitudinal $\leq a / 50$. • Misalignment between collar plates across the longitudinal $\leq t_{CP} / 2$. • Cut-outs in the web free of sharps notches. • Gap between collar plates and longitudinal to be not greater than 4 mm. 		Visual examination 100%.
WELDING AND MATERIALS:		
<ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - continuous fillet welding along the connection of collar plates with longitudinal and at the lap joint between web and collar plates, - throat thickness according to Ch 4, Sec 5, [5.2]; in case of gap g greater than 2 mm, increase the throat thickness by: 0,7 (g – 2) mm, - avoid burned notches on web. • Fillet welding of overlapped joint to be done all around. 		

Table 18 : OIL TANKERS, CHEMICAL TANKERS

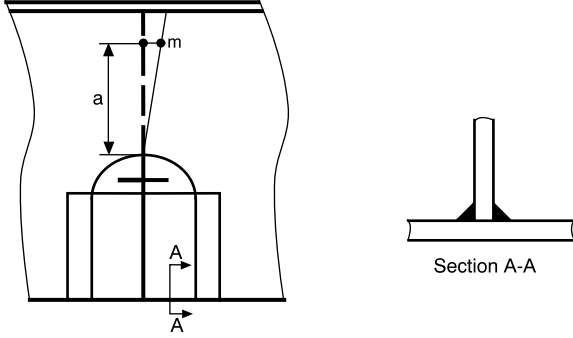
<p>AREA 2: Inner side and longitudinal bulkheads above 0,5H</p>	<p>Connection of inner side or bulkhead longitudinal ordinary stiffeners with transverse primary supporting members - Two large collar plates</p>	<p>Sheet 2.5</p>
<div style="text-align: center;">  <p>t_w = web thickness of transverse primary supporting member t_{CP} = collar plate thickness</p> </div>		
<p>SCANTLINGS:</p>		<p>FATIGUE:</p>
<p>Net sectional area of the web stiffener according to Ch 4, Sec 5, [5.2].</p>		<p>Fatigue check not required.</p>
<p>CONSTRUCTION:</p>		<p>NDE:</p>
<ul style="list-style-type: none"> • Web stiffener not compulsory. When fitted, its misalignment m with the web of the longitudinal $\leq a / 50$. • Misalignment between collar plates across the longitudinal $\leq t_{CP} / 2$. • Cut-outs in the web free of sharp notches. • Gap between collar plates and longitudinal to be not greater than 4 mm. 		<p>Visual examination 100%.</p>
<p>WELDING AND MATERIALS:</p>		
<ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - continuous fillet welding along the connection of collar plates with longitudinal and at the lap joint between web and collar plates, - throat thickness according to Ch 4, Sec 5, [5.2]; in case of gap g greater than 2 mm, increase the throat thickness by: $0,7 (g - 2)$ mm, - T joint connection of collar plates with the plating: see section A-A, - avoid burned notches on web. • Fillet welding of overlapped joint to be done all around. 		

Table 19 : OIL TANKERS, CHEMICAL TANKERS

<p>AREA 2: Inner side and longitudinal bulkheads above 0,5H</p>	<p>Watertight connection of inner side or bulkhead longitudinal ordinary stiffeners with watertight side diaphragms or transverse bulkheads – Example of connection with lugs</p>	<p>Sheet 2.6</p>
<div style="text-align: center;"> <p>t_w = transverse bulkhead web thickness t_l = lug thickness</p> </div>		
<p>SCANTLINGS:</p>		<p>FATIGUE:</p>
<ul style="list-style-type: none"> $d = 30 \div 60$ mm. $t_l \geq t_w$. 		<p>Fatigue check not required.</p>
<p>CONSTRUCTION:</p>		<p>NDE:</p>
<ul style="list-style-type: none"> Web stiffener not compulsory. When fitted, its misalignment m with the web of the longitudinal $\leq a / 50$. Misalignment between lugs across the longitudinal $\leq t_l / 2$. Misalignment at the butts within lug parts $\leq t_l / 5$. Gap between bulkhead plating and lugs to be not greater than 4 mm. 		<ul style="list-style-type: none"> Visual examination 100%. Magnetic particle or dye penetrant examination: when deemed necessary depending on the quality of the lap joint weld.
<p>WELDING AND MATERIALS:</p>		
<p>Welding requirements:</p> <ul style="list-style-type: none"> - continuous fillet welding along the connection of lugs with the longitudinal and at the lap joints between web and lugs, - throat thickness according to Ch 4, Sec 5, [5.2]; in case of gap g greater than 2 mm, increase the throat thickness by: $0,7 (g - 2)$ mm, - T joint connection of collar plates with the plating: see section A-A, - welding sequence: 1 to 5 (see sketch). 		

Table 20 : OIL TANKERS, CHEMICAL TANKERS

<p>AREA 2: Inner side and longitudinal bulkheads above 0,5H</p>	<p>Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - No bracket</p>	<p>Sheet 2.7</p>
<div style="display: flex; justify-content: space-between;"> <div data-bbox="188 376 403 696"> </div> <div data-bbox="507 472 914 779"> </div> <div data-bbox="930 338 1374 454"> <p>t = minimum thickness between those of:</p> <ul style="list-style-type: none"> - web of longitudinal, - stiffener of transverse primary supporting member. </div> </div>		
<p>SCANTLINGS:</p>		<p>FATIGUE:</p>
<p>d to be as small as possible, maximum 35 mm recommended.</p>		<p>Fatigue check to be carried out according to NI611.</p>
<p>CONSTRUCTION:</p>		<p>NDE:</p>
<ul style="list-style-type: none"> • Misalignment between longitudinal and web stiffener $\leq t / 3$. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but $\leq t / 2$. For bulbs, a misalignment of 6 mm may be accepted. 		<p>Visual examination 100%.</p>
<p>WELDING AND MATERIALS:</p>		
<p>Welding requirements:</p> <ul style="list-style-type: none"> - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction. 		

Table 21 : OIL TANKERS, CHEMICAL TANKERS

<p>AREA 2: Inner side and longitudinal bulkheads above 0,5H</p>	<p>Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One bracket</p>	<p>Sheet 2.8</p>
<p style="text-align: center;">t = minimum thickness among those of the connected elements</p>		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • $\alpha \geq 2$. • Bracket to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener. 		<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment between longitudinal, web stiffener and bracket $\leq t / 3$. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but $\leq t / 2$. For bulbs, a misalignment of 6 mm may be accepted. 		<p>NDE:</p> <p>Visual examination 100%.</p>
<p>WELDING AND MATERIALS:</p> <p>Welding requirements:</p> <ul style="list-style-type: none"> - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction. 		

Table 22 : OIL TANKERS, CHEMICAL TANKERS

<p>AREA 2: Inner side and longitudinal bulkheads above 0,5H</p>	<p>Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One radiused bracket</p>	<p>Sheet 2.9</p>
<p style="text-align: center;">t = minimum thickness among those of the connected elements</p>		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • $\alpha \geq 2$. • Bracket to be symmetric. • $R \geq 1,5 (\alpha - 1) h_w$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment between longitudinal, web stiffener and bracket $\leq t / 3$. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but $\leq t / 2$. For bulbs, a misalignment of 6 mm may be accepted. 	<p>NDE:</p> <p>Visual examination 100%.</p>	
<p>WELDING AND MATERIALS:</p> <p>Welding requirements:</p> <ul style="list-style-type: none"> - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction. 		

Table 23 : OIL TANKERS, CHEMICAL TANKERS

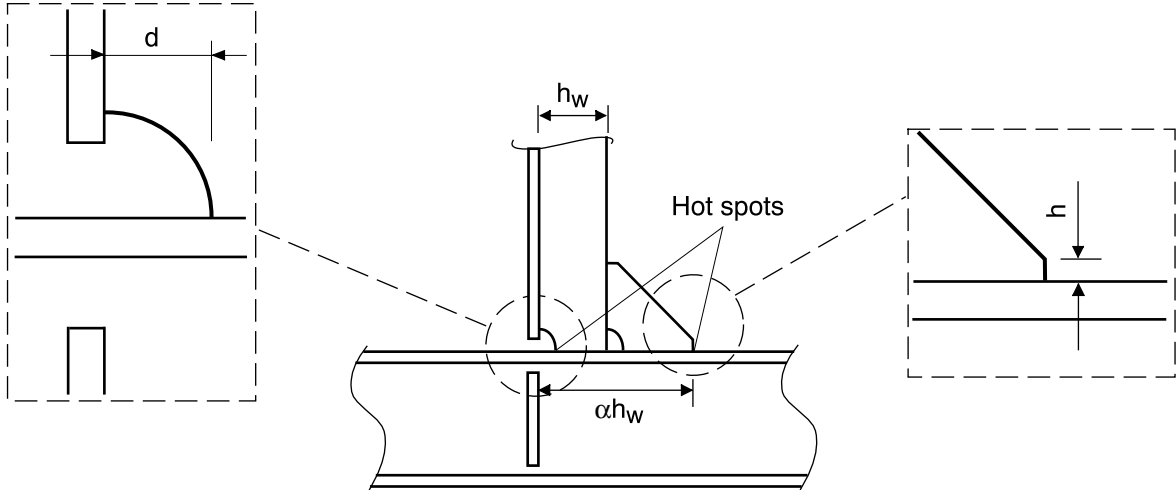
AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One bracket	Sheet 2.10
 <p style="text-align: center;">t = minimum thickness among those of the connected elements</p>		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • $\alpha \geq 2$. • Bracket to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment between longitudinal, web stiffener and bracket $\leq t / 3$. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but $\leq t / 2$. For bulbs, a misalignment of 6 mm may be accepted. 	<p>NDE:</p> <p>Visual examination 100%.</p>	
<p>WELDING AND MATERIALS:</p>		
<p>Welding requirements:</p> <ul style="list-style-type: none"> - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction. 		

Table 24 : OIL TANKERS, CHEMICAL TANKERS

<p>AREA 2: Inner side and longitudinal bulkheads above 0,5H</p>	<p>Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One radiused bracket</p>	<p>Sheet 2.11</p>
<p style="text-align: center;">t = minimum thickness among those of the connected elements</p>		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • $\alpha \geq 2$. • Bracket to be symmetric. • $R \geq 1,5 (\alpha - 1) h_w$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener. 		<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment between longitudinal, web stiffener and bracket $\leq t / 3$. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but $\leq t / 2$. For bulbs, a misalignment of 6 mm may be accepted. 		<p>NDE:</p> <p>Visual examination 100%.</p>
<p>WELDING AND MATERIALS:</p>		
<p>Welding requirements:</p> <ul style="list-style-type: none"> - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction. 		

Table 25 : OIL TANKERS, CHEMICAL TANKERS

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - Two brackets	Sheet 2.12
<p style="text-align: center;">t = minimum thickness among those of the connected elements</p>		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • $\alpha \geq 2$. • $\beta \geq 1$. • Brackets to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the brackets to be not less than that of web stiffener. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment between longitudinal, web stiffener and brackets $\leq t / 3$. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but $\leq t / 2$. For bulbs, a misalignment of 6 mm may be accepted. 	<p>NDE:</p> <p>Visual examination 100%.</p>	
<p>WELDING AND MATERIALS:</p> <ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction. • Material requirements: <ul style="list-style-type: none"> - material of brackets to be the same of longitudinals. 		

Table 26 : OIL TANKERS, CHEMICAL TANKERS

<p>AREA 2: Inner side and longitudinal bulkheads above 0,5H</p>	<p>Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - Two radiused brackets</p>	<p>Sheet 2.13</p>
<p style="text-align: center;">$t = \text{minimum thickness among those of the connected elements}$</p>		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • $\alpha \geq 2$. • $\beta \geq 1$. • Brackets to be symmetric. • $R_1 \geq 1,5 (\alpha - 1) h_w$ • $R_2 \geq 1,5 \beta h_w$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the brackets to be not less than that of web stiffener. 		<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment between longitudinal, web stiffener and brackets $\leq t / 3$. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but $\leq t / 2$. For bulbs, a misalignment of 6 mm may be accepted. 		<p>NDE:</p> <p>Visual examination 100%.</p>
<p>WELDING AND MATERIALS:</p> <ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction. • Material requirements: <ul style="list-style-type: none"> - material of brackets to be the same of longitudinals. 		

Table 27 : OIL TANKERS, CHEMICAL TANKERS, LIQUEFIED GAS CARRIERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

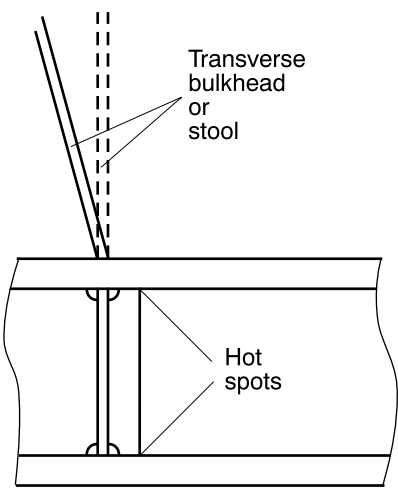
<p>AREA 3: Double bottom in way of transverse bulkheads</p>	<p>Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors - No bracket</p>	<p>Sheet 3.1</p>
<div style="display: flex; justify-content: space-between; align-items: flex-start;"> <div style="text-align: center;">  </div> <div style="margin-left: 20px;"> <p>t = minimum thickness between those of:</p> <ul style="list-style-type: none"> - web of bottom or inner bottom longitudinal, - floor stiffener. </div> </div>		
<p>SCANTLINGS:</p>	<p>FATIGUE:</p>	
	<p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p>	<p>NDE:</p>	
<ul style="list-style-type: none"> • Misalignment between webs of bottom and inner bottom longitudinal with floor stiffener $\leq t / 3$. • In case of fillet weld, misalignment may be as necessary to allow the required fillet leg size, but $\leq t / 2$. For bulbs, a misalignment of 6 mm may be accepted. 	<p>Visual examination 100%.</p>	
<p>WELDING AND MATERIALS:</p>		
<p>Welding requirements:</p> <ul style="list-style-type: none"> - floor stiffeners to be connected with continuous fillet welding to bottom and inner bottom longitudinals, - weld all around the stiffeners, - fair shape of fillet at toes in longitudinal direction. 		

Table 28 : OIL TANKERS, CHEMICAL TANKERS, LIQUEFIED GAS CARRIERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

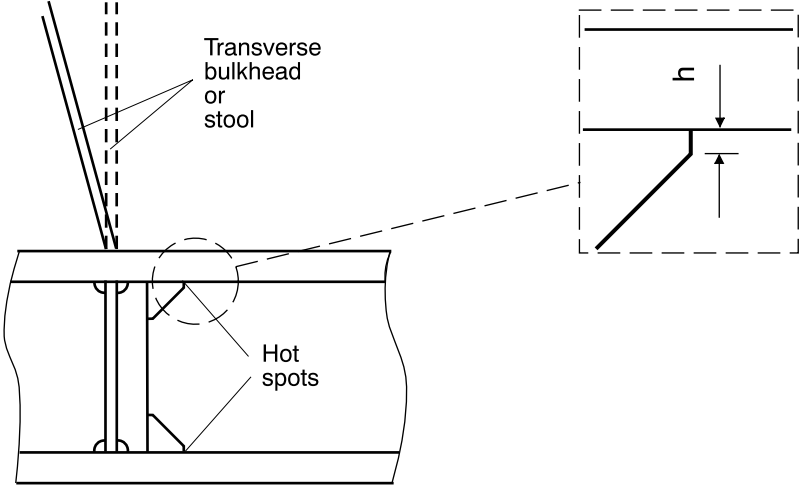
<p>AREA 3: Double bottom in way of transverse bulkheads</p>	<p>Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors - Brackets</p>	<p>Sheet 3.2</p>
<div style="text-align: center;">  <p>t = minimum thickness among those of the connected elements</p> </div>		
<p>SCANTLINGS:</p>		<p>FATIGUE:</p>
<p>h as necessary to allow the required fillet throat size, but ≤ 15 mm.</p>		<p>Fatigue check to be carried out according to NI611.</p>
<p>CONSTRUCTION:</p>		<p>NDE:</p>
<ul style="list-style-type: none"> • Misalignment between webs of bottom and inner bottom longitudinal with floor stiffener $\leq t / 3$. • In case of fillet weld, misalignment may be as necessary to allow the required fillet leg size, but $\leq t / 2$. For bulbs, a misalignment of 6 mm may be accepted. 		<p>Visual examination 100%.</p>
<p>WELDING AND MATERIALS:</p>		
<p>Welding requirements:</p> <ul style="list-style-type: none"> - floor stiffeners and brackets to be connected with continuous fillet welding to bottom and inner bottom longitudinals, - partial penetration welding between stiffeners and brackets, - weld all around the stiffeners and brackets, - fair shape of fillet at toes in longitudinal direction. 		

Table 29 : OIL TANKERS, CHEMICAL TANKERS, LIQUEFIED GAS CARRIERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

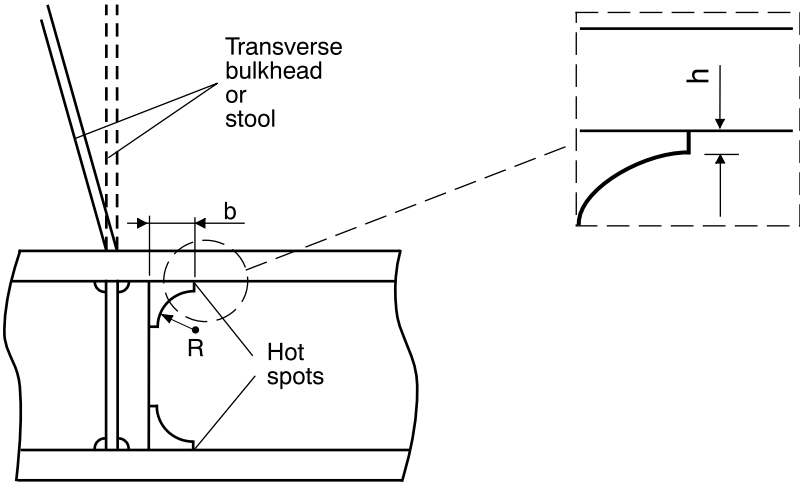
<p>AREA 3: Double bottom in way of transverse bulkheads</p>	<p>Connection of bottom and inner bottom longitudinal stiffeners with floors - Radiused brackets</p>	<p>Sheet 3.3</p>
 <p>t = minimum thickness among those of the connected elements</p>		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • Brackets to be symmetric. • $R \geq 1,5 b$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment between webs of bottom and inner bottom longitudinal with floor stiffener $\leq t / 3$. • In case of fillet weld, misalignment may be as necessary to allow the required fillet leg size, but $\leq t / 2$. For bulbs, a misalignment of 6 mm may be accepted. 	<p>NDE:</p> <p>Visual examination 100%.</p>	
<p>WELDING AND MATERIALS:</p> <p>Welding requirements:</p> <ul style="list-style-type: none"> - floor stiffeners and brackets to be connected with continuous fillet welding to bottom and inner bottom longitudinals, - partial penetration welding between stiffeners and brackets, - weld all around the stiffeners and brackets, - fair shape of fillet at toes in longitudinal direction. 		

Table 30 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

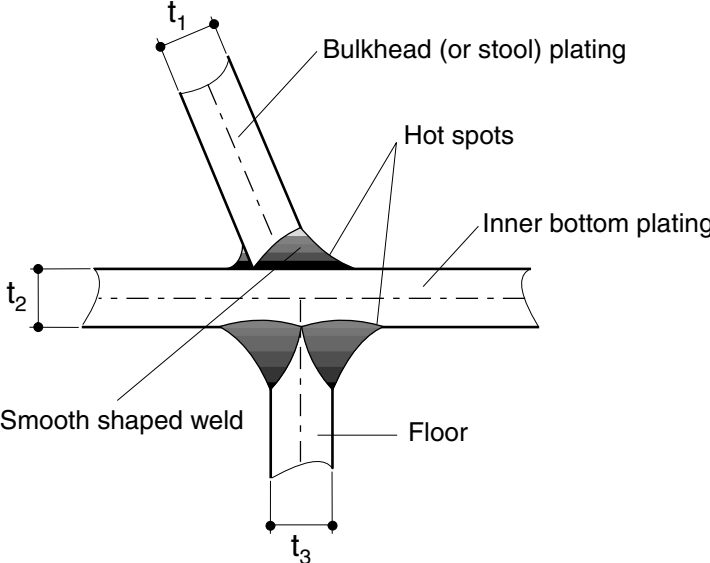
AREA 3: Double bottom in way of transverse bulkheads	Connection of inner bottom with transverse bulkheads or lower stools	Sheet 3.4
 <p style="text-align: right;">$t = \min (t_1 , t_2 , t_3)$</p>		
SCANTLINGS:	FATIGUE:	
	Fatigue check to be carried out according to NI611.	
CONSTRUCTION:	NDE:	
<ul style="list-style-type: none"> • Misalignment (median lines) between floor and bulkhead (or stool) plating $\leq t / 3$. • Cut-outs for connections of the inner bottom longitudinals to double bottom floors to be closed by collar plates welded to the inner bottom. 	The following NDE are required: <ul style="list-style-type: none"> • VE 100%, • UE 35% of full penetration weld for absence of cracks, lack of penetration and lamellar tears. 	
WELDING AND MATERIALS:		
<ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - bulkhead (or stool) plating and supporting floors generally to be connected with full penetration welding to inner bottom plating (if not full penetration welding, the weld preparation is to be indicated on the approved drawings), - special approval of the procedure on a sample representative of the actual conditions foreseen in production, - welding sequence against the risk of lamellar tearing, - weld finishing well faired to the inner bottom plating. • Material requirements: <ul style="list-style-type: none"> - the strake of inner bottom plating in way of the connection is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding. 		

Table 31 : LIQUEFIED GAS CARRIERS

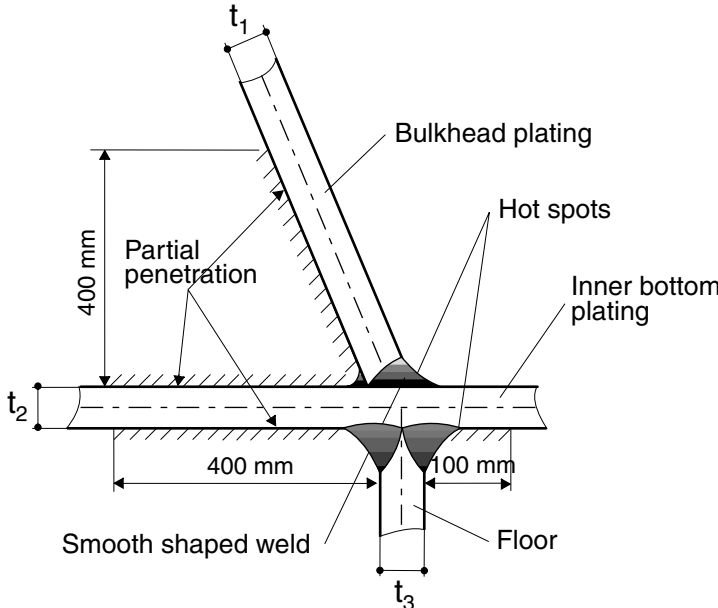
<p>AREA 3: Double bottom in way of transverse bulkheads</p>	<p>Connection of inner bottom with transverse cofferdam bulkheads</p>	<p>Sheet 3.5</p>
<div style="display: flex; justify-content: space-between; align-items: center;">  <div style="text-align: right;"> $t = \min (t_1, t_2, t_3)$ </div> </div>		
<p>SCANTLINGS:</p>	<p>FATIGUE:</p>	
	<p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p>	<p>NDE:</p>	
<ul style="list-style-type: none"> • Misalignment (median lines) between floor and bulkhead plating $\leq t / 3$, max 6 mm. • Cut-outs for connections of the inner bottom longitudinals to double bottom floors to be closed by collar plates, welded to the inner bottom. 	<p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, • UE 35% of full penetration weld for absence of cracks, lack of penetration and lamellar tears. 	
<p>WELDING AND MATERIALS:</p>		
<ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - bulkhead plating and supporting floors to be connected with full penetration welding to inner bottom plating, - bulkhead vertical girders and bottom girders are to be connected with partial penetration to inner bottom plating for the extension shown in the sketch, - special approval of the procedure on a sample representative of the actual conditions foreseen in production, - welding sequence against the risk of lamellar tearing, - weld finishing well faired to the inner bottom plating. • Material requirements: <ul style="list-style-type: none"> - the strake of inner bottom plating in way of the connection is to be of Z grade steel. In particular cases, grade E/EH steel may be accepted by the Society provided that the results of 100% UE of the plate in way of the weld, carried out prior to and after welding, are submitted for review. 		

Table 32 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

AREA 4: Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates	Sheet 4.1
<p style="text-align: right;"> $t_A = \min(t_1, t_2, t_3),$ $t_B = \text{minimum among:}$ - floor thickness, - hopper transverse web thickness, - $t_3.$ </p> <p style="text-align: center;">Section a - a</p>		
SCANTLING:	FATIGUE:	
$d \geq 50 \text{ mm.}$	Fatigue check to be carried out according to NI611.	
CONSTRUCTION:	NDE:	
<ul style="list-style-type: none"> Misalignment (median lines) between girder and sloping plate $\leq t_A / 3.$ Misalignment (median lines) between floor and hopper transverse web $\leq t_B / 3.$ 	The following NDE are required: <ul style="list-style-type: none"> VE 100%, UE 25% of full penetration weld for absence of cracks, lack of penetration and lamellar tears. 	
WELDING AND MATERIALS:		
<ul style="list-style-type: none"> Welding requirements: <ul style="list-style-type: none"> sloping plate to be connected with partial penetration welding to inner bottom plating, approval of the procedure on a sample representative of the actual conditions foreseen in production, welding sequence against the risk of lamellar tearing, weld finishing well faired to the inner bottom plating on tank side. Material requirements: <ul style="list-style-type: none"> the strake of inner bottom plating in way of the connection is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding. 		

Table 33 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

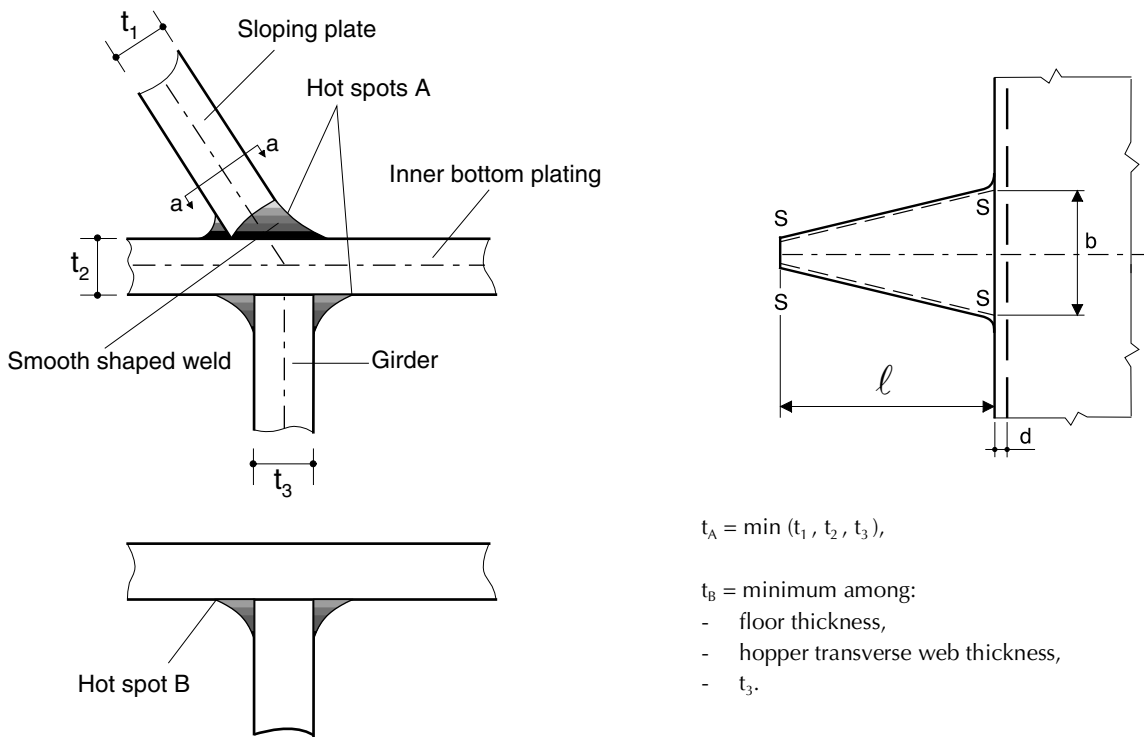
AREA 4: Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates - Prolonging brackets	Sheet 4.2
 <p> $t_A = \min(t_1, t_2, t_3),$ $t_B = \text{minimum among:}$ - floor thickness, - hopper transverse web thickness, - $t_3.$ </p>		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • Inner bottom plating to be prolonged within the hopper tank structure by brackets as shown in the sketch. • $d \geq 50$ mm. • Guidance values, to be confirmed by calculations carried out according to Ch 7, Sec 6: <ul style="list-style-type: none"> - thickness of the above brackets $\geq t_2,$ - $b \geq 0,4$ times the floor spacing, - $l \geq 1,5 b.$ 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment (median lines) between girder and sloping plate $\leq t_A / 3.$ • Misalignment (median lines) between floor and hopper transverse web $\leq t_B / 3.$ 	<p>NDE:</p> <p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, • UE 25% of full penetration weld for absence of cracks, lack of penetration and lamellar tears. 	
<p>WELDING AND MATERIALS:</p> <ul style="list-style-type: none"> • Welding requirement: <ul style="list-style-type: none"> - sloping plate to be connected with partial penetration welding to inner bottom plating, - brackets to be connected with full penetration welding to inner bottom plating, - approval of the procedure on a sample representative of the actual conditions foreseen in production, - welding sequence against the risk of lamellar tearing, - weld finishing well faired to the inner bottom plating on tank side. • Material requirement: <ul style="list-style-type: none"> - the strake of inner bottom plating in way of the connection is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding, - material properties of prolonging brackets to be not less than those of the inner bottom plating. 		

Table 34 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

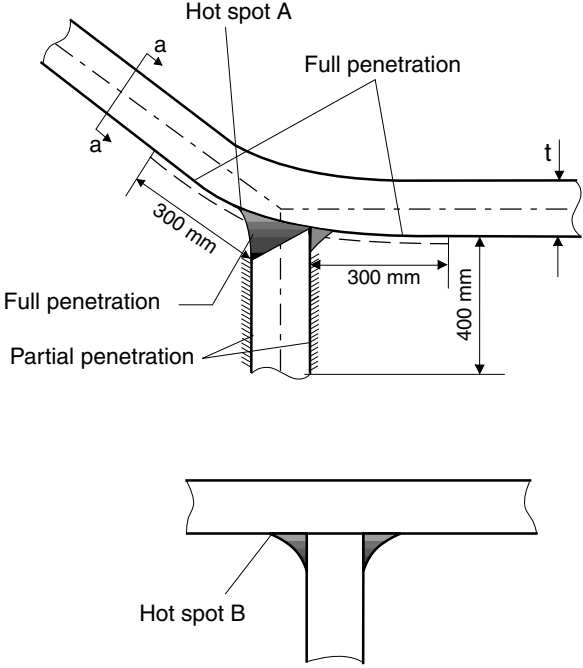
AREA 4: Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates - Radiused construction	Sheet 4.3
 <p style="text-align: right;"> t_A = minimum thickness between those of the girder and sloping plate, t_B = minimum among: • floor thickness, • hopper transverse web thickness, • girder thickness. </p> <p style="text-align: center;">Section a - a</p>		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • Transverse brackets extended to the closest longitudinals to be fitted on each side of the girder, at mid-span between floors. • Thickness of these brackets, in mm $\geq 9 + 0,03 L_1 k^{1/2}$. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment (median lines) between girder and sloping plate $\leq t_A / 3$. • Misalignment (median lines) between floor and hopper transverse web $\leq t_B / 3$. • In floor or transverse webs, in way of the bent area, scallops to be avoided or closed by collar plates. 	<p>NDE:</p> <p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, • UE 25% of full penetration weld for absence of cracks, lack of penetration and lamellar tears. 	
<p>WELDING AND MATERIALS:</p> <ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - floors to be connected (see sketches): <ul style="list-style-type: none"> with full penetration welding to the inner bottom for a length ≥ 300 mm, with partial penetration welding to the girder for a length ≥ 300 mm, with continuous fillet welding in the remaining areas, - approval of the procedure on a sample representative of the actual conditions foreseen in production, - welding sequence against the risk of lamellar tearing, - welding procedures of longitudinal girder to the bent plate to be submitted to the Society for review, with evidence given that there is no risk of ageing after welding, - weld finishing of butt welds well faired to the inner bottom plating on ballast tank, - fair shape of fillet at hot spots. • Material requirements: <ul style="list-style-type: none"> - the radiused construction may be accepted provided that the folding procedure is submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation. 		

Table 35 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

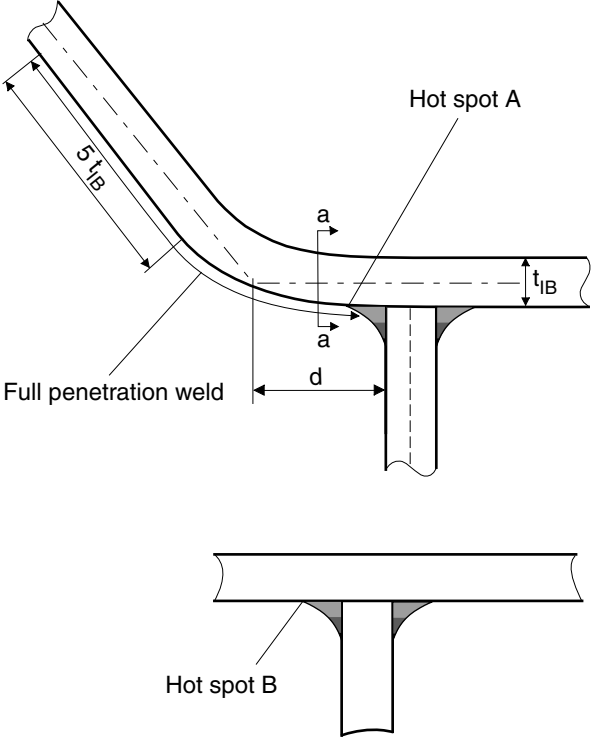
AREA 4: Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates - Radiused construction	Sheet 4.4
 <p style="text-align: right;"> t = minimum among: • floor thickness, • hopper transverse web thickness, • girder thickness, t_{IB} = inner bottom plating. </p>		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • $d \leq 40$ mm. • Transverse brackets extended to the closest longitudinals to be fitted on each side of the girder, at mid-span between floors. • Thickness of these brackets, in mm $\geq 9 + 0,03 L_1 k^{1/2}$. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment (median lines) between floor and hopper transverse web $\leq t / 3$. • In floor or transverse webs, in way of the bent area, scallops to be avoided or closed by collar plates. 	<p>NDE:</p> <p>Visual examination 100%.</p>	
<p>WELDING AND MATERIALS:</p> <ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - floors to be connected with full penetration welding to the inner bottom plating for a length $\geq 5 t_{IB}$, - where girder is welded within the bent area, welding procedures to be submitted to the Society for review. • Material requirements: <ul style="list-style-type: none"> - where girder is welded within the bent area, folding procedure to be submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation. 		

Table 36 : LIQUEFIED GAS CARRIERS

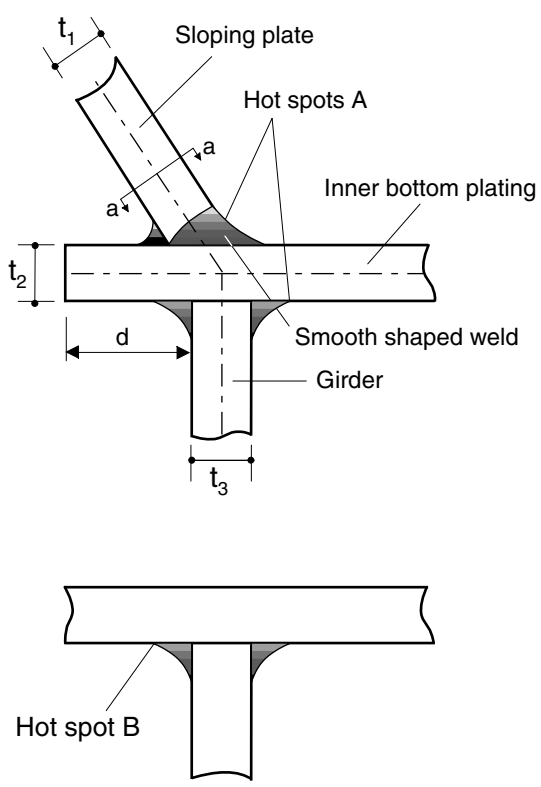
<p>AREA 4: Double bottom in way of hopper tanks</p>	<p>Connection of inner bottom with hopper tank sloping plates</p>	<p>Sheet 4.5</p>
<div style="display: flex; align-items: center;">  <div style="margin-left: 20px;"> <p>$t_A = \min (t_1, t_2, t_3),$</p> <p>$t_B =$ minimum among:</p> <ul style="list-style-type: none"> • floor thickness, • hopper transverse web thickness, • $t_3.$ </div> </div> <p style="text-align: center;">Section a - a</p>		
<p>SCANTLINGS:</p>	<p>FATIGUE:</p>	
<p>$d \geq 50$ mm.</p>	<p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment (median lines) between girder and sloping plate $\leq t_A / 3$, max 6 mm. • Misalignment (median lines) between floor and hopper transverse web $\leq t_B / 3$, max 6 mm. 	<p>NDE:</p> <p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, • UE 35% of full penetration weld for absence of cracks, lack of penetration and lamellar tears. 	
<p>WELDING AND MATERIALS:</p>		
<ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - sloping plate to be connected with full penetration welding to inner bottom plating, except in way of void spaces where partial penetration may be accepted, - approval of the procedure on a sample representative of the actual conditions foreseen in production, - welding sequence against the risk of lamellar tearing, - weld finishing well faired to the inner bottom plating on tank side. • Material requirements: <ul style="list-style-type: none"> - the strake of inner bottom plating in way of the connection is to be of Z grade steel. In particular cases, grade E/EH low temperature steel may be accepted by the Society provided that the results of 100% UE of the plate in way of the weld, carried out prior to and after welding, are submitted for review. 		

Table 37 : LIQUEFIED GAS CARRIERS

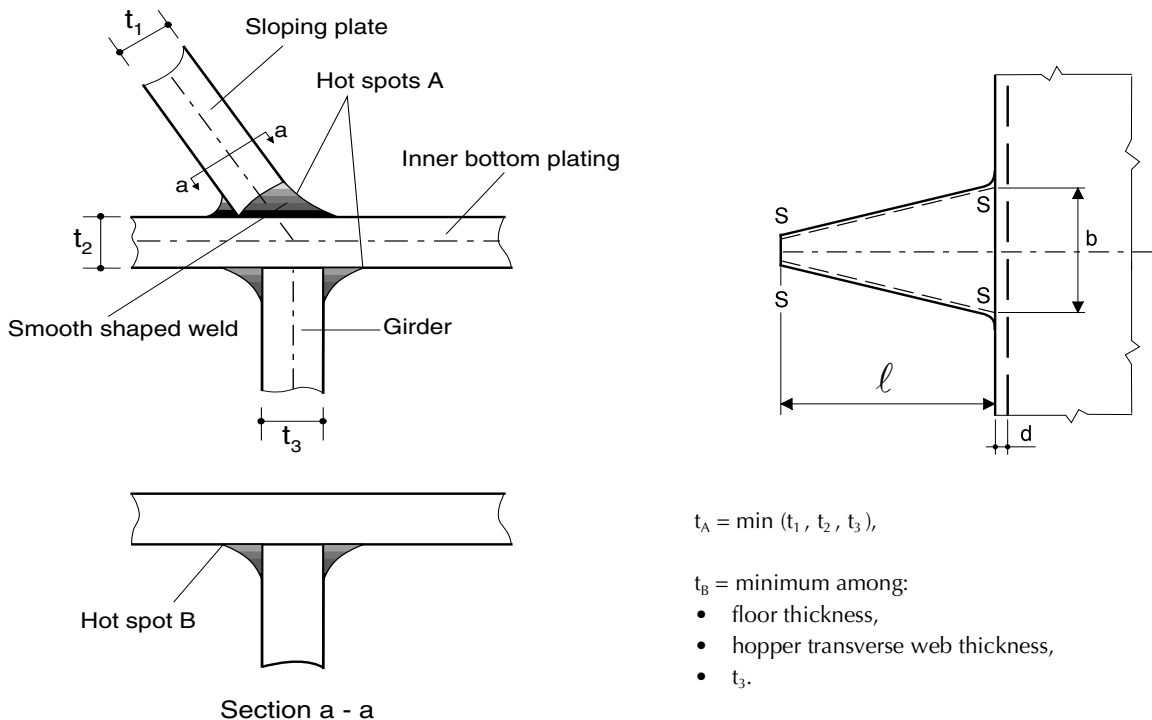
AREA 4: Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates - Prolonging brackets	Sheet 4.6
 <p style="text-align: center;">Section a - a</p> <p style="text-align: right;"> $t_A = \min (t_1, t_2, t_3),$ $t_B = \text{minimum among:}$ <ul style="list-style-type: none"> • floor thickness, • hopper transverse web thickness, • t_3. </p>		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • Inner bottom plating to be prolonged within the hopper tank structure by brackets as shown in the sketch. • $d \geq 50 \text{ mm.}$ • Guidance values, to be confirmed by calculations carried out according to Ch 7, Sec 6: <ul style="list-style-type: none"> - thickness of the above brackets $\geq t_2,$ - $b \geq 0,4$ times the floor spacing, - $l \geq 1,5 b.$ 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment (median lines) between girder and sloping plate $\leq t_A / 3,$ max 6 mm. • Misalignment (median lines) between floor and hopper transverse web $\leq t_B / 3,$ max 6 mm. 	<p>NDE:</p> <p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, • UE 35% of full penetration weld for absence of cracks, lack of penetration and lamellar tears. 	
<p>WELDING AND MATERIALS:</p> <ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - sloping plate to be connected with full penetration welding to inner bottom plating, except in way of void spaces where partial penetration may be accepted, - prolonging brackets to be connected with full penetration welding to inner bottom plating, - approval of the procedure on a sample representative of the actual conditions foreseen in production, - welding sequence against the risk of lamellar tearing, - weld finishing well faired to the inner bottom plating on tank side. • Material requirements: <ul style="list-style-type: none"> - the strake of inner bottom plating in way of the connection to be of Z grade steel. In particular cases, grade E/EH low temperature steel may be accepted by the Society provided that the results of 100% UE of the plate in way of the weld, carried out prior to and after welding, are submitted for review, - material properties of prolonging brackets to be not less than those of the inner bottom plating. 		

Table 38 : LIQUEFIED GAS CARRIERS

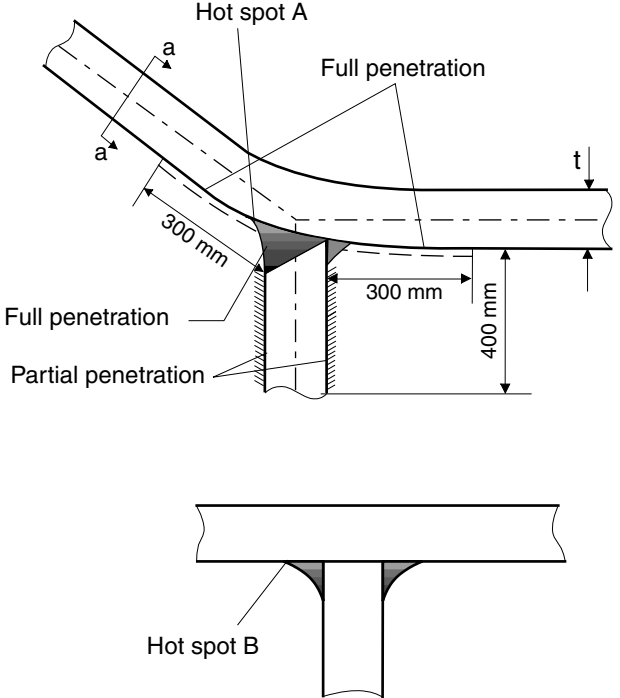
AREA 4: Double bottom in way of hopper tanks	Connection of inner bottom with hopper tank sloping plates - Radiused construction	Sheet 4.7
 <p> t_A = minimum thickness between those of the girder and sloping plate, t_B = minimum among: • floor thickness, • hopper transverse web thickness, • girder thickness. </p>		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • Transverse brackets extended to the closest longitudinals to be fitted on each side of the girder, at mid-span between floors. • Thickness of these brackets, in mm $\geq 9 + 0,03 L_1 k^{1/2}$. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment (median lines) between girder and sloping plate $\leq t_A / 3$. • Misalignment (median lines) between floor and hopper transverse web $\leq t_B / 3$. • In floor or transverse webs, in way of the bent area, scallops to be avoided or closed by collar plates. 	<p>NDE:</p> <p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, • UE 25% of full penetration weld for absence of cracks, lack of penetration and lamellar tears. 	
<p>WELDING AND MATERIALS:</p> <ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - floors to be connected (see sketches): <ul style="list-style-type: none"> with full penetration welding to the inner bottom for a length ≥ 300 mm, with partial penetration welding to the girder for a length ≥ 300 mm, with continuous fillet welding in the remaining areas, - approval of the procedure on a sample representative of the actual conditions foreseen in production, - welding sequence against the risk of lamellar tearing, - welding procedures of longitudinal girder to the bent plate to be submitted to the Society for review, with evidence given that there is no risk of ageing after welding, - weld finishing of butt welds well faired to the inner bottom plating on ballast tank, - fair shape of fillet at hot spots. • Material requirements: <ul style="list-style-type: none"> - the radiused construction may be accepted provided that the bent plate is of grade E or EH and the folding procedure is submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation. 		

Table 39 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

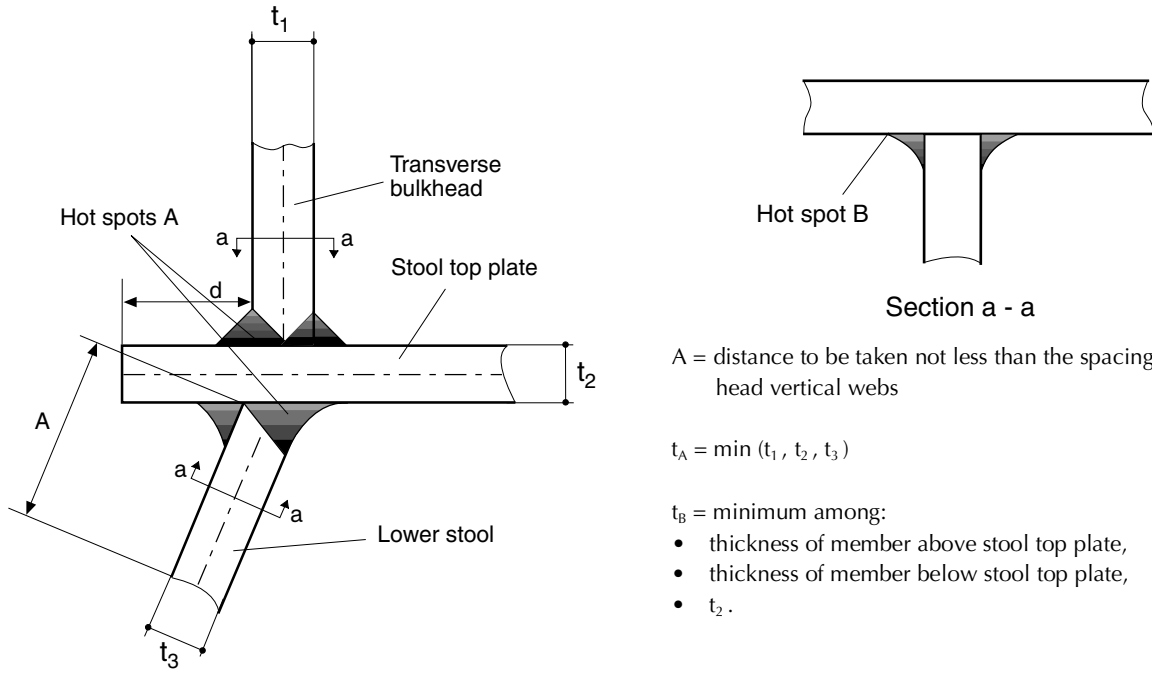
AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads	Sheet 5.1
 <p>A = distance to be taken not less than the spacing of bulk-head vertical webs</p> $t_A = \min(t_1, t_2, t_3)$ <p>t_B = minimum among:</p> <ul style="list-style-type: none"> • thickness of member above stool top plate, • thickness of member below stool top plate, • t_2. 		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • $d \geq 1,5 t_1$. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of members above and below stool top plate to be not less than that of bulkhead vertical webs. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to N1611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment (median lines) between bulkhead plating and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between members above and below stool top plate $\leq t_B / 3$. 	<p>NDE:</p> <p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears. 	
<p>WELDING AND MATERIALS:</p> <ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - bulkhead and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings), - approval of the procedure on a sample representative of the actual conditions foreseen in production, - welding sequence against the risk of lamellar tearing is recommended in case Z material is not adopted for the stool top plate, - weld finishing well faired to the stool top plate. • Material requirements: <ul style="list-style-type: none"> - the stool top plate is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding, - material properties of: <ul style="list-style-type: none"> the stool top plate, the portion A of the stool side plating, <p>to be not less than those of the transverse bulkhead plating.</p>		

Table 40 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

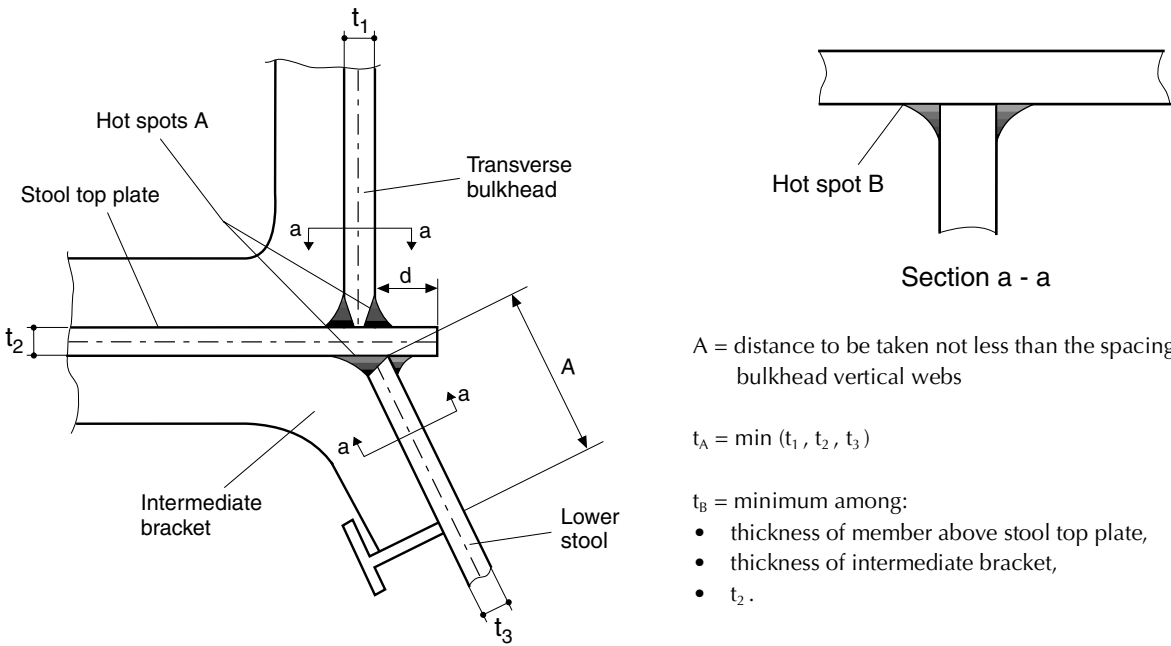
AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads in way of intermediate brackets	Sheet 5.2
 <p>A = distance to be taken not less than the spacing of bulkhead vertical webs</p> <p>$t_A = \min(t_1, t_2, t_3)$</p> <p>$t_B = \text{minimum among:}$</p> <ul style="list-style-type: none"> • thickness of member above stool top plate, • thickness of intermediate bracket, • t_2. 		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • $d \geq 1,5 t_1$. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of intermediate brackets and members above stool top plate to be not less than that of bulkhead vertical webs. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment (median lines) between bulkhead plating and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between intermediate bracket and member above stool top plate $\leq t_B / 3$. • Intermediate brackets to be fitted in place and welded after the welding of the joint between the stool side plating and the stool top plate. 	<p>NDE:</p> <p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears. 	
<p>WELDING AND MATERIALS:</p> <ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - bulkhead and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings), - brackets to be connected with continuous fillet welding to plating and stiffeners, - approval of the procedure on a sample representative of the actual conditions foreseen in production, - welding sequence against the risk of lamellar tearing is recommended in case Z material is not adopted for the stool top plate, - weld finishing well faired to the stool top plate. • Material requirements: <ul style="list-style-type: none"> - the stool top plate is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding, - material properties of: <ul style="list-style-type: none"> the stool top plate, the portion A of the stool side plating, <p>to be not less than those of the transverse bulkhead plating.</p>		

Table 41 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

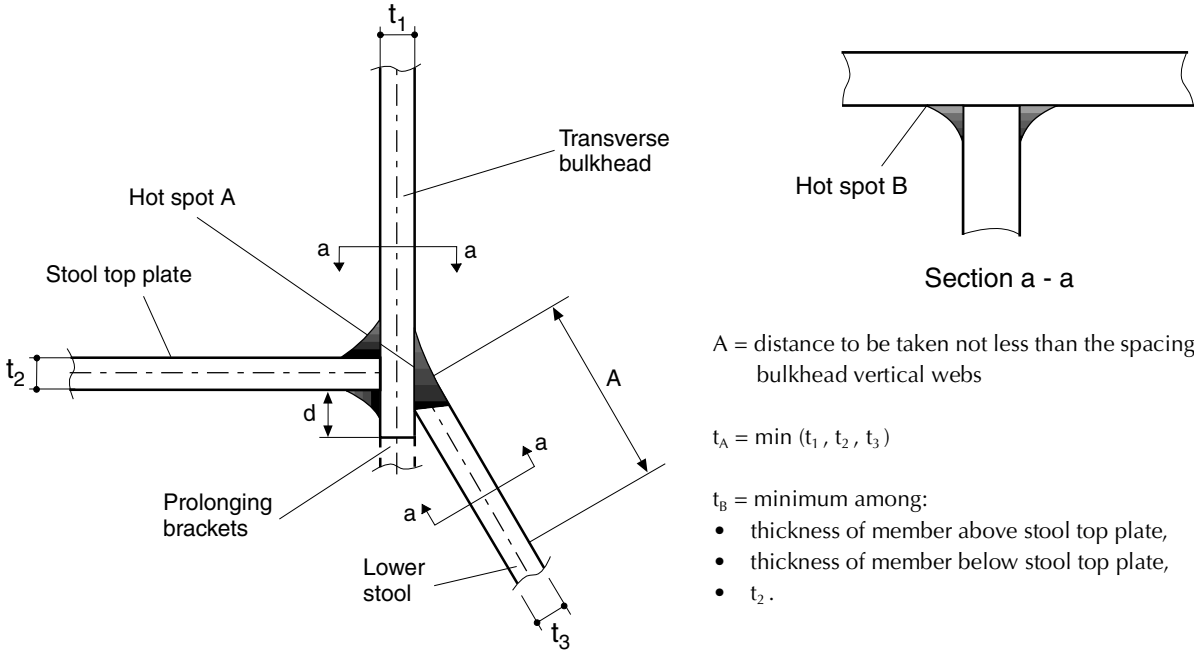
AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads - Prolonging brackets	Sheet 5.3
 <p>A = distance to be taken not less than the spacing of bulkhead vertical webs</p> $t_A = \min(t_1, t_2, t_3)$ <p>t_B = minimum among:</p> <ul style="list-style-type: none"> • thickness of member above stool top plate, • thickness of member below stool top plate, • t_2. 		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • $d \geq 50$ mm. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of prolonging brackets $\geq t_1$. • Thickness of members above and below stool top plate to be not less than that of bulkhead vertical webs. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment (median lines) between stool top plate and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between members above and below stool top plate $\leq t_B / 3$. 	<p>NDE:</p> <p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears. 	
<p>WELDING AND MATERIALS:</p> <ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - stool side plating to be connected with full penetration welding to the bulkhead plating. Root gap to be checked along the production steps as appropriate, - brackets to be connected with full penetration welding to transverse bulkhead plating, - full penetration weld of stool side plating to bulkhead plating to be welded first, - welding sequence against the risk of lamellar tearing in the bulkhead plating is recommended. • Material requirements: <ul style="list-style-type: none"> - the lower strake of transverse bulkhead plating is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the strake in way of the weld is required prior to and after welding, - material properties of: <ul style="list-style-type: none"> the stool top plate, the portion A of the stool side plating, to be not less than those of the transverse bulkhead plating, - material properties of prolonging brackets to be not less than those of the bulkhead plating. 		

Table 42 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

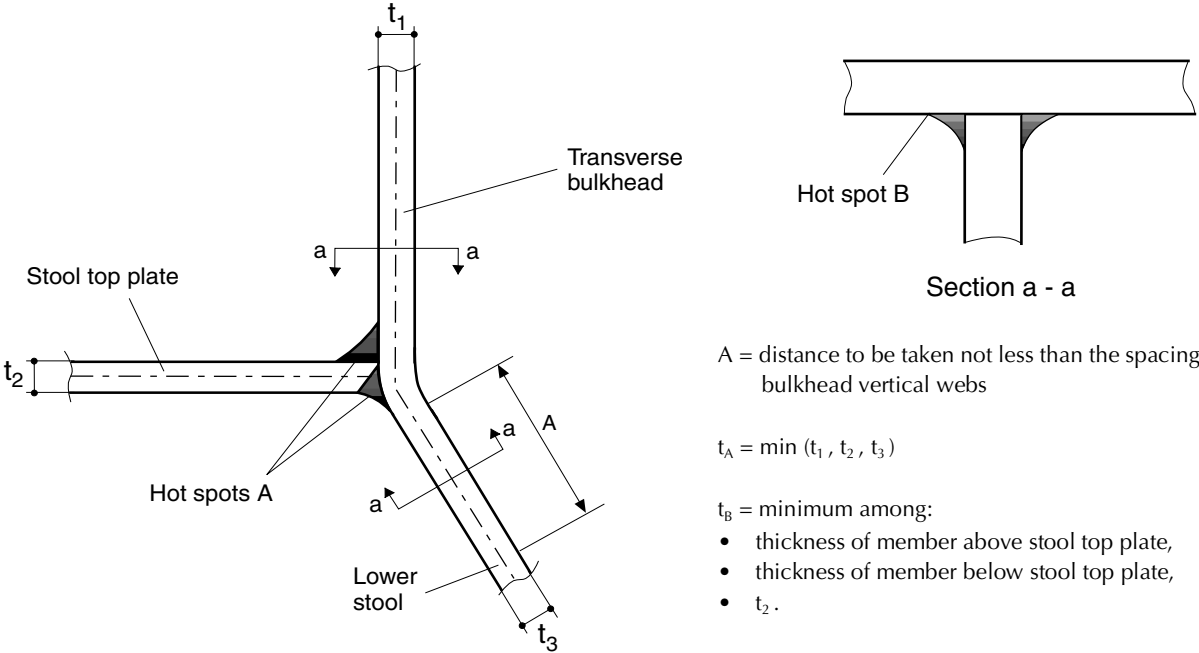
AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads - Radiused construction	Sheet 5.4
 <p>A = distance to be taken not less than the spacing of bulkhead vertical webs</p> $t_A = \min(t_1, t_2, t_3)$ <p>t_B = minimum among:</p> <ul style="list-style-type: none"> • thickness of member above stool top plate, • thickness of member below stool top plate, • t_2. 		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of members above and below stool top plate to be not less than that of bulkhead vertical webs. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment (median lines) between stool top plate and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between members above and below stool top plate $\leq t_B / 3$. • If not full penetration welding of stool top plate to bulkhead, the weld preparation is to be indicated on the approved drawings. • Butt welds between transverse bulkhead and stool side plating at a distance greater than 500 mm from the stool top plate. 	<p>NDE:</p> <p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, • UE 35% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears. 	
<p>WELDING AND MATERIALS:</p> <ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - welding sequence against the risk of lamellar tearing in the bulkhead plate is recommended, - weld finishing well faired to the bulkhead plating and stool side plating. • Material requirements: <ul style="list-style-type: none"> - the radiused construction may be accepted provided that the folding procedure is submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation. - material properties of: <ul style="list-style-type: none"> the stool top plate, the portion A of the stool side plating, to be not less than those of the transverse bulkhead plating. 		

Table 43 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

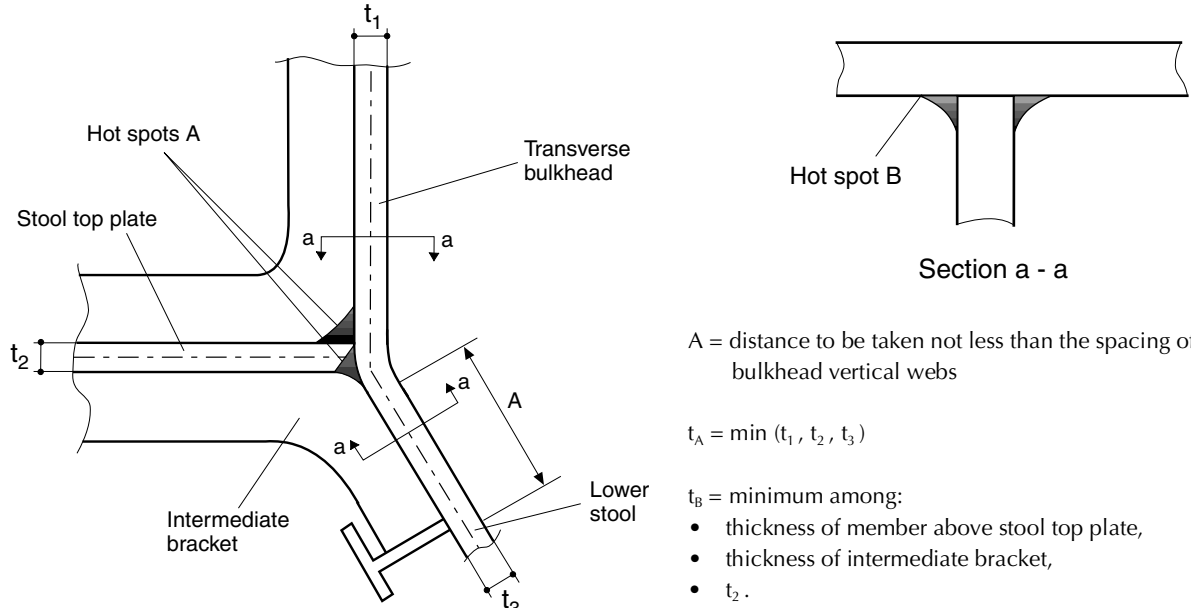
AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads in way of intermediate brackets - Radiused construction	Sheet 5.5
 <p>A = distance to be taken not less than the spacing of bulkhead vertical webs</p> $t_A = \min(t_1, t_2, t_3)$ <p>t_B = minimum among:</p> <ul style="list-style-type: none"> • thickness of member above stool top plate, • thickness of intermediate bracket, • t_2. 		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of intermediate brackets and members above stool top plate to be not less than that of bulkhead vertical webs. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment (median lines) between stool top plate and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between intermediate bracket and member below stool top plate $\leq t_B / 3$. • If not full penetration welding of stool top plate to bulkhead, the weld preparation is to be indicated on the approved drawings. • Intermediate brackets to be fitted in place and welded after the welding of the joint between the stool top plate and the bulkhead plating. • Butt welds between transverse bulkhead and stool side plating at a distance greater than 500 mm from the stool top plate. 	<p>NDE:</p> <p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, • UE 35% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears. 	
<p>WELDING AND MATERIALS:</p> <ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - brackets to be connected with continuous fillet welding to plating and stiffeners, - welding sequence against the risk of lamellar tearing in the bulkhead plate is recommended, - weld finishing well faired to the bulkhead plating and stool side plating. • Material requirements: <ul style="list-style-type: none"> - the radiused construction may be accepted provided that the folding procedure is submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation. - material properties of: <ul style="list-style-type: none"> the stool top plate, the portion A of the stool side plating, <p>to be not less than those of the transverse bulkhead plating.</p>		

Table 44 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

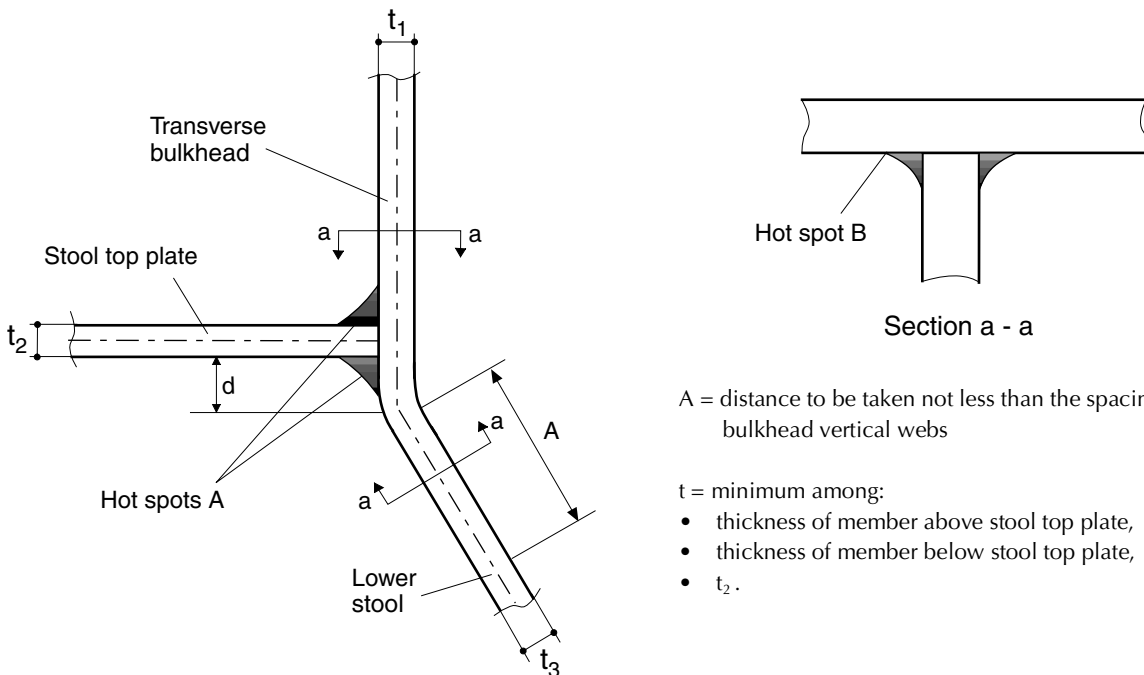
AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads - Radiused construction	Sheet 5.6
 <p>A = distance to be taken not less than the spacing of bulkhead vertical webs</p> <p>t = minimum among:</p> <ul style="list-style-type: none"> • thickness of member above stool top plate, • thickness of member below stool top plate, • t_2. 		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • $d \leq 40$ mm. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of members above and below stool top plate to be not less than that of bulkhead vertical webs. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment (median lines) between members above and below stool top plate $\leq t / 3$. • If not full penetration welding of stool top plate to bulkhead, the weld preparation is to be indicated on the approved drawings. • Butt welds between transverse bulkhead and stool side plating at a distance greater than 500 mm from the stool top plate. 	<p>NDE:</p> <p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, • UE 35% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears. 	
<p>WELDING AND MATERIALS:</p> <p>Material requirements:</p> <ul style="list-style-type: none"> - where stool top plate is welded within the bent area, folding procedure to be submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation, - material properties of: <ul style="list-style-type: none"> the stool top plate, the portion A of the stool side plating, to be not less than those of the transverse bulkhead plating. 		

Table 45 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

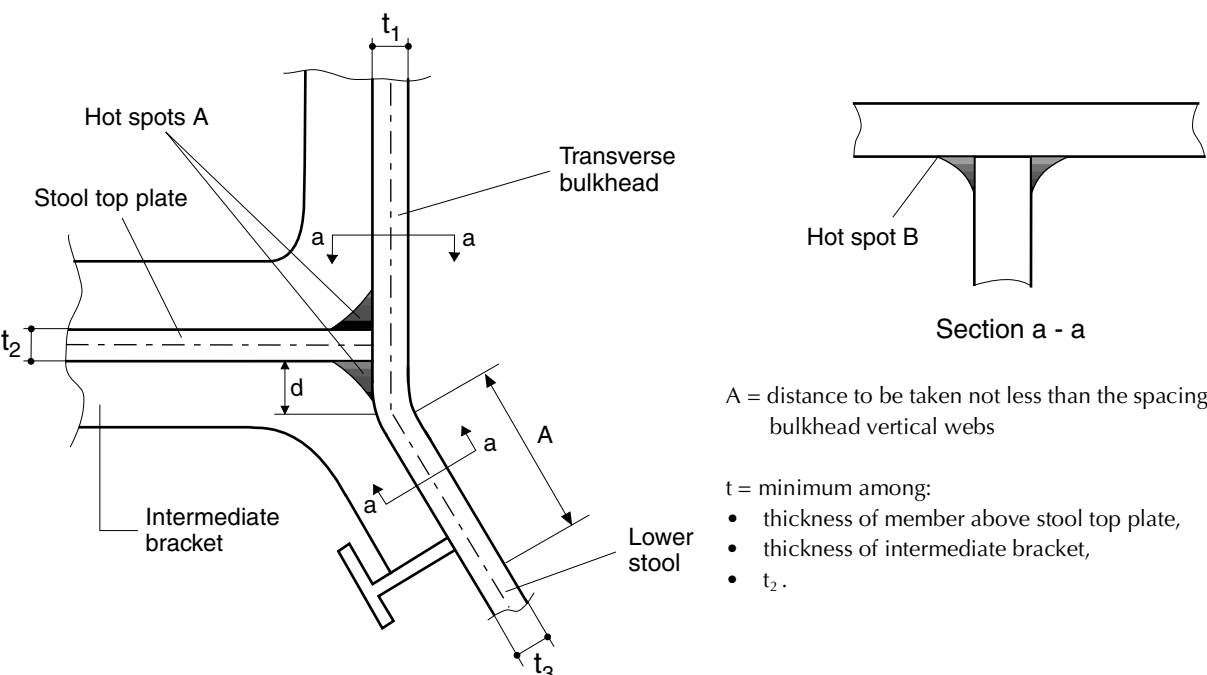
AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with plane bulkheads in way of intermediate brackets - Radiused construction	Sheet 5.7
 <p>A = distance to be taken not less than the spacing of bulkhead vertical webs</p> <p>t = minimum among:</p> <ul style="list-style-type: none"> • thickness of member above stool top plate, • thickness of intermediate bracket, • t_2. 		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • $d \leq 40$ mm. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of intermediate brackets and members above stool top plate to be not less than that of bulkhead vertical webs. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment (median lines) between intermediate bracket and member above stool top plate $\leq t / 3$. • If not full penetration welding of stool top plate to bulkhead, the weld preparation is to be indicated on the approved drawings. • Intermediate brackets to be fitted in place and welded after the welding of the joint between the stool top plate and the bulkhead plating. • Butt welds between transverse bulkhead and stool side plating at a distance greater than 500 mm from the stool top plate. 	<p>NDE:</p> <p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, • UE 35% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears. 	
<p>WELDING AND MATERIALS:</p> <p>Material requirements:</p> <ul style="list-style-type: none"> - where stool top plate is welded within the bent area, folding procedure to be submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation, - material properties of: <ul style="list-style-type: none"> the stool top plate, the portion A of the stool side plating, to be not less than those of the transverse bulkhead plating. 		

Table 46 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

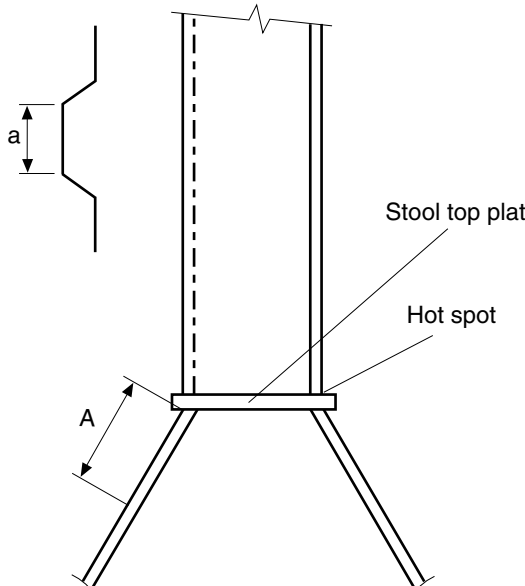
AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads	Sheet 5.8
 <p style="text-align: right;"> $A \geq a$ t_f = corrugation flange thickness, t_T = stool top plate thickness, t_S = stool side plating thickness, $t = \min(t_f, t_T, t_S)$. </p>		
SCANTLINGS:	FATIGUE:	
<ul style="list-style-type: none"> • $t_T \geq t_f$. • $t_S \geq t_f$ in portion A. 	Fatigue check to be carried out according to NI611.	
CONSTRUCTION:	NDE:	
<ul style="list-style-type: none"> • Misalignment (median lines) between corrugation flanges and stool side plating $\leq t / 3$. • Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq 1,5 t_f$. • Corrugation radius according to Ch 13, Sec 1, [3.2.1]. 	The following NDE are required: <ul style="list-style-type: none"> • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears. 	
WELDING AND MATERIALS:		
<ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - corrugations and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings); root gap to be checked along the production, - welding sequence against the risk of lamellar tearing, - start and stop welding away from the locations of corrugation bents, - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating. • Material requirements: <ul style="list-style-type: none"> - the stool top plate is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding, - material properties of: <ul style="list-style-type: none"> the stool top plate, the portion A of the stool side plating, to be not less than those of the corrugation flanges. 		

Table 47 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

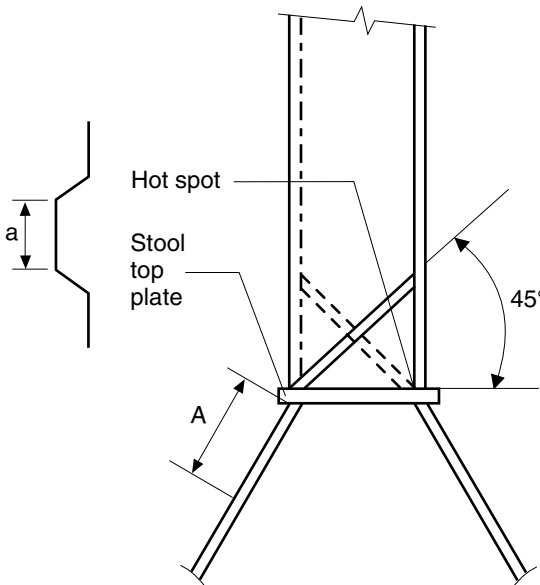
AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Shedder plates 45°	Sheet 5.9
<div style="display: flex; align-items: center;"> <div style="flex: 1;">  </div> <div style="flex: 1; padding-left: 20px;"> <p>$A \geq a$</p> <p>t_F = corrugation flange thickness, t_T = stool top plate thickness, t_S = stool side plating thickness, t_{SH} = shedder plate thickness,</p> <p>$t_A = \min(t_F, t_T, t_S)$</p> <p>$t_B = \min(t_{SH}, t_T, t_S)$.</p> </div> </div>		
SCANTLINGS:	FATIGUE:	
<ul style="list-style-type: none"> • $t_T \geq t_F$. • $t_S \geq t_F$ in portion A. • $t_{SH} \geq 0,75 t_F$. 	Fatigue check to be carried out according to N1611.	
CONSTRUCTION:	NDE:	
<ul style="list-style-type: none"> • Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between lower edge of shedder plates and stool side plating $\leq t_B / 3$. • Knuckled shedder plates are to be avoided. • Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq 1,5 t_F$. • Corrugation radius according to Ch 13, Sec 1, [3.2.1]. • In ships with service notations combination carrier, oil tanker or chemical tanker, closed spaces to be filled with suitable compound compatible with the products carried. 	The following NDE are required: <ul style="list-style-type: none"> • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears. 	
WELDING AND MATERIALS:		
<ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - corrugations and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings); root gap to be checked along the production, - shedder plates to be connected with one side penetration, or equivalent, to corrugations and stool top plate, - welding sequence against the risk of lamellar tearing, - start and stop welding away from the locations of corrugation bents, - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating. • Material requirements: <ul style="list-style-type: none"> - the stool top plate is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding, - material properties of: <ul style="list-style-type: none"> the shedder plates, the stool top plate, the portion A of the stool side plating, to be not less than those of the corrugation flanges. 		

Table 48 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

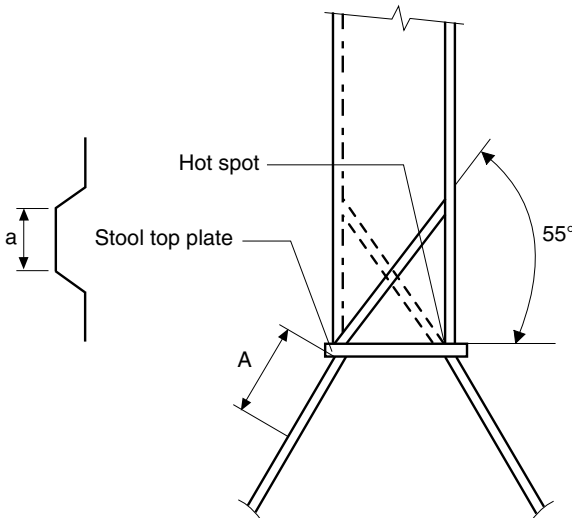
AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Shedder plates 55°	Sheet 5.10
<div style="display: flex; align-items: center;">  <div style="margin-left: 20px;"> <p>$A \geq a$</p> <p>t_F = corrugation flange thickness, t_T = stool top plate thickness, t_S = stool side plating thickness, t_{SH} = shedder plate thickness,</p> <p>$t_A = \min(t_F, t_T, t_S)$,</p> <p>$t_B = \min(t_{SH}, t_T, t_S)$.</p> </div> </div>		
SCANTLINGS:	FATIGUE:	
<ul style="list-style-type: none"> $t_T \geq t_F$. $t_S \geq t_F$ in portion A. $t_{SH} \geq 0,75 t_F$. 	Fatigue check to be carried out according to N1611.	
CONSTRUCTION:	NDE:	
<ul style="list-style-type: none"> Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$. Misalignment (median lines) between lower edge of shedder plates and stool side plating $\leq t_B / 3$. Knuckled shedder plates are to be avoided. Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq 1,5 t_F$. Corrugation radius according to Ch 13, Sec 1, [3.2.1]. In ships with service notations combination carrier, oil tanker or chemical tanker, closed spaces to be filled with suitable compound compatible with the products carried. 	<p>The following NDE are required:</p> <ul style="list-style-type: none"> VE 100%, UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears. 	
WELDING AND MATERIALS:		
<ul style="list-style-type: none"> Welding requirements: <ul style="list-style-type: none"> corrugations and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings); root gap to be checked along the production, shedder plates to be connected with one side penetration, or equivalent, to corrugations and stool top plate, welding sequence against the risk of lamellar tearing, start and stop welding away from the locations of corrugation bents, weld finishing well faired to the stool top plate, corrugation flanges and stool side plating. Material requirements: <ul style="list-style-type: none"> the stool top plate is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding, material properties of: <ul style="list-style-type: none"> the shedder plates, the stool top plate, the portion A of the stool side plating, <p>to be not less than those of the corrugation flanges.</p>		

Table 49 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

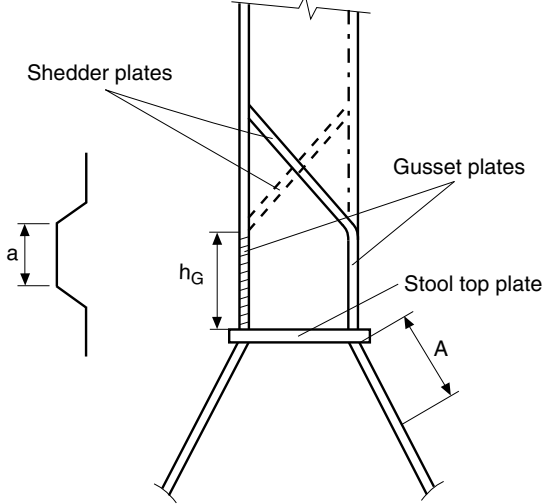
AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Gusset and shedder plates	Sheet 5.11
<div style="display: flex; align-items: center;"> <div style="flex: 1;">  </div> <div style="flex: 2; padding-left: 20px;"> <p>$A \geq a$</p> <p>t_F = corrugation flange thickness, t_T = stool top plate thickness, t_S = stool side plating thickness, t_G = gusset plate thickness, t_{SH} = shedder plate thickness,</p> <p>$t_A = \min(t_F, t_T, t_S)$,</p> <p>$t_B = \min(t_G, t_T, t_S)$.</p> </div> </div>		
SCANTLINGS:		FATIGUE:
<ul style="list-style-type: none"> • $t_T \geq t_F$. • $t_G \geq t_F$. • $t_S \geq t_F$ in portion A. • $t_{SH} \geq 0,75 t_F$. • $h_G \geq a / 2$. 		Fatigue check not required.
CONSTRUCTION:		NDE:
<ul style="list-style-type: none"> • Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between lower edge of gusset plates and stool side plating $\leq t_B / 3$. • Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq 1,5 t_F$. • Corrugation radius according to Ch 13, Sec 1, [3.2.1]. • In ships with service notations combination carrier, oil tanker or chemical tanker, closed spaces to be filled with suitable compound compatible with the products carried. 		<p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.
WELDING AND MATERIALS:		
<ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - corrugations and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings); root gap to be checked along the production, - gusset plates generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings) and with one side penetration, or equivalent, to corrugations and shedder plates, - shedder plates to be connected with one side penetration, or equivalent, to corrugations and gusset plates, - welding sequence against the risk of lamellar tearing, - start and stop welding away from the locations of corrugation bents, - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating. • Material requirements: <ul style="list-style-type: none"> - the stool top plate is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding, - material properties of: <ul style="list-style-type: none"> the gusset plates, the shedder plates, the stool top plate, the portion A of the stool side plating, <p style="padding-left: 20px;">to be not less than those of the corrugation flanges.</p>		

Table 50 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

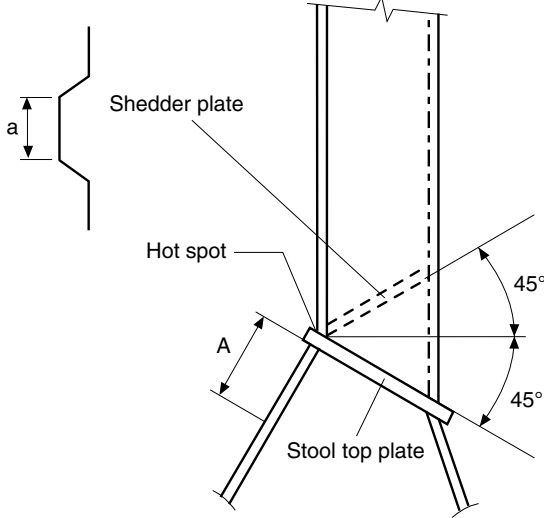
AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Sloping stool top plate	Sheet 5.12
<div style="display: flex; align-items: center;"> <div style="flex: 1;">  </div> <div style="flex: 1; padding-left: 20px;"> <p>$A \geq a$</p> <p>t_F = corrugation flange thickness, t_T = stool top plate thickness, t_S = stool side plating thickness, t_{SH} = shedder plate thickness,</p> <p>$t_A = \min(t_F, t_T, t_S).$</p> <p>$t_B = \min(t_{SH}, t_T, t_S).$</p> </div> </div>		
SCANTLINGS:	FATIGUE:	
<ul style="list-style-type: none"> • $t_T \geq t_F.$ • $t_S \geq t_F$ in portion A. • $t_{SH} \geq 0,75 t_F.$ 	Fatigue check to be carried out according to N1611.	
CONSTRUCTION:	NDE:	
<ul style="list-style-type: none"> • Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3.$ • Misalignment (median lines) between lower edge of shedder plates and stool side plating $\leq t_B / 3.$ • Knuckled shedder plates are to be avoided. • Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq 1,5 t_F.$ • Corrugation radius according to Ch 13, Sec 1, [3.2.1]. • In ships with service notations combination carrier, oil tanker or chemical tanker, closed spaces to be filled with suitable compound compatible with the products carried. 	The following NDE are required: <ul style="list-style-type: none"> • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears. 	
WELDING AND MATERIALS:		
<ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - corrugations and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings); root gap to be checked along the production, - shedder plates to be connected with one side penetration, or equivalent, to corrugations and stool top plate, - welding sequence against the risk of lamellar tearing - start and stop welding away from the locations of corrugation bents, - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating. • Material requirements: <ul style="list-style-type: none"> - the stool top plate is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding, - material properties of: <ul style="list-style-type: none"> the shedder plates, the stool top plate, the portion A of the stool side plating, to be not less than those of the corrugation flanges.		

Table 51 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

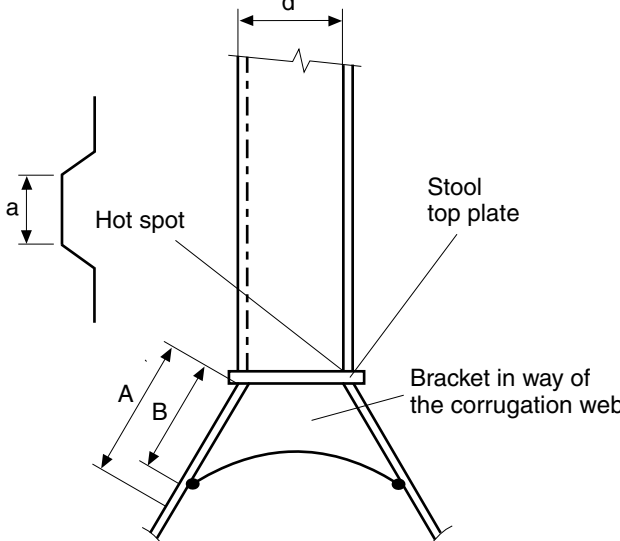
AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Brackets below stool top plate	Sheet 5.13
<div style="display: flex; justify-content: space-between; align-items: flex-start;"> <div style="width: 45%;">  </div> <div style="width: 50%;"> <p>$A \geq a$, $B =$ bracket dimension.</p> <p>$t_F =$ corrugation flange thickness, $t_W =$ corrugation web thickness, $t_T =$ stool top plate thickness, $t_S =$ stool side plating thickness, $t_B =$ bracket thickness,</p> <p>$t_A = \min(t_F, t_T, t_S)$.</p> <p>$t_B = \min(t_W, t_T, t_S)$.</p> </div> </div>		
SCANTLINGS:	FATIGUE:	
<ul style="list-style-type: none"> • $t_T \geq t_F$ • $t_S \geq t_F$ in portion A • $t_B \geq t_W$ • $B \geq d$ 	Fatigue check to be carried out according to Nl611.	
CONSTRUCTION:	NDE:	
<ul style="list-style-type: none"> • Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between corrugation webs and brackets below stool top plate $\leq t_B / 3$. • Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq 1,5 t_F$. • Corrugation radius according to Ch 13, Sec 1, [3.2.1]. 	The following NDE are required: <ul style="list-style-type: none"> • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears. 	
WELDING AND MATERIALS:		
<ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - corrugations and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings); root gap to be checked along the production, - welding sequence against the risk of lamellar tearing, - start and stop welding away from the locations of corrugation bents, - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating. • Material requirements: <ul style="list-style-type: none"> - the stool top plate is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding, - material properties of: <ul style="list-style-type: none"> the stool top plate, the portion A of the stool side plating, to be not less than those of the corrugation flanges.		

Table 52 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

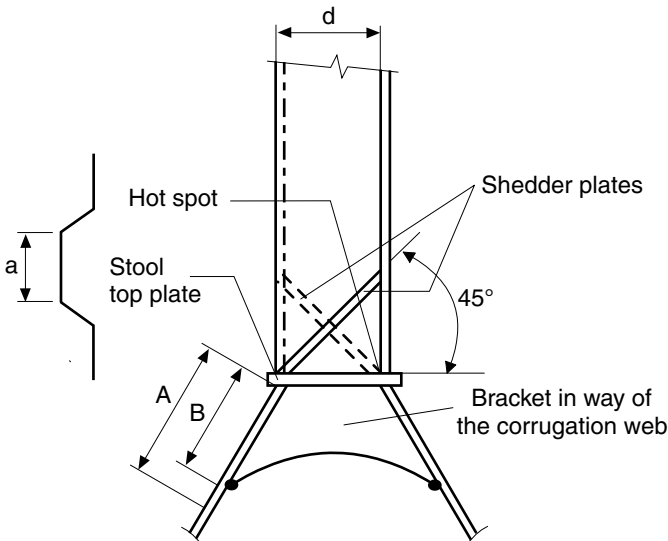
AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Shedder plates 45° and brackets below stool top plate	Sheet 5.14
 <p style="margin-left: 590px;"> $A \geq a,$ $B = \text{bracket dimension.}$ $t_F = \text{corrugation flange thickness,}$ $t_W = \text{corrugation web thickness,}$ $t_T = \text{stool top plate thickness,}$ $t_S = \text{stool side plating thickness,}$ $t_{SH} = \text{shedder plate thickness,}$ $t_B = \text{bracket thickness,}$ $t_A = \min(t_F, t_T, t_S)$ $t_B = \min(t_{SH}, t_T, t_S)$ $t_C = \min(t_W, t_T, t_B).$ </p>		
SCANTLINGS:		FATIGUE:
<ul style="list-style-type: none"> • $t_T \geq t_F$ • $t_{SH} \geq 0,75 t_F$ • $t_S \geq t_F$ in portion A • $t_B \geq t_W$ • $B \geq d$ 		Fatigue check to be carried out according to NI611.
CONSTRUCTION:		NDE:
<ul style="list-style-type: none"> • Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between lower edge of shedder plates and stool side plating $\leq t_B / 3$. • Misalignment (median lines) between corrugation webs and brackets below stool top plate $\leq t_C / 3$. • Knuckled shedder plates are to be avoided. • Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq 1,5 t_F$. • Corrugation radius according to Ch 13, Sec 1, [3.2.1]. • In ships with service notations combination carrier, oil tanker or chemical tanker, closed spaces to be filled with suitable compound compatible with the products carried. 		The following NDE are required: <ul style="list-style-type: none"> • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.
WELDING AND MATERIALS:		
<ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - corrugations and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings); root gap to be checked along the production, - shedder plates to be connected with one side penetration, or equivalent, to corrugations and stool top plate, - welding sequence against the risk of lamellar tearing - start and stop welding away from the locations of corrugation bents, - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating. • Material requirements: <ul style="list-style-type: none"> - the stool top plate is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding, - material properties of: <ul style="list-style-type: none"> the shedder plates, the stool top plate, the portion A of the stool side plating, to be not less than those of the corrugation flanges. 		

Table 53 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

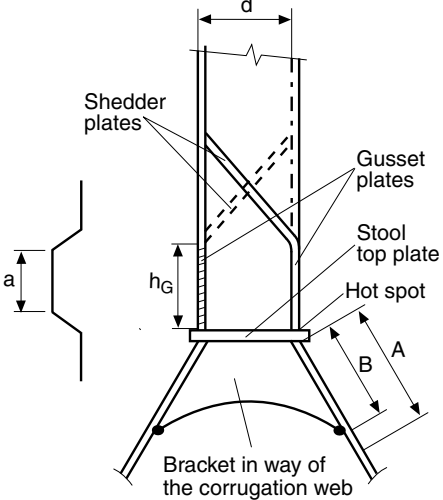
AREA 5: Lower part of transverse bulkheads with lower stools	Connection of lower stools with corrugated bulkheads - Gusset and shedder plates and brackets below stool top plate	Sheet 5.15
 <div style="margin-left: 500px;"> <p>$A \geq a$, $B =$ bracket dimension.</p> <p>$t_F =$ corrugation flange thickness, $t_W =$ corrugation web thickness, $t_T =$ stool top plate thickness, $t_S =$ stool side plating thickness, $t_G =$ gusset plate thickness, $t_{SH} =$ shedder plate thickness, $t_B =$ bracket thickness,</p> <p>$t_A = \min(t_F, t_T, t_S)$ $t_B = \min(t_G, t_T, t_S)$ $t_C = \min(t_W, t_T, t_B)$.</p> </div>		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • $t_T \geq t_F$ • $t_S \geq t_F$ in portion A • $t_G \geq t_F$ • $t_{SH} \geq 0,75 t_F$ • $t_B \geq t_W$ • $h_G \geq a / 2$ • $B \geq d$ 		<p>FATIGUE:</p> <p>Fatigue check not required.</p>
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment (median lines) between corrugation flanges and stool side plating $\leq t_A / 3$. • Misalignment (median lines) between lower edge of gusset plates and stool side plating $\leq t_B / 3$. • Misalignment (median lines) between corrugation webs and brackets below stool top plate $\leq t_C / 3$. • Distance from the edge of the stool top plate to the surface of the corrugation flanges $\geq 1,5 t_F$. • Corrugation radius according to Ch 13, Sec 1, [3.2.1]. • In ships with service notations combination carrier, oil tanker or chemical tanker, closed spaces to be filled with suitable compound compatible with the products carried. 		<p>NDE:</p> <p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.
<p>WELDING AND MATERIALS:</p> <ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - corrugations and stool side plating generally to be connected with full penetration welding to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings); root gap to be checked along the production, - gusset plates generally to be connected with full penetration to stool top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings) and with one side penetration, or equivalent, to corrugations and shedder plates, - shedder plates to be connected with one side penetration, or equivalent, to corrugations and gusset plates, - welding sequence against the risk of lamellar tearing - start and stop welding away from the locations of corrugation bents, - weld finishing well faired to the stool top plate, corrugation flanges and stool side plating. • Material requirements: <ul style="list-style-type: none"> - the stool top plate is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding, - material properties of: <ul style="list-style-type: none"> the gusset plates, the shedder plates, the stool top plate, the portion A of the stool side plating, <p>to be not less than those of the corrugation flanges.</p>		

Table 54 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

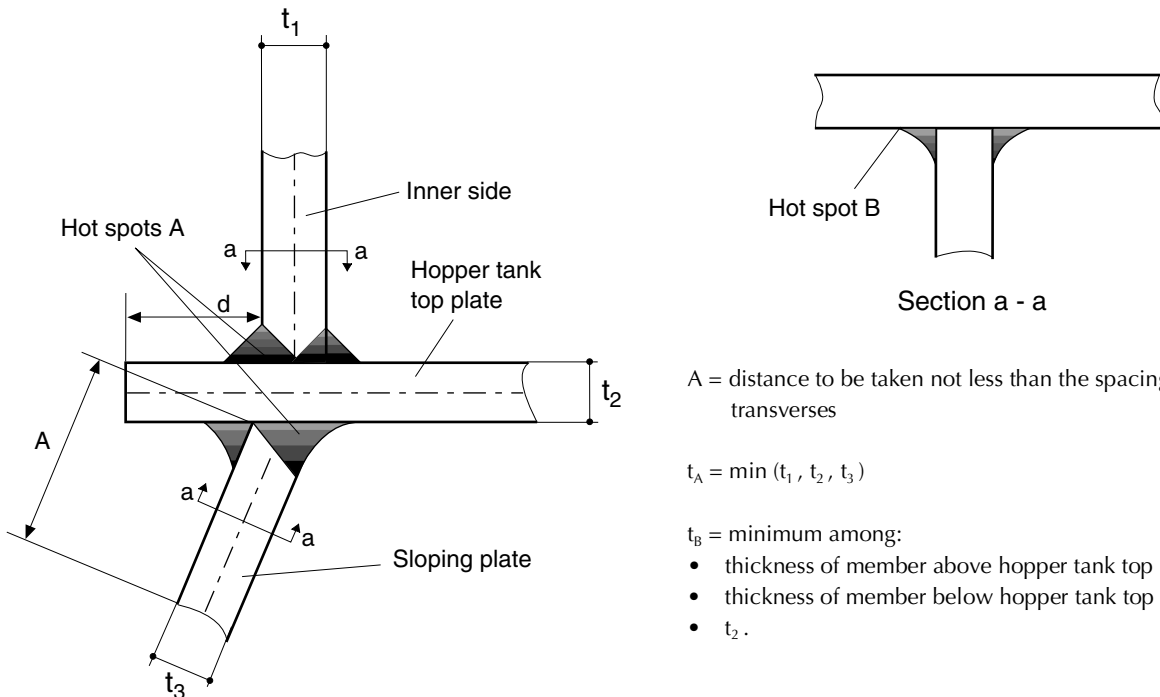
AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side	Sheet 6.1
 <p>A = distance to be taken not less than the spacing of side transverses</p> <p>$t_A = \min(t_1, t_2, t_3)$</p> <p>$t_B = \text{minimum among:}$</p> <ul style="list-style-type: none"> • thickness of member above hopper tank top plate, • thickness of member below hopper tank top plate, • t_2. 		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • $d \geq 1,5 t_1$. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of members above and below hopper tank top plate to be not less than that of side transverses. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment (median lines) between inner side plating and hopper tank sloping plate $\leq t_A / 3$. • Misalignment (median lines) between members above and below hopper tank top plate $\leq t_B / 3$. 	<p>NDE:</p> <p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, • UE 25% of full penetration welds for absence of cracks, lack of penetration and lamellar tears. 	
<p>WELDING AND MATERIALS:</p> <ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - inner side and hopper tank sloping plate generally to be connected with full penetration welding to hopper tank top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings), - approval of the procedure on a sample representative of the actual conditions foreseen in production, - welding sequence against the risk of lamellar tearing is recommended in case Z material is not adopted for the hopper tank top plate, - weld finishing well faired to the hopper tank top plate. • Material requirements: <ul style="list-style-type: none"> - the hopper tank top plate is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding, - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating. 		

Table 55 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

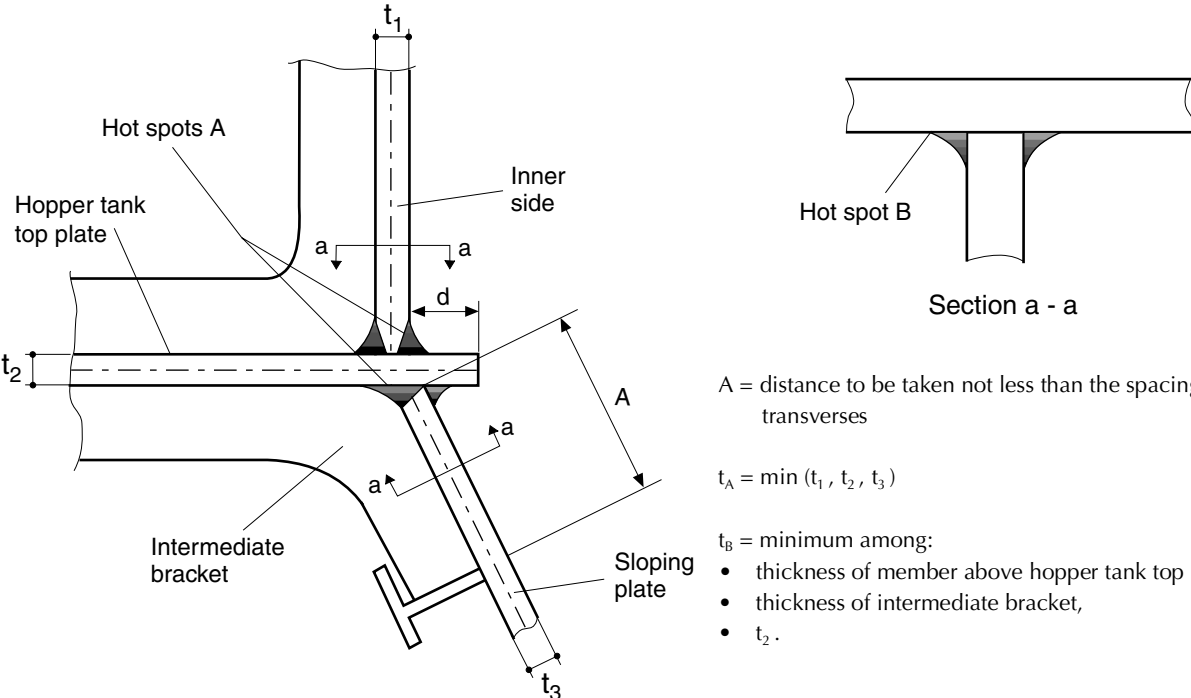
AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side in way of intermediate brackets	Sheet 6.2
 <p> $A =$ distance to be taken not less than the spacing of side transverses $t_A = \min(t_1, t_2, t_3)$ $t_B =$ minimum among: <ul style="list-style-type: none"> • thickness of member above hopper tank top plate, • thickness of intermediate bracket, • t_2. </p>		
<p>SCANTLING:</p> <ul style="list-style-type: none"> • $d \geq 1,5 t_1$. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of intermediate brackets and members above hopper tank top plate to be not less than that of side transverses. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment (median lines) between inner side plating and hopper tank sloping plate $\leq t_A / 3$. • Misalignment (median lines) between intermediate bracket and member above hopper tank top plate $\leq t_B / 3$. • Intermediate brackets to be fitted in place and welded after the welding of the joint between the hopper tank sloping plate and the hopper tank top plate. 	<p>NDE:</p> <p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, • UE 25% of full penetration welds for absence of cracks, lack of penetration and lamellar tears. 	
<p>WELDING AND MATERIALS:</p> <ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - inner side and hopper tank sloping plate generally to be connected with full penetration welding to hopper tank top plate (if not full penetration welding, the weld preparation is to be indicated on the approved drawings), - brackets to be connected with continuous fillet welding to plating and stiffeners, - approval of the procedure on a sample representative of the actual conditions foreseen in production, - welding sequence against the risk of lamellar tearing is recommended in case Z material is not adopted for the hopper tank top plate, - weld finishing well faired to the hopper tank top plate. • Material requirements: <ul style="list-style-type: none"> - the hopper tank top plate is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding, - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating. 		

Table 56 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

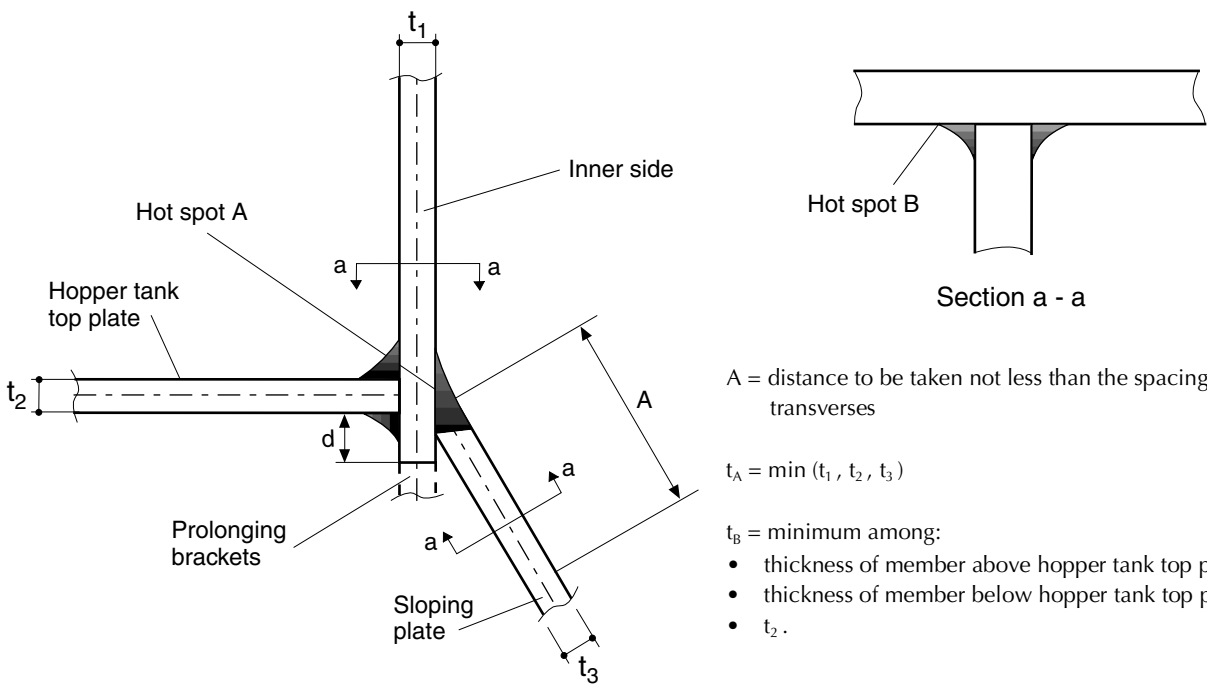
AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side - Prolonging brackets	Sheet 6.3
 <p> $A =$ distance to be taken not less than the spacing of side transverses $t_A = \min (t_1, t_2, t_3)$ $t_B =$ minimum among: <ul style="list-style-type: none"> • thickness of member above hopper tank top plate, • thickness of member below hopper tank top plate, • t_2. </p>		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • $d \geq 50$ mm. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of prolonging brackets $\geq t_1$. • Thickness of members above and below hopper tank top plate to be not less than that of side transverses. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment (median lines) between hopper tank top plate and hopper tank sloping plate $\leq t_A / 3$. • Misalignment (median lines) between members above and below hopper tank top plate $\leq t_B / 3$. 	<p>NDE:</p> <p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, • UE 25% of full penetration welds for absence of cracks, lack of penetration and lamellar tears. 	
<p>WELDING AND MATERIALS:</p> <ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - hopper tank sloping plate to be connected with full penetration welding to the inner side plating. Root gap to be checked along the production steps as appropriate, - prolonging brackets to be connected with full penetration welding to inner side plating, - full penetration weld of hopper tank sloping plate to inner side plating to be welded first, - welding sequence against lamellar tearing in the inner side plating is recommended. • Material requirements: <ul style="list-style-type: none"> - the lower strake of inner side plating is recommended to be of Z grade steel. If a steel of such a quality is not adopted, 100% UE of the strake in way of the weld is required prior to and after welding, - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating, - material properties of prolonging brackets to be not less than those of the inner side plating. 		

Table 57 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

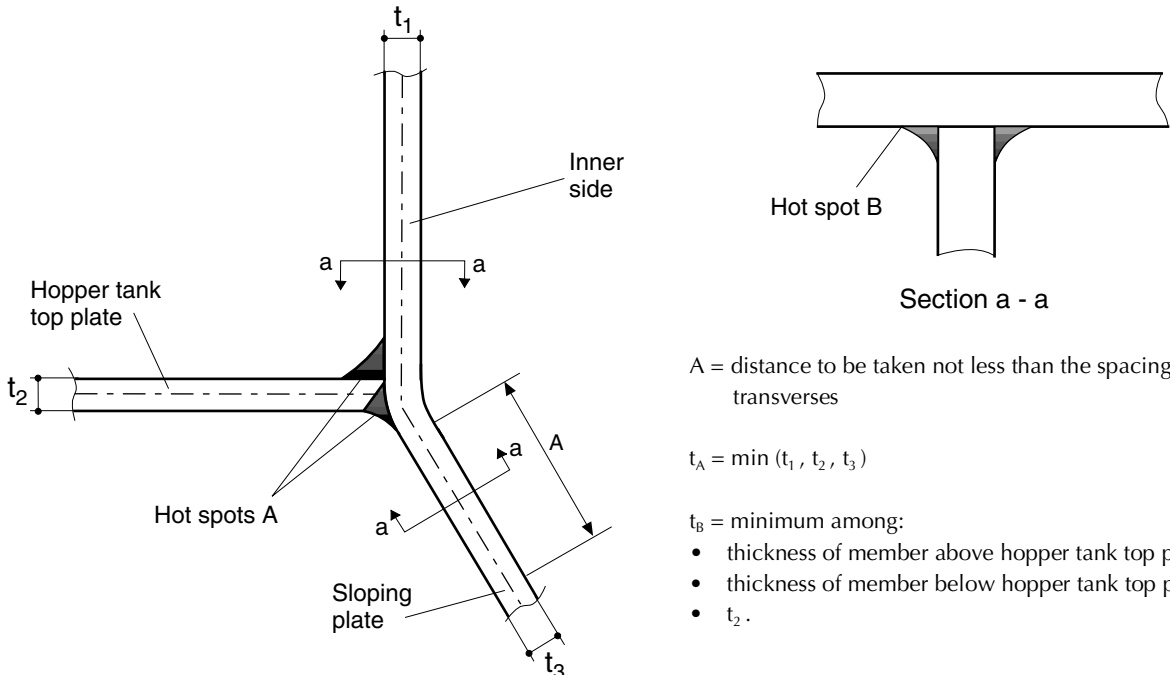
AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side - Radiused construction	Sheet 6.4
 <p>Section a - a</p> <p>A = distance to be taken not less than the spacing of side transverses</p> <p>$t_A = \min(t_1, t_2, t_3)$</p> <p>$t_B =$ minimum among:</p> <ul style="list-style-type: none"> • thickness of member above hopper tank top plate, • thickness of member below hopper tank top plate, • t_2. 		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of members above and below hopper tank top plate to be not less than that of side transverses. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment (median lines) between hopper tank top plate and hopper tank sloping plate $\leq t_A / 3$. • Misalignment (median lines) between members above and below hopper tank top plate $\leq t_B / 3$. • If not full penetration welding of hopper tank top plate to inner side, the weld preparation is to be indicated on the approved drawings. • Butt welds between inner side and hopper tank sloping plate at a distance greater than 500 mm from the hopper tank top plate. 	<p>NDE:</p> <p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, • UE 25% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears. 	
<p>WELDING AND MATERIALS:</p> <ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - welding sequence against the risk of lamellar tearing in the inner side plate is recommended, - weld finishing well faired to the inner side plating and hopper tank sloping plate. • Material requirements: <ul style="list-style-type: none"> - the radiused construction may be accepted provided that the folding procedure is submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation, - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating. 		

Table 58 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

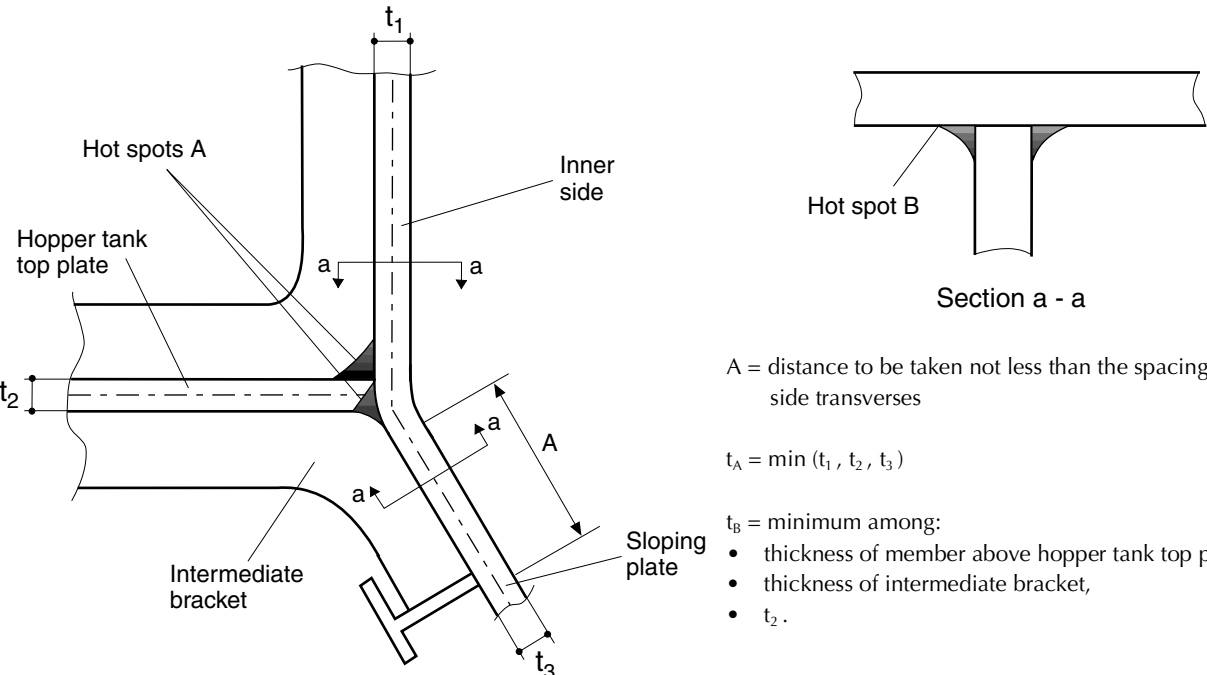
AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side in way of intermediate brackets - Radiused construction	Sheet 6.5
 <p>Section a - a</p> <p>A = distance to be taken not less than the spacing of side transverses</p> <p>$t_A = \min(t_1, t_2, t_3)$</p> <p>$t_B =$ minimum among:</p> <ul style="list-style-type: none"> • thickness of member above hopper tank top plate, • thickness of intermediate bracket, • t_2. 		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of intermediate brackets and members above hopper tank top plate to be not less than that of side transverses. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment (median lines) between hopper tank top plate and hopper tank sloping plate $\leq t_A / 3$. • Misalignment (median lines) between intermediate bracket and member above hopper tank top plate $\leq t_B / 3$. • If not full penetration welding of hopper tank top plate to inner side, the weld preparation is to be indicated on the approved drawings. • Intermediate brackets to be fitted in place and welded after the welding of the joint between the hopper tank top plate and the inner side plating. • Butt welds between inner side and hopper tank sloping plate at a distance greater than 500 mm from the hopper tank top plate. 	<p>NDE:</p> <p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, • UE 25% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears. 	
<p>WELDING AND MATERIALS:</p> <ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - brackets to be connected with continuous fillet welding to plating and stiffeners, - welding sequence against the risk of lamellar tearing in the inner side plate is recommended, - weld finishing well faired to the inner side plating and hopper tank sloping plate. • Material requirements: <ul style="list-style-type: none"> - the radiused construction may be accepted provided that the folding procedure is submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation, - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating. 		

Table 59 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

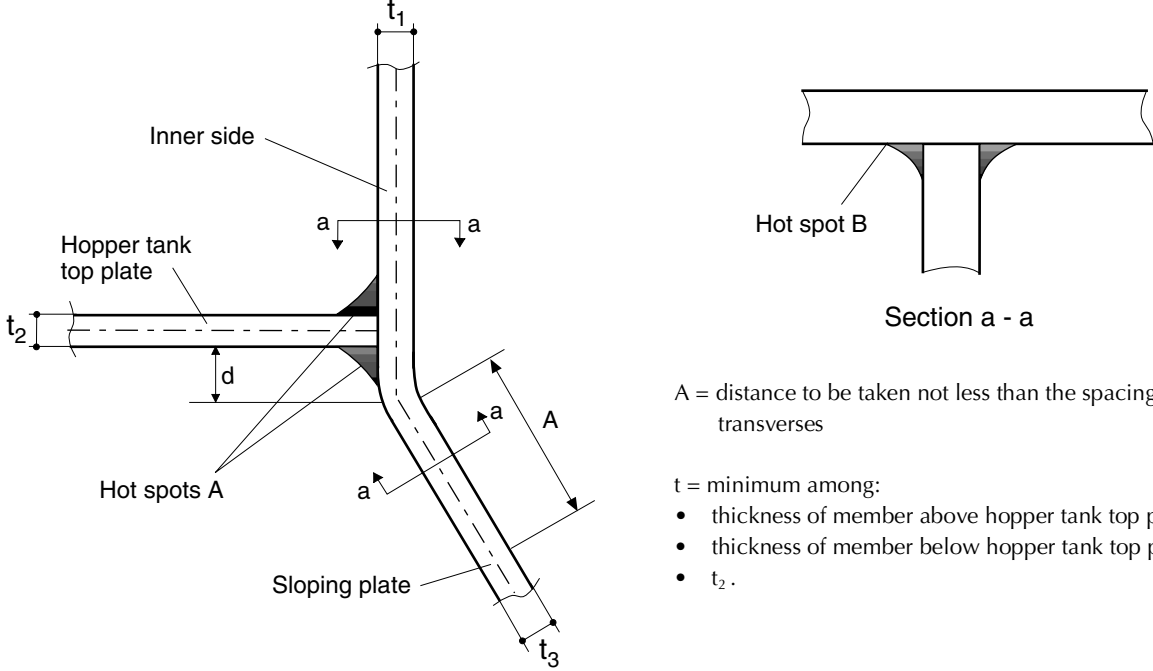
AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side - Radiused construction	Sheet 6.6
 <p>A = distance to be taken not less than the spacing of side transverses</p> <p>t = minimum among:</p> <ul style="list-style-type: none"> • thickness of member above hopper tank top plate, • thickness of member below hopper tank top plate, • t_2. 		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • $d \leq 40$ mm. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of members above and below hopper tank top plate to be not less than that of side transverses. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment (median lines) between members above and below hopper tank top plate $\leq t / 3$. • If not full penetration welding of hopper tank top plate to inner side, the weld preparation is to be indicated on the approved drawings. • Butt welds between inner side and hopper tank sloping plate at a distance greater than 500 mm from the hopper tank top plate. 	<p>NDE:</p> <p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, • UE 25% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears. 	
<p>WELDING AND MATERIALS:</p> <p>Material requirements:</p> <ul style="list-style-type: none"> - where hopper tank top plate is welded within the bent area, folding procedure to be submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation, - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating. 		

Table 60 : OIL TANKERS, CHEMICAL TANKERS, BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

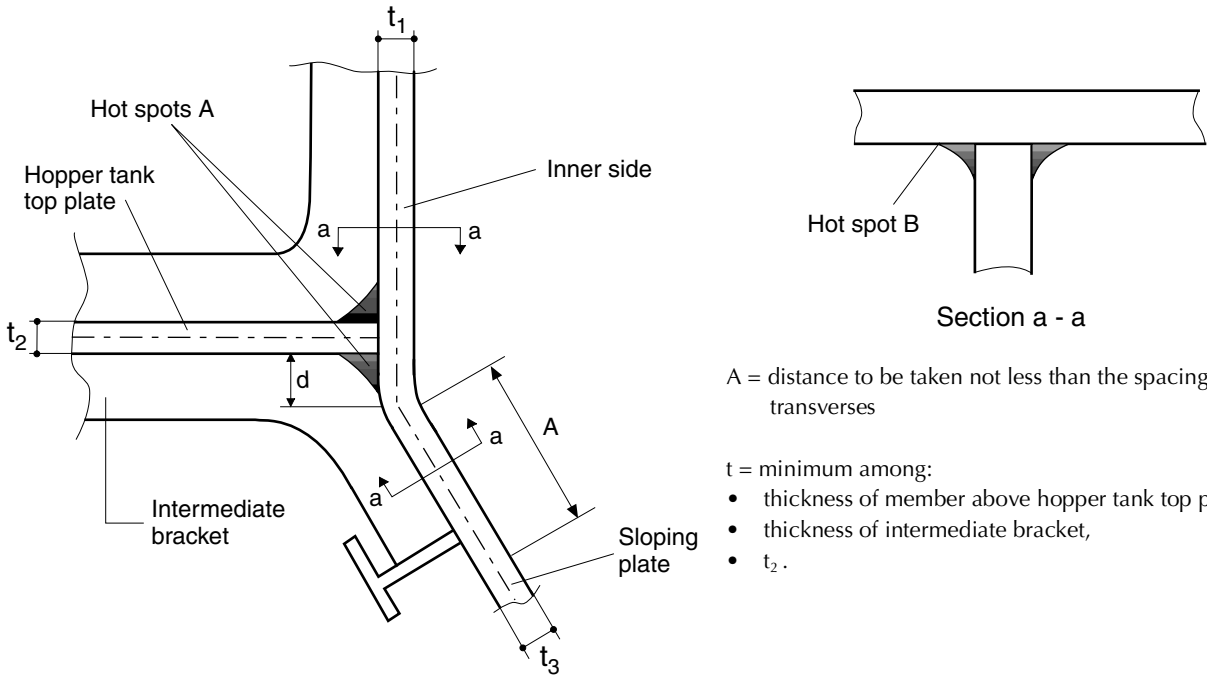
AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side in way of intermediate brackets - Radiused construction	Sheet 6.7
 <p>Section a - a</p> <p>A = distance to be taken not less than the spacing of side transverses</p> <p>t = minimum among:</p> <ul style="list-style-type: none"> • thickness of member above hopper tank top plate, • thickness of intermediate bracket, • t_2. 		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • Inner radius of the bent plate to be between 3,5 and 5 times the thickness of the bent plate and to be indicated in the approved plan. • $d \leq 40$ mm. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of intermediate brackets and members above hopper tank top plate to be not less than that of side transverses. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment (median lines) between intermediate bracket and member above hopper tank top plate $\leq t / 3$. • If not full penetration welding of hopper tank top plate to inner side, the weld preparation is to be indicated on the approved drawings. • Intermediate brackets to be fitted in place and welded after the welding of the joint between the hopper tank top plate and the inner side plating. • Butt welds between inner side and hopper tank sloping plate at a distance greater than 500 mm from the hopper tank top plate. 	<p>NDE:</p> <p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, • UE 25% of full penetration welds, if any, for absence of cracks, lack of penetration and lamellar tears. 	
<p>WELDING AND MATERIALS:</p>		
<p>Material requirements:</p> <ul style="list-style-type: none"> - where hopper tank top plate is welded within the bent area, folding procedure to be submitted to the Society for review, with evidence given that the mechanical properties and, in particular, the impact properties are not deteriorated by the folding operation, - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating. 		

Table 61 : LIQUEFIED GAS CARRIERS

AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side	Sheet 6.8
<p>A = distance to be taken not less than the spacing of side transverses</p> <p>$t_A = \min(t_1, t_2, t_3)$</p> <p>$t_B =$ minimum among:</p> <ul style="list-style-type: none"> • thickness of member above hopper tank top plate, • thickness of member below hopper tank top plate, • t_2. 		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • $d \geq 1,5 t_1$. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of members above and below hopper tank top plate to be not less than that of side transverses. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment (median lines) between inner side plating and hopper tank sloping plate $\leq t_A / 3$, max 6 mm. • Misalignment (median lines) between members above and below hopper tank top plate $\leq t_B / 3$, max 6 mm. 	<p>NDE:</p> <p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears. 	
<p>WELDING AND MATERIALS:</p> <ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - inner side and hopper tank sloping plate to be connected with full penetration welding to hopper tank top plate, except in way of void spaces where partial penetration may be accepted, - approval of the procedure on a sample representative of the actual conditions foreseen in production, - welding sequence against the risk of lamellar tearing is recommended in case Z material is not adopted for the hopper tank top plate, - weld finishing well faired to the hopper tank top plate. • Material requirements: <ul style="list-style-type: none"> - the hopper tank top plate is to be of Z grade steel. In particular cases, grade E/EH low temperature steel may be accepted by the Society provided that the results of 100% UE of the plate in way of the weld, carried out prior to and after welding, are submitted for review, - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating. 		

Table 62 : LIQUEFIED GAS CARRIERS

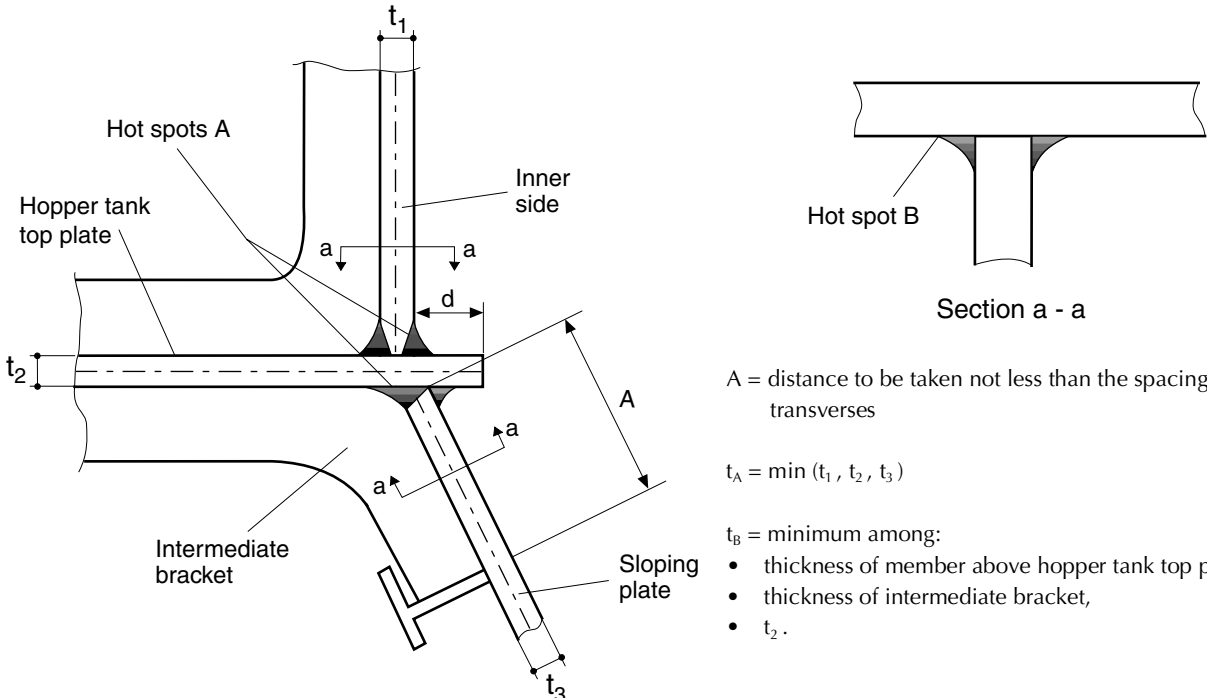
AREA 6: Lower part of inner side	Connection of hopper tank sloping plates with inner side in way of intermediate brackets	Sheet 6.9
 <p>Section a - a</p> <p>A = distance to be taken not less than the spacing of side transverses</p> <p>$t_A = \min(t_1, t_2, t_3)$</p> <p>$t_B$ = minimum among:</p> <ul style="list-style-type: none"> • thickness of member above hopper tank top plate, • thickness of intermediate bracket, • t_2. 		
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • $d \geq 1,5 t_1$. • $t_2 \geq t_1$. • $t_3 \geq t_1$ in portion A. • Thickness of intermediate brackets and members above hopper tank top plate to be not less than that of side transverses. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611.</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Misalignment (median lines) between inner side plating and hopper tank sloping plate $\leq t_A / 3$, max 6 mm. • Misalignment (median lines) between intermediate bracket and member above hopper tank top plate $\leq t_B / 3$, max 6 mm. • Intermediate brackets to be fitted in place and welded after the welding of the joint between the hopper tank sloping plate and the hopper tank top plate. 	<p>NDE:</p> <p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, • UE 35% of full penetration welds for absence of cracks, lack of penetration and lamellar tears. 	
<p>WELDING AND MATERIALS:</p> <ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - inner side and hopper tank sloping plate to be connected with full penetration welding to hopper tank top plate, except in way of void spaces where partial penetration may be accepted, - brackets to be connected with continuous fillet welding to plating and stiffeners, - approval of the procedure on a sample representative of the actual conditions foreseen in production, - welding sequence against the risk of lamellar tearing is recommended in case Z material is not adopted for the hopper tank top plate, - weld finishing well faired to the hopper tank top plate. • Material requirements: <ul style="list-style-type: none"> - the hopper tank top plate is to be of Z grade steel. In particular cases, grade E/EH low temperature steel may be accepted by the Society provided that the results of 100% UE of the plate in way of the weld, carried out prior to and after welding, are submitted for review, - material properties of the portion A of the hopper tank sloping plate to be not less than those of the inner side plating. 		

Table 63 : BULK CARRIERS

AREA 7: Side frames	Connection of side frames with hopper and topside tanks - Symmetric face plate frame with integral brackets	Sheet 7.1
<p>t_w = fitted thickness, in mm, of side frame web b_f = bracket flange width, in mm</p> <p>$t_{w,min} = (7,0 + 0,03 L_1)$ mm t_f = bracket flange thickness, in mm.</p>		
SCANTLINGS:		FATIGUE:
<ul style="list-style-type: none"> • Thickness of lower bracket, in mm, $\geq \max(t_w, t_{w,min} + 2)$. • Thickness of upper bracket, in mm, $\geq \max(t_w, t_{w,min})$. • Section modulus of the frame with the upper or lower bracket, at the locations shown in the sketch, to be not less than twice the section modulus required for the frame mid-span area. • Dimensions of lower and upper brackets to be not less than those shown in the sketch. • Structural continuity with the upper and lower end connections of side frames is to be ensured within hopper tanks and upper wing tanks by connecting brackets. • Frame flange to be curved (not knuckled) at the connection with the end brackets, $r \geq 0,4 b_f^2 / t_f$. • Ends of flange to be sniped. 		Fatigue check not required.
CONSTRUCTION:	NDE:	
<ul style="list-style-type: none"> • Misalignment between frame web and the connecting brackets inside hopper tank and upper wing tank $\leq t / 3$, where t is the minimum thickness among those of the connected elements. • Soft toe: tapering of frame flange at ends: thickness 1:3, width 1:5. 	The following NDE are required: <ul style="list-style-type: none"> • VE 100%, with particular care for fillet shape and undercuts on the plating at the soft toes, • ME or dye penetrant depending on the results of VE. 	
WELDING AND MATERIALS:		
Welding requirements: <ul style="list-style-type: none"> - frames and brackets to be connected with continuous fillet welding to side plating, hopper tank and upper wing tank plating, with throat thickness to be not less than: <ul style="list-style-type: none"> 0,45 t in "zone a", 0,40 t in "zone b", where t is the minimum thickness between those of the two connected elements, - welding sequence to minimise restraints at the frame butt joints, i.e.: <ul style="list-style-type: none"> leaving about 200 mm unwelded, each side of butt joint, of the connections between frame web and side plating and between frame web and flange, performing the frame butt joints, completing the fillet welding, - turn the fillet weld all around the end of integral brackets and scallops giving an elongated shape, well faired to the plating, - avoid burned notches at the scallops, if existing, in way of frame flange butt joints; if scallops not adopted, care to be taken to avoid end defects at web butt joints. 		

Table 64 : BULK CARRIERS

AREA 7: Side frames	Connection of side frames with hopper and topside tanks - Non symmetric face plate frame with separate brackets	Sheet 7.2
<p> t_w = fitted thickness, in mm, of side frame web $t_{w,min} = (7,0 + 0,03 L_1)$ mm b_f = bracket flange width, in mm t_f = bracket flange thickness, in mm. </p>		<p>This solution is permitted only for ships less than 190 m in length with side frames built in normal strength steel.</p>
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> Thickness of lower bracket, in mm, $\geq \max(t_w, t_{w,min} + 2)$. Thickness of upper bracket, in mm, $\geq \max(t_w, t_{w,min})$. Section modulus of the frame with the upper or lower bracket, at the locations shown in the sketch, to be not less than twice the section modulus required for the frame mid-span area. Dimensions of lower and upper brackets to be not less than those shown in the sketch. Structural continuity with the upper and lower end connections of side frames is to be ensured within hopper tanks and upper wing tanks by connecting brackets. Ends of flange to be sniped. $z \leq 50$ mm. 		<p>FATIGUE:</p> <p>Fatigue check not required.</p>
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> Misalignment between frame brackets and the connecting brackets inside hopper tank and upper wing tank $\leq t / 3$, where t is the minimum thickness among those of the connected elements. Bracket overlap: $\geq 1,5 d$, in mm. Soft toe: tapering of frame flange at ends: thickness 1:3, width 1:5. 	<p>NDE:</p> <p>The following NDE are required:</p> <ul style="list-style-type: none"> VE 100%, with particular care for fillet shape and undercuts on the plating at the soft toes, ME or dye penetrant depending on the results of VE. 	
<p>WELDING AND MATERIALS:</p> <p>Welding requirements:</p> <ul style="list-style-type: none"> frames and brackets to be connected with continuous fillet welding to side plating, hopper tank and upper wing tank plating, with throat thickness to be not less than: <ul style="list-style-type: none"> 0,45 t in "zone a", 0,40 t in "zone b", where t is the minimum thickness between those of the two connected elements, brackets to be connected with continuous fillet welding to frames, with throat thickness to be not less than half thickness of brackets, welding procedure of frame butt joint, if any, to be approved with particular care for the welding of the bulbs and of the corner in case of L sections, welding sequence to minimise restraints at the frame butt joints, i.e.: <ul style="list-style-type: none"> leaving about 200 mm unwelded, each side of butt joint, of the connections between frame web and side plating and between frame web and flange, performing the frame butt joints, completing the fillet welding, turn the fillet weld all around the end of integral brackets and scallops giving an elongated shape, well faired to the plating, avoid burned notches at fillet welds of overlapped joints and at scallops. 		

Table 65 : BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS

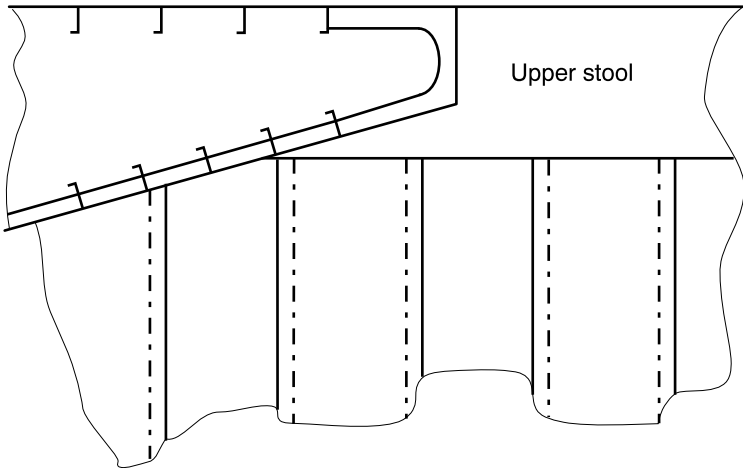
AREA 8: Topside tanks	Connection of transverse corrugated bulkheads with topside tanks	Sheet 8.1
 <p style="text-align: center;">t = minimum thickness among those of the connected elements.</p>		
SCANTLINGS:	FATIGUE:	
<p>A transverse web or an intercostal reinforcement is to be fitted inside the topside tank in line with the flanges of corrugation and the upper stool side plating. Its arrangement is to be indicated in the approved plan.</p>	<p>Fatigue check not required.</p>	
CONSTRUCTION:	NDE:	
<p>Misalignments between:</p> <ul style="list-style-type: none"> - transverse web or intercostal reinforcement fitted inside the upper wing tank and corrugation flanges, - transverse web or intercostal reinforcement fitted inside the upper wing tank and upper stool side plating, - upper stool side plating and corrugation flanges, <p>are to be $\leq t / 3$.</p>	<p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, with particular care for fillet shape and undercuts on the plating, • UE 100% of full penetration weld for absence of cracks, lack of penetration and lamellar tears. 	
WELDING AND MATERIALS:		
<p>Welding requirements:</p> <ul style="list-style-type: none"> - bulkhead plating to be connected with continuous fillet welding to topside plating and upper stool plating, full penetration weld is recommended in way of corner of vertical and inclined plating of upper wing tank, - throat thickness = $0,45 t$, where t is the minimum thickness between those of the two connected elements, - gap at T joint reduced to the minimum, - welding sequence to minimise restraints. 		

Table 66 : BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS, CONTAINER SHIPS

AREA 9: Hatch corners	Deck plating in way of hatch corners	Sheet 9.1
<p>SCANTLINGS:</p> <ul style="list-style-type: none"> • Insert plates with circular profiles in general to be fitted in way of corners of hatchways located within the cargo area. The radius of circular corners to be in accordance with Ch 4, Sec 5, [6.4.1] • Insert plates not required in way of corners of hatchways located in the above positions, where corners have an elliptical or parabolic profile according to Ch 4, Sec 5, [6.4.2]. • Where insert plates are required, their thickness to be defined according to Ch 4, Sec 5, [6.4.3] and their extension to be such that d_1, d_2, d_3 and $d_4 \geq s$, s being the ordinary frame spacing. 	<p>FATIGUE:</p> <p>Fatigue check to be carried out according to NI611</p>	
<p>CONSTRUCTION:</p> <ul style="list-style-type: none"> • Corners of insert plates to be rounded, unless corresponding to joints of deck strakes. • Insert cut edges to be carefully executed. 	<p>NDE:</p> <p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, • RE / UE in areas indicated in the sketch. 	
<p>WELDING AND MATERIALS:</p> <ul style="list-style-type: none"> • Welding requirements: <ul style="list-style-type: none"> - welds recommended to be continued on auxiliary pieces temporarily fitted at the free end of each joint, to be cut away; the joint ends are to be carefully ground. • Materials requirements: <ul style="list-style-type: none"> - insert plate material of same or higher quality than the adjacent deck plating, depending on the insert thickness according to Ch 4, Sec 1, [2]. 		

Table 67 : BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS, CONTAINER SHIPS

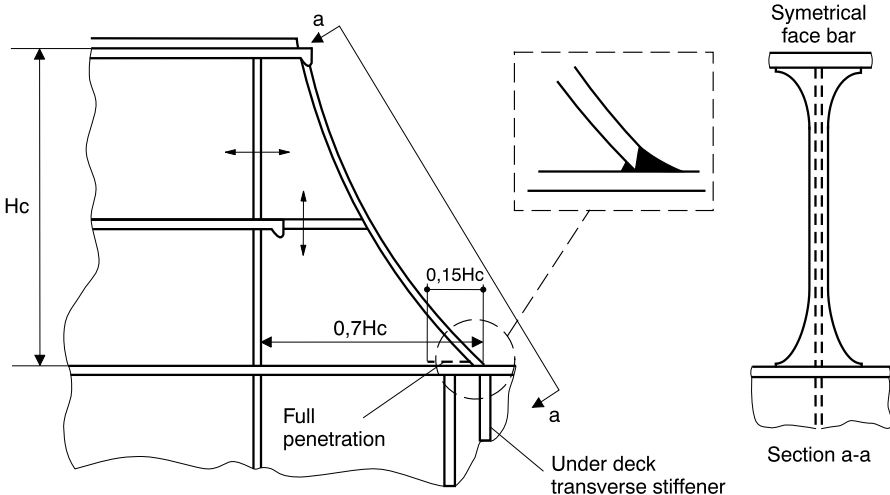
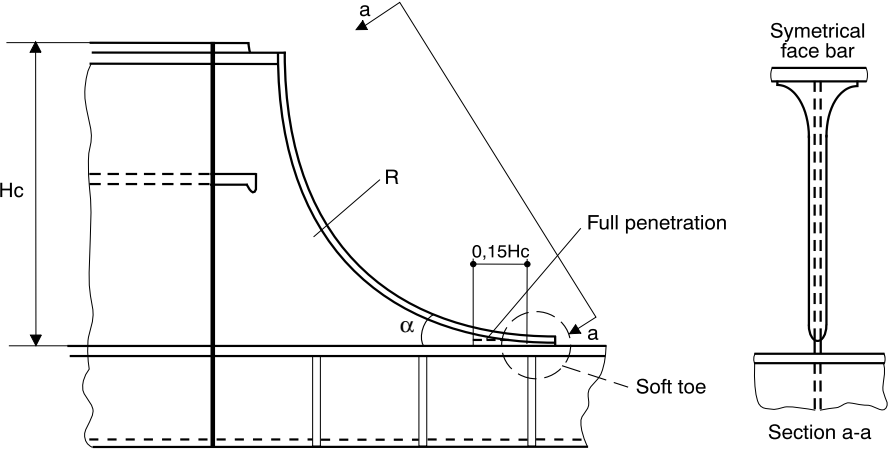
AREA 9: Hatch corners	Ends of longitudinal hatch coamings - Bracket welded to deck plating	Sheet 9.2
 <p>t_A = minimum among:</p> <ul style="list-style-type: none"> - thickness of bracket flange at lower end, - deck plating thickness, - under deck transverse stiffener web thickness, <p>t_B = minimum among:</p> <ul style="list-style-type: none"> - bracket web thickness, - deck plating thickness, - thickness of the under deck longitudinal member. 		
SCANTLINGS:	FATIGUE:	
An additional under deck transverse stiffener is to be fitted in way of termination bracket toe, where the toe is clear of normal stiffener.	Fatigue check to be carried out according to NI611	
CONSTRUCTION:	NDE:	
<ul style="list-style-type: none"> • Misalignment between bracket flange and under deck transverse stiffener $\leq t_A / 3$. • Misalignment between bracket and under deck longitudinal $\leq t_B / 3$. 	<p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, with particular care for the weld shape and undercuts on deck plating at the bracket flange connection, • UE 100% of full penetration welds for absence of cracks, lack of penetration and lamellar tears. 	
WELDING AND MATERIALS:		
<p>Welding requirements:</p> <ul style="list-style-type: none"> - bracket flange to be connected with full penetration welding to deck plating, with half V bevel and weld shape elongated on deck plating (see sketch), - ends of bracket webs to be connected with full penetration welding to deck plating for the extension shown in the sketch, with half X bevel, - under deck transverse stiffener to be connected with full penetration welding to deck plating in way of the bracket flange, - care is to be taken to ensure soundness of the crossing welds at the bracket toe, if the case, adopting small scallop to be closed by welding. 		

Table 68 : BULK CARRIERS, ORE CARRIERS, COMBINATION CARRIERS, CONTAINER SHIPS

AREA 9: Hatch corners	Ends of longitudinal hatch coamings - Bracket sniped at deck plating	Sheet 9.3
		<p>t = minimum among:</p> <ul style="list-style-type: none"> - bracket web thickness, - deck plating thickness, - thickness of the under deck longitudinal member.
SCANTLINGS:	FATIGUE:	
<p>$R \geq 500 \text{ mm.}$ $\alpha \leq 30^\circ.$</p>	<p>Fatigue check to be carried out according to NI611</p>	
CONSTRUCTION:	NDE:	
<ul style="list-style-type: none"> • Misalignment between bracket and under deck longitudinal $\leq t_B / 3.$ • Soft toe: tapering of bracket flange at ends: thickness 1:3, width 1:5. 	<p>The following NDE are required:</p> <ul style="list-style-type: none"> • VE 100%, with particular care for the weld shape and undercuts on deck plating, • UE 100% of full penetration welds for absence of cracks, lack of penetration and lamellar tears. 	
WELDING AND MATERIALS:		
<p>Welding requirements:</p> <ul style="list-style-type: none"> - ends of bracket webs to be connected with full penetration welding to deck plating for the extension shown in the sketch, with half X bevel. 		



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