RULES FOR CLASSIFICATION OF

Ships

PART 3 CHAPTER 2

NEWBUILDINGS
HULL AND EQUIPMENT – MAIN CLASS

Hull Structural Design, Ships with Length Less than 100 metres

JULY 2011

DET NORSKE VERITAS AS

FOREWORD

DET NORSKE VERITAS (DNV) is an autonomous and independent foundation with the objectives of safeguarding life, property and the environment, at sea and onshore. DNV undertakes classification, certification, and other verification and consultancy services relating to quality of ships, offshore units and installations, and onshore industries worldwide, and carries out research in relation to these functions.

The Rules lay down technical and procedural requirements related to obtaining and retaining a Class Certificate. It is used as a contractual document and includes both requirements and acceptance criteria.

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CHANGES

General

The present edition of the rules includes additions and amendments approved by the Executive Committee as of June 2011 and supersedes the January 2011 edition of the same chapter.

The rule changes come into force as indicated below.

Text affected by the main rule changes is highlighted in red colour in the electronic pdf version. However, where the changes involve a whole chapter, section or sub-section, only the title may be in red colour.

This chapter is valid until superseded by a revised chapter.

Main changes coming into force 1 July 2011

- **General**

Slenderness coefficient (g) for web of stiffeners has been amended as follows:

— 75 for flanged profile webs (changed from 65 to 75)
— 41 for bulb profiles (added)
— 22 for flat bar profiles (changed from 20 to 22).

- **Sec.5 Bottom Structures:**

— Items C503, C602 and C803 have been amended.

- **Sec.6 Side Structures:**

— Item C302 has been amended.

- **Sec.7 Deck Structures:**

— Item C302 has been amended.

- **Sec.8 Bulkhead Structures:**

— Item C202 has been amended.

Corrections and Clarifications

In addition to the above stated rule requirements, a number of corrections and clarifications have been made in the existing rule text.

CONTENTS

SECTION 1
GENERAL REQUIREMENTS

A. Classification

A 100 Application

101 The rules in this chapter apply to steel hull structures for assignment of the main class for ships with length less than 100 metres.

102 The rules also apply to aluminium structures and wooden decks to the extent that these materials are acceptable as alternative materials.

A 200 Class notations

201 The class notations applicable for the assignment of the main class are described in Pt.1 Ch.2 Sec.1.

202 The following special features notations are specified in this chapter:

ICM	increased corrosion margin (Sec.2 D300)
IB-X	inner bottom strengthened for grab loading and discharging (Sec.5 G400)

B. Definitions

B 100 Symbols

101 The following symbols are used:

L = length of the ship in m defined as the distance on the summer load waterline from the fore side of the stem to the axis of the rudder stock.

L is not to be taken less than 96%, and need not to be taken greater than 97%, of the extreme length on the summer load waterline. For ships with unusual stern and bow arrangement, the length L will be especially considered.

F.P. = the forward perpendicular is the perpendicular at the intersection of the summer load waterline with the fore side of the stem. For ships with unusual bow arrangements the position of the F.P. will be especially considered.

A.P. = the after perpendicular is the perpendicular at the after end of the length L.

Amidships = the middle of the length L.

L_F = length of the ship as defined in the International Convention on Load Lines:

The length shall be taken as 96 per cent of the total length on a waterline at 85 per cent 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. In ships designed with a rake of keel the waterline on which this length is measured shall be parallel to the designed waterline.

B = greatest moulded breadth in m, measured at the summer waterline.

D = moulded depth defined as the vertical distance in m from baseline to moulded deckline at the uppermost continuous deck measured amidships.

D_F = least moulded depth taken as the vertical distance in m from the top of the keel to the top of the freeboard deck beam at side.

In ships having rounded gunwales, the moulded depth shall be measured to the point of intersection of the moulded lines of the deck and side shell plating, the lines extending as though the gunwale 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 shall be measured to a line of reference extending from the lower part of the deck along a line parallel with the raised part.

T = mean moulded summer draught in m.

Δ = moulded displacement in t in salt water (density 1.025 t/m^3) on draught T.

C_B = block coefficient,

$$= \frac{\Delta}{1.025\ L\ B\ T}$$

For barge rigidly connected to a push-tug is to be calculated for the combination barge / push-tug.

C_{BF} = block coefficient as defined in the International Convention of Load Lines:

$$= \frac{\nabla}{L_F\, B\, T_F}$$

∇ = volume of the moulded displacement, excluding bossings, taken at the moulded draught T_F.
T_F = 85% of the least moulded depth.
V = maximum service speed in knots, defined as the greatest speed which the ship is designed to maintain in service at her deepest seagoing draught.
g_0 = standard acceleration of gravity.
= 9.81 m/s^2.
f_1 = material factor depending on material strength group. See Sec.2.
t_k = corrosion addition as given in Sec.2 D200 and D300, as relevant.
x = axis in the ship's longitudinal direction.
y = axis in the ship's athwartships direction.
z = axis in the ship's vertical direction.
E = modulus of elasticity of the material,
= $2.06 \cdot 10^5$ N/mm^2 for steel.
= $0.69 \cdot 10^5$ N/mm^2 for aluminium alloy.
C_W = wave load coefficient given in Sec.4 B200.

B 200 Terms

201 *Moulded deck line, rounded sheer strake, sheer strake,* and *stringer plate* are as defined in Fig.1.

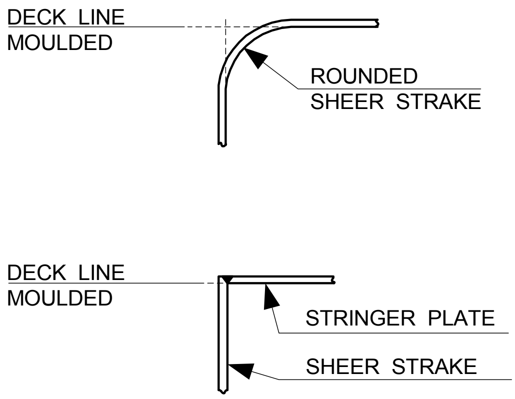

Fig. 1
Deck corners

202 *Freeboard.* The freeboard assigned is the distance measured vertically downwards amidships from the upper edge of the deck line to the upper edge of the related load line.

203 The *freeboard deck* is normally the uppermost complete deck exposed to weather and sea, which has permanent means of closing all openings in the weather part thereof, and below which all openings in the sides of the ship are fitted with permanent means of watertight closing. In a ship having a discontinuous freeboard deck, the lowest line of the exposed deck and the continuation of that line parallel to the upper part of the deck is taken as the freeboard deck. At the option of the owner and subject to the approval of the Administration, a lower deck may be designated as the freeboard deck provided it is a complete and permanent deck continuous in a fore and aft direction at least between the machinery space and peak bulkheads and continuous athwartships. When this lower deck is stepped the lowest line of the deck and the continuation of that line parallel to the upper part of the deck is taken as the freeboard deck. When a lower deck is designated as the freeboard deck, that part of the hull which extends above the freeboard deck is treated as a superstructure so far as concerns the application of the conditions of assignment and the calculation of freeboard. It is from this deck that the freeboard is calculated.

204 *Strength deck* is in general defined as the uppermost continuous deck. A superstructure deck which within 0.4 L amidships has a continuous length equal to or greater than

$$3\left(\frac{B}{2} + H\right) \quad \text{(m)}$$

is to be regarded as the strength deck instead of the covered part of the uppermost continuous deck.

H = height in m between the uppermost continuous deck and the superstructure deck in question.

Another deck may be defined as the strength deck after special consideration of its effectiveness.

205 *Double bottom structure* is defined as shell plating with stiffeners below the top of inner bottom, see Fig.2 and other elements below and including the inner bottom plating. Note that sloping hopper tank side is to be regarded as longitudinal bulkhead.

206 *Single bottom structure* is defined as shell plating with stiffeners and girders below the upper turn of bilge or the top of bottom girders, whichever is the highest.

207 *Side structure* is defined as shell plating with stiffeners and girders between the bottom structure and the uppermost deck at side.

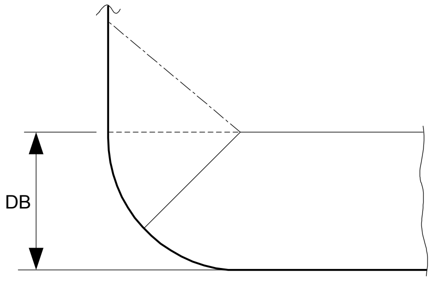

Fig. 2
Double bottom

208 *Deck structure* is defined as deck plating with stiffeners, girders and supporting pillars.

209 *Bulkhead structure* is defined as transverse or longitudinal bulkhead plating with stiffeners and girders.

Watertight bulkhead is a collective term for transverse bulkheads required according to Sec.3 A.

Cargo hold bulkhead is a boundary bulkhead for cargo hold.

Tank bulkhead is a boundary bulkhead in tank for liquid cargo, ballast or bunker.

Wash bulkhead is a perforated or partial bulkhead in tank.

210 *Forepeak and afterpeak* are defined as the areas forward of collision bulkhead and aft of after peak bulkhead, respectively, up to the heights defined in Sec.3 A500.

211 *Superstructure*

a) 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 4 per cent of the breadth (B). A raised quarter deck is regarded as a superstructure.
b) An enclosed superstructure is a superstructure with:

- enclosing bulkheads of efficient construction,
- access openings, if any, in these bulkheads fitted with doors complying with the requirements of Ch.3 Sec.6 B101,
- all other openings in sides or ends of the superstructure fitted with efficient weathertight means of closing.

  A bridge or poop shall not be regarded as enclosed unless access is provided for the crew to reach machinery and other working spaces inside these superstructures by alternative means which are available at all times when bulkhead openings are closed.

c) The height of a superstructure is the least vertical height measured at side from the top of the superstructure deck beams to the top of the freeboard deck beams.
d) The length of a superstructure (S) is the mean length of the part of the superstructure which lies within the length (L).
e) A *long forward superstructure* is defined as an enclosed forward superstructure with length S equal to or greater than 0.25 L.

212 A *flush deck ship* is one which has no superstructure on the freeboard deck.

213 *Girder* is a collective term for primary supporting members, usually supporting stiffeners.

Other terms used are:

- floor (a bottom transverse girder)
- stringer (a horizontal girder).

214 *Stiffener* is a collective term for a secondary supporting member. Other terms used are:

- frame
- bottom longitudinal
- inner bottom longitudinal
- reversed frame (inner bottom transverse stiffener)
- side longitudinal
- beam
- deck longitudinal
- bulkhead longitudinal.

215 *Supporting structure.* Strengthening of the vessel structure, e.g. a deck, in order to accommodate loads and moments from a heavy or loaded object.

216 *Foundation*. A device transferring loads from a heavy or loaded object to the vessel structure.

C. Documentation

C 100 Plans and particulars

101 The following plans are normally to be submitted for approval:

- midship section including class notations, main particulars (L, B, D, T, C_B), maximum service speed V, see B100.
- deck and double bottom plans including openings
- longitudinal section
- shell expansion and framing including openings and extent of flat part of bottom forward, watertight bulkheads including openings
- cargo tank structures
- deep tank structures
- engine room structures including tanks and foundations for heavy machinery components
- afterpeak structures
- forepeak structures
- superstructures and deckhouses including openings
- supporting structure for containers and container securing equipment
- arrangement of cathodic protection in tankers.

Identical or similar structures in various positions should preferably be covered by the same plan. Welding details are to be submitted.

102 Plans and particulars for closing appliances (doors, hatches, windows etc.) to be submitted for approval are specified in Ch.3 Sec.6 A300.

103 A manual containing information on the loading conditions on which the hull scantlings are based, is to be submitted for approval for ships which may experience large still water binding moments, e.g. ships with large ballast capacities forwards ends.

104 The following plans are to be submitted for information:

- general arrangement
- engine room arrangement
- tank arrangement
- capacity plan.

105 For instrumentation and automation, including computer based control and monitoring, see Pt.4 Ch.9 Sec.1.

C 200 Specifications and calculations

201 Information which is necessary for longitudinal strength calculations:

- maximum still water bending moments and shear forces (if different from standard values)
- still water bending moment limits
- mass of light ship and its longitudinal distribution
- cargo capacity in t
- buoyancy data
- cargo, ballast and bunker distribution.

202 Information which is necessary for local strength calculations:

— minimum and maximum ballast draught and corresponding trim
— load on deck, hatch covers and inner bottom
— stowage rate and angle of repose of dry bulk cargo
— maximum density of intended tank contents
— height of air pipes
— mass of heavy machinery components
— design forces for cargo securing and container supports
— any other local loads or forces which will affect the hull structure.

203 Specifications for corrosion prevention systems for water ballast tanks, comprising selection, application and maintenance, are to be submitted as defined in Ch.3 Sec.7.

C 300 Specific purpose documentation

301 For hull equipment and appendages, see Ch.3.

302 For additional class notations see Pt.5 and Pt.6.

303 For installations for which no notation is available or requested, all relevant information or documentation affecting hull structure or ships safety is to be submitted.

SECTION 2
MATERIALS

A. General

A 100 Introduction

101 In this section requirements regarding the application of various structural materials as well as protection methods and materials are given.

A 200 Material certificates

201 Rolled steel and aluminium for hull structures are normally to be supplied with Det Norske Veritas' material certificates in compliance with the requirements given in Pt.2.

202 Requirements for material certificates for forgings, castings and other materials for special parts and equipment are stated in connection with the rule requirements for each individual part.

B. Hull Structure Steel

B 100 General

101 Where subsequent rules for material grade are dependent on plate thickness, the requirements are based on the thickness as built.

Guidance note:

Attention should be drawn to the fact when the hull plating is being gauged at periodical surveys and the wastage considered in relation to reductions allowed by the Society, such allowed reductions are based on the nominal thicknesses required by the rules.

The under thickness tolerances acceptable for classification are to be seen as the lower limit of a total «minus-plus» standard range of tolerances which could be met in normal production with a conventional rolling mill settled to produce in average the nominal thickness.

However, with modern rolling mills it might be possible to produce plates to a narrow band of thickness tolerances which could permit to consistently produce material thinner than the nominal thickness, satisfying at the same time the under thickness tolerance given in Pt.2 Ch.2 Sec.1.

Therefore in such a case the material will reach earlier the minimum thickness allowable at the hull gaugings.

It is upon the shipyard and owner, bearing in mind the above situation, to decide whether, for commercial reasons, stricter under thickness tolerances are to be specified in the individual cases.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

B 200 Material designations and classes

201 Hull materials of various strength groups will be referred to as follows:

— NV-NS denotes normal strength structural steel with yield point not less than 235 N/mm^2
— NV-27 denotes high strength structural steel with yield point not less than 265 N/mm^2
— NV-32 denotes high strength structural steel with yield point not less than 315 N/mm^2
— NV-36 denotes high strength structural steel with yield point not less than 355 N/mm^2
— NV-40 denotes high strength structural steel with yield point not less than 390 N/mm^2.

Normal and high strength steel may also be referred to as NS-steel and HS-steel respectively.

202 Hull materials of various grades will be referred to as follows:

— A, B, D and E denotes NS-steel grades
— AH, DH and EH denotes HS-steel grades. HS-steel may also be referred to by a combination of grade and strength group. In that case the letter H is substituted by one of the numbers indicated in 201, e.g. A 36-steel.

203 The material factor f_1 which may be included in the various formulae for scantlings and in expressions giving allowable stresses, as specified in Sec.3, is dependent on strength group as follows:

— for NV-NS: f_1 = 1.00
— for NV-27: f_1 = 1.08
— for NV-32: f_1 = 1.28
— for NV-36: f_1 = 1.39
— for NV-40: f_1 = 1.47

204 In order to distinguish between the material grade requirements for different hull parts, various material classes are applied as defined in Table B1.

The steel grade is to correspond to the as-built plate thickness when this is greater than the rule requirement.

Table B1 Material classes

Thickness in mm	*Class*			
	I	*II*	*III*	*IV*
t ≤ 15	A/AH	A/AH	A/AH	A/AH
15 < t ≤ 20	A/AH	A/AH	A/AH	B/AH
20 < t ≤ 25	A/AH	A/AH	B/AH	D/DH
25 < t ≤ 30	A/AH	A/AH	D/DH	D/DH
30 < t ≤ 35	A/AH	B/AH	D/DH	E/EH
35 < t ≤ 40	A/AH	B/AH	D/DH	E/EH
40 < t ≤ 50*)	B/AH	D/DH	E/EH	E/EH

*) Plating of Class III or IV and with a thickness between 50 mm < t ≤ 150 mm, shall be of grade E/EH.
For other cases, D/DH (according to Class II) will be minimum quality for thicknesses above 50 mm

B 300 Basic requirements

301 Materials in the various strength members are not to be of lower grade than those corresponding to the material classes and grades specified in Table B2 to Table B3. General requirements are given in Table B2, while additional minimum requirements for ships with ice strengthening in accordance with Pt.5 Ch.1 are given in Table B3.

For strength members not mentioned in Table B2, Class I may be applied.

302 Materials in local strength members are not to be of lower grades than those corresponding to the material class I. However, for heavy foundation plates in engine room, grade A may also be accepted for NS-steel with thickness above 40 mm.

303 Materials in:

— hull equipment and appendages (sternframes and rudders, anchoring and mooring equipment, masts and rigging, crane pedestals etc.) see Ch.3
— structure and equipment related to class notations, see Pt.5 and Pt.6
— hull structures related to installations for which no notation is available or requested, will be considered and notation requirements usually maintained.

Table B2 Material Classes and Grades for ships in general	
Structural member category	*Material class/grade*
SECONDARY: A1. Longitudinal bulkhead strakes, other than that belonging to the Primary category A2. Deck plating exposed to weather, other than that belonging to the Primary or Special category A3. Side plating	— Class II within 0.4L amidships — Grade A/AH outside 0.4L amidships
PRIMARY: B1. Bottom plating, including keel plate B2. Strength deck plating, excluding that belonging to the Special category B3. Continuous longitudinal members above strength deck, excluding hatch coamings B4. Uppermost strake in longitudinal bulkhead B5. Vertical strake (hatch side girder) and uppermost sloped strake in top wing tank	— Class III within 0.4L amidships — Grade A/AH outside 0.4L amidships
SPECIAL: C1. Sheer strake at strength deck *) C2. Stringer plate in strength deck *) C3. Deck strake at longitudinal bulkhead, excluding deck plating in way of inner-skin bulkhead of double-hull ships *)	— Class IV within 0.4L amidships — Class III outside 0.4L amidships — Class II outside 0.6L amidships
C4. Strength deck plating at outboard corners of cargo hatch openings in container carriers and other ships with similar hatch opening configurations	— Class IV within 0.4L amidships — Class III outside 0.4L amidships — Class II outside 0.6L amidships — Min. Class IV within the cargo region
C5. Strength deck plating at corners of cargo hatch openings in bulk carriers, ore carriers combination carriers and other ships with similar hatch opening configurations	— Class IV within 0.6L amidships — Class III within rest of cargo region
C6. Bilge strake in ships with double bottom over the full breadth and length less than 150 m *)	— Class III within 0.6L amidships — Class II outside 0.6L amidships
C7. Bilge strake in other ships *)	— Class IV within 0.4L amidships — Class III outside 0.4L amidships — Class II outside 0.6L amidships
C8. Longitudinal hatch coamings of length greater than 0.15L C9. End brackets and deck house transition of longitudinal cargo hatch coamings	— Class IV within 0.4L amidships — Class III outside 0.4L amidships — Class II outside 0.6L amidships — Not to be less than Grade D/DH
*) Single strakes required to be of Class IV within 0.4L amidships are to have breadths not less than 800 + 5L (mm), need not be greater than 1800 (mm), unless limited by the geometry of the ship's design.	

Table B3 Minimum Material Grades for ships with ice strengthening	
Structural member category	*Material grade*
Shell strakes in way of ice strengthening area for plates	Grade B/AH

(Adapted from IACS UR S6)

B 400 Requirements for low air temperatures

401 In ships intended to operate for longer periods in areas with low air temperatures (i.e. regular service during winter to Arctic or Antarctic water), the materials in exposed structures will be specially considered. Applicable rule requirements are found in Pt.5 Ch.1 Sec.7.

B 500 Material at cross-joints

501 In important structural cross-joints where high tensile stresses are acting perpendicular to the plane of the plate, special consideration will be given to the ability of the plate material to resist lamellar tearing. For a special test, see Pt.2 Ch.2 Sec.1.

C. Alternative Structural Materials

C 100 Aluminium

101 Aluminium alloy for marine use may be applied in superstructures, deckhouses, hatch covers, hatch beams and other local items.

102 In weld zones of rolled or extruded products (heat affected zones) the mechanical properties given for extruded products may in general be used as basis for the scantling requirements.

Note that for the alloy NV-A1MgSil the most unfavourable properties corresponding to -T4 condition are to be used.

103 Welding consumables giving a deposit weld metal with mechanical properties not less than those specified for the weld zones of the parent material are to be chosen.

104 The various formulae and expressions involving the factor f_1 may normally also be applied for aluminium alloys where:

$$f_1 = \frac{\sigma_f}{235}$$

σ_f = yield stress in N/mm^2 at 0.2% offset. σ_f is not to be taken greater than 70% of the ultimate tensile strength.

105 For aluminium structures earthing to steel hull is to be in accordance with Pt.4 Ch.8.

D. Corrosion Additions for Steel Ships

D 100 General

101 In tanks for cargo oil and/or water ballast the scantlings of the steel structures are to be increased by corrosion additions as specified in 200. In the following *cargo oil* will be used as a collective term for liquid cargoes which may be carried by oil carriers (see list of cargoes in appendix to Pt.5 Ch.3).

D 200 Corrosion additions

201 Plates, stiffeners and girders in tanks for water ballast and/or cargo oil and of holds in dry bulk cargo carriers are to be given a corrosion addition t_k as stated in Table D1.

Table D1 Corrosion addition t_k in mm

Internal members and plate boundary between spaces of the given category	*Tank/hold region*	
	Within 1.5 m below weather deck tank or hold top	*Elsewhere*
Ballast tank 1)	3.0	1.5
Cargo oil tank only	2.0	1.0 (0) 2)
Hold of dry bulk cargo carriers 4)	1.0	1.0 (3) 5)
Plate boundary between given space categories	*Tank/hold region*	
	Within 1.5 m below weather deck tank or hold top	*Elsewhere*
Ballast tank 1)/Cargo oil tank only	2.5	1.5 (1.0) 2)
Ballast tank 1)/Hold of dry bulk cargo carrier 4)	2.0	1.5
Ballast tank 1)/Other category space 3)	2.0	1.0
Cargo oil tank only/ Other category space 3)	1.0	0.5 (0) 2)
Hold of dry bulk cargo carrier 4)/Other category space 3)	0.5	0.5

1) The term ballast tank also includes combined ballast and cargo oil tanks, but not cargo oil tanks which may carry water ballast according to MARPOL 73/78 Annex I Reg. 18.

2) The figure in brackets refers to non-horizontal surfaces.

3) Other category space denotes the hull exterior and all spaces other than water ballast and cargo oil tanks and holds of dry bulk cargo carriers.

4) Hold of dry bulk cargo carriers refers to the cargo holds, including ballast holds, of vessels with class notations **Bulk Carrier** and **Ore Carrier**, see Pt.5 Ch.2 Sec.5.

5) The figure in brackets refers to webs and bracket plates in lower part of main frames in bulk carrier holds.

202 For members within or being part of boundary of tanks for ballast water only, for which a corrosion protection system according to 300 is not fitted, the magnitude of the corrosion addition t_k is subject to special consideration.

203 It is assumed that tanks for ballast water only are protected by an effective coating or an equivalent protection system.

204 The requirement to section modulus of stiffeners in tanks for water ballast or cargo oil given in relevant chapters is to be multiplied by a factor:

w_k = $1 + 0.05 (t_{kw} + t_{kf})$ for flanged sections
= $1 + 0.06\, t_{kw}$ for bulbs

t_{kw} = corrosion addition t_k with respect to the profile web
t_{kf} = corrosion addition t_k with respect to the profile flange.

For flat bars the corrosion addition may be added directly to the reduced thickness.

D 300 Class notation ICM (Increased Corrosion Margin)

301 For the main class a corrosion addition t_k in mm as given in Table D1 is added to the reduced scantlings in ballast tanks, cargo oil tanks and cargo holds in bulk cargo carriers as specified in 200.

For an additional class notation **ICM** a further corrosion addition t_c in mm will be added in ballast tanks, cargo oil tanks and cargo holds in bulk cargo carriers. The following class notations may be chosen:

ICM(BT), ICM(BTu), ICM(BTs)	for ballast tanks
ICM(CT), ICM(CTu), ICM(CTs)	for cargo oil tanks
ICM(CH), ICM(CHu), ICM(CHs)	for cargo holds in bulk carriers

or combinations of these notations as e.g. **ICM(BT/CTu)** meaning all ballast tanks and upper part (above D/2) of all cargo oil tanks where:

BT All ballast tanks.
CT All cargo oil tanks.
CH All cargo holds in the bulk carrier.
u Upper part of the ship (above D/2).
s Strength deck of the ship and 1.5 m below.

The practical procedure in applying t_c in the rule scantling formula is outlined in the following items.

The corrosion addition t_c in mm is defined in Table D2.

302 The hull girder actual section modulus is to be based on the thickness t of plating, and web and flanges of stiffeners and girders taken as:

$$t = t_{actual} - t_c \quad \text{(mm)}$$

303 The local scantlings of plates, stiffener webs/flanges and girder web/flanges where formulae are given in the rules with the corrosion addition (t_k), the total addition is to be taken as:

$$t'_k = t_k + t_c \quad \text{(mm)}$$

304 For stiffeners where formulae are given in the rules with the w_k increase in section modulus for compensation of the corrosion addition (t_k), the w_k need not be additionally adjusted for the corrosion addition (t_c).

Table D2 Corrosion addition t_c in mm		
Internal members and plate boundary between spaces of the given category	*Tank/hold region*	
	Within 1.5 m below weather deck tank or hold top	*Elsewhere*
Ballast tank [1)]	3.0	1.5
Cargo oil tank only	2.0	1.0
Hold of dry bulk cargo carriers [3)]	1.0	1.0
Plate boundary between given space categories [4)]	*Tank/hold region*	
	Within 1.5 m below weather deck tank or hold top	*Elsewhere*
Ballast tank [1)]/Cargo oil tank only	2.5	1.5
Ballast tank [1)]/Hold of dry bulk cargo carrier [3)]	2.0	1.5
Ballast tank [1)]/Other category space [2)]	2.0	1.0
Cargo oil tank only/ Other category space [2)]	1.0	0.5
Hold of dry bulk cargo carrier [3)]/Other category space [2)]	0.5	0.5

1) The term ballast tank also includes combined ballast and cargo oil tanks, but not cargo oil tanks which may carry water ballast according to MARPOL 73/78 Annex I Reg. 18.

2) Other category space denotes the hull exterior and all spaces other than water ballast and cargo oil tanks and holds of dry bulk cargo carriers.

3) Hold of dry bulk cargo carriers refers to the cargo holds, including ballast holds, vessels with class notations **Bulk Carrier** and **Ore Carrier**, see Pt.5 Ch.2 Sec.5.

4) For vessels with the notation **ICM(BT)**, **ICM(BTu)** or **ICM(BTs)**, cargo oil tanks and holds of dry bulk cargo carriers may be treated as “other category space”.

305 For web frames and girder systems where scantlings are based on a direct strength analysis, the allowable stresses in the rules are given with reference to reduced scantlings. The reduced thickness used in such analysis is to be:

$$t_{reduced} = t_{actual} - (t_k + t_c) \quad \text{(mm)}.$$

306 The throat thickness of continuous and intermittent fillet welding is given in Sec.11 with an addition of 0.5 t_k mm. The total corrosion addition is to be taken as:

$$(0.5\, t'_k) = 0.5\,(t_k + t_c) \quad \text{(mm)}.$$

307 The additional corrosion thickness t_c is to be given in the design drawings in the form of a general note.

Guidance note:

Example on marking on the design drawing:

ICM( ) Plating , mm
Stiffeners web/flange , mm
Girders web/flange , mm

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

SECTION 3
DESIGN PRINCIPLES

A. Subdivision and Arrangement

A 100 General

101 The hull is to be subdivided into watertight compartments.

Guidance note:

The following requirements are considered to meet the relevant regulations of the International Convention on Load Lines, and SOLAS 74/78 with later amendments. Attention should, however, be given to possible additional requirements of the Maritime Authorities in the country in which the ship is to be registered.

For passenger ships, see Pt.5 Ch.2 Sec.2.

For dry cargo ships see also Pt.5 Ch.2 Sec.8.

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A 200 Definitions

201 Symbols:

L_F = length in m as defined in Sec.1 B
P_F = perpendicular coinciding with the foreside of the stem on the waterline on which L_F is measured.
For ships with unconventional stem curvatures, e.g. a bulbous bow protruding the waterline, the position of P_F will be specially considered
H = height of superstructure in m
D_F = least moulded depth to the freeboard deck in m.

A 300 Number of transverse watertight bulkheads

301 The following transverse, watertight bulkheads are to be fitted in all ships:

— a collision bulkhead
— an afterpeak bulkhead
— a bulkhead at each end of the machinery space(s).

The afterpeak bulkhead may occasionally be regarded as the after machinery bulkhead.

302 For ships without longitudinal bulkheads in the cargo region, the total number of watertight transverse bulkheads is normally not to be less than given in Table A1.

Table A1 Number of transverse bulkheads

Ship length in m	*Engine room*	
	Aft	*Elsewhere*
L < 65	3	4
65 < L < 85	4	4
85 < L < 100	4	5

303 After special consideration of arrangement and strength, the number of watertight bulkheads may be reduced. The actual number of watertight bulkheads will be entered in the «Register of vessels classed with DNV».

A 400 Position of collision bulkhead

401 The distance x_c from the perpendicular P_F to the collision bulkhead is to be taken between the following limits:

x_c (minimum) = $0.05\ L_F - x_r$ (m)
x_c (maximum) = $0.05\ L_F + 3 - x_r$ (m)

For ships with ordinary bow shape:

$x_r = 0.$

For ships having any part of the underwater body extending forward of P_F such as a bulbous bow, x_r is to be taken as the smallest of:

$x_r = 0.5\ x_b$ (m)

x_r = 0.015 L_F (m)
x_b = distance from P_F to the forward end of the bulbous bow, see Fig.1.

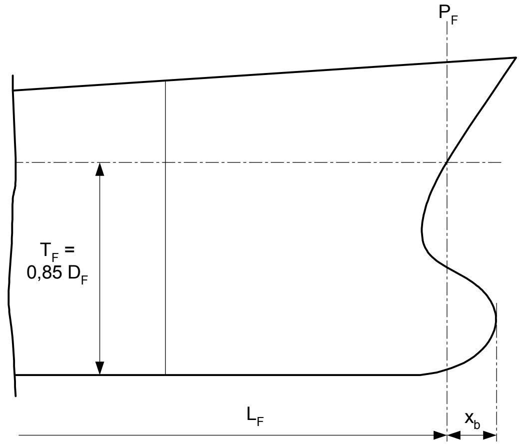

Fig. 1
Bulbous bow shape

402 An increase of the maximum distance given by 401 may be acceptable upon consideration in each case, provided a floatability and stability calculation shows that, with the ship fully loaded to summer draught on even keel, flooding of the space forward of the collision bulkhead will not result in any other compartments being flooded, nor in an unacceptable loss of stability.

403 Minor steps or recesses in the collision bulkhead may be accepted, provided the requirements to minimum and maximum distance from P_F are complied with.

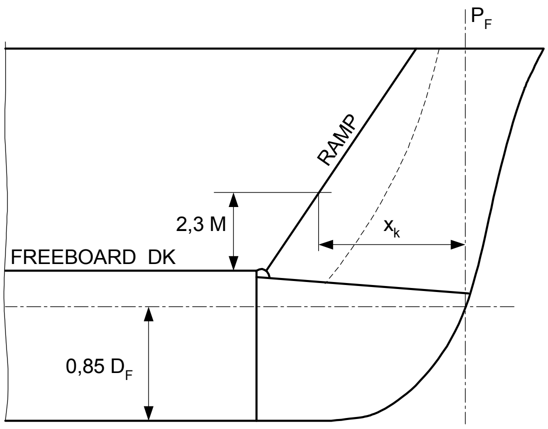

Fig. 2
Bow visor or door

404 In ships having a visor of doors in the bow and a sloping loading ramp forming part of the collision bulkhead above the freeboard deck, that part of the closed ramp which is more than 2.30 m above the freeboard deck may extend forward of the limits specified in 401, see Fig.2.

The ramp is to be arranged for weathertight closing over its complete length.

The distance x_k in Fig.2 is not to be less than the minimum value of x_c as given in 401.

A 500 Height of watertight bulkheads

501 The watertight bulkheads are in general to extend to the freeboard deck. Afterpeak bulkheads may, however, terminate at the first watertight deck above the waterline at draught T.

For an afterpeak bulkhead also being a machinery bulkhead, see 503.

502 For ships having complete or long forward superstructures, the collision bulkhead is to extend to the next deck above the freeboard deck. The extension need not be fitted directly over the bulkhead below, provided the requirements for distances from P_F are complied with, and the part of the freeboard deck forming the step is made weathertight.

For ships without a long forward superstructure and for which the collision bulkhead has not been extended to the next deck above the freeboard deck, any openings within the forward superstructure giving access to spaces below the freeboard deck, are to be made weathertight.

503 Bulkheads are to be fitted separating the machinery space from cargo and passenger spaces forward and aft and made watertight up to the freeboard deck. Afterpeak/ machinery space bulkheads may terminate as given in 501 when the aft space is not utilized for cargo or passengers.

504 For ships with a continuous deck below the freeboard deck and where the draught is less than the depth to this second deck, all bulkheads except the collision bulkheads may terminate at the second deck. The engine casing between second and upper deck, however, is to be arranged as a watertight bulkhead. In addition the second deck is to be watertight outside the casing above the engine room.

505 In ships with a raised quarter deck, the watertight bulkheads within the quarter deck region are to extend to this deck.

A 600 Openings and closing appliances

601 Openings may be accepted in watertight bulkheads, except in that part of the collision bulkhead which is situated below the freeboard deck. However, see 605.

602 Openings situated below the freeboard deck and which are intended for use when the ship is at sea, are to have watertight doors, which are to be closeable from the freeboard deck or place above the deck. The operating device is to be well protected and accessible.

603 Watertight doors are accepted in the engine room 'tween deck bulkheads, provided a signboard is fitted at each door stipulating that the door be kept closed while the ship is at sea. This assumption will be stated in the appendix to the classification certificate.

604 Openings in the collision bulkhead above the freeboard deck are to have weathertight doors or an equivalent arrangement. The number of openings in the bulkhead are to be reduced to the minimum compatible with the design and normal operation of the ship.

605 No door, manhole or ventilation duct or any other opening will be accepted in the collision bulkhead below the freeboard deck.

The collision bulkhead may, however, be pierced by necessary pipes to deal with fluids in the forepeak tank, provided the pipes are fitted with valves capable of being operated from above the freeboard deck. The valves are generally to be fitted on the collision bulkhead inside the forepeak. The valves may be fitted on the after side of the bulkhead provided that the valves are readily accessible under all service conditions and the space in which they are located is not a cargo space. See also Pt.4 Ch.6 Sec.3 A300.

A 700 Cofferdams and tank contents

701 The following dedicated tank types are to be separated from each other by cofferdams:

— tanks for mineral oil
— tanks for vegetable oil
— tanks for fresh water.

Furthermore, cofferdams shall be arranged separating tanks carrying fresh water for human consumption from other tanks containing substances hazardous to human health.

Guidance note:
Normally tanks for fresh water and water ballast are considered non-hazardous.

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A 800 Forward compartment contents

801 In ships of 400 gross tonnage and above, compartments forward of the collision bulkhead are not to be arranged for carriage of oil or other liquid substances which are flammable.

A 900 Minimum bow height

901 Minimum bow height requirements are:

1) The bow height 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 shall be not less than:

$$F_b = [6\,075(L_F/100) - 1\,875(L_F/100)^2 + 200(L_F/100)^3] \times [2.08 + 0.609C_B - 1.603C_{wf} - 0.0129(L_F/T_1)]$$

F_b = the minimum bow height (mm)
C_{wf} = water plane area coefficient forward of L/2

$$= \frac{A_{wf}}{0.5 L_F B}$$

A_{wf} = water plane area forward of L/2 at draught T_1 (m^2)
T_1 = the draught at 85% of the least moulded depth, D_F.

2) Where the bow height required in paragraph (1) of this Regulation is obtained by sheer, the sheer shall extend for at least 15% of the length of the ship measured from the forward perpendicular. Where it is obtained by fitting a superstructure, such superstructure shall extend from the stem to a point at least 0.07 L abaft the forward perpendicular, and it shall be enclosed.
3) Ships which, to suit exceptional operational requirements, cannot meet the requirements of paragraphs (1) and (2) of this Regulation may be given special consideration.

(ICLL 39)

902 *Interpretations*

On ships to which timber freeboards are assigned Regulation 39 should relate to the summer load waterline and not to the timber summer load waterline.

(IACS LL43)

When calculating the bow height, the sheer of the forecastle deck may be taken into account, even if the length of the forecastle is less than 0.15 L, but greater than 0.07 L, provided that the forecastle height is not less than one half of standard height of superstructure as defined in Regulation 33 between 0.07 L and the forward terminal.

Where the forecastle height is less than one half of standard height of superstructure, as defined in Regulation 33, the credited bow height may be determined as follows (Figs. 3 and 4 illustrate the intention of 1 and 2 respectively):

1) When the freeboard deck has sheer extending from abaft 0.15 L, by a parabolic curve having its origin at 0.15 L abaft the forward terminal 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 terminal not higher than the level of the forecastle deck. However, if the value of the height denoted h_t on Fig.3 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.
2) When the freeboard deck has sheer extending for less than 0.15 L or has no sheer, by a line from the forecastle deck at side at 0.07 L extended parallel to the base line to the forward terminal.

(IACS LL38)

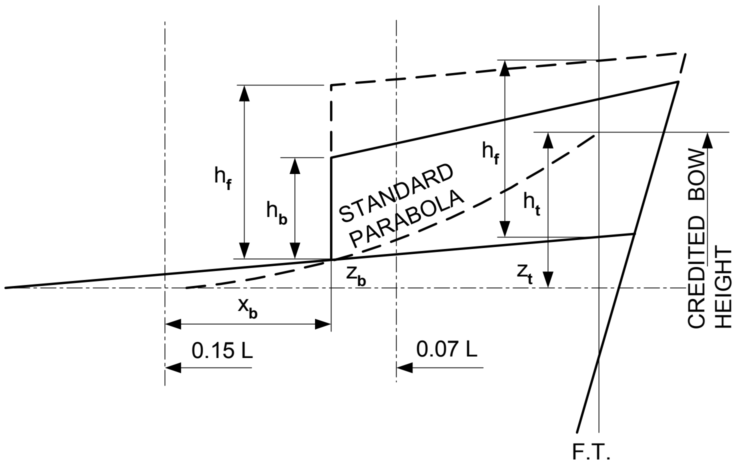

Fig. 3
Forecastle, procedure 1

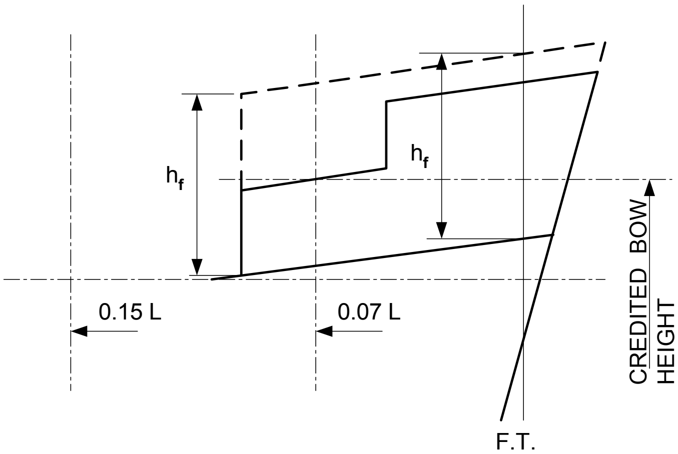

Fig. 4
Forecastle, procedure 2

h_f = half standard height of superstructure as defined in Regulation 33

$$h_t = Z_b\left(\frac{0.15L}{x_b}\right)^2 - Z_t$$

Guidance note:

ICLL 39 require additional reserve buoyancy in the fore end for all ships assigned a type B freeboard, other than oil tankers, chemical tankers and gas carriers.

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A 1000 Access to and within narrow ballast tanks

1001 Vessels, except those exclusively intended for the carriage of containers, are to comply with 1002.

1002 Narrow ballast tanks (such as double-skin construction) are to be provided with permanent means of access, such as fixed platforms, climbing/foothold rails, ladders etc., supplemented by limited portable equipment to give safe and practical access to the internal structure for adequate inspection, including close-up survey as defined in Pt.7 Ch.1 Sec.3 B and Pt.7 Ch.1 Sec.4 B.

Guidance note:

In order to obtain a practical arrangement it is recommended to provide for a fixed platform spacing of 3 to 5 m.

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A 1100 Steering gear compartment

1101 The steering gear compartment shall be readily accessible, and as far as practicable, separated from machinery spaces.

(SOLAS Ch. II-1/29.13.1)

A 1200 Navigation bridge design

Guidance note:

It should be noted that the navigation bridge design is affected by requirements for navigation bridge visibility. Reference is made to SOLAS Ch.V Reg.22.

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A 1300 Oil fuel tank protection

Guidance note:

Oil fuel tank design is affected by requirements for fuel tank protection. Reference is made to MARPOL Annex I Reg. 12A.

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B. Structural Design Principles

B 100 Loading conditions

101 Static loads are derived from loading conditions submitted by the builder or standard conditions prescribed in the rules. The standard conditions are expected to give suitable flexibility with respect to the loading of ordinary ship types.

102 Unless specifically stated, dry cargoes are assumed to be general cargo or bulk cargo (coal, grain) stowing at 0.7 t/m^3. Liquid cargoes are assumed to have density equal to or less than that of seawater.

103 Unless especially stated to be otherwise, or by virtue of the ship's class notation (e.g. **Container Carrier**) or the arrangement of cargo compartments, the ship's cargo and ballast conditions are assumed to be symmetric about the centreline. For ships for which unsymmetrical cargo or ballast condition(s) are intended, the effect of this is to be considered in the design.

104 The determination of dynamic loads is based on long term distribution of motions that the ship will experience during her operating life. These loads are basically given in Ch.1. In the following sections the dynamic loads are modified and included in the relevant formulas.

105 The requirements given in Sec.5 to Sec.11 refer to structures made of mild steel with yield strength σ_y = 235 N/mm^2. If steel of higher yield strength is used, reduced scantlings according to formulas in 300 to 600 with $f_1 > 1.0$ may be accepted.

B 200 Hull girder strength

201 A minimum longitudinal strength standard determined by the section modulus at bottom and deck is required for the hull girder cross-section.

B 300 Transverse strength

301 The overall or local transverse strength need occasionally to be specially considered. In such cases the ship is assumed to have an angle of heel not less than 30 degrees. No additional dynamic loads need to be added.

Acceptable stress levels will normally be:

σ = 160 f_1 N/mm^2 for structural members without longitudinal bending stresses
= as given in relevant chapters for longitudinal members
τ = 90 f_1 N/mm^2
f_1 = material factor given in Sec.2 B200.

B 400 Plate strength

401 For plating exposed to lateral pressure the thickness requirement is generally given by:

$$t = \frac{15.8\, k_a\, s \sqrt{p}}{\sqrt{\sigma f_1}} + t_k \quad \text{(mm)}$$

$$t_{min} = t_0 + \frac{kL}{\sqrt{f_1}} + t_k \quad \text{(mm)}$$

k_a = correction factor for aspect ratio of plate field
= $(1.1 - 0.25\, s/l)^2$
= maximum 1.0 for s/l = 0.4
= minimum 0.72 for s/l = 1.0
s = stiffener spacing in m
p = maximum lateral pressure in kN/m^2
σ = allowable local stress in N/mm^2 for mild steel
t_0, k = as given in relevant chapters
f_1 = material factor given in Sec.2 B200.

B 500 Stiffeners, local bending and shear strength

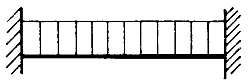
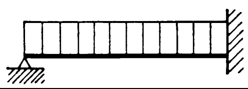
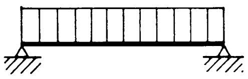
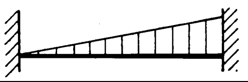
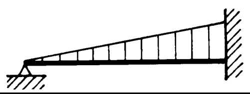
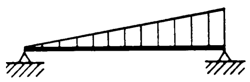
501 For stiffeners exposed to lateral pressure, the section modulus requirement is generally given as function of bending moments and nominal allowable bending stress as follows:

$$Z = \frac{1000\, l^2 s\, p\, w_k}{m\, \sigma f_1} \quad (\text{cm}^3)$$

p = lateral pressure in kN/m^2
l = length of the member in m as defined in Fig.5 and Fig. 6
s = spacing in m
m = bending moment factor
w_k = section modulus corrosion factor in tanks as given in Sec.2 D200
σ = allowable stress in N/mm^2 for mild steel
f_1 = material factor given in Sec.2 B200.

For elastic deflections the m-value is derived directly from general elastic bending theory. In Table B1 m-values are given for some defined load and boundary conditions.

Table B1 Values of m and k_s

Load and boundary conditions			*Bending moment and shear force factors*		
Positions			1	2	3
1 Support	2 Field	3 Support	m_1 ks_1	m_2 -	m_3 ks_3
			12.0 0.50	24.0 -	12.0 0.50
			- 0.38	14.2 -	8.0 0.63
			- 0.50	8.0 -	- 0.50
			15.0 0.30	23.3 -	10.0 0.70
			- 0.20	16.8 -	7.5 0.80
			- 0.33	7.8 -	- 0.67

502 The effective shear area requirements are given as a function of boundary conditions and nominal allowable shear stress as follows:

$$A_s = \frac{10\,Q}{\tau f_1} + A_k$$

Q = k_s P
 = expected shear force in kN
P = total load force on the member in kN
k_s = shear force factor
τ = 90 N/mm^2 in general
f_1 = material factor given in Sec.2 B200
A_K = corrosion addition area for the effective shear area. A_K may be obtained by adding the corrosion addition t_k to the net web thickness or increasing the web height correspondingly.

The k_s-value is derived directly from general elastic beam theory. In Table B1 k_s-values are given for some defined load and boundary conditions.

B 600 Girders, local bending and shear strength

601 Strength formulas for girders are limited to simple girders. The boundary conditions and the nominal allowable stresses are given in a similar way as for stiffeners.

For girder systems the stress pattern is assumed to be derived by direct calculations. The loadings and bending stresses are to comply with the values given in the relevant rule sections. Acceptable shear stresses = 90 f_1.

B 700 Buckling strength

701 Requirements for stability of local strength members are given in Sec.10.

B 800 Impact strength

801 Ships designed for a small draught at F.P. may have to be strengthened to resist slamming. Requirements are given for bottom structures forward. The draught upon which the slamming strength is based, will be stated in the appendix to the classification certificate.

B 900 Vibrations

901 The rules do not give any requirements to prevent harmful vibrations in global or local structural elements.

B 1000 Miscellaneous strength requirements

1001 Requirements for scantlings of foundations, minimum plate thickness and other requirements not relating relevant load and strength parameters may reflect criteria other than those indicated by these parameters. Such requirements may have been developed from experience or may represent simplifications considered appropriate by the society.

B 1100 Service restrictions

1101 For ships with restricted service, reductions in the strength requirements may be given.

1102 The requirement to longitudinal strength may be reduced as given in Sec.4 B201 and C104.

1103 The dynamic terms in the requirements for local strength may generally be reduced as given in Table B2.

Table B2 Reduction of dynamic terms

Class notation	*Reduction (x%)*
R0	No reduction
R1	10%
R2	20%
R3	30%
R4	40%
RE	50%

The reductions should be applied to the parameters referred to in the relevant tables for design loads.

For local pressures given with a factor k (or 1.3) in the formula, only the part of k exceeding 1.0 is to be reduced.

Guidance note:

In formulae given for combined loads the load factor k may be reduced as follows:

$$\tilde{k} = 1 + (k - 1)\,\frac{100 - x}{100}$$

x = reduction factor given in table.

Where factor C_W is included as the dynamic factor a direct reduction of C_W may be applied.

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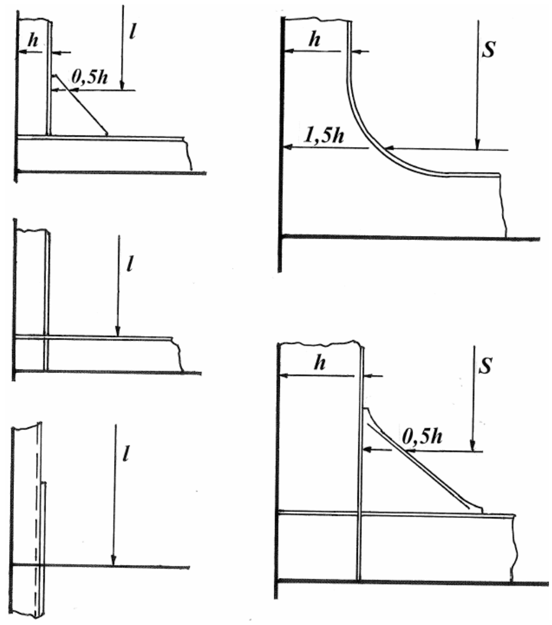
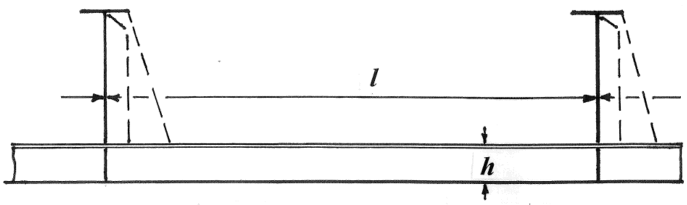
C. Local Design

C 100 Definition of span for stiffeners and girders

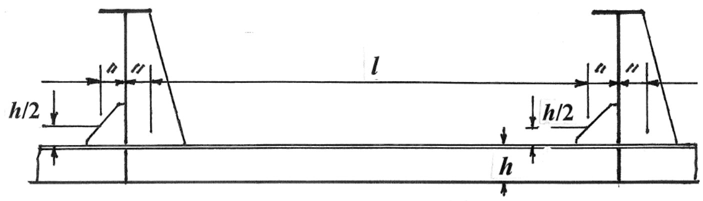
101 The effective span of a stiffener (*l*) or girder (S) depends on the design of the end connections in relation to adjacent structures. Unless otherwise stated the span points at each end of the member, between which the span is measured, is in general to be determined as shown in Fig.5 and Fig.6. When the adjacent structure is ineffective in support of the bracket, or when the end bracket does not comply with requirements in this section and is fitted for stiffening of supporting structures, the span point shall be defined by the intersection of the line defined by the stiffener face plate and the end support structure.



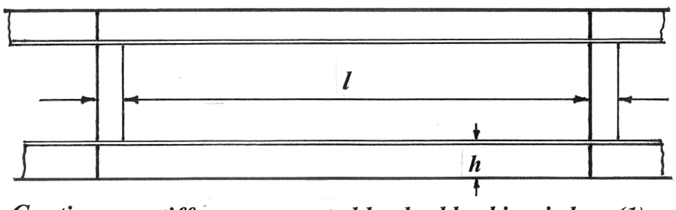
Stiffeners **Girders**



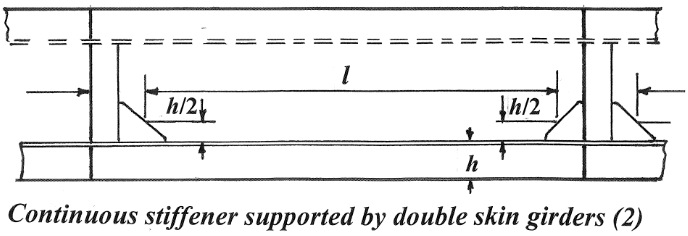
Continuous stiffener supported by single skin girders (1)



Continuous stiffener supported by single skin girders (2)



Continuous stiffener supported by double skin girders (1)



Continuous stiffener supported by double skin girders (2)

Fig. 5
Span points

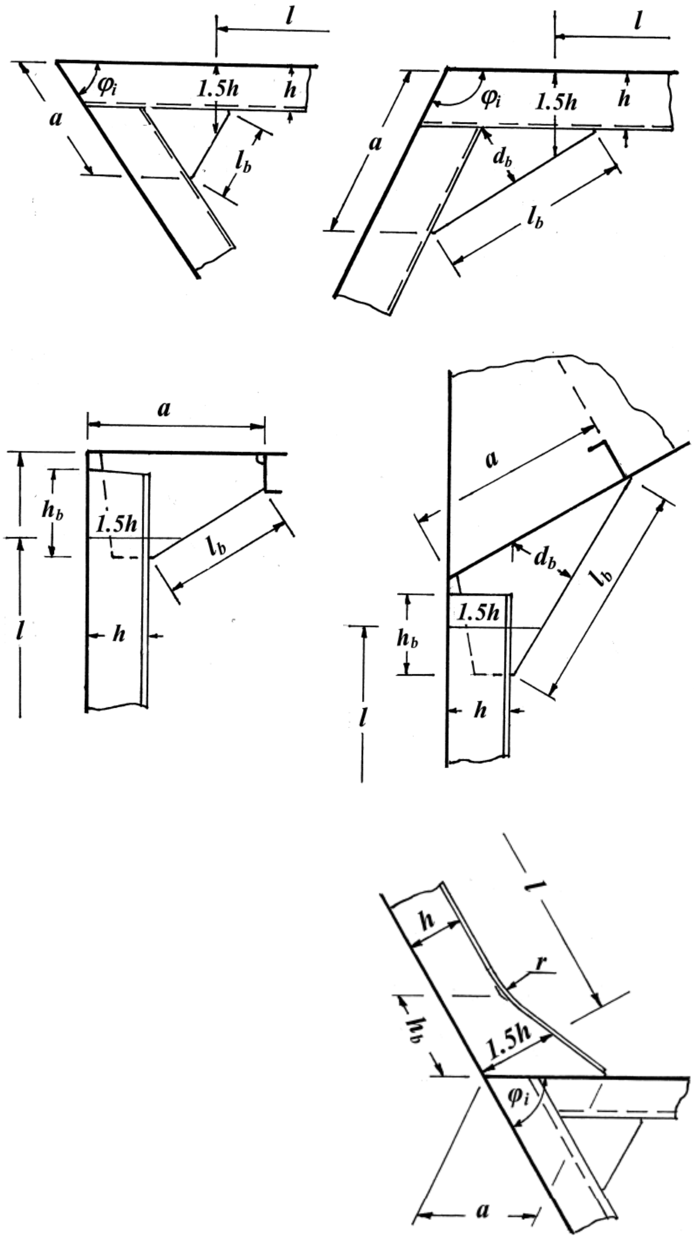


Fig. 6
Stiffener end brackets

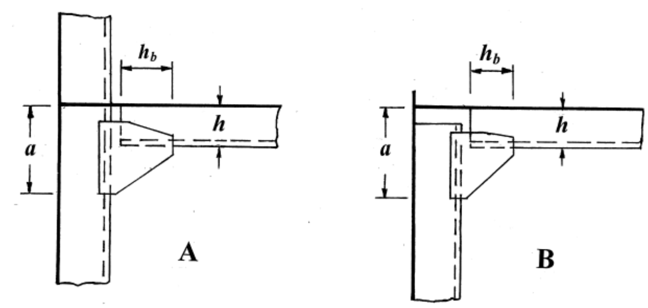


Fig. 7
Overlap end brackets

C 200 End connections of stiffeners

201 Normally all types of stiffeners (longitudinals, beams, frames, bulkhead stiffeners) shall be connected at their ends. In special cases, however, sniped ends may be allowed, see 204. General requirements for the various types of connections (with brackets, bracketless, sniped ends) are given below.

Special requirements may be given for the specific structures in other sections.

Requirements for weld connections are given in Pt.3 Ch.1 Sec.11.

202 The arm lengths of brackets for stiffeners not taking part in longitudinal strength may normally be taken as:

$$a = c\sqrt{\frac{Z/w_k}{t_b - t_k}} \quad \text{(mm)}$$

c = 70 for brackets with flange or edge stiffener
 = 75 for brackets without flange or edge stiffener
Z = rule section modulus in cm^3 of stiffener
t = thickness of bracket in mm
t_k = as given in Sec.2 D200, but need not be taken greater than 1.5 mm.

The arm length, a, shall in no case be taken less than $(1 + 1/\sin\phi_i)$ h, where ϕ_i represents the angle between the stiffeners connected by the bracket, and h the depth of the lowest of the connected stiffeners. In addition the height of the bracket, h_b, see Fig.6 and 7, shall not be less than h.

Brackets shall be arranged with flange or edge stiffener if free lengths exceed 50 (t_b - t_k) except when the depth of the bracket defined as the distance from the root to the edge is less than 22 (t_b - t_k).

The connection between stiffener and bracket shall be so designed that the effective section modulus is not reduced to a value less than required for the stiffener.

203 Bracketless end connections may be applied for longitudinals and other stiffeners running continuously through girders (web frames, transverses, stringer, bulkheads, etc.), provided sufficient connection area is arranged for.

For longitudinals, see special requirements in Sec.5 and 7.

204 Stiffeners with sniped ends may be allowed in compartments and tanks where dynamic loads are small and where vibrations are considered to be of small importance, provided the thickness of plating supported by the stiffener is not less than:

$$t = 1.25\sqrt{(l - 0.5s)s\,p} + t_k \quad \text{(mm)}$$

l = stiffener span in m
s = stiffener spacing in m
p = pressure on stiffener in kN/m^2.

C 300 End connections of girders

301 Normally ends of single girders or connections between girders forming ring systems shall be provided with brackets. Brackets are generally to be radiused or well rounded at their toes. The free edge of the brackets shall be arranged with flange or edge stiffener. Scantlings and details are given below.

Bracketless connections may be applied provided adequate support of the adjoining free flanges is arranged for.

302 The thickness of brackets on girders shall not be less than that of the girder web plate.

303 The arm length including depth of girder web may normally be taken as:

$$a = 63\sqrt{\frac{Z/w_k}{t - t_k}} \quad \text{(mm)}$$

Z = Rule section modulus in cm^3 of the strength member to which the bracket is connected
t = thickness of bracket in mm
t_k = as given in Sec.2 D200, but need not be taken greater than 1.5 mm
w_k = corrosion factor as given in Sec.2 D200.

304 Flanges on girder brackets are normally to have a cross-sectional area not less than:

$$A = l\,t \quad (cm^2)$$

l = length of free edge of brackets in m
t = thickness of brackets in mm.

305 The thickness of the web plate at the cross joint of bracketless connection (see Fig.8) is not to be less than the greater of:

$$t_3 = \frac{1}{f_{1(3)}}\left(\frac{\sigma_1 A_1}{h_2} - t_2 \frac{\tau_2}{100}\right) \quad \text{(mm)}$$

or

$$t_3 = \frac{1}{f_{1(3)}}\left(\frac{\sigma_2 A_2}{h_1} - t_1 \frac{\tau_1}{100}\right) \quad \text{(mm)}$$

A_1, A_2 = flange area in cm^2 of girder 1 and 2
σ_1, σ_2 = bending stresses in N/mm^2 in girder 1 and 2
τ_1, τ_2 = shear stresses in N/mm^2 in webs of girder 1 and 2
h_1, h_2 = height in mm of girder 1 and 2
$f_{1(3)}$ = material factor for corner plate t_3.
$f_1(3)$ corresponds to f_1 given in Sec.2 B200.

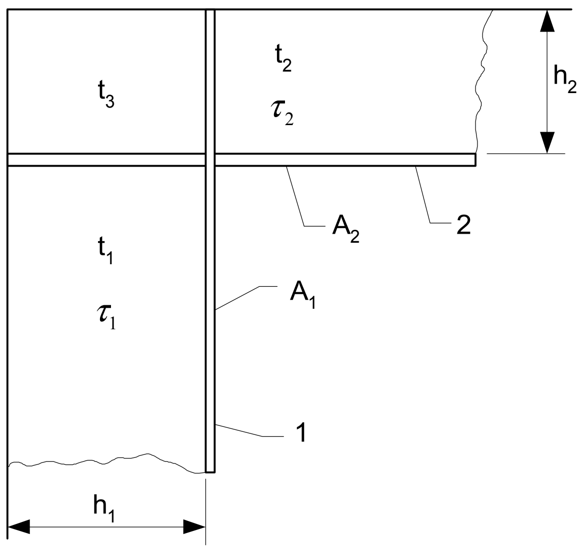


Fig. 8
Bracketless joint

C 400 Effective flange of girders

401 The section modulus of the girder is to be taken in accordance with particulars as given in the following.

Structural modelling in connection with direct stress analysis is to be based on the same particulars when applicable. Note that such structural modelling will not reflect the stress distribution at local flange cut-outs or at supports with variable stiffness over the flange width.

The local effective flange which may be applied in stress analysis is indicated for construction details in various Classification Notes on «Strength Analysis of Hull Structures».

402 The effective plate flange area is defined as the cross-sectional area of plating within the effective flange width. Continuous stiffeners within the effective flange may be included. The effective flange width b_e is determined by the following formula:

$$b_e = C\, b$$

C = as given in Table C1

Table C1 Values of C

a/b	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*≥ 7*
C (r ≥ 6)	0.00	0.38	0.67	0.84	0.93	0.97	0.99	1.00
C (r = 5)	0.00	0.33	0.58	0.73	0.84	0.89	0.92	0.93
C (r = 4)	0.00	0.27	0.49	0.63	0.74	0.81	0.85	0.87
C (r ≤ 3)	0.00	0.22	0.40	0.52	0.65	0.73	0.78	0.80

a = distance between points of zero bending moments, see Fig.9
= S for simply supported girders

= 0.6 S for girders fixed at both ends
S = span of girder
b = plate flange width taken as the sum of half spans of adjacent stiffeners, see Fig.8
r = number of stiffeners along girder span.

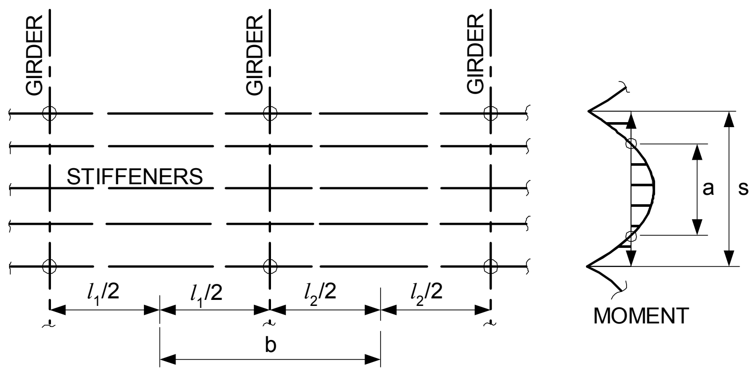


Fig. 9
Effective flange

403 For plate flanges having corrugations parallel to the girder, the effective width is as given in 402. If the corrugations are perpendicular to the direction of the girder, the plate flange is considered not effective unless otherwise demonstrated.

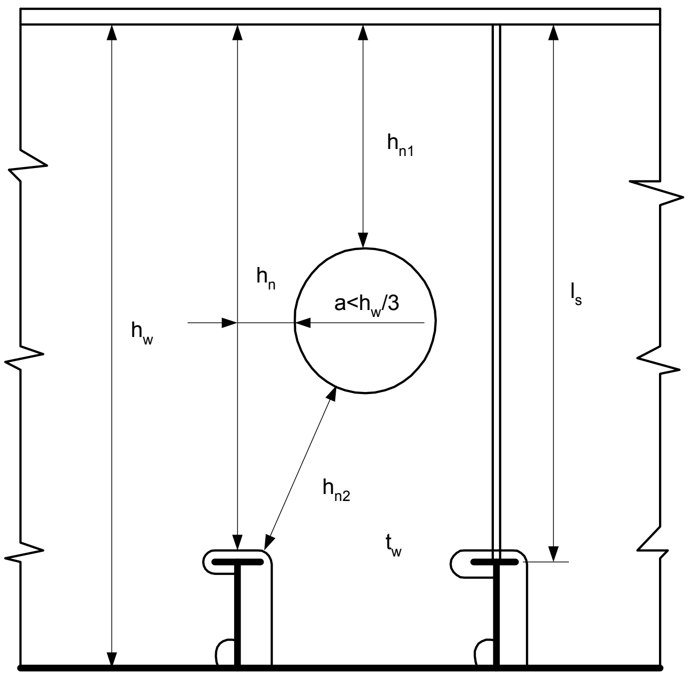


Fig. 10
Effective web area in way of openings

C 500 Effective web of girders

501 The web area of a girder is to be taken in accordance with particulars as given below. Structural modelling in connection with direct stress analysis is to be based on the same particulars when applicable.

502 Holes in girders will generally be accepted provided the shear stress level is acceptable and the buckling strength is sufficient. Holes are to be kept well clear of end of brackets, pillars, crossties and locations where shear stresses are high.

503 For ordinary girders the effective web area is to be taken as:

$$A_W = 0.01\ h_n\ t_w \quad (cm^2)$$

h_n = net girder height in mm after deduction of cut-outs in the cross-section considered
= $h_{n1} + h_{n2}$
t_w = web thickness in mm, t_k not included.

If an opening is located at a distance less than $h_w/3$ from the cross-section considered, h_n is to be taken as the smaller of the net height and the net distance through the opening. See Fig.10.

C 600 Stiffening of girders

601 In general girders are to be provided with tripping brackets and web stiffeners to obtain adequate lateral and web panel stability. The requirements given below are providing for an acceptable standard. The stiffening system may, however, be modified based on direct stress analysis and stability calculations according to accepted methods.

602 The web plate of girders are to be stiffened where:

$$h_w > 75\ t_w \quad \text{(mm)}$$

t_w = web thickness in mm, t_k not included

with stiffeners of maximum spacing:

$$s = 60\ t_w \quad \text{(mm)}$$

within 20% of the span from each end of the girder and where high shear stresses.

Elsewhere stiffeners are required where:

$$h_w > 90\ t_w \quad \text{(mm)}$$

with stiffeners of maximum spacing:

$$s = 90\ t_w \quad \text{(mm)}$$

603 The web plate is to be specially stiffened at openings when the mean shear stress exceeds 60 N/mm^2.

Stiffeners are to be fitted along free edges of the openings parallel to the vertical and horizontal axis of the opening. Stiffeners may be omitted in one direction if the shortest axis is less than 400 mm and in both directions if length of both axes is less than 300 mm. Edge reinforcement may be used as an alternative to stiffeners.

604 The spacing S_T of tripping brackets is normally not to exceed the values given in Table C2 valid for girders with symmetrical face plates. For others the spacing will be specially considered.

Table C2 Spacing between tripping brackets

Girder type	S_T (m)
Transverse girders Vertical girders Longitudinal girders outside 0.5 L amidships	$0.02\ b_f$ 1) maximum 6
Longitudinal girders within 0.5 L amidships	$0.014\ b_f$ 2) maximum 4

b_f = flange breadth in mm
S = distance between transverse girders in m.

1) For girders in tanks and machinery spaces S_T is not to exceed $0.014\ b_f$.
2) If the web of a strength member forms an angle with the perpendicular to the ship's side of more than 10°, S_T is not to exceed $0.007\ b_f$.

605 Tripping brackets on girders are to be stiffened by a flange or stiffener along the free edge if the length of the edge exceeds:

$$0.06\ t_t \quad \text{(m)}$$

t_t = thickness in mm of tripping bracket, t_k not included.

The area of the stiffening is not to be less than:

$$10\ l_t \quad (\text{cm}^2)$$

l_t = length in m of free edge.

The tripping brackets are to have a smooth transition to adjoining longitudinals or stiffeners exposed to large longitudinal stresses.

Tripping brackets are to be fitted as required in 604, and are further to be fitted near the toe of bracket, near rounded corner of girder frames and in line with any cross ties. The tripping brackets are to be fitted in line with longitudinals or stiffeners, and are to extend the whole height of the web plate. The arm length of the brackets along the longitudinals or stiffeners, is not to be less than 40% of the depth of the web plate, the depth of the longitudinal or stiffener deducted. The requirement may be modified for deep transverses.

606 Hatch end beams supporting hatch side coamings are to have tripping brackets located in the centre line and between the hatch side coaming and the ship's side.

607 The minimum thickness of tripping brackets and stiffeners is given in Sec.5 to Sec.8 covering the various local structures.

C 700 Properties of sections in relation to rule requirements

701 The geometric properties (moment of inertia I and section modulus Z) of stiffeners and girders may be calculated directly from the given dimensions in connection with the effective plate flange (for girders, see 400), or obtained from published tables and curves. Diagrams and tables for such properties are given in Appendix B. For stiffeners the plate flange may normally be taken equal to the stiffener spacing.

702 The requirement for standard section modulus is valid about an axis parallel to the plate flange. For profiles with web plate angle α from the perpendicular to the flange greater than 15°, the requirement for standard section modulus may be determined by multiplying the rule requirement by 1 / cos α.

703 Where several members in a group with some variation in requirement are selected as equal, the section modulus may be taken as the average of each individual requirement in the group. However, the requirement for the group is not to be taken less than 90% of the largest individual requirement.

704 For stiffeners and girders in tanks and in cargo holds of dry bulk cargo carriers, corrosion additions corresponding to the requirements given in Sec.2 D are to be applied. For built up sections the appropriate t_k-value may be added to the web and flange thicknesses after fulfilment of the net modulus requirement. For rolled sections the net section modulus requirement may be multiplied by a corrosion factor w_k as given in Sec.2 D200.

C 800 Continuity of local strength members

801 Attention is drawn to the importance of structural continuity in general.

802 Structural continuity is to be maintained at the junction of primary supporting members of unequal stiffness by fitting well rounded brackets.

Brackets are not to be attached to unsupported plating. Brackets are to extend to the nearest stiffener, or local plating reinforcement is to be provided at the toe of the bracket.

803 Where practicable, deck pillars are to be located in line with pillars above or below.

804 Below decks and platforms, strong transverses are to be fitted between verticals and pillars, so that rigid continuous frame structures are formed.

C 900 Welding of outfitting details to hull

901 Generally connections of outfitting details to the hull are to be such that stress concentrations are minimised and welding to high stressed parts are avoided as far as possible.

Connections are to be designed with smooth transitions and proper alignment with the hull structure elements. Terminations are to be supported.

902 Equipment details as clips for piping, support of ladders, valves, anodes etc. are to be kept clear of the toe of brackets, edge of openings and other areas with high stresses.

Connections to top flange of girders and stiffeners are to be avoided if not well smoothened. Preferably supporting of outfittings are to be welded to the stiffener web.

903 All materials welded to the hull shell structure are to be of ship quality steel, or equivalent, preferably with the same strength group as the hull structure to which the item is welded.

904 Gutterway bars on strength deck are to be arranged with expansion joints unless the height/thickness ratio complies with the formula

$$\frac{h}{t} < \frac{2}{3}\sqrt{1.28\,\frac{E}{\sigma_F}}$$

where

E = as given in Sec.1 B101.
σ_F = minimum upper yield stress of material in N/mm^2. May be taken as 235 N/mm^2 for normal strength steel

905 For welding of deck fittings to a rounded sheer strake, see also Sec.6 C206.

C 1000 Cold formed plating

1001 For important structural members, e.g. corrugated bulkheads and hopper knuckles, the inside bending radius in cold formed plating is not to be less than 4.5 times the plate thickness for carbon-manganese steels and 2 times the plate thickness for austenitic- and ferritic-austenitic (duplex) stainless steels, corresponding to 10% and 20% theoretical deformation, respectively.

1002 For carbon-manganese steels the allowable inside bending radius may be reduced below 4.5 times the plate thickness providing the following additional requirements are complied with:

a) The steel is killed and fine grain treated, i.e. grade NV D/DH or higher.
b) 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/(2 R + t), where t is the thickness of the plate material and R is the bending radius. Ageing is to be carried out at 250°C for 30 minutes. The average impact energy after strain ageing is to be at least 27 J at 20°C.
c) 100% visual inspection of the deformed area is to be carried out. In addition, random check by magnetic particle testing is to be carried out.
d) The bending radius is in no case to be less than 2 times the plate thickness.

SECTION 4
LONGITUDINAL STRENGTH

A. General

A 100 Introduction

101 In this section the requirements regarding the longitudinal hull girder scantlings with respect to bending are given.

102 The wave bending moments are given as the design values at probability level = 10^{-8}.

These values are applied when determining the section modulus of the hull girder and in connection with control of buckling and ultimate strength. Reduced values will have to be used when considering combined local and longitudinal stresses, see B202.

103 The buckling strength of plating is given in Sec.12.

104 For ships with small block coefficient, high speed and large flare the section modulus in the forebody may have to be specially considered.

105 For ships with openings in shipside/deck the combined effects of vertical and horizontal bending of the hull girder may have to be specially considered.

106 For ships with large deck openings (total width of hatch openings in one transverse section exceeding 65% of the ship's breadth or length of hatch opening exceeding 75% of hold length) the longitudinal strength including torsion may be required to be considered as given in Pt.5 Ch.2 Sec.6 B200. For ships with block coefficient < 0.7, the longitudinal/local strength outside of the midship region may, subject to special consideration in each case, be taken according to Pt.5 Ch.2 Sec.6 B.

A 200 Definitions

201 Symbols: L, B, D, T, C_B, see Sec.1 B.

C_W = wave coefficient
= 0.0792 L
M_S = design stillwater bending moment in kNm as given in B100
M_W = Rule wave bending moment in kNm as given in B200.

202 Terms:

Loading manual is a document which describes:

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

A *Loading computer system* is a system, which unless stated otherwise is digital, 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 the still water torsional moments and lateral loads, where applicable, in any load or ballast condition will not exceed the specified permissible values.

Guidance note:
The term “Loading computer system” covers the term “Loading instrument” as commonly used in IACS UR S1.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

An operation manual is always to be provided for the loading computer system. Single point loading computer systems are not acceptable.

Category I Ships. Ships with large deck openings where combined stresses due to vertical and horizontal hull girder bending and torsional and lateral loads have to be considered.

Ships liable to carry non-homogeneous loadings, where the cargo and/or ballast may be unevenly distributed. Ships less than 120 m in length, when their design takes into account uneven distribution of cargo or ballast, belong to Category II.

Chemical tankers and gas carriers.

Category II Ships. Ships with arrangement giving small possibilities for variation in the distribution of cargo and ballast, and ships on regular and fixed trading pattern where the loading manual gives sufficient guidance, and in addition the exception given under Category I.

B. Vertical Bending Moments

B 100 Stillwater conditions

101 The design stillwater bending moments within 0.4 L amidships are normally not to be taken less than:

$$M_{SO} = 0.0052\ L^3\ B\ (C_B + 0.7)\quad (kNm)$$

Outside 0.4 L amidships M_{SO} may be gradually decreased for zero at F.P. and A.P.

102 The stillwater bending moments are normally taken as the design stillwater bending moments in 101.

They may, however, have to be calculated for ballast and particular non-homogeneous load conditions after special considerations.

For each condition the calculations are to be based on relevant and realistic amounts of bunker, fresh water and stores at departure and arrival.

If the calculated bending moment exceeds the design value given in 101 the calculated value is to be used in C101.

103 An approximate formula for the stillwater bending moment is given in Appendix A. The formula should be regarded as a guidance and may be overruled by a direct calculation.

B 200 Wave load conditions

201 The rule vertical wave bending moment amidships is given by:

$$M_{WO} = 0.11\ C_W\ L^2\ B\ (C_B + 0.7)\quad (kNm)\ \text{in sagging}$$
$$= 0.19\ C_W\ L^2\ B\ C_B\quad (kNm)\ \text{in hogging.}$$

C_B is normally not to be taken less than 0.6.

M_W is to be taken equal to M_{WO} between 0.4 L and 0.65 L from A.P. Outside this region M_W may be reduced linearly to zero at F.P. and A.P.

202 When combining longitudinal stresses with local stresses in local elements, M_W is to be divided by 1.7.

203 For reduction of C_W in connection with service restrictions, twice the reductions given in C104 may be used.

C. Bending Strength and Stiffness

C 100 Section modulus

101 The section modulus requirements within 0.4 L amidships about the transverse neutral axis based on cargo and ballast conditions are given by:

$$Z = \frac{M_S + M_W}{175}\ 10^3 \qquad (cm^3)$$

102 When stillwater bending moments calculated for harbour and sheltered water conditions (enclosed fjords, lakes, rivers) are inserted in the formula in 101, the unrestricted service wave bending moments may be reduced by 30%.

103 The buckling strength of longitudinally compressed structures is to be checked according to Sec.12.

104 The midship section modulus about the transverse neutral axis is not to be less than:

$$Z_O = C_{WO}\ L^2\ B\ (C_B + 0.7)\quad (cm^3)$$

C_{WO} = 5.7 + 0.022 L, minimum 7.0.

C_B is in this case not to be taken less than 0.50. For ships with restricted service, C_{WO} may be reduced as given in Table C1.

Table C1 Reduction of C_{wo}	
Service area notation	*Reduction*
R0	No reduction
R1	5%
R2	10%
R3	15%
R4	20%
RE	25%

For service area restrictions, see Pt.1 Ch.2 Sec.1.

105 As a basis for the section modulus calculation, the following sectional area of the deck may give an approximate section modulus:

$$A = \frac{0.11 L^2 B}{D} \quad (\text{cm}^2)$$

A = total sectional area of deck plating including deck longitudinals outside line of hatches, and the sheer strake plating, the width of which being limited to the Rule value.

C 200 Midship section particulars

201 When calculating the moment of inertia and section modulus, the effective sectional area of continuous longitudinal strength members is in general the net area.

The effective sectional area of strength members between hatch openings in ships with twin or triple hatchways is to be taken as the net area multiplied by a factor 0.6 unless a higher factor is justified by direct calculations.

Superstructures which do not form a strength deck, are not to be included in the net section. This applies also to deckhouses, bulwarks and non-continuous hatch side coamings.

For definition of strength deck, see Sec.1 B204.

202 If openings are arranged in the ship sides, the shearing area of the remaining side plating is to be specially considered.

203 The section modulus at deck is normally referred to the moulded deck line at side. For ships having a continuous trunk, long hatch side coamings or other continuous strength members above deck taking part in the longitudinal strength, the section modulus is to be referred to a point at a distance z above the neutral axis:

$$z = z_1 \left(0.9 + 0.2 \frac{y}{B}\right)$$

z_1 = vertical distance from the neutral axis to the top of the continuous strength member
y = horizontal distance from top of the continuous strength member to the ship's centre line.

y and z_1 are to be measured to the point giving the greatest value of z.

z is not to be taken less than the distance from the neutral axis to the moulded deck line at side.

204 At ends of effective continuous longitudinal strength members in deck and bottom region large transition brackets are to be fitted.

205 If the section modulus of midship section at deck as built is based on use of high strength steel the ship side plating should be made of the same high strength steel for a distance h_{ht} below the deck:

$$h_{ht} = z_d \frac{f_1 - 1}{f_1}$$

z_d = distance from deck to neutral axis of the midship section
f_1 = material factor given in Sec.2 B200.

D. Openings in Longitudinal Strength Members

D 100 Positions

101 The keel plate is normally not to have openings. In the bilge plate, within 0.5 L amidships, openings are to be avoided as far as practicable. Any necessary openings in the bilge plate are to be kept clear of the bilge keel.

102 Openings in strength deck are as far as practicable to be located well clear of ship's side and hatch corners.

D 200 Effect of openings

201 The effect of openings are assumed to have longitudinal extensions as shown by the shaded areas in Fig.1, i.e. inside tangents at an angle of 30° to each other. Example for transverse section III:

$$b_{III} = b' + b'' + b'''$$

D 300 Hatchway corners

301 Openings in strength deck are to have corners with rounded or stream lined shape.

302 For corners with rounded shape the radius is not to be less than:

$$r = 0.025\ B \quad (m)$$

r need not be taken greater than 0.1 b (m) where b = breadth of opening in m. For local reinforcement of deck plating at circular corners, see Sec.7 A300.

303 If the corners are given a streamlined shape according to Fig.2 and Table D1 with the ordinate a equal to r given in 302, the deck plating need not be reinforced.

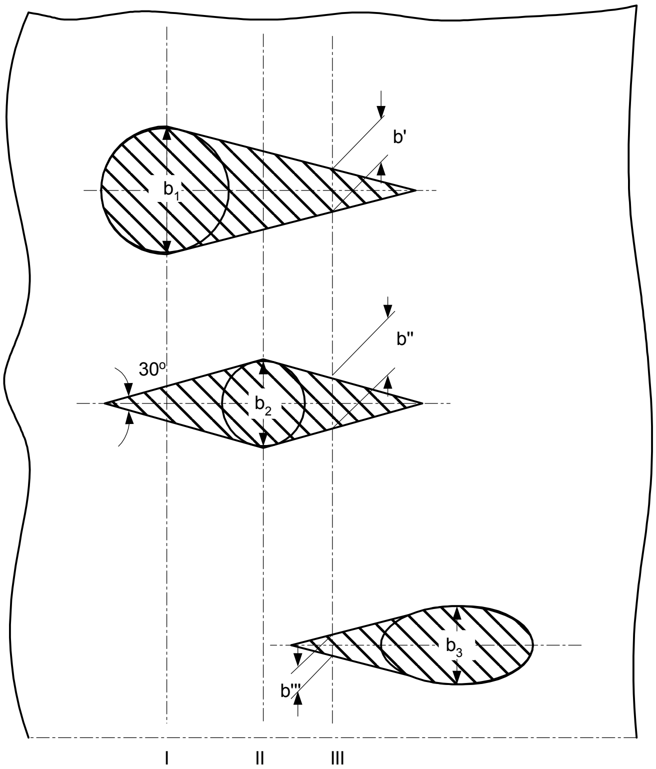


Fig. 1
Effect of openings

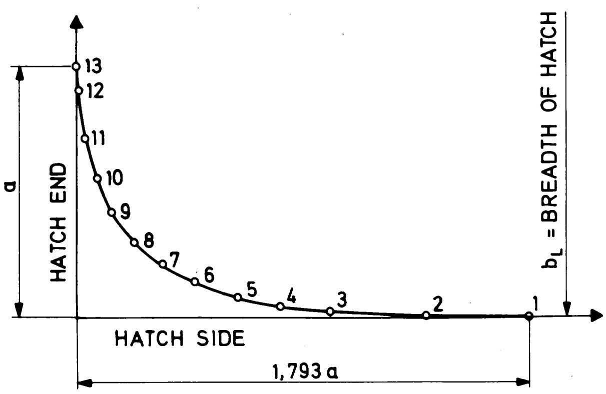


Fig. 2
Streamlined deck corner

304 For very long hatches or if large cut-outs are taken at deck/shipside corners of streamlined shape may be required.

Reinforcement of the deck plating may also be considered.

305 Alternative hatch corner designs (e.g. key hole) may be accepted subject to special consideration in each case.

D 400 Miscellaneous

401 Edges of openings are to be smooth. Machine flame cut openings with smooth edges may be accepted. Small holes are to be drilled.

Hatch corners may in special cases be required to be ground smooth. Welds to the deck plating within the curved hatch corner region are as far as possible to be avoided.

402 Studs for securing small hatch covers are to be fastened to the top of a coaming or a ring of suitable thickness welded to the deck. The studs are not to penetrate the deck plating.

403 The design of the hatch corners will be specially considered for ships with very large hatch openings («open» ships), where additional local stresses occur in the hatch corner area.

Table D1 Ordinates of streamlined corner

Point	*Abscissa x*	*Ordinate y*
1	1.793 a	0
2	1.381 a	0.002 a
3	0.987 a	0.021 a
4	0.802 a	0.044 a
5	0.631 a	0.079 a
6	0.467 a	0.131 a
7	0.339 a	0.201 a
8	0.224 a	0.293 a
9	0.132 a	0.408 a
10	0.065 a	0.548 a
11	0.022 a	0.712 a
12	0.002 a	0.899 a
13	0	1.000 a

E. Loading Guidance Information

E 100 General

101 All ships covered by Reg. 10 of the Load Line Convention are to be provided with an approved loading manual.

The requirements given in this subsection are considered to fulfil Reg. 10(1) of the Load Line Convention for all classed ships of 65 m in length and above. However, a loading manual, considering longitudinal strength, is not required for a category II ship with length less that 90 m where the maximum deadweight does not exceed 30% of the maximum displacement.

102 All ships of category I (see A202) are in addition to the loading manual to be provided with a loading instrument, approved and certified for calculation and control of hull strength in accordance with the requirements given in Pt.6 Ch.9.

E 200 Conditions of approval of loading manuals

201 The approved loading manual is to be based on the final data of the ship. The manual is to include the design loading conditions and ballast conditions upon which the approval of the hull scantlings is based, see B102.

Possible specifications are:

— draught limitations (in ballast etc.)
— load specifications for cargo decks
— cargo mass and cargo angle of repose restrictions
— cargo density and filling heights for cargo tanks
— restrictions to GM-value.

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

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

E 300 Condition of approval of loading computer systems

301 With respect to the approval of the loading computer system, see Pt.6 Ch.9.

SECTION 5
BOTTOM STRUCTURES

A. General

A 100 Introduction

101 The requirements in this section apply to bottom structures.

Direct stress calculations as outlined in E100 will be considered as alternative basis for the scantlings.

A 200 Definitions

201 Symbols: L, B, D, T, see Sec.1 B.

t = rule thickness in mm of plating
Z = rule section modulus in cm^3 of stiffeners and simple girders
k_a = correction factor for aspect ratio of plate field
= $(1.1 - 0.25\ s/l)^2$
= maximum 1.0 for $s/l = 0.4$
= minimum 0.72 for $s/l = 1.0$
s = stiffener spacing in m, measured along the plating
l = stiffener span in m, measured along the top flange of the member. For definition of span point, see Sec.3 C100. For curved stiffeners l may be taken as the cord length
w_k = section modulus corrosion factor in cargo oil and ballast tanks, see Sec.2 D200
σ = nominal allowable bending stress in N/mm^2 due to lateral pressure
Z_B = midship section modulus in cm^3 as built at bottom
Z_R = rule midship section modulus in cm^3 as given in Sec.4 C101.

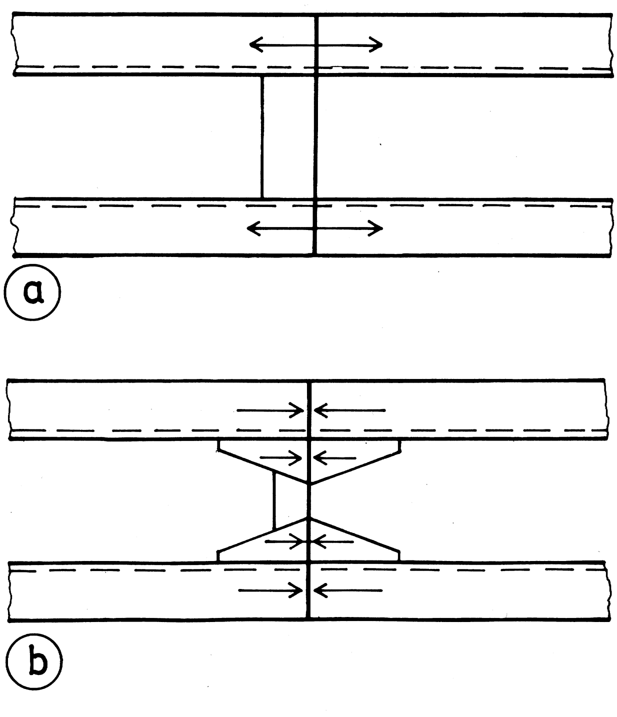


Fig. 1
Longitudinal connections

A 300 Structural arrangement and details

301 When the bottom or inner bottom is longitudinally stiffened the following arrangements of longitudinal connections will normally be accepted (see Fig.1):

1) The longitudinals are normally to be continuous through transverse members within 0.5 L amidships.

2) The longitudinals may be welded against the floors in ships length L < 50 m, and in larger ships outside 0.5 L amidships. Brackets are to be fitted.

302 The bilge keel and the flat bar to which it is attached, is not to terminate abruptly. Ends are to be tapered to an internal stiffening.

303 Weld connections are to satisfy the general requirements given in Ch.1 Sec.11.

304 For end connections of stiffeners and girders, see Sec.3 C.

A 400 Bottom arrangement

401 For passenger vessels and cargo ships other than tankers a double bottom shall be fitted extending from the collision bulkhead to the afterpeak bulkhead, as far as this is practicable and compatible with the design and proper working of the ship.

402 The depth of the double bottom is given in D100. The inner bottom shall be continued out to the ship's side in such a manner as to protect the bottom to the turn of the bilge.

403 Small wells constructed in the double bottom, in connection with the drainage arrangements of holds, are not to extend in depth more than necessary. A well extending to the outer bottom may, however, be permitted if the arrangement gives protection equivalent to that afforded by a double bottom complying with this regulation. In no case shall the vertical distance from the bottom of such a well to a plane coinciding with the keel line be less than 500 mm.

404 A double bottom need not be fitted in way of watertight compartments used exclusively for the carriage of liquids, provided the safety of the ship in the event of a bottom damage is not thereby impaired.

For oil tankers, see Pt.5 Ch.3 Sec.3, for chemical carriers, see Pt.5 Ch.4 Sec.3 and for liquefied gas carriers, see Pt.5 Ch.5 Sec.3.

(SOLAS Ch. II-1)

405 Any part of the ship that is not fitted with a double bottom in accordance with 401 and 404 shall be capable of with-standing bottom damage. Ref.SOLAS Reg.II-1/9.8.

B. Design Loads

B 100 Local loads on bottom structures

101 Generally applicable local loads on bottom structures are given in Table B1. In connection with the various local structures, reference is made to this table, indicating the relevant loads in each case.

Table B1 Design loads

Structure		*p (kN/m²)* 1)
Outer bottom:	Sea pressure	$p_1 = 10\ T + p_{dp}$
	Liquid cargo in tank above	$p_2 = g_0\ \rho\ h_s$
Inner bottom:	Dry cargo in cargo holds	$p_3 = 1.3\ g_0\ \rho_c\ H_C$
	Liquids in tank above 2)	$p_4 = 1.3\ g_0\ \rho\ h_s$ $p_5 = 0.67\ (\rho\ g_0\ h_p + \Delta\ p_{dyn})$ $p_6 = \rho\ g_0\ h_s + p_0$ $p_7 = \rho\ g_0\ (h_s + 0.3\ b)$ $p_8 = \rho\ g_0\ (h_s + 0.1\ l)$
	Minimum pressure	$p_9 = 10\ T$
Floors and girders:	Pressure on tank boundaries in double bottom	$p_{10} = 0.67\ (10\ h_p + \Delta\ p_{dyn})$ $p_{11} = 10\ h_s + p_0$

1) For ships with service restrictions, p_3, p_4 and the last term in p_1 may be reduced as given in Sec.3 B1103.

2) p_7 and p_8 refer to tank sides and ends, respectively.
Adjacent structures to be reinforced accordingly.

T = Rule draught in m, see Sec.1 B

The pressure p_{dp} is taken as:

$$p_{dp} = p_l + 135 \frac{y}{B + 75} - 1.2\,(T - z) \quad (kN/m^2)$$

$p_l = k_s C_W + k_f$

$= (k_s C_W + k_f)\left(0.8 + 0.15 \frac{V}{\sqrt{L}}\right)$ if $\frac{V}{\sqrt{L}} > 1.5$

$k_s = 3C_B + \frac{2.5}{\sqrt{C_B}}$ at AP and aft

$= 2$ between 0.2 L and 0.7 L from AP

$= 3C_B + \frac{4.0}{C_B}$ at F.P. and forward

Between specified areas k_s is to be varied linearly.

a = 1.0 for ship's sides and for weather decks forward of 0.15 L from F.P., or forward of deckhouse front, whichever is the foremost position
= 0.8 for weather decks elsewhere
h_0 = vertical distance from the waterline at draught T to the load point (m)
z = vertical distance from the baseline to the load point, maximum T (m)
y = horizontal distance from the centre line to the load point, minimum B/4 (m)
C_W = 0.0792 L
k_f = the smallest of T and f
f = vertical distance from the waterline to the top of the ship's side at transverse section considered, maximum 0.8 C_W (m)
h_s = vertical distance in m from load point to top of tank
h_p = vertical distance in m from the load point to the top of air pipe
H_C = stowage height in m of dry cargo. Normally the height to 'tween deck or top of cargo hatchway is to be used in combination with a standard cargo density $\rho_c = 0.7\ t/m^3$
ρ_c = dry cargo density in t/m^3, if not otherwise specified to be taken as 0.7
ρ = density of liquid cargo in t/m^3, normally not to be taken less than 1.025 t/m^3
p_0 = 0.3 L – 5 (kN/m^2), minimum 10 generally
= 25 kN/m^2 in cargo tanks
= pressure valve opening pressure when exceeding the general value
b = breadth of tank in m
l = total length of tanks in m.

Δp_{dyn} = calculated pressure drop according to Pt.4 Ch.6 Sec.4 K201.

Guidance note 1:

If the pressure drop according to Pt.4 Ch.6 Sec.4 K201 is not available, Δp_{dyn} may normally be taken as 25 kN/m^2 for ballast tanks and zero for other tanks. If arrangements for the prevention of overpumping of ballast tanks in accordance with Pt.4 Ch.6 Sec.4 K200 are fitted, Δp_{dyn} may be taken as zero.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

Guidance note 2:

When a ship is designed with VCS notation (high-high level alarm) or provided with equivalent systems to prevent overflow through air pipes, the tank pressure for liquid cargo, based on air pipe height h_p, may be omitted.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

B 200 Total loads on double bottom

201 In connection with direct stress calculations on double bottom structures, total loads are to be taken as differences between internal and external pressures. These loads are specified in E100.

C. Plating and Stiffeners

C 100 Keel plate and garboard strake

101 The keel plate or garboard strake is to extend over the complete length of the ship. The breadth is not to be less than:

$$b = 800 + 5\,L \quad \text{(mm)}$$

102 The thickness is not to be less than:

$$t = 7.0 + 0.05\,L + t_k \quad \text{(mm)}$$

The thickness is in no case to be less than that of the adjacent bottom plate.

C 200 Bottom and bilge plating

201 The thickness requirement corresponding to lateral pressure is given by:

$$t = \frac{15.8 k_a s \sqrt{p}}{\sqrt{\sigma}} + t_k \quad \text{(mm)}$$

p = p_1 or p_2 in Table B1
σ = as given in Table C1.

Table C1 Values of σ	
	Allowable stress σ [1)]
Transverse stiffening:	$60\frac{Z_B}{Z_R}$, maximum 120 within 0.4 L 160 within 0.1 L from the perpendiculars
Longitudinal stiffening:	120 within 0.4 L 160 within 0.1 L from the perpendiculars
1) Between specified regions the σ-value may be varied linearly.	

202 The thickness is not to be less than:

$$t = 5.0 + 0.04\,L + t_k \quad \text{(mm)}.$$

203 The thickness of the bilge plate is not to be less than that of the adjacent bottom and side plates whichever is the greater.

204 The thickness of bottom plating is also to comply with the requirements for buckling strength as given in Sec.12.

205 If the bilge plate is not stiffened or has only one stiffener inside the curved plate, the thickness is not to be less than:

$$t = \frac{\sqrt[3]{R^2 l p}}{900} + t_k \quad \text{(mm)}$$

R = radius of curvature
l = distance between circumferential stiffeners, e.g. bilge brackets (mm)
p = $2\,p_1 - 10\,T$ (kN/m^2)

In case of longitudinal stiffening positioned outside the curvature, R is substituted by R1 = R + 0.5 (a + b), see Fig.2. The lengths a and b are normally not to be greater than s/3.

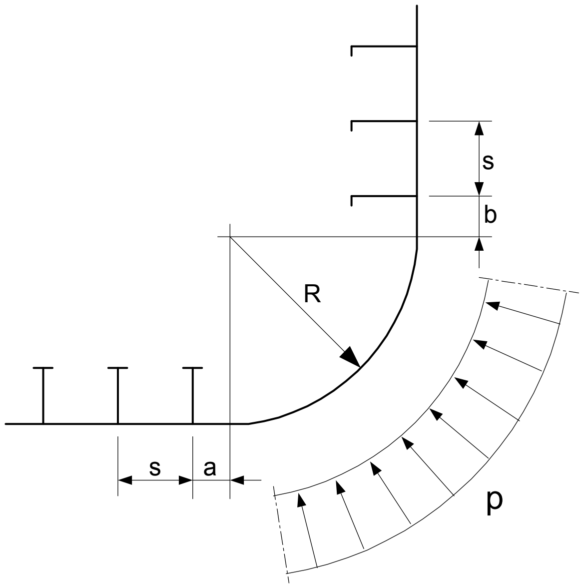


Fig. 2
Bilge without longitudinal stiffening

C 300 Inner bottom plating

301 The thickness requirement corresponding to lateral pressure is given by:

$$t = \frac{15.8 k_a s \sqrt{p}}{\sqrt{\sigma}} + t_k \quad \text{(mm)}$$

p = $p_3 - p_9$ whichever is relevant, as given in Table B1
σ = 140 within 0.4 L
= 160 within 0.1 L from the perpendiculars.

Between specified regions the σ-value may be varied linearly.

302 The thickness is not to be less than:

$$t = t_0 + 0.03\ L + t_k \quad \text{(mm)}$$

t_0 = 7.0 in holds below dry cargo hatchway opening if ceiling is not fitted
= 6.0 elsewhere in holds if ceiling is not fitted
= 5.0 in holds if ceiling is fitted
= 5.0 in void spaces, machinery spaces and tanks.

C 400 Floors and longitudinal girders

401 The thickness requirement of floors and longitudinal girders forming boundaries of double bottom tanks is given by:

$$t = \frac{15.8 k_a s \sqrt{p}}{\sqrt{\sigma}} + t_k \quad \text{(mm)}$$

p = $p_9 - p_{11}$ whichever is relevant, as given in Table B1
= p_1 for sea chest boundaries (including top and partial bulkheads).
σ = 130 within 0.4 L for longitudinal girders
= 160 within 0.1 L from perpendiculars
= 160 for floors.
= 120 f_1 for sea chest boundaries (including top and partial bulkheads)

Between specified regions the σ-value may be varied linearly.

402 The thickness of longitudinal girders, floors, supporting plates and brackets is not to be less than:

$$t = 6 + k\ L + t_k \quad \text{(mm)}$$

k = 0.04 for centre girder

= 0.02 for other girders.
= 0.05 for sea chest boundaries (including top and partial bulkheads).

C 500 Transverse frames

501 The section modulus requirement of bottom and inner bottom frames is given by:

$$Z = 0.63\, l^2\, s\, p\, w_k \quad (cm^3)$$

p = $p_1 - p_9$ whichever is relevant, as given in Table B1.

502 Struts fitted between bottom and inner bottom frames are in general not to be considered as effective supports for the frames.

The requirement given in 501, however, may be reduced after special consideration. When bottom and inner bottom frames have the same scantlings and the strut is at middle length of span a reduction of 35% will be accepted.

503 The thickness of web and flange is not to be less than the larger of:

$t = 4.5 + k + t_k$ (mm)

$$= 1.5 + \frac{h_w \sqrt{f_1}}{g} + t_k$$

k = 0.015 L
h_w = web height in mm
g = 75 for flanged profile webs
= 41 for bulb profiles
= 22 for flat bar profiles.

C 600 Bottom longitudinals

601 The section modulus requirement is given by:

$$Z = \frac{83\, l^2 s\, p\, w_k}{\sigma} \quad (cm^3)$$

p = p_1 or p_2 in Table B1
σ = 95 within 0.4 L when $Z_B = Z_R$
= 160 within 0.4 L when $Z_B \geq 2\, Z_R$
= 160 within 0.1 L from the perpendiculars.

Between specified regions the σ-value may be varied linearly.

602 The thickness of web and flange is not to be less than the larger of:

$t = 4.5 + k + t_k$ (mm)

$$= 1.5 + \frac{h_w \sqrt{f_1}}{g} + t_k$$

k = 0.015 L
h_w = web height in mm
g = 75 for flanged profile webs
= 41 for bulb profiles
= 22 for flat bar profiles.

603 Struts fitted between bottom and inner bottom longitudinals are in general not to be considered as effective supports for the longitudinals.

The requirements given in 601, however, may be reduced after special consideration. When bottom and inner bottom longitudinals have the same scantlings and the strut is at middle length of span, a reduction of 35% will be accepted.

604 A longitudinal is to be fitted at the bottom where the curvature of the bilge plate starts.

C 700 Inner bottom longitudinals

701 The section modulus requirement is given by:

$$Z = \frac{83\, l^2 s\, p\, w_k}{\sigma} \quad (cm^3)$$

p = p_3 to p_9 whichever is relevant, as given in Table B1
σ = 110 within 0.4 L when $Z_B = Z_R$
= 160 within 0.4 L when $Z_R \geq 2\, Z_R$
= 160 within 0.1 L from the perpendiculars.

Between specified regions the σ-value may be varied linearly.

C 800 Stiffening of floors and girders

801 The section modulus requirement of stiffeners on floors and longitudinal girders forming boundary of double bottom tank is given by:

$$Z = \frac{100\, l^2 s\, p\, w_k}{\sigma} \quad (cm^3)$$

p = p_9 to p_{11} whichever is relevant, as given in Table B1
= p_1 for sea chest boundaries (including top and partial bulkheads).
σ = 140 within 0.4 L for longitudinal stiffeners
= 160 within 0.1 L from perpendiculars
= 160 for other stiffeners.
= 120 f_1 for sea chest boundaries (including top and partial bulkheads)

Between specified regions the σ-value may be varied linearly.

802 Stiffeners in accordance with the requirement in 801 are assumed to have end connections. When Z is increased by 40%, however, stiffeners other than longitudinals may be sniped at ends if the thickness of plating supported by the stiffener is not less than:

$$t = 1.25\sqrt{(l - 0.5s)\, s\, p} + t_k \quad (mm)$$

803 The thickness of web and flange is not to be less than the larger of:

t = $4.5 + k + t_k$ (mm)

$$= 1.5 + \frac{h_w \sqrt{f_1}}{g} + t_k$$

k = 0.015 L
h_w = web height in mm
g = 75 for flanged profile webs
= 41 for bulb profiles
= 22 for flat bar profiles.

804 The longitudinal girders are to be stiffened at every transverse frame.

805 The longitudinal girders are to be satisfactorily stiffened against buckling.

D. Arrangement of Double Bottom

D 100 General

101 Where a double bottom is required to be fitted the inner bottom shall be continued out to the ship side in such a manner as to protect the bottom to the turn of bilge. Such protection will 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:

$$h = 1000 \cdot B/20 \text{ (mm), minimum 760 mm}$$

The height, h, need not be taken more than 2000 mm.

The height is to be sufficient to give good access to all parts of the double bottom. For ships with a great rise of floors, the minimum height may have to be increased after special consideration.

Guidance note:

In the engine room, the height of the tank top above the keel should be 45% and 30% greater than the required centre girder height, respectively, with and without a sump in way of the main engine.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

D 200 Double bottom with transverse framing

201 Side girders are to be fitted so that the distance between the side girders and the centre girder or the margin plate or between the side girders themselves does not exceed 4 m. In the engine room additional side girders are normally to be fitted.

202 Under the main engine, girders extending from the bottom to the top plate of the engine seating, are to be fitted. The height of the girders is not to be less than that of the floors. If the engine is bolted directly to the inner bottom, the thickness of the plating in way of the engine is to be at least twice the rule thickness of inner bottom plating given in C300.

Engine holding-down bolts are to be arranged as near as practicable to floors and longitudinal girders.

Guidance note:

The thickness of the top plate of seatings for main engine and reduction gear should preferably not be less than:

$t = 25$ mm for $P_S \leq 1000$ kW

$t = 30$ mm for $1000 < P_S \leq 1750$ kW

$t = 35$ mm for $1750 < P_S \leq 2500$ kW

$t = 40$ mm for $2500 < P_S \leq 3500$ kW

$t = 45$ mm for $P_S > 3500$ kW

P_S = maximum continuous output of propulsion machinery.

The thickness of the engine girders should preferably not be less than 40 per cent of the recommended top plate thickness.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

203 The floor spacing is normally not to be greater than given in Table D1. In the engine room floors are to be fitted at every frame. In way of thrust bearing and below pillars, additional strengthening is to be provided.

Table D1 Plate floors

Draught in m	*Under deep tanks* 1)	*Clear of deep tanks and machinery space* 2)
$T \leq 2$	Every 4th frame	Every 6th frame
$2 < T \leq 5.4$	Every 3rd frame	Every 5th frame
$5.4 < T \leq 8.1$	Every 3rd frame	Every 4th frame
$T > 8.1$	Every 2nd frame	Every 3rd frame

1) With height greater than 0.7 times the distance between the inner bottom and the main deck.

2) The distance between plate floors is not to exceed 3 m.

204 Supporting plates for the transverse bottom frames are to be fitted at the centre girder and the margin plate on frames without floors. The breadth is to be at least one frame spacing, and the free edge is to be provided with a flange.

D 300 Double bottom with longitudinal framing

301 Side girders are to be fitted so that the distance between the side girders and the centre girder or the margin plate or between the side girders themselves does not exceed 5 m. In the engine room additional side girders are normally to be fitted.

302 Under the main engine, girders extending from the bottom to the top plate of the engine seating, are to be fitted. The height of the girders is not to be less than that of the floors. If the engine is bolted directly to the inner bottom, the thickness of the plating in way of the engine is to be at least twice the rule thickness of inner bottom plating given in C300.

Engine holding-down bolts are to be arranged as near as practicable to floors and longitudinal girders.

303 The floor spacing is normally not to be greater than 3.6 m. In way of deep tanks with height exceeding 0.7 times the distance between the inner bottom and the main deck, the floor spacing is normally not to exceed 2.5 m. In the engine room, floors are to be fitted at every second side frame. Bracket floors are to be fitted at intermediate frames, extending to the first ordinary side girder outside the engine seating.

In way of thrust bearing and below pillars additional strengthening is to be provided.

304 Supporting plates are to be fitted at the centre girder. The free edge of the supporting plates is to be provided with flange. The breadth of supporting plates is to be at least one longitudinal spacing.

The spacing is normally not to exceed two frame spacings. Between supporting plates on the centre girder docking brackets are to be fitted.

Alternative arrangements of supporting plates and docking brackets require special consideration of local buckling strength of centre girder/duct keel and local strength of docking longitudinal subject to the forces from docking blocks.

E. Single Bottom Girders

E 100 General

101 The strength of single bottom girders within cargo area should generally be based on direct stress calculations.

102 The calculation should be based on a 2- or 3- dimensional frame analysis with the following loadings:

In ships with possibility for uneven loading of cargo it should be assumed that the bottom will be subject to external water pressure equal to 10 T + 0.12 L (kN/m^2) with empty hold.

In ships with even loading the net external load (i.e. sea pressure — part load in hold) on the bottom should not be taken less than 5 T + 0.12 L (kN/m^2).

The load on bottom in cargo holds intended for liquid with specific gravity greater than 1 t/m^3 will be specially considered.

103 Acceptable stress levels for the calculation will be:

σ = 160 N/mm^2 for transverse structural elements
= as given for bottom longitudinals in C600
τ = 90 N/mm^2.

104 The strength of single bottom girders outside holds for liquid cargo may also be based on the requirements given in 200.

E 200 Arrangement of single bottom girders outside holds for liquid cargo

201 If direct stress calculations of the single bottom girders are not carried out the following requirements may be applied.

202 The height of centre girder and floors at centre line is not to be less than:

$$h = 250 + 20\,B + 50\,T \quad \text{(mm)}.$$

203 Floors are to be fitted at every frame.

204 A centre line girder is to be fitted.

205 Side girders are normally to have spacing not exceeding 2.5 m. Forward of 0.25 L from F.P. the spacing should not exceed 1.25 m.

E 300 Scantlings

301 The flange area of floors and side girders with minimum height in accordance with 201 is normally not to be less than:

3.5 T (cm^2) in way of cargo holds and
5.0 T (cm^2) in way of engine room.

When cement is filled to top of floors, the flange may be omitted in cargo holds.

302 Within 0.5 L amidships the centre girder flange area is not to be less than:

$$A = 0.6\,L \quad (\text{cm}^2)$$

303 The flange area of side girders and centre girder outside 0.5 L may be 80% of the value given in 301 and 302.

304 The minimum height of floors anywhere between the engine or gear girders is not to be less than 50% of the height given in 202. For this reduction the requirement for flange area given in 301 is to be increased by 100% and the web thickness by 50%. For intermediate reduced heights the increase of flange area should be correspondingly.

305 The thickness of web plates, flanges, stiffeners and brackets is not to be less than:

$$t = 6 + k\,L + t_k \quad \text{(mm)}$$

k = 0.04 for centre girder

= 0.02 elsewhere
= 0.01 for stiffeners of girders.

The thickness of girder web plates is in addition not to be less than:

$$t = 15\ s + t_k$$

s = spacing of web stiffening in m.

For thickness of top plate of seatings for main engine and reduction gear, see C202.

306 Girder flanges are to have a thickness not less than 1/30 of the flange width when the flange is symmetrical, and not less than 1/15 of the flange width when the flange width is asymmetrical. The width is not to be less than 1/20 of the distance between tripping brackets.

307 For stiffening of girders, see Sec.3 C600.

F. Peak Tank Girders

F 100 General

101 In the after peak of single screw ships, the floors are to have such a height that their upper edge is well above the sterntube.

102 The thickness of floors is not to be less than:

$$t = 6 + 0.02\ L + t_k \quad \text{(mm)}.$$

G. Special Requirements

G 100 Bar keel

101 The scantlings are not to be less than:

— depth: 100 + 1.5 L (mm)
— thickness: 10 + 0.6 L (mm).

G 200 Vertical struts

201 Where bottom and inner bottom longitudinals or frames are supported by vertical struts, the sectional area of the strut is not to be less than:

$$A = k\ l\ s\ T \quad (\text{cm}^2)$$

k = 0.7 in way of ballast tanks
= 0.6 elsewhere
l = stiffener span in m disregarding the strut.

The moment of inertia of the strut is not to be less than:

$$I = 2.5\ h^2_{db}\ A \quad (\text{cm}^4)$$

h_{db} = double bottom height in m.

G 300 Strengthening against slamming

301 The strengthening is to be based on the minimum forward draught in a departure/arrival ballast condition where ballast is carried in dedicated ballast tanks only.

302 The flat part of the bottom forward may have to be strengthened against slamming. The slamming pressure forward of 0.25 L from F.P. may be taken as:

$$p_{sl} = 240\sqrt{L}\left(1 - \frac{20\,d_b}{L}\right) \quad (\text{kN/m}^2)$$

d_b = design ballast draught in m at F.P.

Aft of 0.25 L the slamming pressure may be reduced linearly to zero at 0.45 L from F.P.

For ships with service restriction notations the strengthening will be specially considered.

303 If the bottom has a rise of floor greater than 15 degrees, strengthening against slamming may be omitted.

304 The thickness of the bottom plating is not to be less than:

$$t = 0.9s\sqrt{p_{sl}} + t_k \quad \text{(mm)}$$

305 Above the strengthened area the thickness is to be gradually reduced to the ordinary requirement at side. For vessels with rise of floor, however, reduction will not be accepted below the bilge curvature.

306 The section modulus of longitudinals or transverse stiffeners supporting the bottom plating defined in 303 and 304 is not to be less than:

$$Z = 0.2\, l^2\, s\, p_{sl}\, w_k \quad (\text{cm}^3).$$

307 If the ballast draught is less than 0.025 L, the following additional floors and longitudinal girders will be required in the slamming area:

Alternative 1: Floors at every frame. Additional side girders.
Alternative 2: Floors at every second frame, side girders at maximum spacing 1.5 m.

If the ballast draught is greater than 0.05 L, the floor and longitudinal girder arrangement should comply with the general rule requirements.

For intermediate draughts the floor and girder arrangement will be specially considered, especially with respect to shear areas of the webs.

The design ballast draught forward will be stated in the appendix to the classification certificate.

G 400 Strengthening for grab loading and discharging - Optional class - special features notation IB-X

401 Vessels with inner bottom, and adjacent bulkheads over a width (measured along the plate) of 1.5 m, and strengthened in accordance with the requirement given in 402 may have the notation **IB-X** assigned, where **X** denotes areas especially strengthened, as specified below:

IB-1 Strengthening of inner bottom.
IB-2 Strengthening of inner bottom, and lower part of transverse bulkhead.
IB-3 Strengthening of inner bottom, and lower part of transverse and longitudinal bulkhead.

402 The plate thickness shall not be less than:

$$t = 9.0 + \frac{12s}{\sqrt{f_1}} + t_k \quad \text{(mm)}$$

SECTION 6
SIDE STRUCTURES

A. General

A 100 Introduction

101 The requirements in this section apply to ship's side structure.

A 200 Definitions

201 Symbols:

L, B, D, T, C_B, see Sec.1 B.

t = rule thickness in mm of plating
Z = rule section modulus in cm^3 of stiffeners and girders
k_a = correction factor for aspect ratio of plate field
= $(1.1 - 0.25\ s/l)^2$
= maximum 1.0 for $s/l = 0.4$
= minimum 0.72 for $s/l = 1.0$
s = stiffener spacing in m, measured along the plating
l = stiffener span in m, measured along the topflange of the member. For definition of span point, see Sec.3 C100. For curved stiffeners *l* may be taken as the cord length
S = girder span in m
w_k = section modulus corrosion factor in tanks, see Sec.2 D200
= 1.0 in other compartments
σ = nominal allowable bending stress in N/mm^2 due to lateral pressure
p = design pressure in kN/m^2 as given in B
Z_A = midship section modulus in cm^3 as built at deck or bottom respectively
Z_R = rule midship section modulus in cm^3 as given in Sec.4 C101.

202 The load point where the design pressure is to be calculated is defined for various strength members as follows:

— for plates: Midpoint of horizontally stiffened plate field. Half of the stiffener spacing above the lower support of vertically stiffened plate field, or at lower edge of plate when the thickness is changed within the plate field
— for stiffeners: Midpoint of span. When the pressure is not varied linearly over the span, the design pressure is to be taken as the greater of:

$$p_m \quad \text{and} \quad \frac{p_a + p_b}{2}$$

p_m, p_a and p_b are calculated pressures at the midpoint and at each end respectively, see Fig.1
— for girders: Midpoint of load area.

A 300 Structural arrangement and details

301 Within 0.5 L amidships, in the areas 0.15 D above the bottom and 0.15 D below the strength deck, the continuity of side longitudinals is to be as required for bottom and deck longitudinals, respectively.

302 Weld connections are to satisfy the general requirements given in Ch.1 Sec.11.

303 For end connections of stiffeners and girders, see Sec.3 C.

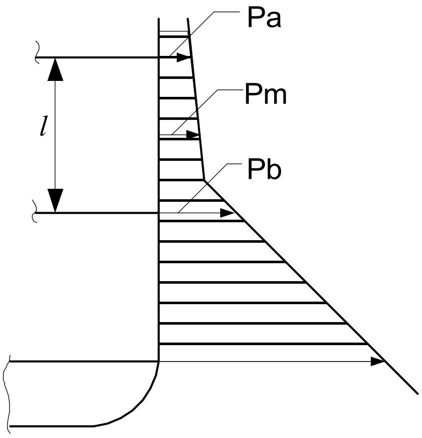


Fig. 1
Design pressures

B. Design Loads

B 100 Local loads on side structures

101 Generally applicable local loads on side structures are given in Table B1. In connection with the various local structures, reference is made to this table, indicating the relevant loads in each case.

Table B1 Design loads	
Load type	*p (kN/m²)*
Sea pressure below summer load waterline	$p_1 = 10\ h_0 + p_{dp}$ 1)
Sea pressure above summer load waterline	$p_2 = (p_{dp} - (4 + 0.2\ k_s)\ h_0)$ 1) minimum 6.25 + 0.025 L
Ballast, bunker or liquid cargo in side tanks in general 2) 3)	$p_3 = k\ \rho\ g_0\ h_s$ $p_4 = \rho\ g_0\ h_s + p_0$ $p_5 = 0.67\ (\rho\ g_0\ h_p + \Delta\ p_{dyn})$ $p_6 = \rho\ g_0\ (h_s + 0.3\ b)$ $p_7 = \rho\ g_0\ (h_s + 0.1\ l)$
1) For ships with service restrictions, p_2 and the last term in p_1 may be reduced as given in Sec.3 B1103.	
2) p_7 is to be applied for 25% of length of tank measured from the tank ends.	
3) For partly filled tanks, see also Sec.8 Table B1.	

h_0 = vertical distance in m from the waterline at draught T to the load point
p_{dp}, k_s = as given in Sec.5 B101
k = 1.3 aft of 0.2 L from F.P.
= 1.5 within 0.2 L from F.P.
L = ship length
h_s = vertical distance in m from load point to top of tank, excluding smaller hatchways
h_p = vertical distance in m from the load point to the top of air pipe
ρ = density of ballast, bunker or liquid cargo in t/m³, normally not to be less than 1.025 (i.e. $\rho\ g_0 \approx 10$)
p_0 = 0.3 L – 5 (kN/m²), minimum 10 generally
= 25 kN/m² in cargo tanks
= pressure valve opening pressure when exceeding the general value
b = breadth of tank in m
l = total length of tank in m.
$\Delta\ p_{dyn}$ = as given in Sec.5 B100.

Guidance note:

When a ship is designed with VCS notation (high-high level alarm) or provided with equivalent systems to prevent overflow through air pipes, the tank pressure for liquid cargo, based on air pipe height h_p, may be omitted.

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C. Plating and Stiffeners

C 100 Side plating, general

101 The thickness requirement corresponding to lateral pressure is given by:

$$t = \frac{15.8\, k_a\, s \sqrt{p}}{\sqrt{\sigma}} + t_k \quad \text{(mm)}$$

p = p_1 to p_7, whichever is relevant, as given in Table B1
σ = as given in Table C1.

102 The thickness is not for any region of the ship to be less than:

$$t = 5.0 + k\,L + t_k \quad \text{(mm)}$$

k = 0.04 up to 4.6 m above the summer load waterline. For each 2.3 m above this level the k-value may be reduced by 0.01 (k (minimum) = 0).
= 0.06 for plating connected to the sternframe.

103 If the end bulkhead of a superstructure is located within 0.5 L amidships, the side plating should be given a smooth transition to the sheer strake below.

Table C1 Allowable stresses

	Allowable stress σ 1)
Transverse stiffening:	120 within 0.4 L at neutral axis $60 \frac{Z_A}{Z_R}$ maximum 120 within 0.4 L at deck or bottom 160 within 0.1 L from the perpendiculars
Longitudinal stiffening:	140 within 0.4 L at neutral axis 120 within 0.4 L at deck or bottom 160 within 0.1 L from the perpendiculars
1) Between specified regions the σ-value may be varied linearly.	

C 200 Sheer strake at strength deck

201 The breadth is not to be less than:

$$b = 800 + 5\,L \quad \text{(mm)}.$$

202 The thickness is not to be less than:

$$t = \frac{t_1 + t_2}{2} \quad \text{(mm)}$$

t_1 = required side plating in mm
t_2 = strength deck plating in mm, not to be taken less than t_1.

203 The thickness of sheer strake is to be increased by 30% on each side of a superstructure end bulkhead located within 0.5 L amidships if the superstructure deck is a partial strength deck.

204 Cold rolling and bending of rounded sheer strakes are not accepted when the radius of curvature is less than 15 t.

205 When it is intended to use hot forming for rounding of the sheer strake, all details of the forming and heat treatment procedures are to be submitted to the Society for approval. Appropriate heat treatment subsequent to the forming operation will normally be required.

Where the rounded sheer strake towards ends forward and aft transforms into a square corner, line flame heating may be accepted to bend the sheer strake.

206 The welding of deck fittings to rounded sheer strakes is to be kept to a minimum within 0.6 L amidships. Subject to the surveyor's consent, such welding may be carried out provided:

— when cold formed, the material is of grade NV D or a grade with higher impact toughness
— the material is hot formed in accordance with 205.

The weld joints are to be subjected to magnetic particle inspection.

The design of the fittings is to be such as to minimize stress concentrations, with a smooth transition towards deck level.

207 Where the sheer strake extends above the deck stringer plate, the top edge of the sheer strake is to be kept free from notches and isolated welded fittings, and is to be ground smooth with rounded edges. Drainage openings with smooth transition in the longitudinal direction may be allowed.

208 Bulwarks are in general not to be welded to the top of the sheer strake within 0.6 L amidships. Such weld connections may, however, be accepted upon special consideration of design (i.e. expansion joints), thickness and material grade.

C 300 Longitudinals

301 The section modulus requirement is given by:

$$Z = \frac{83\, l^2 s\, p\, w_k}{\sigma} \quad (\text{cm}^3), \text{ minimum } 15 \text{ cm}^3$$

p = p_1 to p_7, whichever is relevant, as given in Table B1
σ = 95 at deck or bottom within 0.4 L when $Z_A = Z_R$
= 160 at deck or bottom within 0.4 L when $Z_A \geq 2\, Z_R$
= 160 within 0.25 D above and below the neutral axis
= 160 within 0.1 L from the perpendiculars.

Between specified regions σ-value may be varied linearly.

302 The thickness of web and flange is not to be less than the larger of:

$$t = 4.5 + k + t_k \quad (\text{mm})$$

$$= 1.5 + \frac{h_w \sqrt{f_1}}{g} + t_k$$

k = 0.01 L in general
= 0.015 L in peaks and in cargo oil tanks and ballast tanks in cargo area
h_w = web height in mm
g = 75 for flanged profile webs
= 41 for bulb profiles
= 22 for flat bar profiles.

C 400 Main frames

401 Main frames are frames located outside the peak tanks, connected to the floors or the double bottom and extending to the lowest deck or stringer on the ship's side.

402 The section modulus requirement is given by the greater of:

$$Z = 0.5\, l^2\, s\, p\, w_k \quad (\text{cm}^3) \quad \text{and}$$

$$Z = 6.5 \sqrt{L} \quad (\text{cm}^3)$$

p = p_1 to p_7, whichever is relevant, as given in Table B1.

403 The thickness of web and flange is not to be less than given in 302.

404 The requirement given in 402 is based on the assumption that effective brackets are fitted at both ends.

The length of brackets is not to be less than:

— 0.12 l for the lower bracket
— 0.07 l for the upper bracket.

where

l = full length of frame including brackets.

The section modulus of frame including bracket is not to be less than:

— 2 Z at lower end
— 1.7 Z at upper end

Z = as given in 402.

When the length of the free edge of the bracket is more than 40 times the plate thickness, a flange is to be fitted, the width being at least 1/15 of the length of the free edge.

405 Brackets may be omitted provided the frame is carried through the supporting member and the section modulus is not less than:

$$1.5\ Z$$

Z = as given in 402 with total span applied.

406 The section modulus for a main frame is not to be less than that for the 'tween deck frame above.

407 The inner edge of frames at hatch end beams is to be reinforced to withstand additional bending moments from the deck structure after special consideration.

C 500 Tween deck frames and vertical peak frames

501 'Tween deck frames are frames between the lowest deck or the lowest stringer on the ship's side and the uppermost superstructure deck between the collision bulkhead and the after peak bulkhead.

502 If the lower end of 'tween deck frames is not welded to the bracket or the frame below, the lower end is to be bracketed above the deck. For end connections, see also Sec.3 C200.

503 The section modulus is not to be less than the greater of:

$$Z = 0.55\ l^2\ s\ p\ w_k \quad (cm^3) \quad \text{and}$$

$$Z = k\sqrt{L} \quad (cm^3)$$

k = 6.5 for peak frames
  = 4.0 for 'tween deck frames

p = p_1 to p_7, whichever is relevant, as given in Table B1.

504 The thickness of web and flange is not to be less than given in 302.

505 The requirement for section modulus given in 503 may be modified as for main frames in 402 provided effective brackets as given in 404 are fitted at both ends.

D. Girders

D 100 General

101 The web plate thickness and the thickness of flanges, brackets and stiffeners on girders is not to be less than:

$$t = 5.0 + k\ L + t_k \quad (mm)$$

k = 0.03 for peak tank girders
  = 0.02 for girders in cargo/ballast tanks in liquid cargo tank areas
  = 0.01 for other girders and for stiffeners on girders in general.

The thickness of girder web plates in single skin constructions is in addition not to be less than:

$$t = 12\ s + t_k \quad (mm)$$

s = spacing of web stiffening in m.

102 In the after peak, engine and boiler room, side verticals are normally to be fitted at every 5th frame.

103 Verticals in the engine room and verticals less than 0.1 L from the perpendiculars are to have a depth not less than:

$$h = 2\ L\ S \quad (mm),\ \text{maximum } 200\ S.$$

104 Girder flanges are to have a thickness not less than 1/30 of the flange width when the flange is symmetrical, and not less than 1/15 of the flange width when the flange is asymmetrical.

For girders in engine room the total flange width is not to be less than 35 S mm.

105 Transverse bulkheads or side verticals with deck transverses are to be fitted in the 'tween deck spaces to ensure adequate transverse rigidity.

106 Vertical peak frames are to be supported by stringers or decks at a vertical distance not exceeding 2.5 m.

107 The end connections and stiffening of girders are to be arranged as given in Sec.3 C.

D 200 Simple girders

201 The section modulus requirement is given by:

$$Z = \frac{100\ S^2 b\ p\, w_k}{\sigma} \qquad (cm^3)$$

p = $p_1 - p_4$
= 1.15 p_5
= $p_6 - p_7$, whichever is relevant, as given in Table B1.
b = loading breadth in m
σ = as given in C300 for continuous longitudinal girders
= 160 f_1 for other girders.

The above requirement apply about an axis parallel to the ship's side.

202 The web area requirement (after deduction of cut-outs) at the girder ends is given by:

$$A = k\ S\ b\ p + 10\ h\ t_k \quad (cm^2)$$

k = 0.06 for continuous horizontal girders and upper end of vertical girders
= 0.08 for lower end of vertical girders
b = as given in 201
h = girder height in m
p = p_1 to p_7, whichever is relevant, as given in Table B1.

The web area at the middle of the span is not to be less than 0.5 A.

The above requirement apply when the web plate is perpendicular to the ship's side.

For oblique angles the requirement is to be increased by the factor 1/cos θ, where θ is the angle between the web plate of the girder and the perpendicular to the ship's side.

D 300 Complex girder systems

301 In addition to fulfilling the general local requirements given in 100, the main scantlings of girders being parts of a complex system may have to be based on a direct stress analysis.

E. Special Requirements

E 100 Bar stem

101 If bar stem is fitted the scantlings are not to be less than:

— width: 90 + 1.2 L below summer load waterline
70 + 0.9 L at the stem head
— thickness: 12 + 0.48 L.

The stem width is to be gradually tapered from the waterline to the stem head.

E 200 Strengthening against bow impact

201 For vessels with high speed, well rounded bow lines and/or large flare, special strengthening of the bow region is to be considered, see Ch.1 Sec.7 E100.

SECTION 7
DECK STRUCTURES

A. General

A 100 Introduction

101 The requirements in this section apply to ship's deck structure.

A 200 Definitions

201 Symbols:

L, B, D, T, C_B, see Sec.1 B.

Z = rule section modulus in cm^3 of stiffeners and simple girders
k_a = correction factor for aspect ratio of plate field
= $(1.1 – 0.25\ s/l)^2$
= maximum 1.0 for $s/l = 0.4$
= minimum 0.72 for $s/l = 1.0$
s = stiffener spacing in m, measured along the plating
l = stiffener span in m, measured along the top flange of the member. For definition of span point, see Sec.3 C100. For curved stiffeners l may be taken as the cord length
S = girder span in m. For definition of span point, see Sec.3 C100
w_k = section modulus corrosion factor in tanks, see Sec.2 D200
= 1.0 in other compartments
σ = nominal allowable bending stress in N/mm^2 due to lateral pressure
p = design pressure in kN/m^2 as given in B
Z_D = midship section modulus in cm^3 as built at deck
Z_R = rule midship section modulus in cm^3 as given in Sec.4 C101.

A 300 Structural arrangement and details

301 When the strength deck is longitudinally stiffened:

— the longitudinals are normally to be continuous at transverse members within 0.5 L amidships
— the longitudinals may be cut at transverse members. In that case continuous brackets connecting the ends of the longitudinals are to be fitted
— the longitudinals may be welded against the transverse members in ships with length L ≤ 50 m and in larger ships outside 0.5 L amidships provided $Z_D > 2\ Z_R$. Brackets to be fitted.

302 Transverse beams are preferably to be used in deck areas between hatches. The beams are to be efficiently supported by longitudinal girders. If longitudinals are used, the plate thickness is to be increased so that the necessary transverse buckling strength is achieved, or transverse buckling stiffeners are to be fitted intercostally. The stiffening of the upper part of a plane transverse bulkhead (or stool tank) is to be such that the necessary transverse buckling strength is achieved.

Transverse beams are to extend to the second deck longitudinal from the hatch side. Where this is impracticable, stiffeners or brackets are to be placed intercostally in extension of beams.

303 If hatch coaming corners with double curvature or hatch corners of streamlined shape are not adopted, the thickness of deck plates in strength deck at hatch corners is to be increased by 25%.

The longitudinal extension of the thicker platings is not to be less than 1.5 R and not more than 3 R on both sides of the hatch end. The transverse extension outside line of hatches is to be at least 2 R.

R = corner radius.

For shape and radius of corners in large hatch openings, see Sec.4 D300.

304 The seam between the thicker plating at the hatch corner and the thinner plating in the deck area between the hatches is to be located at least 100 mm inside the point at which the curvature of the hatch corner terminates.

If the difference between the deck plate thickness at the hatch corners and in the deck area between hatches is greater than
1/2 of the thickest plate, a transition plate is to be laid between the thick plating and the thin deck area plating.

The material strength group of the transition plate is typically to be of an intermediate strength group to that of the connecting plates.

305 Weld connections are to satisfy the general requirements given in Ch.1 Sec.8.

306 For end connections of girders and stiffeners, see Sec.3 C.

A 400 Construction and initial testing of watertight decks, trunks etc.

.1 Watertight decks, trunks, tunnels, duct keels and ventilators are to be of the same strength as watertight bulkheads at corresponding levels (see Table B, p_{12}). The means for making them watertight, and the arrangements adopted for closing openings in them are to satisfy the requirements of this section and Ch.3 Sec.6. 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 cargo ships.

.2 Where a ventilation trunk passing through a structure penetrates the bulkhead deck, the trunk shall be capable of withstanding the water pressure that may be present within the trunk, after having taken into account the maximum heel angle allowable during intermediate stages of flooding, in accordance with SOLAS Ch. II-1/8.5.

.3 Where all or part of the penetration of the bulkhead deck is on the main ro-ro deck, the trunk shall be capable of withstanding impact pressure due to internal water motions (sloshing) of water trapped on the ro-ro deck.

.4 In ships constructed before 1 July 1997, the requirements of paragraph 2 shall apply not later than the date of the first periodical survey after 1 July 1997.

.5 After completion, a hose or flooding test is to be applied to watertight decks and a hose test to watertight trunks, tunnels and ventilators.

(SOLAS Ch. II-1/19)

B. Design Loads

B 100 Local loads on deck structures

101 Generally applicable local loads on deck structures are given in Table B1. In connection with the various local structures, reference is made to this table, indicating the relevant loads in each case.

Table B1 Design loads

Structure	*p (kN/m²)*
Weather deck 1) 3)	$p_1 = a\,(p_{dp} - (4 + 0.2\,k_s)\,h_0)$ $= \text{minimum } 5.0$
Cargo 'tweendecks	$p_2 = k\,g_0\,q$ $p_3 = k\,\rho_c\,g_0\,H_C$
Platform deck in machinery spaces	$p_4 = k\,g_0\,1.6$
Accommodation decks	$p_5 = k\,g_0\,0.35$
Deck as tank bottom or top in general 2) 4)	$p_6 = k\,\rho\,g_0\,h_s$ $p_7 = 0.67\,(\rho\,g_0\,h_p + \Delta\,p_{dyn})$ $p_8 = \rho\,g_0\,h_s + p_0$ $p_9 = \rho\,g_0\,(h_s + 0.3\,b)$ $p_{10} = \rho\,g_0\,(h_s + 0.1\,l)$
Top of deckhouse	$p_{11} = 4$
Watertight deck submerged in damaged condition 5)	$p_{12} = 10\,h_b$

1) On weather decks combination of the design pressures p_1 and p_2 may be required for deck cargo with design stowage height less than 2.3 m.
2) For partly filled tanks, see Sec.8 Table B1.
3) For ships with service restrictions, p_1 may be reduced by the percentages given in Sec.3 B1103.
4) p_9 and p_{10} refer to tank sides and ends, respectively. Adjacent structures are to be reinforced accordingly.
5) The strength may be calculated with allowable stresses for plating, stiffeners and girders increased by 60.

a = 1.0 for weather decks forward of 0.15L from FP, or forward of deckhouse front, whichever is the foremost position
= 0.8 for weather decks elsewhere

p_{dp}, k_s = as given in Sec.5 B101

h_0 = vertical distance in m from the waterline at draught T to the deck
T = rule draught in m, see Sec.1 B
k = 1.3 aft of 0.2 L from F.P.
= 1.5 forward of 0.2 L
q = deck cargo load in t/m^2, as specified.
Weather decks above cargo holds in dry cargo ships are normally to be designed for a minimum cargo load q_{min} = 1.0.
When it is specially stated that no deck cargo is to be carried, the q_{min} may be disregarded
ρ_c = dry cargo density in t/m^3, if not otherwise specified to be taken as 0.7
ρ = density of ballast, bunker or liquid cargo in t/m^3, normally not to be less than 1.025 (i.e. $\rho\, g_0 \approx 10$)
H_C = stowage height in m of dry cargo. Normally the 'tweendeck height or height to top of cargo hatchway to be used
h_s = vertical distance in m from the load point to top of tank, excluding smaller hatchways
h_p = vertical distance in m from the load point to the top of air pipe
h_b = vertical distance in metres from the load point to the deepest equilibrium waterline in damaged condition obtained from applicable damage stability calculations. The deepest equilibrium waterline in damaged condition should be indicated on the drawing of the deck in question.
The vertical distance is not to be less than up to the margin line (a line drawn at least 76 mm below the upper surface of the bulkhead at side)
p_0 = 0.3 L – 5 (kN/m^2), minimum 10 generally
= 25 kN/m^2 in cargo tanks
= pressure valve opening pressure when exceeding the general value
b = breadth of tank in m
l = total length of tank in m.
Δp_{dyn} = as given in Sec.5 B100.

Guidance note:

When a ship is designed with VCS notation (high-high level alarm) or provided with equivalent systems to prevent overflow through air pipes, the tank pressure for liquid cargo, based on air pipe height h_p, may be omitted.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

C. Plating and Stiffeners

C 100 Strength deck plating

101 The breadth of stringer plate and strakes in way of possible longitudinal bulkheads which are to be of grade B, D or E is not to be less than:

$$b = 800 + 5\,L \quad \text{(mm)}.$$

102 The thickness requirement corresponding to lateral pressure is given by:

$$t = \frac{15.8 k_a s \sqrt{p}}{\sqrt{\sigma}} + t_k \quad \text{(mm)}$$

p = p_1 to p_{10}, whichever is relevant, as given in Table B1
σ = as given in Table C1.

Table C1 Allowable stresses	
	σ (N/mm^2) 1)
Transverse stiffening:	$60 \frac{Z_D}{Z_R}$, maximum 120 within 0.4 L 160 within 0.1 L from the perpendiculars
Longitudinal stiffening:	120 within 0.4 L 160 within 0.1 L from the perpendiculars
1) Between specified regions the σ-value may be varied linearly.	

103 The thickness is not to be less than:

$$t = t_0 + k\,L + t_k \quad \text{(mm)}$$

t_0 = 5.5 for unsheathed weather and cargo decks
= 5.0 for accommodation decks and for weather and cargo decks sheathed with wood or an approved composition
k = 0.02 in vessels with single continuous deck
= 0.01 in vessels with two continuous decks above 0.7 D from the baseline
= 0 in vessels with more than two continuous decks above 0.7 D from the baseline.

104 If the end bulkhead of a long superstructure is located within 0.5 L amidships, the stringer plate is to be increased in thickness for a length of 3 m on each side of the superstructure end bulkhead. The increase in thickness is to be 20%.

105 The thickness of transversely stiffened strength deck should comply with the requirements to buckling strength as given in Sec.12.

C 200 Plating of decks below or above strength deck

201 The thickness requirement corresponding to lateral pressure is given by the formula in 102 when $\sigma = 160$.

202 The thickness of steel decks is not to be less than:

$$t = t_0 + t_k \quad \text{(mm)}$$

t_0 = as given in 103.

C 300 Longitudinals

301 The section modulus requirement is given by:

$$Z = \frac{83\, l^2 s\, p\, w_k}{\sigma} \quad (\text{cm}^3),\ \text{minimum } 15\ \text{cm}^3$$

p = p_1 to p_{10}, whichever is relevant, as given in Table B1
σ = 95 within 0.4 L midship when $Z_D = Z_R$
= 160 within 0.4 L midship when $Z_D \geq 2\,Z_R$
= 160 within 0.1 L from the perpendiculars.

Between the specified regions the σ-value shall be varied linearly.

For definition of other parameters used in the formula, see A200.

302 The thickness of web and flange shall not be less than the larger of:

t = $4.5 + k + t_k$ (mm)

= $1.5 + \frac{h_w \sqrt{f_1}}{g} + t_k$

k = 0.01 L in general
= 0.015 L in peaks and for boundaries of cargo oil tanks and ballast tanks in cargo area
= 0.5 for accommodations decks above strength deck
h_w = web height in mm
g = 75 for flanged profile webs
= 41 for bulb profiles
= 22 for flat bar profiles.
t_k = corrosion addition, see Sec.1B
peaks = extent is defined in Sec.1B.

C 400 Transverse beams

401 The section modulus requirement is given by:

$$Z = 0.63\, l^2\, s\, p\, w_k \quad (\text{cm}^3),\ \text{minimum } 15\ \text{cm}^3$$

p = p_1 to p_{10}, whichever is relevant, as given in Table B1.

402 The thickness of web and flange is not to be less than given in 302.

403 For end connections, see Sec.3 C200.

D. Girders

D 100 General

101 The thickness of web and flange, brackets and stiffeners on girders is not to be less than:

$$t = 5.0 + k\, L + t_k \quad \text{(mm)}$$

k = 0.03 for peak tank girders
= 0.02 for girders in cargo/ballast tanks in liquid cargo tank areas
= 0.01 for other girders and for stiffeners on girders in general.

The thickness of girder web plates is in addition not to be less than:

$$t = 12\, s + t_k \quad \text{(mm)}$$

s = spacing of web stiffening in m.

102 Longitudinal deck girders above tanks are to be fitted in line with transverse bulkhead verticals. The flange area is to be at least 1/7 of the sectional area of the web plate, and the flange thickness is to be at least 1/30 of the flange width.

103 Deck transverses are to be fitted in the lowest deck in engine room, in line with the side verticals. The depth of the deck transverses is to be at least 50% of the depth of the side verticals, web thickness and face plate scantlings being as for side verticals.

104 The thickness of girder stiffeners and brackets is not to be less than given in 101.

105 The end connections and stiffening of girders are to be arranged as given in Sec.3 C.

106 The deck flange of the girder is to comply with the requirements to buckling strength as given in Sec.12.

D 200 Simple girders

201 The section modulus requirement is given by:

$$Z = \frac{100\, S^2 b\, p\, w_k}{\sigma} \quad (\text{cm}^3)$$

p = $p_1 - p_6$
= 1.15 p_7
= $p_8 - p_{10}$ whichever is relevant, as given in Table B1
b = loading breadth in m
σ = allowable stress as given in C301 for longitudinal girders
= 160 for other girders.

202 The web area requirement (after deduction of cut-outs) at the girder ends is given by:

$$A = 0.06\, S\, b\, p + 10\, h\, t_k \quad (\text{cm}^2)$$

p = as given in 201
b = as given in 201
h = girder height in m.

The web area at the middle of the span is not to be less than 0.5 A.

D 300 Complex girder systems

301 In addition to fulfilling the general local requirements given in 100, the main scantlings of deck girders being parts of complex girder systems in holds or tanks for heavy cargo or liquids may have to be based on a direct stress analysis.

E. Special Requirements

E 100 Transverse strength of deck between hatches

101 In ships with large hatch openings, it is to be examined that the effective deck area between hatches is sufficient to withstand the transverse load acting on the ship's sides. Reinforcements to reduce the additional stresses will be considered in each case.

The effective area is defined as:

— deck plating
— transverse beams
— deck transverses
— hatch end beams (after special consideration).

When calculating the effective area, corrosion additions are to be deducted.

The compressive stress is not to exceed 120 N/mm^2 nor 80% of the critical buckling stress of the deck, bulkhead and stool tank plating.

The buckling strength of stiffeners and girders is to be examined.

E 200 Strength of deck outside large hatches

201 The strength of deck and ship's side in way of long and wide hatches as given in Sec.4 A106 is, as applicable, to be examined by direct calculation of bending moments, torsional moments, shear forces and deflections due to loads caused by the sea and the deck cargo as given in Pt.5 Ch.2 Sec.6 C.

E 300 Pillars in tanks

301 Hollow pillars are not accepted.

302 Where the hydrostatic pressure may give tensile stresses in the pillars, their sectional area is not to be less than:

$$A = 0.07\, A_{dk}\, p_t \quad (\text{cm}^2)$$

A_{dk} = deck area in m^2 supported by the pillar
p_t = design pressure p in kN/m^2 giving tensile stress in the pillar.

Doubling plates at ends are not allowed.

SECTION 8
BULKHEAD STRUCTURES

A. General

A 100 Introduction

101 The requirements in this section apply to bulkhead structures.

A 200 Definitions

201 Symbols:

L, B, D, T, C_B, see Sec.1 B.

t = rule thickness in mm of plating
Z = rule section modulus in cm^3 of stiffeners and single girders
k_a = correction factor for aspect ratio of plate field
= $(1.1 - 0.25\ s/\ l)^2$
= maximum 1.0 for $s/\ l = 0.4$
= minimum 0.72 for $s/\ l = 1.0$
s = stiffener spacing in m, measured along the plating. For corrugations, see 203
l = stiffener span in m, measured along the topflange of the member. For definition of span point, see Sec.3 C100. For curved stiffeners l may be taken as the cord length
S = girder span in m. For definition of span point, see Sec.3 C100
w_k = section modulus corrosion factor in tanks, see Sec.2 D200
= 1.0 in other compartments
σ = nominal allowable bending stress in N/mm^2 due to lateral pressure
p = design pressure in kN/m^2 as given in B
Z_A = midship section modulus in cm^3 as built at deck or bottom respectively
Z_R = rule midship section modulus in cm^3 as given in Sec.4 C101.

202 The load point where the design pressure is to be calculated is defined for various strength members as follows:

— for plates: Midpoint of horizontally stiffened plate field. Half of the stiffener spacing above the lower support of vertically stiffened plate field, or at lower edge of plate when the thickness is changed within the plate field
— for stiffeners: Midpoint of span. When the pressure is not varied linearly over the span, the design pressure is to be taken as the greater of:

$$p_m \quad \text{and} \quad \frac{p_a + p_b}{2}$$

p_m, p_a and p_b are calculated pressures at the midpoint and at each end respectively, see Fig.1. Sec.6
— for girders: Midpoint of load area.

203 For corrugated bulkheads the following definition of spacing applies (see Fig.1):

s = s_1 for section modulus calculations
= $1.05\ s_2$ or $1.05\ s_3$ for plate thickness calculations in general
= s_2 or s_3 for plate thickness calculation when 90 degrees corrugations.

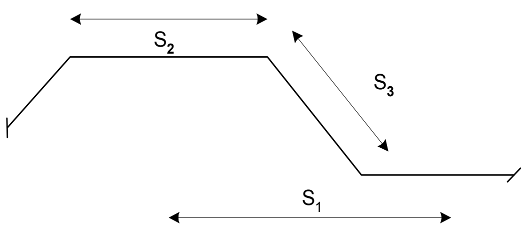

Fig. 1
Corrugated bulkhead

A 300 Structural arrangement and details

301 Number and location of transverse watertight bulkheads are to be in accordance with the requirements given in Sec.3.

302 The peak tanks are to have centre line wash bulkheads when the breadth of the tank is greater than 2/3 of the moulded breadth of the ship.

303 The free distance between transverse tank bulkheads is normally not to exceed 10 m. The free distance may be increased to 0.13 L (when L > 77 m) provided the tank structure is strengthened to resist the additional dynamic load p_8 in tanks with unrestricted filling heights.

If the free distance exceeds 0.13 L (when L > 77 m) the dynamic load will be specially considered.

304 The free breadth of tanks should normally not exceed 0.56 B. For greater breadths the strength of the tank structure will be specially considered

305 Within 0.5 L amidships, in the areas 0.15 D above the bottom and 0.15 D below the strength deck, the continuity of bulkhead longitudinals is to be as required for bottom and deck longitudinals respectively.

306 Weld connections are to satisfy the general requirements given in Sec.11.

307 *Stern tubes shall be enclosed in a watertight space (or spaces) of moderate volume.* In case the stern tube terminates at an afterpeak bulkhead also being a machinery space bulkhead, a pressurized stern tube sealing system may be accepted as an alternative to the watertight enclosure.

(SOLAS Ch. II-1)

B. Design Loads

B 100 Local loads on bulkhead structures

101 Generally applicable local loads on bulkhead structures are given in Table B1. In connection with the various local structures, reference is made to this table, indicating the relevant loads in each case.

Table B1 Design loads

Structure		*p (kN/m²)*
Watertight bulkheads		$p_1 = 10\ h_b$
Cargo hold bulkheads		$p_2 = k\ \rho_c\ g_0\ K\ h_c$ 1)
Tank bulkheads	general	$p_3 = k\ \rho\ g_0\ h_s$ 1) $p_4 = 0.67\ (\rho\ g_0\ h_p + \Delta\ p_{dyn})$ $p_5 = \rho\ g_0\ h_s + p_0$
	sides	$p_6 = \rho\ g_0\ (h_s + 0.3\ b)$ 2)
	ends	$p_7 = \rho\ g_0\ (h_s + 0.1\ l)$ 2) $p_8 = \rho\left[4 - \left(\frac{L}{200}\right)\right] l_b$ 2) 3)

1) For ships with service restrictions, p_2 and p_3 may be reduced as given in Sec.3 B1103.
2) Adjacent ends and sides are to be reinforced for 25% of the breadth and length, respectively. When b > 0.56 B, p_6 is to be specially considered.
3) p_8 refers to tanks with unrestricted filling heights and $10 < l_b < 0.13$ L. When $l > 0.13$ L, p_8 is to be specially considered.

k = 1.3 aft of 0.2 L from F.P.
= 1.5 within 0.2 L from F.P.

h_b = vertical distance in metres from the load point to the deepest equilibrium waterline in damaged condition obtained from applicable damage stability calculations. The deepest equilibrium waterline in damaged condition should be indicated on the drawing of the bulkhead in question.

The vertical distance is not to be less than up to the margin line (a line drawn at least 76 mm below the upper surface of the bulkhead at side)

ρ_c = dry cargo density in t/m³, if not otherwise specified to be taken as 0.7
ρ = density of ballast, bunker or liquid cargo in t/m³, normally not to be taken less than 1.025 (i.e. $\rho\ g_0 \approx 10$)
K = $\sin^2 \alpha \tan^2 (45 - 0.5\ \delta) + \cos^2 \alpha$
= $\cos \alpha$ minimum
α = angle between panel in question and the horizontal plane in degrees
δ = angle of repose of cargo in degrees, not to be taken greater than 20 degrees for light bulk cargo (coal, grain) and not greater than 35 degrees for heavy bulk cargo (ore)

h_s = vertical distance in m from the load point to the top of tank or hatchway excluding smaller hatchways
h_p = vertical distance in m from the load point to the top of air pipe
h_c = vertical distance in m from the load point to the highest point of the hold including hatchway in general. For sloping and vertical sides and bulkheads, h_c may be measured to deck level only, unless the hatch coaming is in line with or close to the panel considered

In dry cargo 'tweendecks, h_c may be taken to the nearest deck above
b = breadth of tank in m
l = total length of tank in m
l_b = free tank length in m
p_0 = 0.3 L – 5 (kN/m^2), minimum 10 generally
= 25 kN/m^2 in cargo tanks
= pressure valve opening pressure when exceeding the general value.
Δp_{dyn} = as given in Sec.5 B100.

Guidance note:
When a ship is designed with VCS notation (high-high level alarm) or provided with equivalent systems to prevent overflow through air pipes, the tank pressure for liquid cargo, based on air pipe height h_p, may be omitted.

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C. Plating and Stiffeners

C 100 Bulkhead plating

101 The thickness requirement corresponding to lateral pressure is given by:

$$t = \frac{15.8\ k_a s \sqrt{p}}{\sqrt{\sigma}} + t_k \quad \text{(mm)}$$

p = $p_1 - p_8$ whichever is relevant, as given in Table B1
σ = as given in Table C1.

Table C1 Allowable stresses

Structure	σ *(N/mm^2)* 1)
Longitudinal bulkhead	Transverse stiffening: 140 within 0.4 L at neutral axis $60\frac{Z_A}{Z_R}$ at deck or bottom 160 within 0.1 L from perpendiculars
	Longitudinal stiffening: 160 within 0.4 L at neutral axis 120 within 0.4 L at deck or bottom 160 within 0.1 L from perpendiculars
Transverse tank bulkheads	160
Collision bulkheads	160
Watertight bulkheads	220
1) Between specified regions the σ-value may be varied linearly.	

102 The thickness is not to be less than:

$$t = 5.0 + k\,L + t_k \quad \text{(mm)}$$

k = 0.03 for longitudinal bulkheads except double skin bulkheads in way of cargo oil tanks and ballast tanks in liquid cargo tank areas
= 0.02 in peak tanks and for transverse and double skin longitudinal bulkheads in way of cargo oil tanks and ballast tanks in liquid cargo tank areas
= 0.01 for other bulkheads.

103 The thickness of longitudinal bulkhead plating not more than 0.1 D above the bottom or below the strength deck is normally to satisfy the buckling strength requirements given in Sec.12.

104 The buckling strength of corrugation flanges at the middle length of corrugations is to be controlled according to Ch.1 Sec.13 B201, taking k*l* equal to 5.

Usage factors to be applied:

η = 0.8 for cargo tank bulkheads, cargo hold bulkheads when exposed to dry cargo or ballast pressure, and collision bulkheads
= 1.0 for watertight bulkheads.

Allowable stresses are given by:

$$\sigma = \eta \sigma_f \left(1 - \frac{\sigma_f}{3.7}\left(\frac{s}{t}\right)^2\right) \quad (\mathrm{N/mm^2})$$

t = net thickness $(t - t_k)$ of corrugation flange in mm
s = breadth of corrugation plate in m
σ_f = 235 N/mm^2 for mild steel.

105 For plates in afterpeak bulkhead in way of sterntube, increased thickness or doubling may be required.

106 For wash bulkhead plating, requirement for thicknesses may have to be based on the reaction forces imposed on the bulkhead by boundary structures.

C 200 Longitudinals

201 The section modulus requirement for stiffeners and corrugations is given by:

$$Z = \frac{83\, l^2 s\, p\, w_k}{\sigma} \quad (\mathrm{cm^3}),\ \text{minimum } 15\ \mathrm{cm^3}$$

p = p_1 to p_8 whichever is relevant, as given in Table B1

σ = 95 at deck or bottom within 0.4 L when $Z_A = Z_R$
= 160 at deck or bottom within 0.4 L when $Z_A \geq 2\, Z_R$
= 160 within 0.25 D above and below the neutral axis
= 160 within 0.1 L from the perpendiculars.

Between specified regions σ-value may be varied linearly.

202 The thickness of web and flange is not to be less than the larger of:

t = $4.5 + k + t_k$ (mm)
= $1.5 + \frac{h_w \sqrt{f_1}}{g} + t_k$

k = 0.01 L in general
= 0.015 L in peaks and in cargo oil tanks and ballast tanks in cargo area
h_w = web height in mm
g = 75 for flanged profile webs
= 41 for bulb profiles
= 22 for flat bar profiles.

C 300 Vertical and transverse stiffeners on tank bulkheads and dry bulk cargo bulkheads

301 Transverse bulkheads for ballast and bulk cargo holds are normally built with strength members only in the vertical direction (corrugations or double plane bulkheads), having unsupported spans from deck to inner bottom.

The scantlings of such bulkheads are to be based on a special calculation, taking into account the reactions from double bottom and deck structure, see Ch.1 Sec.12.

302 The section modulus requirement for simple stiffeners and corrugations is given by:

$$Z = \frac{6.25\, l^2 s\, p\, w_k}{m} \quad (\mathrm{cm^3})$$

p = p_2 to p_8 whichever is relevant, as given in Table B1
m = 7.5 for vertical stiffeners simply supported at one or both ends

= 10 for transverse stiffeners and vertical stiffeners which may be considered fixed at both ends.

303 The thickness of web and flange is not to be less than given in 202.

304 Brackets are normally to be fitted at ends of non- continuous stiffeners. For end connections, see also Sec.3 C200.

C 400 Stiffeners on watertight bulkheads and wash bulkheads

401 The section modulus requirement is given by:

$$Z = \frac{1000\, l^2 s\, p\, w_k}{m \sigma} \quad (cm^3)$$

p = p_1 as given in Table B1 for watertight bulkheads
= p_8 for wash bulkheads
w_k = corrosion factor, see Sec.2 D200
σ = 160 for collision bulkhead
= 220 for other watertight bulkheads
m = 16 for member fixed at both ends
= 12 for member fixed at one end (lower) and simply supported at the other
= 8 for member simply supported at both ends.

The m-value may be adjusted for members with boundary conditions not corresponding to the above specification.

Guidance note:

The m-value is based on plastic deformation at fixed supports and is not to be compared with the bending moment factor corresponding to elastic bending.

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402 The thickness of web and flange is not to be less than given in 202.

D. Girders

D 100 General

101 The web plate thickness and the thickness of, flanges brackets and stiffeners are not to be less than:

$$t = 5.0 + k\,L + t_k \quad (mm)$$

k = 0.03 for peak tank girders
= 0.02 for girders in cargo/ballast tanks in liquid cargo tank areas
= 0.01 for other girders and for stiffeners on girders in general.

The thickness of girder web plates is in addition not to be less than:

$$t = 12\,s + t_k \quad (mm)$$

s = spacing of web stiffening in m.

102 The end connections and stiffening of girders are to be arranged as given in Sec.3 C.

D 200 Simple girders

201 The section modulus requirement is given by:

$$Z = \frac{100\, S^2 b\, p\, w_k}{\sigma} \quad (cm^3)$$

p = $p_1 - p_3$
= 1.15 p_4
= $p_5 - p_8$ whichever is relevant, as given in Table B1
b = loading breadth in m
σ = as given in C200 for continuous longitudinal girders
= 160 for other girders.

The allowable stress may be increased by 60 for watertight bulkheads, except the collision bulkhead, when p_1 is applied.

202 The web area requirement (after deduction of cut-outs) at the girder ends is given by:

$$A = k\,S\,b\,p + 10\,h\,t_k \quad (cm^2)$$

p = as given in 201
k = 0.06 for stringers and upper end of vertical girders
= 0.08 for lower end of vertical girders.
k may be reduced by 25% when watertight bulkheads, except collision bulkhead, when p_1 is applied
b = as given in 201
h = girder height in m.

The web area at the middle of the span is not to be less than 0.5 A.

D 300 Complex girder systems

301 In addition to fulfilling the general local requirements given in 100, the main scantlings of bulkhead girders being parts of complex girder systems in holds or tanks for heavy cargo or liquids, may have to be based on a direct stress analysis.

E. Special Requirements

E 100 Shaft tunnels

101 In ships with engine room situated amidships, a watertight shaft tunnel is to be arranged. Openings in the forward end of shaft tunnels are to be fitted with watertight sliding doors capable of being operated from a position above the load waterline.

102 The thickness of curved top plating may be taken as 90% of the requirement to plane plating with the same stiffener spacing.

103 If ceiling is not fitted on top plating under dry cargo hatchway openings, the thickness is to be increased by 2 mm.

104 The shaft tunnel may be omitted in ships with service area notations **R2, R3, R4** and **RE** provided the shafting is otherwise effectively protected. Bearings and stuffing boxes are to be accessible.

E 200 Corrugated bulkheads

201 The lower and upper ends of corrugated bulkheads and those boundaries of vertically corrugated bulkheads connected to ship sides and other bulkheads are to have plane parts of sufficient width to support the adjoining structures.

202 Girders on corrugated bulkheads are normally to be arranged in such a way that application of the bulkhead as girder flange is avoided.

203 End connections for corrugated bulkheads terminating at deck or bottom are to be carefully designed. Supporting structure in line with corrugation flanges are to be arranged below an inner bottom.

E 300 Supporting bulkheads

301 Bulkheads supporting decks are to be regarded as pillars. The compressive loads and buckling strength are to be calculated as indicated in Sec.9 assuming:

i = radius of gyration in cm of stiffener with adjoining plate. Width of adjoining plate is to be taken as 40 t, where t = plate thickness.

Local buckling strength of adjoining plate and torsional buckling strength of stiffeners are to be checked.

302 Section modulus requirement to stiffeners:

$$Z = 2\,l^2\,s \quad (cm^3).$$

303 The distance between stiffeners is not to be greater than 2 frame spacings, and is not to exceed 1.5 m.

304 The plate thickness is not to be less than 7.5 mm in the lowest hold and 6.5 mm in 'tween decks.

305 On corrugated bulkheads, the depth of the corrugations is not to be less than 150 mm in the lower holds and 100 mm in the upper 'tween deck.

SECTION 9
PILLARS AND SUPPORTING BULKHEADS

A. General

A 100 Introduction

101 The requirements in this section apply to pillars and supporting bulkheads made of mild steel.

A 200 Definitions

201 Symbols:

l = length in m of pillar or bulkhead stiffener
i = $\sqrt{I/A}$ = radius of gyration in cm
I = moment of inertia in cm^4 about the axis perpendicular to the expected direction of buckling
A = cross-sectional area in cm^2.

When calculating I and A for bulkhead stiffeners, a plate flange with breadth equal to 40 t, where t = thickness of bulkhead, may be included.

P = load in kN acting on the pillar or bulkhead stiffener.

Unless otherwise specified P should be based on the deck loadings given in Sec.7 B.

Guidance note:

For round pillars:

$$i = 0.25\sqrt{(\text{Outer diameter})^2 + (\text{Inner diameter})^2}$$

For square hollow pillars:

$$i = 0.29\sqrt{(\text{Outer breadth})^2 + (\text{Inner breadth})^2}$$

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A 300 Cross sectional area

301 The requirement to the sectional area is given by:

$$A = k\,P \quad (cm^2)$$

k is given in Fig.1.

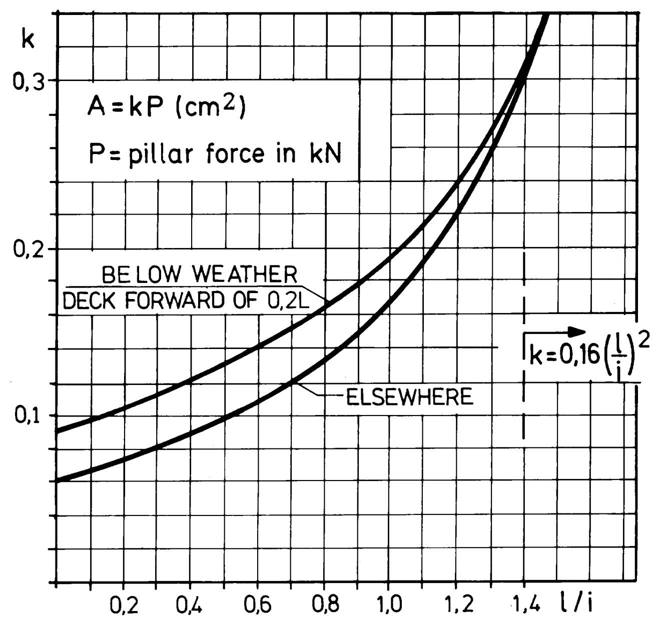

Fig. 1
Values of k

SECTION 10
SUPERSTRUCTURE ENDS, DECKHOUSE SIDES AND ENDS, BULWARKS

A. General

A 100 Introduction

101 In this section the requirements applicable to superstructure end bulkheads, deckhouse sides and ends and bulwarks are collected. The requirements for sides of superstructures and decks above superstructures and deckhouses are given in Sec.7 and 8 respectively.

Requirements for protection of crew as given by ICLL Regulation 25 supplemented by relevant IACS interpretations are also included (see Ch.3 Sec.8). Other relevant requirements given in the ICLL regulations are included in Ch.3 Sec.6.

A 200 Definitions

201 Symbols:

L = rule length in m, see Sec.1 B
B = rule breadth in m, see Sec.1 B
C_B = rule block coefficient, see Sec.1 B
t = rule thickness in mm of plating
Z = rule section modulus in cm^3 of stiffeners and simple girders
L_1 = L, but need not be taken greater than 300 m
k_a = correction factor for aspect ratio of plate field
= $(1.1 - 0.25\, s/\, l)^2$
= maximum 1.0 for $s/\, l = 0.4$
= minimum 0.72 for $s/\, l = 1.0$
s = stiffener spacing in m, measured along the plating
l = stiffener span in m, measured along the topflange of the member. For definition of span point, see Sec.3 C100. For curved stiffeners *l* may be taken as the cord length
f_1 = material factor
= 1.0 for NV-NS steel [1)]
= 1.08 for NV-27 steel [1)]
= 1.28 for NV-32 steel [1)]
= 1.39 for NV-36 steel [1)]
= 1.47 for NV-40 steel [1)]
σ = nominal allowable bending stress in N/mm^2 due to lateral pressure
p = design pressure in kN/m^2 as given in C.

1) For details see Sec.2 B and C.

202 *Superstructure* is defined as a decked structure on the freeboard deck, extending from side to side of the ship or with the side plating not inboard of the shell plating more than 4% of the breadth (B).

203 *Deckhouse* is defined as a decked structure above the strength deck with the side plating being inboard of the shell plating more than 4% of the breadth (B).

Long deckhouse = deckhouse having more than 0.2 L of its length within 0.4 L amidships.

Short deckhouse = deckhouse not defined as a long deckhouse.

B. Structural Arrangement and Details

B 100 Structural continuity

101 In superstructures and deckhouses aft, the front bulkhead is to be in line with a transverse bulkhead in the hull below or be supported by a combination of partial transverse bulkheads, girders and pillars. The after end bulkhead is also to be effectively supported. As far as practicable, exposed sides and internal longitudinal and transverse bulkheads are to be located above tank bulkheads and/or deep girder frames in the hull structure and are to be in line in the various tiers of accommodation. Where such structural arrangement in line is not possible, there is to be other effective support.

102 Sufficient transverse strength is to be provided by means of transverse bulkheads or girder structures.

103 At the break of superstructures, which have no set-in from the ship's side, the side plating of poop and bridge is to extend beyond the ends of the superstructure, and is to be gradually reduced in height down to the sheer strake. The transition is to be smooth and without local discontinuities. A substantial stiffener is to be fitted at the upper edge of plating, which extends beyond the superstructure. The plating is also to be additionally stiffened.

104 The end bulkheads of long superstructures are to be effectively supported by bulkheads or heavy girders below deck.

105 In long deckhouses, openings in the sides are to have well rounded corners. Horizontal stiffeners are to be fitted at the upper and lower edge of large openings for windows.

Openings for doors in the sides are to be substantially stiffened along the edges, and the side plates forming coamings below and above the doors, are to be continuous and extended well beyond the door openings. The thickness is to be increased locally or doubling plates are to be fitted.

The connection area between deckhouse corners and deck plating is to be increased locally.

Deck girders are to be fitted below long deckhouses in line with deckhouse sides. The girders are to extend three frame spaces forward and aft of the deckhouse ends. The depth of the girders is not to be less than that of the beams plus 100 mm. Girders are to be stiffened at the lower edge. The girder depth at ends may be equal to the depth of the beams.

Guidance note:

Expansion of long deckhouse sides should be taken into account by setting in parts of the sides towards the centre line of the ship.

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106 Casings situated within 0.5 L amidships are to be stiffened longitudinally at the strength deck (e.g. at the lower edge of the half beams) to avoid buckling due to longitudinal compression forces.

B 200 Connections between steel and aluminium

201 To prevent galvanic corrosion a non-hygroscopic insulation material is to be applied between steel and aluminium when bolted connection.

202 Aluminium plating connected to steel boundary bar at deck is as far as possible to be arranged on the side exposed to moisture.

203 A rolled compound (aluminium/steel) bar may be used in a welded connection after special approval.

204 Direct contact between exposed wooden materials, e.g. deck planking, and aluminium is to be avoided.

205 Bolts with nuts and washers are either to be of stainless steel or cadmium plated or hot galvanized steel. The bolts are to be fitted with sleeves of insulating material. The spacing is normally not to exceed 4 times the bolt diameter.

206 For earthing of insulated aluminium superstructures, see Pt.4 Ch.8.

B 300 Miscellaneous

301 Companionways situated on exposed decks are to be of steel and efficiently stiffened.

302 Bulwark plates are in general not to be welded to side plating or deck plating (see also Sec.7 C208).

Long bulwarks are to have expansion joints within 0.6 L amidships.

303 Where bulwarks on exposed decks form wells, ample provision is to be made for freeing the decks of water.

304 Weld connections are to satisfy the general requirements given in Sec.11.

C. Design Loads

C 100 External pressure

101 The design sea pressure for the various end and side structures is given in Table C1.

Table C1 Design loads		
Structure		*p (kN/m2)*
Unprotected front bulkheads	General	$p_1 = 5.7\ a\ (k\ C_W - h_o)\ c$
	Minimum lowest tier	$p_2 = 12.5 + 0.05\ L_1$
	Minimum elsewhere	$p_3 = 6.25 + 0.025\ L_1$
Unprotected sides in deckhouses		$p_4 = p_{dp} - (4 + 0.2\ k_s)\ h_o$, minimum p_3
Unprotected aft end bulkheads		$p_5 = 0.85\ p_4$, minimum p_3
1) For ships with service restrictions, p_1 and p_4 may be reduced with the percentages given in Ch.1 Sec.4 B202. C_W should not be reduced.		
2) The minimum design pressure for sides and aft end of deckhouses 1.7 C_W (m) above S.W.L. may be reduced to 2.5 kN/m^2.		

a = $2.0 + \frac{L}{120}$ maximum 4.5 for the lowest tier front

= $1.0 + \frac{L}{120}$ maximum 3.5 for 2nd tier front

= $0.5 + \frac{L}{150}$ maximum 2.5 for 3rd tier front and above

k = $1.3 - 0.6\frac{x}{L}$ for $\frac{x}{L} \leq 0.5$

k = $0.3 + 1.4\frac{x}{L}$ for $\frac{x}{L} > 0.5$

x = longitudinal distance in m from A.P. to the load point
h_o = vertical distance in m from the waterline at draught T to the load point

c = $0.3 + 0.7\frac{b_1}{B_1}$

b_1 = breadth of deckhouse at position considered
B_1 = maximum breadth of ship on the weather deck at position considered

$\frac{b_1}{B_1}$ is not to be taken less than 0.25.

For unprotected parts of machinery casings c is not to be taken less than 1.0.

C_W = wave coefficient as given in Sec.4 A201
p_{dp}, k_s = as given in Sec.5 B101

D. Scantlings

D 100 End bulkheads of superstructures and deckhouses, and exposed sides in deckhouses

101 The thickness requirement for plating corresponding to lateral external pressure is given by:

$$t = \frac{15.8 k_a s \sqrt{p}}{\sqrt{\sigma}} \quad \text{(mm)}$$

p = $p_1 - p_5$, whichever is relevant, as given in Table C1
σ = 160 f_1 N/mm^2.

102 The thickness is not to be less than:

— for the lowest tier:

$$t = 5 + 0.01\ L\ \text{(mm), maximum 8 mm}$$

— for higher tiers:

$$t = 4 + 0.01\ L\ \text{(mm), maximum 7 mm, minimum 5 mm.}$$

103 The section modulus requirement for stiffeners is given by:

$$Z = \frac{100 l^2 s p}{\sigma} \quad (cm^3)$$

p = as given in 101
σ = 160 f_1 for longitudinals, vertical and transverse stiffeners in general
= 90 f_1 σ for longitudinals at strength deck in long deckhouse within 0.4 L amidships. The -value may be increased linearly to the general value at the first deck above the strength deck and at 0.1 L from the perpendiculars.

104 Front stiffeners are to be connected to deck at both ends with a connection area not less than:

$$a = \frac{0.07}{f_1} l s p \quad (cm^2)$$

Sniped ends may be allowed, however, for stiffeners above the 3rd tier provided the formula in Sec.3 C204 is fulfilled.

Side and after end stiffeners in the lowest tier of erections are to have end connections.

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

D 200 Protected casings

201 The thickness of plating is not to be less than:

t = 8.5 s minimum 6.0 mm in way of cargo holds
= 6.5 s minimum 5.0 mm in way of accommodation.

202 The section modulus of stiffeners is not to be less than:

$$Z = \frac{3 l^2 s}{f_1} \quad (cm^3)$$

l = length of stiffeners in m, minimum 2.5 m.

203 Casings supporting one or more decks above are to be adequately strengthened.

D 300 Bulwarks

301 The thickness of bulwark plates is not to be less than required for side plating in a superstructure in the same position, if the height of the bulwarks is 1.8 m.

If the height of the bulwark is 1 metre or less the thickness need not be greater than 6.0 mm.

For intermediate heights, the thickness of the bulwark may be found by interpolation.

302 A strong bulb section or similar is to be continuously welded to the upper edge of the bulwark. Bulwark stays are to be spaced not more than 2 m apart, and are to be in line with transverse beams or local transverse stiffening, alternatively the toe of stay may be supported by a longitudinal member. The stays are to have sufficient width at deck level. The deck beam is to be continuously welded to the deck in way of the stay. Bulwarks on forecastle decks are to have stays fitted at every frame where the flare is considerable.

Stays of increased strength are to be fitted at ends of bulwark openings. Openings in bulwarks should not be situated near the end of superstructures.

D 400 Aluminium deckhouses

401 The strength of aluminium deckhouses is to be related to that required for steel deckhouses, see below.

The scantlings are to be based on the mechanical properties of the applied alloy. See Sec.2 C.

402 The minimum thicknesses given in 102 and 201 are to be increased by 1 mm.

403 For the section moduli requirements given in 100 and 200, f_1 need not be taken less than 0.6.

SECTION 11
WELDING AND WELD CONNECTIONS

A. General

A 100 Introduction

101 In this section requirements related to welding and various connection details are given.

A 200 Definitions

201 Symbols:

t_k = corrosion addition in mm as specified in Sec.2 D200.

B. Types of Welded Joints

B 100 Butt joints

101 For panels with plates of equal thickness, the joints are normally to be butt welded with edges prepared as indicated in Fig.1.

102 For butt welded joints of plates with thickness difference exceeding 4 mm, the thicker plate is normally to be tapered. The taper is generally not to exceed 1 : 3. After tapering, the end preparation may be as indicated in 101 for plates of equal thickness.

103 All types of butt joints are normally to be welded from both sides. Before welding is carried out from the second side, unsound weld metal is to be removed at the root by a suitable method.

104 Butt welding from one side against permanent backing will only be permitted after special consideration when the stress level is low.

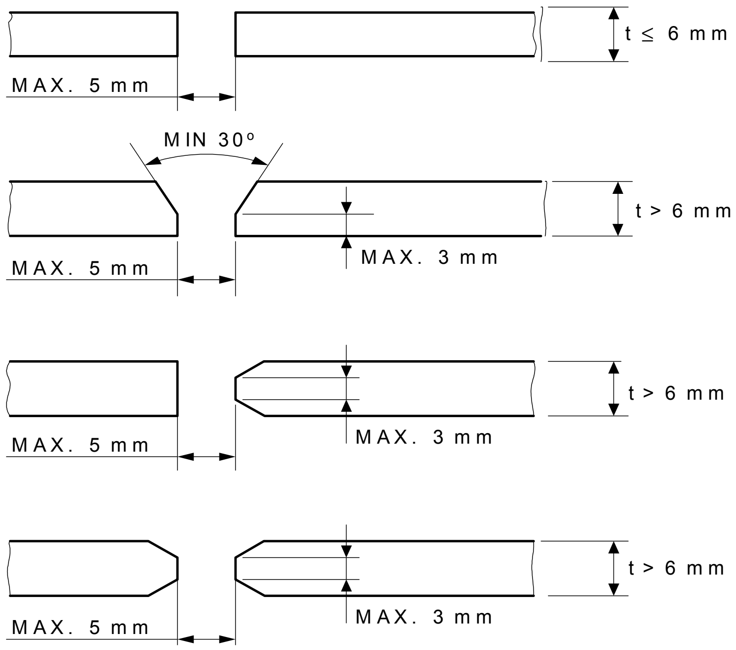

Fig. 1
Manually welded butt joint edges

B 200 Lap joints and slot welds

201 Various types of overlapped joints are indicated in Fig.2.

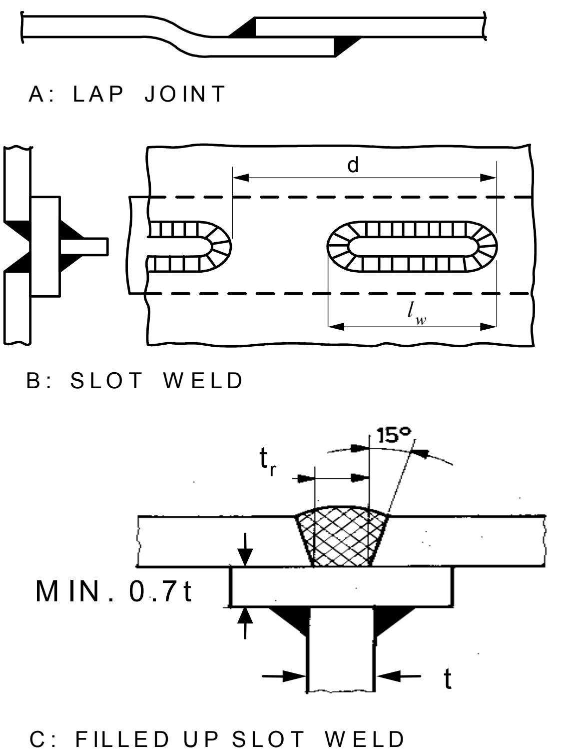

Fig. 2
Lap joints and slot welds

Type «A» (lap joint) may be used for connections dominated by shear or in plane stresses acting parallel to the weld. Such overlaps will normally not be accepted for connections with high in plane stresses transverse to the weld. Stresses above 0.5 x yield are taken as high in this context.

Type «B» (slot weld) may be used for connection of plating to internal webs, where access for welding is not practicable. For requirements to slot welds, see C600.

Type "C" (filled slot weld) for plates subject to larger in plane transverse stresses where type "B" slot welding is not acceptable.

Type "B" and "C" joints are not to be used in case of pressure from abutting plate side or in tank boundaries.

B 300 Tee or cross joints

301 The connection of girder and stiffener webs to plate panel as well as plating abutting on another plate panel, is normally to be made by fillet welds as indicated in Fig.3.

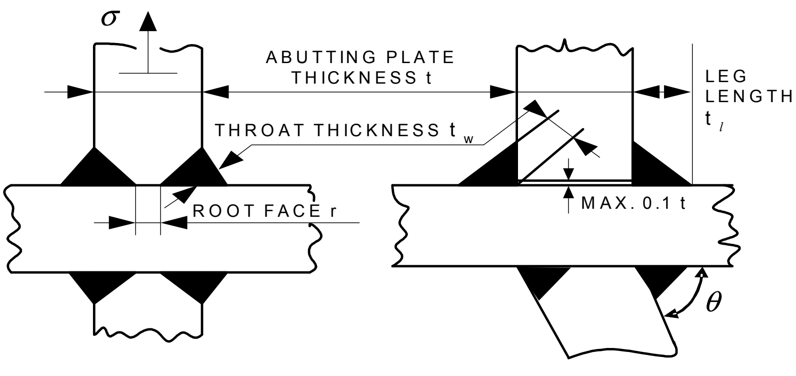

Fig. 3
Tee or cross joints

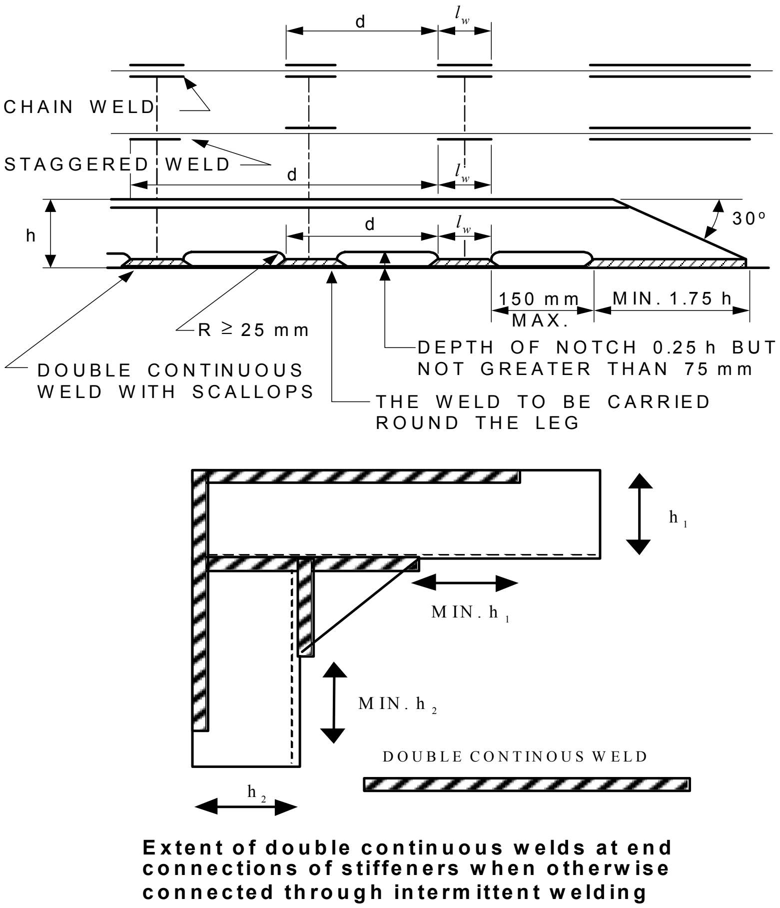

Fig. 4
Intermittent welds

For fillet weld with opening angle θ (see Fig.3.) less than 75 deg., the net requirement in C103, C202 and C302 is to be increased by a factor $\sqrt{2}\cos(\theta/2)$.

Where the connection is highly stressed or otherwise considered critical, the edge of the abutting plate may have to be bevelled to give partial or full penetration welding, see also C304.

For penetration welds, root face r and throat thickness t_w are defined as shown in Fig.3. In case of partial penetration welding with an abutting plate bevelled only at one side, the fillet weld at opposite side should not be less than 80% of that required for a double continuos fillet weld according to C103 and C202.

Where the connection is moderately stressed, intermittent welds may be used. With reference to Fig.4, the various types of intermittent welds are as follows:

— chain weld
— staggered weld
— scallop weld (closed).

302 Double continuous welds are required in the following connections irrespective of the stress level:

— weathertight, watertight and oiltight connections
— connections in foundations and supporting structures for machinery
— all connections in after peak
— connections in rudders, except where access difficulties necessitate slot welds
— connections at supports and ends of stiffeners, pillars, cross ties and girders
— centre line girder to keel plate.

303 Where intermittent welds are accepted, scallop welds are to be used in tanks for water ballast, cargo oil or fresh water. Chain and staggered welds may be used in dry spaces and tanks arranged for fuel oil only.

When chain and staggered welds are used on continuous members penetrating oil- and watertight boundaries, the weld termination towards the tank boundary is to be closed by a scallop, see Fig.5.

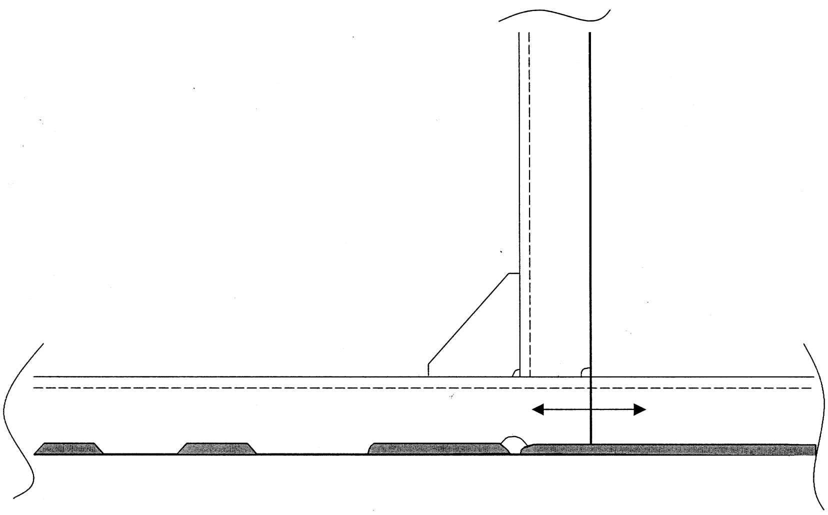

Fig. 5
Weld termination towards tank boundary

304 Full penetration welds are in any case to be used in the following connections:

— rudder horns and shaft brackets to shell structure
— rudder side plating to rudder stock connection areas
— end brackets of hatch side coamings both to deck and coaming side. For brackets of thickness above 20 mm, partial penetration weld can be applied except for the last 150 mm of the bracket toe to deck
— edge reinforcements or pipe penetrations both to strength deck (including sheer strake) and bottom plating within 0.6 L amidships when the transverse dimension of opening exceeds 300 mm, see Fig.6. For machine cut holes, partial penetration with root face r = t/3 may be accepted
— abutting plate panels (see Fig.3) forming boundaries to sea below summer load waterline. For thickness t above 12 mm, partial penetration weld with root face r = t/3 may be accepted
— lower end of vertical corrugated bulkheads that are situated in the cargo area and arranged without lower stool.

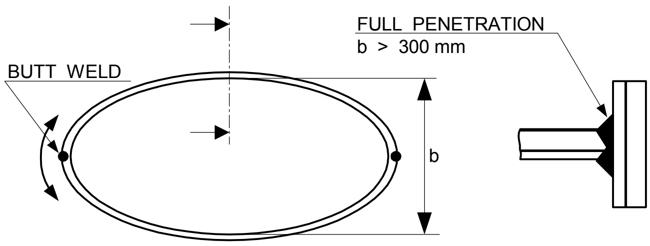

Fig. 6
Deck and bottom penetration

C. Size of Weld Connections

C 100 Continuous fillet welds, general

101 Unless otherwise stated, it is assumed that the welding consumables used will give weld deposit with yield strength σ_{fw} as follows:

σ_{fw} = 355 N/mm^2 for welding of normal strength steel
= 375 N/mm^2 for welding of the high strength steels NV-27, NV-32 and NV-36
= 390 N/mm^2 for welding of high strength steel NV-40.

If welding consumables with deposits of lower yield strength than specified above are used, the σ_{fw}-value is to be stated on the drawings submitted for approval. The yield strength of the weld deposit is in no case to be less than required in Pt.2 Ch.3.

102 When deep penetrating welding processes are applied, the required throat thicknesses may be reduced by 15% of that required in C103 provided sufficient weld penetration is demonstrated.

Guidance note:

An electrode is considered to be of deep penetration type when the penetration is at least 4 mm when welding a fillet weld with a maximum gap of 0,25 mm. The electrode is to be type approved as a deep penetration electrode.

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Table C1 Weld factor C		
Item	*60% of span*	*At ends*
Local buckling stiffeners	0.14	0.14
Stiffeners, frames, beams or longitudinals to shell, deck, oil tight or watertight girders or bulkhead plating, except in after peaks 1)	0.16	0.26
Web plates of non-watertight girders except in after peaks	0.20	0.32
Girder webs and floors in double bottom and double hull below the summer load waterline. Stiffeners and girders in after peaks	0.26	0.43
Swash bulkheads Perforated decks	0.32	
Watertight centre line girder to bottom plating and inner bottom plating Boundary connection of ballast tanks and liquid cargo tanks Hatch coamings at corners and transverse hatch end brackets to deck Strength deck plating to shell Scuppers and discharges to deck	0.52	
Fillet welds subject to compressive stresses only	0.25	
All other welds not specified above or in 200 to 400, e.g. boundary connection of watertight compartments and fuel oil tanks	0.43	
1) Welding of longitudinals of flat-bar type may normally be according to 104.		

103 The throat thickness of double continuous fillet welds is not to be less than:

$$t_w = \frac{C\, t_0 \sqrt{f_1}}{f_w} + 0.5 t_k \qquad \text{(mm)}$$

minimum as given in C104.

C = weld factor given in Table C1
t_0 = net thickness in mm of abutting plate, corrosion addition not included (see Fig.3)
= $t - t_k$, where:

t = gross thickness of abutting plate in mm (see Fig.3)
t_k = corrosion addition in mm, see Sec.2 D

f_1 = material factor as defined in Sec.2 B203 of abutting plate
f_w = material factor for weld deposit.

$$= \left(\frac{\sigma_{fw}}{235}\right)^{0.75}, \text{ maximum } (2f_1)^{0.5}$$

σ_{fw} = yield strength in N/mm^2 of weld deposit.

When welding consumables with deposits as assumed in 101 are used, f_w may be taken as follows dependent on parent material:

f_w = 1.36 for NV-NS
= 1.42 for NV-27, NV-32 and NV-36
= 1.46 for NV-40.

104 The throat thickness of fillet welds is in no case to be taken less than given in the following table:

Plate thickness (web thickness) t_0 (mm) 3)	*Minimum throat thickness (mm)* 1)
$t_0 \leq 4$	2.0
$4 < t_0 \leq 6.5$	2.5
$6.5 < t_0 \leq 9.0$	2.75
$9.0 < t_0 \leq 12.5$	3.0
$t_0 > 12.5$	$0.21\ t_0$, minimum 3.25 2)

1) Corrosion addition $0.5\ t_k$ to be added where relevant, see Sec.2 D.
The values may be reduced by 10% for local buckling stiffeners (sniped ends).

2) $0.18\ t_0$, minimum 3.0 when automatic deep penetration welding is applied.

3) Net thickness of abutting plate as defined in 103 with the following reductions:
$t_0 = 0.5\ (25 + t - t_k)$
for net plate thickness ($t-t_k$) above 25 mm
$t_0 = 25 + 0.25\ (t - t_k - 25)$
for longitudinals of flat-bar type with net thickness ($t - t_k$) above 25 mm.

C 200 Fillet welds and penetration welds subject to high tensile stresses

201 In structural parts where high tensile stresses act through an intermediate plate (see Fig.3) increased fillet welds or penetration welds are to be used.

Examples of such structures are:

— transverse bulkhead connection to the double bottom
— vertical corrugated bulkhead connection to the top of stooltank or directly to the inner bottom
— stooltanks to inner bottom and hopper tank
— structural elements in double bottoms below bulkhead and stooltanks
— transverse girders in centre tanks to longitudinal bulkheads.

202 In case full penetration welding is not used, the throat thickness of double continuous welds is not to be less than:

$$t_w = C_1\ t_0 + 0.5\ t_k \quad \text{(mm)}$$

$$C_1 = \frac{1.36}{f_w}\left[0.2 + \left(\frac{\sigma}{270} - 0.25\right)\frac{r}{t_0}\right]$$

σ = calculated maximum tensile stress in abutting plate in N/mm^2
r = root face in mm (see Fig.3)
t_0 = net thickness in mm of abutting plate, corrosion addition not included, as given in 103
f_w = as given in 103.

Typical design values for C_1 are given in Table C3.

Table C3 Values of C_1

Plate material	σ	*C_1*	
		Fillet weld: $r = t_0$	*Partial penetration weld with root face: $r = t_0/3$*
NS	160	0.54	0.31
NV-32	205	0.68	0.35
NV-36	222	0.74	0.37

C 300 End connections of girders, pillars and cross ties

301 The weld connection area of bracket to adjoining girders or other structural parts is to be based on the calculated normal and shear stresses. Double continuous welding is to be used. Where large tensile stresses are expected, welding according to 200 is to be applied.

The section modulus of the weld area at the end connection of simple girders is to satisfy the requirement for section modulus given for the girder in question.

302 Where high shear stresses in web plates, double continuous boundary fillet welds are to have throat thickness not less than:

$$t_w = \frac{t_0 \tau}{2\tau_w} + 0.5 t_k \quad \text{(mm)}$$

τ = calculated shear stress in N/mm^2

τ_w = 100 f_w when calculated shear stress (τ) is *average* shear stress in web plate
τ_w = 115 f_w when calculated shear stress (τ) is *local* shear stress in web plate
t_0 = net thickness of abutting plate, corrosion addition not included, as given in 103
f_w = as given in 103.

303 End connection of pillars and cross ties are to have a weld area not less than:

$$a = \frac{kP}{f_w} + a_k \quad (cm^2)$$

P = axial load in pillar of cross tie (kN)
a_k = corrosion addition corresponding to t_k
f_w = as given in 103
k = 0.05 when pillar in compression only
= 0.14 when pillar in tension.

C 400 End connections of stiffeners

401 Stiffeners may be connected to the web plate of girders in the following ways:

— welded directly to the web plate on one or both sides of the frame
— connected by single- or double-sided lugs
— with stiffener or bracket welded on top of frame
— a combination of the above.

In locations with great shear stresses in the web plate, a double-sided connection or a stiffening of the unconnected web plate edge is normally required. A double-sided connection may be taken into account when calculating the effective web area.

402 The connection area at supports of stiffeners is normally not to be less than:

$$a_o = c\,k\,(l - 0.5\,s)\,s\,p \quad (cm^2)$$

c = factor as given in Table C4
k = $r_1 r_2$
r_1 = 0.125 when pressure acting on stiffener side
= 0.1 when pressure acting on opposite side
r_2 = $1.0/f_1$ for stiffeners with mainly loading from one side (pressure ratio less than 0.3 or greater than 3.3)
= 1.0 for stiffeners with loading from two sides
f_1 = material factor of abutting plate as defined in Sec.2 B203.
l = distance between girder web plates in m
s = spacing between stiffeners in m
p = design pressure in kN/m^2.

Corrosion addition as specified in Sec.2 D200 is not included in the formulae for a_0, and is to be added where relevant.

Weld area is not to be less than:

$$a = \frac{1.15\,a_0\sqrt{f_1}}{f_w} + a_k \quad (cm^2)$$

a_k = corrosion addition corresponding to t_k
f_w = as given in 103.

Table C4 Values of c			
Type of connection (see figure)	*Stiffener/bracket on top of stiffener*		
	None	*Single- sided*	*Double- sided*
a	1.00	1.25	1.00
b	0.90	1.15	0.90
c	0.80	1.00	0.80

403 Various standard types of connections are shown in Fig.7.

Other types of connection will be considered in each case.

When stiffeners and supporting web frames are made of high strength steel, stiffeners on ship's side in ballast and cargo tanks are to be specially considered as given in Ch.1 Sec.7 E500.

Guidance note:

In ballast and cargo tanks the connection types b or c should be used for stiffeners on ship sides, unless double-sided brackets are arranged.

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404 Connection lugs are to have a thickness not less than 75% of the web plate thickness.

405 Lower ends of peak frames are to be connected to the floors by a weld area not less than:

$$a = 0.105\, l\, s\, p + a_k \quad (\text{cm}^2)$$

l, s, p and a_k = as given in 402.

406 For stiffeners which may be sniped at the ends according to the requirements given in Sec.3 C202, the required connection area is satisfied by the plating.

407 Bracketed end connections as mentioned below, are to have a weld area not less than:

$$a = \frac{kZ}{h} + a_k \qquad (\text{cm}^2)$$

Z = net section modulus of stiffener in cm^3, corrosion addition not included
h = stiffener height in mm
k = 24 for connections between supporting plates in double bottoms and transverse bottom frames or reversed frames
= 25 for connections between the lower end of main frames and brackets (minimum weld area = 10 cm^2)
= 15 for brackets fitted at lower end of 'tween deck frames, and for brackets on stiffeners
= 10 for brackets on 'tween deck frames carried through the deck and overlapping the underlying bracket
a_k = corrosion addition corresponding to t_k.

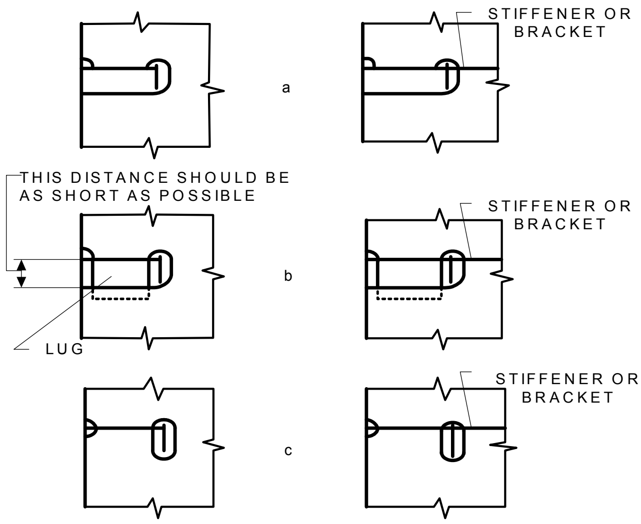

Fig. 7
End connections

408 Brackets between transverse deck beams and frames or bulkhead stiffeners are to have a weld area not less than:

$$a = 0.41\sqrt{Z t_b} + a_k \qquad (\text{cm}^2)$$

t_b = net thickness in mm of bracket
Z = as defined in 407
a_k = as defined in 407.

409 The weld area of brackets to longitudinals is not to be less than the sectional area of the longitudinal. Brackets are to be connected to bulkhead by a double continuous weld.

C 500 Intermittent welds

501 The throat thickness of intermittent fillet welds is not to be less than:

$$t_w = \frac{C\ t_0 \sqrt{f_1}}{f_w} \frac{d}{l_w} + 0.5 t_k \quad \text{(mm)}$$

C, t_0, f_1 and f_w are as given in 103.
C-values given Table C1 for 60% of span may be applied.

d = distance, in mm, between successive welds, see Fig.4.
l_w = length, in mm, of weld fillet, not to be less than 75 mm (see Fig.4).

502 In addition to the minimum requirements in 501 the following apply:

— for chain intermittent welds and scallop welds the throat thickness is not to exceed 0.6 t_0
— for staggered intermittent welds, the throat thickness is not to exceed 0.75 t_0.

Double continuous welds to be applied at ends, see Fig.4.

C 600 Slot welds

601 Slots are to have a minimum length of 75 mm and, normally, a width of twice the plate thickness. The ends are to be well rounded, see Fig.2. The distance d between slots is not to exceed 2 l, maximum 250 mm.

602 Fillets welds in slots are to have a throat thickness as given by the formula in 501 with:

t_0 = net thickness of adjoining web plate
d = distance between slots, see Fig.2
l = length of slots.

603 Slots through plating subject to large in-plane tensile stresses across the slots may be required to be completely filled by weld. Narrow slots with inclined sides (minimum 15° to the vertical) and a minimum opening of t_r at bottom should then be used. t_r should be minimum 0.75t but not less than 6 mm (see Fig.2). A continuous slot weld may, however, in such cases be more practical.

SECTION 12
BUCKLING CONTROL

A. General

A 100 Introduction

101 In this section requirements to buckling control of plating subject to compressive stresses are given.

A 200 Definitions

201 Symbols:

M_{SW} = still water bending moments in kNm
M_W = wave bending moments in kNm as given in Sec.4 B201.

For ships with restricted service the wave bending moment may be reduced as given in Sec.4 B203.

s = spacing in m of transverse beams
l = distance in m between longitudinal stiffeners
t = plating thickness in mm
Z_A = Z_D or Z_B
Z_R = rule section modulus in cm^3

Z_D, Z_B = midship section modulus in cm^3 as built at deck or bottom, respectively.

B. Plating Subject to Longitudinal Compressive Bending Stresses

B 100 General

101 The longitudinal bending stresses to be used for buckling control of deck and bottom plating is generally given by:

$$\sigma_l = \frac{M_{SW} + M_W}{Z_A} 10^3 \quad (\text{N/mm}^2)$$

102 The critical buckling strength σ_{cr} of a transversely stiffened plate may be found from the following formulae:

$$\sigma_{cr} = \sigma_e \text{ when } \sigma_e < 0.5\,\sigma_y$$

$$= \sigma_y\left(1 - \frac{\sigma_y}{4\sigma_e}\right) \text{ when } \sigma_e > 0.5\,\sigma_y$$

$$\sigma = 2.3\left[1 + \left(\frac{s}{l}\right)^2\right]^2 \left(\frac{t - t_k}{1000\,s}\right)^2 10^5 \quad (\text{N/mm}^2)$$

103 The plating thickness in deck and bottom amidships should comply with the requirement

$$\sigma_{cr} \geq \sigma_l$$

B 200 Deck plating

201 Sagging water bending moments are to be applied in 101.

202 If it is confirmed that the stillwater bending moments for all relevant loading conditions will not be sagging moments it may be accepted to use M_{SW} = 0 for the buckling control of the deck plating.

Guidance note:

When M_{SW} is as given in 202 and $l \geq$ s, the buckling strength of a transversely stiffened strength deck will normally be satisfactory when

$$t \geq 2.2\, s \sqrt{L} \sqrt{\frac{Z_R}{Z_D}} + t_k \quad \text{(mm)}$$

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B 300 Bottom plating

301 Hogging bending moments are to be applied in B101.

Guidance note:

When M_{SW} is as given in 301 and $l \geq s$, the buckling strength of transversely stiffened bottom plating will normally be satisfactory when

$$t \geq 2.8\, s \sqrt{L} \sqrt{\frac{Z_R}{Z_B}} + t_k \quad \text{(mm)}$$

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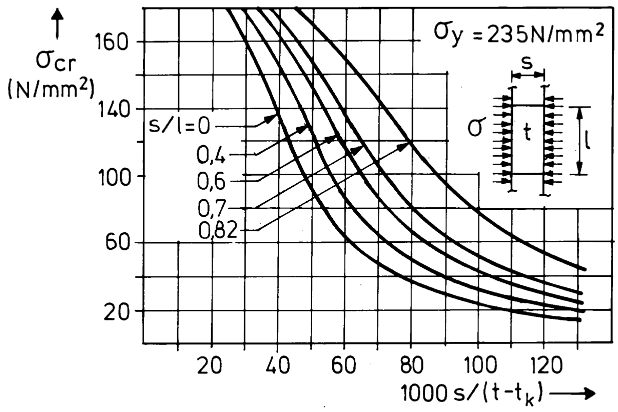


Fig. 1
Critical stress for transversely stiffened plating made of mild steel

C. Deck Plating Acting as Effective Flange for Deck Girders

C 100 General

101 Deck plating acting as effective flange for deck girders which support crossing stiffeners should have a satisfactory buckling strength.

102 Compressive stresses arising in the deck plating due to local loading of girders are to be less than 80% of the critical buckling strength, see 103. When calculating the compressive stress the section modulus of the girder may be based on a deck plate flange breadth equal to the distance between girders (100% effective flange).

103 The critical buckling strength is given in B102, where l = span of stiffener or distance from girder to any buckling stiffener parallel to the girder.

104 Elastic buckling of deck plating may be accepted after special consideration.

Reference is made to Ch.1 Appendix A.

D. Longitudinals Subject to Longitudinal Compressive Stresses

D 100 General

101 The buckling strength of longitudinals is to comply with the requirements given in B101 and B102 when using:

$$\sigma_e = 210 \frac{I_A}{A l^2} \quad (\text{N/mm}^2)$$

I_A = moment of inertia in cm^4 of the longitudinal

A = cross-sectional area in cm^2 of the longitudinal
l = span in m of longitudinals.

When calculating I_A and A, a plate flange corresponding to 0.8 times the longitudinal spacing is included.

102 The buckling strength of longitudinals is to comply with the requirement:

$$\sigma_{cr} \geq 1.2\ \sigma_l\ .$$

APPENDIX A
APPROXIMATE CALCULATIONS

A. Stillwater Bending Moment for Hull Girder

A 100 Method of calculation

101 If the stillwater bending moment M_{SV} is not determined by a direct calculation, the following approximate calculation method may be applied:

$$M_{SV} = 5 \left[(\Delta - DW)\, z + \Sigma (p\, y) - \Delta\, x \right] \text{ (kNm)}$$

Δ = displacement of ship in tonnes
DW = deadweight of ship in tonnes
Σp = DW
p = individual weights in tonnes
y = distance in metres from L/2 to centre of gravity of the respective individual weights. Weights extending beyond L/2 are divided at L/2 and each part is considered separately
x = $0.18 (C_B + 0.35) L$ in metres
C_B = block coefficient of ship at draught in question
z = 0.2 L for ships with machinery amidships
= 0.24 L for ships with machinery at quarter length aft
= 0.27 L for ships with machinery aft
L = length of ship in metres.

The expression for M_{SV} may be positive or negative, and the moments are defined as follows:

— M_{SV} positive = hogging moment
— M_{SV} negative = sagging moment.

When calculating M_{SV} the deadweight is to be so located that the ship will have no trim at full draught.

APPENDIX B
DIAGRAMS OF SECTION MODULI AND MOMENTS OF INERTIA

A. Built Sections (Diagram A)

A 100 Description

101 Diagram A, which may be applied to built sections of the type shown in Fig.1, gives as parameters the flange area (A_F) and the depth of the section (h) for values of moments of inertia (I) and section moduli (Z) about the neutral axis x—x, based on the following simplified equations:

$$I = A_P a^2 + \frac{h^3 t}{12} + A_W \left(\frac{h}{2} - a\right)^2 + A_F (h - a)^2$$

$$Z = \frac{I}{h - a} \quad \text{cm}^3\text{, where}$$

$$a = h \frac{0.5 A_W + A_F}{A_F + A_W + A_P}$$

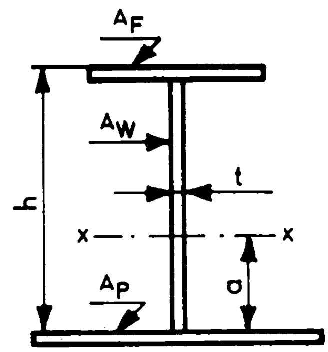


Fig. 1
Built section for which Diagram A may be used

Notations are otherwise as follows:

A_F = sectional area of face plate in cm^2
A_P = sectional area of effective plating in cm^2
A_W = sectional area of web in cm^2, approximate value = ht
h = depth of section in cm
t = web thickness in cm.

The sectional area of effective plating A_P is based on rules for effective flange. It is assumed that $A_F \leq A_P$. The equations for I and Z are further simplified by putting A_P = 60 cm^2, respectively 100 cm^2 and t =1 cm.

B. Built Sections Nomogram (Diagram B)

B 100 Description

101 Diagram B is based on the same equations for I and Z as diagram A, but this diagram has been given the form of a nomogram or alignment chart for which the only restriction is that $A_F \leq A_P$.

The fan-shaped diagram is constructed with the ratios A_W/A_P and I/h, and the product h A_P as parameters, with values of Z and the ratio A_W/A_P marked off on the two vertical scales. Powers are given to the nth value in order to increase the range of diagram. The actual power is the same for all scales which contain n.

A few examples will illustrate the practical use of the diagram (see 200 to 400 below) in connection with Fig.2.

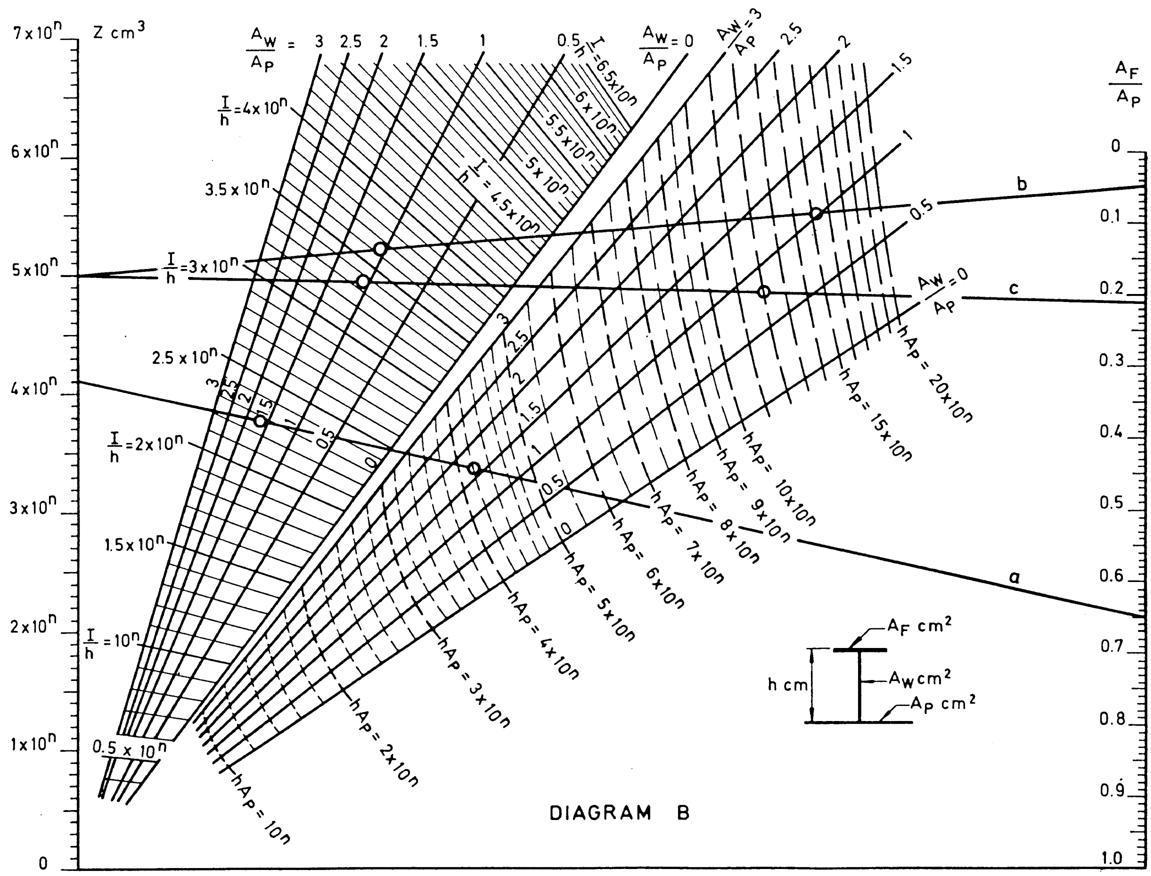


Fig. 2
Build sections nomogram

B 200 Example a)

201 Determine the section modulus and moment of inertia of a girder having the following dimensions:

h = 240 cm
A_P = 175 cm^2 (= effective flange area)
A_F = 114 cm^2
t = 1.2 cm.

This gives:

A_F/A_P = 0.65and $A_W/A_P \approx 1.65$ and $A_P = 4.2 \times 10^4$ (i.e.
n = 4, to be used for all scales containing n in the diagram).

Through the point determined by the parameters A_W/A_P = 1.65 and h $A_P = 4.2 \times 10^4$ in the diagram and the point A_F/A_P = 0.65 on the right vertical scale a straight line a is drawn, intersecting the Z scale at 4.1×10^n. The sought value of Z is therefore 4.1×10^4 cm^3. The intersection between the straight line drawn and the parameter A_W/A_P = 1.65 gives the value of $I/h = 2.27 \times 10^4$, i.e. $I = 5.45 \times 10^6$ cm^4.

B 300 Example b)

301 Determine the scantlings of a girder having a given section modulus $Z = 5 \times 10^3$ cm^3 and an effective area of plating A_P = 140 cm^2.

It is necessary in this case to choose the depth h and thickness t of the web (a suitable depth may be obtained by means of diagram A). Taking in this instance h = 110 cm and t = 1.3 cm, the flange area A_F is determined as follows:

Through the point determined by the intersection of the parameters A_W/A_P = 1.02 and h $A_P = 15.4 \times 10^3$ and the point 5 on the Z scale a straight line b is drawn intersecting the vertical scale A_F/A_P on the right at 0.05 i.e. $A_F = 0.05 \times 140 = 7$ cm^2.

B 400 Example c)

401 The moment of inertia I of the girder in example b) may be found from the I/h value determined by the point of intersection of the parameter $A_W/A_P = 1.02$ in the left part of the diagram and the straight line drawn. Thus $I/h = 3.66 \times 10^3$, i.e. $I = 402 \times 10^3$ cm^4.

If it is desired to obtain the particulars of a girder having an I value which does not exceed a certain definite rule value, say 300×10^3 cm^4, a smaller value of h is chosen by trial and error. For instance if h = 86 cm, then $h\,A_P = 12.05 \times 10^3$ and $A_W/A_P = 0.80$. A straight line c is then drawn from the point 5 on the Z scale through the point of intersection of the parameters $h\,A_P = 12.05 \times 10^3$ and $A_W/A_P = 0.80$. This intersects the A_F/A_P scale at 0.21 and gives a value of $A_F = 29.4$ cm^2 and an I/h value = 3.49 from which $I \approx 300 \times 10^3$ cm^4.

C. Flat Bars, Angles and Bulbs (Diagram C and Table C1)

C 100 Description

101 Diagram C may be applied to flats and inverted welded angle stiffeners. The diagram is based on the usual information given in handbooks of sections. This diagram has been constructed in the same manner as diagram A with h and t plotted as parameters and values of Z and I marked off on the horizontal and vertical axis respectively.

102 In Table C1 values of I and Z are given for bulb flats with attached plate.

Table C1 Moment of inertia I and section modulus Z for bulbprofile (HP) with attached plate. Profile (mm)

Profile (mm)	*I (cm^4)*	*Z (cm^3)*	*Plate included (mm)*
80 × 5	165	21	600 × 7
80 × 6	181	24	
80 × 7	196	26	
100 × 6	338	36	
100 × 7	365	39	
100 × 8	391	43	
120 × 6	567	52	
120 × 7	610	56	
120 × 8	653	61	
140 × 7	968	78	
140 × 8	1 025	83	
140 × 9	1 082	89	
160 × 7	1 590	110	600 × 10
160 × 8	1 684	117	
160 × 9	1 783	125	
180 × 8	2 477	157	
180 × 9	2 594	166	
180 × 10	2 733	177	
180 × 11	2 863	187	
200 × 9	3 630	214	
200 × 10	3 779	225	
200 × 11	3 950	238	
200 × 12	4 110	250	
220 × 10	5 177	288	
220 × 11	5 353	300	
220 × 12	5 500	311	
240 × 10	6 721	351	
240 × 11	7 031	371	
240 × 12	7 236	385	
260 × 11	9 015	450	
260 × 12	9 269	467	
260 × 13	9 511	483	
280 × 11	11 312	537	
280 × 12	11 657	559	
280 × 13	11 955	578	
300 × 11	14 073	639	
300 × 12	14 481	664	
300 × 13	14 589	688	
300 × 14	15 199	709	
300 × 11	14 961	653	600 × 12
300 × 12	15 412	678	
300 × 13	15 833	703	
300 × 14	16 209	725	
320 × 12	18 780	792	
320 × 13	19 272	820	
320 × 14	19 742	847	
320 × 15	20 157	871	
340 × 12	22 568	915	
340 × 13	23 165	947	
340 × 14	23 691	976	
340 × 15	24 195	1 004	

D. Corrugated Bulkhead (Diagram D)

D 100 Description

101 Diagram D, which may be applied to corrugated bulkheads, is based on the following equation for the section modulus:

$$Z = \frac{ht}{2}\left(\frac{h}{3\sin\alpha} + s\right) \qquad (cm^3)$$

Notations are as shown on sketch in the diagram, h, t and s being in cm. The value of Z in the diagram applies to a length *l* of corrugation having a width of effective flange on each side equal to 0.5 s. The diagram has been constructed as a nomogram or alignment chart with the depth of corrugation h and the angle α as parameters and values of s and Z/t marked off on the vertical axes. As the moment of inertia I = Zh/2, Z/t may be written 2 I/ht.

D 200 Example

201 Find Z/t or I/t of a corrugated bulkhead having the following particulars:

s = 400 mm
h = 500 mm
α = 45°.

Through the point of intersection (see Fig.3) between the parameters h = 500 and α = 45° and the point 400 on the s scale, a straight line is drawn intersecting the Z/t scale at 1 600. The sought value of Z/t or 2 I/ht is therefore 1 600 cm^2. If the thickness t of the bulkhead is known, Z or I may be found.

Conversely, if a certain section modulus and/or moment of inertia is stipulated, the least depth of corrugation may be evaluated from the equation h = 2 I/Z. If the angle of corrugation is known, the point of intersection between the parameters h and α may be found. Through this point and the point corresponding to the known value of Z/t on the left vertical scale, a straight line may be drawn intersecting the scale of s. This the size of s may be obtained.

E. Swedged Plating (Diagram E)

E 100 Description

101 This diagram may be used for estimating Z/t - values for swedged stiffeners applied on light walls and bulkheads in accommodation, deckhouses etc.

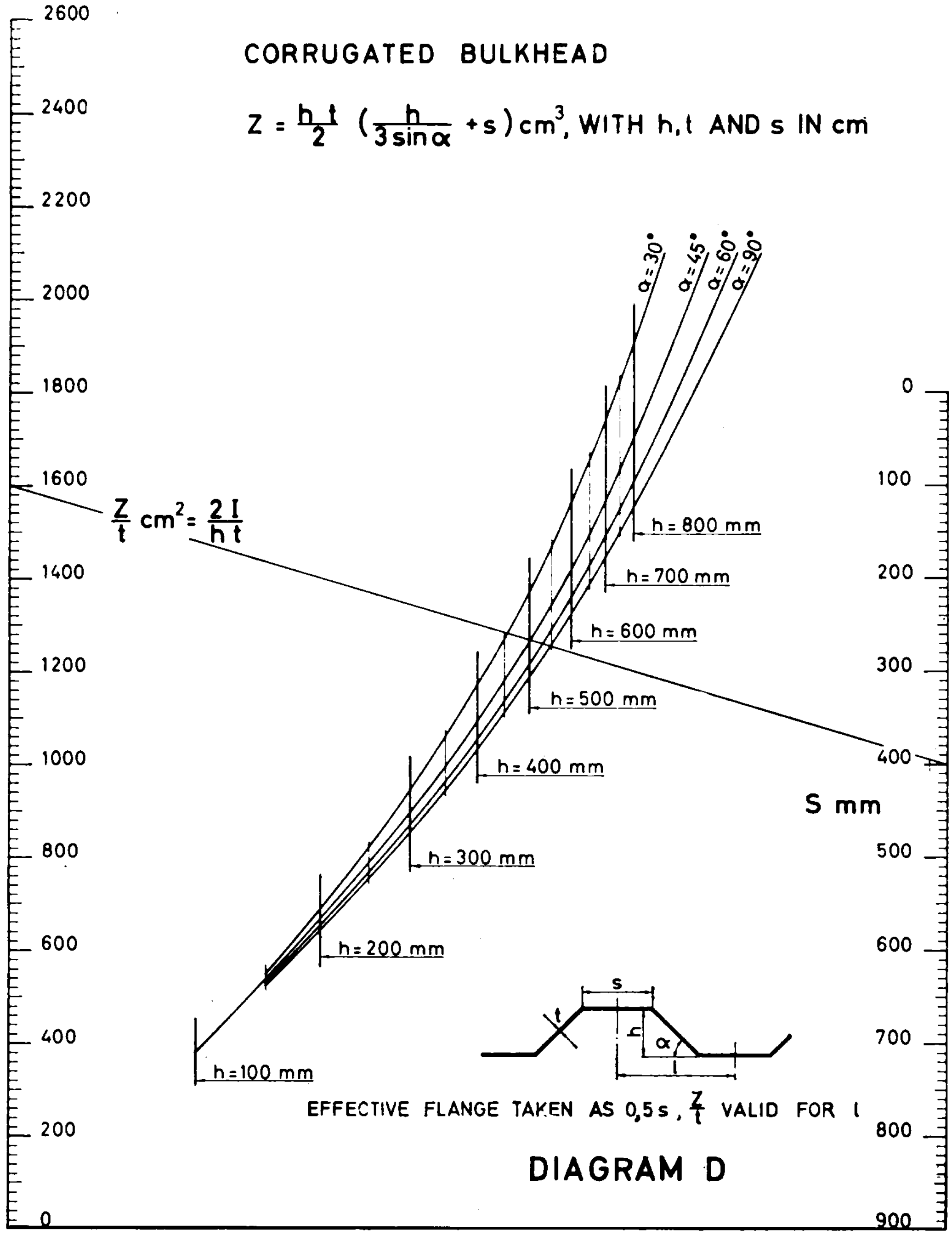
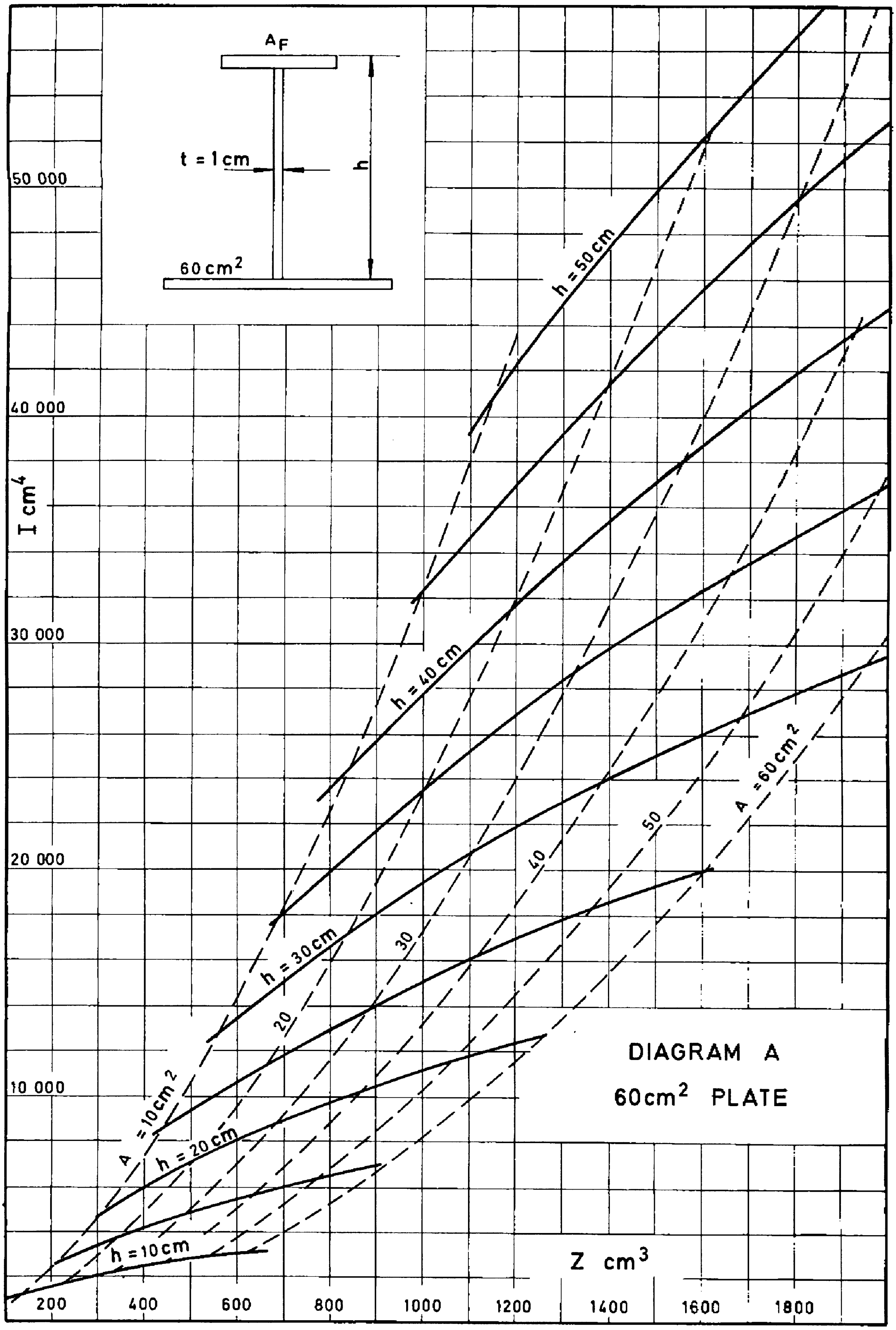
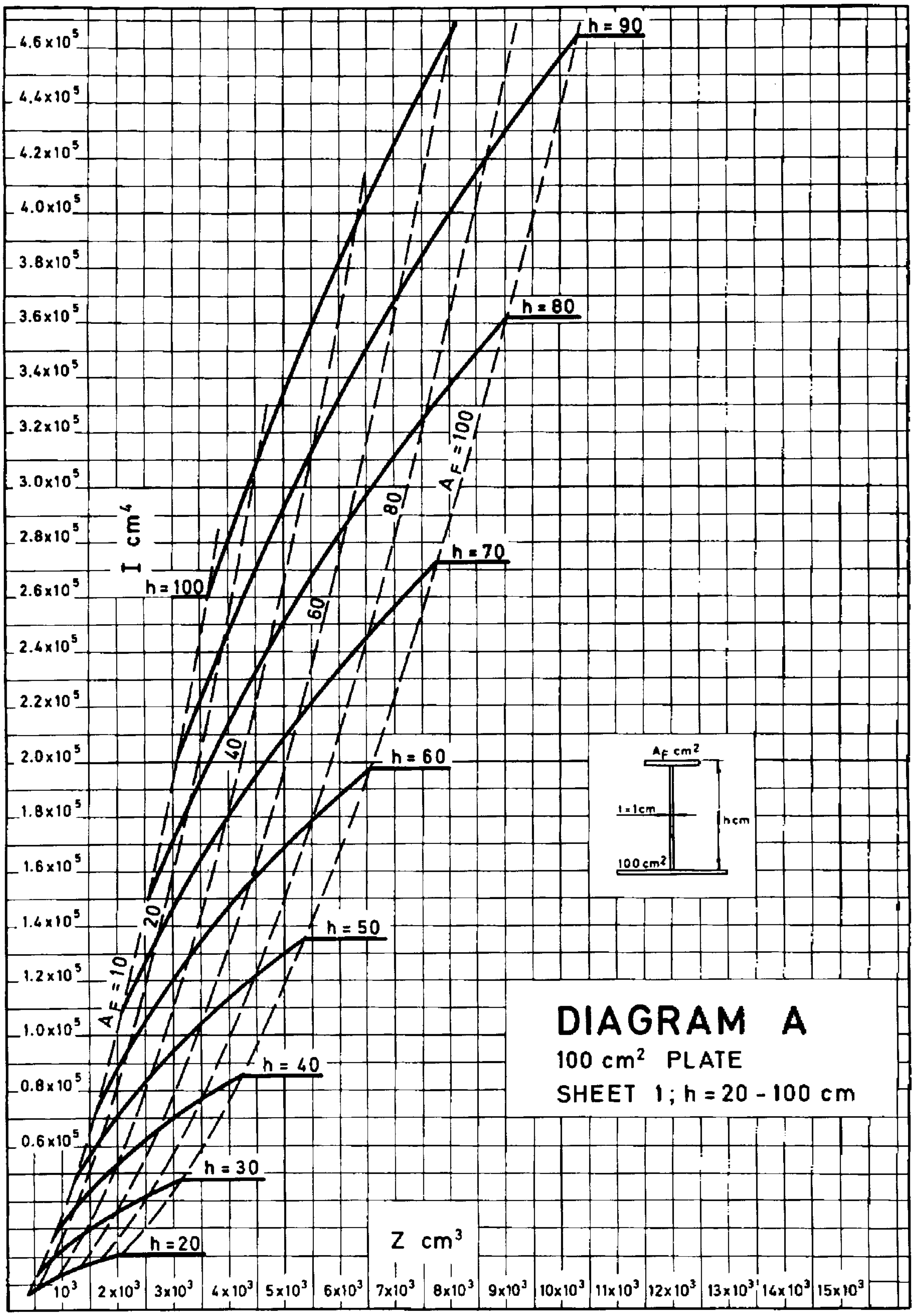


Fig. 3
Corrugated bulkhead nomogram


A F
t = 1 cm
h
60 cm2
50 000
40 000
I cm4
30 000
20 000
10 000
h = 50 cm
h = 40 cm
h = 30 cm
h = 20 cm
h = 10 cm
A = 10cm 2
20
30
40
50
A = 60 cm 2
DIAGRAM A
60cm2 PLATE
Z cm3
200
400
600
800
1000
1200
1400
1600
1800


4.6x10⁵
4.4x10⁵
4.2x10⁵
4.0x10⁵
3.8x10⁵
3.6x10⁵
3.4x10⁵
3.2x10⁵
3.0x10⁵
2.8x10⁵
2.6x10⁵
2.4x10⁵
2.2x10⁵
2.0x10⁵
1.8x10⁵
1.6x10⁵
1.4x10⁵
1.2x10⁵
1.0x10⁵
0.8x10⁵
0.6x10⁵
I cm⁴
h = 90
h = 80
h = 70
h = 60
h = 50
h = 40
h = 30
h = 20
h = 100
A_F = 100
80
60
40
20
A_F = 10
A_F cm²
t = 1cm
h cm
100 cm²
DIAGRAM A
100 cm² PLATE
SHEET 1; h = 20 - 100 cm
Z cm³
10³
2x10³
3x10³
4x10³
5x10³
6x10³
7x10³
8x10³
9x10³
10x10³
11x10³
12x10³
13x10³
14x10³
15x10³

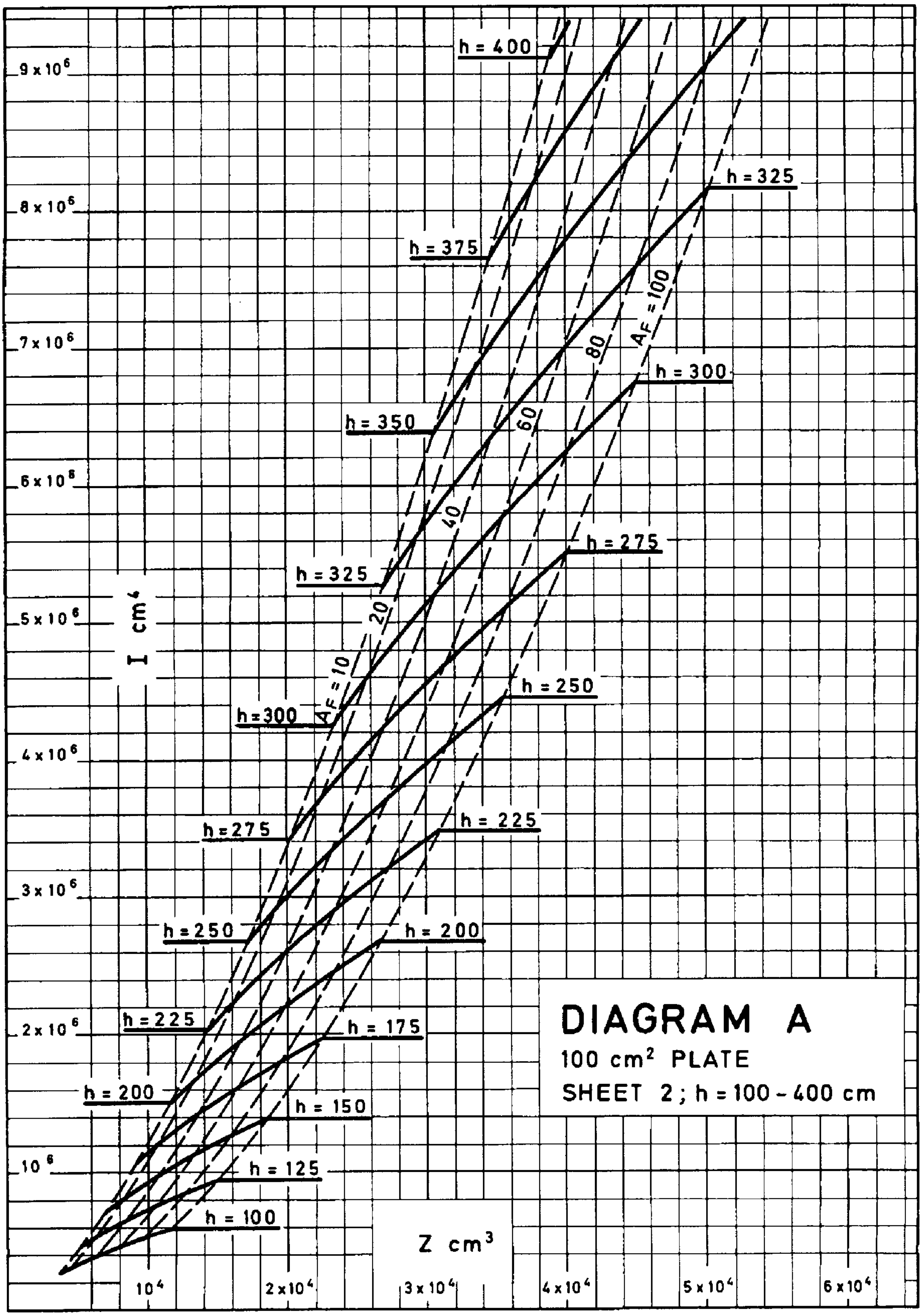


DIAGRAM A
100 cm² PLATE
SHEET 2 ; h = 100 - 400 cm
I cm⁴
Z cm³
9 x 10⁶
8 x 10⁶
7 x 10⁶
6 x 10⁶
5 x 10⁶
4 x 10⁶
3 x 10⁶
2 x 10⁶
10⁶
10⁴
2 x 10⁴
3 x 10⁴
4 x 10⁴
5 x 10⁴
6 x 10⁴
h = 400
h = 375
h = 350
h = 325
h = 300
h = 275
h = 250
h = 225
h = 200
h = 175
h = 150
h = 125
h = 100
A_F = 10
20
40
60
80
A_F = 100

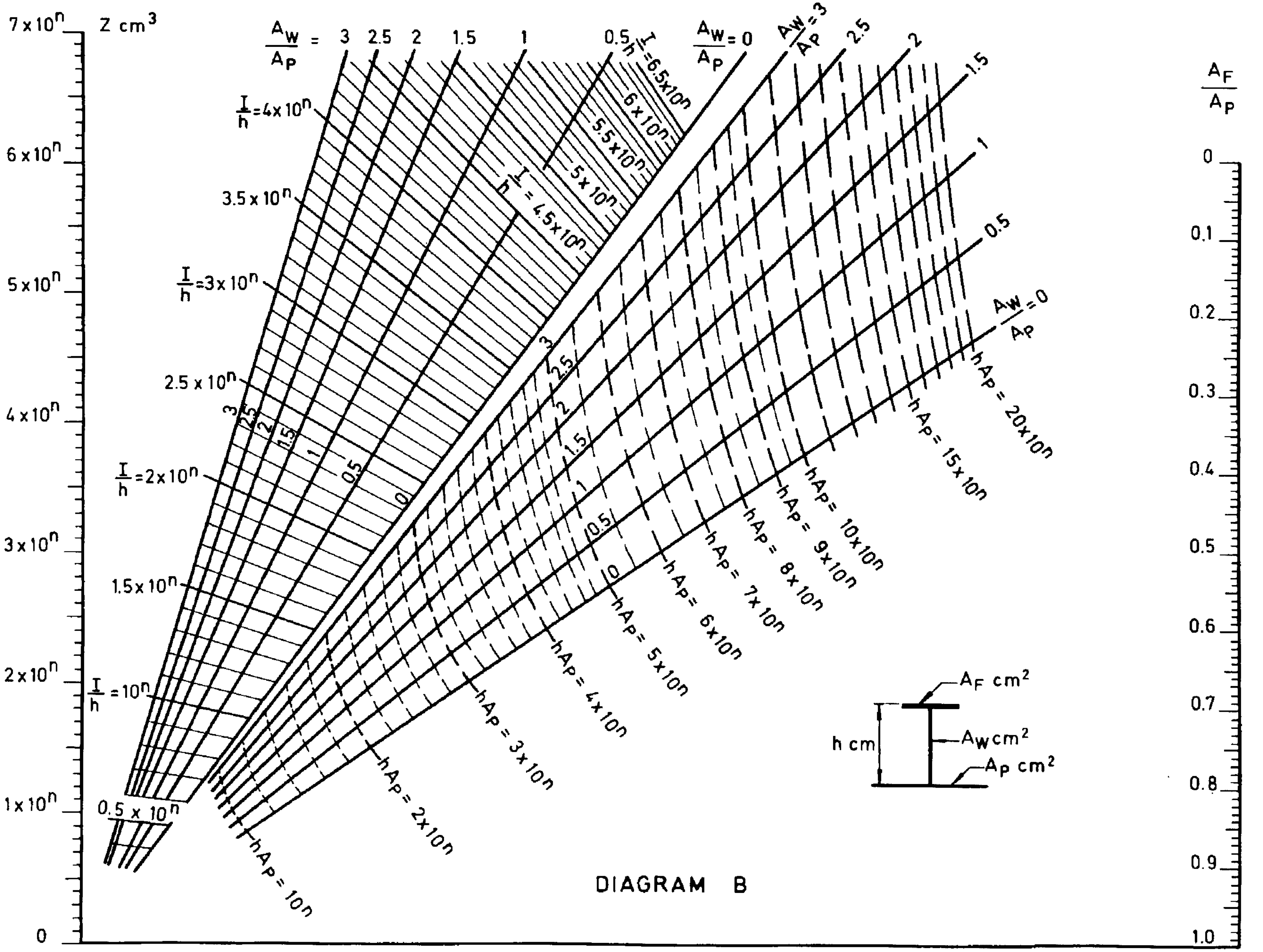
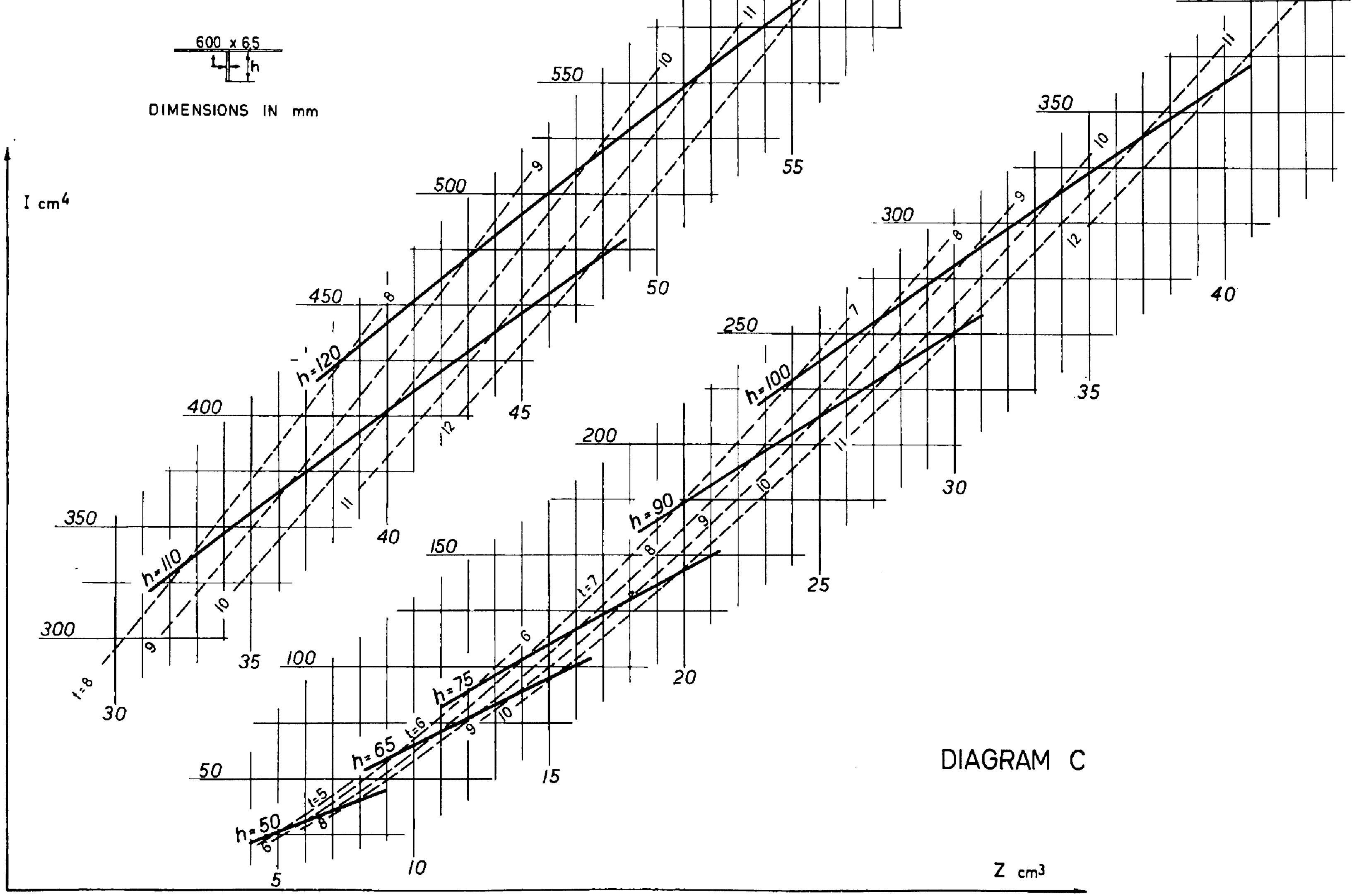

Z cm³
7 x 10ⁿ
6 x 10ⁿ
5 x 10ⁿ
4 x 10ⁿ
3 x 10ⁿ
2 x 10ⁿ
1 x 10ⁿ
0
Aw/Ap = 3 2.5 2 1.5 1 0.5
Aw/Ap = 0
Aw/Ap = 3
2.5
2
1.5
1
0.5
Aw/Ap = 0
I/h = 6.5x10ⁿ
6 x 10ⁿ
5.5 x 10ⁿ
5 x 10ⁿ
I/h = 4.5x10ⁿ
I/h = 4x10ⁿ
3.5 x 10ⁿ
I/h = 3x10ⁿ
2.5 x 10ⁿ
I/h = 2x10ⁿ
1.5 x 10ⁿ
I/h = 10ⁿ
0.5 x 10ⁿ
hAp = 10ⁿ
hAp = 2x10ⁿ
hAp = 3x10ⁿ
hAp = 4x10ⁿ
hAp = 5x10ⁿ
hAp = 6x10ⁿ
hAp = 7x10ⁿ
hAp = 8x10ⁿ
hAp = 9x10ⁿ
hAp = 10x10ⁿ
hAp = 15x10ⁿ
hAp = 20x10ⁿ
AF/AP
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
AF cm²
Aw cm²
Ap cm²
h cm

DIAGRAM B

MOMENT OF INERTIA & SECTION MODULUS (I & Z)
FOR FLAT BARS WITH 600 x 6,5 mm PLATE



MOMENT OF INERTIA & SECTION MODULUS (I & Z)

FOR FLAT BARS WITH 600 x 10 mm PLATE

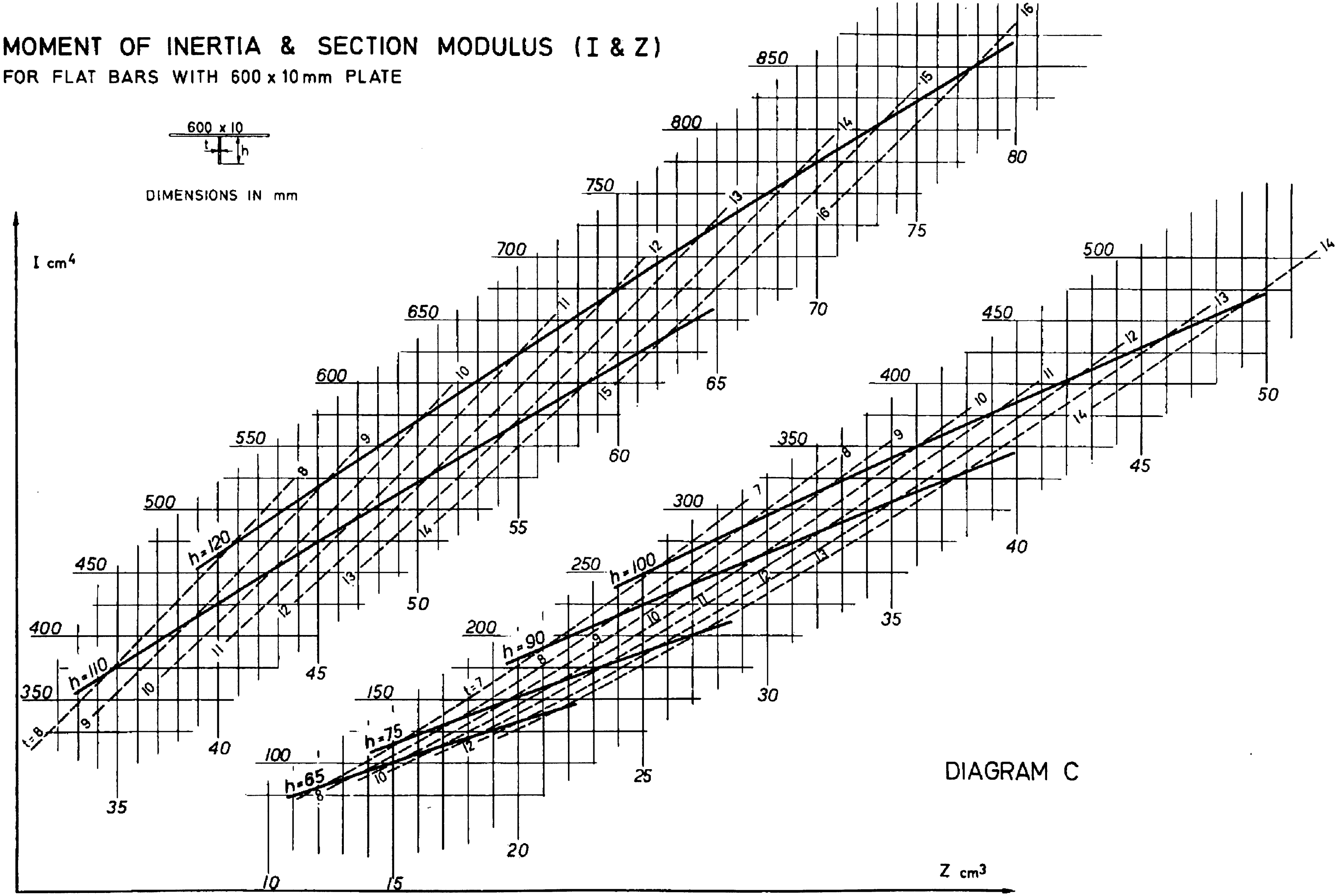


DIAGRAM C

MOMENT OF INERTIA & SECTION MODULUS (I & Z)

FOR FLAT BARS WITH 600 x 10mm PLATE

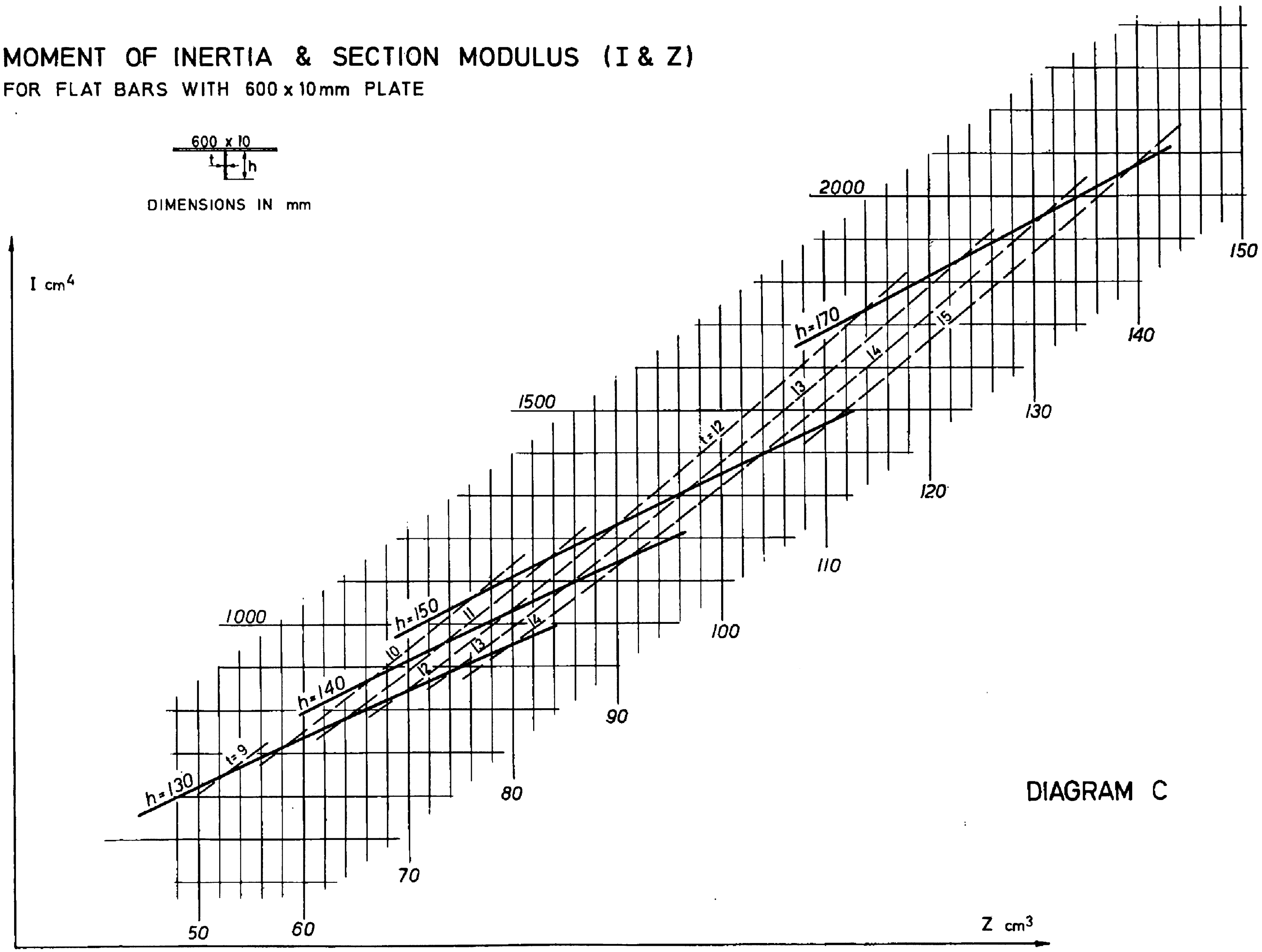
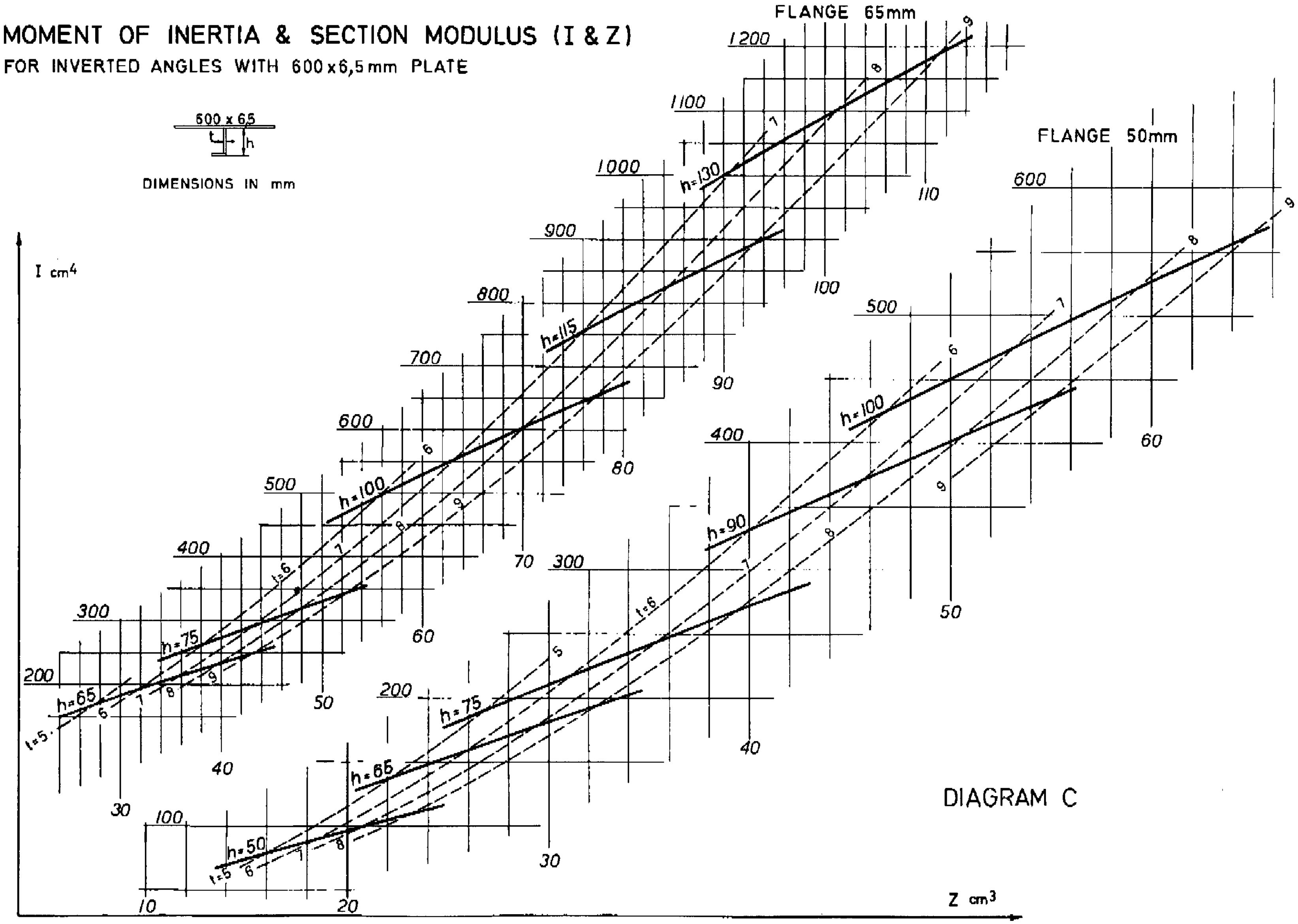


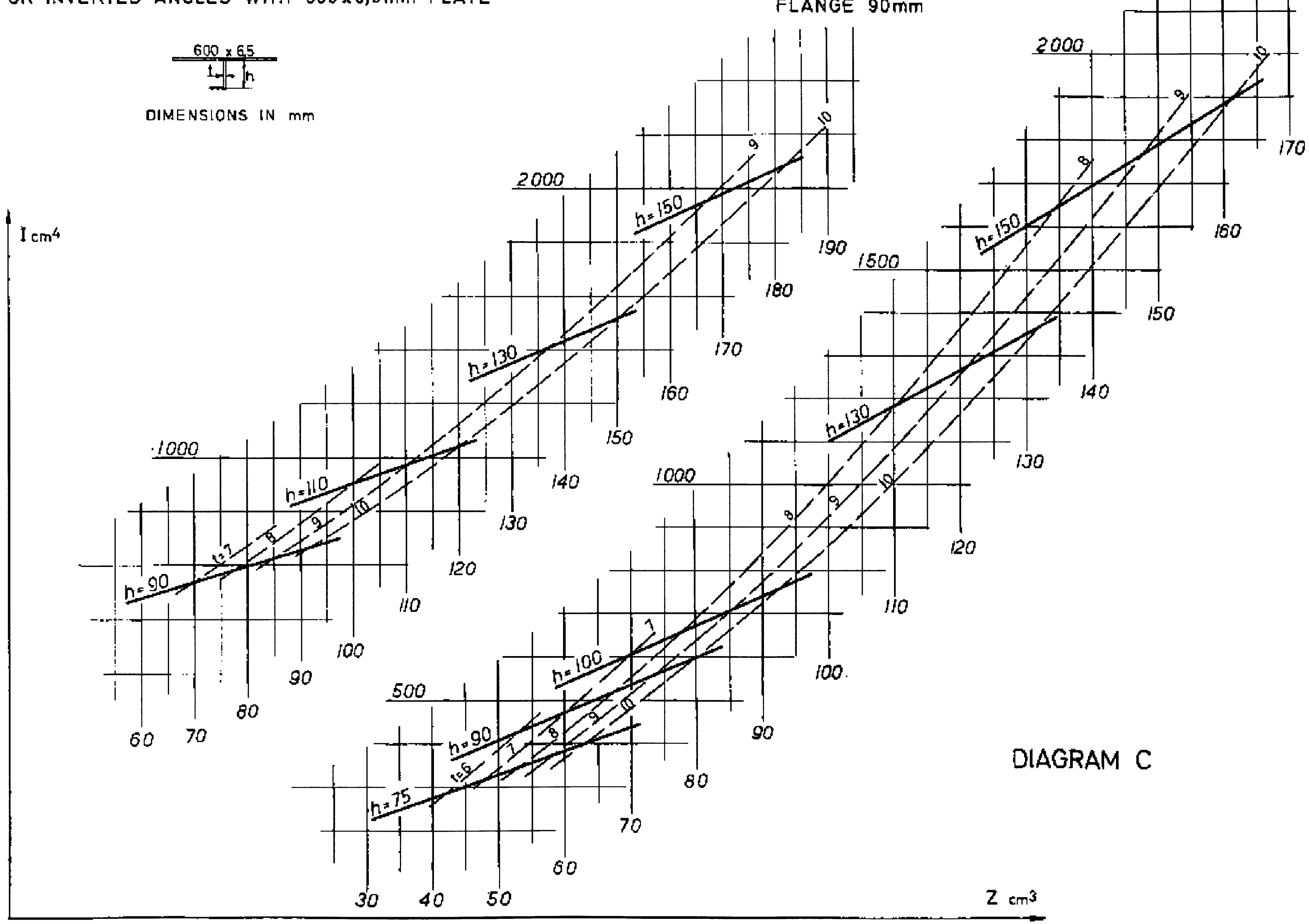
DIAGRAM C



MOMENT OF INERTIA & SECTION MODULUS (I & Z)
FOR INVERTED ANGLES WITH 600x6,5mm PLATE
600 x 6,5
t
h
DIMENSIONS IN mm
FLANGE 65mm
FLANGE 50mm
I cm4
Z cm3
h=65
h=75
h=100
h=115
h=130
h=50
h=90
DIAGRAM C

MOMENT OF INERTIA & SECTION MODULUS (I & Z)

FOR INVERTED ANGLES WITH 600 x 6,5mm PLATE



FOR INVERTED ANGLES WITH 600 x 10 mm PLATE

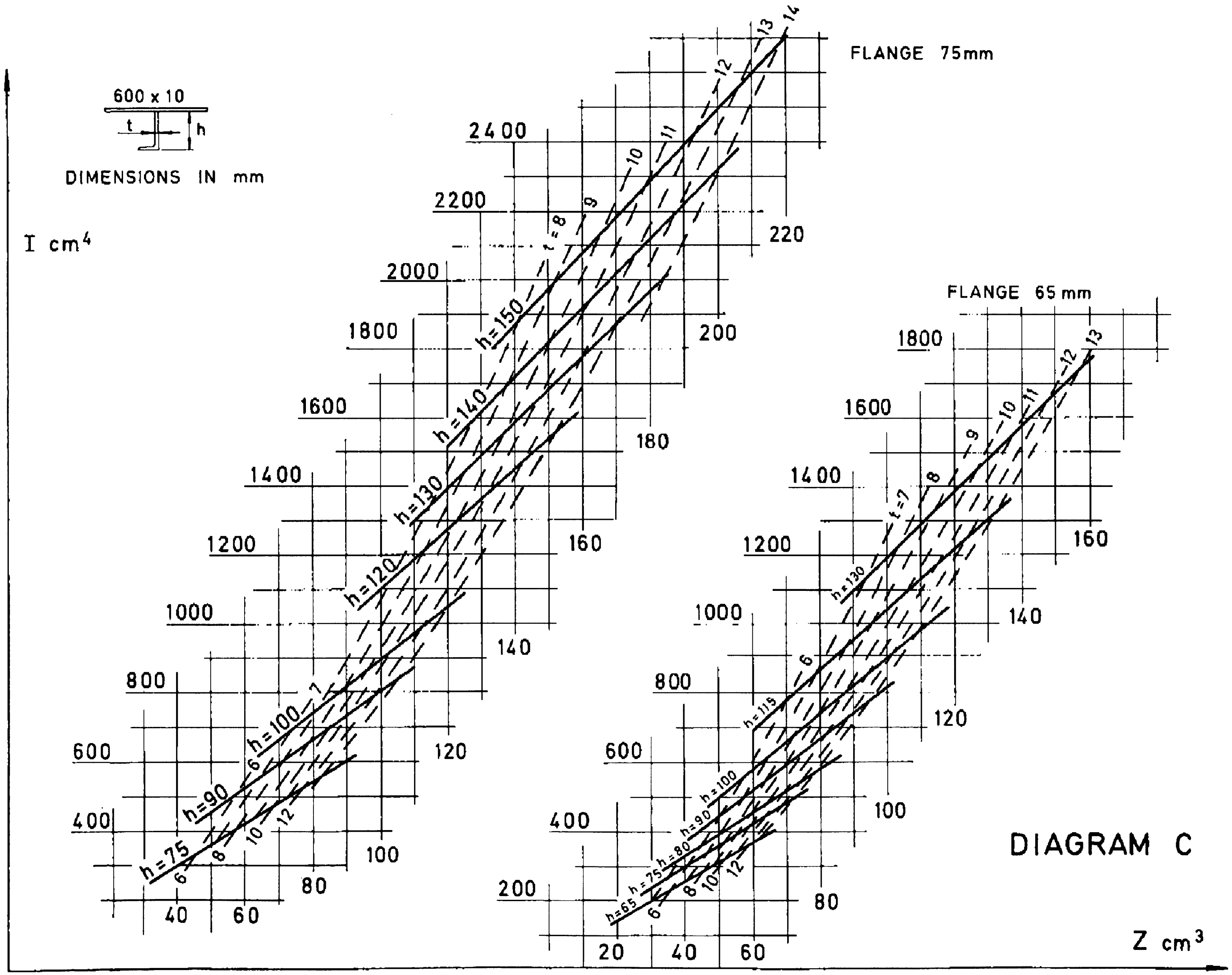


DIAGRAM C

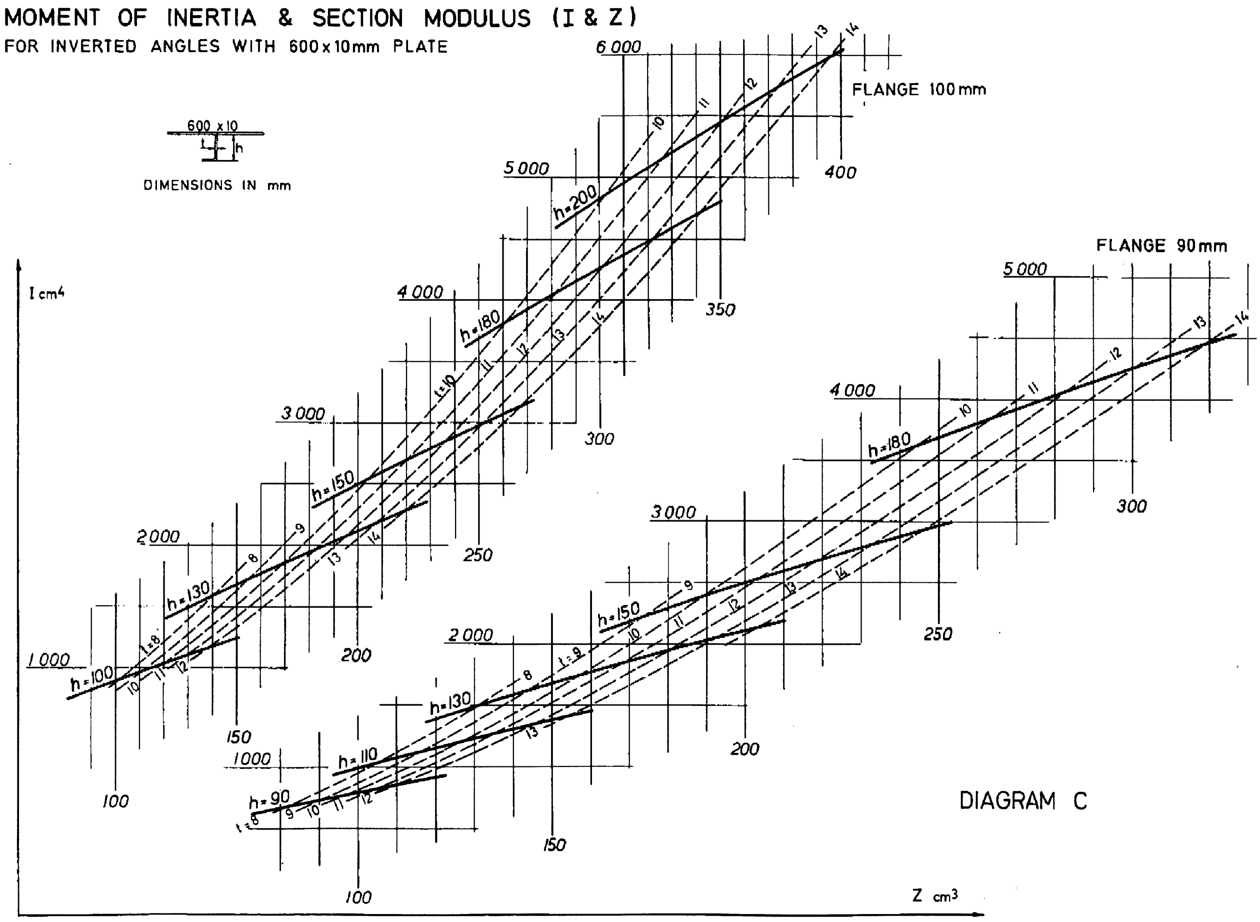

MOMENT OF INERTIA & SECTION MODULUS (I & Z)
FOR INVERTED ANGLES WITH 600x10mm PLATE
600 x10
t
h
DIMENSIONS IN mm
I cm4
Z cm3
FLANGE 100mm
FLANGE 90mm
1 000
2 000
3 000
4 000
5 000
6 000
100
150
200
250
300
350
400
h=90
h=100
h=110
h=130
h=150
h=180
h=200
t=8
t=10
9
10
11
12
13
14

DIAGRAM C

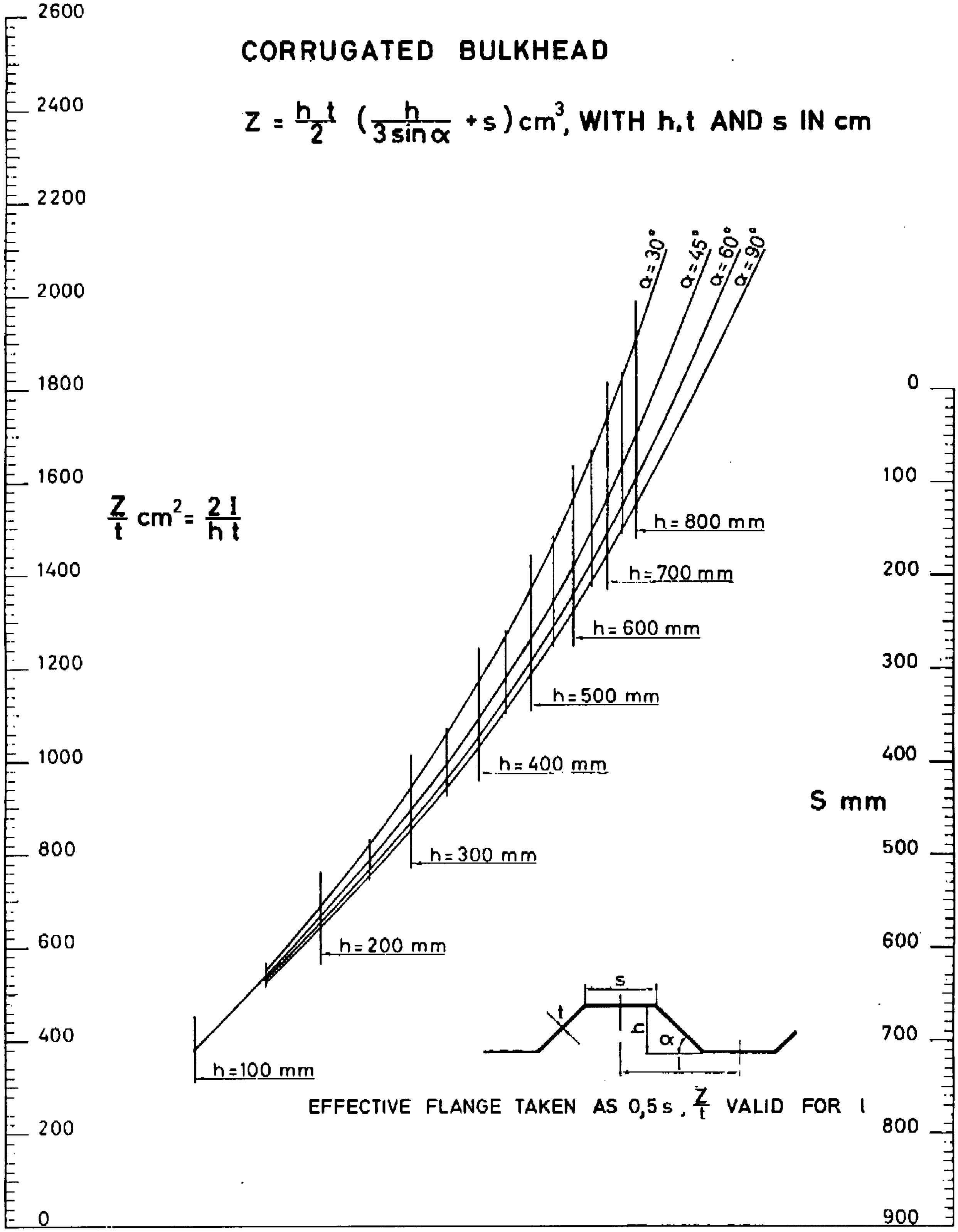

CORRUGATED BULKHEAD
Z = h t/2 (h/(3 sin α) + s) cm³, WITH h, t AND s IN cm
Z/t cm² = 2 I/h t
S mm
α = 30°
α = 45°
α = 60°
α = 90°
h = 100 mm
h = 200 mm
h = 300 mm
h = 400 mm
h = 500 mm
h = 600 mm
h = 700 mm
h = 800 mm
EFFECTIVE FLANGE TAKEN AS 0,5 s, Z/t VALID FOR l
s
t
h
α
l
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
100
200
300
400
500
600
700
800
900

DIAGRAM D

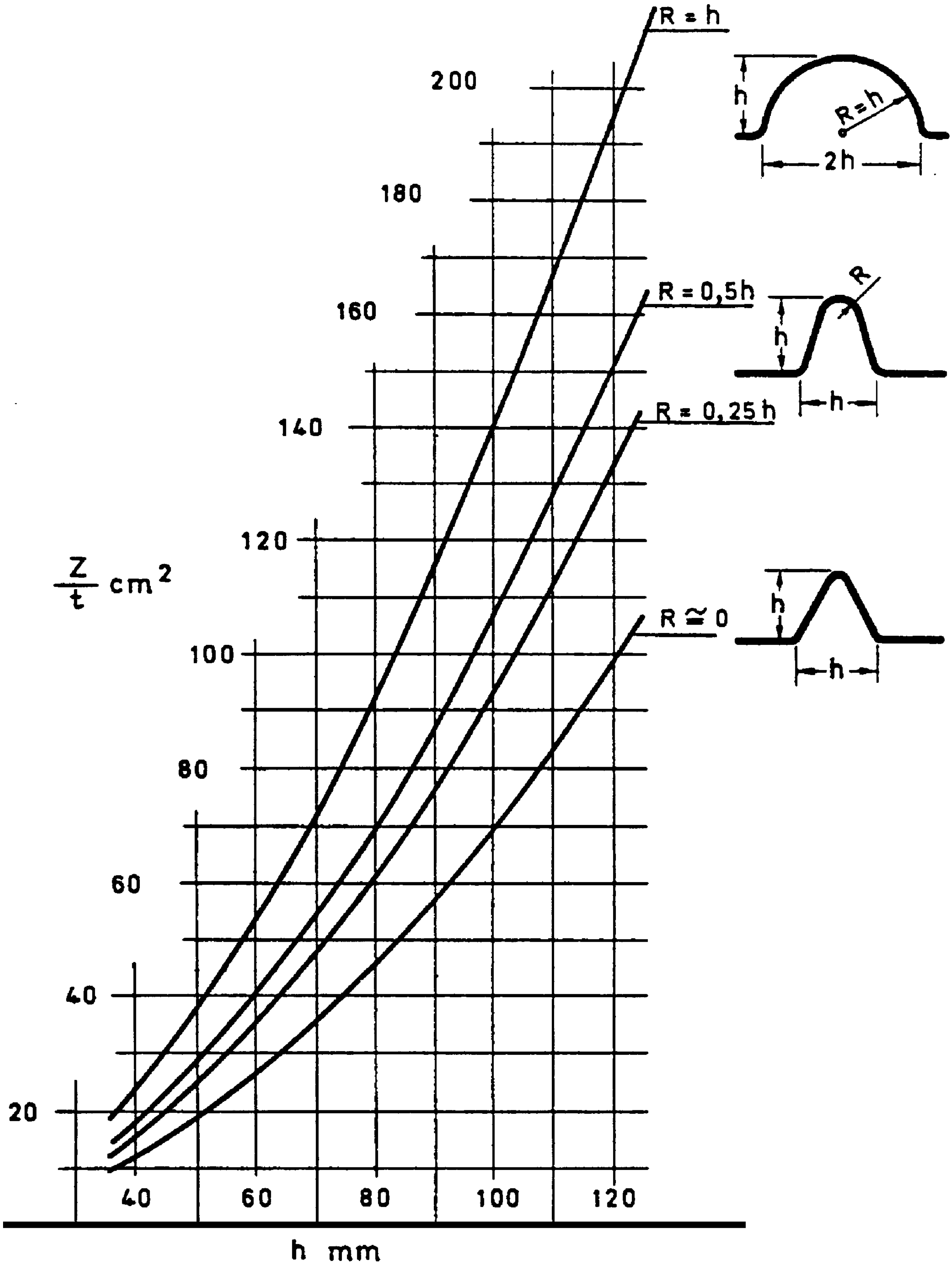

R = h
R = 0,5h
R = 0,25 h
R ≅ 0
200
180
160
140
120
100
80
60
40
20
Z/t cm²
40
60
80
100
120
h mm
h
R=h
2h
R
h
h
h
h

DIAGRAM E