BIRO KLASIFIKASI INDONESIA

RULES
FOR THE CLASSIFICATION
AND CONSTRUCTION OF
SEAGOING STEEL SHIPS

RULES FOR FISHING VESSELS

EDITION 2003

The following Rules come into force on 1st March 2003

Biro Klasifikasi Indonesia Head Office
Jl. Yos Sudarso No.38-39-40 Tanjung Priok - Jakarta 14320 PO.Box : 1010/JKU
Indonesia
☎ +62(021) 497021, 4300993, 4301017, 4301703, 4353291, 4353292
✆ FAX +62(021) 492509, 496175, 4371813
e-mail: pt-bkib1@rad.net.id or
bki1964 @indosat.net.id
Web site: http://www.bki.co.id

Published by : Biro Klasifikasi Indonesia

P.T. (Persero) Biro Klasifikasi Indonesia
Head Office : Jl. Yos Sudarso No. 38-39-40
Tanjung Priok - Jakarta 14320
PO.Box : 1010/JKU
Indonesia
Telephone : +62 (021) 497021, 4300993, 4301017, 4301703, 4353291, 4353292
Telefax : +62 (021) 492509, 496175, 4371813
e-mail: pt-bkib1@rad.net.id or
bki1964 @indosat.net.id
Web site: http://www.bki.co.id

STATUTORY DIVISION	: Ir. Fathorrachman Said, M.Sc
Load Line & Cargo Gear Sect.	: Ir. Bambang Tri Suharto
SOLAS, MARPOL & ISM Sect.	: Ir. Heintje Angganois
QUALITY ASSURANCE DEPARTMENT	: Ir. Saifuddin Wijaya, MBA
PLANNING DEPARTMENT	: Ir. Ajatiman
Budget & Reporting Sect.	: Taufik Hidayat, SE, MM
Information & System Sect.	: Ir. Azril Bayma
RESEARCH & DEVELOPMENT DEPARTMENT	: Ir. Mohamad Sugeng
INTERNAL CONTROL DEPARTMENT	: Ir. I.N.G Arimbawa
FINANCE DIVISION	: Drs. Sukiyo
Finance Adm. Sect.	: Dra. Yayuk Mahanani, MM
Accounting Sect.	: R. Sudaryo, SE
PERSONNEL & GENERAL AFFAIRS DIVISION	: Su'ad Syuhada, SE, MM
Administration & General Affairs Sect.	: Asep Sutrisna S, SH, MM
Personnel & Training Sect.	: Herry Sudrajat, SH, MM
SUPERVISION & CONSULTATION DIVISION	: Hendra Bawono, MBA
Production & Operational Sect.	: Ir. Jeffrey B. Massie
Marketing Sect.	: Ir. Agung Prihanto

BKI BRANCH OFFICES

AMBON

Address : Jl. Raya Pelabuhan, Kompleks Pelabuhan, Ambon 97216
Telephone : (0911) 361105
Telefax : (0911) 361105
E-mail : -
Head : Ir. Pieter Petrus Paulus

BALIKPAPAN

Address : Jl. MT. Haryono No. 3 Ring Road - Balikpapan 76111
Telephone : (0542) 876637, 876641 876642, 876643
Telefax : (0542) 876639, 876645
E-mail : -
Head : Ir. Priyo Santosa
Deputies : Ir. Setudju Dangkeng
Ir. A. Bachrun Saad

BANJARMASIN

Address : Jl. Skip Lama No. 19 Banjarmasin 70112
Telephone : (0511) 50175, 58311
Telefax : (0511) 50175
E-mail : -
Head : Ir. Ridwan Djajanto

BATAM

Address : Jl. Gajah Mada, Komplek Pondok Indah Mc. Dermot Blok A No. 1 Batam 29421
Telephone : (0778) 322178, 322083
Telefax : (0778) 322118
E-mail : ptbkibtm@indosat.net.id
Head : Ir. Darwis Ali

BELAWAN

Address : Jl. Sulawesi II - Belawan, Medan 20413
Telephone : (061) 6941025
Telefax : (061) 6941276
E-mail : -
Head : Ir. Zil Zal HM.

BITUNG

Address : Jl. DS. Sumolang No. 1 Depan Pos IV Pelabuhan, Bitung 95522
Telephone : (0438) 21129
Telefax : (0438) 21282
E-mail : -
Head : Ir. Acep Subarkah

CIGADING

Address : Jl. Gerem Raya No. 01 Pulomerak KM. 5, Cilegon 42438
Telephone : (0254) 571007, 573955
Telefax : (0254) 571007
E-mail : -
Head : Ir. Totok Achmad

CIREBON

Address : Jl. Tuparev KM.3 Cirebon 45153
Telephone : (0231) 205266
Telefax : (0231) 205266
E-mail : -
Head : Ir. Alfonsus Susilarso, AMK-B

DUMAI

Address : Jl. Sungai Rokan No. 96 Dumai 28814
Telephone : (0765) 32574
Telefax : (0765) 31364
E-mail : -
Head : Ir. Yunasri Zainal

KENDARI

Address : Jl. Bunga Matahari No. 64 Kemaraya - Kendari 93121
Telephone : (0401) 321622
Telefax : (0401) 322847
E-mail : -
Head : Ir. Rachmady S.

MAKASSAR

Address : Jl. Sungai Cerekang No. 28
Makassar 90115
Telephone : (0411) 311993, 315460
Telefax : (0411) 315460
E-mail : bkimks@indosat.ned.id
Head : Ir. Arsalnan Latief

PADANG

Address : Jl. St. Syahrir No. 208
Padang 25216
Telephone : (0751) 61553, 765436
Telefax : (0751) 61553
E-mail : -
Head : Ir. Bambang Noeljanto

PALEMBANG

Address : Jl. Perintis Kemerdekaan 5 Ilir,
Palembang 30115
Telephone : (0711) 713171, 713172, 713680
Telefax : (0711) 713173
E-mail : -
Head : Ir. Siswanto

PONTIANAK

Address : Jl. Gusti Hamzah No. 211
Pontianak 78116
Telephone : (0561) 739579, 743107
Telefax : (0561) 739579
E-mail : -
Head : Ir. Saiful Bachri

SEMARANG

Address : Jl. M. Pardi No. 5, Pelabuhan
Tanjung Emas, Semarang 50129
Telephone : (024) 3543917 , 3545805, 3567260
Telefax : (024) 3543917
E-mail : -
Head : Ir. Yansen Miri

SINGAPORE

Address : 111 North Bridge Road
08-07 Peninsula Plaza
Singapore 179098
Telephone : (65) 68830634 - 43 - 51
Telefax : (65) 63393631
E-mail : -
Head : Ir. Onot Subagyo

SORONG

Address : Jl. Jend. Sudirman No. 140
Sorong 98414
Telephone : (0951) 322600
Telefax : (0951) 323870
E-mail : -
Head : Ir. Pardy Abbas

SURABAYA

Address : Jl. Kalianget No. 14
Surabaya 60165
Telephone : (031) 3295448, 3295449,
3295450, 3295451
Telefax : (031) 3294520
E-mail : -
Head : Ir. M. Nasrun Djafar
Deputies : Ir. Umar Faisal
Ir. Mohamad Cholil

TANJUNG PRIOK

Address : Jl. Yos Sudarso 38-39-40
Tanjung Priok, Jakarta 14320
Telephone : (021) 490990, 4301701, 4371488,
43910583, 4300993,
4301017, 4301703
Telefax : (021) 4301702, 497020
E-mail : -
Head : Radjin Sitorus
Deputy : Ir. Nurdin Gading

OFFICES OF FOREIGN CLASSIFICATION SOCIETIES CARRYING OUT SURVEY ON BEHALF OF BIRO KLASIFIKASI INDONESIA

1. AMERICAN BUREAU OF SHIPPING (ABS)

Head Office	: ABS PLAZA 16855 NORTHCHASE DRIVE HOUSTON, TX 77060 USA
Telephone	: (1) (281) 877-5800
Telefax	: (1) (281) 877-5803
Telex	: 6737929 ABS HQ
E-mail	: abs-worldhq@eagle.org
Web site	: www.eagle.org

2. BUREAU VERITAS (BV)

Head Office	: 17 BIS, PLACE DES REFLETS, LA DEFENCE 2 ADR. POST. CEDEX 44 92077 PARIS LA DEFENCE 92400 COURBEVOIE, FRANCE
Telephone	: (33) (1) 4291-5291
Telefax	: (33) (1) 4291-5447
Telex	: 615370 F BV ADM SHIPS IN SERVICE MANAGEMENT 615368 F BV SMS
E-mail	: info@bureauveritas.com
Web site	: www.bureauveritas.com

3. CHINA CLASSIFICATION SOCIETY (CCS)

Head Office	: 40 DONG HUANG CHENG GEN NAN JIE, BEIJING - 100006 PEOPLE'S REPUBLIC OF CHINA
Telephone	: (86) (010) 65136633, 65136787
Telefax	: (86) (010) 65130188
Telex	: 210407 CCSBJ CN
Cable	: CHINAREG
Web site	: www.ccs.org.cw

4. DET NORSKE VERITAS (DnV)

Head Office	: VERITASVEIEN 1, N-1322 HOVIK, NORWAY
P.O.Box	: 300,1322 HOVIC, NORWAY
Telephone	: (47) 6757 9900
Telefax	: (47) 6757 9911
Telex	: 76 192 VERIT N
Cable	: VERITAS OSLO
Web site	: www.dnv.no

5. GERMANISCHER LLOYD (GL)

Head Office	: VORSETZEN 32. D-20459 HAMBURG
Telephone	: (49) (0) 40-36149 - 0
Telefax	: (49) (0) 40-36149 - 200
Telex	: 2 12828 glhh d
Cable	: klassenlloyd hamburg
E-mail	: headoffice@germanlloyd.org
Web site	: www.germanlloyd.org

6. HELLENIC REGISTER OF SHIPPING (HR)

Head Office	: 23 AKTI MIAOULI, 185 35 PIRAEUS, GREECE
Telephone	: (30) (1) 4221900-909
Telefax	: (30) (1) 4221913/4221914
Telex	: 211564/241149 HRS GR
Cable	: HELREGSHIP-PIRAEUS
E-mail	: hrs@hrs.gr
Web site	: www.hrs.gr

7. INDIAN REGISTER OF SHIPPING (IRS)

Head Office	: 52A, ADI SHANKARA- CHARYA MARG, OPP. POWAI LAKE, POWAI, MUMBAY - 400 072.
Telephone	: (91) (22) 5703627 (8 LINES)
Telefax	: (91) (22) 5703611
Telex	: 011-72109 IRS IN
E-mail	: irsho@bom3.vsni.net.in
Web site	: www.irclass.org

8. KOREAN REGISTER OF SHIPPING (KRS)

Head Office	: 23-7 JANG-DONG, YUSUNG-KU, TAEJON REP. OF KOREA 305-600
P.O. Box	: 29 TAEJON REP.OF KOREA
Telephone	: (82) (42) 869-9114
Telefax	: (82) (42) 862-6011 - 6
Web site	: www.krs.co.kr

9. KOREAN CLASSIFICATION SOCIETY DPR OF KOREA (KCS)

Head Office : P.O. BOX 416. PYONGYANG
DEMOCRATIC PEOPLES
REPUBLIC OF KOREA
Telephone : 850-2 331 8059
Telefax : 850-2 331 4416/4427
Telex : 38041 HS KP

10. LLOYD'S REGISTER OF SHIPPING (LR)

Head Office : 100 LEADENHALL STREET,
LONDON, EC 3A 3BP
UNITED KINGDOM
Telephone : (44) (171) 709 9166
Telefax : (44) (171) 4884796
Telex : 888379 LR LON. G
E-mail : it. helpdesk@lr.org
Web site : www.lr. org

11. NIPPON KAIJI KYOKAI (NK)

Head Office : 4-7. KIOI-CHO, CHIYODA-KU,
TOKYO
102-8567, JAPAN
Telephone : (81) (3) 3230-1201
Telefax : (81) (3) 5226-2012
Telex : J22975 CLASSNK,
2324280 CLASSNKJ
Cable : CLASSNK
E-mail : cld@class nk.or.jp
Web site : www.class nk.or.jp

12. REGISTRUL NAVAL ROMAN (RNR)

Head Office : BD, DINICU GOLESCU NR. 38
SECTOR 1,
BUCURESTI 77113,
ROMANIA.
Telephone : (40) (01) 2223768, 6146431
Telefax : (40) (01) 2231972
Telex : 10256 rnrr

13. RINAVE PORTUGUESA

Head Office : REGISTRO INTERNATIONAL
NAVAL, SARL AV. 24 DE
JULHO 126-5
LISBOA, PORTUGAL.

14. SHIPS CLASSIFICATION MALAYSIA (SCM)

Head Office : NO. 1A, TINGKAT 1, BLOK 4
WORLDWIDE BUSINESS
CENTRE, JALAN KARATE
13/49, SEKSYEN 13, 40675
SHAH ALAM, SELANGOR
MALAYSIA
Telephone : (60) (03) 55138170
Telefax : (60) (03) 55138086
E-mail : scmhq@pd.jaring.my

15. VIETNAM REGISTER (VR)

Head Office : 1C KIM NGUU STR
RONAI - VIETNAM
Telephone : (84) (4) 9714243/8219583;
MOBILE : 091205853
Telefax : (84) (4) 8211320/9715839
E-mail : vr@hn.vnn.vn
Web site : www.vr.vnn.vn

COOPERATION WITH FOREIGN CLASSIFICATION SOCIETIES

NO	CLASSIFICATION SOCIETIES	STATE	KIND OF COOPERATION
1	American Bureau of Shipping (ABS)	USA	Dual Class
2	Bureau Veritas (BV)	France	Dual Class
3	China Classification Society (CCS)	China	Mutual Representation
4	Det Norske Veritas (DnV)	Norway	Dual Class
5	Germanischer Lloyd (GL)	Germany	Mutual Representation
6	Hellenic Register of Shipping (HR)	Greece	Mutual Representation
7	Indian Register of Shipping (IRS)	India	Mutual Representation
8	Korean Register of Shipping (KRS)	Rep. of Korea	Mutual Representation
9	Korean Classification Society DPR of Korea (KCS)	DPR of Korea	Mutual Representation
10	Lloyd's Register of Shipping (LR)	U K	Dual Class
11	Nippon Kaiji Kyokai (NK)	Japan	Mutual Representation
12	Registrul Naval Roman (RNR)	Romania	Mutual Representation
13	Rinave Portuguesa	Portugal	Mutual Representation
14	Ships Classification Malaysia (SCM)	Malaysia	Mutual Representation
15	Vietnam Register (VR)	Vietnam	Mutual Representation

Table of Contents

Section 1

General, Definitions

A. Validity, Class Notation

1. The Rules apply to seagoing steel Fishing Vessels[1] classed A 100 whose breadth to depth ratio is within the range common for seagoing ships and the depth H of which is not less than:

   L/16 for unlimited range of service and P (Restricted Ocean Service)

   L/18 for L (Coasting Service)

   L/19 for T (Shallow Water Service)

Exemptions may be accepted if proof is submitted of equal strength, rigidity and safety of the ship.

2. The scantlings given in the Rules are to be adhered to, if the Character of Classification A 100 is to be assigned without any restricting Navigation Notations.

3. Fishing vessels complying with these requirements will have the notation "Fishing Vessel" affixed to their character of classification.

4. If deemed necessary by the Society, compliance with specific strength requirements as per Rules for Hull, Volume II may be required.

5. Upon request BKI will examine the fishing gear for compliance with Section 21.E and the structural fire Protection, life saving appliances and other equipment for compliance with the provisions of the "Torremolinos International Convention for the Safety of Fishing Vessels, 1977" and so certify.

B. Restricted Service

1. For determining the scantlings of the longitudinal and transverse structures of ships intended to operate within one of the restricted service ranges P, L and T, the dynamic loads may be reduced as specified in Sections 4 and 5.

2. For the definition of the service ranges P, L and T see Rules for Classification and Surveys, Volume I, Section.2, C. 3.1.1.2.

[1] Fishing vessel means any vessel used commercially for catching fish, whales, seals, walrus or other living resources of the sea.

C. International Conventions, Codes and Guidelines

Where reference is made of International Conventions and Codes these are defined as follows:

1. Safety of Fishing Vessels

Torremolinos International Convention for the Safety of Fishing Vessels, 1977 as amended.

2. MARPOL 73/78

International Convention for the Prevention of Pollution from Ships, 1973 including the 1978 Protocol as amended.

3. Code of Safety for Fisherman and Fishing Vessels Part B

IMO Code for Fishermen and Fishing Vessels Part B, Safety and Health Requirements for the Construction and Equipment of Fishing Vessels.

4. Guidelines

FAO/ILO/IMO Voluntary Guidelines for the Design, Construction and Equipment of Small Fishing Vessels.

D. Equivalence

Ships deviating from the Construction Rules in their types, equipment or in some of their parts may be classed, provided that their structures or equipment are found to be equivalent to the Society's requirements for the respective class.

E. Accessibility

All parts of the hull are to be accessible for survey and maintenance.

F. Stability

Steel fishing vessels will be assigned class only after it has been demonstrated that their intact stability is adequate for the service intended.

Adequate intact stability means compliance with standards laid down by the relevant Administration. BKI reserve to deviate therefrom, if required for special reasons, taking into account the ships' size and type. The level of intact stability for ships of all sizes in any case should not be less than that provided by IMO Resolution A.168 as amended by A.268.

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

G. Vibrations and Noise

1. Vibrations

Operating conditions which are encountered most frequently should be kept free as far as possible from resonance vibrations of the ship hull and individual structural components. Therefore, the exciting forces coming from the propulsion plant and pressure fluctuations should be limited as far as possible. Besides the selection of the propulsion units particular attention is to be given to the ship's lines including the stern post, as well as to the minimization of possible cavitation. In the shaping of the bow of large ships, consideration is to be given to limit excitation from the seaway.

As far as critical excitation loads cannot be eliminated, appropriate measures are to be taken on the basis of theoretical investigations at an early design stage. Fatigue considerations must be included. For machinery, equipment and other installations the vibration level is to be kept below that specified in Rules for Machinery Installations, Volume III., Section 1, as far as possible.

The evaluation of vibrations in living and working areas should follow ISO 6954 except where other national or international rules or standards are mandatory. It is recommended to use the lower transition curve of ISO 6954 as a criteria for design, whereas the upper curve may serve for the evaluation of vibration measurements.

2. Noise

Suitable precautions are to be taken to keep noises as low as possible particularly in the crew's quarters, working spaces, passengers' accommodations etc.

Attention is drawn to regulations concerning noise level limitations, if any, of the flag administration.

H. Submission of Plans

1. To ensure conformity with the Rules the following drawings and documents are to be submitted in triplicate showing the arrangement and the scantlings of structural members:

.1 Midship section

The cross sectional plans (midship section, other typical sections) must contain all necessary data on the scantlings of the longitudinal and transverse hull structure as well as details of anchor and mooring equipment.

.2 Longitudinal section

The plan of longitudinal sections must contain all necessary details on the scantlings of the longitudinal and transverse hull structure and on the location of the watertight bulkheads and the deck supporting structures, arrangement of superstructures and deck houses, as well as fastening of cargo masts and boat davits in the hull.

.3 Decks

Plans of the decks showing the scantlings of the deck structures, length and breadth of cargo hatches, openings above the engine and boiler room, and other deck openings. On each deck, it has to be stated which deck load caused by cargo is to be assumed in determining the scantlings of the decks and their supports.

.4 Shell

Drawings of shell expansion, containing full details on the location and size of the openings and drawings of the sea chests.

.5 Ice strengthening

The drawings listed in 1.1 – 1.4 and 1.9 must contain all necessary details on ice strengthening where applicable.

.6 Bulkheads

Drawings of the transverse, longitudinal and wash bulkheads and of all tank boundaries, with details on the densities of the liquids, the heights of overflow pipes and set pressures of the pressure vacuum relief valves (if any).

.7 Bottom structure

Drawings of single and double bottom showing the arrangement of the transverse and longitudinal girders as well as the water and oiltight subdivision of the double bottom.

.8 Engine and boiler seatings

Drawings of the engine and boiler seatings, the bottom structure under the seatings and of the transverse structures in the engine room, with details on fastening of the engine foundation plate to the seating, as well as type and output of engine.

.9 Stem and stern construction

Drawings of stem, stern and rudder, including rudder support. The rudder drawings must contain details on the ship's speed, the bearing materials to be employed, and the ice strengthening. Drawings of propeller brackets and shaft exits.

.10 Hatchways

Drawings of hatchway construction and of covers of all hatches, containing full details affecting strength.

.11 Intact stability

Intact stability particulars containing all information required to assess the stability for every loading condition. For assigning class for the first time to a newbuilding, preliminary particulars may be accepted.

.12 Materials

The drawings mentioned in 1.1 – 1.10 must contain details on the hull structural steels to be employed and their grades.

Where higher tensile steels are used, drawings for possible repairs have to be placed on board.

.13 Weld connections

The drawings listed in items 1.1 – 1.10 must contain details on the weld connections of the structural elements.

.14 Substructures

Drawings of substructures below trawl gallows, steering gears, windlasses and chain stoppers as well as masts and boat davits together with details on loads to be transmitted into structural elements.

.15 Structural fire protection

In addition to the fire control and safety plan also drawings of the arrangement of divisions (insulation, A-, B- and C-divisions) including information regarding BKI-approval number.

Drawings of air conditioning and ventilation plants.

2. Additional documents and drawings may be required, if deemed necessary.

3. Any deviations from approved drawings are subject to approval before work is commenced.

J. Definitions

1. General

Unless otherwise mentioned, the dimensions according to 2. and 3. are to be inserted in [m] into the formulae stated in the following Sections.

2. Principal dimensions

2.1 Length L: The length is L the distance, on the deepest operating waterline, from the foreside of stem to the after side of the rudder post, or the centre of the rudder stock if there is no rudder post (L_{pp}). Where L_{pp} is less than 96% of the length on the deepest operating waterline (L_{DOWL}) L is not to be less than $0{,}96 \times L_{DOWL}$. Where L_{pp} is greater than 97 % of L_{DOWL} the length L need not be greater than $0{,}97 \times L_{DOWL}$. In ships with unusual stem and bow arrangement the length L will be specially considered.

2.2 Length L_c (according to MARPOL 73/78): The length L_c is to be taken as 96 % of the total length on a waterline at 85 % of the least moulded depth measured from the top of the keel, or as the length from the fore side of the stem to the axis of the rudder stock on that waterline, if that be greater. In ships designed with a rake of keel the waterline on which this length is measured shall be parallel to the designed waterline.

2.3 Forward perpendicular F.P.: The forward perpendicular coincides with the foreside of the stem on the waterline on which the respective length L or L_c is measured.

2.4 Breadth B: The breadth B is the greatest moulded breadth of the ship.

2.5 Depth H: The depth H is the vertical distance, at the middle of the length L, from the base line to top of the deck beam at side on the uppermost continuous deck.

In way of effective superstructures the depth H is to be measured up to the superstructure deck for determining the ship's scantlings.

2.6 Deepest operating waterline T: Deepest operating waterline T is the waterline related to the maximum permissible operating draught.

3. Frame spacing a: The frame spacing a will be measured from moulding edge to moulding edge of frame.

4. Block coefficient C_B: Moulded block coefficient at load draught T, based on rule length L.

$$C_B = \frac{\text{moulded displacement } [m^3] \text{ at draught } T}{L \cdot B \cdot T}$$

5. Ship's speed v_0: Expected maximum ahead speed of the ship in [kn] in calm water at rated engine speed of the propulsion plant.

6. Definition of decks

6.1 Bulkhead deck is the deck up to which the watertight bulkheads are carried.

6.2 Strength deck is the deck or the parts of a deck which form the upper flange of the effective longitudinal structure.

6.3 Weather deck: All free decks and parts of decks exposed to the sea are defined as weather deck.

6.4 Working deck is generally the lowest complete deck above the deepest operating waterline from which fishing is undertaken. In vessels fitted with two or more complete decks, the BKI may accept a lower deck as a working deck provided that deck is situated above the deepest operating waterline.

6.5 Lower decks: Starting from the uppermost continuous deck, the lower decks are defined as Deck No. 2, 3, etc.

6.6 Superstructure decks: The Superstructure Decks situated immediately above the uppermost continuous deck are termed Forecastle Deck, Bridge Deck, and Poop Deck. Superstructure Decks above the Bridge Deck are termed Second Superstructure Deck, Third Superstructure Deck, etc.

6.7 For the arrangement of hatches, doors and ventilators the following areas are defined:

Pos. 1 :
- on exposed bulkhead decks
- on raised quarter decks
- on exposed superstructure decks within the forward quarter of **L**.

Pos. 2 :
- on exposed superstructure decks aft of the forward quarter of **L**.

K. Rounding-off Tolerances

Where in determining plate thicknesses in accordance with the provisions of the following Sections the figures differ from full or half mm, they may be rounded off to full or half milimeters up to 0,2 or 0,7, above 0,2 or 0,7 mm they are to be rounded up.

L. Computer Programs

1. General

1.1 In order to increase the flexibility in the structural design of ships Biro Klasifikasi Indonesia also accepts direct calculations with computer programs. The aim of such analyses should be the proof of equivalence of a design with the rule requirements.

1.2 Direct calculations may also be used in order to optimise a design; in this case only the final results are to be submitted for examination.

2. Programs

2.1 The choice of computer programs is free. The programs may be checked by Biro Klasifikasi Indonesia through comparative calculations with predefined test examples. A generally valid approval for a computer program is, however, not given by Biro Klasifikasi Indonesia.

2.2 Direct calculations may be used in the following fields

- global strength
- longitudinal strength
- beams and grillages
- detailed strength.

2.3 For such calculation the computer model, the boundary condition and load cases are to be agreed upon with Biro Klasifikasi Indonesia.

The calculation documents are to be submitted including input and output. During the examination it may prove necessary that Biro Klasifikasi Indonesia perform independent comparative calculations.

M. Workmanship

1. General

1.1 Requirements to be complied with by manufacturer

1.1.1 The manufacturing plant must be provided with suitable equipment and facilities to enable proper handling of the materials, manufacturing processes, structural components, etc. BKI reserves the right to inspect the manufacturing plant accordingly or to restrict the scope of manufacture to the potential available.

1.1.2 The manufacturing plant must have at its disposal sufficiently qualified personnel. BKI must be advised of the names and areas of responsibility of all supervisory and control personnel. BKI reserves the right to require proof of qualification.

1.2 Quality control

1.2.1 As far as required and expedient, the manufacturer's personnel has to control all structural components both during manufacture and on completion, to ensure that they are complete, that the dimensions are correct and that workmanship is satisfactory and meets the standard of good shipbuilding practice.

1.2.2 Upon control and corrections by the manufacturing plant, the structural components are to be shown to the BKI Surveyor for inspection, in suitable sections, normally in unpainted condition and enabling proper access for inspection.

1.2.3 The Surveyor may reject components that have not been adequately controlled by the plant and may demand their resubmission upon successful completion of such checks and corrections by the plant.

2. Structural Details

2.1 Details in manufacturing documents

2.1.1 All significant details concerning quality and functional ability of the component concerned shall be entered in the manufacturing documents (workshop drawings etc.). This includes not only scantlings but, where relevant, such items as permissible tolerances, surface conditions (finishing), and special methods of manufacture involved as well as inspection and acceptance requirements.

2.1.2 If, due to missing or insufficient details in the manufacturing documents, the quality or functional ability of the component cannot be guaranteed or is doubtful, BKI may require appropriate improvements. This includes the provision of supplementary or additional parts (for example reinforcements) even if these were not required at the time of plan approval or if, as a result of insufficient detailing, such requirement was not obvious.

2.2 Cut-outs, plate edges

2.2.1 The free edges (cut surfaces) of cut-outs, hatch corners, etc. are to be properly prepared and are to be free from notches. As a general rule, cutting drag lines etc. must not be welded out, but are to be smoothly ground. All edges should be broken or in cases of highly stressed parts, should be rounded off.

2.2.2 Free edges on flame or machine cut plates or flanges are not to be sharp cornered and are to be finished off as laid down in para. 2.1. This also applies to cutting drag lines etc., in particular to the upper edge of shear strake and analogously to weld joints, changes in sectional areas or similar discontinuities.

2.3 Cold forming

2.3.1 For cold forming (bending, flanging, beading) of plates the minimum average bending radius should not fall short of 3 t (t = plate thickness) and must be at least 2 t. Regarding the welding of cold formed areas, see Section 19, B.2.6

2.3.2 In order to prevent cracking, flame cutting flash or sheering burrs must be removed before cold forming. After cold forming all structural components and, in particular, the ends of bends (plate edges) are to be examined for cracks. Except in cases where edge cracks are negligible, all cracked components are to be rejected. Repair welding is not permissible.

2.4 Assembly, alignment

2.4.1 The use of excessive force is to be avoided during the assembly of individual structural components or during the erection of sections. As far as possible major distortions of individual structural components should be corrected before further assembly.

2.4.2 Girders, beams, stiffeners, frames etc. that are interrupted by bulkheads, decks etc. must be accurately aligned.

2.4.3 After completion of welding, straightening and aligning must be carried out in such a manner that the material properties will not be influenced significantly. In case of doubt, BKI may require a procedure test or a working test to be carried out.

3. Corrosion Protection

3.1 General

Hollow spaces, such as those in box girders, tube supports etc., which can either be shown to be air tight or are accepted as such from normal ship building experience, need not have their internal surfaces protected. During construction, however, such hollow spaces must be kept clean and dry.

3.2 Coatings

3.2.1 Surfaces of plates and profiles are to be freed from rust, cleaned and then coated in a dry state with a proved coating material in accordance with manufacturers' instructions.

3.2.2 Swedish Standard SIS 055900 can be taken as a guide in evaluating the degree of rust and quality grade involved. Unless otherwise agreed the preparation of the surface must be at least up to derusting grade Sa 2 ½.

3.2.3 Shop primers are to be of an approved type.

3.2.4 Primers and coatings to be used for the under water portion of the ship must be non-hydrolyzable or saponifiable.

3.3 Cathodic protection

3.3.1 Cathodic protection can be provided either by use of sacrificial anodes or by the provision of impressed current protection.

3.3.2 Over-protection due to too low potential is to be avoided. In cases of combinations with cathodic protection the coating must not be susceptible to cathodic loading. The immediate vicinity of the anodes has to be shielded off.

3.4 Pairing of materials

3.4.1 Where metals having different potentials are bounded together in an electrolytic solution, such as sea water, preventive measures must be taken against anticipated contact corrosion.

3.4.2 Apart from selecting the most suitable materials for the particular application, the use of appropriate insulation, an effective coating and the use of cathodic protection are possible ways of preventing contact corrosion.

3.5 Fitting-out and berthing periods

3.5.1 If vagrant currents are loading the ship's structure during fitting-out and berthing periods, sufficiently large sacrificial anodes are to be hung around the ship and electrically bonded to the ship's structure.

3.5.2 Foreign currents, such as those caused by inappropriate provision of direct current sources to the ship for the purpose of welding and for single-poled auxiliary lighting, must be eliminated by providing properly located return cables of appropriate size.

Section 2

Materials

A. General

1. All materials to be used for the structural members are to be in accordance with the Rules for Materials, Volume V and Rules for Welding, Volume VI. Materials the properties of which deviate from these Rule requirements may only be used upon special approval.

B. Hull Structural Steel for Plates and Sections

1. Ordinary hull structural steel

1.1 Ordinary hull structural steel is a hull structural steel with a minimum nominal upper yield point R_{eH} of 235 [N/mm^2] and a tensile strength of 400 – 520 [N/mm^2].

1.2 The material factor k in the formulae of the following sections is to be taken 1,0 for ordinary hull structural steel.

1.3 Ordinary hull structural steel is grouped into the grades KI-A, KI-B, KI-D, KI-E, which differ from each other in their toughness properties. For the application of the individual grades for the structural hull members, see 3.

2. Higher tensile hull structural steel

2.1 Higher tensile hull structural steel is a hull structural steel the yield and tensile properties of which exceed those of ordinary hull structural steel. According to the Rules for Materials, Volume V for four groups of higher tensile hull structural steel the nominal upper yield point R_{eH} has been fixed at 265, 315, 355 and 390 [N/mm^2] respectively. Where higher tensile hull structural steel is used, for scantling purposes the following values in Table 2.1 are to be taken for the material factor k mentioned the various Sections.

Table 2.1

R_{eH} [N/mm^2]	k
265	0,91
315	0,78
355	0,72
390	0,66

For higher tensile hull structual steel with other nominal yield stresses, the material factor k may be determined by the following formula:

$$k = \frac{295}{R_{eH} + 60}$$

Note

Especially when higher tensile structural steels are used, limitation of permissible stresses due to buckling and fatigue strength criteria may be required.

2.2 Higher tensile hull structural steel is grouped into the following grades, which differ from each other in their toughness properties:

KI–A 27 S,
KI–D 27 S,
KI–E 27 S,
KI–A 32/36/40,
KI–D 32/36/40,
KI–E 32/36/40.
KI–F 32/36/40.

In Table 2.2 the grades of the higher tensile steels are marked by the letter "H".

2.3 Where structural members are completely or partly made from higher tensile hull structural steel, a suitable notation will be entered into the ship's certificate.

2.4 In the drawings submitted for approval it is to be shown which structural members are made of higher tensile hull structural steel. These drawings are to be placed on board in case any repairs are to be carried out.

2.5 Regarding welding of higher tensile hull structural steel, see Rules for Welding, Volume VI, Section 12.

3. Material selection for the hull

3.1 Material classes

For the material selection for hull structural members the following material classes as given in Table 2.2 are defined.

3.2 Material selection for longitudinal structural members

3.2.1 Materials of the various structural members are not to be of lower grades than those obtained from the Table 2.3. Depending on the categories of structural members (**Secondary, Primary** and **Special**) for structural members not specifically mentioned in Table 2.3, grade A/AH material may generally be used. Single plate strakes within 0,4 L amidships for which class III or E/EH material is required are to have a breadth b = 800 + 5 L, max. 1800 mm.

3.3 Material selection for local structural members

3.3.1 The material selection for local structural members, which are not part of the longitudinal hull structure, may be effected according to Table 2.4.

Table 2.2

Thickness t [mm] [1] / Material class	≤ 15	> 15 ≤ 20	> 20 ≤ 25	> 25 ≤ 30	> 30 ≤ 35	> 35 ≤ 40	> 40 ≤ 50	> 50 ≤ 100
I	A/AH	A/AH	A/AH	A/AH	B/AH	B/AH	D/DH	D/DH [2]
II	A/AH	A/AH	B/AH	D/DH	D/DH	D/DH	E/EH	E/EH
III	A/AH	B/AH	D/DH	D/DH	E/EH	E/EH	E/EH	E/EH

1) Actual thickness of the structural member.

2) For thicknesses t > 60 mm E/EH.

Table 2.3

Structural member category	Material class or grade within 0,4 L amidships	Material class or grade outside 0,4 L amidships
Secondary : Lower strake of longitudinal bulkhead Deck plating exposed to weather, in general Side plating	I	A/AH
Primary: Bottom plating, including keel plate Strength deck plating [1] Continuous longitudinal members above strength deck, excluding longitudinal hatch coamings Upper strake in longitudinal bulkhead Vertical strake (hatch side girder) and upper sloped strake in top wing tank	II	A/AH
Special: Sheer strake at strength deck Stringer plate in strength deck Deck strake at longitudinal bulkhead Bilge strake [2] Continuous longitudinal hatch coamings [3]	III	II (I outside 0,6 L)

1) Plating at corners of large hatch openings to be specially considered. Class III or grade E/EH to be applied in positions where high local stresses may occur.

2) May be of class II in ships with a double bottom over the full breadth and with length less than 150 metres.

3) At least grade D/DH.

3.3.2 Rudder body plates, which are subjected to stress concentrations (e.g. in way of lower support of semispade rudders), are to be of class III material.

3.3.3 For topplates of machinery foundations located outside 0,6 L amidships, grade A ordinary hull structural steel may also be used for thicknesses above 40 mm.

For members not specifically mentioned normally grade A/AH may be used. However, BKI may require also higher grades depending on the stress level.

Table 2.4

Structural member	Material class
face plates and webs of girder systems, hatch covers	II [1]
rudder body [2], rudder horn, sole piece, stern frame, propeller brackets	II

[1] Class I material sufficient, where rolled sections are used or the parts are machine cut from plates with condition on delivery of either "normalised", "rolled normalized" or "rolled thermo-mechanical".

[2] See 3.3.2.

3.4 Material selection for structural members which are exposed to low temperatures

3.4.1 The material selection for structural members, which are continuously exposed to temperatures below 0 °C, e.g. in or adjacent to refrigerated cargo holds, is governed by the design temperature of the strength members. The design temperature is the temperature derived at by a temperature distribution calculation taking into account the design environmental temperatures. The design environmental temperatures for unrestricted service are:

air : + 5 °C

sea water : 0 °C.

3.4.2 For ships intended to operate permanently in areas with low air temperatures (below and including – 20 °C), e.g. regular service during winter seasons to Arctic or Antarctic waters, the materials in exposed structures are to be selected based on the design temperature t_D, to be taken as defined in 3.4.5.

Materials in the various strength members above the lowest ballast water line (BWL) exposed to air are not to be of lower grades than those corresponding to classes I, II and III, as given in Table 2.5, depending on the categories of structural members (**Secondary**, **Primary** and **Special**). For non-exposed structures and structures below the lowest ballast water line, see 3.3.

3.4.3 The material grade requirements of each material class depending on thickness and design temperature are defined in Table 2.6. For design temperatures $t_D < -55$°C, materials are to be specially considered.

3.4.4 Single strakes required to be of class III or of grade E/EH or FH are to have breadths not less than 800 + 5 · L mm, maximum 1800 mm.

Plating materials for stern frames, rudder horns, rudders and shaft brackets are not to be of lower grades than those corresponding to the material classes given in 3.3.

3.4.5 The design temperature t_D is to be taken as the lowest mean daily average air temperature in the area of operation. The following definitions apply:

Mean: Statistical mean over an observation period of at least 20 years

Average: Average during one day and night.

Lowest: Lowest during year.

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

4. Structural members which are stressed in direction of their thickness

4.1 Rolled materials, which are significantly stressed in direction of their thickness, are recommended to be examined for doublings and nonmetallic inclusions by ultrasonic testing.

4.2 In case of high local stresses in the thickness direction, e.g. due to shrinkage stresses in single bevel or double bevel T-joints with a large volume of weld metal, steels with guaranteed material properties in the thickness direction according to the Rules for Materials, Volume V are to be used in order to avoid lamellar tearing.

C. Forged Steel and Cast Steel

Forged steel and cast steel for stem, stern frame, rudder post etc. is to comply with the Rules for Materials, Volume V. The tensile strength of forged steel is not to be less than 400 [N/mm^2], the tensile strength of cast steel is not to be less than 375 [N/mm^2].

D. Aluminium Alloys

1. Where seawater resisting aluminium alloys, as specified in the Rules for Materials, Volume V, are used for the construction of superstructures, deckhouses, hatchway covers and similar parts, the conversion from steel to aluminium scantlings is to be carried out by using the material factor:

$$k_{A\ell} = \frac{635}{R_{p0,2} + R_m}$$

$R_{p0,2}$ = 0,2 % proof stress of the aluminium alloy in [N/mm^2]

R_m = tensile strength of the aluminium alloy in [N/mm^2].

For welded connections the respective values in welded condition are to be taken. Where these figures are not available, the respective values for the softannealed condition are to be used.

Method of conversion:

– section modulus: $W = W_{St} \cdot k_{A\ell}$

– plate thickness: $t = t_{St} \cdot \sqrt{k_{A\ell}}$

2. The smaller modulus of elasticity is to be taken into account when determining the buckling strength of structural elements subjected to compression. This is to be applied accordingly to structural elements for which maximum allowable deflections are prescribed.

3. The conversion of the scantlings of the main hull structural elements from steel into aluminium alloy is to be specially considered taking into account the smaller modulus of elasticity, as compared with steel, and the fatigue strength aspects, specifically those of the welded connections.

E. Austenitic Steels

Where austenitic steels are applied having a ratio $R_{p0,2}/R_m \le 0{,}5$, after special approval the 1% proof stress $R_{p1,0}$ may be used for scantling purposes instead of the 0,2% proof stress $R_{p0,2}$.

Table 2.5

Material classes and grades for structures exposed to low temperatures		
Structural member category	**Material class**	
	Within 0,4 L amidships	**Outside 0,4 L amidships**
Secondary: Deck plating exposed to weather, in general Side plating above BWL [3] Transverse bulkheads above BWL [3]	I	I
Primary: Strength deck plating [1] Continuous longitudinal members above strength deck, excluding longitudinal hatch coamings Longitudinal bulkhead above BWL [3] Top wing tank plating above BWL [3]	II	I
Special: Sheer strake at strength deck Stringer plate in strength deck Deck strake at longitudinal bulkhead Continuous longitudinal hatch coamings [2]	III	II

1) Plating at corners of large hatch openings to be specially considered. Class III or grade E/EH to be applied in positions where high local stresses may occur.

2) Not to be less than grade D/DH

3) BWL = ballast water line.

Table 2.6

Material grade requirements for classes I, II and III at low temperatures				
Class I – Secondary				
Plate thickness [mm]	t_D −20 / −25 °C	t_D −26 / −35 °C	t_D −36 / −45 °C	t_D −46 / −55 °C
t ≤ 10	A / AH	B / AH	D / DH	D / DH
10 < t ≤ 15	B / AH	D / DH	D / DH	D / DH
15 < t ≤ 20	B / AH	D / DH	D / DH	E / EH
20 < t ≤ 25	D / DH	D / DH	D / DH	E / EH
25 < t ≤ 30	D / DH	D / DH	E / EH	E / EH
30 < t ≤ 35	D / DH	D / DH	E / EH	E / EH
35 < t ≤ 45	D / DH	E / EH	E / EH	FH
45 < t ≤ 50	E / EH	E / EH	FH	FH
Class II – Primary				
Plate thickness [mm]	t_D −20 / −25 °C	t_D −26 / −35 °C	t_D −36 / −45 °C	t_D −46 / −55 °C
t ≤ 10	B / AH	D / DH	D / DH	E / EH
10 < t ≤ 20	D / DH	D / DH	E / EH	E / EH
20 < t ≤ 30	D / DH	E / EH	E / EH	FH
30 < t ≤ 40	E / EH	E / EH	FH	FH
40 < t ≤ 45	E / EH	FH	FH	
45 < t ≤ 50	E / EH	FH	FH	
Class III – Special				
Plate thickness [mm]	t_D −20 / −25 °C	t_D −26 / −35 °C	t_D −36 / −45 °C	t_D −46 / −55 °C
t ≤ 10	D / DH	D / DH	E / EH	E / EH
10 < t ≤ 20	D / DH	E / EH	E / EH	FH
20 < t ≤ 25	E / EH	E / EH	FH	FH
25 < t ≤ 30	E / EH	E / EH	FH	FH
30 < t ≤ 35	E / EH	FH	FH	
35 < t ≤ 40	E / EH	FH	FH	
40 < t ≤ 50	FH	FH		

Section 3

Design Principles

A. General

1. This section contains definitions and principles for using the formulae in the following sections as well as indications concerning structural details.

2. Permissible stresses

In the following sections permissible stresses have been stated in addition to the formulae for calculating the section moduli and cross sectional areas of webs of frames, beams, girders, stiffeners etc. and may be used when determining the scantlings of those elements by means of direct strength calculations.

3. Plate panels subjected to lateral pressure The formulae for plate panels subjected to lateral pressure as given in the following Sections are based on the assumption of an uncurved plate panel having an aspect ratio $b/a \leq 2{,}24$.

For curved plate panels and/or plate panels having aspect ratios smaller than $b/a \approx 2{,}24$, the thickness may be reduced as follows:

$$t = C \cdot a \sqrt{p \cdot k}\; f_1 \cdot f_2 \cdot + t_k$$

C = constant, e.g. C = 1,1 for tank plating

$$f_1 = 1 - \frac{a}{2\,r}$$

f_{1min} = 0,75

r = radius of curvature in [m]

$$f_2 = \sqrt{1{,}1 - 0{,}5\left(\frac{a}{b}\right)^2}$$

f_{2max} = 1,0

a = smaller breadth of plate panel

b = larger breadth of plate panel

p = applicable design load.

The factor f_2 is not to be applied when determining the side shell thickness in case of longitudinal framing according to Section 6.

B. Upper and Lower Hull Flange

1. All continuous longitudinal structural members up to z_0 below the strength deck at side and up to z_u above base line are considered to be the upper and lower hull flange respectively.

2. Where the upper and/or the lower hull flange are made from ordinary hull structural steel their vertical extent $z_0 = z_u$ equals 0,1 **H**.

3. The vertical extent z of the upper and lower hull flange respectively made from higher tensile steel is not to be less than:

$$z = e\,(1 - n \cdot k)$$

$$z_{min} = 0{,}1\ H$$

e = distance of deck at side or of the base line from the neutral axis of the midship section. For ships with continuous longitudinal structural members above the strength deck, see Section 5, C.4.1

n = $W_{(a)}/W$

$W_{(a)}$ = actual deck or bottom section modulus

W = Rule deck or bottom section modulus.

C. Unsupported Span

1. Stiffeners, frames

1.1 The unsupported span ℓ is the length of stiffeners or frames between two supporting girders or else their length including end attachments (brackets).

1.2 Knuckles can be credited as points of support for frames if angle α according to Fig. 3.1 less than or equal to 150°.

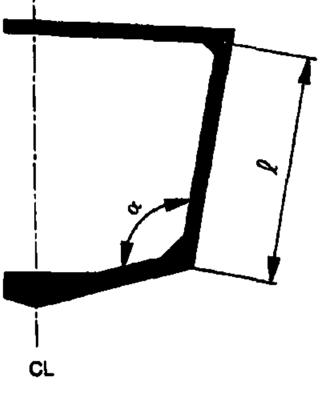


Fig 3.1

2. Corrugated bulkhead elements

The unsupported span ℓ of corrugated bulkhead elements is their length between bottom and deck or their length between vertical or horizontal girders. Where corrugated bulkhead elements are connected to box type elements of comparatively low rigidity, their depth is to be included into the span ℓ unless otherwise proved by calculations.

3. Transverses and girders

The unsupported span ℓ of transverses and girders is to be determined according to Fig. 3.2, depending on the type of end attachment.

In special cases, the rigidity of the adjoining girders is to be taken into account when determining the span of girder.

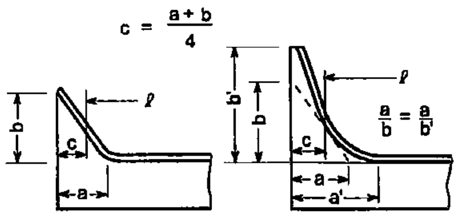


Fig. 3.2

D. End Attachments

1. Definitions

For determining scantlings of beams, stiffeners and girders the terms "constraint" and "simple support" will be used.

"Constraint" will be assumed where for instance the stiffeners are rigidly connected to other members by means of brackets or are running through over supporting girders.

"Simple support" will be assumed where for instance the stiffener ends are sniped or the stiffeners are connected to plating only, see also 3.

2. Brackets

2.1 For the scantlings of brackets the required section modulus of the section is decisive. Where sections of different section moduli are connected to each other, the scantlings of the brackets are generally governed by the smaller section.

2.2 The thickness of brackets is not to be less than:

$$t = c \cdot \sqrt[3]{\frac{W}{k_1}} + t_k \quad [\text{mm}]$$

c = 1,2 for non-flanged brackets

c = 0,95 for flanged brackets

k_1 = material factor k for the section according to Section 2, B.2.

t_K = corrosion allowance according to K

W = section modulus of smaller section in [cm^3]

t_{min} = 6,5 mm

t_{max} = web thickness of smaller section.

The thickness of brackets in tanks is not to be less than the minimum thickness t_{min} as per Section 12, A.6.

2.3 The arm length of brackets is not to be less than:

$$\ell = 50{,}6 \sqrt{\frac{W \cdot k_2}{t \cdot k_1}} \quad [\text{mm}]$$

ℓ_{min} = 100 mm

W see 2.2

k_2 = material factor k for the bracket according to Section 2, B.2.

The arm length ℓ is the length of the welded connection.

When determining the arm length ℓ, t is to be taken as the thickness of the non-flanged bracket.

2.4 The scantlings of the brackets (thickness, arm length) as well as their relation to the various sections may be taken from the tables in the Annex.

2.5 The throat thickness a of the welded connection is to be determined according to Section 19.

2.6 Where flanged brackets are used the width of flange is to be determined according to the following formula:

$$b = 40 + \frac{W}{30}$$

b is not to be taken less than 50 mm and need not be taken greater than 90 mm.

2.7 The free length of non-flanged brackets shall not exceed $40 \cdot t$.

3. Sniped ends of stiffeners

Stiffeners may be sniped at the ends, if the thickness of the plating supported by stiffeners is not less than:

$$t = c \sqrt{\frac{p \cdot a\,(\ell - 0{,}5 \cdot a)}{R_{eH}}} \quad [\text{mm}]$$

p = design load in [kN/m^2]

ℓ = unsupported length of stiffener in [m]

a = spacing of stiffeners in [m]

R_{eH} = yield stress of the plating's material in [N/mm^2]

c = 15,8 for watertight bulkheads

c = 19,6 otherwise.

4. Corrugated bulkhead elements

Carlings, girders or floors are to be fitted below the corrugated bulkhead elements, at their supports, for transmitting the acting forces. These elements are to be fitted in alignment with the face plate strips (see Fig. 3.3).

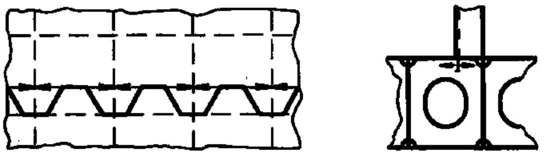


Fig. 3.3

E. Effective Width of Plating

1. Frames and stiffeners

Generally, the spacing of frames and stiffeners may be taken as effective width of plating.

2. Transverses and girders (general)

2.1 The effective width of plating e_m of the frames and girders may be determined according to Table 3.1 considering the type of loading.

Table 3.1

ℓ/e	0	1	2	3	4	5	6	7	≥8
e_{m1}/e	0	0,36	0,64	0,82	0,91	0,96	0,98	1,00	1,0
e_{m2}/e	0	0,20	0,37	0,52	0,65	0,75	0,84	0,89	0,9

e_{m1} is to be applied where girders are loaded by uniformly distributed loads or else by not less than 6 equally spaced single loads.

e_{m2} is to be applied where girders are loaded by 3 or less single loads.

Intermediate values may be obtained by direct interpolation.

The length ℓ to be used in the table may be taken as the unsupported span in case of simply supported girders and 60 % of the unsupported span where girders are constrained at both ends.

e = width of plating supported, measured from centre to centre of the adjacent unsupported fields.

2.2 The effective cross sectional area of plates is not to be less than the cross sectional area of the face plate.

2.3 Where the angle α between web of stiffeners or else of girders and the attached plating is less than 75° the required section modulus is to be multiplied by the factor 1/sin α.

3. Cantilevers

Where cantilevers are fitted at every frame, the effective width of plating may be taken as the frame spacing.

Where cantilevers are fitted at a greater spacing the effective width of plating at the respective cross section may approximatively be taken as the distance of the cross section from the point on which the load is acting, however, not greater than the spacing of the cantilevers.

F. Proof of Buckling Strength [1)]

1. Definitions

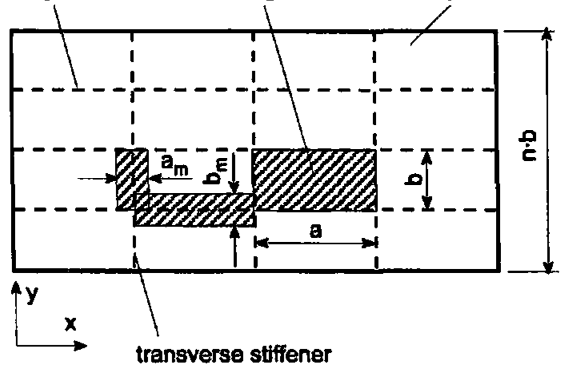
a = length of single or partial plate field in [mm]

b = breadth of single plate field in [mm]

α = aspect ratio of single plate field

α = a/b

n = number of single plate field breadths within the partial or total plate field



longitudinal : stiffener in the direction of the length a
transverse : stiffener in the direction of the breath b

Fig. 3.4

t = nominal plate thickness in [mm]

t = $t_a - t_K$ in [mm]

t_a = plate thickness as built in [mm]

t_K = corrosion allowance according to K. in [mm]

σ_x = membrane stress in x-direction in [N/mm²]

σ_y = membrane stress in y-direction in [N/mm²]

τ = shear stress in the x-y plane in [N/mm²]

Compressive and shear stresses are to be taken positive, tension stresses are to be taken negative.

---

1) The calculation method is based on DIN-Standard 18800.

Guidance

If the stresses in the x- and y-direction contain already the Poisson - effect, the following modified stress values may be used:

$$\sigma_x = \frac{\sigma_x^* - 0{,}3 \cdot \sigma_y^*}{0{,}91}$$

$$\sigma_y = \frac{\sigma_y^* - 0{,}3 \cdot \sigma_x^*}{0{,}91}$$

σ_x^*, σ_y^* = *stresses containing the Poisson-effect*

ψ = edge stress ratio according to Table 3.3

F_1 = correction factor for boundary condition at the long. stiffeners according to Table 3.2

Table 3.2

Correction factor F_1		
1,0 for stiffeners sniped at both ends		
Guidance values * :	1,05	for flat bars
where both ends	1,10	for bulb sections
are effectively	1,20	for angle and tee-sections
connected to	1,30	for girders of high rigidity
adjacent structures		(e.g. bottom transverses)
* Exact values may be determined by direct calculations.		

F_2 = weighting factor according to Table 3.3 and/ or 3.4 accounting for the effect of linear buckling on plate buckling for the stress direction considered, linear buckling occurs when $F_2 > 0$.

σ_e = reference stress

$$\sigma_e = 0{,}9 \cdot E \left(\frac{t}{b} \right)^2 \ [\text{kN/m}^2]$$

E = Young's modulus

E = $2{,}06 \cdot 10^5$ [N/mm²] for steel

E = $0{,}69 \cdot 10^5$ [N/mm²] for aluminium alloys

R_{eH} = nominal yield point in [N/mm²] for hull structural steels according to Section 2, B.2.

R_{eH} = 0,2 % proof stress in [N/mm²] for aluminium alloys

S = safety factor

S = 1,1 in general

S = 1,2 for structures which are exclusively exposed to local loads

S = 1,05 for combinations of statistically independent loads

λ = reference degree of slenderness

$$\lambda = \sqrt{\frac{R_{eH}}{K \cdot \sigma_e}}$$

K = buckling factor according to Tables 3.3 and 3.4.

Table 3.3 Plane Plate Fields

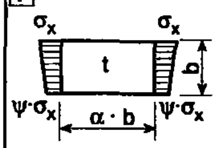
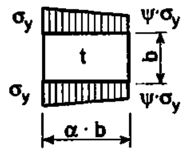
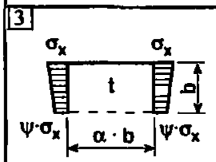
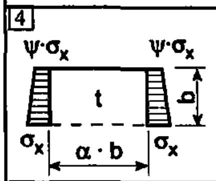
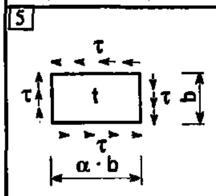
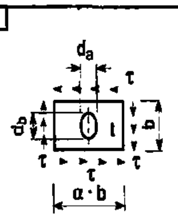
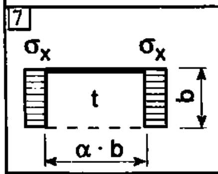
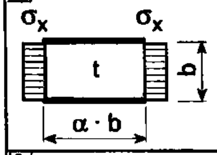
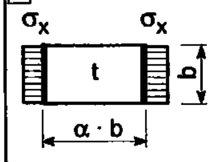
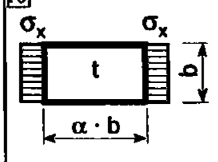
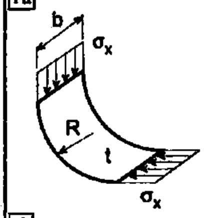
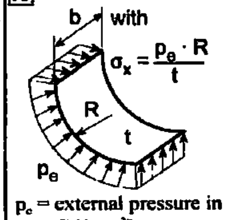
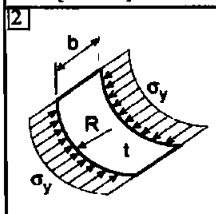
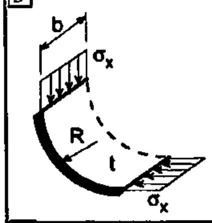
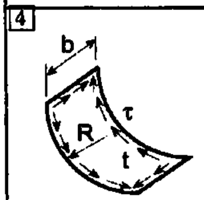
Load case	Edge stress ratio ψ	Aspect ratio α	Buckling factor K	Reductions factor κ Weighting factor F_2
1 	$1 \ge \psi \ge 0$ $0 > \psi > -1$ $\psi \le -1$	$\alpha > 1$	$K = \frac{8,4}{\psi + 1,1}$ $K = 7,63 - \psi\,(6,26 - 10\,\psi)$ $K = (1 - \psi)^2 \cdot 5,975$	$\kappa_x = c\left(\frac{1}{\lambda} - \frac{0,22}{\lambda^2}\right) \le 1$ $\lambda \ge 0,673$ to be used $c = 1,25 - 0,12\,\psi \le 1,25$ $F_2 = 0$
2 	$1 \ge \psi \ge 0$	$\alpha \ge 1$	$K = F_1\left(1 + \frac{1}{\alpha^2}\right)^2 \frac{2,1}{(\psi+1,1)}$	$\kappa_y = c\left(\frac{1}{\lambda} - \frac{0,22}{\lambda^2}\right) \le 1$ $\lambda \ge 0,673$ to be used $c = 1,25 - 0,12\,\psi$ $\le 1,25$ $F_2 = \frac{\lambda_p^2 + 0,5 - \frac{K}{0,91}}{\lambda_p^2 - 0,5}$ $\lambda_p = \lambda$ $1,225 \le \lambda_p \le 1,87$
	$0 > \psi > -1$	$1 \le \alpha \le 1,5$	$K = F_1\left[\left(1 + \frac{1}{\alpha^2}\right)^2 \frac{2,1}{1,1}(1 + \psi) - \frac{\psi}{\alpha^2}(13,9 - 10\,\psi)\right]$	
		$\alpha > 1,5$	$K = F_1\left[\left(1 + \frac{1}{\alpha^2}\right)^2 \frac{2,1}{1,1}(1 + \psi) - \frac{\psi}{\alpha^2}(5,87 + 1,87\,\alpha^2 + \frac{8,6}{\alpha^2} - 10\,\psi)\right]$	
	$\psi \le -1$	$1 \le \alpha \le (1 - \psi)\frac{3}{4}$	$K = F_1\left(\frac{1 - \psi}{\alpha}\right)^2 \cdot 5,975$	
		$\alpha > (1 - \psi)\frac{3}{4}$	$K = F_1\left[\left(\frac{1 - \psi}{\alpha}\right)^2 \cdot 3,9675 + 0,5375\left(\frac{1 - \psi}{\alpha}\right)^4 + 1,87\right]$	
3 	$1 \ge \psi \ge 0$	$\alpha > 0$	$K = \frac{1,3333\left(0,425 + \frac{1}{\alpha^2}\right)}{\psi + 0,3333}$	$\kappa_x = \frac{1}{\lambda^2 + 0,51} \le 1$ $F_2 = \frac{\lambda_p^2 + 0,5 - \frac{K \cdot \alpha^2}{0,91}}{\lambda_p^2 - 0,5}$ $\lambda_p = \lambda$ $1,225 \le \lambda_p \le 1,87$
	$0 > \psi \ge -1$		$K = 4\left(0,425 + \frac{1}{\alpha^2}\right)(1 + \psi) - 5 \cdot \psi\,(1 - 3,42\,\psi)$	
4 	$1 \ge \psi \ge -1$	$\alpha > 0$	$K = \left(0,425 + \frac{1}{\alpha^2}\right)(1,5 - 0,5 \cdot \psi)$	
5 	—	$\alpha \ge 1$ $0 < \alpha < 1$	$K = K_\tau \cdot \sqrt{3}$ $K_\tau = \left[5,34 + \frac{4}{\alpha^2}\right]$ $K_\tau = \left[4 + \frac{5,34}{\alpha^2}\right]$	$\kappa_\tau = \frac{0,84}{\lambda} \le 1$ $F_2 = 0$
6 	—		$(a - d_a) \ge (b - d_b) : K = K'\left[1 - \frac{d_b}{b}\right]$ $(a - d_a) < (b - d_b) : K = K'\left[1 - \frac{d_a}{a}\right]$ K' = K according to line 5	

Table 3.3 Plane Plate Fields (Cont.)

Load case	Edge stress ratio ψ	Aspect ratio α	Buckling factor K	Reductions factor κ Weighting factor F_2
7 	—	$\alpha \geq 1{,}64$ $\alpha < 1{,}64$	$K = 1{,}28$ $K = \frac{1}{\alpha^2} + 0{,}56 + 0{,}13\ \alpha^2$	see load case 4
8 	—	$\alpha \geq \frac{2}{3}$ $\alpha < \frac{2}{3}$	$K = 6{,}97$ $K = \frac{1}{\alpha^2} + 2{,}5 + 5\ \alpha^2$	$\kappa_x = 1{,}13\left[\frac{1}{\lambda} - \frac{0{,}22}{\lambda^2}\right] \leq 1$ $\lambda \geq 0{,}673$ to be used $F_2 = \dfrac{\lambda_p^2 + 0{,}5 - \dfrac{K - \alpha^2}{0{,}91}}{\lambda_p^2 - 0{,}5}$ $\lambda_p = \lambda$ $1{,}225 \leq \lambda_p \leq 1{,}87$
9 	—	$\alpha \geq 4$ $4 > \alpha > 1$ $\alpha \leq 1$	$K = 4$ $K = 4 + \left[\frac{4 - \alpha}{3}\right]^4 2{,}74$ $K = \frac{4}{\alpha^2} + 2{,}07 + 0{,}67\ \alpha^2$	
10 	—	$\alpha \geq 4$ $4 > \alpha > 1$ $\alpha \leq 1$	$K = 6{,}97$ $K = 6{,}97 + \left[\frac{4 - \alpha}{3}\right]^4 3{,}1$ $K = \frac{4}{\alpha^2} + 2{,}07 + 4\ \alpha^2$	

Explanations for boundary conditions :
- - - - - - plate edge free
———— plate edge simply supported
━━━━ plate edge clamped

Table 3.4 Curved plate field R/t ≤ 2500

Load case	Aspect ratio b / R	Buckling factor K	Reduction factor κ * Weighting faktor F 2
1a  1b  p_e = external pressure in [N/mm²]	$\frac{b}{R} \le 1{,}63\sqrt{\frac{R}{t}}$ $\frac{b}{R} > 1{,}63\sqrt{\frac{R}{t}}$	$K = \frac{b}{\sqrt{R \cdot t}} + 3\,\frac{(R \cdot t)^{0{,}175}}{b^{0{,}35}}$ $K = 0{,}3\,\frac{b^2}{R^2} + 2{,}25\left(\frac{R^2}{b \cdot t}\right)^2$	$\lambda < 1{,}2$ $\kappa_x = 1{,}274 - 0{,}686\,\lambda$ ≤ 1 $\lambda \ge 1{,}2$ $\kappa_x = \frac{0{,}65}{\lambda^2}$ $F_2 = 0$
2 	$\frac{b}{R} \le 0{,}5\sqrt{\frac{R}{t}}$ $\frac{b}{R} > 0{,}5\sqrt{\frac{R}{t}}$	$K = 1 + \frac{2}{3}\,\frac{b^2}{R \cdot t}$ $K = 0{,}267\,\frac{b^2}{R \cdot t}\left[3 - \frac{b}{R}\sqrt{\frac{t}{R}}\right]$ $\ge 0{,}4\,\frac{b^2}{R \cdot t}$	$\lambda < 1{,}0$ $\kappa_y = 1{,}233 - 0{,}933\,\lambda$ ≤ 1 $1 \le \lambda \le 1{,}5$ $\kappa_y = 0.3 / \lambda^3$ $\lambda > 1{,}5$ $\kappa_y = 0.2 / \lambda^2$ $F_2 = 0$
3 	$\frac{b}{R} \le \sqrt{\frac{R}{t}}$ $\frac{b}{R} > \sqrt{\frac{R}{t}}$	$K = \frac{0{,}6 \cdot b}{\sqrt{R \cdot t}} + \frac{\sqrt{R \cdot t}}{b} - 0{,}3\,\frac{R \cdot t}{b^2}$ $K = 0{,}3\,\frac{b^2}{R^2} + 0{,}291\left(\frac{R^2}{b \cdot t}\right)^2$	see load case 1a
4 	$\frac{b}{R} \le 8{,}7\sqrt{\frac{R}{t}}$ $\frac{b}{R} > 8{,}7\sqrt{\frac{R}{t}}$	$K = K_\tau \cdot \sqrt{3}$ $K_\tau = \left[28{,}3 + \frac{0{,}67 \cdot b^3}{R^{1{,}5} \cdot t^{1{,}5}}\right]^{0{,}5}$ $K_\tau = 0{,}28\,\frac{b^2}{R\sqrt{R \cdot t}}$	$\lambda < 1{,}2$ $\kappa_\tau = 1{,}274 - 0{,}686\,\lambda$ ≤ 1 $\lambda \ge 1{,}2$ $\kappa_\tau = \frac{0{,}65}{\lambda^2}$ $F_2 = 0$

Explanations for boundary conditions : ------- plate edge free
——— plate edge simply supported
━━━ plate edge clamped

* For curved single fields. e.g. the bilge strake, which are located within plane partial or total fields, the reduction factor κ may be taken as follows :

Load case 1b : $\kappa_x = 0{,}8/\lambda^2 \le 1{,}0$; load case 2: $\kappa_y = 0{,}65/\lambda^2 \le 1{,}0$

Table 3.5

Plane plate fields	
Factors κ_{px}, κ_{py}, F 3	**Exponents e_1, e_2, e_3**
1. $\sigma_x > 0$ (compressive stress) $F_2 \leq 0$: $\kappa_{px} = \kappa_x$ κ_x acc. to Table 3.3 $F_2 > 0$: $\kappa_{px} = \left(1 - F_2^2\right)\kappa_x + F_2^2 \cdot \kappa_k$ Where compressive stresses σ_x and σ_y are not resulting from direct stress inducement but are caused by constant edge displacement, the following values may be used for F_2^2 for load case 2 of Table 3.3: – value F_2^2 multiplied by $(1 - F_1/\alpha)$ for dynamic loadings; – $F_2 = 0$ for static loads (e.g. for girders of watertight bulkheads). $\kappa_k = 1{,}0$ for $\lambda \leq 0{,}2$ $\kappa_k = \dfrac{1}{\phi + \sqrt{\phi^2 - \lambda^2}}$ for $\lambda > 0{,}2$ $\phi = 0{,}5\left(1 + 0{,}34\,(\lambda - 0{,}2) + \lambda^2\right)$ 2. $\sigma_x \leq 0$ (tension stress) $\kappa_{px} = 1$	$e_1 = 1 + \kappa_{px}^4$ $e_2 = 1 + \kappa_{py}^4$ $e_3 = 1 + \kappa_{px} \cdot \kappa_{py} \cdot \kappa_\tau^2$ κ_τ acc.to Table 3.3
Factor κ_{py} to be calculated analoguously as factor κ_{px} for stress σ_y in y-direction.	
1. σ_x and σ_y positive (compressive stress): $F_3 = \left(\kappa_{px} \cdot \kappa_{py}\right)^5$ 2. σ_x or σ_y negative (tension stress): $F_3 = 1{,}0$	
Curved plate fields	
σ_x and σ_y positive (compressive stress) $\kappa_{px} = \kappa_x$ $\kappa_{py} = \kappa_y$ $F_3 = 0$	$e_1 = 1{,}25$ $e_2 = 1{,}25$ $e_3 = 2{,}00$

2. Proof of single plate fields

2.1 Proof is to be provided that the following condition is complied with for the single plate field a · b:

$$\left(\frac{|\sigma_x| \cdot S}{\kappa_{px} \cdot R_{eH}}\right)^{e_1} + \left(\frac{|\sigma_y| \cdot S}{\kappa_{py} \cdot R_{eH}}\right)^{e_2} - F_3\left(\frac{\sigma_x \cdot \sigma_y \cdot S^2}{R_{eH}^2}\right) + \left(\frac{|\tau| \cdot S \cdot \sqrt{3}}{\kappa_\tau \cdot R_{eH}}\right)^{e_3} \le 1{,}0$$

Each term of the above condition must be less than 1,0.

The factors κ_{px}, κ_{py}, F_3 and the exponents e_1, e_2 and e_3 are given in Table 3.5. The factor κ_τ is given in Table 3.3 and/or 3.4.

In general, the ratio plate field breadth to plate thickness shall not exceed b/t = 100.

2.2 Effective width of plating

The effective width of plating may be determined by the following formulae:

$b_m = \kappa_{px} \cdot b$ for longitudinal stiffeners

$a_m = \kappa_{py} \cdot a$ for transverse stiffeners

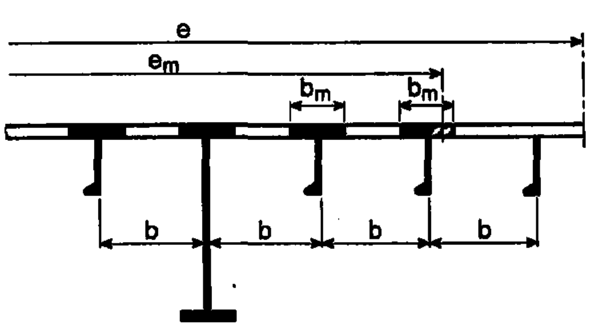
see also Fig. 3.4.

The effective width of plating is not to be taken greater than the value obtained from E.2.1.

Note

The effective width e'_m of stiffened flange plates of girders may be determined as follows:

Stiffening parallel to web of girder :.

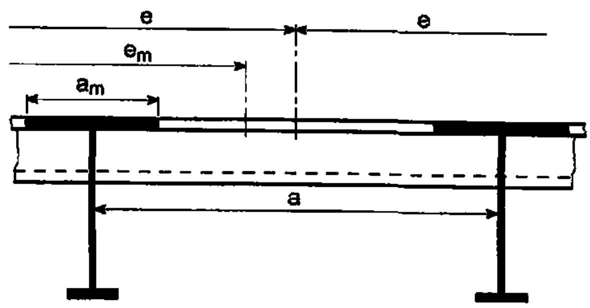


e'_m = $n \cdot b_m$

n = *integral number of the stiffener spacing b inside the effective width "e_m" according to Table 3.1 in E.2.1*

$$n = int\left(\frac{e_m}{b}\right)$$

Stiffening vertical to web of girder:



$$e'_m = a_m \cdot \frac{e_m}{e}$$

e = *width of plating supported according to E.2.1*

2.3 Webs and flanges

For non-stiffened webs and flanges of sections and girders proof of sufficient buckling strength as for single plate fields is to be provided according to 2.1.

Guidance

Within 0,6 L amidships the following guidance values are recommended for the ratio web depth to web thickness and/or flange breadth to flange thickness:

flat bars: $h \quad \frac{h_w}{t_w} \le 19{,}5\sqrt{k}$

angle-, tee and bulb sections:

web: $\frac{h_w}{t_w} \le 60{,}0\sqrt{k}$

flange: $\frac{b_i}{t_f} \le 19{,}5\sqrt{k}$

b_i = *b_1 or b_2 according to Fig. 3.3, the larger value is to be taken.*

3. Proof of partial and total fields

3.1 Longitudanal and transverse stiffeners

Longitudinal and transverse stiffeners Proof is to be provided that the longitudinal and transverse stiffeners of partial and total plate fields comply with the conditions set out in 3.2 and 3.3.

3.2 Lateral buckling

$$\frac{\sigma_a + \sigma_b}{R_{eH}} S \le 1$$

σ_a = uniformly distributed compressive stress in the direction of the stiffener axis in [N/mm²]

σ_a = σ_x for longitudinal stiffeners

σ_a = σ_y for transverse stiffeners

σ_b = bending stress in the stiffeners

$$\sigma_b = \frac{M_0 + M_1}{W_{st} \cdot 10^3} \quad [N/mm^2]$$

M_0 = bending moment due to deformation w of stiffener

$$M_0 = F_{Ki} \frac{p_z \cdot w}{c_f - p_z} \quad [N \cdot mm]$$

$$(c_f - p_z) > 0$$

M_1 = bending moment due to the lateral load p for continuous longitudinal stiffeners:

$$M_1 = \frac{p \cdot b \cdot a^2}{24 \cdot 10^3} \quad [N \cdot mm]$$

for transverse stiffeners:

$$M_1 = \frac{p \cdot a\,(n \cdot b)^2}{c_s \cdot 8 \cdot 10^3} \quad [N \cdot mm]$$

p = lateral load in [kN/m²] according to Section 4

F_{Ki} = ideal buckling force of the stiffener in [N]

$$F_{Kix} = \frac{\pi^2}{a^2} E \cdot I_x \cdot 10^4 \qquad \text{for long. stiffeners}$$

$$F_{Kiy} = \frac{\pi^2}{(n \cdot b)^2} E \cdot I_y \cdot 10^4 \quad \text{for transv. stiffeners}$$

I_x, I_y = moments of inertia of the longitudinal or transverse stiffener including effective width of plating according to 2.2 in [cm⁴]

p_z = nominal lateral load of the stiffener due to σ_x, σ_y and τ in [N/mm²]

for longitudinal stiffeners:

$$p_{zx} = \sigma_y \frac{2 \cdot t_a}{b} + \sigma_x \frac{\pi^2}{a^2}(A_x + b \cdot t_a) + \tau_1 \frac{\sqrt{2} \cdot t_a}{b}$$

for transverse stiffeners:

$$p_{zy} = \sigma_{x1} \frac{2 \cdot t_a}{a} + \sigma_y \frac{\pi^2}{(n \cdot b)^2}(A_y + a \cdot t_a) + \tau_1 \frac{\sqrt{2} \cdot t_a}{a}$$

$$\sigma_{x1} = \sigma_x \left(1 + \frac{A_x}{b \cdot t_a}\right) \quad [N/mm^2]$$

A_x, A_y = sectional area of the longitudinal or transverse stiffener respectively in [mm²]

$$\tau_1 = \left[\tau - t\sqrt{R_{eH} \cdot E\left(\frac{m_1}{a^2} + \frac{m_2}{b^2}\right)}\right] \geq 0$$

for longitudinal stiffeners:

$$\frac{a}{b} \geq 2{,}0 \ : \quad m_1 = 1{,}47 \; m_2 = 0{,}49$$

$$\frac{a}{b} < 2{,}0 \ : \quad m_1 = 1{,}96 \; m_2 = 0{,}37$$

for transverse stiffeners:

$$\frac{a}{n \cdot b} \geq 0{,}5 \ : \ m_1 = 0{,}37 \quad m_2 = \frac{1{,}96}{n^2}$$

$$\frac{a}{n \cdot b} < 0{,}5 \ : \ m_1 = 0{,}49 \quad m_2 = \frac{1{,}47}{n^2}$$

w = $w_0 + w_1$

w_0 = numerical imperfection in [mm],

$\frac{a}{250} \geq w_{0x} \leq \frac{b}{250}$ for long. stiffeners

$\frac{n \cdot b}{250} \geq w_{0y} \leq \frac{a}{250}$ for transv. stiffeners

however $w_0 \leq 10$ mm

w_1 = deformation of stiffener due to lateral load pat midpoint of stiffener span in [mm]

in case of uniformly distributed load the following values for w_1 may be used:

for longitudinal stiffeners:

$$w_1 = \frac{p \cdot b \cdot a^4}{384 \cdot 10^7 \cdot E \cdot I_x}$$

for transverse stiffeners:

$$w_1 = \frac{5 \cdot a \cdot p\,(n \cdot b)^4}{384 \cdot 10^7 \cdot E \cdot I_y \cdot c_s^2}$$

c_f = elastic support provided by the stiffener in [N/mm²]

$$c_{fx} = F_{Kix} \cdot \frac{\pi^2}{a^2} \qquad \text{for long. stiffeners}$$

$$c_{fy} = c_s \cdot F_{Kiy} \cdot \frac{\pi^2}{(n \cdot b)^2} \qquad \text{for transv. stiffeners}$$

c_s = factor accounting for the boundary conditions of the transverse stiffener

c_s = 1,0 for simply supported stiffeners

c_s = 2,0 for partially constraint stiffeners

W_{st} = section modulus of stiffener (long. or transverse) in [cm³] including effective width of plating according to 2.2.

If no lateral load p is acting the bending stress σ_b is to be calculated at the midpoint of the stiffener span for the fibre which results in the largest stress value. If lateral load p is acting, the stress calculation is to be carried out for both fibres of the stiffener's cross sectional area.

Guidance

Longitudinal and transverse stiffeners not subjected to lateral load p have sufficient scantlings if their moments of inertia I_x and I_y are not less than obtained by the following formulae :

$$I_x = \frac{p_{zx} \cdot a^2}{\pi^2 \cdot 10^4} \left(\frac{w_{ox} \cdot h_w}{\frac{R_{eH}}{S} - \sigma_x} + \frac{a^2}{\pi^2 \cdot E} \right) \quad [cm^4]$$

$$I_y = \frac{p_{zy} \cdot (n \cdot b)^2}{\pi^2 \cdot 10^4} \left(\frac{w_{oy} \cdot h_w}{\frac{R_{eH}}{S} - \sigma_y} + \frac{(n \cdot b)^2}{\pi^2 \cdot E} \right) \quad [cm^4]$$

3.3 Torsional buckling

.1 Longitudinal stiffeners:

$$\frac{\sigma_x \cdot S}{\kappa_T \cdot R_{eH}} \le 1{,}0$$

κ_T = $1{,}0$ for $\lambda_T \le 0{,}2$

κ_T = $\dfrac{1}{\phi + \sqrt{\phi^2 - \lambda_T^2}}$ for $\lambda_T > 0{,}2$

φ = $0{,}5 \left(1 + 0{,}34 \, (\lambda_T - 0{,}2) + \lambda_T^2 \right)$

λ_T = reference degree of slenderness

λ_T = $\sqrt{\dfrac{R_{eH}}{\sigma_{KiT}}}$

σ_{KiT} = $\dfrac{E}{I_P} \left(\dfrac{\pi^2 \cdot I_\omega \cdot 10^2}{a^2} \varepsilon + 0{,}385 \cdot I_T \right)$ [N/mm^2]

For I_P, I_T, I_ω see Fig.3.5 and Table 3.6.

I_P = polar moment of inertia of the stiffener related to the point C in [cm^4]

I_T = St. Vernant's moment of inertia of the stiffener in [cm^4]

I_ω = sectorial moment of inertia of the stiffener related to the point C.in [cm^4]

ε = degree of fixation

ε = $1 + 10^{-4} \sqrt{\dfrac{a^4}{I_\omega \left(\dfrac{b}{t^3} + \dfrac{4 \, h_w}{3 \, t_w^3} \right)}}$

h_w = web height [mm]

t_w = web thickness [mm]

b_f = flange breadth [mm]

t_f = flange thickness [mm]

A_w = web area $h_w \times t_w$

A_f = flange area $b_f \times t_f$.

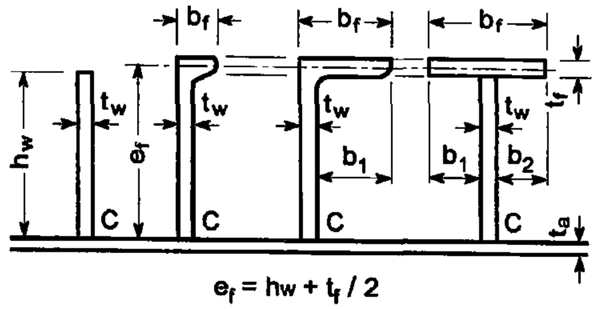


Fig. 3.5

.2 Transverse stiffeners

For transverse stiffeners loaded by compressive stresses and which are not supported by longitudinal stiffeners, proof is to be provided in accordance with .1 analogously.

G. Rigidity of Transverses and Girders

The moment of inertia of deck transverses and girders as well as of girders which are supporting other girders, is not to be less than:

J = $c \cdot W \cdot \ell$ [cm^4]

c = 4,0 if both ends are simply supported

c = 2,5 if one or both ends are constrained

W = section modulus of the structural member considered in [cm^2]

ℓ = unsupported span of the structural member considered in [m].

H. Structural Details

1. Longitudinal members

1.1 Abrupt discontinuities of strength of longitudinal members are to be avoided as far as practicable. Where longitudinal members having different scantlings are connected with each other, smooth transitions are to be provided.

1.2 At the ends of longitudinal bulkheads or continuous longitudinal walls suitable scarphing brackets are to be provided.

2. Transverses and girders

2.1 Where transverses and girders fitted in the same plane are connected to each other, major discontinuities of strength shall be avoided. The web depth of the smaller girder shall, in general, not be less than 60 % of the web depth of the greater one.

2.2 The taper between face plates with different dimensions is to be gradual. In general the taper shall not exceed 1 : 3. At intersections the forces acting in the face plates are to be properly transmitted.

3. Knuckles (general)

Flanged structural elements transmitting forces perpendicular to the knuckle, are to be adequately supported at their knuckle, i.e. the knuckles of the inner bottom are to be located above floors, longitudinal girders or bulkheads (see Fig. 3.6).

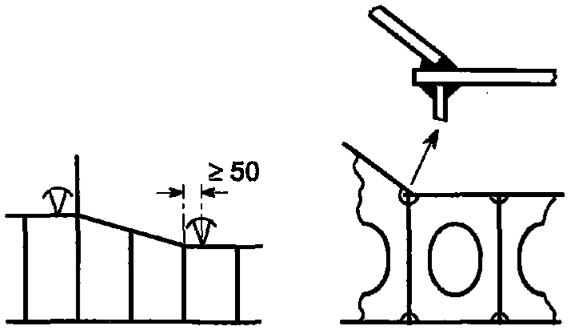


Fig. 3.6

J. Evaluation of Notch Stresses

The notch stress σ_K evaluated for linear-elastic material behaviour at free plate edges, e.g. at hatch corners, openings in decks, walls, girders etc., should, in general, fulfill the following criterion:

$$\sigma_K \leq f \cdot R_{eH}$$

f = 1,1 for ordinary hull structural steel

f = 1,0 for higher tensile steel with R_{eH} = 265 N/mm²

f = 0,9 for higher tensile steel with R_{eH} = 315 N/mm²

f = 0,8 for higher tensile steel with R_{eH} = 355 N/mm².

If plate edges are free of notches and corners are rounded-off, a 20 % higher notch stress σ_K may be permitted.

A further increase of stresses may be permitted on the basis of a fatigue strength analysis as per Section 20.

Where notch stresses are not evaluated by finite element analysis, they can be determined by multiplying the nominal stress with the notch factor K_t. For some types of openings the notch factors are given in Figs. 3.7 and 3.8.

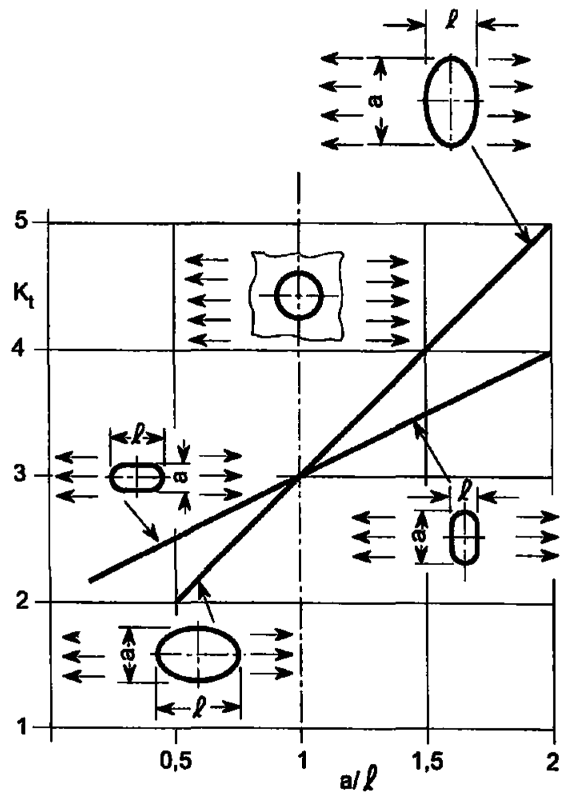


Fig.3.7 Notch faktor K_t for rounded openings

Table 3.6

Section	I_P	I_T	I_ω
Flat bar	$\frac{h_w^3 \cdot t_w}{3 \cdot 10^4}$	$\frac{h_w \cdot t_w^3}{3 \cdot 10^4}\left[1 - 0{,}63\,\frac{t_w}{h_w}\right]$	$\frac{h_w \cdot t_w^3}{36 \cdot 10^6}$
Sections with bulb or flange	$\left[\frac{A_w \cdot h_w^2}{3} + A_f \cdot e_f^2\right] 10^{-4}$	$\frac{h_w \cdot t_w^3}{3 \cdot 10^4}\left[1 - 0{,}63\,\frac{t_w}{h_w}\right]$ + $\frac{b_f \cdot t_f^3}{3 \cdot 10^4}\left[1 - 0{,}63\,\frac{t_f}{b_f}\right]$	for bulb and angle sections: $\frac{A_f \cdot e_f^2 \cdot b_f^2}{12 \cdot 10^6}\left[\frac{A_f + 2{,}6\,A_w}{A_f + A_w}\right]$ for tee-sections: $\frac{b_f^3 \cdot t_f \cdot e_f^2}{12 \cdot 10^6}$

K. Corrosion Allowances and Corrosion Control

1. Corrosion allowance

1.1 The scantling requirements of the subsequent Sections imply the following general corrosion allowances t_K:

$t_K = 1{,}5$ mm for $t' \leq 10$ mm

$$t_K = \frac{0{,}1 \cdot t}{\sqrt{k}} + 0{,}5 \text{ mm}, \quad \text{for } t' > 10 \text{ mm}$$

t_K (max) = 3,0 mm

t' = required rule thickness excluding t_K in [mm].

k = material factor according to Section 2, B.2.

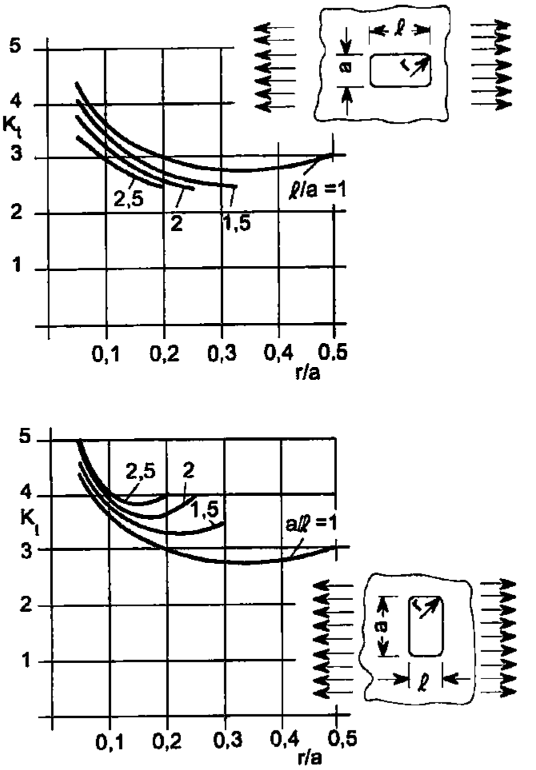


Fig. 3.8 Notch factor K_t for rectangular openings with rounded corners

1.2 For structural elements in specified areas t_K is not to be less than given in Table 3.7:

Table 3.7

Area	t_{Kmin} [mm]
In ballast tanks where the weather deck forms the tank top, 1,5 m below tank top.	2,5
Deck plating below elastically mounted deckhouses	3,0

2. Corrosion control

2.1 Where an effective protection against corrosion is employed approval may be given for the reduction of material thickness - even to less than the minimum thickness by the following values Δt_K:

Extent of protection *	Δt_K
both sides protected	t_K, max. 2 mm
one side protected	$t_K/2$, max. 1 mm

* For corrosion protection see Rules for Hull, Volume II, Section 38.

2.2 Where structural elements are subjected to compression, the reduction of thicknesses is permissible only where proof of adequate buckling strength is submitted in accordance with F.1.4.

2.3 Where this rules is applied, the Classification of Notation "CORR" will assigned.

2.4 In the drawing to be submitted for approval both the envisaged reduced material thicknesses and the rules thicknesses required by the Construction Rules are to be indicated. The drawings are to be placed on board the ship.

2.5 Together with the drawings, a description of the envisaged corrosion protection system as well as particulars on its suitability for the respective ranges of application are to be submitted.

2.6 When selecting the materials in accordance with Section 2, B. the unreduced Rule Thicknesses are decisive.

L. Additional Stresses in Non - symmetric Sections

The additional stress σ_h occurring in non-symmetric sections may be calculated by the following formula:

$$\sigma_h = \frac{Q \cdot \ell_f \cdot t_f}{c \cdot W_y \cdot W_z}\left(b_1^2 - b_2^2\right) \quad [\text{N/mm}^2]$$

Q = load on section parallel to its web within the unsupported span ℓ_f in [kN]

Q = $p \cdot a \cdot \ell_f$ [kN] in case of uniformly distributed load p [kN/m²]

ℓ_f = unsupported span of flange in [m]

t_f, b_1, b_2 = flange dimensions in [mm] as shown in Fig. 3.9.

$b_1 \geq b_2$

W_y = Section modulus of section related to the y-y axis including the effective width of plating in [cm³]

W_z = section modulus of the partial section consisting of flange and half of web area related to the z-z axis in [cm^3] (Bulb sections may be converted into a similar L-section)

c = factor depending on kind of load and of the unsupported span, support condition, and rigidity of the section's web. As a first approximation c = 80 may be taken for L-sections constrained at both ends.

Exact determination of the factor c may be required, e.g. for longitudinals in tankers.

This additional stress σ_h is to be added to other stresses such as those resulting from local and hull girder bending.

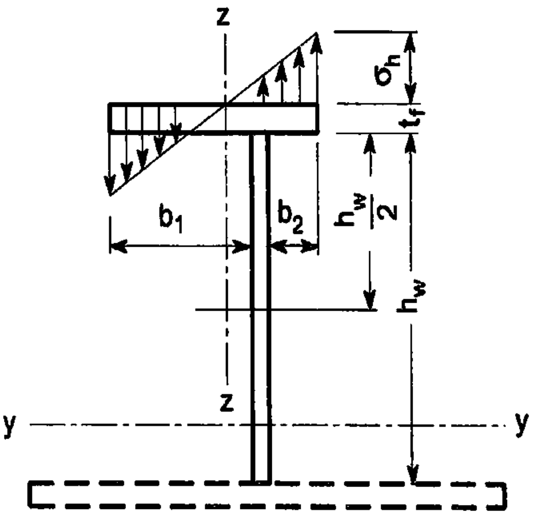


Fig. 3.9 Non - symmetrical profile

Section 4

Design Loads

A. General, Definitions

1. General

This Section provides data regarding design loads for determining the scantlings of the hull structural elements by means of the design formula given in the following Section or by means of direct calculations. The dynamic portions of the design loads are design values which can only be applied within the design concept of this Volume.

2. Definitions

2.1 Load centre

2.1.1 For plates:

- Vertical stiffening system: 0,5 · stiffener spacing above the lower support of plate field, or lower edge of plate when the thickness changes within the plate field.
- Horizontal stiffening system: Midpoint of plate field.

2.1.2 For stiffeners and girders:

- Centre of span ℓ.

2.2 Definition of symbols

v_0 = ship's speed according to Section 1, J.5.

ρ_s = density of cargo as stowed in [t/m³]

ρ = density of liquids in [t/m³]

ρ = 1,0 t/m³ for fresh water and sea water

z = vertical distance of the structure's load centre above base line in [m]

x = distance from aft end of length **L** in [m]

p_o = basic external dynamic load

$p_o = 2{,}1 \cdot (C_B + 0{,}7) \cdot c_0 \cdot c_L \cdot f \cdot c_{RW}$ [kN/m²]

C_B = moulded block coefficient according to Section 1, H.4., where C_B is not to be taken less than 0,60.

c_o = wave coefficient

$$c_o = \frac{L}{25} + 4{,}1 \qquad \text{for } L < 90 \text{ m}$$

$$c_0 = 10{,}75 - \left[\frac{300 - L}{100}\right]^{1{,}5} \qquad \text{for } L \geq 90 \text{ m}$$

$$c_L = \sqrt{\frac{L}{90}} \qquad \text{for } L < 90 \text{ m}$$

c_L = 1,0 for **L** ≥ 90 m

c_{RW} = service range coefficient

c_{RW} = 1,00 for unlimited service range

= 0,90 for service range P

= 0,75 for service range L

= 0,60 for service range T

f = probability factor

f = 1,0 for plate panels of the outer hull (shell plating, weather decks)

f = 0,75 for secondary stiffening members of the outer hull (frames, deck beams)

f = 0,60 for girders and girder systems of the outer hull (web frames, stringers, grillage systems)

c_D, c_F = distribution factors according to Table 4.1.

B. External Sea Loads

1. Load on weather decks

1.1 The load on weather deck is to determined according to the following formula:

$$p_D = p_0 \frac{20 \cdot T}{(10 + z - T)\, H} c_D \quad [\text{kN/m}^2]$$

c_D = factor according to Table 4.1

1.2 For strength decks which are to be treated as weather decks as well as for forecastle decks the load is not to be less than the greater of the following two values:

$p_{Dmin} = 16 \cdot f$ [kN/m²] or

$p_{Dmin} = 0{,}7 \cdot p_0$ [kN/m²]

2. Load on ship's sides and bow structures

2.1 Load on ship's sides

The external load p_s on the ship's sides is to be determined according to 2.1.1 and 2.1.2.

Table 4.1

Range		Factor c_D	Factor c_F [1)]
A	$0 \leq \frac{x}{L} < 0{,}2$	$1{,}2 - \frac{x}{L}$	$1{,}0 + \frac{5}{C_B}\left(0{,}2 - \frac{x}{L}\right)$
M	$0{,}2 \leq \frac{x}{L} < 0{,}7$	1,0	1,0
F	$0{,}7 \leq \frac{x}{L} < 1{,}0$	$1{,}0 + \frac{c}{3}\left(\frac{x}{L} - 0{,}7\right)$ $c = 0{,}15\,L - 10$ where: $L_{min} = 100$ m $L_{max} = 200$ m	$1{,}0 + \frac{20}{C_B}\left(\frac{x}{L} - 0{,}7\right)^2$

1) Within the range A the ratio x/L need not be taken less than 0,1, within the range F the ratio x/L need not be taken greater than 0,93

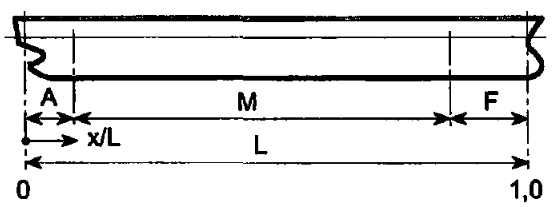


Fig. 4.1

2.1.1 For elements the load centre of which is located below load waterline:

$$p_s = 10(T - z) + p_0 \cdot c_F \left(1 + \frac{z}{T}\right) \quad [kN/m^2]$$

2.1.2 For elements the load centre of which is located above the load water line:

$$p_s = p_0 \cdot c_F \frac{20}{10 + z - T} \quad [kN/m^2]$$

2.2 Load on bow structures

The design load for bow structures from forward to 0,1 L behind **F.P.** and above the ballast water line in accordance with draft T_b in 4.1 is to be determined according to the following formula:

$$p_e = c\left[0{,}20 \cdot v_0 + 0{,}6\sqrt{L}\right]^2 \quad [kN/m^2]$$

with $L_{max} = 250$ m.

c = 0,8 in general

$$c = \frac{0{,}45}{(1{,}2 - \sin\alpha)}$$

for extremely flared sides where the flare angle α is larger than 40°

For unusual bow shapes p_e can be specially considered.

p_e must not be smaller than p_s according to 2.1.1 or 2.1.2 respectively.

Aft of 0,1 L from F.P. up to 0,15 L from F.P. the pressure between p_e and p_s is to be graded steadily.

The design load for bow doors is given in Section 6, H.3.

3. Load on the ship's bottom

The external load p_B of the ship's bottom is to be determined according to the following formula:

$$p_B = 10 \cdot T + p_0 \cdot c_F \quad [kN/m^2].$$

4. Design slamming pressure

4.1 The design slamming pressure may be determined by the following formula:

$$p_{SL} = 162\sqrt{L} \cdot c_1 \cdot c_{SL} \cdot c_A \cdot c_s \quad [kN/m^2]$$

for $L \leq 150$ m

$$p_{SL} = 1984\,(1{,}3 - 0{,}002\,L)\; c_1 \cdot c_{SL} \cdot c_A \cdot c_s \; [kN/m^2]$$

for $L > 150$ m

$$c_1 = 3{,}6 - 6{,}5\left[\frac{T_b}{L}\right]^{0{,}2}$$

c_{1max} = 1,0

T_b = smallest design ballast draught at F.P for normal ballast conditions in [m], according to which the strengthening of bottom forward, see Section 6, has to be done. This value has to be recorded in the Class Certificate and in the loading manual.

c_{SL} = distribution factor, see also Fig. 4.2

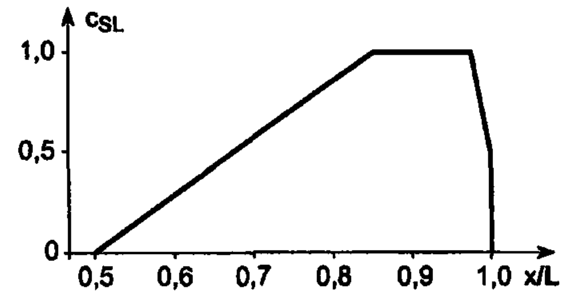


Fig. 4.2

c_{SL} = 0 for $\frac{x}{L} \leq 0,5$

$c_{SL} = \frac{\frac{x}{L} - 0,5}{c_2}$ for $0,5 \leq \frac{x}{L} \leq 0,5 + c_2$

c_{SL} = 1,0 for $0,5 + c_2 \leq \frac{x}{L} \leq 0,65 + c_2$

$c_{SL} = 0,5 \left[1 + \frac{1 - \frac{x}{L}}{0,35 - c_2}\right]$ for $\frac{x}{L} > 0,65 + c_2$

$c_2 = 0,33 \cdot C_B + \frac{L}{2500}$

c_{2max} = 0,35

c_A = 10/A

A = loaded area between the supports of the structure considered in [m^2]

$0,3 \leq c_A \leq 1,0$

c_A = 1,0 for plate panels and stiffeners.

$c_s = \frac{1 + c_{RW}}{2}$

5. Load on decks of superstructures and deckhouses

5.1 The load on exposed decks and parts of superstructure and deckhouse decks, which are not to be treated as strength deck, is to be determined as follows:

$p_{DA} = p_D \cdot n$ [kN/m^2]

p_D = load according 1.1

$n = 1 - \frac{z - H}{10}$

n_{min} = 0,5

n = 1,0 for the forecastle deck

For deckhouses the value so determined may be multiplied by the factor

$$\left(0,7 \frac{b'}{B'} + 0,3\right)$$

b' = breadth of deckhouse

B' = largest breadth of ship at the position considered.

Except for the forecastle deck the minimum load is:

p_{DAmin} = 4 [kN/m^2]

5.2 For exposed wheel house tops the load is not to be taken less than

p = 2,5 [kN/m^2]

C. Cargo Loads, Load on Accommodation Decks

1. Load on cargo decks

1.1 The load on cargo decks is to be determined according to the following formula:

$p_L = p_c (1 + a_v)$ [kN/m^2]

p_c = static cargo load in [kN/m^2]

if no cargo load is given: $p_c = 7 \cdot h$ for 'tween decks but not less than 15 kN/m^2.

h = mean 'tween deck height in [m].

In way of hatch casings the increased height of cargo is to be taken into account

a_v = acceleration factor as follows:

$a_v = F \cdot m$

$F = 0,11 \frac{v_0}{\sqrt{L}}$

$m = m_o - 5 (m_o - 1) \frac{x}{L}$ for $0 \leq \frac{x}{L} < 0,2$

m = 1,0 for $0,2 \leq \frac{x}{L} \leq 0,7$

$m = 1 + \frac{m_1 + 1}{0,3} \left[\frac{x}{L} - 0,7\right]$ for $0,7 < \frac{x}{L} \leq 1,0$

$m_o = 1,5 + F$

$m_1 = 3,5 + F$

v_0 = see Section 1 J.5.

v_0 is not to be taken less than $\sqrt{L}$ [knot]

For ship classed for a restricted range of service the acceleration factor may be reduced by service range coefficient c_{RW}.

2. Load on inner bottom

2.1 The inner bottom cargo load is to be determined as follows:

$p_i = 9,81 \cdot \frac{G}{V} \cdot h\ (1 + a_v)\quad [kN/m^2]$

G = mass of cargo in the hold in [t]

V = volume of the hold in [m^3] (hatchways excluded)

h = height of the highest point of the cargo above the inner bottom in [m], assuming hold to be completely filled.

a_v see 1.1

For calculating a_v the distance between the centre of gravity of the hold and the aft end of the length **L** is to be taken.

3. Loads on accommodation decks

3.1 The deck load in accommodation and service spaces is:

$p = 3,5\ (1 + a_v)\qquad [kN/m^2]$

3.2 The deck load of machinery decks is:

$p = 8\ (1 + a_v)\qquad [kN/m^2]$

3.3 Significant single forces are also to be considered, if necessary.

D. Load on Tank Structures

1. Design pressure for filled tanks

1.1 The design pressure for service conditions is the greater of the following values:

$p_1 = 9,81 \cdot h_1 \cdot \rho \cdot (1 + a_v)\qquad [kN/m^2]$

or

$p_1 = 9,81 \cdot \rho \cdot [h_1 \cdot \cos\varphi + (0,3 \cdot b + y)\sin\varphi]\quad [kN/m^2]$

h_1 = distance of load centre from tank top in [m]

a_v see C.1.1

b = upper breadth of tank in [m]

y = distance of load centre from the vertical longitudinal central plane of tank in [m]

φ = design angle of heel in degrees, normally $\varphi = 20°$

1.2 The maximum static design pressure is:

$p_2 = 9,81 \cdot h_2\quad [kN/m^2]$

h_2 = distance of load centre from top of overflow or from a point 2,5 m above tank top, whichever is the greater. Tank venting pipes of cargo tanks of tankers are not to be regarded as overflow pipes.

2. Design pressure for partially filled tanks

2.1 For tanks which may be partially filled between 20% and 90% of their height, the design pressure is not to be taken less than given by the following formulae:

2.1.1 For structures located within 0,25 ℓ_t from the bulkheads limiting the free liquid surface in the ship's longitudinal direction:

$$p_d = \left(4 - \frac{L}{150}\right) \ell_t \cdot \rho \cdot n_x\quad [kN/m^2]$$

ℓ_t = distance in [m] between transverse bulkheads or effective transverse wash bulkheads at the height where the structure is located.

2.1.2 For structures located within 0,25 b_t from the bulkheads limiting the free liquid surface in the ship's transverse section:

$$p_d = \left[5,5 - \frac{B}{20}\right] b_t \cdot \rho \cdot n_y\quad [kN/m^2]$$

b_t = distance in [m] between tank sides or effective longitudinal wash bulkhead at the height where the structure is located.

$$n_x = 1 - \frac{4}{\ell_t} x_1$$

$$n_y = 1 - \frac{4}{b_t} y_1$$

x_1 = distance of structural element from the tank's end in the ship's longitudinal direction in [m]

y_1 = distance of structural element from the tank's sides in the ship's transverse direction in [m]

2.2 For tanks with ratios $\ell_t/L > 0,1$ or $b_t/B > 0,6$ a direct calculation of the pressure p_d may be required.

E. Design Values of Acceleration Components

1. Acceleration components

The following formulae may be taken for guidance when calculating the acceleration components owing to ship's motions.

Vertical acceleration:

$$a_z = \pm a_0 \sqrt{1 + \left[5,3 - \frac{45}{L}\right]^2 \left[\frac{x}{L} - 0,45\right]^2 \left[\frac{0,6}{C_B}\right]^{1,5}}$$

Transverse acceleration:

$$a_y = \pm a_0 \sqrt{0{,}6 + 2{,}5\left[\frac{x}{L} - 0{,}45\right]^2 + k\left[1 + 0{,}6 \cdot k \frac{z - T}{B}\right]^2}$$

Longitudinal acceleration:

$$a_x = \pm a_0 \sqrt{0{,}06 + A^2 - 0{,}25\,A}$$

where

$$A = \left[0{,}7 - \frac{L}{1200} + 5\,\frac{z - T}{L}\right]\frac{0{,}6}{C_B}$$

The acceleration components take account of the following components of motion:

Vertical acceleration (vertical to the base line) due to heave, pitch, and roll.

Transverse acceleration (vertical to the ship's side) due to roll, pitch, yaw and sway including gravity component of roll.

Longitudinal acceleration (in longitudinal direction) due to surge and pitch including gravity component of pitch.

a_x, a_y and a_z are maximum dimensionless accelerations (i.e., relative to the acceleration gravity g) in the related direction x, y and z. For calculation purposes they are considered to act separately.

$$a_0 = \left[0{,}2\,\frac{v_0}{\sqrt{L}} + \frac{3 \cdot c_0 \cdot c_{RW}}{L}\right] f$$

For determination of a_0 the length L need not be taken less than 100 m

$$k = \frac{13 \cdot \overline{GM}}{B}$$

$\overline{GM}$ = metacentric height in [m]

k_{min} = 1,0

f = probability factor depending on probability level Q as outline in Table 4.2.

Table 4.2

Q	f
10^{-8}	1,000
10^{-7}	0,875
10^{-6}	0,750
10^{-5}	0,625
10^{-4}	0,500

2. Combined acceleration

The combined acceleration a_β may be determined by means of the "acceleration ellipse" according to Fig. 4.3 (e.g. y-z-plane).

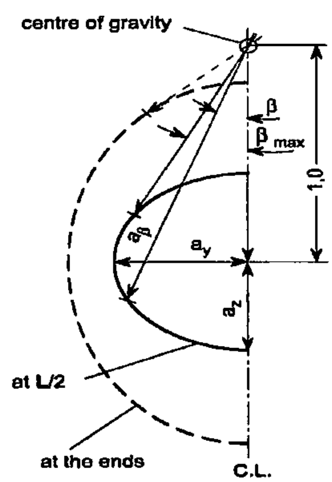


Fig. 4.3

Section 5

Longitudinal Strength

A. General

1. Vessels are to have a longitudinal hull girder section modulus in accordance with the requirements of this section. The midship section modulus requirement in B.1 is, in general, valid for all vessels having L/H-ratios specified in Section 1, A.1 and breadths which do not exceed twice their depths, H, as defined in Section 1, J.2.5. Vessels whose proportions exceed these limits will be subject to special consideration.

2. For ships of 90 m in length and over, calculation of still water bending moments is required.

B. Vertical Longitudinal Bending Moments and Vertical Shear Forces

1. Definitions

k = material factor according to Section 2, B.2.

C_B = block coefficient according to Section 1, J.4. C_B is not to be taken less than 0,6

x = distance in [m] between aft end of length L and the position considered

v_0 = speed of the ship in [kn] according to Section 1, J.5.

I_y = moment of inertia of the midship section in [m^4] around the horizontal axis

e_B = distance in [m] between neutral axis of section and base line

e_D = distance in [m] between neutral axis of section and deck line at side

W_B = section modulus of section in [m^3] related to base line

W_D = section modulus of section in [m^3] related to deck line at side

S = first moment of the sectional area considered in [m^3] related to the neutral axis

M_T = total bending moment in the seaway in [kNm]

M_{SW} = still water bending moment in [kNm] of the actual loading or ballast condition considered (positive sign for hogging, negative sign for sagging condition)

M_{WV} = vertical wave bending moment according to B.3. in [kNm] (positive sign for hogging, negative sign for sagging condition)

M_{BF} = additional bending moment according to B.6. in [kNm] (positive sign for hogging, negative sign for sagging condition)

M_{ST} = static torsional moment in [kNm]

M_{WT} = wave induced torsional moment in [kNm]

Q_T = total vertical shear force in the seaway in [kN]

Q_{SW} = still water shear force in [kN] of the actual loading or ballast condition considered

Q_{WV} = vertical wave shear force in [kN]

Q_{WH} = horizontal wave shear force in [kN].

2. Vertical longitudinal bending moments

The total longitudinal bending moments in the seaway at the position x considered are to be determined according to the following formula:

$$M_T = M_{SW} + M_{WV} + M_{BF} \ \text{[kNm]}$$

3. Vertical wave bending moments

3.1 The vertical wave bending moment amidships is to be determined by the following formula:

$$M_{WV} = L^2 \cdot B \cdot c_0 \cdot c_1 \cdot c_L \cdot c_M \quad \text{[kNm]}$$

c_0 = wave coefficient as follows:

$c_0 = L/25 + 4{,}1$ for $L < 90$ m

$c_0 = 10{,}75 - \left[\frac{300 - L}{100}\right]^{1{,}5}$ for $L \geq 90$ m

c_1 = hogging/sagging factor as follows:

$c_{1H} = 0{,}19 \cdot C_B$ hogging condition

$c_{1S} = -0{,}11\,(C_B + 0{,}7)$ sagging condition

$c_L = \frac{1}{2 - L/90}$ for $L < 90$ m

$c_L = 1{,}0$ for $L \geq 90$m

c_M = distribution factor, see also Fig. 5.1

$c_M = 2{,}5 \cdot \frac{x}{L}$ for $\frac{x}{L} < 0{,}40$

$c_M = 1{,}0$ for $0{,}40 \leq \frac{x}{L} \leq 0{,}65$

$c_M = \frac{1 - \frac{x}{L}}{0{,}35}$ for $\frac{x}{L} > 0{,}65$

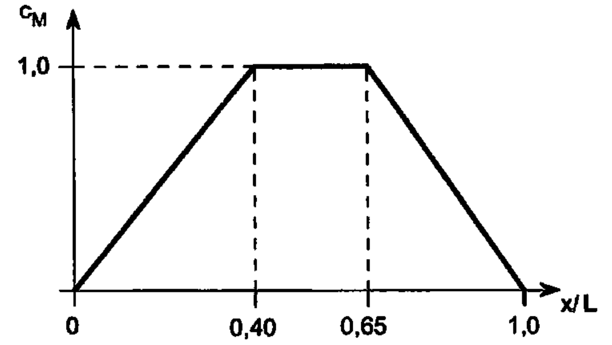


Fig. 5.1

3.2 For ships of unusual form and design (e.g. $L/B \leq 5$, $B/H \geq 2{,}5$, or $C_B < 0{,}6$) and for ships with a speed $v_0 \geq 1{,}6\sqrt{L}$ [kn], as well as for ships with large bow and stern flare and with cargo on deck in these areas BKI may require determination of wave bending moments as well as their distribution over the ship's length by approved calculation procedures. Such calculation procedures must take into account heaving and pitching motions in a natural seaway.

3.3 For ships classed for a restricted range of service, the wave bending moments may be reduced as follows:

P (Restricted Ocean Service)	: by 10%
L (Coasting Service)	: by 25%
T (Shallow Water Service)	: by 40%.

3.4 For harbour and offshore terminal conditions the wave bending moments may be multiplied with the following factors:

.1 harbour condition : 0,1 (normally)

.2 offshore terminal conditions : 0,5.

4. Vertical shear forces

4.1 The vertical shear force in the seaway at the position x considered is to be determined according to the following formula:

$$Q_T = Q_{SW} + Q_{WV} \quad [kN]$$

4.2 The still water and wave shear forces are to be added according to their signs. The sign rule according to Fig. 5.2 applies:

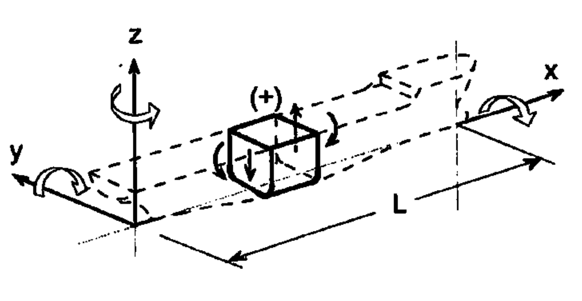


Fig. 5.2

5. Vertical wave shear forces

5.1 The vertical wave shear forces are to be determined by the following formula:

Q_{WV} = $c_0 \cdot c_{RW} \cdot c_L \cdot L \cdot B\,(C_B + 0{,}7)\,c_Q$ [kN]

c_Q = distribution factor according to Table 5.1, see also Fig. 5.3.

$m = -\dfrac{c_{1H}}{c_{1S}}$

c_{1H}, c_{1S} see 2.1.

c_0, c_L see 2.1

c_{RW} see Section 4. A.2.2.

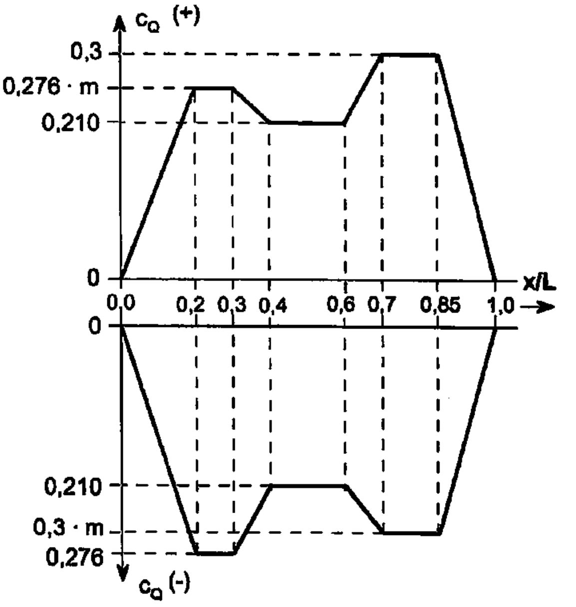


Fig 5.3

5.2 For direct calculation of wave shear forces the requirements of 3.2 apply analogously.

5.3 For restricted range of service and for harbour and offshore terminal conditions the wave shear forces may be reduced as stipulated in 3.3 and 3.4.

6. Additional bending moments due to slamming loads in the fore body region

6.1 For ships with lengths between 110 m and 180 m, the mean bow flare of which amounts to $\alpha > 30°$ within the fore body region 0,2 L aft of $x/L = 1{,}0$, the following additional bending moment M_{BF} due to slamming loads in the fore body region is to be considered when determining the total bending moment M_T. The additional bending moment may be determined approximately by the following formula:

M_{BF} = $w \cdot L^4 \cdot B \cdot n_1 \cdot n_2 \cdot n_3 \cdot c_{BF} \cdot 10^{-5}$ [kNm]

w = 1,4 hogging condition

w = $-2{,}2$ sagging condition

$n_1 = 1 - \frac{(145 - L)^2}{1225}$

$n_2 = \frac{b_1 - b_2}{1{,}2\ (H - T^*)} - 1$

n_1, n_2 may not be less then 0

b_1 = breadth of the uppermost continuous deck in [m] at $\frac{x}{L} = 0{,}8$

b_2 = breadth of the waterline in [m] at $\frac{x}{L} = 0{,}8$

$n_3 = 0{,}33 + 0{,}67 \frac{v_0}{1{,}6\sqrt{L}}$

$c_{BF} = 2{,}5 \frac{x}{L}$ for $\frac{x}{L} < 0{,}4$

$c_{BF} = 1{,}0$ for $0{,}4 \le \frac{x}{L} \le 0{,}8$

$c_{BF} = 5\left[1 - \frac{x}{L}\right]$ for $\frac{x}{L} > 0{,}8$

T* = draught of the actual loading or ballast condition in [m].

6.2 For restricted range of service and for harbour and offshore terminal conditions additional bending moments due to slamming loads may be reduced as stipulated in 3.3 and 3.4.

C. Section Moduli and Moments of Inertia

1. Section moduli as function of longitudinal bending moments

1.1 The section moduli related to deck or bottom are not to be less than:

$$W = \frac{M_T}{\sigma_p \cdot 10^3} \quad [m^3]$$

M_T = see B.2.

σ_p = permissible hull girder bending stress in [N/mm²]

$\sigma_p = c_s \cdot \sigma_{p0}$

Table 5.1 Distribution factor c_Q

Range	Positive shear forces	Negative shear forces
$0 \le \frac{x}{L} < 0{,}2$	$1{,}38 \cdot m \frac{x}{L}$	$-1{,}38 \frac{x}{L}$
$0{,}2 \le \frac{x}{L} < 0{,}3$	$0{,}276 \cdot m$	$-0{,}276$
$0{,}3 \le \frac{x}{L} < 0{,}4$	$1{,}104\ m - 0{,}63 + (2{,}1 - 2{,}76\ m)\frac{x}{L}$	$-\left[0{,}474 - 0{,}66 \frac{x}{L}\right]$
$0{,}4 \le \frac{x}{L} < 0{,}6$	$0{,}21$	$-0{,}21$
$0{,}6 \le \frac{x}{L} < 0{,}7$	$0{,}9 \frac{x}{L} - 0{,}33$	$-\left[1{,}47 - 1{,}8\ m + 3\ (m - 0{,}7) \frac{x}{L}\right]$
$0{,}7 \le \frac{x}{L} < 0{,}85$	$0{,}3$	$-0{,}3\ m$
$0{,}85 \le \frac{x}{L} < 1{,}0$	$2\left[1 - \frac{x}{L}\right]$	$-2\ m\left[1 - \frac{x}{L}\right]$

$\sigma_{p0} = 18{,}5\ \frac{\sqrt{L}}{k}$ for $L < 90$ m

$\sigma_{p0} = 175/k$ for $L \geq 90$ m

$c_s = 0{,}5 + \frac{5}{3}\frac{x}{L}$ for $\frac{x}{L} < 0{,}30$

$c_s = 1{,}0$ for $0{,}30 \leq \frac{x}{L} \leq 0{,}70$

$c_s = \frac{5}{3}\left[1{,}3 - \frac{x}{L}\right]$ for $\frac{x}{L} > 0{,}70$.

For the ranges outside 0,4 L amidships the factor may be increased up to $c_s = 1{,}0$, if this is justified under consideration of combined stresses due to longitudinal hull girder bending and local loads and of buckling strength.

1.2 The scantlings of all continuous longitudinal members based on the minimum section modulus requirement as per 2. are to be maintained within 0,4 L amidships. However, in special cases, based on consideration of type of ship, hull form and loading condition, e.g. for slender and fast ships having no parallel midship portion, the scantlings may be gradually reduced to the end of the 0,4 L part, bearing in mind the desire not to inhibit the vessel's loading flexibility.

2. Minimum midship section modulus

The section modulus related to deck and bottom is not to be less than the following minimum value:

$$W_{min} = k \cdot c_0 \cdot L^2 \cdot B\,(C_B + 0{,}7)\ 10^{-6}\ [m^3]$$

c_0 see B.3.1.

For ships classed for a restricted range of service, the minimum section modulus may be reduced as follows:

P (Restricted Ocean Service) : by 5%

L (Coasting Service) : by 15%

T (Shallow Water Service) : by 25%

3. Midship section moment of inertia

The moment of inertia related to the horizontal axis is not to be less than:

$$I_y = 3 \cdot 10^{-2} \cdot W \cdot L/k\ [m^4]$$

W see 1.1 and/or 2., the greater value is to be taken.

4. Calculation of section moduli

4.1 The bottom section modulus W_B and the deck section modulus W_D are to be determined by the following formulae:

$$W_B = \frac{I_y}{e_B}\quad [m^3]$$

$$W_D = \frac{I_y}{e_D}\quad [m^3]$$

4.2 When calculating the midship section modulus the sectional area of all continuous longitudinal strength members may be taken into account.

Large openings, i.e. openings exceeding 2,5 m in length or 1,2 m in breadth and scallops, where scallop-welding is applied, are to be deducted from the sectional areas used in the section modulus calculation. Smaller openings (manholes, lightening holes, single scallops in way of seams etc.) need not be deducted provided that the sum of their breadths or shadow area breadths in one transverse section is not reducing the section modulus at deck or bottom by more than 3 % and provided that the height of lightening holes, draining holes and single scallops in longitudinals or longitudinal girders does not exceed 25 % of the web depth, for scallops 75 mm at most.

A deduction-free sum of smaller opening breadths in one transverse section in the bottom or deck area of 0,06 (B - Σb) (where Σb = sum of breadth of openings) may be considered equivalent to the above reduction in section modulus by 3%.

The shadow area will be obtained by drawing two tangent lines with an opening angle of 30° (see Fig. 5.4).

4.3 Where in the upper and lower flange thicknesses of continuous longitudinal structures forming boundaries of oil or ballast tanks have been reduced due to arrangement of an effective corrosion protection system, these thickness reduction shall not result in a reduction of midship section modulus of more than 5%

Guidance

In case of large openings local strengthenings may be required which will be considered in each individual case (see also Section 7, A.3.1).

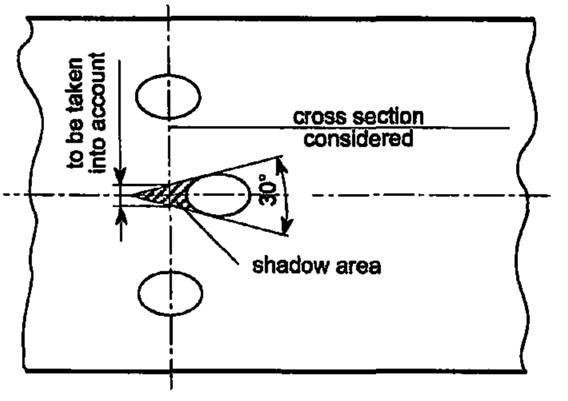


Fig 5.4

D. Shear Stresses

1. Permissible shear stress

The shear stress in the side shell and in the longitudinal bulkheads due to the shear force Q_T according to B.4.1 is not to exceed 110/k [N/mm²].

2. Resistance to buckling

Longitudinal bulkheads are to be examined for sufficient resistance to buckling considering the longitudinal bending and shear stresses according to Section 3, F.

3. Calculation of shear stresses

3.1 The shear stress distribution may be determined by means of calculation procedures approved by BKI. For ships having more than 2 longitudinal bulkheads and for double hull ships, particularly with uneven load distribution over the ship's cross section, the application of such approved calculation procedures may be required.

3.2 For ships without longitudinal bulkheads and with two longitudinal bulkheads respectively the shear stress distribution in the side shell and in the longitudinal bulkheads may be determined by the following formula:

$$\tau = \frac{M_T}{\sigma_p \cdot 10^3} \quad [m^3]$$

t = thickness of side shell or longitudinal bulkhead plating in [mm] at the section considered

α = 0 for ships having no longitudinal bulkhead

Where 2 longitudinal bulkheads are fitted:

$\alpha = 0{,}16 + 0{,}08 \dfrac{A_s}{A_L}$ for the longitudinal bulkheads

$\alpha = 0{,}34 - 0{,}08 \dfrac{A_s}{A_L}$ for the side shell

A_s = sectional area of side shell plating in [cm²] within the depth **H**

A_L = sectional area of longitudinal bulkhead plating in [cm²] within the depth **H**.

For ships with usual design and form the ratio S/I_y determined for the midship section may be used for other sections also.

3.3 Where stringers on transverse bulkheads are supported at longitudinal bulkheads or at the side shell, the supporting forces of these girders are to be considered when determining the shear stresses in longitudinal bulkheads or side shell. The shear stress introduced by the stringer into the longitudinal bulkhead or side shell may be determined by the following formula:

$$\tau_{St} = \frac{P_{St}}{b_{St} \cdot t} \quad [N/mm^2]$$

P_{St} = supporting force of stringer in [kN]

b_{St} = breadth of stringer including end bracket (if any) in [m] at the supporting point.

t = thickness of stringer web.

The additional shear stress τ_{St} is to be added to the shear stress due to longitudinal bending in the following area:

- 0,5 m on both sides of the stringer in the ship's longitudinal direction
- 0,25 x b_{St} above and below the stringer.

4. Correction of still water shear force curve

4.1 In case of alternate loading the conventional shear force curve may be corrected according to the direct load transmission by the longitudinal structure at the transverse bulkheads. See also Fig. 5.5.

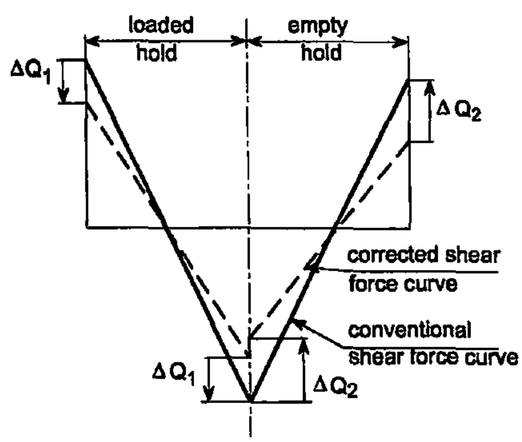


Fig. 5.5

4.2 The supporting forces of the bottom grillage at the transverse bulkheads may either be determined by direct calculation or by approximation, according to 4.3.

4.3 The sum of the supporting forces of the bottom grillage ℓ x b at the aft or forward boundary bulkhead of the hold considered may be determined by the following formulae:

$$\Delta Q = u \cdot P - v \cdot T^* \quad [kN]$$

P = mass of cargo or ballast in [t] in the hold considered, including any contents of bottom tanks within the flat part of the double bottom

T* = draught in [m] at the centre of the hold

u, v = correction coefficients for cargo and buoyancy as follows:

$u = \frac{10 \cdot \kappa \cdot \ell \cdot b \cdot h}{V}$ [kN/t]

$v = 10 \cdot \kappa \cdot \ell \cdot b$ [kN/m]

$\kappa = \frac{\mathbf{B}}{2{,}3\ (\mathbf{B} + \ell)}$

ℓ = length of the flat part of the double bottom in [m]

b = breadth of the flat part of the double bottom in [m]

h = height of the hold in [m]

V = volume of the hold in [m^3].

E. Permissible Still Water Bending Moments and Shear Forces

1. Still water bending moments

1.1 The permissible still water bending moments for a section within the length **L** are to be determined by the following formulae:

$M_{SW} = M_T - (M_{WV} + M_{BF})$ [kNm]

$M_T = \sigma_p \cdot W_{D(a)} \cdot 10^3 / f_R$ [kNm]

and/or

$M_T = \sigma_p \cdot W_{B(a)} \cdot 10^3 / f_R$ [kNm]

the smaller value is to be taken.

σ_p see C.1.1, for harbour conditions $\sigma_p = \sigma_L$ according to 4.1 is to be used.

$W_{D(a)}$ = actual deck section modulus in [m^3] at the position x

$W_{B(a)}$ = actual bottom section modulus in [m^3] at the position x

f_R = 1,0 (in general).

In the range x/L = 0,3 to x/L = 0,7 the permissible still water bending moment should generally not exceed the value obtained for x/L = 0,5.

2. Still water shear forces

2.1 The permissible still water shear forces for any cross section within the length **L** are to be determined by the following formulae:

$Q_{SW} = Q_T - Q_{WV}$ [kN]

Q_T = permissible total shear force in [kN], for which the permissible shear stress $\tau_p = 110/k$ [N/mm^2] will be reached but not exceeded at any point of the section considered.

3. Special arrangements

Where a special programme for the control of the longitudinal hull structure for corrosion has been agreed upon with the owner, still water bending moments and shear forces 10% larger than those derived from 1. and 2. above may be permitted, if the reduction in section modulus and shear area due to corrosion does not exceed 5% in those sections, for which according to A.4. permissible still water bending moments and shear forces have been fixed.

This arrangement does not apply for certain zones as e.g. "Winter-North-Atlantic".

4. Design stresses σ_L and τ_L

The design hull girder bending stress σ_L for calculating combined stresses and for fatigue analysis is to be calculated by the following formulae:

$$\sigma_L = \frac{|M_{SW}| + 0{,}75 \cdot |M_{WV}| + |M_{BF}|}{(W \cdot 10^3) / f_R}$$

W = $W_{D(a)}$ or $W_{B(a)}$ for deck or bottom according to 1.1.

$W_{D(a)}$ = actual deck section modulus in [m^3] at the position x

$W_{B(a)}$ = actual bottom section modulus in [m^3] at the position x

The design shear stress τ_L for calculating combined stresses and for fatigue analysis is to be calculated as follows:

$\tau_L = \tau_{SW} + 0{,}75 \cdot \tau_{WV}$ [N/mm^2]

τ_{SW} = shear stress due to Q_{SW}

τ_{WV} = shear stress due to Q_{WV}

f_R see E.1.

5. Proof of buckling strength

All longitudinal hull structural elements subjected to compressive stresses resulting from M_T according to B.1 and Q_T according to B.3.1 are to be examined for sufficient resistance to buckling according to Section 3, F. For this purpose the following load combinations are to be investigated:

.1 M_T and $0{,}7 \times Q_T$

.2 $0{,}7 \times M_T$ and Q_T

Section 6

Shell Plating

A. General, Definitions

1. General

1.1 The application of the design formulae given in B.1.2 and C.1.3 to ships of less than 90 m in length may be accepted by the Society when a proof of longitudinal strength has been carried out.

1.2 The plate thicknesses are to be tapered gradually, if different.Gradual taper is also to be effected between the thicknesses required for strengthening of the bottom forward as per E.2. and the adjacent thicknesses.

2. Definitions

k = material factor according to Section 2, B.2.

p_B = load on bottom in [kN/m^2] according to Section 4, B.3.

p_s = load on sides in [kN/m^2] according to Section 4, B.2.1

p_e = design pressure for the bow area in [kN/m^2] according to Section 4, B.2.2

p_{SL} = design slamming pressure in [kN/m^2] according to Section 4, B.4.

n_f = 1,0 for transverse framing

n_f = 0,83 for longitudinal framing

σ_{LB} = Maximum bottom design hull girder bending stress in [N/mm^2] according to Section 5, E.4.

σ_{LS} = maximum design hull girder bending stress in the side shell at the station considered according to Section 5, E.4. in [N/mm^2].

τ_L = maximum design shear stress due to longitudinal hull girder bending in [N/mm^2], according to Section 5, E.4.

σ_{perm} = permissible design stress in [N/mm^2]

$$\sigma_{perm} = \left(0,8 + \frac{L}{450}\right)\frac{230}{k} \quad [\text{N/mm}^2] \text{ for } L < 90 \text{ m}$$

$$\sigma_{perm} = \frac{230}{k} \quad [\text{N/mm}^2] \qquad \text{for } L \geq 90 \text{ m}$$

t_K = corrosion allowance according to Section 3, K.1.

B. Bottom Plating

1. Plate thickness based on load stress criteria

1.1 Ships with lengths L < 90 m

The thickness of the bottom shell plating within 0,4 **L** amidships is not to be less than:

$$t_{B1} = 1,9 \cdot n_f \cdot a \sqrt{p_B \cdot k} + t_K \quad [\text{mm}]$$

Within 0,1 **L** forward of the aft end of the length **L** and within 0,05 **L** aft of **F.P.** the thickness is not to be less than t_{B2} according to 1.2.

1.2 Ships with length L ≥ 90 m

The thickness of the bottom plating is not to be less than the greater of the two following values:

$$t_{B1} = 18,3 \cdot n_f \cdot a \sqrt{\frac{p_B}{\sigma_{p\ell}}} + t_K \quad [\text{mm}]$$

$$t_{B2} = 1,21 \cdot a \sqrt{p_B \cdot k} + t_K \quad [\text{mm}]$$

$$\sigma_{p\ell} = \sqrt{\sigma_{perm}^2 - 3 \cdot \tau_L^2} - 0,89 \cdot \sigma_{LB} [\text{N/mm}^2]$$

Note :

As a first approximation σ_{LB} may be taken as follows

$$\sigma_{LB} = \frac{12,6\sqrt{L}}{k} \ [\text{N/mm}^2] \qquad \text{for } L < 90 \text{ m}$$

$$\sigma_{LB} = \frac{120}{k} \ [\text{N/mm}^2] \qquad \text{for } L \geq 90 \text{ m}$$

$$\tau_L = 0$$

2. Critical plate thickness, buckling strength

2.1 Guidance values for critical plate thickness

For ships, for which proof of longitudinal strength is required or carried out respectively, the following guidance values for the critical plate thickness are recommended:

for $\sigma_{LB} \leq 0,6 \cdot R_{eH}$:

$$t_{crit} = c \cdot 2,32 \cdot a \sqrt{\sigma_{LB}} + t_K \quad [mm]$$

for $\sigma_{LB} > 0,6 \cdot R_{eH}$:

$$t_{crit} = c \cdot 1,57 \cdot a \frac{\sqrt{R_{eH}}}{1,474 - \frac{\sigma_{LB}}{R_{eH}}} + t_K \ [mm]$$

$c = 0,5$ *for longitudinal framing*

$c = \frac{1}{(1 + \alpha^2)\sqrt{F_1}}$ *for transverse framing*

α = *aspect ratio a/b of plate panel considered (see Section 3, F. 1.)*

σ_{LB} = *largest compressive stress in the bottom due to longitudinal hull girder bending*

F_1 *see Section 3, F.1. (Table 3.2)*

F_1 = *1,0 for longitudinal framing.*

2.2 Buckling strength

The guidance values obtained from 2.1 are to be verified according to Section 3, F. Section 5, E.5. applies where solely longitudinal hull girder bending stress need to be considered.

3. Minimum thickness

3.1 At no point the thickness of the bottom shell plating shall be less than :

$$t_{min} = (1,5 - 0,01 \cdot L)\sqrt{L \cdot k} \quad [mm]$$

for $L < 50$ m

$$t_{min} = \sqrt{L \cdot k} \quad [mm]$$

for $L \geq 50$ m

or 16,0 mm, whichever is less.

L need not be taken greater than 12 **H**.

4. Bilge strake

4.1 The thickness of the bilge strake is to be determined as required for the bottom plating according to 1.

The thickness so determined is to be verified for sufficient buckling strength according to the requirements of Section 5, C.6. and Section 3, F., see Table 3.4, load cases 1 a, 1 b, 2 and 4.

If this verification shows that a smaller thickness than that of the bottom plating is possible, such smaller thickness may be permitted.

4.2 If according to Section 2, B. a higher steel grade than A/AH is required for the bilge strake, the width of the bilge strake is not to be less than:

$$b = 800 + 5 \cdot L \quad [mm]$$

4.3 Bilge keels of suitable height and length are to be provided (see also Section 6, F.2).

5. Flat plate keel and garboard strake

5.1 The width of the flat plate keel is not to be less than:

$$b = 800 + 5\ L \quad [mm]$$

$$b_{max} = 1800 \quad [mm]$$

The thickness of the flat plate keel within 0,7 **L** amidships is not to be less than:

$$t_{FK} = t + 2,0 \quad [mm]$$

t = thickness of the adjacent bottom plating in [mm].

The thickness of flat plate keel may be reduced by 10 percent for 0,15 **L** from the ends. This reduction is not permitted in way of the engine foundation. In no case the thickness of the flat plate keel is to be less than that of the adjoining bottom plating.

5.2 It is recommended for ships exceeding 100 m in length, the bottom of which is longitudinally framed, to stiffen the flat plate keel by additional intercostal stiffeners fitted at a distance of not more than 400 mm from centre line. The sectional area of one longitudinal stiffener should not be less than 0,2 **L** [cm^2].

5.3 Where a single bottom is provided, the thickness of the flat plate keel and the garboard strake is to be adequately increased in the machinery and boiler room. Moreover, in the boiler room, the bottom is to be covered continuously from the centreline girder to the longitudinal bunker bulkheads by cement.

5.4 Where a bar keel is arranged, the adjacent garboard strake is to have the scantlings of a flat plate keel.

The scantlings of bar keel are to be determined by the following formulae:

height $h = 1,1\ L + 110 \quad [mm]$

thickness $t = 1,1\ L + 12 \quad [mm]$

Minor deviations from these values are admissible provided the required sectional area is maintained.

6. Strengthening of Bottom Forward

6.1. Extent of strengthening

The bottom structure forward is to be strengthened within 0,3 **L** abaft the forward perpendicular :

6.2. Arrangement of floors

For transverse framing, plate floors are to be fitted at every frame. Where the longitudinal framing system or the longitudinal girder system is adopted the spacing of plate floors may be equal to two transverse frame spaces.

6.3. Arrangement of side girders

For transverse framing, the spacing of side girders is not to exceed L/250 + 0,9 [m], up to a maximum of 1,4 m.

Where the longitudinal framing system is adopted, the side girders are to be fitted not more than two longitudinal frame spacings apart.

6.4. Bottom plating and stiffeners

6.4.1 General

Bottom plates fitted partly or completely in the flat portion of the range specified under 1. are to be strengthened according to 4.2 - 4.3.

6.4.2 Plate thickness

$$t = 2{,}6 \cdot a \sqrt{L \cdot k} \cdot f_2 + \Delta t \quad [mm]$$

f_2 = factor according to Section 3,A.3

Where the ship's speed v_0 exceeds the greater of the following values $1{,}2\sqrt{L}$ [kN] or 10 kn the plate thickness is to be additionally increased by $\Delta t = 0{,}5$ mm for each knot exceeding the above values.

The increase Δt on account of higher speed is not to be less than 0,5 mm and need not exceed 2 mm.

6.4.3. Stiffeners

Where the transverse framing system is adopted the flat plate keel and the bottom plating are to be stiffened by means of intercostal longitudinals between the side girders.

The longitudinals are to be extended forward as far as practicable. Any scalloping in the longitudinals is to be restricted to holes required for welding and limbers.

The section modulus of the stiffeners is to be less than :

$$W = 3 \cdot L - 80 \quad [cm^3]$$

Where the longitudinal framing system is adopted, the bottom longitudinals are to be extended forward as far as practicable.

For dimensioning the longitudinals the span is not to be taken less than 1,8 m.

C. Side Shell Plating

1. Plate thickness based on load stress criteria

1.1 Ships with lengths L < 90 m

The thickness of the side shell plating within 0,4 L amidship is not to be less than:

$$t_{S1} = 1{,}9 \cdot n_f \cdot a \sqrt{p_s \cdot k} + t_K + 0{,}5 \quad [mm]$$

Within 0,1 **L** forward of the aft end of the length **L** and within 0,05 **L** aft of **F.P.** the thickness is not to be less than t_{S2} according to 1.2.

1.2 Ships with lengths L ≥ 90 m

The thickness of the side shell plating is not to be less than the greater of the two following values:

$$t_{S1} = 18{,}3 \cdot n_f \cdot a \sqrt{\frac{p_s}{\sigma_{p\ell}}} + t_K + 0{,}5 \quad [mm]$$

$$t_{S2} = 1{,}21 \cdot a \sqrt{p \cdot k} + t_K + 0{,}5 \quad [mm]$$

$$\sigma_{p\ell} = \sqrt{\sigma^2_{perm} - 3 \cdot \tau^2_L} - 0{,}89 \cdot \sigma_{LS} \quad [N/mm^2]$$

p = p_s or p_e as the case may be

Note :

As a first approximation σ_{LS} and τ_L may be taken as follows:

σ_{LS} = $0{,}76 \cdot \sigma_{LB}$

τ_L = $P_e \cdot A_x$ $[N/mm^2]$

σ_{LB} = *see B.1.2.*

1.3 In way of large shear forces, the shear stresses are to be checked in accordance with Section 5,D.

2. Minimum thickness

For the minimum thickness of the side shell plating C.3. applies accordingly.

3. Sheerstrake

3.1 The width of the sheerstrake is not to be less than:

b = 800 + 5 L [mm]

b_{max} = 1800 [mm]

3.2 The thickness of the sheerstrake shall, in general, not be less than the greater of the following two values:

$t = 0{,}5\,(t_D + t_S)$ [mm]

$t = t_S$ [mm]

t_D = required thickness of strength deck

t_S = required thickness of side shell.

3.3 Where the connection of the deck stringer with the sheerstrake is rounded, the radius is to be at least 15 times the plate thickness

3.4 Welds on upper edge of sheerstrake are subject to special approval.

Holes for scuppers and other openings are to be carefully rounded, any notches shall be avoided.

4. The following additional strengthening are required for side trawlers :

4.1 The thickness of the sheer strake is to be increased by at least 3 mm in way of the trawl gallows. It is recommended to also increase the thickness of the sheer strake between the forward and aft gallows throughout by 1 to 2 mm.

4.2 In way of the path of the bobbins at the gallows during hauling operations, the side plating above the middle of the bilge turn is to be 50 per cent greater in thickness than required.

4.3 At the forward gallows, the side plating above the upper turn of the bilge is to be strengthened correspondingly.

4.4 The seams at the lower edge of the sheerstrake and the upper turn of the bilge are to be protected by half round bars running from the fore to the aft gallows, and by further half round bars arranged between them or diagonally in such a way that the rivet heads or welds cannot be worn by the trawl wire ropes.

4.5 In way of the strengthened shell plating under the aft gallows, intermediate frames are to be arranged, which are to be connected to the deck and the plate floors, or to be supported by a stringer at the lower edge of the strengthened plates. The section modulus of the intermediate frames is not to be less than 75 percent of that of the frames they are fitted between.

4.6 In stern trawlers the bottom plating in way of the "overhanging" part of the stern shall not be less than required by E.2.

4.7 In stern trawlers the shell strake in way of the construction water line from stern to the aft perpendicular is recommended to have a thickness as required for the stern ramp in Section 7, A.5 for protection against local damage.

4.8 The bulwark at the operating side are to be 2 mm thicker, and under the gallows 3 mm thicker than required by G. In way of the slip hook, the thickness of bulwark is not to be less than 10 mm.

5. Buckling strength

For ship for which proof of longitudinal strength is required or carried out proof of buckling strength of the side shell is to be carried out according to Section 5, E.5 and Section 3, F.

6. Strengthenings for harbour and tug manoeuvres

6.1 In those zones of the side shell which may be exposed to concentrated loads due to harbour manoeuvres the plate thickness is not to be less than required by 5.2. These zones are mainly the plates in way of the ship's fore and aft shoulder. The length of the strengthened areas shall not be less than approximately 5 m. The height of the strengthened areas shall extend from about 0,5 m above ballast waterline to about 1,5 m above load water line.

For ships of 100 m in length and over at least one strengthened area is to be provided amidships in addition to the two strengthened areas at the ship's shoulders.

Where the side shell thickness so determined exceeds the thickness required by C.1. - 3. it is recommended to specially mark these areas.

6.2 The plate thickness in the strengthened areas is to be determined by the following formula:

$$t = 0{,}65 \cdot \sqrt{P_f \cdot k} + t_K \quad [mm]$$

P_f = design impact force in [kN]

P_f = D/100 [kN] with a minimum of 200 kN and a maximum of 1000 kN

D = displacement of the ship in [t].

Any reductions in thickness for restricted service are not permissible.

6.3 In the strengthened areas the section modulus of side longitudinals is not to be less than:

$$W = 0{,}35 \cdot P_f \cdot \ell \cdot k \quad [cm^3]$$

ℓ = unsupported span of longitudinal in [m].

6.4 Longitudinally stiffened 'tween decks and vertically stiffened transverse bulkheads are to be investigated for sufficient buckling strength against loads acting in the ship's transverse direction. For scantlings of side transverses supporting side longitudinals see Section 9, B.4.4.

D. Side Plating of Superstructures

1. The side plating of effective superstructures is to be determined according to C.

2. The side plating of non-effective superstructures is to be determined according to Section 16.

3. For the definition of effective and non-effective superstructures see Section 16, A.1.

For strengthening at ends of superstructures see Section 16, A.3.

E. Strengthenings in Way of Stern Frames, Propeller Brackets and Bilge Keels

1. Strengthenings in way of propellers and propeller brackets

1.1 In way of propeller brackets and shaft bossings, the thickness of the shell plating is to be the same as required for 0,4 **L** amidships. In way of the struts, the shell plating is to have a strengthened plate of 1,5 times the midship thickness.

1.2 Where propeller revolutions are exceeding 300 rpm (approx.), particularly in case of flat bottoms intercostal carlings are to be fitted above or forward of the propeller in order to reduce the size of the bottom plate panels (see also Section 8, A.1.2.4.4).

2. Bilge keels

2.1 Bilge keels are to be provided. They are to be continuous over their full length. The bilge keels are to be welded to continuous flat bars which are connected to the shell plating with their flat side by means of a closed watertight welded seam.

2.2 The ends of the bilge keels are to have soft transition zones according to Fig. 6.1. The ends of the bilge keels shall terminate above an internal stiffening element.

2.3 Any scallops or cut-outs in the bilge keels are to be avoided.

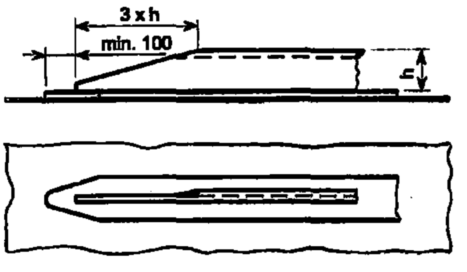


Fig 6.1

F. Openings in the Shell Plating

1. General

1.1 Where openings are cut in the shell plating for windows or side scuttles, hawses, scuppers, sea valves etc., they are to have well rounded corners. If they exceed 500 mm in width in ships up to **L** = 70 metres, and 700 mm in ships having a length **L** of more than 70 metres, the openings are to be surrounded by framing, a thicker plate or a doubling.

1.2 Above openings in the sheerstrake within 0,4 **L** amidships, generally a strengthened plate or a continuous doubling is to be provided compensating the omitted plate sectional area. For shell doors and similar large openings see G. Special strengthening is required in the range of openings at ends of superstructures.

1.3 The shell plating in way of the hawse pipes is to be reinforced.

2. Pipe connections at the shell plating

Scupper pipes and valves are to be connected to the shell by weld flanges. Instead of weld flanges short flanged sockets of adequate thickness may be used if they are welded to the shell in an appropriate manner. Reference is made to Section 21, B.

Construction drawings are to be submitted for approval.

G. Side Shell Doors and Stern Doors

The design and construction of side shell doors and stern doors, if any, are to comply with the requirements of the Rules for Hull, Volume II, Section 6, J.

H. Bulwarks

1. The thickness of bulwark plating is not to be less than:

$$t = \left[0{,}75 - \frac{L}{1000}\right]\sqrt{L} + 0{,}5 \text{ [mm] for } L \le 100 \text{ m}$$

$$t = 0{,}65 \cdot \sqrt{L} + 0{,}5 \text{ [mm] for } L > 100 \text{ m}$$

L need not be taken greater than 200 m. The thickness of bulwark plating forward particularly exposed to wash of sea is to be equal to the thickness of the forecastle side plating according to Section 16, B.1.

In way of superstructures above the freeboard deck abaft 0,25 **L** from **F.P.** the thickness of the bulwark plating may be reduced by 0,5 mm.

2. The bulwark height or height of guard rail is not to be less than 1,0 m provided that, where this would interfere with the normal operation of the vessel, a lesser height may be approved if adequate protection is provided.

3. Plate bulwarks are to be stiffened at the upper edge by a bulwark rail section.

4. The bulwark is to be supported by bulwark stays fitted at every alternate frame. Where the stays are designed as per Fig. 6.2, the section modulus of their cross section effectively attached to the deck is not to be less than:

$$W = 4 \cdot p \cdot e \cdot \ell^2 \quad [cm^3]$$

p = p_s or p_e as the case may be

p_{min} = 15 kN/m^2

e = spacing of stays in [m]

ℓ = length of stay in [m].

The dimension for calculation of W are to be taken vertical of the plating starting from the base of the stays.

In addition Section 3, E.2.3. must be considered.

The stays are to be fitted above deck beams, beam knees or carlings. It is recommended to provide flat bars in the lower part which are to be effectively connected to the deck plating. Particularly in ships the strength deck of which is made of higher tensile steel, smooth transitions are to be provided at the end connection of the flat bar faces to deck.

5. An adequate number of expansion joints is to be provided in the bulwark. In longitudinal direction the stays adjacent to the expansion joints shall be as flexible as practicable.

The number of expansion joints for ships exceeding 60 m in length should not be less than:

$$n = L / 40,$$

but need not be greater than $n = 5$.

6. Openings in the bulwarks shall have sufficient distance from the end bulkheads of superstructures. For avoiding cracks the connection of bulwarks to deckhouse supports is to be carefully designed.

7. For the connection of bulwarks with the sheer strake C.3.4 is to be observed.

8. Bulwarks are to be provided with freeing ports of sufficient size. See also Section 21, B. 2.

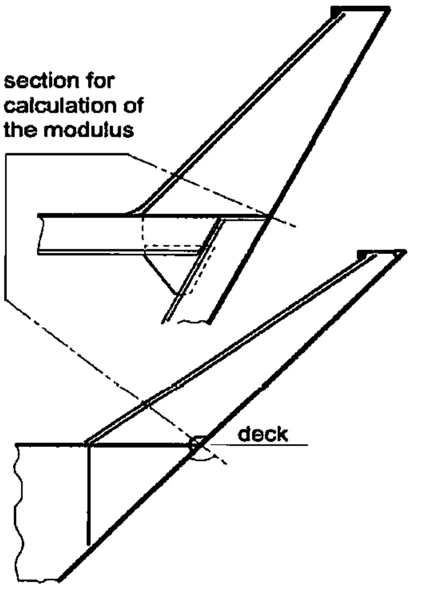


Fig. 6.2

Section 7

Decks

A. Strength Deck

1. General, Definition

1.1 The strength deck is:

.1 the uppermost continuous deck which is forming the upper flange of the hull structure,

.2 a superstructure deck which extends into 0,4 L amidships and the length of which exceeds 0,15 L,

.3 a quarter deck or the deck of a sunk superstructure which extends into 0,4 L amidships.

At the option of the designer below super structure deck may be taken as strength deck.

1.2 In way of a superstructure deck which is to be considered as a strength deck, the deck below the superstructure deck is to have the same scantlings as a 2[nd] deck, and the deck below this deck the same scantlings as a 3[rd] deck. The thicknesses of a strength deck plating are to be extended into the superstructure for a distance equal to the width of the deck plating abreast the hatchway. For strengthening of the stringer plate in the breaks, see Section 16, A.2.

1.3 If the strength deck is protected by sheathing a smaller corrosion allowance t_K than required by Section 3, K may be permitted. Where a sheathing other than wood is used, attention is to be paid that the sheathing does not affect the steel. The sheathing is to be effectively fitted to the deck.

1.4 For ships with a speed $v_0 > 1,6\sqrt{L}$ [kn], additional strengthening of the strength deck and the sheerstrake may be required.

1.5 The following definitions apply throughout this Section:

k = material factor according to Section 2, B.2.

p_D = load according to Section 4, B.1.

p_L = load according to Section 4, C.1.

t_K = corrosion allowance according to Section 3, K.1.

2. Connection between strength deck and sheerstrake

2.1 The welded connection between strength deck and sheerstrake may be effected by fillet welds according to Table 19.3. Where the plate thickness exceeds approximately 25 mm, a double bevel weld connection according to Section 19, B.3.2, shall be provided for instead of fillet welds. Bevelling of the deck stringer to 0,65 times of its thickness in way of the welded connection is admissible. In special cases a double bevel weld connection may also be required, where the plate thickness is less than 25 mm.

2.2 Where the connection of deck stringer to sheerstrake is rounded, the requirements of Section 6, C.3.3 are to be observed.

3. Openings in the strength deck

3.1 All openings in the strength deck are to have well rounded corners. circular openings are to be edge-reinforced. The sectional area of the face bar is not to be less than:

A_f = $0,25 \cdot d \cdot t$ [cm²]

d = diameter of openings in [cm]

t = deck thickness in [cm].

The reinforcing face bar may be dispensed with, where the diameter is less than 300 mm and the smallest distance from another opening is not less than 5 x diameter of the smaller opening. The distance between the outer edge of openings for pipes etc. and the ship's side is not to be less than the opening diameter.

3.2 The hatchway corners are to be surrounded by strengthened plates which are to extend over at least one frame spacing fore-and-aft and athwartships. Within 0,5 L amidships, the thickness of the strengthened plate is to be equal to the deck thickness abreast the hatchway plus the deck thickness between the hatchways. Outside 0,5 L amidships the thickness of the strengthened plated need not exceed 1,6 times the thickness of the deck plating abreast the hatchway.

3.3 The hatchway corner radius is not to be less than:

$r = n \cdot b\,(1 - b/B)$

$r_{min} = 0,1$ m

$n = \ell/200$

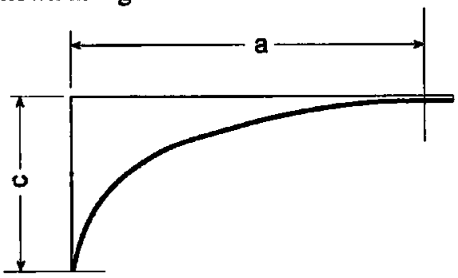
$n_{min} = 0,1$

$n_{max} = 0,25$

ℓ = length of hatchway in [m]

b = breadth in [m], of hatchway or total breadth of hatchways in case of more than one hatchway. b/B need not be taken smaller than 0,4.

3.4 Where the hatchway corners are elliptic or parabolic, strengthening according to 3.2 is not required. The dimensions of the elliptical and parabolical corners shall be as shown in Fig. 7.1:



$a \geq 2c$

$c = r$ according to 3.3

Fig. 7.1

Where smaller values are taken for a and c, reinforced insert plates are required which will be considered in each individual case.

3.5 At the corners of the engine room casings, strengthenings according to 3.2 may also be required, depending on the position and the dimensions of the casing.

4. Scantlings of strength deck

1. The sectional area of the strength deck within 0,4 L amidships is to be determined such that the requirements for the minimum midship section modulus according to Section 5, C.2, are complied with.

2. The thickness of strength deck plating over the entire length of the ship is not to be less than:

$$t = (5{,}5 + 0{,}02\ L)\sqrt{k} \quad [mm]$$

where **L** is not to be taken less than 50 m.

3. If the thickness of the strength deck plating is less than that of the side shell plating, a stringer plate is to be fitted having the width of the sheerstrake and the thickness of the side shell plating.

4. The critical deck thickness for ships of 90 m in length and over may be determined according to Section 6, C.2 analogously.

5. Minimum thickness

5.1 The thickness of deck plating for 0,4 L amidships outside line of hatchways, after all corrections and reductions for restricted service, is not to be less than the greater of the two following values:

t_E according to 7.1, or

$$t_{min} = (4{,}5 + 0{,}05\ L)\sqrt{k} \quad [mm]$$

L need not be taken greater than 200 m.

5.2 When the deck is located above a level of $T + c_0$ above basis a smaller thickness than t_{min} may be accepted if the stress level permits such reduction. c_0 see Section 4, A.2.2.

6. End thickness, thickness inside line of hatchways

6.1 The thickness of strength deck plating for 0,1 **L** from the ends and between hatchways is not to be less than :

$$t_{E1} = 1{,}21 \cdot a\sqrt{p_D \cdot k} + t_K \quad [mm]$$

$$t_{E2} = 1{,}1 \cdot a\sqrt{p_{bL} \cdot k} + t_K \quad [mm]$$

$$t_{Emin} = (5{,}5 + 0{,}02\ L)\sqrt{k} \quad [mm]$$

L need not be taken greater than 200 m.

6.2 Between the midship thickness and the end thickness, the thicknesses are to be tapered gradually.

6.3 The deck structure inside line of hatchways is to be so designed that the compressive stresses acting in the ship's transverse direction can be safely transmitted. Proof of buckling strength is to be provided according to Section 3, F.

7. Aft ramp

7.1 The ramp should be preferably stiffened in its longitudinal direction. The transition radius between deck and ramp should be as large as possible but should not be less than 300 mm.

7.2 The plate thickness of the aft ramp of stern trawlers is not to be less than :

$$t = (8 + 0{,}1\ L)\sqrt{k} \quad [mm]$$

$$t_{min} = 12\sqrt{k} \quad [mm]$$

$$t_{max} = 16\sqrt{k} \quad [mm]$$

7.3 The thickness of inner plating of the ramp forming the ramp sides is not to be less than required by 4.2 increased by 2 mm. In the lower part adjacent to the ramp, a strengthened strake is to be provided having a thickness of not less than the thickness required under 7.2. See Fig. 7.2.

8. Additional strengthenings

Under trawl winches, trawl gallows, windlasses and centre fairleads, beams and substructures of adequate strength are to be fitted.

The thickness of the deck plating is to be suitably increased even it wood sheating will be fitted.

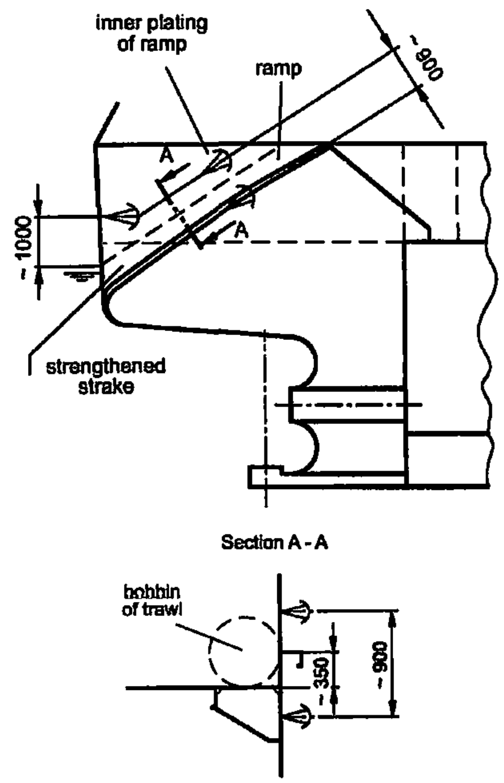


Fig. 7.2

B. Lower Decks, Superstructure Decks

The plate thickness is not to be less than:

$$t = 1{,}1\ a\ \sqrt{p_L \cdot k} + t_K\ [\text{mm}]$$

$$t_{min} = (5{,}5 + 0{,}02\ L)\ \sqrt{k} \quad [\text{mm}]$$
for the 2nd deck

$= 6{,}0$ mm for other lower decks

L need not be taken greater than 200 m.

For the critical deck thickness see A.5.2.

The thickness of the forecastle deck is not to be less than 7,0 mm, under wood sheathing 6,0 mm.

C. Helicopter Decks

1. General

1.1 The starting/landing zone is to be dimensioned for the largest helicopter type expected to use the helicopter deck.

1.2 For scantling purposes, other loads (cargo, snow/ice, etc.) are to be considered simultaneously or separately, depending on the conditions of operation to be expected. Where these conditions are not known, the data contained in 2. below may be used as a basis.

1.3 The following provisions in principle apply to starting/landing zones on special pillar-supported landing decks or on decks of superstructures and deckhouses.

Guidance

For the convenience of the users of these Rules reference is made to the "Guide to Helicopter/Ship Operations' published by the International Chamber of Shipping (ICS).

2. Load assumptions

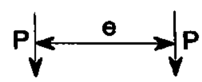
The following load cases (LC) are to be considered:

2.1 LC 1

Helicopter lashed on deck, with the following vertical forces acting simultaneously:

.1 Wheel and/or skid force P acting at the points resulting from the lashing position and distribution of the wheels and/or supports according to helicopter construction.

$$P = 0{,}5 \cdot G\ (1 + a_v)\ [\text{kN}]$$



G = maximum permissible take-off weight in [kN]

a_v see Section 4, C.1.1

P = evenly distributed force over the contact area f = 30 x 30 cm for single wheel or according to data supplied by helicopter manufacturers; for dual wheels or skids to be determined individually in accordance with given dimensions.

e = wheel or skid distance according to helicopter types to be expected

.2 Force due to weight of helicopter deck M_e as follows:

$$M_e\ (1 + a_v) \quad [\text{kN}]$$

.3 Load $p = 2{,}0$ kN/m^2 evenly distributed over the entire landing deck.

2.2 LC 2

Helicopter lashed on deck, with the following horizontal and vertical forces acting simultaneously:

.1 Forces acting horizontally:

$$H = 0{,}6\ (G + M_e) + W \quad [\text{kN}]$$

W = Wind load, taking into account the lashed helicopter and deck cargo of an average height of 0,5 m;

wind velocity $v_w = 50$ m/s.

.2 Forces acting vertically:

$V = G + M_e$ [kN]

2.3 LC 3

Normal landing impact, with the following forces acting simultaneously:

.1 Wheel and/or skid load P at two points simultaneously, at an arbitrary (most unfavourable) point of the helicopter deck (landing zone + safety zone)

$P = 0{,}75\ G$ [kN]

.2 Load $p = 0{,}5\ kN/m^2$ evenly distributed

(for taking into account snow or other environmental loads)

.3 Weight of the helicopter deck

.4 Wind load in accordance with the wind velocity admitted for helicopter operation (v_w), where no data are available, $v_w = 25$ m/s may be used.

3. Scantlings of structural members

3.1 Stresses and forces in the supporting structure are to be evaluated by means of direct calculations.

3.2 Permissible stresses for stiffeners, girders and substructure:

$$\sigma_{perm} = \frac{235}{k \cdot v_S}$$

v_S = Safety factors according to Table 7.1.

3.3 The thickness of the plating is to be determined according to B.2. where the coefficient c may be reduced by 5%.

Table 7.1

Structural element	v_S	
	LC1, LC2	LC 3
Stiffeners (deck beam)	1,25	1,1
main girders (deck girder)	1,45	1,45
load-bearing structure (pillar system)	1,7	2,0

3.4 Proof of sufficient buckling strength is to be carried out in accordance with Section 3, F. for structures subjected to compressive stresses.

Section 8

Bottom Structures

A. Single Bottom

1. Floor plates

1.1 General

1.1.1 The floors are to be fitted at every frame.

1.1.2 Deep floors, particularly in the after peak, are to be provided with buckling stiffeners.

1.1.3 The floor plates are to be provided with limbers to permit the water to reach the pump suctions.

1.2 Scantlings

1.2.1 Floor plates in the cargo hold area

On ships without double bottom or outside any double bottom the scantlings of floors fitted between after peak bulkhead and collision bulkhead are to be determined according to the following formulae.

$$W = c \cdot T \cdot a \cdot \ell^2 \quad [cm^3]$$

c = 7,5 for spaces which may be empty at full draught, machinery spaces, storerooms

= 4,5 elsewhere

ℓ = unsupported span in [m], generally measured on upper edge of floor from side shell to side shell.

ℓ_{min} = 0,7 **B**.

In compartments which are usually empty when the ship is sailing at full draught, e.g. engine rooms, stores etc. the section modulus of the floors is to be increased by 65 percent. Regarding floors in the engine room see also C. 1.

The depth of the floor plates is not to be less than:

$$h = 55 \cdot \mathbf{B} - 45 \quad [mm]$$

$$h_{min} = 180 \text{ mm.}$$

In ships having rise of floors, at 0,1 ℓ from the ends of the length l where possible, the depth of the floor plate webs shall be half the required depth.

In ships having a considerable rise of floor, the depth of the floor plate webs at the beginning of the turn of bilge is not to be less than the depth of the frame.
The web thickness is not to be less than:

$$t = h/100 + 3 \quad [mm]$$

1.2.2 Outside the engine room and aft of 0,25 L from F.P. the floor plates may be fitted with flanges instead of the flat bar face plates.

1.2.3 The face plates of the floor plates are to be continuous over the span ℓ. If they are interrupted at the centre keelson, they are to be connected to the centre keelson by means of full penetration welding.

1.2.4 Floor plates in the peaks

.1 The thickness of the floor plates in the peaks is not to be less than:

$$t = 0{,}035\,\mathbf{L} + 5{,}0 \quad [mm]$$

The thickness, however, need not be greater than required by B.6.2.1.

.2 The floor plate height in the fore peak above top of keel or stem shoe is not to be less than:

$$h = 0{,}06\,\mathbf{H} + 0{,}7 \quad [mm]$$

.3 The floor plates in the after peak are to extend over the stern tube. See also Section 13, C.1.4.

.4 Where propeller revolutions are exceeding 300 rpm (approx.) the peak floors above the propeller are to be strengthened. Particularly in case of flat bottoms additional longitudinal stiffeners are to be fitted above or forward of the propeller.

2. Longitudinal girders

2.1 General

2.1.1 Single bottom ships are to have a centre girder. Where the breadth measured on top of floors does not exceed 9 m one additional side girder is to be fitted, and two side girders where the breadth exceeds 9 m. Side girders are not required where the breadth does not exceed 6 m.

2.1.2 For arrangement of side girders in way of bottom strengthening forward, see Section 6, B.6.3.

2.1.3 The centre and side girders are to extend as far forward and aft as practicable. They are to be connected to the girders of a non-continuous double bottom or are to be scarphed into the double bottom by two frame spacings.

2.2 Scantlings

2.2.1 Centre girder

The web thickness within 0,7 L amidships is not to be less than:

$t = 0{,}07\ \mathbf{L} + 5{,}5$ [mm]

The sectional area of the top plate within 0,7 **L** amid-ships is not to be less than:

$f = 0{,}7\ \mathbf{L} + 12$ [cm^2]

Towards the ends the thickness of the web plate as well as the sectional area of the top plate may be reduced by 10 percent. Lightening holes are to be avoided.

2.2.2 Side girder

The thickness of the web plate within 0,7 **L** amidships is not to be less than:

$f = 0{,}04\ \mathbf{L} + 5{,}0$ [cm^2]

The sectional area of face plate within 0,7 **L** amidships is not to be less than:

$f = 0{,}2\ \mathbf{L} + 6{,}0$ [cm^2]

Towards the ends, the thickness of the web plate and the sectional area of the face plate may be reduced by 10 percent.

B. Double Bottom

1. General

1.1 For reasons of safety a double bottom is recommended, unless the size of the ship (ships less than 50 m) make this arrangement unsuitable.

1.2 In deep tanks and in fore and after peak a double bottom need not be arranged.

1.3 The centre girder should be watertight at least for 0,5 **L** amidships, unless the double bottom is subdivided by watertight side girders.

2. Centre girder

2.1 Lightening holes

Lightening holes in the centre girder are generally permitted only outside 0,75 **L** amidships. Their depth is not to exceed half the depth of the centre girder and their lengths are not to exceed half the frame spacing.

2.2 Scantlings

Depth and thickness of the centre girder are not to be less than:

.1 Depth

$h = 350 + 45 \cdot \mathbf{B}$ [mm]

$h_{min} = 600$ mm

Where longitudinal wing bulkheads are fitted, the distance between the bulkheads may be inserted in lieu of **B**, however, not less than 0,8 **B**.

.2 Thickness

For 0,7 **L** amidships :

$t = (h/100 + 1{,}0)\sqrt{k}$ [mm]

for $h \le 1200$ [mm]

$t = (h/120 + 3{,}0)\sqrt{k}$ [mm]

for $h \ge 1200$ [mm]

The thickness may be reduced by 10 percent for 0,15 **L** at the ends.

.3 Where the actual depth of the centre girder exceeds the rule depth h according to .1, the thickness t may be reduced accordingly, provided sufficient buckling and shear strength is maintained.

3. Side girders

3.1 Arrangement

At least one side girder shall be fitted in the engine room and forward of 0,25 **L**. In the other parts of the double bottom, one side girder shall be fitted where the horizontal width from lower edge of margin plate to centre girder exceeds 4,5 m. Two side girders shall be fitted where the width exceeds 8 m, and three side girders where it exceeds 10,5 m. The distance of the side girders from each other and from centre girder and margin plate respectively shall not be greater than:

- 1,8 m in the engine room within the breadth of engine seatings,
- 4,5 m where one side girder is fitted in the other parts of double bottom,
- 4,0 m where two side girders are fitted in the other parts of double bottom,
- 3,5 m where three side girders are fitted in the other parts of double bottom.

In way of the strengthening of the bottom forward, the spacing of side girders is to be determined according to Section 6, C.6.3.

3.2 Scantlings

3.2.1 The thickness of the side girders is not to be less than:

$$t = \frac{h^2}{120 \cdot h_a}\sqrt{k} \quad [\text{mm}]$$

h = depth of the centre girder in [mm] according to 2.2.

h_a = as built depth of side girders in [mm]
h_a need not be taken less than h to calculate t

t = must not be less than t according to 7.5.

For strengthenings under the engine seating, see C.

4. Inner bottom

4.1 The thickness of inner bottom plating is not to be less than required by the following formulae:

$$t = 1{,}1 \cdot a \sqrt{p \cdot k} + t_K \ [mm]$$

p = design pressure in [kN/m²]

p is the greater of the following values:

p_1 = $10\,(T - h_{DB})$

p_2 = $10 \cdot h$

p_3 = p_i according to Section 4, C.2.

h = height of top of overflow pipe above inner bottom in [m]

h_{DB} = double bottom height in [m].

4.2 If no ceiling is fitted on the inner bottom, the thickness determined in accordance with 4.1 is to be increased by 2 mm.

4.3 For strengthening of inner bottom in machinery spaces, see C.2.4.

5. Double bottom tanks

5.1 Fuel and lubrication oil tanks

5.1.1 In double bottom tanks, fuel oil may be carried, the flash point (closed cup test) of which is above 60 °C.

5.1.2 Where practicable, lubrication oil discharge tanks or circulating tanks shall be separated from the shell.

5.1.3 For the separation of fuel oil tanks and tanks for other liquids see Section 12, A.5.

5.1.4 For air, overflow and sounding pipes, see Section 21,D.

5.2 Bilge wells

Bilge wells shall have a capacity of more than 0,2 m³. Small holds may have smaller bilge wells. For the use of manhole covers or hinged covers for the access to the bilge suctions, see Rules for Machinery Installations, Volume III, Section 11. Bilge wells are to be separated from the shell.

5.3 Sea chests

5.3.1 The plate thickness of sea chests is not to be less than:

$$t = 12 \cdot a \sqrt{p \cdot k} + t_K \ [mm]$$

a = spacing of stiffeners in [m]

p = blow out pressure at the safety valve in [bar]
p is not to be less than 2 bar (see also Rules for Machinery Installations, Volume III, Section 11).

5.3.2 The section modulus of the sea chest stiffeners is not to be less than:

$$W = k \cdot 56 \cdot a \cdot p \cdot \ell^2 \ [cm^3]$$

a and p see 5.3.1

ℓ = unsupported span of stiffeners in [m].

5.3.3 The seawater inlet openings in the shell are to be protected by gratings.

5.3.4 A cathodic corrosion protection with galvanic anodes made of zinc or aluminium is to be provided in sea chests with chest coolers. For the suitably coated plates a current density of 30 mA/m² is to be provided and for the cooling area a current density of 180 μ/m².

6. Double bottom in transverse framing system

6.1 Plate floors

6.1.1 It is recommended to fit plate floors at every frame in the double bottom if transverse framing is adopted.

6.1.2 Plate floors are to be fitted at every frame:

.1 in way of the stengthening of the bottom forward according to Section 6, B.6.,

.2 in the engine room,

.3 under the boiler bearers.

6.1.3 Plate floors are to be fitted under bulkheads.

6.1.4 For the remaining part of the double bottom, the spacing of plate floors shall not exceed approximately 3 m.

6.2 Scantlings

6.2.1 The thickness of plate floors is not to be less than:

$$t_{pf} = t_m - 2{,}0 \quad [mm]$$

t_m = thickness of centre girder according to 2.2.2.

The thickness need not exceed 16,0 mm.

If the floor depth exceeds the height h according to 2.2.1, the thickness may be reduced accordingly, provided that the buckling strength is examined according to Section 3, F.

6.2.2 The web sectional area of the plate floors is not to be less than:

$$A_w = \varepsilon \cdot T \cdot \ell \cdot e\,(1 - 2y/\ell)\,k \quad [cm^2]$$

e = spacing of plate floors in [m]

ℓ = span between longitudinal bulkheads, if any, in [m]

ℓ = **B**, if longitudinal bulkheads are not fitted

y = distance between supporting point of the plate floor (ship's side, longitudinal bulkhead) and the section considered in [m]. The distance y is not to be taken greater than 0,4 ℓ.

ε = 0,5 for spaces which may be empty at full draught, e.g. machinery spaces, store rooms, etc.

= 0,3 elsewhere.

6.2.3 Where in small ships no side girders are required (see 3.1) at least one vertical stiffener is to be fitted at every plate floor; its thickness is to be equal to that of the floors and its depth of web at least one fifteenth of the height of centre girder.

6.2.4 In way of strengthening of bottom forward according to Section 6, D., the plate floors are to be connected to the shell plating and inner bottom by continuous fillet welding. Any scalloping in the plate floors is to be restricted to holes required for welding, and for limbers.

6.2.5 For strengthening of floors in machinery spaces, see C.2.2.

6.3 Watertight floors

6.3.1 The thickness of watertight floors is not to be less than that required for tank bulkheads according to Section 12, B. In no case their thickness is to be less than required for plate floors according to 6.2.

6.3.2 The scantlings of stiffeners at watertight floors are to be determined according to Section 12, B.3.

6.4 Bracket floors

6.4.1 Where no plate floors are required according to 6.1 bracket floors may be fitted.

6.4.2 Bracket floors consist of bottom frames at the shell plating and reversed frames at the inner bottom, attached to centre girder, side girders and ship's side by means of brackets.

6.4.3 The section modulus of the bottom and inner bottom frames is not to be less than:

$$W = k \cdot n \cdot c \cdot a \cdot \ell^2 \cdot p \quad [cm^3]$$

p = design load, as applicable, in [kN/m²] as follows:

for bottom frames

p = p_B according to Section 4, B.3.

for inner bottom frames

p = p_i according to Section 4, C.2.

= p_1 or p_2 according to Section 4, D.1.

= $10\,(T - h_{DB})$

The greater value is to be used.

h_{DB} = double bottom height in [m]

n = 0,44 if $p = p_2$

n = 0,55 if $p = p_i$ or p_1

n = 0,70 if $p = p_B$

c = 0,60 where struts according to 6.6 are provided at $\ell/2$, otherwise c = 1,0

ℓ = unsupported span in [m] disregarding struts, if any.

6.5 Brackets

6.5.1 The brackets are to be of same thickness as the plate floors. Their breadth is to be 0,75 of the depth of the centre girder as per 2.2. The brackets are to be flanged at their free edges, where the unsupported span of bottom frames exceeds 1 m or where the depth of floors exceeds 750 mm.

6.5.2 At the side girders, bottom frames and inner bottom frames are to be supported by flat bars having the same depth as the inner bottom frames.

6.6 Struts

The cross sectional area of the struts is to be determined according to Section 10, C.2. analogously. The design force is to be taken as the following value:

$$P = 0{,}5 \cdot p \cdot a \cdot \ell \quad [kN]$$

ℓ = unsupported span according to 6.4.3 in [m]

p = load according to 6.4.3.

7. Double bottom in longitudinal framing system

7.1 General

Where the longitudinal framing system changes to the transverse framing system, structural continuity or sufficient scarphing is to be provided for.

7.2 Bottom and inner bottom longitudinals

7.2.1 The section moduli are to be calculated according to Section 9, B.

7.2.2 Where bottom and inner bottom longitudinals are coupled by struts in the centre of their unsupported span ℓ their section moduli may be reduced to 60 % of the values required by Section 9 B. the scantling of the struts are be determined in accordance with 6.6.

7.3 Plate floors

7.3.1 The floor spacing shall, in general, not exceed 5 times the transverse frame spacing.

7.3.2 Floors are to be fitted at every frame in the machinery space under the main engine. In the remaining part of the machinery space and under the boiler bearers, floors are to be fitted at every alternate frame. Floors are to be fitted also in location according to 6.1.3

7.3.3 Regarding floors in way of the strengthening of the bottom forward, Section 6, B. is to be observed.

7.3.4 The scantlings of floors are to be determined according to 6.2.

7.3.5 The plate floors are to be stiffened at every longitudinal by a vertical stiffener having the same scantlings as the inner bottom longitudinals. The depth of the stiffener need not exceed 150 m. If necessary a strength check can be required.

7.4 Brackets

7.4.1 Where the ship's sides are framed transversely flanged brackets having a thickness of the floors are to be fitted between the plate floors at every transverse frame, extending to the outer longitudinals at the bottom and inner bottom.

7.4.2 One bracket is to be fitted at each side of the centre girder between the plate floors where the plate floors are spaced not more than 2,5 m apart. Where the floor spacing is greater, two brackets are to be fitted.

7.5 Longitudinal girder system

7.5.1 Where longitudinal girders are fitted instead of bottom longitudinals, the spacing of floors may be greater than permitted by 7.3.1, provided that adequate strength of the structure is proved.

7.5.2 The plate thickness of the longitudinal girders is not to be less than:

$$t = (5{,}0 + 0{,}03\ L)\sqrt{k} \quad [mm]$$

$$t_{min} = 6{,}0\ \sqrt{k} \quad [mm]$$

7.5.3 The longitudinal girders are to be examined for sufficient safety against buckling according to Section 3, F.

C. Bottom Structure in Machinery Spaces in Way of the Main Propulsion Plant

1. Single bottom

1.1 The scantlings of floors are to be determined according to A.1.2.1 for the greatest span measured in the engine room.

1.2 The web depth of the floor plates in way of the engine foundation should be as large as possible. The depth of floor plates connected to web frames shall be similar to the depth of the longitudinal foundation girders. In way of the crank case, the depth shall not be less than 0,5 x h. The web thickness is not to be less than:

$$t = h/100 + 4 \quad [mm]$$

h see A.1.2.1

1.3 The thickness of the longitudinal foundation girders is to be determined according to 3.2.1.

1.4 No centre girder need be fitted in way of longitudinal foundation girders. Intercostal docking profiles are to be fitted instead. The sectional area of the docking profiles is not to be less than:

$$f = 10 + 0{,}2\ L \quad [cm^2]$$

Docking profiles are not required where a bar keel is fitted. Brackets connecting the floor plates to the bar keel are to be fitted on either side of the floors.

2. Double bottom

2.1 General

2.1.1 Lightening holes in way of the engine foundation are to be kept as small as possible with due regard, however, to accessibility. Where necessary, the edges of lightening holes are to be strengthened by means of face bars or the plate panels are to be stiffened.

2.1.2 Local stengthenings are to be provided beside the following minimum requirements, taking into account to the construction and the local conditions.

2.2 Floor plates

Plate floors are to be fitted at every frame. The floor thickness according to B.6.2 is to be increased by the following percentage:

$$3{,}6 + P/500 \ [\%]$$

minimum 5 %, maximum 15 %

P = single engine output in [kW].

2.3 Side girders

2.3.1 The thickness of side girders under an engine foundation top plate inserted into the inner bottom is to be similar to the thickness of side girders above the inner bottom according to 3.2.1.

2.3.2 Side girders with the thickness of longitudinal girders according to 3.2 are to be fitted under the foundation girders in full height of the double bottom. Where two side girders are fitted on either side of the engine, one may be a half height girder under the inner bottom for engines up to 3000 kW.

2.3.3 Side girders under foundation girders are to be extended into the adjacent spaces and to be connected to the bottom structure. This extension abaft or forward of the engine room bulkheads shall be 2 - 4 frame spaces if practicable.

2.3.4 No centre girder is required in way of the engine seating (see 1.4).

2.4 Inner bottom

Between the foundation girders, the thickness of the inner bottom plating required according to B.4.1 is to be increased by 2 mm. The strengthened plate is to be extended beyond the engine seating by three to five frame spacings.

3. Engine seating

3.1 General

3.1.1 The following regulations apply to low speed engines. Seating for medium and high speed engines as well as for turbines will be specially considered. Structural arrangements deviating from these requirements may be considered provided that the strength and rigidity of the foundation is to satisfaction of BKI

3.1.2 The rigidity of the engine seating and the surrounding bottom structure must be adequate to keep the deformations of the system due to the loads within the permissible limits. In special cases, evidence may be required of deformations and stresses.

Guidance

At the draught resulting in the maximum deflection in way of the foundation the deflection of two stroke, cross head engines including foundation ought to be less than 1 mm over the length of the engine. In addition to the deflection of engine and foundation the crank web deflections by which the admissible engine deflection may be limited to values less than 1 mm have to be considered as well. For medium speed and high speed engines not only the deflections of crank webs have to be taken into account but for assuring trouble free bearing conditions of the crank shaft the bending deflection of the engine is to be limited.

Note

If in special cases a direct calculation of motorseatings may become necessary, the following is to be observed:

- *For seatings of slow speed two-stroke diesel engines and elastically mounted medium speed four-stroke diesel engines the total deformation $\Delta f = f_u + f_o$ shall not be greater than:*

  $\Delta f = 0,2 \cdot \ell_M$

  ℓ_M = *length of motor in [m]*

  f_u = *maximum vertical deformation of the seating downwards within the length ℓ_M in [mm]*

  f_o = *maximum vertical deformation of the seating upwards within the length ℓ_M in [mm].*

  The individual deformations f_u and f_o shall not be greater than:

  $f_{u\,max}, f_{o\,max} = 0,7 \times \Delta f$

  For the calculation of the deformations the maximum static and wave induced dynamic internal and external differential loads due to local loads and the longitudinal hull girder bending moments as well as the rigidity of the motor are to be considered.

- *For seatings of non-elastically mounted medium speed four-stroke diesel engines the deformation values shall not exceed 50% of the above values.*

3.1.3 Due regard is to be paid, at the initial design stage, to a good transmission of forces in transverse and longitudinal direction.

3.1.4 The foundation bolts for fastening the engine at the seating shall be spaced no more than 3 · d apart from the longitudinal foundation girder. Where the distance of the foundation bolts from the longitudinal foundation girder is greater, proof of equivalence is to be provided.

d = diameter of the foundation bolts.

3.1.5 In the whole speed range of main propulsion installations for continuous service resonance vibrations with inadmissible vibration amplitudes must not occur; if necessary structural variations have to be provided for avoiding resonance frequencies. Other-wise, a barred speed range has to be fixed. Within a range of – 10 % to + 5 % related to the rated speed no barred speed range is permitted. The Society may require a vibration analysis and, if deemed necessary, vibration measurement.

3.2 Longitudinal girders

3.2.1 The thickness of the longitudinal girders above the inner bottom is not to be less than:

$$t = \sqrt{\frac{P}{15}} + 6 \quad [mm]$$

for P < 1500 kW

$$t = \frac{P}{750} + 14 \quad [mm]$$

for $1500 \leq P < 7500$ kW

$$t = \frac{P}{1875} + 20 \quad [mm]$$

for $P \geq 7500$ kW

For P see 2.2.

3.2.2 Where two longitudinal girders are fitted on either side of the engine, their thickness required according to 3.2.1 may be reduced by 4 mm.

3.2.3 The sizes of the top plate (width and thickness) shall be sufficient to attain efficient attachment and seating of the engine and - depending on seating height and type of engine - adequate transverse rigidity.

The thickness of the top plate shall approximately be equal to the diameter of the fitted-in bolts. The cross sectional area of the top plate is not to be less than:

$$F_T = \frac{P}{15} + 30 \quad [cm^2]$$

for $P \leq 750$ kW

$$F_T = \frac{P}{75} + 70 \quad [cm^2]$$

for $P > 750$ kW

Where twin engines are fitted, a continuous top plate is to be arranged in general if the engines are coupled to one propeller shaft.

3.2.4 The longitudinal girders of the engine seating are to be supported transversely by means of web frames or wing bulkheads. The scantlings of web frames are to be determined according to Section 9, A.8.

3.2.5 Top plates are preferably to be connected to longitudinal and transverse girders thicker than approx. 15 mm by means of a double bevel butt joint (K butt joint). See also Section 19, B.3.3.

Section 9

Framing System

A. Transverse Framing

1. General

1.1 Frame spacing

1.1.1 The rule frame spacing a_0 (transverse frame spacing) from 0,2 L abaft F.P. to the after peak bulkhead is to be determined from the following formula:

$$a_0 = \frac{L}{500} + 0{,}48 \text{ [m]}$$

$$a_{0\,max} = 1{,}0$$

1.1.2 Forward of the collision bulkhead and aft of the after peak bulkhead, the frame spacing shall in general not exceed 600 mm.

1.2 Definitions

ℓ = span in [m], see also Section 3, B.

p_s = load in [kN/m²] according to Section 4, B.2.

1.3 Curved frames

Where the frames are curved the section modulus may be multiplied with the coefficient

$f = 1{,}0 - 2\,\frac{s}{\ell}$, see Fig. 9.1.

s = depth of curvature

f_{min} = 0,75.

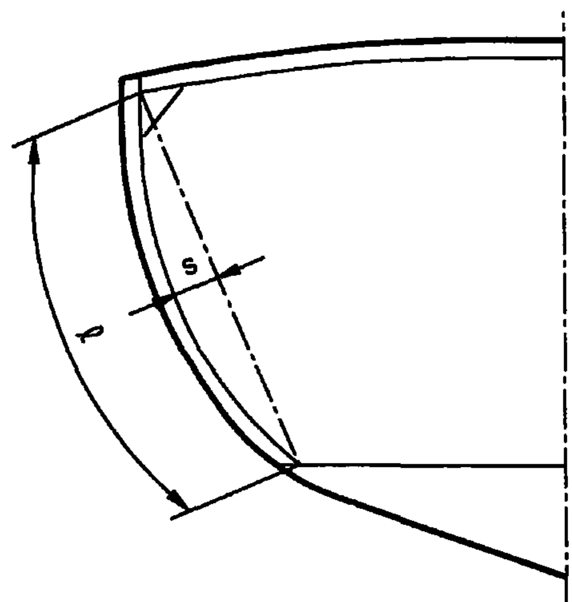


Fig. 9.1

2. Main frames

2.1 Scantlings

2.1.1 The section modulus of the main frames is not to be less than:

$$W = k \cdot 0{,}8 \cdot \ell^2 \cdot a \cdot p_s \quad [\text{cm}^3]$$

2.1.2 The main frames are to extend at least to the lowest deck and in ships with more than 3 decks, at least to the deck above the lowest deck.

2.1.3 Where frames are supported by a longitudinally framed deck, the frames fitted between web frames are to be connected to the adjacent longitudinals by brackets.

3. Frames in tanks

3.1 The section modulus of frames in tanks is not to be less than required by Section 12, B.3. for W_2.

4. Tank side bracket

4.1 The thickness of tank side brackets or frame brackets on the inner bottom is not to be less than:

$$t = 0{,}5\,H + 5{,}0 \quad [\text{mm}]$$

$$t_{max} = 15{,}0 \text{ mm}$$

For ships having 3 or more decks, H need not be taken greater than L/12.

For single deck ships, the thickness is to be increased by 10 %.

4.2 Tank side brackets or bilge brackets are to be flanged where the section modulus of the frame exceeds 30 cm³. The flange width shall not be less than 75 mm.

4.3 For the connection of main frames and tank side brackets, see Section 19, B. 4.2.

5. Tween deck and superstructure frames

5.1 Scantlings

5.1.1 The section modulus of the 'tween deck and superstructure frames is not to be less than:

$$W = k \cdot 0{,}8 \cdot a \cdot \ell^2 \cdot p_s \quad [cm^3]$$

p_s is not to be taken less than:

$$p_{min} = 0{,}4 \cdot p_L \cdot (b/\ell)^2 \quad [kN/m^2]$$

b = length of the deck beam below the respective 'tween deck frame, in [m]

p_L = load on the 'tween deck, for tank tops a load corresponding to half the distance from the tank top to the top of overflow, however, not less than 12,3 [kN/m²].

Where 'tween decks are framed longitudinally, p_{min} is to be ignored for 'tween deck frames fitted between deck transverses.

For 'tween deck frames connected at their lower ends to the deck transverses, p_{min} is to be multiplied by the factor

$$f_1 = 0{,}75 + 0{,}25 \; e/a$$

e = spacing of deck transverses, in [m].

5.1.2 For 'tween deck frames, the value W/ℓ^2 need not be greater than for the main frames fitted below.

5.2 End attachment

'Tween deck and superstructure frames are to be connected to the main frames below, or to the deck. The end attachment may be carried out in accordance with Fig. 9.2.

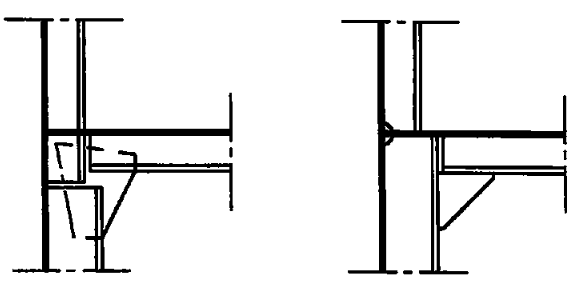


Fig. 9.2

6. Peak frames and frames in way of the stern

6.1 Peak frames

6.1.1 The section modulus of the peak frames is not to be less than:

$$W = k \cdot 0{,}8 \cdot a \cdot \ell^2 \cdot p_s \quad [cm^3]$$

ℓ = unsupported span of frames, in [m] according to Section 3, B. The span ℓ is not to be taken less than 2,0 m.

6.1.2 Where the length of the fore peak does not exceed 0,06 L the section modulus required at half fore peak length may be maintained throughout the entire fore peak.

6.1.3 The peak frames are to be connected to the stringer plates in such a way that sufficient shear strength is guaranteed.

6.1.4 Where peaks are to be used as tanks, the section modulus of the peak frames is not to be less than required by Section 12, B.3. for W_2.

6.2 Frames in way of the stern

6.2.1 The frames in way of the cruiser stern arranged at changing angles to the transverse direction are to have a spacing not exceeding 600 mm and are to extend up to the deck above peak tank top maintaining the scantlings of the peak frames.

6.2.2 An additional stringer may be required in the after ship outside the afterpeak where frames are inclined considerably and not fitted vertically to the shell.

7. Strengthenings in fore- and aft body

7.1 Tiers of beams

7.1.1 Forward of the collision bulkhead, tiers of beams (beams at every other frame) generally spaced not more than 2,6 m apart, measured vertically, are to be arranged below the lowest deck within the fore peak. Stringer plates are to be fitted on the tiers of beams which are to be connected by continuous welding to the shell plating and by a bracket to each frame. The scantlings of the stringer plates are to be determined from the following formulae:

width $b = 75\sqrt{L}$ [mm]

thickness $t = 6{,}0 + L/40$ [mm]

7.1.2 The cross sectional area f_B of each beam of a tier is not to be less than:

$$f_B = \frac{10 \cdot P}{95 - 0{,}0045\,\lambda^2} \quad [cm^2] \text{ for } \lambda \le 100$$

$$f_B = \frac{P \cdot \lambda^2}{5 \cdot 10^4} \quad [cm^2] \text{ for } \lambda > 100$$

λ = ℓ/i = degree of slenderness of the beam

ℓ = unsupported span of the beam in [cm]

i = $\sqrt{J/f_B}$ = radius of gyration of the beam in [m]

J = smallest moment of inertia of the beam in [cm⁴]

P = $A \cdot p$ [kN]

A = load area of a beam, in [m²].

p = p_s or p_e, whichever is applicable

Where the length of the fore peak does not exceed 0,06**L**, the load at half fore peak length may be applied for determining the scantlings of all beams.

7.1.3 In the after peak, tiers of beams with stringer plates generally spaced 2,6 m apart, measured vertically, are to be arranged as required under 7.1.1, as far as practicable with regard to the ship's shape.

7.1.4 Intermittent welding at the stringers in the after peak is to be avoided. Any scallopping at the shell plating is to be restricted to holes required for welding and for limbers.

7.1.5 Where peaks are used as tanks, the stringer plates are to be flanged or face bars are to be fitted at their inner edges. The stringers are to form a continuous line of support with the horizontal stiffeners at the collision bulkhead.

7.2 Web frames and stringers

7.2.1 Where web frames and supporting stringers are fitted instead of tiers of beams, their scantlings are to be determined as follows:

.1 Section modulus:

$$W = 0{,}6 \cdot e \cdot \ell^2 \cdot p_s \cdot n \cdot k \ [cm^3]$$

.2 Web sectional area at the supports:

$$A_w = 0{,}06 \cdot e \cdot \ell_1 \cdot p_s \cdot k \quad [cm^2]$$

ℓ = unsupported span in [m], without consideration of cross ties, if any

ℓ_1 = similar to ℓ, however, considering cross ties, if any

n = coefficient according to the following Table 9.1.

Table 9.1

Number of cross ties	n
0	1,0
1	0,5
2	0,3
≥ 3	0,2

7.2.2 Vertical transverses are to be interconnected by cross ties the cross sectional area of which is to be determined according to 7.1.2.

7.3 Web frames and stringers in 'tween decks and superstructure decks

Where the speed of the ship exceeds $1{,}6\sqrt{L}$ [kn] or in ships with a considerable bow flare respectively, stringers and transverses according to 7.2 are to be fitted within 0,2 **L** from forward in 'tween deck spaces and superstructures.

7.4 Tripping brackets

7.4.1 Between the point of greatest breadth of the ship at maximum draft and the collision bulkhead tripping brackets spaced not more than 2,6 m, measured vertically, according to the following sketches are to be fitted. The thickness of the brackets is to be determined according to 7.1.1; see also Fig. 9.3.

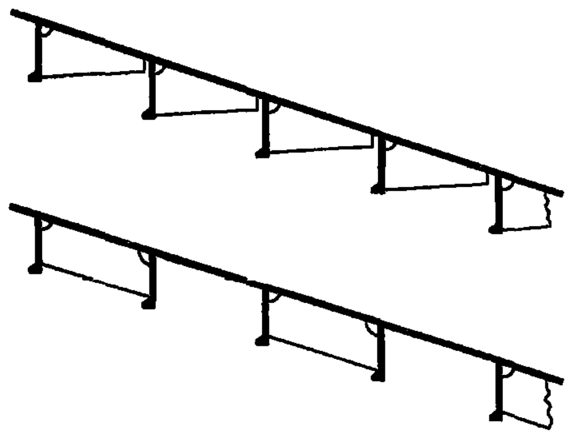


Fig. 9.3

7.4.2 In the same range, in 'tween deck spaces and superstructures of 3 m and more in height, tripping brackets according to 7.4.1 are to be fitted.

7.4.3 Where peaks or other spaces forward of the collision bulkhead are intended to be used as tanks, tripping brackets according to 7.4.1 are to be fitted between tiers of beams as per 7.1.

8. Web frames in machinery spaces

8.1 Arrangement

8.1.1 In the engine room, web frames are to be fitted. Generally, they should extend up to the upper-most continuous deck. The web frames are to be spaced 3,5 m apart on an average.

8.1.2 For combustion engines up to about 400 kW, the web frames shall generally be fitted at the forward and aft ends of the engine. For combustion engines of 400 to 1500 kW, an additional web frame is to be provided at half length of the engine, and for engines with higher outputs, at least two further web frames are to be provided.

8.1.3 Where combustion engines are fitted aft, stringers spaced 2,6 m apart are to be fitted in the engine room, in alignment with the stringers in the after peak, if any, or else, the main frames are to be adequately strengthened. The scantlings of the stringers shall be similar to those of the web frames. At least one stringer is required where the depth up to the lowest deck is less than 4 m.

8.2 Scantlings

8.2.1 The section modulus of the web frames is not to be less than:

$$W = k \cdot 0{,}8 \cdot e \cdot \ell^2 \cdot p_s \quad [cm^3]$$

e = spacing of web frames, in [m]

ℓ = span, in [m], see Section 3, C.

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

$$J = \mathbf{H}\,(4{,}5\,\mathbf{H} - 3{,}75)\; c \cdot 10^2 \quad [cm^4]$$

where $3\ m \le \mathbf{H} \le 10\ m$

$$J = \mathbf{H}\,(7{,}25\,\mathbf{H} - 31)\; c \cdot 10^2 \quad [cm^4]$$

where $\mathbf{H} > 10\ m$

c = $1 + (\mathbf{H}_u - 4)\,0{,}07$

$\mathbf{H}_u$ = depth measured to the lowest deck, in [m].

The scantlings of the webs are to be calculated as follows:

depth	h	=	$50 \cdot \mathbf{H}$	[mm],
	h	=	250 mm	
thickness	t	=	$h/(32 + 0{,}03\,h)$	[mm]
	t_{min}	=	8,0 mm	

8.2.2 Ships with a depth of less than 3 m are to have web frames with web scantlings not less than 250 x 8 mm and a minimum face sectional area of 12 cm^2.

B. Bottom, Side- and Deck Longitudinals, Side Transverses

1. General

1.1 Longitudinals shall preferably be continuous through floor plates and transverses. Attachments of their webs to the webs of floor plates and transverses shall be such that the reaction forces of support will be transmitted. The permissible shear stress of 100/k [N/mm^2] is not to be exceeded.

Ahead of 0,1 L from F.P. webs of longitudinals are to be connected effectively at both ends. If the flare angle is more than 40° additional heel stiffeners or brackets are to be arranged.

1.2 Where longitudinals abut at transverse bulkheads, brackets are to be passed through the transverse bulkheads. Within the upper and lower hull flange, the sectional area of the bracket at the bulkheads is to be 1,25 times the sectional area of the longitudinal. The length of the weld connecting brackets and longitudinals is to be about twice the depth of the section so that the cross sectional area of the welded joint is at least 1,5 times that of the section. Consideration may be given to equivalent designs.

1.3 Outside the upper and the lower hull flange, the cross sectional areas stipulated in 1.2 may be reduced by 20 percent.

1.4 Where longitudinals are sniped at watertight floors and bulkheads, they are to be attached to the floors by brackets of the thickness of plate floors, and with a length of weld at the longitudinals equal to 2 x depth of the bottom longitudinals. (For longitudinal framing systems in double bottoms, see Section 8, B.7.)

1.5 For buckling strength of longitudinals see Section 3, F.2.3 and 3.

2. Definitions

k = material factor according to Section 2, B.2.

ℓ = unsupported span in [m] according to Section 3, C., see also Fig.9.4

p = load in [kN/m^2]

= p_B according to section 4.B.3. for bottom longitudinals.

= p_s or p_e according to Section 4, B.2.1 for side longitudinals

= p_l according to Section 4, D.1. for longitudinals at ship's sides, at longitudinal bulkheads and inner bottom in way of tanks.

For bottom longitudinals in way of tanks p due to tank pressure need not to be taken larger than

$$p_l - \left(10 \cdot T_{min} - p_0 \cdot c_F\right)[kN/m^2]$$

For side longitudinals p need not to be taken larger than:

$$p_l - \left[\left(10 \cdot T_{min} - z\right) - p_0 \cdot c_F \left(1 + \frac{z}{T_{min}}\right)\right] \quad [kN/m^2]$$

= p_d according to Section 4, D.2. for longitudinals at ship's sides, at deck and at longitudinal bulkheads in tanks intended to be partially filled.

= p_D according to Section 4, B.1. for deck longitudinals of the strength deck

= p_{DA} according to Section 4, B.5. for exposed decks which are not to be treated as strength deck

= p_i according to Section 4, C.2. for inner bottom longitudinals, however, not less than the load corresponding to the distance between inner bottom and deepest load waterline

= p_L according to Section 4, C.1. for longitudinals of cargo decks and for inner bottom longitudinals

T_{min} = smallest ballast draught

σ_{LD} = maximum normal stress σ_L due to longitudinal hull girder bending in [N/mm²] in the strength deck level at side

σ_{LB} = maximum normal stress σ_L due to longitudinal hull girder bending in [N/mm²] in the bottom

σ_L see Section 5, E.4.

Where σ_{LD} and σ_{LB} are not known the following values may be taken:

σ_{LD} = σ_{Lmax}

σ_{LB} = $0{,}8\ \sigma_{Lmax}$

z = distance of structure in [m] above base line.

3. Scantlings of longitudinals and longitudinal beams

3.1 The section modulus of longitudinals and longitudinal beams of the strength deck is not to be less than:

$$W_l = c \cdot m \cdot a \cdot \ell^2 \cdot p \quad [\mathrm{cm}^3]$$

$$A_l = (1 - 0{,}817 \cdot m_a)\, 0{,}05 \cdot a \cdot \ell \cdot p \cdot k \quad [\mathrm{cm}^2],$$

The factor m is to be determined for 0,4 L amidships as follows:

$$c = \frac{83{,}3}{\sigma_{pr}}$$

$$m = \left(m_K^2 - m_a^2\right)$$

$$m_K = 1 - \Sigma\left[\frac{\ell_K}{\ell}\sin^2\alpha_K\right]$$

ℓ_K = in [m] acc. to Fig 9.4

α_K = according to Fig. 9.4 in [°]

m_a = see A.1.2

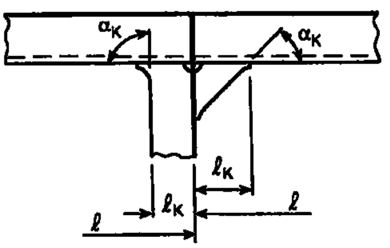


Fig. 9.4

The permissible stress σ_{pr} is to be determined according to the following formulae.

Below the neutral axis of the respective cross section:

$$\sigma_{pr} = \sigma_{perm} - \sigma_{LB} + z\,\frac{\sigma_{LB} + \sigma_{LD}}{H} \quad [\mathrm{N/mm}^2]$$

Above the neutral axis of the respective cross section:

$$\sigma_{pr} = \sigma_{perm} + \sigma_{LB} - z\,\frac{\sigma_{LB} + \sigma_{LD}}{H} \quad [\mathrm{N/mm}^2]$$

$$\sigma_{pr\,max} = \frac{150}{k} \quad [\mathrm{N/mm}^2]$$

$$\sigma_{perm} = \left(0{,}8 + \frac{L}{450}\right)\frac{230}{k} \quad [\mathrm{N/mm}^2]$$

$$\sigma_{perm\,max} = \frac{230}{k} \quad [\mathrm{N/mm}^2]$$

Where σ_{LD} and σ_{LB} are not known the following values may be taken:

$\sigma_{LD} = \sigma_{Lmax}$

$\sigma_{LB} = 0{,}8 \times \sigma_{Lmax}$.

For calculation σ_{pr} the absolute stress values are to be taken for σ_{LB} and σ_{LD}.

3.2 In tanks, the section modulus is not to be less than W_2 according to Section 12, B.3.1.

3.3 For determining the section modulus of longitudinals located adjacent to a bilge strake which is not stiffened longitudinally, the width

$$\frac{r}{3} + \frac{a}{2}$$

is to be inserted, in lieu of **a**, into the formula as per 3.1 (see Fig. 9.5).

For safety against tripping, the spacing of transverses is to be less than 12 x width of the longitudinal face. Otherwise, an additional bracket is to be fitted at half transverses' spacing.

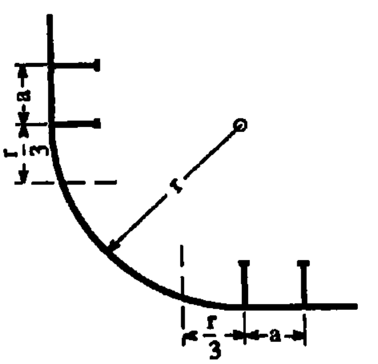


Fig. 9.5

3.4 Where the scantlings of longitudinals are determined by strength calculations, the total equivalent stress comprising local bending and shear stresses and normal stresses due to longitudinal hull girder bending is not to exceed the total stress value σ_t as defined in 3.1.

3.5 For a fatigue strength analysis as per Section 20, additional stresses due to the use of non-symmetrical sections are to be considered which may be determined by the procedure outlined in Section 3, 1,.

3.6 Where necessary, for longitudinals between transverse bulkheads and side transverses additional stresses resulting from the deformation of the side transverses are to be taken into account.

3.7 Where struts are fitted between bottom and inner bottom longitudinals, see Section 8, B.7.2.

3.8 For scantlings of side longitudinals in way of those areas which are to be strengthened against loads due to harbour and tug manoeuvres see Section 6, C.4.

3.9 In the fore body where the flare angle α is more than 40° and in the aft body where the flare angle α is more than 75° the unsupported span of the longitudinals located between $T_{min} - c_o$ and $T + c_o$ must not be larger than 2,6 m; c_o see Section 4, A.2. Otherwise tripping brackets according to A.5.5 are to be arranged.

4. Side transverses

4.1 The section modulus of side transverses supporting side longitudinals is not to be less than:

$$W = 0{,}6 \cdot e \cdot \ell^2 \cdot p \cdot k \ [cm^3]$$

Minimum cross sectional area of the web:

$$A_w = 0{,}06 \cdot e \cdot \ell \cdot p \cdot k \ [cm^2]$$

4.2 Where the side transverses are designed on the basis of strength calculations the following stresses are not to be exceeded:

σ_b = 150/k [N/mm²]

τ = 80/k [N/mm²]

$\sigma_v = \sqrt{\sigma_b^2 + 3\,\tau^2} \leq 180/k$ [N/mm²]

Side transverses and their supports (e. g. decks) are to be checked according to Section 3, F. with regard to their buckling strength.

Note:

The web thickness can be dimensioned depending on the size of the unstiffened web field as follows:

$$t = \frac{f \cdot b}{1 + \frac{b^2}{a^2}} \sqrt{\frac{200}{k}\left(2 + \frac{b^2}{a^2}\right)}$$

a, b = length of side of the unstiffened web plate field, $a \geq b$

f = 0,75 in general

f = 0,9 in the aft body with extreme flare and in the fore body with flare angles α are less or equal 40°

f = 1,0 in the fore body where flare angles α are greater than α > 40°

In the fore body where flare angles α are larger than 40° the web in way of the deck beam has to be stiffened.

4.3 In tanks, the section modulus and the cross sectional area are not to be less than W_2 and A_{w2} according to Section 12, B.3.

4.4 The webs of side transverses in those areas, where concentrated loads due to ship manoeuvres at terminals may be expected, are to be examined for sufficient buckling strength according to Section 3, F. The force induced by a fender into the web frame may approximately be determined by the following formula:

$$P_f = \frac{D \cdot v^2}{2 \cdot f} \quad [kN]$$

D = displacement of the ship in [t]

D_{max} = 100.000 t

f = displacement of fender and/or pile in [m], guidance values for f are given in Table 9.2

v = manoeuvring speed of the ship in [m/s], guidance values are given in Table 9.2.

Table 9.2

D[t]	f [m]	v [m/s]
≤1000	0,25	0,20
>1000 ≤10000	$0{,}22 + 2{,}8 \cdot D \cdot 10^{-5}$	$0{,}21 - 1{,}1 \cdot D \cdot 10^{-5}$
>10000	0,50	0,10

4.5 The compressive stress in the web of the transverse due to the action of the force P_f may be determined by the following formula:

$$\sigma_D = \frac{P_f \cdot 10^3}{c \cdot t_s} \ [N/mm^2]$$

c = vertical length of application of the force P_f, if c is not known, c = 300 mm may be used as a guidance value

t_s = web thickness in [mm].

Section 10

Deck Beams and Supporting Deck Structures

A. Definitions

ℓ = unsupported span in [m] according to Section 3, B.

e = width of deck supported in [m]

p = deck load p_D and p_{DA} in [kN/m^2], according to Section 4, B.

B. Deck Beams and Girders

1. Deck beams and deck longitudinals

The section modulus of transverse deck beams and of deck longitudinals is not to be less than:

$$W = k \cdot a \cdot p \cdot \ell^2 \quad [cm^3]$$

2. Attachment

2.1 Transverse deck beams are to be connected to the frames by brackets according to Section 3, C.2.

2.2 Deck beams running continuously above longitudinal walls and girders may be attached by welding to the stiffeners of longitudinal walls and the webs of girders respectively without knees.

2.3 The deck beams may be connected to hatchway coamings and girders by double fillet welds where there is no constraint. The length of weld is not to be less than 0,6 × depth of the section.

3. Girders and transverses

3.1 The section modulus is not to be less than:

$$W = k \cdot e \cdot p \cdot \ell^2 \quad [cm^2]$$

3.2 At the supports the web sectional area is not to be less than:

$$f_{web} = k \cdot 0{,}05 \cdot p \cdot e \cdot \ell \quad [cm^2]$$

3.3 The depth of the girders is not to be less than 1/25 of the unsupported span. The web depth of girders scalloped for continuous deck beams is to be at least 1,5 times the depth of the deck beams. Scantlings of girders of tank decks are to be determined according to Section 12, B.3.

3.4 Where a girder does not have the same section modulus throughout all girder fields, the larger scantlings are to be maintained above the supports and are to be reduced gradually to the smaller scantlings.

3.5 The end attachments of the girders at the bulkheads are to be so dimensioned that the bending moments and shear forces can be transferred. The bulkhead stiffeners under the girders are to be sufficiently dimensioned to support the girders.

3.6 Tripping brackets are to be fitted on girders and transverses at spacings of about 2,5 m.

4. Supporting structure of winches, windlasses and chain stoppers

4.1 For the supporting structure under windlasses and chain stoppers, the following permissible stresses are to be observed:

$$\sigma_b = \frac{150}{k} \quad [N/mm^2]$$

$$\tau = \frac{100}{k} \quad [N/mm^2]$$

$$\sigma_v = \sqrt{\sigma_b^2 + 3\tau^2} = \frac{180}{k} \quad [N/mm^2]$$

4.2 The acting forces are to be calculated for 80 % and 45 % respectively of the rated breaking load of the chain cable, i.e.:

for chain stoppers	80 %
for windlasses	80 % where chain stoppers are not fitted
	45 % where chain stoppers are fitted.

See also Rules for Machinery Installations Volume III, Section 14.

C. Pillars

1. General

1.1 Structural members at the heads and heels of pillars as well as the substructures are to be constructed according to the forces they are subjected to. At the head and the heel of tubular pillars, plates are generally to be arranged. The connection is to be so dimensioned that at least 1 cm^2 cross sectional area is available for 10 kN of load.

1.2 Pillars in tanks are to be checked for tension. Tubular pillars are not to be fitted in tanks for flammable liquids.

2. Scantlings

The sectional area of pillars is not to be less than:

$A_{s\,req}$ = $10 \cdot P_s/\sigma_p$ [cm²]

σ_p = permissible compressive stress according to Table 10.1.

P_s = pillar load

P_s = $P \cdot A + P_i$ [kN]

A = load area for one pillar in [m²]

P_i = load from pillars located above the pillar considered in [kN]

λ_s = degree of slenderness of the pillar

$$\lambda_s = \frac{\ell_s}{i_s}$$

ℓ_s = length of the pillar in [cm]

i_s = radius of gyration of the pillar

$$i_s = \sqrt{\frac{I_s}{A_s}} \text{ [cm]}$$

I_s = moment of inertia of the pillar in [cm⁴]

A_s = sectional area of the pillar in [cm²]

i_s = $0{,}25\, d_s$ for solid pillars of circular cross section

i_s = $0{,}25 \sqrt{d_a^2 + d_i^2}$ for tubular pillars

d_s = pillar diameter in [cm]

d_a = outside diameter of pillar in [cm]

d_i = inside diameter of pillar in [cm].

Table 10.1.

Degree of slenderness λ_s	Permissible compressive stress σ_p [N/mm²] for	
	pillars within accommodation	elsewhere
≤ 100	$140 - 0{,}0067 \cdot \lambda_s^2$	$117 - 0{,}0056 \cdot \lambda_s^2$
> 100	$7{,}3 \cdot 10^5/\lambda_s^2$	$6{,}1 \cdot 10^5/\lambda_s^2$

D. Cantilevers

1. General

1.1 In order to withstand the bending moment arising from the load P, cantilevers for supporting girders, hatchway coamings, engine casings and unsupported parts of decks are to be connected to transverses, web frames, reinforced main frames, or walls.

1.2 When determining the scantlings of the cantilevers and the aforementioned structural elements, it is to be taken into consideration that the cantilever bending moment depends on the load capacity of the cantilever, the load capacity being dependent on the ratio of rigidity of the cantilever to that of the members supported by it.

1.3 Face plates are to be secured against tilting by tripping brackets fitted to the webs at suitable distances (see also Section 3, H.2.).

1.4 Particulars of calculation, together with drawings of the cantilever construction are to be submitted for approval.

2. Permissible stresses

2.1 When determining the cantilever scantlings, the following permissible stresses are to be observed:

.1 Where single cantilevers are fitted at greater distances:

bending stress:

$$\sigma_b = \frac{125}{k} \quad \text{[N/mm}^2\text{]}.$$

shear stress:

$$\tau = \frac{80}{k} \quad \text{[N/mm}^2\text{]}.$$

.2 Where several cantilevers are fitted at smaller distances (e.g. at every frame):

bending stress:

$$\sigma_b = 150/k \quad \text{[N/mm}^2\text{]}.$$

shear stress:

$$\tau = 80/k \quad \text{[N/mm}^2\text{]}.$$

equivalent stress:

$$\sigma_v = \sqrt{\sigma^2 + 3\tau^2} = 180/k \quad \text{[N/mm}^2\text{]}.$$

.3 The stresses in web frames are not to exceed the values specified in .2 above.

Section 11

Watertight Bulkheads

A. General

1. Watertight subdivision

1.1 All ships are to have a collision bulkhead, a stern tube bulkhead and one watertight bulkhead at each end of the engine room. In ships with machinery aft, the stern tube bulkhead may substitute the aft engine room bulkhead.

1.2 Number and location of transverse bulkheads fitted in addition to those specified in 1.1 are to be so selected as to ensure sufficient transverse strength of the hull.

2. Arrangement of watertight bulkheads

2.1 Collision bulkhead

2.1.1 Ships shall have the collision bulkhead the distance of which from forward perpendicular ℓ as follows :

.1 For $L_c \geq 45$ m

$0{,}05\ L_c \leq \ell \leq 0{,}08\ L_c$

.2 For $L_c < 45$ m

$0{,}05\ L_c \leq \ell \leq 0{,}05\ L_c + 1{,}35$ m

2.1.2 In no case is the distance ℓ to be less than 2,0 m.

2.1.3 In the case of ships having any part of the underwater body extending forward of the forward perpendicular, e.g. a bulbous bow, the required distances specified in 2.1.1 and 2.1.2 are to be measured from a reference point located at a distance x forward of the forward perpendicular which shall be the least of:

$$x = \frac{a}{2}$$

$$x = 0{,}015\ L_c$$

$$x = 3{,}0\ \text{m.}$$

The length L_c and the distance a are to be specified in the approval documents.

2.1.4 The collision bulkhead shall extend watertight up to the freeboard deck. Steps or recesses may be permitted provided 2.1.1, 2.1.2 and 2.1.3 are observed. See Fig. 11.1.

2.1.5 In ships having continuous or long superstructures, the collision bulkhead shall extend to the first deck above the freeboard deck. The extension need not be fitted directly in line with the bulkhead below, provided the requirements of 2.1.1, 2.1.2 and 2.1.3 are fulfilled and the scantlings of the part of the freeboard deck which forms the step or recess are not less than required for a collision bulkhead. Openings with weatherthight closing appliances may be fitted above the freeboard deck in the collision bulkhead and in the aforementioned step and recess.

The number of openings shall be reduced to the minimum compatible with the design and proper working of the ship.

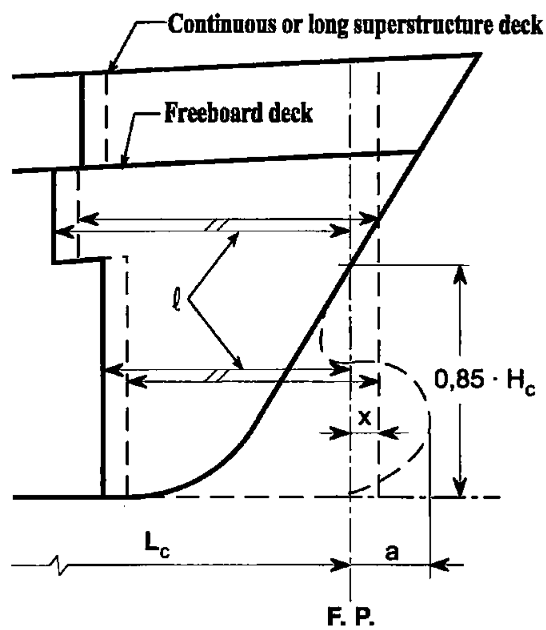


Fig. 11.1

2.1.6 No doors, manholes, access openings, or ventilation ducts are permitted in the collision bulkhead below the freeboard deck and above the double bottom.

Where pipes are piercing the collision bulkhead below the freeboard deck, screwdown valves are to be fitted directly at the collision bulkhead. Where such valves are fitted within the forepeak they are to be operable from above the freeboard deck.

Where a readily accessible space which is not a hold space is located directly adjacent to the forepeak (e.g. a bow-thruster space), the screwdown valves may be fitted within this space directly at the collision bulkhead and need not be operable from a remote position.

2.2 Stern tube bulkhead

All ships are to have a stern tube bulkhead which is, in general, to be so arranged that the stern tube and the rudder trunk are enclosed in a watertight compartment. The stern tube bulkhead should extend to the freeboard deck or to a watertight platform situated above the load waterline.

2.3 Remaining watertight bulkheads

2.3.1 The remaining watertight bulkheads are, in general, depending on the ship type, to extend to the freeboard deck. Wherever practicable, they shall be situated in one frame plane, otherwise those portions of decks situated between parts of transverse bulkheads are to be watertight. B.2.4 and B.3.2 is to be observed.

3. Openings in watertight bulkheads

3.1 General

3.1.1 Type and arrangement of doors are to be submitted for approval.

3.1.2 Regarding openings in the collision bulkhead see 2.1.5 and 2.1.6.

3.1.3 In the other watertight bulkheads, watertight doors may be fitted. Below the deepest load waterline, they are to be constructed as sliding doors, above that waterline, hinged doors may be approved.

3.1.4 Deviating from 3.1.3 on ships for which proof of floatability in damaged condition is to be provided, hinged doors are permitted above the most unfavourable damage waterline for the respective compartment only.

3.1.5 In the stern tube bulkhead hinged doors extending below the deepest load waterline may be approved in special cases upon application. This applies to doors of accommodation and service spaces only.

3.1.6 Watertight doors are to be sufficiently strong and of an approved design. The thickness of plating is not to be less than the minimum thickness according to B.2.

3.1.7 Openings for watertight doors in the bulkheads are to be effectively framed such as to facilitate proper fitting of the doors and to guarantee perfect watertightness.

3.1.8 Before being fitted, the watertight bulkhead doors, together with their frames, are to be tested by a head of water corresponding to the bulkhead deck height. After having been fitted, the doors are to be hose- or soap-tested for tightness and to be subjected to an operational test.

3.2 Hinged doors

Hinged doors are to be provided with rubber sealings and toggles or other approved closing appliances which guarantee a sufficient sealing pressure. The toggles and closing appliances are to be operable from both sides of the bulkhead. Hinges are to have oblong holes. Bolts and bearings are to be of corrosion resistant material. A warning notice requiring the doors to be kept closed at sea is to be fitted at the doors.

3.3 Sliding doors

Sliding doors are to be carefully fitted and are to be properly guided in all positions. Heat sensitive materials are not to be used in systems which penetrate watertight subdivision bulkheads, where deterioration of such systems in the event of fire would impair the watertight integrity of the bulkheads.

The closing mechanism is to be safely operable from each side of the bulkhead and from above the freeboard deck. If closing of the door cannot be observed with certainty, an indicator is to be fitted which shows, if the door is closed or open; the indicator is to be installed at the position from which the closing mechanism is operated.

3.4 Penetrations through watertight bulkheads

Where bulkhead fittings are penetrating watertight bulkheads, care is to be taken to maintain watertightness. For penetrations through the collision bulkhead, 2.1.6 is to be observed.

B. Scantlings

1. General, Definitions

1.1 Where holds are intended to be filled with ballast water, their bulkheads are to comply with the requirements of Section 12.

1.2 Bulkheads of holds intended to be used for carrying ore are to comply with the requirements of Section 23., as far as their strength is concerned.

1.3 Definitions

t_K = corrosion addition according to Section 3, K.

a = spacing of stiffeners in [m]

ℓ = unsupported span in [m], according to Section 3, C.

p = 9,81 h [kN/m²]

h = distance from the load centre of the structure to a point 1 m above the bulkhead deck at the ship's side, for the collision bulkhead to a point 1 m above the upper edge of the collision bulkhead at the ship's side.

c_p, c_s = coefficients according to Table 11.1

$f = \frac{235}{R_{eH}}$

R_{eH} = minimum nominal upper yield point in [N/mm²] according to Section 2, B.2.

Table 11.1

Coefficient c_p and c_s		Collision bulkhead	Other bulkheads
Plating	c_p	$1{,}1\ \sqrt{f}$	$0{,}9\ \sqrt{f}$
Stiffeners, corrugated bulkhead elements	c_s : in case of constraint of both ends	$0{,}33 \cdot f$	$0{,}265 \cdot f$
	c_s : in case of simple support of one end and constraint at the other end	$0{,}45 \cdot f$	$0{,}36 \cdot f$
	c_s : both ends simply supported	$0{,}66 \cdot f$	$0{,}53 \cdot f$
For the definition of "constraint" and "simply supported",see Section 3, D.1. For the definition of "load centre" see Section 4, A.2.			

2. Bulkhead plating

2.1 The thickness of the bulkhead plating is not to be less than:

$$t = c_p \cdot a\ \sqrt{p} + t_K \quad \text{[mm]}$$

$$t_{min} = 6{,}0\ \sqrt{f} \quad \text{[mm]}$$

2.2 In small ships, the thickness of the bulkhead plating need not exceed the thickness of the shell plating for a frame spacing corresponding to the stiffener spacing.

2.3 The stern tube bulkhead is to be provided with a strengthened plate in way of the stern tube.

2.4 In horizontal parts of bulkheads, as additional corrosion allowance, the plating is to be 1 mm thicker than required by 2.1 according to a pressure head measured to the horizontal part of the bulkhead.

3. Stiffeners

3.1 The section modulus of bulkhead stiffeners is not to be less than:

$$W = c_s \cdot a \cdot \ell^2 \cdot p \quad \text{[cm}^3\text{]}$$

3.2 In horizontal part of bulkheads, the stiffeners are also to comply with the rules for deck beams according to Section 10.

3.3 The scantlings of the brackets are to be determined in dependence of the section modulus of the stiffeners according to Section 3, D.2. If the length of the stiffener is 3,5 m and over, the brackets are to extend to the next beam or the next floor.

3.4 Unbracketed bulkhead stiffeners are to be connected to the decks by welding. The length of weld is to be at least 0,6 x depth of the section.

3.5 If the length of stiffeners between bulkhead deck and the deck below is 3 m and less, no end attachment according to 3.4 is required. In this case the stiffeners are to be extended to about 25 mm from the deck and sniped at the ends.

3.6 Bulkhead stiffeners cut in way of watertight doors are to be supported by carlings or stiffeners.

4. Corrugated bulkheads

4.1 The plate thickness of corrugated bulkheads is not to be less than required according to 2.1. For the spacing a, the greater one of the values b or s in [m] according to 4.3 is to be taken.

4.2 The section modulus of a corrugated bulkhead element is to be determined according to 3.1. For the spacing a, the width of an element e, in [m] according to 4.3 is to be taken. For the end attachment see Section 3, D.4.

4.3 The actual section modulus of a corrugated bulkhead element is to be assessed according to the following formula:

$$W = t \cdot d \left(b + \frac{s}{3}\right) \quad \text{[cm}^3\text{]}$$

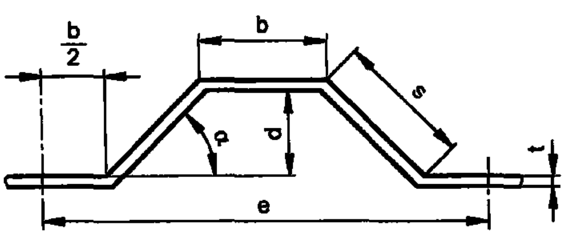


Fig. 11.2

e = width of element in [cm]

b = breadth of face plate in [cm]

s = breadth of web plate in [cm]

d = distance between face plates in [cm]

t = plate thickness in [cm]

$\alpha \geq 45°$.

C. Shaft Tunnels

1. General

1.1 Shaft and stuffing box are to be accessible. Where one or more compartments are situated between stern tube bulkhead and engine room, a watertight shaft tunnel is to be arranged. The size of the shaft tunnel is to be adequate for service and maintenance purposes.

1.2 The access opening between engine room and shaft tunnel is to be closed by a watertight sliding door complying with the requirements according to A.3.3. For extremely short shaft tunnels watertight doors between tunnel and engine room may be dispensed with subject to special approval.

1.3 Tunnel ventilators and the emergency exit are to be constructed watertight up to the freeboard deck.

2. Scantlings

2.1 The plating of the shaft tunnel is to be dimensioned as for a bulkhead according to B.2.1.

2.2 The plating of the round part of tunnel tops may be 10 percent less in thickness.

2.3 In the range of hatches, the plating of the tunnel top is to be strengthened by not less than 2 mm unless protected by a ceiling.

2.4 The section modulus of shaft tunnel stiffeners is to be determined according to B.3.1.

2.5 Horizontal parts of the tunnel are to be treated as horizontal parts of bulkheads and as cargo decks respectively.

2.6 Shaft tunnels in tanks are to comply with the requirements of Section 12.

2.7 The tunnel is to be suitably strengthened under pillars.

D. Portable Fish Hold Divisions

1. General

1.1 Every portable fish hold division is to extend from the bottom of the hold to the deck.

1.2 One longitudinal division is to be fitted where the greatest internal cargo hold breadth is 6 m. If the breadth exceeds 6 m, at least 2 longitudinal divisions are to be fitted, so that the distance between longitudinal divisions or between these and the ships side does not exceed 3 m. Longitudinal divisions are to be positioned symmetrically to the ship's centre line.

1.3 It is assumed that in ships having one longitudinal division, the level of cargo is at any time during loading approximately the same on both sides of the division.

1.4 The requirements of this sub-section are based on the assumption that the portable fish hold divisions consist of vertical uprights with horizontal wooden boards (see Fig. 11.3).

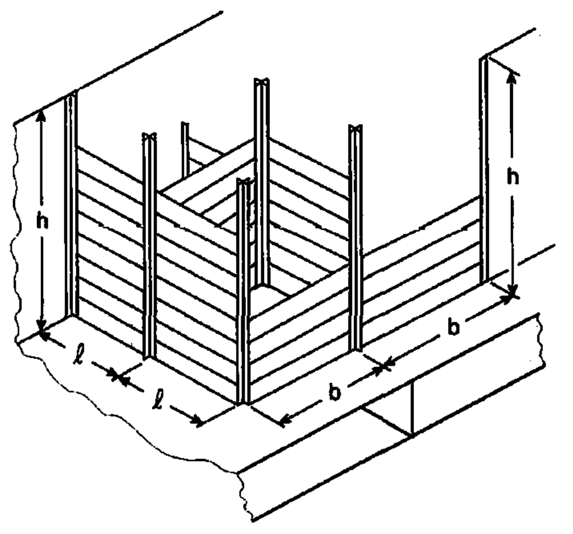


Fig. 11.3

1.5 The longitudinal distance ℓ between uprights or between permanent transverse bulkheads and up-rights should normally not exceed 2,0 m.

1.6 Arrangement and details of the fish hold divisions are to be submitted for approval.

2. Uprights

2.1 The section modulus of steel or aluminium uprights is not to be less than:

$$w = c \cdot h^3 (b + \ell)\, k \quad [\mathrm{cm}^3]$$

c = 1,6 where one longitudinal division is fitted

c = 2,0 where two or more longitudinal divisions are fitted

h = free span of upright in [m]

b = distance between uprights in the ship's transverse direction in [m]

ℓ = distance between uprights in the ship's longitudinal direction in [m]

k = material factor according to Section 2, B.2 or D.1 respectively.

2.2 The minimum section modulus is $40 \cdot k$ [cm^3].

2.3 The uprights are to be secured at top and bottom as to allow transmission of reaction forces to adjacent structures.

2.4 If openings are cut in the uprights for fitting of the upper boards, the boards in the opening are to be locked in position to prevent their slipping out of the guide.

3. Portable wooden boards

3.1 The board thickness is not to be less than the greater of the following:

$$t = 25 \cdot \ell \sqrt{h} \quad [mm]$$

or

$$t = 25 \cdot b \sqrt{h} \quad [mm].$$

3.2 The minimum board thickness is 65 mm.

Section 12

Tank Structures

A. General

1. Subdivision of tanks

1.1 In tanks extending over the full breadth of the ship intended to be used for partial filling, at least one longitudinal bulkhead is to be fitted, which may be a swash bulkhead.

1.2 Where the forepeak is intended to be used as tank, at least one complete or partial longitudinal swash bulkhead is to be fitted, if the tank breadth exceeds 0,5 x **B** or 6 m, whichever is the greater.

When the aft peak is intended to be used as tank, at least one complete or partial longitudinal swash bulk-head is to be fitted. The largest breadth of the liquid surface should not exceed 0,3 **B** in the aft peak.

1.3 Peak tanks exceeding 0,06 **L** or 6 m in length shall be provided with a transverse wash bulkhead.

2. Air, overflow and sounding pipes

Each tank is to be fitted with air pipes, overflow pipes and sounding pipes. The air pipes are to be led to above the exposed deck. The arrangement is to be such as to allow complete filling of the tanks. The height from upper surface of deck to their openings is to be at least 760 mm on the freeboard deck and 450 mm on a superstructure deck. See also Section 21, D.

The sounding pipes are to be led to the bottom of the tanks. (See also Section 6, F.1.4.)

3. Fore peak tank

The fore peak shall not be used for carrying fuel oil. Exemption from this requirement may be considered, in special cases.

4. General requirements

4.1 Where a tank bulkhead forms part of a watertight bulkhead, its strength is not to be less than required by Section 11.

For pumping and piping, see also Rules for Machinery Installations, Volume III, Section 11.

4.2 For testing of tanks, see F.

4.3 For fuel oil tanks see also Rules for Machinery Installations, Volume III, Section 10.

4.4 The openings in fuel oil tanks with oiltight covers necessary for surveying and cleaning purposes are to be arranged at the tank top or in the upper part of tank bulkheads. If any opening is required in the lower part of a tank bulkhead, it shall not be larger than a manhole.

5. Separation of fuel oil tanks from tanks for other liquids

5.1 Fuel oil tanks are to be separated from tanks for lubricating oil, hydraulic oil, thermal oil, vegetable oil, feedwater, condensate water and potable water by cofferdams [1].

5.2 Upon special approval on small ships the arrangement of cofferdams between fuel oil and lubricating oil tanks may be dispensed with provided that:

.1 the common boundary is continuous, i.e. it does not abutt at the adjacent tank boundaries, see Fig. 12.1;

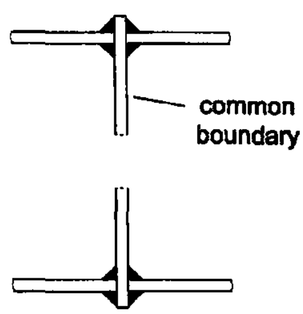


Fig. 12.1

where the common boundary cannot be constructed continuously according to Fig. 12.1, the fillet welds on both sides of the common boundary are to be welded in two layers and the throat thickness is not to be less than 0,5 · t (t = plate thickness);

.2 stiffeners or pipes do not penetrate the common boundary;

.3 the corrosion allowance t_K for the common boundary is not less than 2,5 mm.

5.3 Fuel oil tanks adjacent to lubricating oil circulation tanks are subject to the provisions of Rules for Machinery Installations, Volume III, Section 10, B.2.1.5 in addition to the requirements stipulated in 5.2 above.

5.4 Fuel oil tanks and lubrication oil tanks adjacent to

---

[1] For Indonesian flag ship, the cofferdams are also required between accommodation spaces and fuel oil tanks.

refrigerated spaces to comply with Rules for the Construction of Refrigerating Installations, Volume VIII.

6. Minimum thickness

The thickness of all tank structures is not to be less than:

$$t_{min} = (5{,}5 + 0{,}02\ L)\sqrt{k} \quad [mm]$$

where L need not be taken greater than 100 m.

B. Scantlings

1. Definitions

a = spacing of stiffeners or load width in [m]

ℓ = unsupported span in [m] according to Section 3, C.

p = load p_1 in [kN/m²] according to Section 4, D.1.1.

p_2 = load in [kN/m²] according to Section 4, D.1.2.

For the terms "constraint" and "simply supported" see Section 3, D.1.

2. Bulkhead plating

2.1 The thickness of the bulkhead plating is not to be less than:

$$t_1 = 1{,}1 \cdot a \cdot \sqrt{p \cdot k} + t_K \quad [mm]$$

$$t_2 = 0{,}9 \cdot a \cdot \sqrt{p_2 \cdot k} + t_K \quad [mm]$$

2.2 The thickness of the shaft tunnel plating in deep tanks is to be determined as for a tank bulkhead, however, it is not to be less than required according to Section 11, C.

3. Stiffeners and girders

3.1 The section modulus of stiffeners and girders constrained at their ends, which are not considered as longitudinal strength members, is not to be less than:

$$W_1 = k \cdot 0{,}55 \cdot a \cdot \ell^2 \cdot p \quad [cm^3]$$

$$W_2 = k \cdot 0{,}44 \cdot a \cdot \ell^2 \cdot p_2 \quad [cm^3]$$

Where one or both ends are simply supported, the section moduli are to be increased by 50 percent.

The cross sectional area of the girder webs is not to be less than:

$$f_1 = k \cdot 0{,}050 \cdot a \cdot \ell \cdot p \quad [cm^2]$$

$$f_2 = k \cdot 0{,}040 \cdot a \cdot \ell \cdot p_2 \quad [cm^2]$$

f_2 is to be increased by 50 percent at the position of constraint for a length of 0,1 ℓ.

3.2 The scantlings of beams and girders of tank decks are also to comply with the requirements of Section 10.

3.3 For frames in tanks, see Section 9, A.3.

3.4 The scantlings of shaft tunnel stiffeners in deep tanks are, however, not to be less than required according to Section 11, C.

3.5 The stiffeners of tank bulkheads are to be attached at their ends by brackets according to Section 3, D.2. The scantlings of the brackets are to be determined according to the section modulus of the stiffeners. Brackets must be fitted where the length of the stiffeners exceeds 2 m.

3.6 The brackets of stiffeners are to extend to the next beam, the next floor, the next frame, or are to be otherwise supported at their ends.

4. Corrugated bulkheads

4.1 The plate thicknesses of corrugated bulkheads as well as the required section moduli of corrugated bulkhead elements are to be determined according to 2. and 3., proceeding analogously to Section 11, B.4.

The plate thickness is not to be less than t min according to A.6. or t_{crit} as follows:

$$t_{crit.} = \frac{b}{823}\sqrt{\sigma_D}\ [mm],$$

if subjected to p_1

$$t_{crit.} = \frac{b}{872}\sqrt{\sigma_D}\ [mm],$$

if subjected to p_2

σ_D = compressive stress in [N/mm²]

b = breadth of face plate strip in [mm].

4.2 For the end attachments Section 3, D.4. is to be observed.

C. Detached Tanks

1. General

1.1 Detached tanks are to be adequately secured because of the ship's motions.

1.2 Detached oil fuel tanks should not be installed in fish holds. Where such an arrangement cannot be avoided, provision is to be made to ensure that the catch cannot be damaged by leakage oil.

1.3 Fittings and pipings on detached tanks are to be protected by battens, and gutterways are to be fitted on the outside of tanks for draining any leakage oil.

2. Scantlings

2.1 The thickness of plating of detached tanks is not to be less than:

$$t = 1{,}1 \cdot a \cdot \sqrt{p} + t_K \text{ [mm]}$$

2.2 The section modulus of stiffeners of detached tanks is not to be less than:

$$W = c \cdot a \cdot \ell^2 \cdot p \quad [cm^3]$$

c = 0,36 if stiffeners are constrained at both ends

c = 0,54 if one or both ends are simply supported

p = load in [kN/m²] corresponding to the head h, measured from the lower edge of plate or from the midpoint of span ℓ to the top of overflow; the height of overflow is not to be taken less than 2,5 m

p = $10 \cdot h$.

D. Potable Water Tanks

1. Potable water tanks shall be separated from such tanks which contain other liquids than potable water, ballast water, distillate or feed water.

2. In no case sanitary arrangements or corresponding piping are to be fitted directly above the potable water tanks.

3. Manholes arranged in the tank top are to have sills.

4. If pipes carrying liquids other than potable water are to be led through potable water tanks, they are to be fitted in a pipe tunnel.

5. Air and overflow pipes of potable water tanks are to be separated from pipes of other tanks.

E. Wash Bulkheads

1. The plate thickness shall, in general, be equal to the minimum thickness according to A.6. Strengthenings may be required for load bearing structural parts.

The free lower edge of a wash bulkhead is to be adequately stiffened..

2. In the peaks, stiffeners are to be fitted at every frame.

F. Testing for Tightness

1. All tanks, are to be tested by a head of water of 2,5 m above top of tank, or to the level of the load water line, if this line is more than 2,5 m above top of tank. The test water head is to be at least in level with the highest point of the overflow or air pipe.

2. The test is in general to be carried out before launching and before any cementing or painting is done. Deviations from this requirement are subject to approval by Head Office. If, after testing, tank walls are pierced for pipes or other purposes, a second test is to be carried out at the Surveyor's request. This test may be carried out at the ship afloat.

3. Fish holds also serving as ballast tanks are to be tested by filling up to the highest point of the overflow pipe.

4. Detached tanks are to be tested to a head of water of 3 m above the tank top, or to a test head of water measured from the tank top to the highest point of overflow pipe or air pipe, whichever is the greater.

G. Membrane Type Tanks for Brines

1. General

1.1 Membrane type tanks for brines are tanks consisting of a liquid tight barrier (membrane) which is supported through insulation by a load bearing tank structure. The load bearing tank is normally formed by the hull structure (bulkheads, decks, shell, inner bottom).

1.2 The load bearing tank structure is to comply with the relevant requirements for decks, shell, inner bottom etc., but must at least have scantlings complying with the requirements stipulated in B.

1.3 Prefabricated membrane tanks are to be dimensioned such that they are capable of being transported without undue overstressing the membrane walls.

1.4 Details of the membrane and the insulation material (preferably, polyurethane foam) are to be submitted for approval.

2. Testing for tightness of the membrane

2.1 Prior to painting the tanks are to be suitably tested for tightness by applying a test pressure (air pressure) of not less than 0,15 bar gauge.

2.2 Hollow spaces between the membrane and the hull are to be tested for tightness as stipulated under 2.1.

2.3 Prior to installation of the membrane, shell, decks, bulkheads etc. are to be hose tested for tightness.

3. Foam material, foam application

3.1 The foam material must have sufficient compressive strength to transmit the liquid pressures from the membrane to the hull.

3.2 The foam application is to be carried out according to manufacturer's instructions.

3.3 It is to be assured that all hollow spaces between hull and membrane are completely filled with foam.

Section 13

Stem and Sternframe Structures

A. Definitions

R_{eH} = minimum nominal upper yield point in [N/mm^2] according to Section 2, B.2.

k = material factor according to Section 2, B.2.1, for cast steel k_r according to Section 14, A.4.2

C_R = rudder force in [N] according to Section 14, B. 1.

B_1 = support force in [N] according to Section 14, C.3.

t_K = corrosion allowance in [mm] according to Section 3, K.1.

B. Stem

1. Bar stem

1.1 The cross sectional area of a bar stem below the load waterline is not to be less than:

$$A_b = 1{,}25\ L\ [cm^2].$$

1.2 Starting from the load waterline, the sectional area of the bar stem may be reduced towards the upper end to 0,75 A_b.

2. Plate stem

2.1 The thickness of welded plate stems is not to be less than:

$$t = (0{,}08\ L + 6)\sqrt{k} \quad [mm]$$

$$t_{max} = 25\sqrt{k} \quad [mm]$$

The extension ℓ of the stem plate from its trailing edge aftwards must not be smaller than:

$$\ell = 50 \cdot \sqrt{L} \quad [mm]$$

Dimensioning of the stiffening has to be done according to Section 9.

2.2 Starting from 600 mm above the load waterline, the thickness may gradually be reduced to 0,8 t.

2.3 Plate stems and bulbous bows are to have diaphragm plates spaced not more than 1 m apart.

2.4 Where the spacing of the diaphragm plates is reduced to 0,5 m the thickness of the plate stem may be reduced by 20 percent.

2.5 The plate thickness of a bulbous bow shall in general not be less than required according to 2.1.

2.6 The plate thickness must not be less than the required thickness according to Section 6.

C. Sternframe

1. General

1.1 Propeller post and rudder post are to be led into the hull in their upper parts and connected to it in a suitable and efficient manner. In way of the rudder post the shell is to be strengthened according to Section 6, F. Due regard is to be paid to the design of the aft body, rudder and propeller well in order to minimize the forces excited by the propeller.

1.2 The following value is recommended for the propeller clearance $d_{0,9}$ related to 0,9 R (see Fig 13.1.1)

$$d_{0,9} \ge 0{,}004 \cdot n \cdot d_p^3 \sqrt{\frac{v_0\left[1 - \sin(0{,}75\gamma)\right]\left(0{,}5 + \frac{z_B}{x_F}\right)}{D}} \quad [m]$$

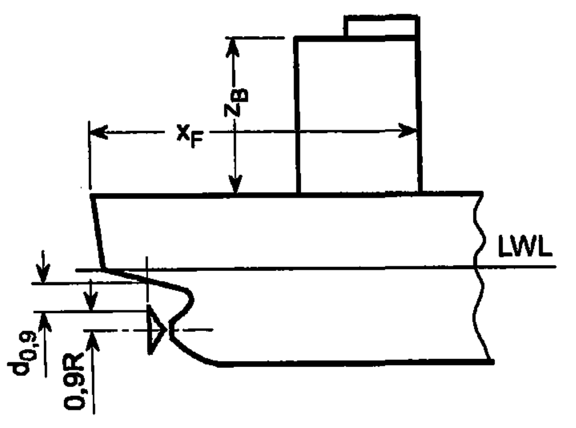


Fig. 13.1.1

R = propeller radius in [m]

v_0 = ship's speed, see Section 1, H.5.in [knot]

n = number of propeller revolutions per minute

D = maximum displacement of ship in [ton]

d_p = propeller diameter in [m]

γ = skew angle of the propeller in [°], see Fig. 13.1.2

z_B = height of wheelhouse deck above weather deck in [m]

x_F = distance of deckhouse front bulkhead from aft edge of stem in [m], see Fig. 13.1.1

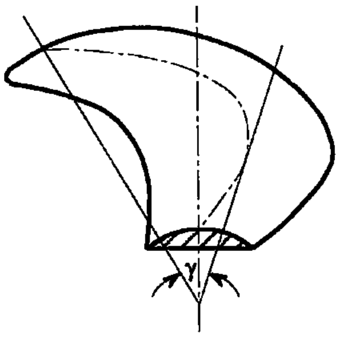


Fig. 13.1.2

1.3 For single screw ships, the lower part of the stern frame is to be extended forward by at least 3 times the frame spacing from fore edge of the boss, for all other ships by 2 times the frame spacing from after edge of the stern frame (rudder post).

1.4 The stern tube is to be surrounded by the floor plates or, when the ship's shape is too narrow to be stiffened by internal rings. Where no sole piece is fitted, the internal rings may be dispensed with.

1.5 The plate thickness of sterns of welded construction for twin screw vessels shall not be less than:

$$t = (0{,}07\,L + 5{,}0)\,\sqrt{k} \quad [\text{mm}]$$

$$t_{max} = 22\,\sqrt{k} \quad [\text{mm}]$$

2. Propeller post

2.1 The scantlings of rectangular, solid propeller posts are to be determined according to the following formulae:

$$\ell = 1{,}54\,L + 100 \quad [\text{mm}]$$

$$b = 1{,}76\,L + 16{,}5 \quad [\text{mm}]$$

Where other sections than rectangular ones are used, their section modulus is not to be less than that resulting from ℓ and b.

2.2 The scantlings of propeller posts of welded construction are to be determined according to the following formulae:

$$\ell = 50\,\sqrt{L} \quad [\text{mm}]$$

$$b = 36\,\sqrt{L} \quad [\text{mm}]$$

$$t = 2{,}9\,\sqrt{L \cdot k} \quad [\text{mm}]$$

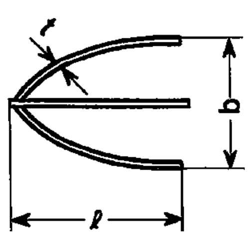


Fig. 13.2

2.3 Where the cross sectional configuration is deviating from Fig. 13.2 and for cast steel propeller posts the section modulus of the cross section related to the longitudinal axis is not to be less than:

$$W_x = 1{,}2 \cdot L^{1,5} \cdot k \quad [\text{cm}^3]$$

2.4 The wall thickness of the boss in the propeller post in its finished condition is to be at least 60 per cent of the breadth b of the propeller post according to 2.1.

3. Rudder post and rudder axle

3.1 The section modulus of the rudder post related to the longitudinal axis of the ship is not to be less than:

$$W = C_R \cdot \ell \cdot k \cdot 10^{-3} \quad [\text{cm}^3]$$

ℓ = unsupported span of the rudder post in [m].

Strength calculations for the rudder post, taking into account the flexibility of the sole piece, may be required where due to its low rigidity in y-direction the sole piece cannot be regarded as an efficient support for the rudder post and, therefore, additional bending stresses may arise at the upper point of constraint. The bending stress σ_b is not to exceed 85 N/mm^2.

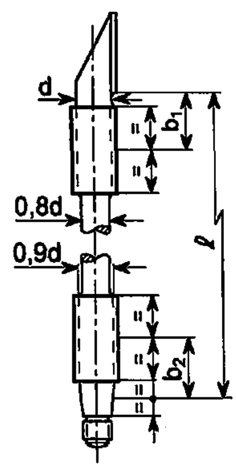


Fig. 13.3

3.2 The diameter of a rudder axle of a balanced rudder is not to be less than:

$$d = 4{,}2\,\sqrt[3]{\frac{C_R \cdot b\,(\ell - b)\,k}{\ell}} \quad [\text{mm}]$$

ℓ = length of rudder axle in [m], see Fig. 13.3

$$b = \frac{b_1 + b_2}{2} \quad [\text{m}]$$

b_1, b_2 see Fig. 13.3.

Regarding strength calculations for the rudder axle, respective remarks under 3.1 are to be observed.

4. Sole piece

4.1 The angle α between sole piece and base line should be greater than the maximum expected aft trim as to avoid damage of the sole piece in case of grounding.

4.2 The section modulus of the sole piece related to the z-axis is not to be less than:

$$W_z = \frac{B_l \cdot x \cdot k}{80} \quad [cm^3]$$

For rudders with two supports the support force without considering the elasticity of the sole piece is $B_l = C_R/2$.

B_l, k see A.

x = distance of the respective cross section from the rudder axis in [m] which is not to be taken less than $\ell_{50}/2$.

x_{min} = $0{,}5 \cdot \ell_{50}$

x_{max} = ℓ_{50}; for ℓ_{50} see Section 14, C.3.2.

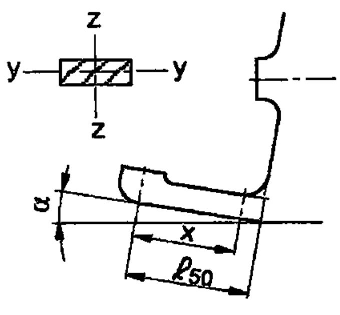


Fig. 13.4

4.3 The section modulus W_z may be reduced by 15 percent where a rudder post according to 3.1 is fitted.

4.4 The section modulus related to the y-axis is not to be less than:

– $W_y = \frac{W_z}{2}$ where no rudder post or rudder axle is fitted:

– $W_y = \frac{W_z}{3}$ where a rudder post or rudder axle is fitted:

4.5 The sectional area at the location $x = \ell_{50}$ is not to be less than:

$$A_s = \frac{B_l}{48} k \quad [mm^2].$$

4.6 The equivalent stress taking into account bending and shear stresses at any location within the length ℓ_{50} is not to exceed:

$$\sigma_v = \sqrt{\sigma_b^2 + 3\tau^2} = \frac{115}{k} \quad [N/mm^2]$$

$$\sigma_b = \frac{B_l \cdot x}{W_z(x)} \quad [N/mm^2]$$

$$\tau = \frac{B_l}{A_s} \quad [N/mm^2]$$

5. Rudder horn of semi spade rudders

5.1 The distribution of the bending moment, shear. force and torsional moment is to be determined according to the following formulae:

– bending moment: $M_b = B_l \cdot z$ [Nm]

$M_{bmax} = B_l \cdot d$ [Nm]

– shear force: $Q = B_l$ [N]

– torsional moment: $M_T = B_l \cdot e_{(z)}$ [Nm].

B_l = support force in the rudder horn as determined according to Section 14, C.3.

For determining preliminary scantlings the flexibility of the rudder horn may be ignored and the supporting force B_l be calculated according to the following formula:

$$B_l = C_R \cdot \frac{b}{c} \quad [N]$$

C_R = rudder force according to Section 14, B.

b, c, d, e(z) and z see Figs. 13.5 and 13.6.

5.2 The section modulus of the rudder horn in transverse direction related to the horizontal x-axis is at any location z not to be less than:

$$W_x = \frac{M_b \cdot k}{67} \quad [cm^3]$$

5.3 At no cross section of the rudder horn the shear stress due to the shear force Q is to exceed the value:

$$\tau = \frac{48}{k} \quad [N/mm^2]$$

The shear stress is to be determined by the following formula:

$$\tau = \frac{B_l}{A_h} \quad [N/mm^2]$$

A_h = effective shear area of the rudder horn in y-direction in $[mm^2]$.

5.4 The equivalent stress at any location (z) of the rudder horn shall not exceed than :

$$\sigma_v = \sqrt{\sigma_b^2 + 3(\tau^2 + \tau_T^2)} = \frac{120}{k} \quad [N/mm^2]$$

$$\sigma_b = \frac{M_b}{W_{(x)}} \quad [N/mm^2]$$

$$\tau_T = \frac{M_T \cdot 10^3}{2 \cdot A_T \cdot t_h} \quad [N/mm^2]$$

A_T = sectional area in [mm^2] surrounded by the rudder horn at the location examined

t_h = thickness of the rudder horn plating in [mm].

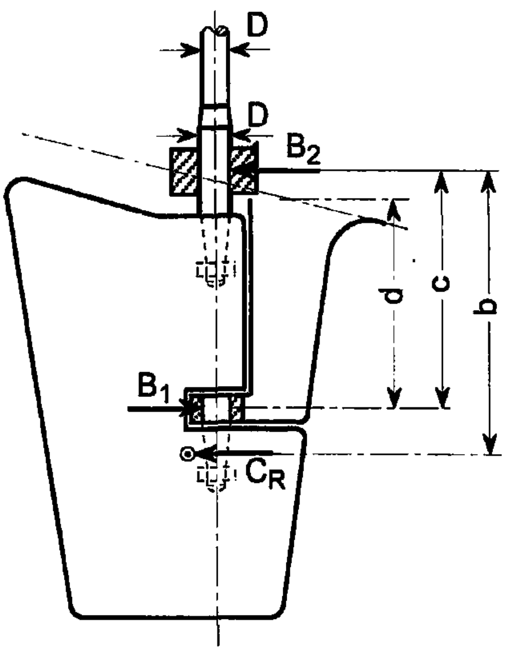


Fig. 13.5

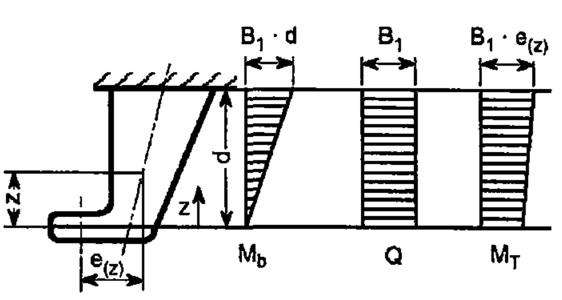


Fig. 13.6

5.5 When determining the thickness of the rudder horn plating the provisions of 5.2 - 5.4 are to be complied with. The thickness is, however, not to be less than:

$$t_{min} = 2{,}4\,\sqrt{L \cdot k} \quad [mm]$$

5.6 The rudder horn plating is to be effectively connected to the aft ship structure, e.g. by connecting the plating to longitudinal girders, in order to achieve a proper transmission of forces, see Fig. 13.7.

5.7 Transverse webs of the rudder horn are to be led into the hull up to the next deck in a sufficient number and must be of adequate thickness.

5.8 Strengthened plate floors are to be fitted in line with the transverse webs in order to achieve a sufficient connection with the hull. The thickness of these plate floors is to be increased by 50 per cent above the Rule values as required by Section 8.

5.9 The centre line bulkhead (wash-plate) in the afterpeak is to be connected to the rudder horn.

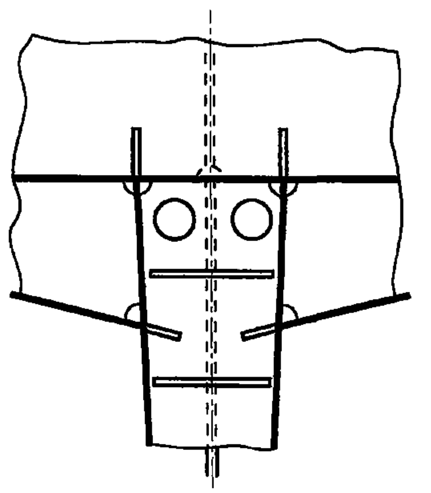


Fig. 13.7

5.10 Where the transition between rudder horn and shell is curved, about 50 % of the required total section modulus of the rudder horn is to be formed by the webs in a Section A - A located in the centre of the transition zone, i.e. 0,7r above the beginning of the transition zone. See Fig. 13.8.

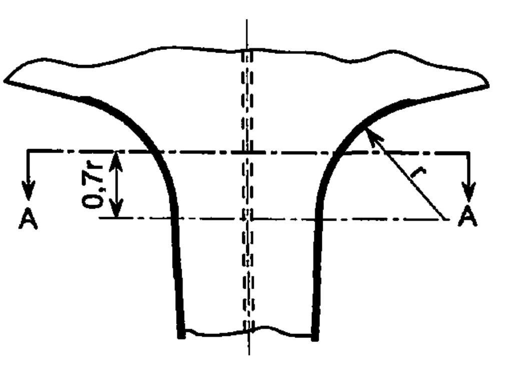


Fig 13.8

D. Propeller Brackets

1. The strut axes should intersect in the axis of the propeller shaft as far as practicable. The struts are to be extended through the shell plating and are to be attached in an efficient manner to the frames and plate floors respectively. The construction in way of the shell is to be

carried out with special care. In case of welded connection, the struts are to have a weld flange or a thickened part or are to be connected with the shell plating in another suitable manner. For- strengthening of the shell in way of struts and shaft bossings, see Section 6, D. The requirements of Section 19, B.4.3 are to be observed.

2. The scantlings of solid struts are to be determined as outlined below depending on shaft diameter d:

thickness	:	0,44 d
cross-sectional area in propeller bracket	:	$0{,}44\ d^2$
length of boss	:	see Rules for Machinery Installations, Volume III, Section 4, D.5.2.
wall thickness of boss	:	0,35 d.

3. Propeller brackets of welded construction and shaft bossings are to have the same strength as solid ones according to 2.

4. For propeller brackets consisting of one strut only a strength analysis according to E.1.2 and a vibration analysis according to E.2. are to be carried out. Due consideration is to be given to fatigue strength aspects.

E. Elastic Stern Tube

1. Strength analysis

When determining the scantlings of the projecting stern tube in way of the connection with the hull, the following stresses are to be proved:

1.1 Static load:

Bending stresses caused by static weight loads are not to exceed 0,35 R_{eH}.

1.2 Dynamic load:

The pulsating load due to loss of one propeller blade is to be determined assuming that the propeller revolutions are equal to 0,75 times the rated speed. The following permissible stresses are to be observed:

σ_{perm} = 0,40 R_{eH} for R_{eH} = 235 N/mm^2

σ_{perm} = 0,35 R_{eH} for R_{eH} = 355 N/mm^2.

The aforementioned permissible stresses are approximate values. Deviations may be permitted in special cases taking into account fatigue strength aspects.

2. Vibration analysis

The bending natural frequency at rated speed of the system comprising stern tube, propeller shaft and propeller is not to be less than 1,5 times the rated propeller revolutions. However, it is not to exceed 0,66 times the exciting frequency of the propeller (number of propeller blades x rated propeller revolutions) and is not to coincide with service conditions, including the damage condition (loss of one propeller blade).

Section 14

Rudder and Manoeuvring Arrangement

A. General

1. Manoeuvring arrangement

1.1 Each ship is to be provided with a manoeuvring arrangement which will guarantee sufficient manoeuvring capability.

1.2 The manoeuvring arrangement includes all parts necessary for steering the ship from the rudder and steering gear to the steering position necessary for steering the ship.

1.3 Rudder stock, rudder coupling, rudder bearings and the rudder body are dealt with in this Section. The steering gear is to comply with Rules for Machinery Installations, Volume III, Section 14.

1.4 The steering gear compartment shall be readily accessible and, as far as practicable, separated from the machinery space. (See also Chapter II-1, Reg. 29.13 of SOLAS 74.)

Guidance

Concerning the use of non-magnetic material in the wheel house in way of a magnetic compass, the requirements of the National Administration concerned are to be observed.

1.5 For ice-strengthening see Section 15.

2. Structural details

2.1 Effective means are to be provided for sup porting the weight of the rudder body without excessive bearing pressure, e.g. by a rudder carrier attached to the upper part of the rudder stock. The hull structure in way of the rudder carrier is to be suitably strengthened.

2.2 Suitable arrangements are to be provided to prevent the rudder from lifting.

2.3 The rudder stock is to be carried through the hull either enclosed in a watertight trunk, or glands are to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline two separate stuffing boxes are to be provided.

3. Size of rudder area

In order to achieve sufficient manoeuvring capability the size of the movable rudder area A is recommended to be not less than obtained from the following formula:

$$A = c_1 \cdot c_2 \cdot c_3 \cdot c_4 \cdot \frac{1{,}75 \cdot L \cdot T}{100} \; [m^2]$$

c_1 = factor for the ship type:
= 1,0 in general
= 0,9 for bulk carriers and tankers having a displacement of more than 50 000 ton
= 1,7 for tugs and trawlers

c_2 = factor for the rudder type:
= 1,0 in general
= 0,9 for semi-spade rudders
= 0,8 for double rudders (per rudder)
= 0,7 for high lift rudders

c_3 = factor for the rudder profile:
= 1,0 for NACA-profiles and plate rudder
= 0,8 for hollow profiles and mixed profiles

c_4 = factor for the rudder arrangement:
= 1,0 for rudders in the propeller jet
= 1,5 for rudders outside the propeller jet

For semi-spade rudder 50% of the projected area of the rudder horn may be included into the rudder area A.

4. Materials

4.1 For materials for rudder stock, pintles, coupling bolts etc. see Rules for Materials, Volume V. Special material requirements are to be observed for the ice notations **ES3** and **ES4** as well as for the arctic ice notations **Arc 1**-**Arc 4**.

4.2 In general materials having a minimum nominal upper yield point R_{eH} of less than 200 N/mm² and a minimum tensile strength of less than 400 N/mm² or more than 900 N/mm² shall not be used for rudder stocks, pintles, keys and bolts. The requirements of this Section are based on a material's minimum nominal upper yield point R_{eH} of 235 N/mm². If material is used having a R_{eH} differing from 235 N/mm², the material factor k_r is to be determined as follows:

$$k_r = \left(\frac{235}{R_{eH}}\right)^{0,75} \quad \text{for } R_{eH} > 235 \; [N/mm^2]$$

$$k_r = \frac{235}{R_{eH}} \quad \text{for } R_{eH} \le 235 \; [N/mm^2]$$

R_{eH} = minimum nominal upper yield point of material used in [N/mm²].

R_{eH} is not to be taken greater than $0{,}7 \cdot R_m$ or 450 N/mm², whichever is less. R_m = tensile strength of the material used.

4.3 Before significant reductions in rudder stock diameter due to the application of steels with R_{eH} exceeding 235 N/mm^2 are granted, the Society may require the evaluation of the elastic rudder stock deflections. Large deflections should be avoided in order to avoid excessive edge pressures in way of bearings.

4.4 The permissible stresses given in E.1. are applicable for ordinary hull structural steel. When higher tensile steels are used, higher values may be used which will be fixed in each individual case.

5. Definitions

C_R = rudder force in [N]

Q_R = rudder torque in [Nm]

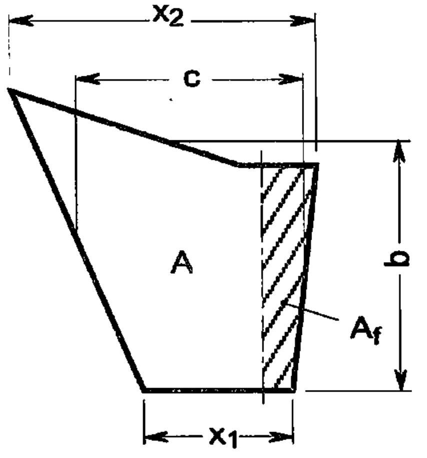
A = total movable area of the rudder in [m^2]
For nozzle rudders, A is not to be taken less than 1,35 times the projected area of the nozzle.

A_t = A + area of a rudder horn, if any, in [m^2]

A_f = portion of rudder area located ahead of the rudder stock axis in [m^2]

b = mean height of rudder area in [m]

c = mean breadth of rudder area in [m] (see Fig. 14.1)



$$c = \frac{x_1 + x_2}{2} \qquad b = \frac{A}{c}$$

Fig. 14.1

Λ = aspect ratio of rudder area A_t

Λ = b^2/A_t

v_0 = ahead speed of ship in [kn] as defined in Section 1, H.5.; if this speed is less than 10 kn, v_0 is to be taken as

$v_{min} = (v_0 + 20)/3$ [kn]

v_a = astern speed of ship in [kn]; if the astern speed $v_a \le 0,4 \cdot v_0$ or 6 kn, whichever is less, determination of rudder force and torque for astern condition is not required. For greater astern speeds special evaluation of rudder force and torque as a function of the rudder angle may be required. If no limitations for the rudder angle at astern condition is stipulated, the factor κ_2 is not to be taken less than given in Table 14.1 for astern condition.

k = material factor according to Section 2, B.2.

B. Rudder Force and Torque

1. Rudder force and torque for normal rudders

1.1 The rudder force is to be determined according to the following formula:

$$C_R = 132 \cdot A \cdot v^2 \cdot \kappa_1 \cdot \kappa_2 \cdot \kappa_3 \cdot \kappa_t \quad [N]$$

v = v_0 for ahead condition

v = v_a for astern condition

κ_1 = coefficient, depending on the aspect ratio Λ

κ_1 = $(\Lambda + 2)/3$, where Λ need not be taken greater than 2

κ_2 = coefficient, depending on the type of the rudder and the rudder profile according to Table 14.1.

Table 14.1

Profile/ type of rudder	κ_2	
	ahead	astern
NACA-00 series Göttingen profiles	1,1	0,8
flat side profiles	1,1	0,9
mixed profiles	1,21	0,9
hollow profiles	1,35	0,9
high lift rudders	1,7	to be specially considered; if not known: 1,7

κ_3 = coefficient, depending on the location of the rudder

κ_3 = 0,8 for rudders outside the propeller jet

κ_3 = 1,15 for rudders aft of the propeller nozzle

κ_3 = 1,0 elsewhere, including also rudders within the propeller jet

κ_t = coefficient depending on the thrust coefficient c_t

κ_t = 1,0 normally

In special cases for thrust coefficients $c_t > 1{,}0$ determination of κ_t according to the following formula may be required:

$$\kappa_t = \frac{C_R\,(c_t)}{C_R\,(c_t = 1{,}0)}$$

1.2 The rudder torque is to be determined by the following formula:

$$Q_R = C_R \cdot r \text{ [Nm]}$$

$r = c\,(\alpha - k_b)$ [m]

α = 0,33 for ahead condition

α = 0,66 for astern condition (general)

α = 0,75 for astern condition (hollow profiles)

For parts of a rudder behind a fixed structure such as a rudder horn:

α = 0,25 for ahead condition

α = 0,55 for astern condition.

For high lift rudders α is to be specially considered. If not known, $\alpha = 0{,}4$ may be used for the ahead condition

k_b = balance factor as follows:

$k_b = A_f/A$

k_b = 0,08 for unbalanced rudders

$r_{min} = 0{,}1 \cdot c$ [m] for ahead condition.

Effects of the provided type of rudder / profile on choice and operation of the steering gear are to be observed.

2. Rudder force and torque for rudder blades with cut-outs (semi-spade rudders)

2.1 The total rudder force C_R is to be calculated according to 1.1. The pressure distribution over the rudder area, upon which the determination of rudder torque and rudder blade strength is to be based, is to be derived as follows:

The rudder area may be divided into two rectangular or trapezoidal parts with areas A_1 and A_2 (see Fig. 14.2).

The resulting force of each part may be taken as:

$$C_{R1} = C_R \frac{A_1}{A} \text{ [N]}$$

$$C_{R2} = C_R \frac{A_2}{A} \text{ [N]}$$

2.2 The resulting torque of each part may be taken as:

$Q_{R1} = C_{R1} \cdot r_1$ [Nm]

$Q_{R2} = C_{R2} \cdot r_2$ [Nm]

$r_1 = c_1\,(\alpha - k_{b1})$ [m]

$r_2 = c_2\,(\alpha - k_{b2})$ [m]

$$k_{b1} = \frac{A_{1f}}{A_1}$$

$$k_{b2} = \frac{A_{2f}}{A_2}$$

A_{1f}, A_{2f} see Fig. 14.2

$c_1 = A_1 / b_1$

$c_2 = A_2 / b_2$

b_1, b_2 = mean heights of the partial rudder areas A_1 and A_2 (see Fig. 14.2).

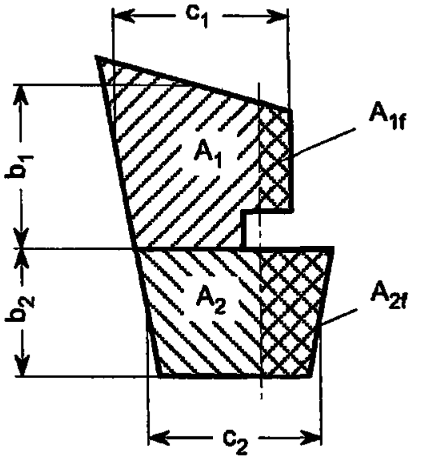


Fig. 14.2

2.3 The total rudder torque is to be determined according to the following formulae:

$Q_R = Q_{R1} + Q_{R2}$ [Nm] or

$Q_{Rmin} = C_R \cdot r_{1,2min}$ [Nm].

$$r_{1,2min} = \frac{0{,}1}{A}\,(c_1 \cdot A_1 + c_2 \cdot A_2) \text{ [m]}$$

for ahead condition

The greater value is to be taken.

C. Scantlings of the Rudder Stock

1. Rudder stock diameter

1.1 The diameter of the rudder stock for transmitting the torsional moment is not to be less than:

$$D_t = 4{,}2\,\sqrt[3]{Q_R \cdot k_r} \text{ [mm]}$$

Q_R see B. 1.2 and B. 2.2 - 2.3.

The related torsional stress is:

$$\tau_t = \frac{68}{k_r} \text{ [N/mm}^2\text{]}$$

k_r see A.4.2.

1.2 The diameter of the rudder stock determined according to 1.1 is decisive for the steering gear, the stoppers and the locking device.

1.3 In case of mechanical steering gear the diameter of the rudder stock in its upper part which is only intended for transmission of the torsional moment from the auxiliary steering gear may be 0,9 D_t. The length of the edge of the quadrangle for the auxiliary tiller must not be less than 0,77 D_t and the height not less than 0,8 D_t.

1.4 The rudder stock is to be secured against axial sliding. The degree of the permissible axial clearance depends on the construction of the steering engine and on the bearing.

2. Strengthening of rudder stock

2.1 If the rudder is so arranged that additional bending stresses occur in the rudder stock, the stock diameter has to be suitably increased. The increased diameter is, where applicable, decisive for the scantlings of the coupling.

For the increased rudder stock diameter the equivalent stress of bending and torsion is not to exceed the following value:

$$\sigma_v = \sqrt{\sigma_b^2 + 3\tau^2} \leq 118/k_r \quad \text{[N/mm}^2\text{]}$$

Bending stress:

$$\sigma_b = \frac{10{,}2 \cdot M_b}{D_1^3} \quad \text{[N/mm}^2\text{]}$$

M_b = bending moment at the neck bearing in [Nm]

Torsional stress:

$$\tau = \frac{5{,}1 \cdot Q_R}{D_1^3} \quad \text{[N/mm}^2\text{]}$$

D_1 = increased rudder stock diameter in [mm]

The increased rudder stock diameter may be determined by the following formula:

$$D_1 = D_t \sqrt[6]{1 + \frac{4}{3}\left[\frac{M_b}{Q_R}\right]^2}$$

Q_R see B.1.2 and B.2.2 - 2.3

D_t see 1.1.

Guidance

Where a double-piston steering gear is fitted, additional bending moments may be transmitted from the steering gear into the rudder stock. These additional bending moments are to be taken into account for determining the rudder stock diameter.

3. Analysis

3.1 General

The evaluation of bending moments, shear forces and support forces for the system rudder - rudder stock may be carried out for some basic rudder types as shown in Figs. 14.3 - 14.5 as outlined below.

3.2 Data for the analysis

ℓ_{10} - ℓ_{50} = lengths of the individual girders of the system in [m]

I_{10} - I_{50} = moments of inertia of these girders in [cm^4]

For rudders supported by a sole piece the length ℓ_{20} is the distance between lower edge of rudder body and centre of sole piece, and I_{20} is the moment of inertia of the pintle in the sole piece.

Load on rudder body (general):

$$p_R = \frac{C_R}{\ell_{10} \cdot 10^3} \quad \text{[kN/m]}$$

Load on semi-spade rudders:

$$p_{R10} = \frac{C_{R2}}{\ell_{10} \cdot 10^3} \text{ [kN/m]}$$

$$p_{R20} = \frac{C_{R1}}{\ell_{20} \cdot 10^3} \quad \text{[kN/m]}$$

C_R, C_{R1}, C_{R2} see B.1. and B.2.

Z = spring constant of support in the sole piece or rudder horn respectively

for the support in the sole piece (Fig. 14.3):

$$Z = \frac{6{,}18 \cdot I_{50}}{\ell_{50}^3} \quad \text{[kN/m]}$$

for the support in the rudder horn (Fig. 14.4):

$$Z = \frac{1}{f_b + f_t} \quad \text{[kN/m]}$$

f_b = unit displacement of rudder horn in [m] due to a unit force of 1 kN acting in the centre of support

f_b = $0{,}21 \dfrac{d^3}{I_n}$ [m/kN] (guidance value)

I_n = moment of inertia of rudder horn around the x-axis at d/2 in [cm^4] (see also Fig. 14.4)

f_t = unit displacement due to torsion

$$f_t = \frac{d \cdot e^2 \cdot \sum u_i / t_i}{3{,}14 \cdot 10^8 \cdot F_T^2} \quad [\text{m/kN}]$$

F_T = mean sectional area of rudder horn in [m^2]

u_i = breadth in [mm] of the individual plates forming the mean horn sectional area

t_i = plate thickness within the individual breadth u_i in [mm]

e, d = distances in [m] according to Fig. 14.4.

3.3 Moments and forces to be evaluated

3.3.1 The bending moment M_R and the shear force Q_l in the rudder body, the bending moment M_b in the neck bearing and the support forces B_l, B_2, B_3 are to be evaluated. The so evaluated moments and forces are to be used for the stress analyses required by 2. and E.1. of this Section and by Section 13, C.4. and C.5.

3.3.2. For spade rudders the moments and forces may be determined by the following formulae:

$$M_b = C_R \left[\ell_{20} + \frac{\ell_{10}\,(2x_1 + x_2)}{3(x_1 + x_2)} \right] \quad [\text{Nm}]$$

$$B_3 = \frac{M_b}{\ell_{30}} \quad [\text{N}]$$

$$B_2 = C_R + B_3 \quad [\text{N}]$$

4. Rudder trunk

Where the rudder stock is arranged in a trunk in such a way that the trunk is stressed by forces due to rudder action, the scantlings of the trunk are to be as such that the equivalent stress due to bending and shear does not exceed 0,35 x R_{eH} of the material used.

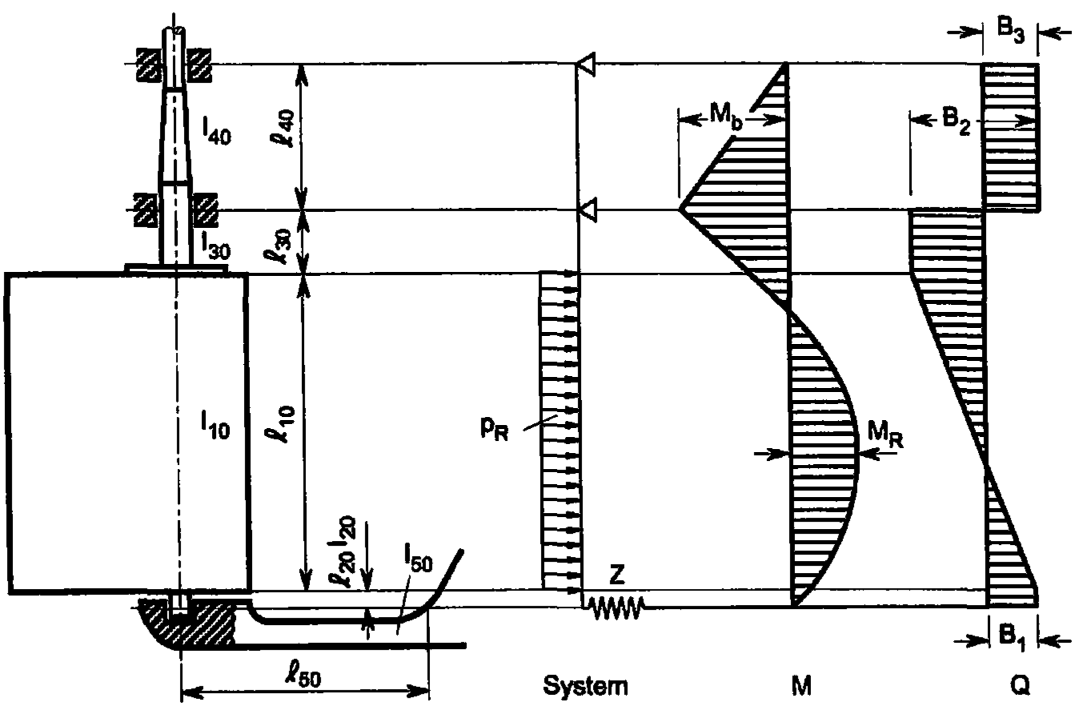


Fig. 14.3 Rudder supported by sole piece

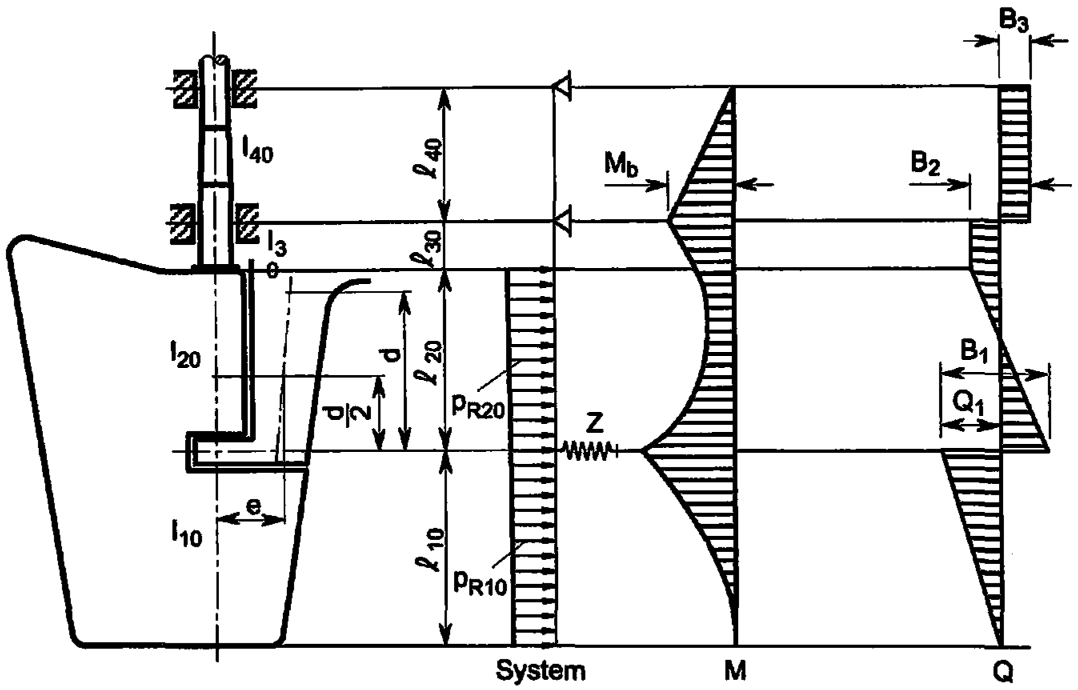


Fig. 14.4 Semi-spade rudder

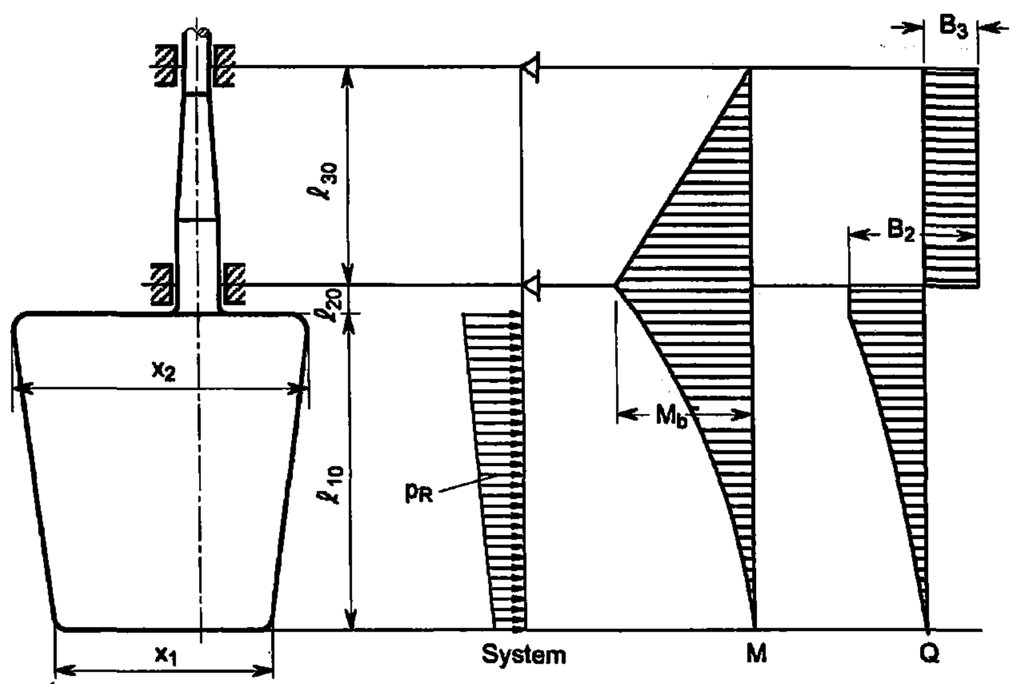


Fig. 14.5 Spade rudder

D. Rudder Couplings

1. General

1.1 The couplings are to be designed in such a way as to enable them to transmit the full torque of the rudder stock.

1.2 The distance of bolt axis from the edges of the flange is not to be less than 1,2 the diameter of the bolt. In horizontal couplings, at least 2 bolts are to be arranged forward of the stock axis.

1.3 The coupling bolts are to be fitted bolts. The bolts and nuts are to be effectively locked, e.g., according to recognized standards.

1.4 For spade rudders horizontal couplings according to 2. are permissible only where the required thickness of the coupling flanges t_f is less than 50 mm, other wise cone couplings according to 4. are to be applied. For spade rudders of the high lift type, only cone couplings according to 4. are permitted.

2. Horizontal couplings

2.1 The diameter of coupling bolts is not to be less than:

$$d_b = 0{,}62 \sqrt{\frac{D^3 \cdot k_b}{k_r \cdot n \cdot e}} \quad [\text{mm}]$$

D = rudder stock diameter according to C. in [mm]

n = total number of bolts, which is not to be less than 6

e = mean distance of the bolt axes from the centre of bolt system in [mm]

k_r = material factor for the rudder stock as given in A.4.2

k_b = material factor for the bolts analogue to A.4.2.

2.2 The thickness of the coupling flanges is not to be less than determined by the following formulae:

$$t_f = 0{,}62 \sqrt{\frac{D^3 \cdot k_f}{k_r \cdot n \cdot e}} \quad [\text{mm}]$$

t_{fmin} = $0{,}9 \cdot d_b$

k_f = material factor for the coupling flanges analogue to A.4.2.

The thickness of the coupling flanges clear of the bolt holes is not to be less than $0{,}65 \cdot t_f$.

The width of material outside the bolt holes is not to be less than $0{,}67 \times d_b$.

2.3 The coupling flanges are to be equipped with a fitted key according to recognized standards for relieving the bolts.

The fitted key may be dispensed with if the diameter of the bolts is increased by 10%.

2.4 Horizontal coupling flanges should be forged together with the rudder stock. If the flanges are welded to the rudder stock, the stock should have a weld flange[1)] with a diameter of 1,1 D (but not less than D + 20 mm) and with a thickness equal to the flange thickness (max. flange thickness + 5 mm).

2.5 For the connection of the coupling flanges with the rudder body see also Section 19, B.4.4.

3. Vertical couplings

3.1 The diameter of the coupling bolts is not to be less than:

$$d_b = \frac{0{,}81 \cdot D}{\sqrt{n}} \sqrt{\frac{k_b}{k_r}} \quad [\text{mm}]$$

D, k_b, k_r, n see 2.1, where n is not to be less than 8.

3.2 The first moment of area of the bolts about the centre of the coupling is not to be less than:

$$S = 0{,}00043\, D^3 \quad [\text{cm}^3].$$

3.3 The thickness of the coupling flanges is not to be less than

$$t_f = d_b \quad [\text{mm}]$$

The width of material outside the bolt holes is not to be less than $0{,}67 \cdot d_b$.

4. Cone couplings

4.1 Cone couplings with key

4.1.1 Cone couplings should have a taper c on diameter of 1: 8 - 1:12.

$$\left(c = \frac{d_0 - d_u}{\ell} \text{ according Fig. 14.6}\right)$$

The cone shape should be very exact. The nut is to be carefully secured, e.g. as shown in Fig. 14.6.

4.1.2 The coupling length ℓ should, in general. not be less than $1{,}5 \times d_0$.

4.1.3 For couplings between stock and rudder a key is to be provided, the shear area of which is not to be less than:

---

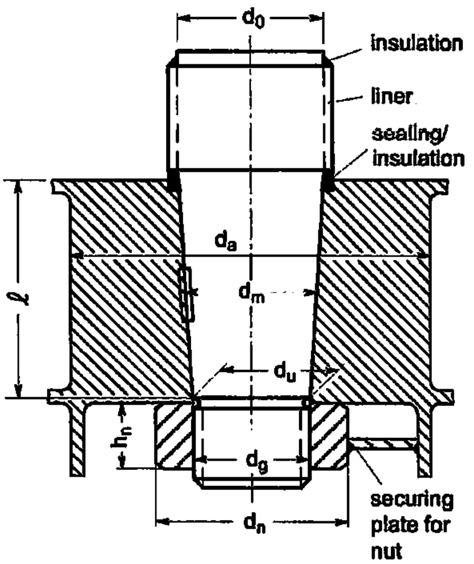
1) In special cases (e.g., for small stock diameter) weld flange may be dispensed with.

$$a_s = \frac{16 \cdot Q_F}{d_k \cdot R_{eH1}} \quad [cm^2]$$

Q_F = design yield moment of rudder stock in [Nm] according to F.

d_k = diameter of the conical part of the rudder stock in [mm] at the key

R_{eH1} = minimum nominal upper yield point of the key material in [N/mm²]



ig. 14.6

4.1.4 The effective surface area of the key (without rounded edges) between key and rudder stock or cone coupling, is not to be less than:

$$a_k = \frac{5 \cdot Q_F}{d_k \cdot R_{eH2}} \quad [cm^2]$$

R_{eH2} = minimum nominal upper yield point of the key, stock or coupling material in [N/mm²], whichever is less.

4.1.5 The dimensions of the slugging nut are to be as follows:

- height:

  $h_n = 0{,}6 \cdot d_g$

- outer diameter (the greater value to be taken):

  $d_n = 1{,}2 \cdot d_u$ or $d_n = 1{,}5 \cdot d_g$

- external thread diameter:

  $d_g = 0{,}65 \cdot d_0$

See Fig. 14.6.

4.1.6 It is to be proved that 50% of the design yield moment will be solely transmitted by friction in the cone couplings. This can be done by calculating the required push-up pressure and push-up length according to 4.2.3 for a torsional moment $Q'_F = 0{,}5 \cdot Q_F$

4.2 Cone couplings with special arrangements for mounting and dismounting the couplings

4.2.1 Where the stock diameter exceeds 200 mm the press fit is recommended to be effected by a hydraulic pressure connection. In such cases the cone should be more slender (c ≈ 1:12 to ≈ 1 : 20).

4.2.2 In case of hydraulic pressure connections the nut is to be effectively secured against the rudder stock or the pintle. A securing plate for securing the nut against the rudder body is to be provided, see Fig. 14.7.

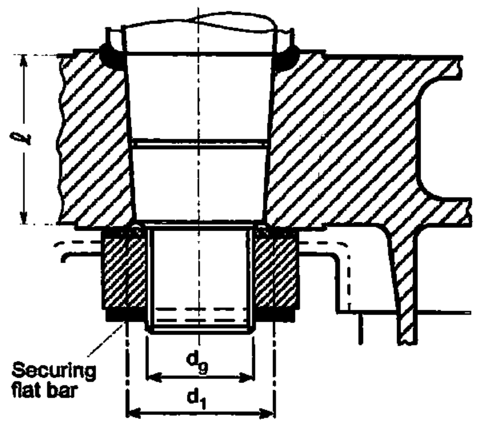


Fig. 14.7

Guidance

A securing flat bar will be regarded as an effective securing device of the nut, if its shear area is not less than:

$$A_s = \frac{P_s \cdot \sqrt{3}}{R_{eH}} \quad [mm^2]$$

P_s = *shear force as follows*

$$P_s = \frac{P_e}{2} \cdot \mu_\ell \left[\frac{d_\ell}{d_g} - 0{,}6\right] [N]$$

P_e = *push-up force according to 4.2.3.2 in [N]*

μ_ℓ = *frictional coefficient between nut and rudder body, normally $\mu_\ell = 0{,}3$*

d_ℓ = *mean diameter of the frictional area between nut and rudder body*

d_g = *thread diameter of the nut*

R_{eH} = *yield point in [N/mm²] of the securing flat bar material.*

4.2.3 For the safe transmission of the torsional moment by the coupling between rudder stock and rudder body the required push-up length and the push-up pressure are to be determined by the following formulae:

.1 required push-up pressure

$$p_{req1} = \frac{2 \cdot Q_F \cdot 10^3}{d_m^2 \cdot \ell \cdot \pi \cdot \mu_0} \quad [N/mm^2]$$

or

$$p_{req2} = \frac{6 \cdot M_b \cdot 10^3}{\ell^2 \cdot d_m} \quad [N/mm^2]$$

Q_F = design yield moment of rudder stock according to F. in [Nm]

d_m = mean cone diameter in [mm]

ℓ = cone length in [mm]

μ_0 = 0,15 (frictional coefficient)

M_b = bending moment in the cone coupling (e.g. case of spade rudders) in [Nm].

The greater of the values p_{req1} or p_{req2} is to be taken.

It has to be proved that the required push-up pressure does not exceed the permissible surface pressure in the cone. The permissible surface pressure is to be determined by the following formula:

$$p_{perm} = \frac{0{,}8 \cdot R_{eH} \left(1 - \alpha^2\right)}{\sqrt{3 + \alpha^4}} \quad [N/mm^2]$$

R_{eH} = yield point in $[N/mm^2]$ of the material of the gudgeon

α = d_m/d_a (see Fig 14.6)

The outer diameter of the gudgeon should not be less than:

d_a = $1{,}5 \cdot d_m$ [mm]

.2 required push-up length

$$\Delta\ell_1 = \frac{p_{req} \cdot d_m}{E \left[\frac{1 - \alpha^2}{2}\right] c} + 0{,}8 \frac{R_{tm}}{c} \quad [mm]$$

R_{tm} = mean roughness in [mm]

$R_{tm} \simeq$ 0,01 mm

c = taper on diameter according to 4.2.1

E = Young's modulus ($2{,}06 \cdot 10^5$ N/mm^2)

A guidance figure for the minimum push-up length is:

$\Delta\ell_{min} = d_m/150$ [mm]

This value is not to be greater than:

$$\Delta\ell_2 = \frac{1{,}6 \cdot R_{eH} \cdot d_m}{\sqrt{3 + \alpha^4}\, E \cdot c} + 0{,}8 \frac{R_{tm}}{c} \quad [mm]$$

Guidance

In case of hydraulic pressure connections the required push-up force P_e for the cone may be determined by the following formula:

$P_e = p_{req} \cdot d_m \cdot \pi \cdot \ell \, (c/2 + 0{,}02)$ *[N]*

Where due to the fitting procedure a partial push-up effect caused by the rudder weight is given, this may be taken into account when fixing the required push-up length, subject to approval by BKI.

4.2.4 The required push-up pressure for pintle bearings is to be determined by the following formula:

$$p_{req} = 0{,}4 \frac{B_1 \cdot d_0}{d_m^2 \cdot \ell} \quad [N/mm^2]$$

B_1 = supporting force in the pintle bearing in [N], see also Fig. 14.4

d_m, ℓ see 4.2.3

d_0 = pintle diameter in [mm] according to Fig. 14.6.

E. Rudder Body, Rudder Bearings

1. Strength of rudder body

1.1 The rudder body is to be stiffened by horizontal and vertical webs in such a manner that the rudder body will be effective as a beam. The rudder should be additionally stiffened at the aft edge.

1.2 The strength of the rudder body is to be proved by direct calculation according to C.3.

1.3 For rudder bodies without cut-outs the permissible stress are limited to:

.1 bending stress due to M_R:

σ_b = 110 $[N/mm^2]$

.2 shear stress due to Q_1:

τ = 50 $[N/mm^2]$

.3 equivalent stress due to bending and shear:

$\sigma_v = \sqrt{\sigma_b^2 + 3\,\tau^2} = 120$ $[N/mm^2]$

M_R, Q_1 see C.3.3.and Fig.14.3 and 14.4.

In case of openings in the rudder plating for access to cone coupling or pintle nut the permissible stresses according to 1.4 apply. Smaller permissible stress values may be required if the corner radii are less than 0,15 · h, where h = height of opening.

1.4 In rudder bodies with cut-outs (semi-spade rudders) the following stress values are not to be exceeded :

.1 bending stress due to M_R :

$$\sigma_b = 90 \quad [\text{N/mm}^2]$$

.2 shear stress due to Q_1 :

$$\tau = 50 \quad [\text{N/mm}^2]$$

.3 torsional stress due to M_t :

$$\tau_t = 50 \quad [\text{N/mm}^2]$$

.4 equivalent stress due to bending and shear and equivalent stress due to bending and torsion:

$$\sigma_{v1} = \sqrt{\sigma_b^2 + 3\,\tau^2} = 120 \quad [\text{N/mm}^2]$$

$$\sigma_{v2} = \sqrt{\sigma_b^2 + 3\,\tau_t^2} = 100 \quad [\text{N/mm}^2]$$

$$M_R = C_{R2} \cdot f_1 + B_1 \frac{f_2}{2} \quad [\text{Nm}]$$

$$Q_1 = C_{R2} \quad [\text{N}]$$

f_1, f_2 see Fig. 14.8.

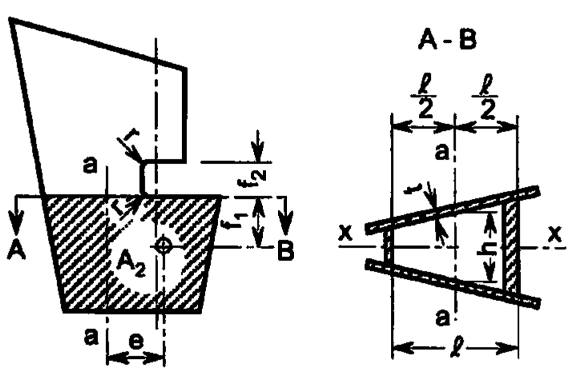


Fig. 14.8

The torsional stress may be calculated in a simplified manner as follows:

$$\tau_t = \frac{M_t}{2 \cdot \ell \cdot h \cdot t} \quad [\text{N/mm}^2]$$

h, ℓ, t, y in [cm], see Fig. 14.8.

The distance ℓ between the vertical webs should not exceed 1,2 · h.

The radii in the rudder plating are not to be less than 4 - 5 times the plate thickness, but in no case less than 50 mm.

M_t = $C_{R2} \cdot e$ [Nm]

C_{R2} = partial rudder force in [N] of the partial rudder area A_2 below the cross section under consideration

e = lever for torsional moment in [m]

(horizontal distance between the centroid of area A_2 and the centre line a-a of the effective cross sectional area under consideration, see Fig. 14.8. The centroid is to be assumed at $0{,}33 \cdot c_2$ aft of the forward edge of area A_2, where c_2 = mean breadth of area A_2)

1.5 It is recommended to keep the natural frequency of the fully immersed rudder at least 10% above the exciting frequency of the propeller (number of revolutions x number of blades).

2. Rudder plating

2.1 Double plate rudders

2.1.1 The thickness of the rudder plating is to be determined according to the following formula:

$$t = 1{,}74 \cdot a \sqrt{p_R \cdot k} + 2{,}5 \quad [\text{mm}]$$

$$p_R = 10 \cdot T + \frac{C_R}{10^3 \cdot A} \quad [\text{kN/m}^2]$$

a = the smaller unsupported width of a plate panel in [m].

The influence of the aspect ratio of the plate panels may be taken into account as given in Section 3, A.3.

The thickness shall, however, not be less than the thickness t_2 of the shell plating at the ends according to Section 6, B.3.

2.1.2 For connecting the side plating of the rudder to the webs tenon welding is not to be used. Where application of fillet welding is not practicable, the side plating is to be connected by means of slot welding to flat bars which are welded to the webs.

2.1.3 The thickness of the webs is not to be less than 70% of the thickness of the rudder plating according to 2.1, but not less than:

$$t_{min} = 8\sqrt{k} \quad [\text{mm}]$$

2.2 Single plate rudders

2.2.1 Main piece diameter

The mainpiece diameter is calculated according to 14.C.1 and 14.C.2 respectively. For spade rudders the lower third may taper down to 0.75 times stock diameter.

2.2.2 Blade thickness

The blade thickness is not to be less than:

$$t_b = 1{,}5 \cdot a \cdot V_o + 2{,}5 \quad [mm]$$

a = spacing of stiffening arms in [m], not to exceed 1 m;

V_o = ahead speed of ship in [kn]

2.2.3 Arms

The thickness of the arms " t_a" is not to be less than the blade thickness according to 2.2.2.

The section modulus is to be determined as follow:

$$W_a = 0{,}5 \cdot a \cdot c_l^2 \cdot V_o^2 \quad [cm^3]$$

c_l = horizontal distance from the aft edge of the rudder to the centreline of the rudder stock,in meters.

3. Transmitting of the rudder torque

3.1 For transmitting the rudder torque, the rudder plating according to 2.1 is to be increased by 25% in way of the coupling. A sufficient number of vertical webs is to be fitted in way of the coupling.

3.2 If the torque is transmitted by a prolonged shaft extended into the rudder, the latter must have the diameter D_t or D_1, whichever is greater, at the upper 10% of the intersection length. Downwards it may be tapered to 0,6 D_t, in spade rudders to 0,4 times the strengthened diameter, if sufficient support is provided for.

4. Rudder bearings

4.1 In way of bearings liners and bushes are to be fitted. Where in case of small ships bushes are not fitted, the rudder stock is to be suitably increased in diameter in way of bearings enabling the stock to be re-machined later.

4.2 An adequate lubrication is to be provided.

4.3 The bearing forces result from the direct calculation mentioned in C.3. As a first approximation the bearing force may be determined without taking account of the elastic supports. This can be done as follows:

.1 normal rudder with two supports:

The rudder force C_R is to be distributed to the supports according to their vertical distances from the centre of gravity of the rudder area.

.2 semi-spade rudders:

support force in the rudder horn:

$B_1 = C_R \cdot b/c$ [N]

support force in the neck bearing:

$B_2 = C_R - B_1$ [N]

For b and c see Fig. 13.5 in Section 13.

4.4 The projected bearing surface A_b (bearing height x external diameter of liner) is not to be less than

$$A_b = \frac{B}{q} \quad [mm^2]$$

B = support force in [N]

q = permissible surface pressure according to Table 14.2

Table 14.2

Bearing material	q [N/mm²]
lignum vitae	2,5
white metal, oil lubricated	4,5
synthetic material[1)]	5,5
steel[2)], bronze and hot-pressed bronze-graphite materials	7,0

1) Synthetic materials to be of approved type.

Surface pressures exceeding 5,5 N/mm² may be accepted in accordance with bearing manufacturer's specification and tests, but in no case more than 10 N/mm².

2) Stainless and wear resistant steel in an approved combination with stock liner. Higher surface pressures than 7 N/mm² may be accepted if verified by tests.

4.5 Stainless and wear resistant steels, bronze and hot-pressed bronze-graphite materials have a considerable difference in potential to non-alloyed steel. Respective preventive measures are required.

4.6 The bearing height shall be equal to the bearing diameter, however, is not to exceed 1,2 times the bearing diameter. Where the bearing depth is less than the bearing diameter, higher specific surface pressures may be allowed.

4.7 The wall thickness of pintle bearings in sole piece and rudder horn shall be approximately ¼ of the pintle diameter.

5. Pintles

5.1 Pintles are to have scantlings complying with the conditions given in 4.4 and 4.6. The pintle diameter is not to be less than:

$$d = 0{,}35 \sqrt{B_1 \cdot k_r} \quad [mm]$$

B_l = support force in [N]

k_r see A.4.2.

5.2 The thickness of any liner or bush shall not be less than:

$t = 0{,}01\sqrt{B_l}$ [mm]

t_{min} = 8 mm for metallic materials and synthetic material

t_{min} = 22 mm for lignum vitae

5.3 Where pintles are of conical shape, they are to comply with the following

taper on diameter 1: 8 to 1: 12 if keyed by slugging nut,

taper on diameter 1: 12 to 1: 20 if mounted with oil injection and hydraulic nut.

5.4 The pintles are to be arranged in such a manner as to prevent unintentional loosening and falling out.

For nuts and threads the requirements of D.4.1.5 and 4.2.2 apply accordingly.

6. Guidance values for bearing clearances

For metallic bearing material the bearing clearance should generally not be less than:

$$\frac{d_b}{1000} + 1{,}0 \text{ [mm] or 1,5 mm as a minimum}$$

d_b = inner diameter of bush.

If non-metallic bearing material is applied, the bearing clearance is to be specially determined considering the material's swelling and thermal expansion properties.

F. Design Yield Moment of Rudder Stock

The design yield moment of the rudder stock is to be determined by the following formula:

$$Q_F = 0{,}02664\ \frac{D_t^3}{k_r} \quad \text{[Nm]}$$

D_t = stock diameter in [mm] according to C.1.

Where the actual diameter D_{ta} is greater than the calculated diameter D_t, the diameter D_{ta} is to be used. However, D_{ta} need not be taken greater than 1,145 . D_t.

G. Stopper, Locking Device

1. Stopper

The motions of quadrants or tillers are to be limited on either side by stoppers. The stoppers and their foundations connected to the ship's hull are to be of strong construction so that the yield point of the applied materials is not exceeded at the design yield moment of the rudder stock.

2. Locking device

Each steering gear is to be provided with a locking device in order to keep the rudder fixed at any position. This device as well as the foundation in the ship's hull are to be of strong construction so that the yield point of the applied materials is not exceeded at the design yield moment of the rudder stock as specified in F. Where the ship's speed exceeds 12 kn, the design yield moment need only be calculated for a stock diameter based on a speed v_0 = 12 [kn].

3. Regarding stopper and locking device see also Rules for Machinery Installations - Volume III, Section 14.

H. Propeller Nozzles

1. General

1.1 The following requirements are applicable to propeller nozzles having an inner diameter of up to 5 m. Nozzles with larger diameters will be specially considered.

1.2 Special attention is to be given to the support of fixed nozzles at the hull structure.

2. Design pressure

The design pressure for propeller nozzles is to be determined by the following formula:

$$p_d = c \cdot p_{do} \quad \text{[kN/m}^2\text{]}$$

$$p_{do} = \varepsilon\ \frac{N}{A_p} \quad \text{[kN/m}^2\text{]}$$

N = maximum shaft power in [kW]

A_p = propeller disc area in [m^2]

$$A_p = \frac{\pi}{4} D^2$$

D = propeller diameter in [m]

ε = factor according to the following formula:

$$\varepsilon = 0{,}21 - 2 \cdot 10^{-4}\ \frac{N}{A_p}$$

$$\varepsilon_{min} = 0{,}10$$

c = 1,0 in zone 2 (propeller zone),

c = 0,5 in zones 1 and 3

c = 0,35 in zone 4 (see Fig. 14.9).

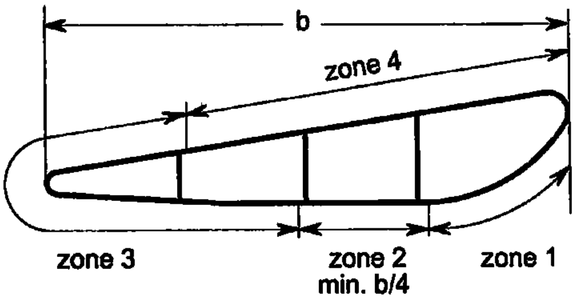


Fig. 14.9

3. Plate thickness

3.1 The thickness of the nozzle shell plating is not to be less than:

$$t = 5 \cdot a \cdot \sqrt{p_d} + t_K \quad [mm]$$

$$t_{min} = 7{,}5 \quad [mm]$$

a = spacing of ring stiffeners in [m].

3.2 The web thickness of the internal stiffening rings shall not be less than the nozzle plating for zone 3, however, in no case be less than 7,5 mm.

4. Section modulus

The section modulus of the cross section shown in Fig. 14.9 around its neutral axis is not to be less than:

$$W = n \cdot d^2 \cdot b \cdot v_0^2 \quad [cm^3]$$

d = inner diameter of nozzle in [m]

b = length of nozzle in [m]

n = 1,0 for rudder nozzles

n = 0,7 for fixed nozzles.

5. Welding

The inner and outer nozzle shell plating is to be welded to the internal stiffening rings as far as practicable by double continuous welds. Plug welding is only permissible for the outer nozzle plating.

Section 15

Strengthening for Navigation in Ice

A. General

1. Class notation ES

Fishing vessels intended to sail in Iceland or Barents Sea services or in similar areas are to be approved for the class notation **A 100 ① ES** without any limiting notation.

2. Class notation ESF

The ice-strengthenings stipulated under C.2 are recommended for fishing vessels intended to sail in the areas near Greenland and Labrador. Ships having these strengthenings will have the notation **ESF** affixed to the character of classification.

3. Finnish-Swedish ice classes, arctic ice classes

3.1 Where compliance with one of the Finnish-Swedish ice classes is required, the requirements of Rules for Hull, Volume II, Section 15 are to be observed.

3.2 Where compliance with one of the arctic ice classes is required, the requirements of Rules for Hull, Volume II Section 15, D. are to be observed.

4. Definitions

4.1 Ice belt

4.1.1 The ice belt is the zone of the shell plating which is to be strengthened. The ice belt is divided into regions as follows (see Fig. 15.1):

.1 Forward region (F)

The region from the stem to a line parallel to and at the distance c aft of the borderline between the parallel midship region and the fore ship:,

.2 Midship region (M)

The region from the aft boundary of the region **F**, as defined in .1 to a line parallel to and at the distance c aft of the borderline between the parallel midship region and the aft ship:,

.3 Aft region (A)

The region from the aft boundary of the region **M**, as defined in .2 to the stern.

$$c = 0{,}04\,L$$

4.1.2 For the class notation **ES** the breadth of the ice belt, vertically measured, extends from 500 mm below **BWL** to 400 mm above **DOWL**. For the class notation **ESF** the breadth of the ice belt, vertically measured, is to be determined as follows:

Table 15.1

Area	Breadth
F	from lower edge of bilge strake but not less than 800 mm below **BWL** to 600 mm above **DOWL**
M, A	from 800 mm below **BWL**to 600 mm above **DOWL**
BWL	= ballast water line at minimum ballast draught
DOWL	= deepest operating waterline at maximum draught.

4.1.3 The vertical minimum extent b_E of the framing to be reinforced extends from 1,3 m below **BWL** to 1,0 m above **DOWL**.

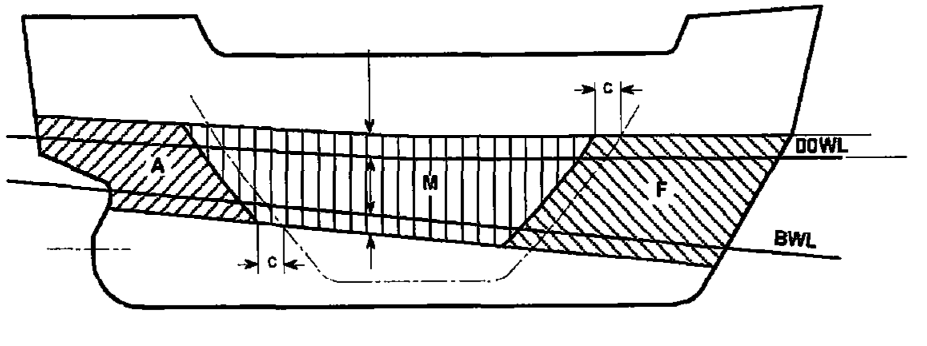


Fig. 15.1

B. Requirements for the Notation ES

1. Shell plating within the ice belt

1.1 Within the ice belt the shell plating must have a strengthened strake extending from the stem to the point where the load waterline reaches its greatest breadth.

1.2 The thickness of this strake is to be increased by 25 %, but at least by 3 mm above the Rule midship thickness as per Section 6. However, the thickness need not exceed 25 mm. The Rule midship thickness is to be related to the actual frame spacing within the ice belt, however, at least to the Rule frame spacing $\mathbf{a_0}$ as per Section 9, A. 1.1.

1.3 The midship thickness of the side shell plating is to be maintained forward of amidships up to the strengthened plating.

2. Frames

2.1 The frame spacing in way of 0,075 **L** from the stem is to be reduced to $0,6 \cdot \mathbf{a_0}$, however, it is not to exceed 500 mm.

2.2 Instead of a reduced frame spacing, intermediate frames having a section modulus of 75 percent of that of the peak frames may be fitted. End attachment of the intermediate frames is not necessary. The intermediate frames shall extend from approximately 1,0 m below **BWL** to 1,0 m above **DOWL**.

2.3 Tripping brackets spaced not more than 1,3 m apart are to be fitted in line with the tiers of beams and stringers required in Section 9, A.7. in order to prevent tripping of the frames. The tripping brackets are to extend to the point where the load waterline reaches its greatest breadth.

3. Stem

The thickness of welded plate stems up to 600 mm above **DOWL** is to be 1,1 times the thickness required according to Section 13, A.2., however, need not exceed 25 mm. The thickness above a point 600 mm above the **DOWL** may be gradually reduced to the thickness required according to Section 13, A.2.

C. Requirements for the Notation ESF

1. General

1.1 Ships built according to the requirements stipulated below will, however, get the notation **ESF** only if the waterlines within the ice belt are of even curvature and convex shape. The angle between the centreline of the ship and the waterline tangent is not to exceed 15°. By no means the waterlines must be of hollow shape.

1.2 For ships substantially deviating from the criteria as per 1.1 as far as their shape is concerned and/or having hollow waterlines within the ice belt, the notation **ESF** will be assigned only after special consideration.

2. Shell plating

2.1 The shell plating is to be reinforced within the ice belt and the thickness is not to be less than:

for area **F**:	1,5 x Rule midship thickness
for areas **M** and **A**:	1,25 x Rule midship thickness

2.2 A flat bottom below the stern slipway shall be sufficiently strengthened by increasing the shell plating thickness to 1,25 times the Rule midship thickness and by fitting longitudinals between the floors.

3. Frames and stringers

3.1 Within the vertical extent b_E as per A.4.1.3 intermediate frames are to be fitted throughout. The intermediate frames are to have the same section modulus as the main frames if fitted within the areas **F** and **M**.

Within the area **A** their section modulus may be 25 percent less than that of the main frames which are fitted in between.

All intermediate frames are, at their upper and lower ends, to be attached to a stringer as per 3.3 or to a deck. Where they are attached to a deck, adequate stiffening of the deck plating is required.

3.2 Within the areas **F** and **M** stringers as per 3.3 and 3.4 spaced not more than 1,3 m apart, vertically measured, are to be fitted in line with the tiers of beams and stringers required in Section 9, A.7.

3.3 Where the intermediate frames are not attached to a deck or to the bottom structure, a stringer forming the upper or lower limit of the vertical minimum extent b_E is to have at least the same scantlings as the intermediate frames.

3.4 For the remaining stringers a flat steel bar fitted on top of the frames and connected to the shell plating and frames by alternately spaced web plates will be sufficient.

The thickness of the flat steel bar shall be equal to the thickness of the strengthened shell plating. The width of the flat steel bar shall be 10 times its thickness.

4. Stem

4.1 The thickness of welded plate stems up to 600 mm above **DOWL** is to be 1,75 times the thickness required according to Section 13, A.2., but need not exceed 30 mm. The thickness above 600 mm above **DOWL** may be gradually reduced to the thickness required according to Section 13, A.2.

4.2 Where a bulbous bow is fitted, the forward portion from the keel to the upper limit of the ice belt should preferably be made of cast steel.

However, if this portion is fabricated from plates, the shape of the bulbous bow and the structural design shall be such as to facilitate fabrication from plates which are rolled or bent in one direction only. The plate thickness may be gradually reduced to the thickness required for the side plating within the forward ice belt.

Intermediate frames, breast hooks and carlings are to be arranged to ensure that the frame spacing within the bulbous bow is not greater than that within the forward ice belt.

Section 16

Superstructures and Deckhouses

A. General

1. Definitions

1.1 For the purpose of this Section forecastle and poop are superstructures if the shell plating is extended up to their decks.

1.2 Structures on strength decks are to be dimensioned according to the rules for deckhouses if they are located outside 0,4 L amidships or are less than 0,2 L or 15 m in length and if their sides are set in at least 1,6 times the Rule frame spacing a_0 according to Section 9, A.1.1. Deckhouses set in less than this distance and deckhouses within 0,4 L amidships and exceeding 0,2 L or 15 m in length will be specially considered.

1.3 Superstructures extending into the range of 0,4 L amidships and the length of which exceeds 0,15 L are defined as effective superstructures. Their side plating is to be treated as shell plating and their deck as strength deck.

1.4 All superstructures being located beyond 0,4 L amidships or having a length of less than 0,15 L or less than 12 metres are, for the purpose of this Section, considered as non-effective superstructures.

1.5 For deckhouses of aluminium, Section 2, D. is to be observed.

1.6 Scantlings of isolated funnels are to be determined as for deckhouses.

2. Strengthenings at the ends of superstructures

2.1 At the ends of the superstructures, the thickness of the sheer strake, the strength deck in a breadth of 0,1 B from the shell and the superstructure side plating are to be strengthened as specified in Table 16.1. The strengthenings shall extend over a region from 4 a_0 abaft the end bulkhead. No strengthenings are required outside 0,5 L amidships.

2.2 Under strength decks in way of 0,6 L amidships, girders are to be fitted in alignment with longitudinal walls, which are to extend at least over three frame spacings beyond the end points of the longitudinal walls. The girders are to overlap with the longitudinal walls by at least two frame spacings.

2.3 Where a centre line bulkhead is arranged under the end bulkhead of a superstructure or of a deckhouse, stiffeners are to be fitted at the centre line bulkhead under the end bulkhead on both sides, and are to be attached to the deck by brackets.

Table 16.1

Type of superstructure	Location of end bulkhead	Strengthening in [%]	
		strength deck and sheer strake	side plating of superstructure
effective according to 1.3	within 0,4 L amidships	50	25
	between 0,4 L and 0,5 L amidship	30	20
non-effective according to 1.4	within 0,4 L amidships	25	10
	between 0,4 L and 0,5 L amidships	20	10

3. Transverse structure of superstructures and deckhouses

The transverse structure of superstructures and deckhouses is to be sufficiently dimensioned by a suitable arrangement of end bulkheads, web frames, steel walls of cabins and casings, or by other measures.

4. Doors in closed superstructures

4.1 All access openings in end bulkheads of closed superstructures shall be fitted with weathertight doors permanently attached to the bulkhead, having the same strength as the bulkhead. The doors shall be so arranged that they can be operated from both sides of the bulkhead. The coaming heights of the access openings above the deck are to be determined according to Section 17.

4.2 Any opening in a superstructure deck or in a deckhouse deck directly above the freeboard deck (deckhouse surrounding companionways), is to be protected by efficient weathertight closures.

B. Side Plating and Decks of Non-effective Superstructures

1. Side plating

1.1 The thickness of the side plating is not to be less than the greater of the following values:

$$t = 1{,}26 \cdot a\sqrt{p_s \cdot k} + t_K \text{ [mm], or}$$

$$t = 0{,}8 \cdot t_2 \qquad \text{[mm]}$$

t_2 see Section 6, B.3.1.

p_s = load in [kN/m²] according to Section 4, B.2.; p_s is to be measured from the lower edge of the plate.

1.2 The thickness of the side plating of upper tier superstructures may be reduced by 0,5 mm.

2. Deck plating

2.1 The thickness of deck plating is not to be less than the greater of the following values:

$$t = 1{,}26 \cdot a\sqrt{p \cdot k} + t_K \quad \text{[mm]}$$

$$t = 5{,}5 + 0{,}02\,L \qquad \text{[mm]}$$

p = p_D or p_L according to Section 4, B.1. or C.1., the greater value is to be taken.

2.2 Where on non-effective superstructures located on the strength deck additional superstructures are arranged, the thickness required by 2.1 may be reduced by 10 percent.

2.3 Where plated decks are protected by sheathing, the thickness of the deck plating according to 2.1 – 2.2 may be reduced by t_K, however, it is not to be less than 5 mm.

Where a sheathing other than wood is used, attention is to be paid that the sheathing does not affect the steel. The sheathing is to be effectively fitted to the deck.

3. Deck beams and supporting deck structure

The scantlings of the deck beams and the supporting deck structure are to be determined in accordance with Section 10.

4. Frames

The scantlings of superstructure frames are given in Section 9, A. 5.

C. Superstructure End Bulkheads and Deckhouse Walls

1. Definitions

The design load for determining the scantlings is:

$$P_A = n \cdot c\,(b \cdot f - z) \quad \text{[kN/m}^2\text{]}$$

n = $20 + L/12$

for the lowest tier of unprotected fronts. The lowest tier is normally that tier which is directly situated above the uppermost continuous deck to which the rule depth **H** is to be measured. However, where the actual distance exceeds the minimum non-corrected tabular freeboard by at least one standard superstructure height, this tier may be defined as the 2nd tier and the tier above as the 3rd tier.

n = $10 + \dfrac{L}{12}$

for 2nd tier of unprotected fronts

n = $5 + \dfrac{L}{15}$

for 3rd tier and tiers above of unprotected fronts, for sides and protected fronts

n = $7 + L/100 - 8\dfrac{x}{L}$

for aft ends abaft amidships

n = $5 + L/100 - 4\dfrac{x}{L}$

for aft ends forward of amidships

$$b = 1{,}0 + \left[\frac{\frac{x}{L} - 0{,}45}{C_B + 0{,}2}\right]^2$$

for $\dfrac{x}{L} \le 0{,}45$

$$b = 1{,}0 + 1{,}5\left[\frac{\frac{x}{L} - 0{,}45}{C_B + 0{,}2}\right]^2$$

for $\dfrac{x}{L} \ge 0{,}45$

$0{,}60 \le C_B \le C\,0{,}80$; when determining scantlings of aft ends forward of amidships, C_B need not be taken less than 0,8.

x = distance in [m] between bulkhead considered and A.P. When determining sides of a deckhouse, the deckhouse is to be subdivided into parts of approximately equal length, not exceeding 0,15 L each, and x is to be taken as the distance between A.P. and the centre of each part considered.

f = $0{,}1\,L \cdot e^{-L/300} - \left[1 - (L/150)^2\right]$

The factor f may be taken from Table 16.2.

z = vertical distance in [m] from summer waterline to midpoint of stiffener span, or to the middle of the plate field.

c = $(0{,}3 + 0{,}7\,b'/B')$

b' = breadth of deckhouse at the position considered

B' = actual maximum breadth of ship on the exposed weather deck at the position considered. b'/B' is not to be taken less For exposed parts of machinery casings, c is not to be taken less than 0,25.

For exposed parts of machinery casings, c is not to be taken less than 1,0.

Table 16.2

L	f	L	f	L	f
20	0,89	65	4,42	110	7,16
25	1,33	70	4,76	115	7,43
30	1,75	75	5,09	120	7,68
35	2,17	80	5,41	125	7,93
40	2,57	85	5,72	130	8,18
45	2,96	90	6,03	135	8,42
50	3,34	95	6,32	140	8,65
55	3,71	100	6,61	145	8.88
60	4,07	105	6,89	150	9,10

The design load p_A is not to be taken less than the minimum values given in the Table 16.3.

Table 16.3

L	$p_{A\,min}$ in [kN/m²] for:	
	lowest tier of unprotected fronts	**elsewhere**
≤ 50	30	15
> 50	25 + L/10	12,5 + L/20

a = spacing of stiffeners in [m]

ℓ = unsupported span in [m]; ℓ is to be taken as the superstructure height or deckhouse height respectively, however, not less than 2,0 m.

2. Scantlings

2.1 Stiffeners

The section modulus of the stiffeners is to be determined according to the following formula:

$$W = 0{,}35 \cdot a \cdot \ell^2 \cdot p_A \quad [cm^3]$$

These requirements assume the webs of lower tier stiffeners to be efficiently welded to the decks. Scantlings for other types of end connections may be specially considered.

The section modulus of house side stiffeners need not be greater than that of side frames on the deck situated directly below; taking account of spacing a and span ℓ.

2.2 Plate thickness

The thickness of the plating is to be determined according to the following formula:

$$t = 0{,}95 \cdot a \cdot \sqrt{p_A \cdot k} + t_K \quad [mm]$$

t_{min} = 5,0 + L/100 for the lowest tier

= 4,0 + L/100 for the upper tiers, however, not less than 4,5 mm.

D. Deckhouse Decks

1. Plating

The thickness of deck plating is not to be less than:

$$t = 8 \cdot a \sqrt{k} + t_K \quad [mm]$$

for decks exposed to weather.

For decks exposed to weather protected by sheathing and for decks within deckhouses the thickness may be reduced by t_K . In no case the thickness is to be less than the minimum thickness t_{min} = 4,5 mm.

2. Deck beams

The deck beams and the supporting deck structure are to be determined according to Section 10.

E. Bulkheads and Walls Openings

1. General

All openings in bulkheads and walls of superstructures and deckhouses are to be provided with efficient means of closing, which are not to permit water to penetrate under any sea conditions. Opening and closing appliances are to be framed and stiffened in such a manner that the whole structure when closed is equivalent to the unpierced bulkhead.

2. Doors

2.1 Exterior doors are to be steel or equivalent, permanently and strongly attached to bulkheads. The doors are to be provided with gaskets and clamping devices, or equivalent arrangements, permanently attached to the bulkheads or to the doors themselves. Each door is to be so arranged that it can be operated from both sides of the bulkhead and is to open outwards.

2.2 Doors in exposed front and after ends bulkheads of superstructures and deck houses located on the weather deck are to be located as near to the centerline of the vessel as practicable and are to be weathertight.

F. Elastic Mounting of Deckhouses

1. General

1.1 The elastic mountings are to be type approved by BKI. The stresses acting in the mountings which have been determined by calculation are to be proved by means of prototype testing on testing machines. Determination of the grade of insulation for transmission of vibrations between hull and deckhouses is not part of this type approval.

1.2 The height of the mounting system is to be such that the space between deck and deckhouse bottom remains accessible for repair, maintenance and inspection purposes. The height of this space shall normally not be less than 600 mm.

1.3 Coaming height for the fixed part of the deckhouse on the working deck to be as required by Section 17, A.

1.4 For pipelines, see Volume III, Section 11.

1.5 Electric cables are to be fitted in bends in order to facilitate the movement. The minimum bending radius prescribed for the respective cable is to be observed. Cable glands are to be watertight. For further details, see Volume IV.

1.6 The following scantling requirements for rails, mountings, securing devices, stoppers and substructures in the hull and the deckhouse bottom apply to ships in unrestricted service. For special ships and for ships intended to operate in restricted service ranges requirements differing from those given below may be applied.

2. Design loads

For scantling purposes the following design loads apply:

2.1 Weight

2.1.1 The weight induced loads result from the weight of the fully equipped deckhouse, considering also the acceleration due to gravity and the acceleration due to the ship's movement in the seaway. The weight induced loads are to be assumed to act in the centre of gravity of the deckhouse.

The individual dimensionless accelerations a_z (vertically), a_y (transversely) and a_x (longitudinally) and the dimensionless resultant acceleration a_β, are to be determined according to Section 4, E. for k = 1,0 and f = 1,0.

Due to the resultant acceleration a_β the following load is acting:

$P = G \cdot a_\beta \cdot g$ [kN]

G = mass of the fully equipped deckhouse in [t]

g = 9,81 [m/s^2]

2.1.2 The support forces in the vertical and horizontal directions are to be determined for the various angles β. The scantlings are to be determined for the respective maximum values (see also Fig. 16.1).

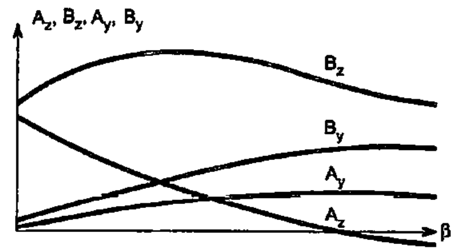


Fig. 16.1

2.2 Water pressure and wind pressure

2.2.1 The water load due to the wash of the sea is assumed to be acting on the front wall in the longitudinal direction only. The design load is:

$p_{wa} = 0{,}5 \cdot p_A$ [kN/m^2]

p_A see C.2

The water pressure is not to be less than:

p_{wa} = 25 [kN/m^2] at the lower edge of the front wall

p_{wa} = 0 at the level of the first tier above the deckhouse bottom

$P_{wa} = p_{wa} \cdot A_f$ [kN]

A_f = loaded part of deckhouse front wall in [m^2]

2.2.2 The design wind load acting on the front wall and on the side walls is:

$P_{wi} = A_D \cdot p_{wi}$ [kN]

A_D = area of wall in [m^2]

p_{wi} = 1,0 [kN/m^2]

2.3 Load on the deckhouse bottom

The load on the deckhouse bottom is governed by the load acting on the particular deck on which the deckhouse is located. Additionally, the support forces resulting from the loads specified in 2.1 and 2.2 are to be taken into account.

2.4 Load on deck beams and girders

For designing the deck beams and girders of the deck on which the deckhouse is located the following loads are to be taken:

.1 Below the deckhouse: Load p_u according to the pressure head due to the distance between the supporting deck and the deckhouse bottom in [kN/m²]

.2 Outside the deckhouse: Load p_D.

.3 Bearing forces in accordance with the load assumptions 2.1 and 2.2.

3. Load cases

3.1 For design purposes the following load cases are to be investigated separately (see also Fig. 16.2):

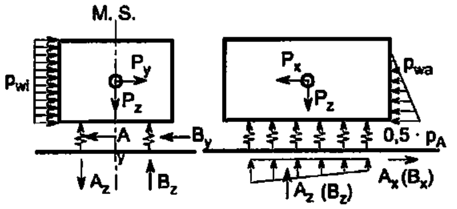


Fig. 16.2

3.2 Service load cases

Forces due to external loads

3.2.1 Transverse direction (z-y-plane)

$$P_{y1} = G \cdot a_{\beta(y)} \cdot g + P_{wi} \text{ [kN]}$$

acting in transverse direction

$$P_{z1} = G \cdot a_{\beta(z)} \cdot g \quad \text{[kN]}$$

acting vertically to the baseline

P_{wi} = wind load as per 2.2.2

$a_{\beta(y)}$ = horizontal acceleration component of a_β

$a_{\beta(z)}$ = vertical acceleration component of a_β.

3.2.2 Longitudinal direction (z-x-plane)

$$P_{x1} = G \cdot a_{\beta(x)} \cdot g + P_{wa} + P_{wi} \quad \text{[kN]}$$

acting in longitudinal direction

$$P_{z1} = G \cdot a_{\beta(z)} \cdot g \quad \text{[kN]}$$

acting vertically to the baseline

$a_{\beta(x)}$ = horizontal acceleration component in the longitudinal plane.

3.2.3 For designing the securing devices to prevent the deckhouse from being lifted, the force (in upward direction) is not to be taken less than determined from the following formula:

$$P_{zmin} = 0{,}5 \cdot g \cdot G \text{ [kN]}$$

3.3 Extraordinary load cases

3.3.1 Collision force in longitudinal direction:

$$P_{x2} = 0{,}5 \cdot g \cdot G \quad \text{[kN]}$$

3.3.2 Forces due to static heel of 45°

$$P_{z2}, P_{y2} = 0{,}71 \cdot g \cdot G \quad \text{[kN]}$$

P_{z2} = force acting vertically to the baseline

P_{y2} = force acting in transverse direction.

3.3.3 The possible consequences of a fire for the elastic mounting of the deckhouse are to be examined (e.g. failure of rubber elastic mounting elements, melting of glue). Even in this case, the mounting elements between hull and deckhouse bottom must be capable of withstanding the horizontal force P_{y2} as per 3.3.2 in transverse direction.

3.3.4 For designing of the securing devices to prevent the deckhouse from being lifted, a force not less than the buoyancy force of the deckhouse resulting from a water level of 2 m above the freeboard deck is to be taken.

4. Scantlings of rails, mounting elements and substructures

4.1 General

4.1.1 The scantlings of those elements are to be determined in accordance with the load cases stipulated under 3. The effect of deflection of main girders need not be considered under the condition that the deflection is so negligible that all elements take over the loads equally.

4.1.2 Strength calculations for the structural elements with information regarding acting forces are to be submitted for approval.

4.2 Permissible stresses

4.2.1 The permissible stresses given in Table 16.4 are not to be exceeded in the rails and the steel structures of mounting elements and in the substructures (deck beams, girders of the deckhouse and the deck, on which the deckhouse is located).

4.2.2 The permissible stresses for designing the elastic mounting elements of various systems will be considered from case to case. Sufficient data are to be submitted for approval.

4.2.3 The stresses in the securing devices to prevent the deckhouse form being lifted are not to exceed the stress values specified in 4.2.1.

4.2.4 In screwed connections, the permissible stresses given in Table 16.5 are not to be exceeded.

4.2.5 Where turnbuckles in accordance with recognized standard are used for securing devices, the load per bolt under load conditions 3.2.3 and 3.3.4 may be equal to the proof load (2 times safe working load).

5. Corrosion Allowance

For deck plating below elastically mounted deckhouse a minimum corrosion allowance of $t_K = 3.0$ mm applies.

Table 16.4

Type of stress	Permissible stress for service load cases	Permissible stress for extraordinary load cases
normal stress σ_n	$0{,}6 \cdot R_{eH}$ or $0{,}4 \cdot R_m$	$0{,}75 \cdot R_{eH}$ or $0{,}5 \cdot R_m$
shear stress τ	$0{,}35 \cdot R_{eH}$ or $0{,}23 \cdot R_m$	$0{,}43 \cdot R_{eH}$ or $0{,}3 \cdot R_m$
equivalent stress $\sigma_v = \sqrt{\sigma_n^2 + 3\tau^2}$	$0{,}75 \cdot R_{eH}$	$0{,}9 \cdot R_{eH}$
R_{eH} = minimum nominal upper yield point R_m = tensile strength		

Table 16.5

Type of stress	Permissible stress for service load cases	Permissible stress for extra-ordinary load cases
longitudinal tension σ_n	$0{,}5 \cdot R_{eH}$	$0{,}8 \cdot R_{eH}$
bearing pressure p_ℓ	$1{,}0 \cdot R_{eH}$	$0{,}9 \cdot R_{eH}$
equivalent stress from longitudinal tension σ_n, torsion τ_t (due to tightening torque) and shear (if applicable) $\sigma_v = \sqrt{\sigma_n^2 + 3(\tau^2 + \tau_t^2)}$	$0{,}6 \cdot R_{eH}$	$1{,}0 \cdot R_{eH}$

Section 17

Protection of Deck Openings

A. General

1. All weatherdeck openings, i.e. hatchways, doors and ventilators are to be sufficiently protected by sills and adequate closing appliances. These openings are classified according to their position as follows:

Position 1: on exposed bulkhead decks, raised quarter decks and on superstructure decks within 0,25 L_c from forward.

Position 2: on exposed superstructure decks abaft 0,25 L_c from forward.

2. For coamings and sills above exposed bulkhead deck and superstructure deck the following minimum heights (Table 17.1) apply:

Table 17.1

	L_c [m]	Coaming / sill height [mm] Pos. 1	Coaming / sill height [mm] Pos. 2
Hatchway coamings	≥ 24 [2]	600	300
	< 12 [2]	300	300
Door'sill of companionways and machinery casings, access hatches coamings	≥ 24 [2]	600 [1]	300 [1]
	< 12 [2]	300 [1]	300 [1]
Ventilator coamings	≥ 45	900	760
	< 45	760	450

[1] On request coaming/door sill height, except doorways giving direct access to machinery spaces, may be reduced to not less than 380 mm on the working deck for vessels of 24 m or more in length and not to be less than 150 mm on the working deck for vessels of 12 m or less in length and on Position 2.

[2] For length between 12 m and 24 m, the minimum height of hatchway and access hatches coamings and door'sill of companionways and machinery casings, are to be obtained by linear interpolation.

B. Fishhold Hatchways, Companionway, Access Hatches

1. For the height of the coamings of fishhold hatchways see A.2. Upon special approval the height of these coamings may be reduced, or the coamings omitted entirely, provided that the safety of vessels is not thereby impaired. In this case the hatchway openings shall be kept as small as practicable and the covers be permanently attached by hinges or equivalent means and be capable of being rapidly closed and battened down.

2. For the height of the coamings of companionways and access hatches see A.2. Alternatively the superstructure or deckshouse enclosing a companionway or a access hatch has to be adequately protected.

3. The doors of the companionways are to be capable of being operated and secured from both sides. They are to be closed weathertight by rubber sealings and toggles.

4. Access hatchways shall have a clear width of at least 600 x 600 mm.

5. Coaming plates for locations indicated in A.2 are not to be less in thickness than that required for the adjacent deck plating corrected for actual unsupported height.

6. Coamings of 450 mm in height or greater are to be sufficiently stiffened at their upper edge by horizontal stiffeners.

7. Efficient brackets or stays are to be fitted from the stiffeners to the deck at intervals of not more than 3 m. Where exposed coamings are 750 mm or more in height, the arrangement of the stiffeners and brackets or stays is to provide equivalent support. Where end coamings are protected, the arrangement of the stiffeners and brackets or stays may be modified.

8. Framing of openings

All openings in decks are to be framed to provide efficient support and attachment for the ends of the deck beams.

C. Hatchway Covers

1. Scantlings of steel hatch covers

1.1 For hatch covers of fish holds the thickness of plating is not to be less than the larger of the following values:

$$t = 10 \cdot a \quad [mm]$$

$$t = C \cdot a \sqrt{p \cdot k} + t_K \quad [mm]$$

a = spacing of stiffeners in [m]

p = p_{DA} or p_L, the greater value is to be taken

$C = 1{,}21$ if $p = p_{DA}$

$C = 1{,}10$ if $p = p_L$

1.2 For hatch covers in fish holds intended to be filled with liquids the plate thickness is not to be less than required according to 1.1 or according to the following formulae, whichever is the greater:

$$t_1 = 1{,}1 \cdot a\sqrt{p_1 \cdot k} + t_K \quad [\text{mm}]$$

$$t_2 = 0{,}9 \cdot a\sqrt{p_2 \cdot k} + t_K \quad [\text{mm}]$$

t_{min} = minimum thickness [mm] according to Section 12, A.6.

p_1, p_2 = load in [kN/m2] according to Section 4, D.1.

1.3 Means for securing weathertightness

The means for securing and maintaining weathertightness is to be such that the tightness can be maintained in any sea condition. The covers are to be hose tested. The water pressure is not to be less than 2 bar and the hose nozzle shall be held at a distance of not more than 1,5 m from the hatch cover to be tested. During frost periods equivalent tightness tests may be carried out to the satisfaction of the Surveyor.

2. Wooden hatchway covers

2.1 Thickness:

$t = 40 \cdot a$ [mm]

a = beam spacing [m]

t_{min} = 40 mm

The width of bearing surface is not to be less than 65 mm.

2.2 Where the 'tween deck height exceeds 2,5 m, or the deck load is greater than 1,8 t/m^2, the thickness of the hatch covers is to be increased at the rate of 12 mm per 1 m greater 'tween deck height, or per 0,72 t/m^2 increased in deck load.

2.3 The grovers for grips are not be arranged too near to the ends of the hatch covers.

2.4 The wood used for the hatch coverings is to be of good quality, free from sap and objectionable defects, and dry.

2.5 The ends of wood hatch covers should be encircled by durable bands, e.g., of galvanized steel.

D. Engine Room and Boiler Room Casings

1. Engine and boiler room openings on bulkhead decks and inside open superstructures are to be protected by casings of sufficient height.

2. The height of casings on the exposed bulk-head deck is to be not less than 1,8 m where **L** does not exceed 75 m, and not less than 2,3 m where **L** is 125 m or more. Intermediate values are to be determined by interpolation.

3. The scantlings of stiffeners, plating and covering of exposed casings are to comply with the requirements for superstructure end bulkheads and for deckhouses according to Section 16, C.

4. The coamings shall, wherever practicable, extend to the lower edge of the beams.

5. The height of casings on superstructure decks is to be at least 760 mm. The thickness of their plating may be 0,5 mm less than derived from 3., and the stiffeners are to have the same thickness and a depth of web of 75 mm, being spaced at 750 mm.

6. The doors in casings on exposed decks and within open superstructures are to be of steel, well stiffened and hinged, and capable of being closed from both sides and secured weathertight by toggles and rubber sealings.

7. The doors are to be at least of the same strength as the casing walls in which they are fitted.

E. Miscellaneous Openings in Exposed Bulkhead Decks and Superstructure Decks

1. Manholes and small flush deck hatches in decks in pos. 1 and 2 or in open superstructures are to be closed watertight.

2. If not bolted watertight, they are to be of substantial steel construction with bayonet joints or screws. The covers are to be hinged or to be permanently attached to the deck by a chain.

3. Openings in exposed bulkhead decks other than hatchways and machinery space openings, may only be arranged in weathertight closed superstructures or deckhouses or in weathertight closed companionways of the same strength.

Section 18

Equipment

A. General

1. Each vessel is to be provided with anchoring equipment designed for quick and safe operation in all foreseeable service conditions and for holding the ship at anchor. Anchor equipment should consist of anchors, anchor chain cables and windlasses or other equivalent arrangements for dropping and lifting the anchor and holding the ship at anchor.

Two bower anchors are to be attached to the chain cable and fitted in hawse pipes.

Ropes may be fitted in lieu of chain cables as stipulated in F.

2. Windlasses, chain stoppers and wire rope winches, if fitted, are to comply with Rules for Machinery Installations, Volume III, Section 14, D.

3. Anchors, chain cables and the recommended mooring ropes are to be determined in accordance with the equipment numeral Z and Z_L respectively.

.1 Where Z exceeds 720 the requirements of Rules for Hull, Volume II, Section 18 apply.

.2 Where Z ≤ 720 Table 18.1 applies.

Vessels equipped in accordance with Table 18.1 will have the index "F" affixed to their equipment register number in the Certificate and in the Register Book.

.3 For vessels having a length **L** ≤ 40 m and which will have the notation **L** (Coastal Service) attached to their character of classification the equipment numeral Z_L and Table 18.2 apply.

For vessels having a length ≤ 20 m the equipment is to be determined for the length L.

Vessels equipped in accordance with Table 18.2 will have the index "L" affixed to their equipment register number in the Certificate and in the Register Book.

4. Where, for special reasons, vessels shall be equipped with a smaller anchor equipment than required by 3., approval may be granted on a case by case basis. These vessels will have the notation "Special anchor equipment" entered into the Certificate and the Register Book.

5. Vessels built under survey of BKI and which are to have the mark ⊛ stated in their Certificate and in the Register Book must be equipped with anchors and chain cables complying with the Rules for Materials Volume V and having been tested on approved machines in the presence of a Surveyor. For ships having the navigation notation **L** (Coasting Service) affixed to their character of classification proof that the anchors and chain cables have been properly tested is sufficient.

B. Equipment Numeral

1. The equipment numeral Z is to be calculated as follows:

$$Z = D^{2/3} + 2\,h\,\mathbf{B} + \frac{A}{10}$$

D = moulded displacement in [t] (in seawater having a density of 1,025 t/m³) to the summer load waterline

h = $f_b + \Sigma h'$ = effective height from the deepest operating waterline to the top of the uppermost house

f_b = freeboard in [m], from the deepest operating waterline amidships to the working deck at side.

Σ h' = sum of height in [m] of superstructures and deckhouses, on the centreline of each tier having a breadth greater than **B**/4. Deck sheer, if any, is to be ignored. For the lowest tier, h' is to be measured at centreline from the working deck or from a notional deckline where there is local discontinuity in the working deck.

Where a deckhouse having a breadth greater than **B**/4 is located above a deckhouse having a breadth of B/4 or less, the wide house is to be included and the narrow house ignored.

A = area, in [m²], in profile view of the hull, superstructures and houses having a breadth greater than **B**/4, above the deepest operating waterline within the length **L** and up to the height h.

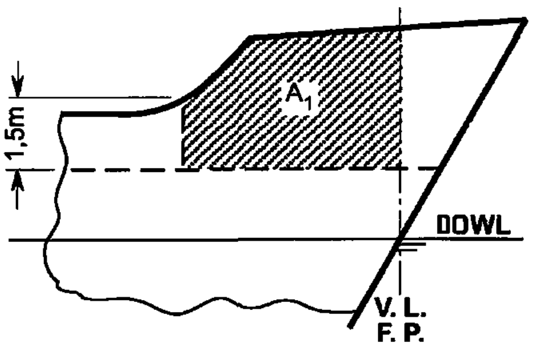
Screens or bulwarks 1,5 m or more in height are to be regarded as parts of houses when determining h and A, e.g. the area shown in Fig. 18.1 as A_1 is to be included in A. The height of the hatch coamings and that of any deck cargo, may be disregarded when determining h and A.

2. The equipment numeral Z_L is to be calculated as follows:

$$Z_L = \mathbf{L}\,(\mathbf{B} + \mathbf{H}) + \Sigma\, 0{,}5 \cdot \ell \cdot h$$

ℓ = length of individual superstructures and deckhouses [m] within length **L** h = height of individual superstructures and deckhouses at centreline ship [m].

Deckhouses having a breadth of less than **B**/4 may be ignored.



DOWL = Deepest Operating Waterline

Fig. 18.1

C. Anchors

1. Anchors must be of an approved design. The weight of the heads of patent (ordinary stockless) anchors, including pins and fittings, is not to be less than 60 percent of the total weight of the anchor.

2. For stock anchors, the total weight of the anchor, including the stock, shall comply with the values in Tables 18.1 and 18.2. The weight of the stock shall be 20 percent of this total weight.

3. The weight of each individual bower anchor may vary by up to 7 percent above or below the required individual weight provided that the total weight of all the bower anchors is not less than the sum of the required individual weights.

4. Where special anchors approved as "High Holding Power Anchors" are used, the anchor weight may be 75 percent of the anchor weight as per Table 18.1 or 18.2.

"High Holding Power Anchors" are anchors which are suitable for ship's use at any time and which do not require prior adjustment or special placement on the sea bed..

For approval as a "High Holding Power Anchor", satisfactory tests are to be made on various types of sea bottom and the anchor is to have a holding power at least twice that of a patent anchor ("Admiralty Standard Stockless").

The dimensioning of the chain cable and of the windlass is to be based on the undiminished anchor weight according to the Tables.

D. Chain Cables

1. The chain cable diameters given in the Tables apply to chain cables made of chain cable materials specified in the Rules for Materials, Volume V for the following grades:

Grade KI - K1 (ordinary quality)

Grade KI - K2 (special quality)

Grade KI - K3 (extra special quality).

2. Grade KI - K1 material used for chain cables in conjunction with "High Holding Power Anchors" must have a tensile strength R_m of not less than 400 [N/mm^2].

3. The total length of chain given in the tables is to be divided into approximately equal parts for the two bower anchors.

4. Short link chain cables in accordance with DIN 766 of same proof load may be taken in lieu of stud link chain cables of up to 16 mm diameter.

5. For connecting the anchor with the chain cable approved Kenter-type anchor shackles may be chosen in lieu of common Dee-shackles.

A forerunner with swivel is to be fitted between anchor and chain cable.

In lieu of a forerunner with swivel an approved swivel shackle may be fitted. However, swivel shackles are not to be connected directly to the anchor shank unless specially approved.

A sufficient number of suitable spare shackles are to be kept on board.

6. The attachment of the inboard ends of the chain cables to the ship's structure is to be provided with a mean suitable to permit, in case of emergency, an easy slipping of the chain cables to sea operable from an accessible position outside the chain locker.

The inboard ends of the chain cables are to be secured to the structures by a fastening able to withstand a force not less than 15 % nor more than 30 % of the rated breaking load of the chain cable.

E. Chain Locker

1. The chain locker is to be of capacity and depth adequate to provide an easy direct lead of the cables through the chain pipes and self-stowing of the cables. The chain locker is to be provided with an internal division so that the port and starboard chain cables may be fully and separately stowed.

2. The chain locker boundaries and their access openings are to be watertight as necessary to prevent accidental flooding of the chain locker from damaging essential auxiliaries or equipment or affecting the proper operation of the vessel.

3. Adequate drainage facilities of the chain locker are to be provided.

4. Where the chain locker boundaries are also tank boundaries their scantlings of stiffeners and plating are to be determined as for tanks in accordance with Section 12.

Where this is not the case the plate thickness is to be determined as for t_2 and the section modulus as for W_2 in accordance with Section 12, B. 2. and B. 3. respectively. The distance from the load centre to the chain locker top is to be taken for calculating the load.

F. Ropes Instead of Chain Cables

1. For vessels of lengths between 30 and 40 m, the chain cable of one anchor may be replaced by a steel wire rope (see also 3.).

2. For vessels of less than 30 m in length the chain cables of both anchors may be replaced by steel wire ropes (see also 3.).

3. Where steel wire ropes are fitted in lieu of chain cables, the following is to be observed:

.1 The length of ropes is to be equal to 1,5 times the corresponding tabular chain cable length. The ropes' breaking load [1] is not to be less than the breaking load of the tabular chain cable of Grade KI - K1.

.2 A short length of chain cable is to be fitted between anchor and wire rope having a length of 12,5 m or equal to the distance between anchor in stowed position and winch, whichever is less.

.3 Wire rope winches are to be fitted which comply with the Rules for Machinery Installations, Volume III, Section 14, B.).

.4 Wire ropes of trawl winches may be used as anchor chain cables. Lead blocks and guide rollers shall be suitably fitted and arranged to prevent the ropes from chafing at deckhouses, superstructures, deck plating and equipment on deck. Where the rope diameter is 18 mm and greater the guide rollers are to be permanently fitted. The trawl winch is to comply with the Rules for Machinery Installations, Volume III, Section 14, B.).

4. For vessels of less than 20 m in length a manila or synthetic fibre rope of not less than 20 mm in diameter may be fitted for the second anchor in lieu of the steel wire rope permitted according to 2. The breaking load of a manila rope is not to be less than the breaking load of the chain cable. Suitable means for holding the vessel at anchor (rope winch, bollard) and for lifting the anchor (rope drum or warping head of a rope winch or a trawl winch) are to be provided. The requirements of Rules for Machinery Installations, Volume III, Section 14, B. are to be observed.

5. Where anchors of 60 kg or less are fitted, the following applies:

.1 Manila or synthetic fibre ropes may be fitted for both anchors. The length of the rope is not to be less than 1,5 times the required chain length. The rope diameter is to be not less than 20 mm.

.2 Between anchor and anchor rope a short length of chain in accordance with 3.2 is to be fitted.

.3 In lieu of the rope winch required in accordance with 3.3 other suitable means for holding the vessel at anchor and for lifting the anchor may be fitted (e.g. bollard, warping head of trawl winch or rope winch). The requirements of Rules for Machinery Installations, Volume III,, Section 14, B. are to be observed. In special cases and upon application of the owner, the winch may be dispensed with if it is proved by trials that the anchor can be dropped and lifted by hand without exposing the crew to any danger.

.4 For vessels of less than 10 m in length a winch is not required.

G. Mooring Equipment

1. The mooring ropes specified in the tables and the contents of the following sub-paragraph 2. are recommendations only, compliance with which is not a condition of Class.

2. For tow lines and mooring lines, steel wire ropes as well as fibre ropes made of natural or synthetic fibres or wire ropes consisting of steel wire and fibre cores may be used. The breaking loads specified in Table 18.1 are valid for wire ropes and ropes of natural fibre (manila) only.

Synthetic fibre ropes of same diameter may be fitted in lieu of manila ropes.

Regardless of the breaking load, the diameter of fibre ropes is not to be less than 20 mm.

3. Hawses, bollards and cleats shall be so designed as to protect the ropes from excessive wear. They are to be of proved construction and shall comply with relevant standards.

[1] The term "breaking load" used throughout this Section means the "nominal aggregate breaking load".

Table 18.1 Anchors, chain cables and ropes of Fishing Vessels

No. for Reg.	Equipment Numeral Z	Bower anchors		Stud link chain cables [1] for bower anchors				Recommended mooring ropes		
		No.	Weight per anchor	Total length	Diameter			No.	Length	Breaking load
					d_1	d_2	d_3			
			kg	m	mm	mm	mm		m	kN
1	2	3	4	5	6	7	8	9	10	11
101	up to 30	2	70	137,5	11	11	11	2	40	25
102	30 – 40	2	80	165	11	11	11	2	50	30
103	40 – 50	2	100	192,5	11	11	11	2	60	30
104	50 – 60	2	120	192,5	12,5	12,5	12,5	2	60	30
105	60 – 70	2	140	192,5	12,5	12,5	12,5	2	80	30
106	70 – 80	2	160	220	14	12,5	12,5	2	100	35
107	80 – 90	2	180	220	14	12,5	12,5	2	100	35
108	90 –100	2	210	220	16	14	14	2	110	35
109	100 –110	2	240	220	16	14	14	2	110	40
110	110 –120	2	270	247,5	17,5	16	16	2	110	40
111	120 –130	2	300	247,5	17,5	16	16	2	110	45
112	130 –140	2	340	275	19	17,5	17,5	2	120	45
113	140 –150	2	390	275	19	17,5	17,5	2	120	50
114	150 –175	2	480	275	22	19	19	2	120	55
115	175 –205	2	570	302,5	24	20,5	20,5	2	120	60
116	205 –240	2	660	302,5	26	22	20,5	2	120	65
117	240 –280	2	780	330	28	24	22	3	120	70
118	280 –320	2	900	357,5	30	26	24	3	140	80
119	320 –360	2	1020	357,5	32	28	24	3	140	85
120	360 –400	2	1140	385	34	30	26	3	140	95
121	400 –450	2	1290	385	36	32	28	3	140	100
122	450 –500	2	1440	412,5	38	34	30	3	140	110
123	500 –550	2	1590	412,5	40	34	30	4	160	120
124	550 –600	2	1740	440	42	36	32	4	160	130
125	600 –660	2	1920	440	44	38	34	4	160	145
126	660 –720	2	2100	440	46	40	36	4	160	160

[1] Studless chain cables in accordance with DIN 766 of at least same proofload may be taken in lieu of stud link chain cables of up to 16 mm diameter.

Table 18.2 Anchors, chain cables and ropes of Fishing Vessels in Coasting Service

No. for Reg.	Length L	Equipment Numeral Z_L	Bower anchors		Stud link chain cables [1)] for bower anchors			Recommended mooring ropes			
			Number	Weight per anchor	Total length	Diameter		Total length	Br. Load	Diameter	
						d_1	d_2			d_4	d_5
	m			kg	m	mm	mm	m	kN	mm	mm
1	2	3	4	5	6	7	8	9	10	11	12
101	up to 6	–	1	10	4 x L	6,0 [2)]	6,0 [2)]	35	10	–	12
102	6 - 8	–	1	20	33,0	8,0 [2)]	8,0 [2)]	40	15	–	14
103	8 - 10	–	1	30	38,0	8,0 [2)]	8,0 [2)]	55	20	–	16
104	10 - 12	–	1	50	45,0	10,0 [2)]	10,0 [2)]	65	25	–	18
105	12 - 14	–	2	60	95,0	11,0	11,0	80	25	–	18
106	14 - 17	–	2	80	110,0	11,0	11,0	100	30	10	20
107	17 - 20	–	2	95	110,0	12,5	12,5	120	30	10	20
108	20 - 40	up to 270	2	110	137,5	12,5	12,5	150	35	10	22
109		270 - 300	2	140	165,0	14,0	12,5	180	35	10	22
110		300 - 330	2	180	165,0	14,0	12,5	200	40	10	22
111		330 - 360	2	210	220,0	16,0	14,0	225	45	10	24
112		360 - 400	2	250	220,0	16,0	14,0	225	45	10	24
113		400 - 450	2	300	247,5	17,5	16,0	225	45	10	24
114		450 - 500	2	370	247,5	19,0	17,5	250	50	12	26
115		above 500	2	440	275,0	22,0	19,0	250	55	12	26

1) Studless chain cables in accordance with DIN 766 of at least same proof load may be taken in lieu of stud link chain cables of up to 16 mm diameter.

2) Studless chain cables in accordance with DIN 766.

Notes to the Tables 18.1 and 18.2

d_1 = Chain diameter Grade KI - K1 (Ordinary quality)
d_2 = Chain diameter Grade KI - K2 (Special quality) } See also D.
d_3 = Chain diameter Grade KI - K3 (Extra special quality)
d_4 = Diameter of wire rope 6 x 24, Nominal Breaking Strength : 1570 N/mm^2
d_5 = Diameter of polyamide ropes of normal construction and of manila ropes (Grade 1)
The breaking load of polyester and polypropylene ropes is to be the same as of polyamide ropes.

Section 19

Welded Joints

Preface

The contents of this Section are very much the same as those of Rules for Welding Volume VI, Section 12, G.

A. General

1. Information contained in manufacturing documents

1.1 The shapes and dimensions of welds and, where proof by calculation is supplied, the requirements applicable to welded joints (the weld quality grade, detail category) are to be stated in drawings and other manufacturing documents (parts lists, welding and inspection schedules). In special cases, e.g. where special materials are concerned, the documents shall also state the welding method, the welding consumables used, heat input and control, the weld build-up and any post-weld treatment which may be required.

1.2 Symbols and signs used to identify welded joints shall be explained if they depart from the symbols and definitions contained in the relevant standards (e.g. DIN standards). Where the weld preparation (together with approved methods of welding) conforms both to normal shipbuilding practice and to these Rules and recognized standards, where applicable, no special description is needed.

2. Materials, weldability

2.1 Only base materials of proven weldability (cf. Section 2) may be used for welded structures. Any approval conditions of the steel or of the procedure qualification tests and the steelmaker's recommendations are to be observed.

2.2 For ordinary hull structural steels grades A, B, D and E which have been tested by BKI, weldability is considered to have been proven. No measures beyond those laid down in these welding rules need therefore be taken.

2.3 Higher tensile hull structural steels grade **AH/DH/EH/FH** which have been approved by BKI in accordance with the relevant requirements of Rules for Material, have had their weldability examined and, provided their handling is in accordance with normal shipbuilding practice, may be considered to be proven.

2.4 High tensile (quenched and tempered) fine grain structural steels, low temperature steels, stainless and other (alloyed) structural steels require special approval by BKI. Proof of weldability of the respective steel is to be presented in connection with the welding procedure and welding consumables.

2.5 Cast steel and forged parts require testing by BKI. The carbon content of components for welded structures must not exceed 0,23% C (piece analysis not exceeding 0,25% C).

2.6 Aluminium alloys require testing by BKI. Proof of their weldability must be presented in connection with the welding procedure and welding consumables.

2.7 Welding consumables used are to be suitable for the parent metal to be welded and are to be approved by BKI. Where filler materials having tensile properties deviating (downwards) from the parent metal are used (upon special agreement by BKI), this fact must be taken into account when dimensioning the weld joints.

3. Manufacture and testing

3.1 The manufacture of welded structural components may only be carried out in workshops or plants that have been approved. The requirements that have to be observed in connection with the fabrication of welded joints are laid down in the Rules for Welding Volume VI.

3.2 The weld quality grade of welded joints without proof by calculation (see 1.1) depends on the significance of the welded joint for the total structure and on its location in the structural element (location to the main stress direction) and on its stressing. For details concerning the type, scope and manner of testing, see Rules for Welding Volume VI, Section 12, I. Where proof of fatigue strength is required, the details listed in Section 20 apply.

B. Design

1. General design principles

1.1 During the design stage welded joints are to be planned such as to be accessible during fabrication, to be located in the best possible position for welding and to permit the proper welding sequence to be followed.

1.2 Both the welded joints and the sequence of welding involved are to be so planned as to enable residual welding stresses to be kept to a minimum in order that no excessive deformation occurs. Welded joints should not be overdimensioned, see also 3.3.3.

1.3 When planning welded joints, it must first be established that the type and grade of weld envisaged, such as full root weld penetration in the case of **HV** or **DHV (K)** weld seams, can in fact be perfectly executed under the conditions set by the limitations of the manufacturing process involved. If this is not the case, a simpler type of weld seam shall be selected and its possibly lower load bearing capacity taken into account when dimensioning the component.

1.4 Highly stressed welded joints - which, therefore, are generally subject to examination are to be so designed that the most suitable method of testing for faults can be used (radiography, ultrasonic, surface crack testing methods) in order that a reliable examination may be carried out.

1.5 Special characteristics peculiar to the material, such as the lower strength values of rolled material in the thickness direction (see 2.5.1) or the softening of cold worked aluminium alloys as a result of welding, are factors which have to be taken into account when designing welded joints. Clad plates where the efficiency of the bond between the base and the clad material is proved may generally be treated as solid plates (up to medium plate thicknesses where mainly fillet weld connections are used).

1.6 In cases where different types of material are paired and operate in sea water or any other electrolytic medium, for example welded joints made between unalloyed carbon steels and stainless steels in the wear-resistant cladding in rudder nozzles or in the cladding of rudder shafts, the resulting differences in potential greatly increase the susceptibility to corrosion and must therefore be given special attention. Where possible, such welds are to be positioned in locations less subject to the risk of corrosion (such as on the outside of tanks) or special protective counter-measures are to be taken (such as the provision of a protective coating or cathodic protection).

2. Design details

2.1 Stress flow, transitions

2.1.1 All welded joints on primary supporting members shall be designed to provide as smooth a stress profile as possible with no major internal or external notches, no discontinuities in rigidity and no obstructions to strains (cf. Section 3, H.).

2.1.2 This applies in analogous manner to the welding of subordinate components on to primary supporting members whose exposed plate or flange edges should, as far as possible, be kept from notch effects due to welded attachments. Regarding the inadmissibility of weldments to the upper edge of the sheer strake, see Section 6, C.3.4. This applies similarly to weldments to the upper edge of continuous hatchway side coamings.

2.1.3 Butt joints in long or extensive continuous structures such as bilge keels, fenders, slop coamings, etc. attached to primary structural members are therefore to be welded over their entire cross section.

2.1.4 Wherever possible, joints (especially site joints) in girders and sections shall not be located in areas of high bending stress. Joints at the knuckle of flanges are to be avoided.

2.1.5 The transition between differing component dimensions shall be smooth and gradual. Where the depth of web of girders or sections differs, the flanges or bulbs are to be bevelled and the web slit and expanded or pressed together to equalize the depths of the members. The length of the transition should be at least equal twice the difference in depth.

2.1.6 Where the plate thickness differs at joints perpendicularly to the direction of the main stress, differences in thickness greater than 3 mm must be accommodated by bevelling the proud edge in the manner shown in Fig. 19.1 at a ratio of at least 1 : 3 or according to the notch category. Differences in thickness of 3 mm or less may be accommodated within the weld.

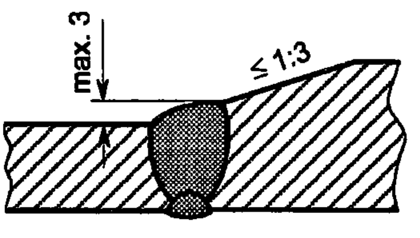


Fig. 19.1 Accommodation of differences of thickness

2.1.7 For the welding on of plates or other relatively thin-walled elements, steel castings and forgings should be appropriately tapered or provided with integrally cast or forged welding flanges in accordance with Fig. 19.2.

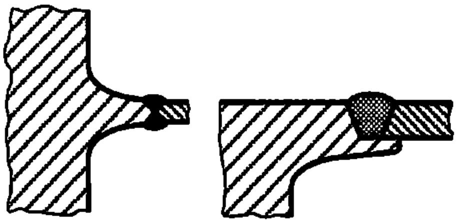


Fig. 19.2 Welding flanges on steel castings or forgings

2.1.8 For the connection of shaft brackets to the hub and shell plating, see 4.3 and Section 13, D.2.; for the connection of horizontal coupling flanges to the rudder body, see 4.4 For the thickened rudder stock collar required with build-up welds and for the connection of the coupling flange, see 2.7 and Section 14, D.2.4. The joint between the rudder stock and the coupling flange must be welded over the entire cross-section.

2.2 Local clustering of welds, minimum spacing

2.2.1 The local clustering of welds and short & distances between welds are to be avoided. Adjacent butt welds should be separated from each other by a distance of at least

50 mm + 4 x plate thickness.

Fillet welds should be separated from each other and from butt welds by a distance of at least

30 mm + 2 x plate thickness.

The width of replaced or inserted plates (strips) should, however, be at least 300 mm or ten times the plate thickness, whichever is the greater.

2.2.2 Reinforcing plates, welding flanges, mountings and similar components socket-welded into plating should be of the following minimum size:

D_{min} = $170 + 3\ (t - 10) \geq 170$ mm

D = diameter of round or length of side of angular weldments in [mm]

t = plating thickness in [mm].

The corner radii of angular socket weldments should be 5t in [mm] but at least 50 mm. Alternatively the "longitudinal seam" are to extend beyond the "transverse seam". Socket weldments are to be fully welded to the surrounding plating. Regarding the increase of stress due to different thickness of plates see also Section 20, B.1.3.

2.3 Welding cut-outs

2.3.1 Welding cut-outs for the (later) execution of butt or fillet welds following the positioning of transverse members should be rounded (minimum radius 25 mm or twice the plate thickness, whichever is the greater) and should be shaped to provide a smooth transition on the adjoining surface as shown in Fig. 19.3 (especially necessary where the loading is mainly dynamic).

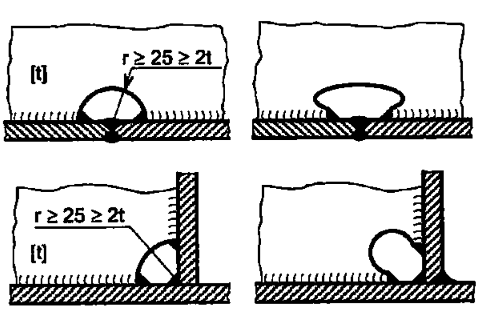


Fig. 19.3 Welding cut-outs

2.3.2 Where the welds are completed prior to the positioning of the crossing members, no welding cut-outs are needed. Any weld reinforcements present are to be machined off prior to the location of the crossing members or these members are to have suitable cut-outs.

2.4 Local reinforcements, doubling plates

2.4.1 Where plating (including girder plates and tube walls) are subjected locally to increased stresses, thicker plates should be used wherever possible in preference to doubling plates. Bearing bushes, hubs etc. shall invariably take the form of thicker sections welded into the plating (cf. 2.2.2).

2.4.2 Where doublings cannot be avoided, the thickness of the doubling plates should not exceed twice the plating thickness. Doubling plates whose width is greater than approximately 30 times their thickness shall be plug welded to the underlying plating in accordance with 3.3.11 at intervals not exceeding 30 times the thickness of the doubling plate.

2.4.3 Along their (longitudinal) edges, doubling plates shall be continuously fillet welded with a throat thickness "a" of 0,3 x the doubling plate thickness. At the ends of doubling plates, the throat thickness "a" at the end faces shall be increased to 0,5 x the doubling plate thickness but shall not exceed the plating thickness (see Fig. 19.4).

The welded transition at the end faces of the doubling plates to the plating should form with the latter an angle of 45° or less.

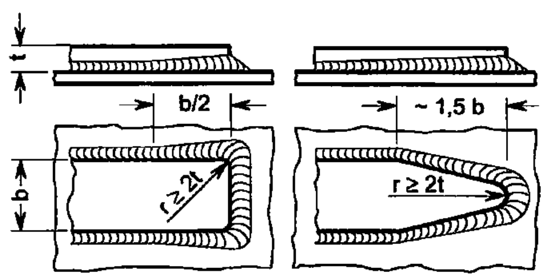


Fig. 19.4 The ends of doubling plates

2.4.4 Where proof of fatigue strength is required (see Section 20), the configuration of the end of the doubling plate must conform to the selected detail category.

2.4.5 Doubling plates are not permitted in tanks for flammable liquids.

2.5 Intersecting members, stress in the thickness direction

2.5.1 Where, in the case of intersecting members, plates or other rolled products are stressed in the thickness direction by shrinking stresses due to the welding and/or applied loads, suitable measures shall be taken in the design and fabrication of the structures to prevent lamellar tearing (stratified fractures) due to the anisotropy of the rolled products.

2.5.2 Such measures include the use of suitable weld shapes with a minimum weld volume and a welding sequence designed to reduce transverse shrinkage. Other measures are the distribution of the stresses over a larger area of the plate surface by using a build-up weld or the joining together of several "fibres" of members stressed in the thickness direction as exemplified by the deck stringer/sheer strake joint shown in Fig. 19.12.

2.5.3 Where there are very severe stresses in the thickness direction due, for example, to the aggregate effect of the shrinkage stresses of bulky single or double-bevel butt welds plus high applied loads, it is advisable to use plates with guarantied through thickness properties (extra high-purity material and guarantied minimum reductions in area of tensile test specimens taken in thickness direction)[1].

2.6 Welding of cold formed sections, bending radii

2.6.1 Wherever possible, welding should be avoided at the cold formed sections with more than 5% permanent elongation[2] and in the adjacent areas of structural steels with a tendency towards strain ageing.

2.6.2 Welding may be performed at the cold formed sections and adjacent areas of hull structural steels and comparable structural steels according to recognized standard provided that the minimum bending radii are not less than those specified in Table 19.1.

Table 19.1

Plate thickness t		Minimum inner bending radius r
up to	4 mm	1,0 x t
up to	8 mm	1,5 x t
up to	12 mm	2,0 x t
up to	24 mm	3,0 x t
over	24 mm	5,0 x t

Note :

The bending capacity of the material may necessitate a larger bending radius.

2.6.3 For other steels and other materials, where applicable, the necessary minimum bending radius shall in case of doubt, be established by test. Proof of adequate toughness after welding may be stipulated for steels with minimum nominal upper yield point of more than 355 N/mm^2 and plate thicknesses of 30 mm and above which have undergone cold forming resulting in 2% or more permanent elongation.

1) See Rules for Welding, Volume VI, Section 3, H and also Supply Conditions as recommended by the steelmaker's.

2) Elongation ε in the outer tensile-stressed zone

$$\varepsilon = \frac{100}{1 + 2\ r/t}\ [\%]$$

r = inner bending radius in [mm]
t = plate thickness in [mm]

2.7 Build - up welds on rudderstocks and pintles

2.7.1 Wear resistance and/or corrosion resistant build-up welds on the bearing surfaces of rudderstocks, pintles etc. shall be applied to a thickened collar exceeding by at least 20 mm the diameter of the adjoining part of the shaft.

2.7.2 Where a thickened collar is impossible for design reasons, the build-up weld may be applied to the smooth shaft provided that relief-turning in accordance with 2.7.3 is possible (leaving an adequate residual diameter).

2.7.3 After welding, the transition areas between the welded and non-welded portions of the shaft shall be relief-turned with large radii, as shown in Fig. 19.5, to remove any base material whose structure close to the concave groove has been altered by the welding operation and in order to effect the physical separation of geometrical and metallurgical "notches".

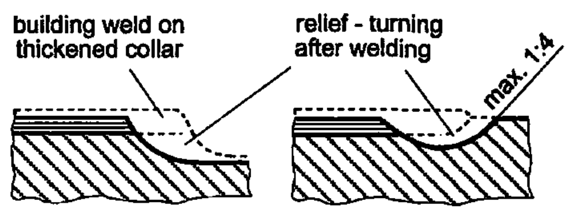


Fig. 19.5 Build-up welds applied to rudderstocks and Pintles

3. Weld shapes and dimensions

3.1 Butt joints

3.1.1 Depending on the plate thickness, the welding method and the welding position, butt joints shall be of the square, V or double-V shape conforming to the relevant standards. Where other weld shapes are applied, these are to be specially described in the drawings. Weld shapes for special welding processes such as single-side or electroslag welding must have been tested and approved in the context of a welding procedure test.

3.1.2 As a matter of principle, the rear sides of butt joints shall be grooved and welded with at least one capping pass. Exceptions to this rule, as in the case of submerged-arc welding or the welding processes mentioned in 3.1.1, require to be tested and approved in connection with a welding procedure test. The effective weld thickness shall be deemed to be the plate thickness, or, where the plate thicknesses differ, the lesser plate thickness. Where proof of fatigue strength is required (see Section 20), the detail category depends on the execution (quality) of the weld.

3.1.3 Where the aforementioned conditions cannot be met, e.g. where the welds are accessible from one side only, the joints shall be executed as lesser bevelled welds with an open root and an attached or an integrally machined or cast, permanent weld pool support (backing) as shown in Fig. 19.6.

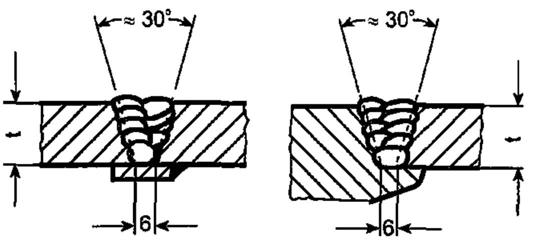


Fig. 19.6 Single-side welds with permanent weld pool support (backings)

3.1.4 The weld shapes illustrated in Fig. 19.7 shall be used for clad plates. These weld shapes shall be used in analogous manner for joining clad plates to (unalloyed and low alloyed) hull structural steels.

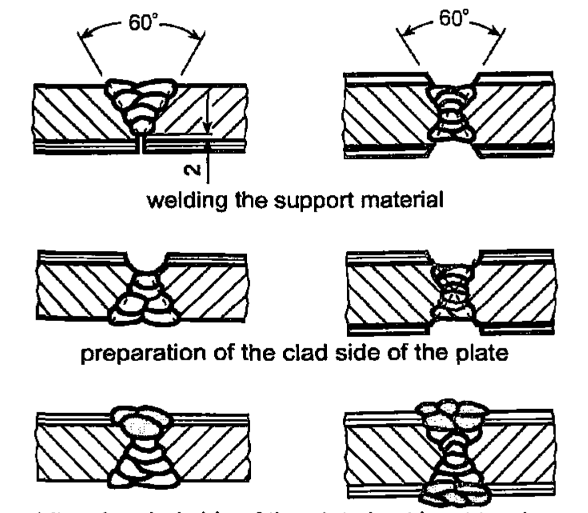


Fig. 19.7 Weld shapes for welding of clad plates

3.2 Corner, T and double-T (cruciform) joints

3.2.1 Corner, T and double-T (cruciform) joints with complete union or the abutting plates shall be made as single or double-bevel welds with a minimum root face and adequate air gap, as shown in Fig. 19.8, and with grooving of the root and capping from the opposite side.

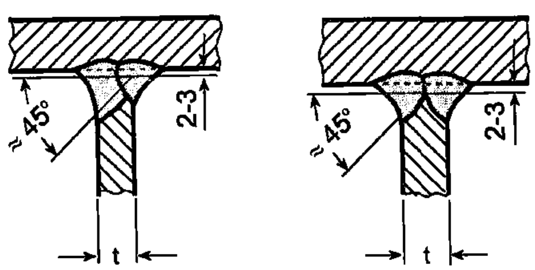


Fig. 19.8 Single and double-bevel welds with full root penetration

The effective weld thickness shall be assumed as the thickness of the abutting plate. Where proof of fatigue strength is required (see Section 20), the detail category depends on the execution (quality) of the weld.

3.2.2 Corner, T and double-T (cruciform) joints with a defined incomplete root penetration, as shown in Fig. 19.9, shall be made as single or double-bevel welds, as described in 3.2.1, with a back-up weld but without grooving of the root.

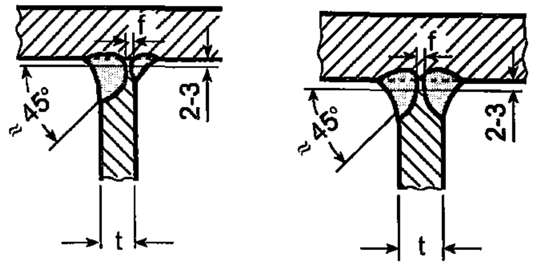


Fig. 19.9 Single and double-bevel welds with defined incomplete root penetration

The effective weld thickness may be assumed as the thickness of the abutting plate t, where f is the incomplete root penetration of 0,2 t with a maximum of 3 mm, which is to be balanced by equally sized double fillet welds on each side. Where proof of fatigue strength is required (see Section 20), these welds are to be assigned to type 21.

3.2.3 Corner, T and double-T (cruciform) joints with both an unwelded root face c and a defined incomplete root penetration f shall be made in accordance with Fig. 19.10.

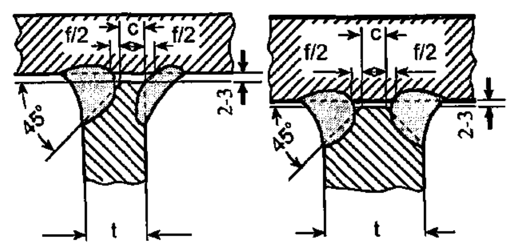


Fig. 19.10 Single and double-bevel welds with unwelded root face and defined incomplete root penetration

The effective weld thickness shall be assumed as the thickness of the abutting plate t minus (c + f), where f is to be assigned a value of 0,2 t subject to a maximum of 3 mm. Where proof of fatigue strength is required (see Section 20), these welds are to be assigned to types 22 or 23.

3.2.4 Corner, T and double-T (cruciform) joints which are accessible from one side only may be made in accordance with Fig. 19.11 in a manner analogous to the butt joints referred to in 3.1.3 using a weld pool support (backing), or as single side, single bevel welds in a manner similar to those prescribed in 3.2.2.

The effective weld thickness shall be determined by analogy with 3.1.3 or 3.2.2, as appropriate. Wherever possible, these joints should not be used where proof of fatigue strength is required (see Section 20).

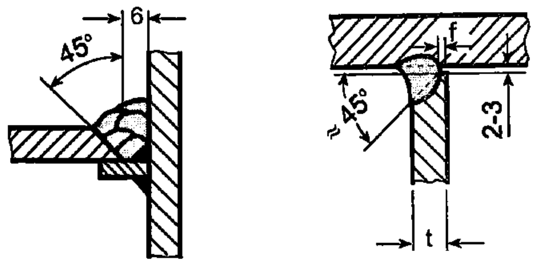


Fig. 19.11 Single-side welded T joints

3.2.5 Where corner joints are flush; the weld shapes shall be as shown in Fig. 19.12 with bevelling of at least 30° of the vertically drawn plates to avoid the danger of lamellar tearing. A similar procedure is to be followed in the case of fitted T joints (uniting three plates) where the abutting plate is to be socketed between the aligned plates.

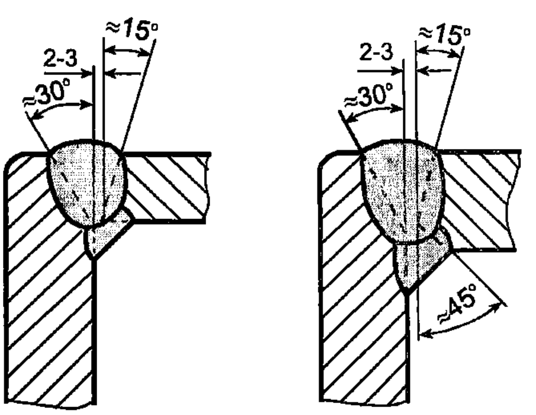


Fig. 19.12 Flush fitted corner joints

3.2.6 Where, in the case of T joints, the direction of the main stress lies in the plane of the horizontal plates (e.g. the plating) shown in Fig. 19.13 and where the connection of the perpendicular (web) plates is of secondary importance, welds uniting three plates may be made in accordance with Fig. 19.13 (with the exception of those subjected mainly to dynamic loads).

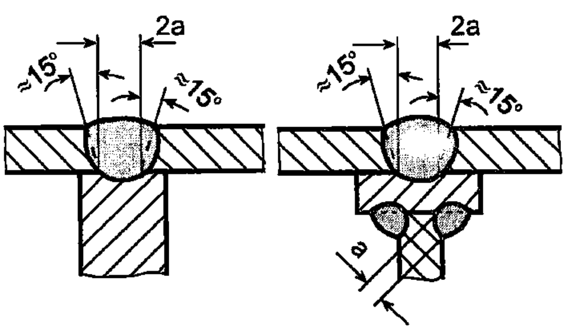


Fig. 19.13 Welding together three plates

The effective thickness of the weld connecting the horizontal plates shall be determined in accordance with 3.2.2. The requisite "a" dimension is determined by the joint uniting the vertical (web) plates and shall, where necessary, be determined an accordance with Table 19.3 or by calculation as for fillet welds.

3.3 Fillet weld connections

3.3.1 In principle fillet welds are to be of the double fillet weld type. Exceptions to this rule (as in the case of closed box girders and mainly shear stresses parallel to the weld) are subject to approval in each individual case. The throat thickness "a" of the weld (the height of the inscribed isosceles triangle) shall be determined in accordance with Table 19.3 or by calculation according to C. The leg length of a fillet weld is to be not less than 1,4 times the throat thickness "a". For fillet welds at doubling plates, see 2.4.3; for the welding of the deck stringer to the sheer strake, see Section 7, A.2.1, and for bracket joints, see C.2.7.

3.3.2 The relative fillet weld throat thicknesses specified in Table 19.3 relate to ordinary and higher tensile hull structural steels and comparable structural steels. They may also be generally applied to high-strength structural steels and non-ferrous metals provided that the "tensile shear strength" of the weld metal used is at least equal to the tensile strength of the base material. Failing this, the "a" dimension shall be increased accordingly and the necessary increment shall be established during the welding procedure test (see Rules for Welding , Volume VI). Alternatively proof by calculation taking account of the properties of the weld metal may be presented.

Note :

In case of higher strength aluminium alloys (e.g. : Al Mg 4,5 Mn), such an increment may be necessary for cruciform joint subject to tensile stresses, as experience shows that in the welding procedure tests the tensile - shear strength of fillet welds (made with matching filler metal) often fails to attain the tensile strength of the base material. See also Rules for Welding, Volume VI. Section 12, F.5.2.3.

3.3.3 The throat thickness of fillet welds shall not exceed 0,7 times the lesser thickness of the parts to be connected (generally the web thickness). The minimum throat thickness is defined by the expression:

$$a_{min} = \sqrt{\frac{t_1 + t_2}{3}} \quad \text{[mm]}$$

but not less than 3 mm

t_1 = lesser (e.g. the web) plate thickness in [mm]

t_2 = greater (e.g. the flange) plate thickness in [mm].

3.3.4 It is desirable that the fillet weld section shall be not faced with smooth transitions to the base material. Where proof of fatigue strength is required (see Section 20), machining of the weld (grinding to remove notches) may be required depending on the notch category. The weld should penetrate at least close to the theoretical root point.

3.3.5 Where mechanical welding processes are used which ensure deeper penetration extending well beyond the theoretical root point and where such penetration is uniformly and dependably maintained under production conditions, approval may be given for this deeper penetration to be allowed for in determining the throat thickness. The effective dimension:

$$a_{deep} = a + \frac{2 \text{ min e}}{3} \quad [\text{mm}]$$

shall be ascertained in accordance with Fig. 19.14 and by applying the term "min e" to be established for each welding process by a welding procedure test. The throat thickness shall not be less than the minimum throat thickness related to the theoretical root point.

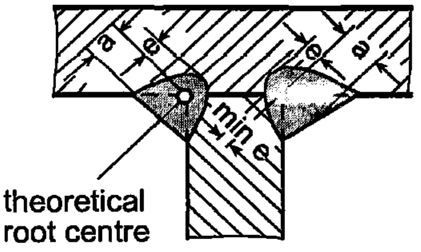


Fig. 19.14 Fillet welds with increased penetration

3.3.6 When welding on top of shop primers which are particularly liable to cause porosity, an increase of the "a" dimension by up to 1 mm may be stipulated depending on the welding process used. This is specially applicable where minimum fillet weld throat thicknesses are employed. The size of the increase shall be decided on a case to case basis considering the nature and severity of the stressing following the test results of the shop primer in accordance with the Rules for Welding, Volume VI. This applies in analogous manner to welding processes where provision has to be made for inadequate root penetration.

3.3.7 Strengthened filled welds continuous on both sides are to be used in areas subjected to severe dynamic loads (e.g. for connecting the longitudinal and transverse girders of the engine base to top plates close to foundation bolts, cf. Section 8, C.3.2.5 and Table 19.3), unless single or double bevel welds are stipulated in these locations. In these areas the "a" dimension shall equal 0,7 times the lesser thickness of the parts to be welded.

3.3.8 Intermittent fillet welds in accordance with Table 19.3 may be located opposite one another (chain intermittent welds, possibly with scallops) or may be staggered (see Fig. 19.15). In case of small sections other types of scallops may be accepted.

In water and cargo tanks, in the bottom area of fuel oil tanks and of spaces where condensed or sprayed water may accumulate and in hollow components (e.g. rudders) threatened by corrosion, only continuous or intermittent fillet welds with scallops shall be used[3]. This applies accordingly also to areas, structures or spaces exposed to extreme environmental conditions or which are exposed to corrosive cargo.

There shall be no scallops in areas where the plating is subjected to severe local stresses (e.g. in the bottom section of the fore ship) and continuous welds are to be preferred where the loading is mainly dynamic.

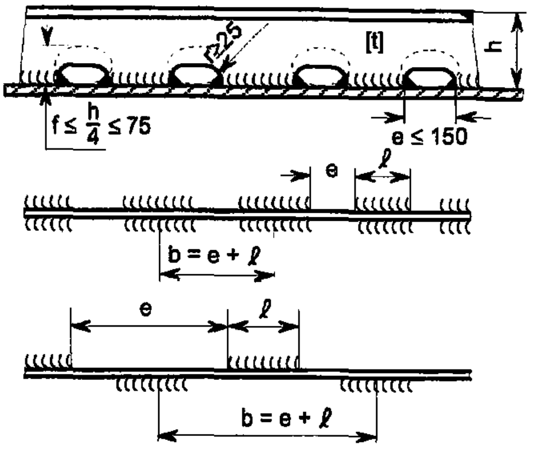


Fig. 19.15 Scallop, chain and staggered welds

3.3.9 The throat thickness a_u of intermittent fillet welds is to be determined according to the selected pitch ratio b/ℓ by applying the formula:

$$a_u = 1{,}1 \cdot a \cdot \left[\frac{b}{\ell}\right] \quad [\text{mm}]$$

a = required fillet weld throat thickness in [mm] for a continuous weld according to Table 19.3 or determined by calculation

b = pitch = e + ℓ in [mm]

e = interval between the welds in [mm]

ℓ = length of fillet weld in [mm]

The pitch ratio b/ℓ should not exceed 5. The maximum unwelded length (b - ℓ with scallop and chain welds, or b/2 - ℓ with staggered welds) should not exceed 25 times the lesser thickness of the parts to be welded. The length of scallops should, however, not exceed 150 mm.

3.3.10 Lap joints should be avoided wherever possible and are not to be used for heavily loaded components. In the case of components subject to low loads lap joints may be accepted provided that, wherever possible, they are orientated parallel to the direction of the main stress. The width of the lap shall be 1,5 t + 15 mm (t = thickness of the thinner plate). Except where another value is determined by calculation, the fillet weld throat thickness "a" shall equal 0,4 times the lesser plate thickness, subject to the

[3] In special cases deviation from this requirement may be considered.

requirement that it shall not be less than the minimum throat thickness required by 3.3.3. The fillet weld must be continuous on both sides and must meet at the ends.

3.3.11 In the case of plug or slot welding, the plugs should, wherever possible, take the form for elongated holes lying in the direction of the main stress. The distance between the holes and the length of the holes may be determined by analogy with the pitch "b" and the fillet weld length "ℓ" in the intermittent welds covered by 3.3.8. The fillet weld throat thickness "a_u" may be established in accordance with 3.3.9. The width of the holes shall be equal to at least twice the thickness of the plate and shall not be less than 15 mm. The ends of the holes shall be semi-circular. Plates or sections placed underneath should at least equal the perforated plate in thickness and should project on both sides to a distance of 1,5 x the plate thickness subject to a maximum of 20 mm. Wherever possible only the necessary fillet welds shall be welded, while the remaining void is packed with a suitable filler. Lug joint welding is not allowed.

4. Welded joints of particular components

4.1 Welds at the ends of girders and stiffeners

4.1.1 As shown in Fig. 19.16, the web at the end of intermittently welded girders or stiffeners is to be continuously welded to the plating or the flange plate, as applicable, over a distance at least equal to the depth "h" of the girder or stiffener subject to a maximum of 300 mm. Regarding the strengthening of the welds at the ends, extending normally over 0,15 of the span, see Table 19.3.

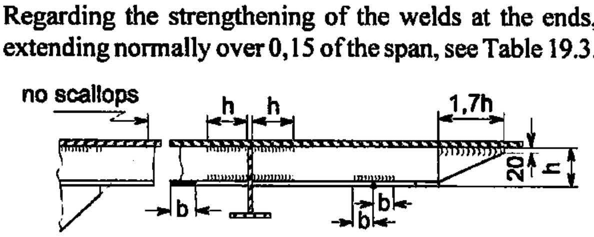


Fig. 19.16 Welds at the ends of girders and stiffeners

4.1.2 The areas of bracket plates should be continuously welded over a distance at least equal to the length of the bracket plate. Scallops are to be located only beyond a line imagined as an extension of the free edge of the bracket plate.

4.1.3 Wherever possible, the free ends of stiffeners shall abut against the transverse plating or the webs of sections and girders so as to avoid stress concentrations in the plating. Failing this, the ends of the stiffeners are to be sniped and continuously welded over a distance of at least 1,7 h subject to a maximum of 300 mm.

4.1.4 Where butt joints occur in flange plates, the flange shall be continuously welded to the web on both sides of the joint over a distance at least equal to the width of the flange.

4.2 Joints between section ends and plates

4.2.1 Welded joints connecting section ends and plates may be made in the same plane or lapped. Where no design calculations have been carried out or stipulated for the welded connections, the joints may be made analogously to those shown in Fig. 19.17.

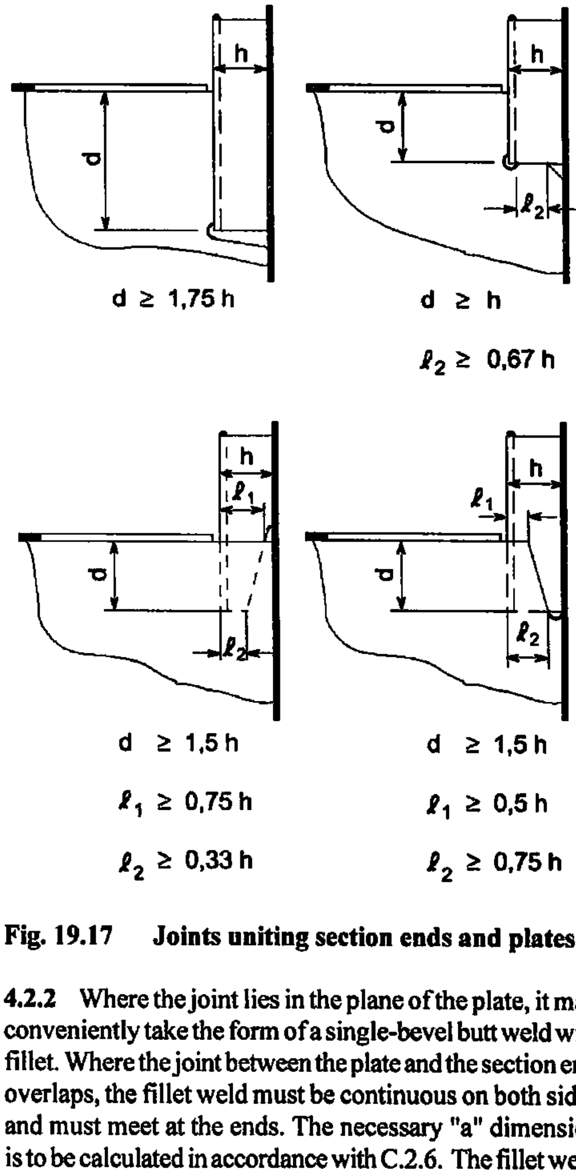


Fig. 19.17 Joints uniting section ends and plates

4.2.2 Where the joint lies in the plane of the plate, it may conveniently take the form of a single-bevel butt weld with fillet. Where the joint between the plate and the section end overlaps, the fillet weld must be continuous on both sides and must meet at the ends. The necessary "a" dimension is to be calculated in accordance with C.2.6. The fillet weld throat thickness is not to be less than the minimum specified in 3.3.3.

4.3 Welded shaft bracket joints

4.3.1 Unless cast in one piece or provided with integrally cast welding flanges analogous to those prescribed in 2.1.7 (see Fig. 19.18), strut barrel and struts are to be connected to each other and to the shell plating in the manner shown in Fig. 19.19.

4.3.2 In the case of single-strut shaft brackets no welding is to be performed on the arm at or close to the position of constraint. Such components must be provided with integrally forged or cast welding flanges.

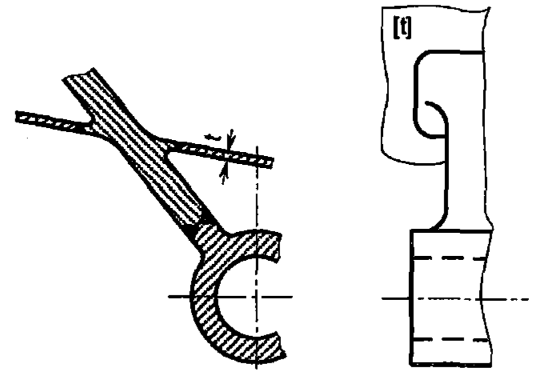
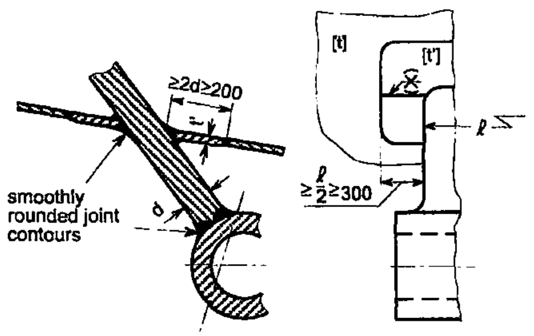


Fig. 19.18 **Shaft bracket with integrally cast welding flanges**



plating thickness in accordance with Section 6, F. in [mm]

$$t' = \frac{d}{3} + 5 \quad [\text{mm}] \quad \text{where } d < 50\text{mm}$$

$$t' = 3\sqrt{d} \quad [\text{mm}] \quad \text{where } d \geq 50\text{mm}$$

For shaft brackets of elliptically shaped cross section d may be substituted by 2/3 d in the above formulae.

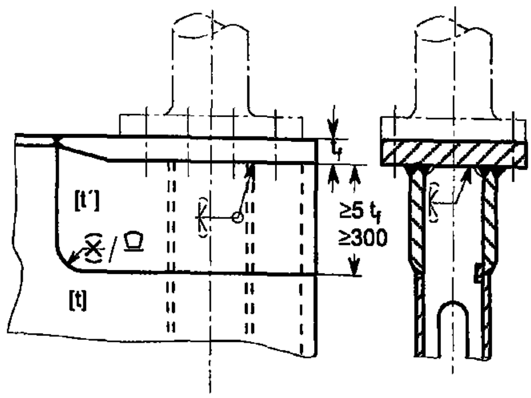
Fig. 19.19 **Shaft bracket without integrally cast welding flanges**

4.4 Rudder coupling flanges

4.4.1 Unless forged or cast steel flanges with integrally forged or cast welding flanges in conformity with 2.1.7 are used, horizontal rudder coupling flanges are to be joined to the rudder body by plates of graduated thickness and full penetration single or double-bevel welds as prescribed in 3.2.1 (see Fig. 19.20). See also Section 14, D.1.4 and D.2.4.

4.4.2 Allowance shall be made for the reduced strength of the coupling flange in the thickness direction (cf. 1.5 and 2.5). In case of doubt, proof by calculation of the adequacy of the welded connection shall be produced.

4.4.3 The welded joint between the rudder stock (with thickened collar, cf. 2.1.8) and the flange shall be made in accordance with Fig. 19.21.



t = plate thickness in accordance with Section 14, E.3.1 [mm]

t_f = actual flange thickness in [mm]

$$t' = \frac{t_f}{3} + 5 \quad [\text{mm}] \quad \text{where } t_f < 50 \text{ mm}$$

$$t' = 3\sqrt{t_f} \quad [\text{mm}] \quad \text{where } t_f \geq 50 \text{ mm}$$

Fig. 19.20 **Horizontal rudder coupling flanges**

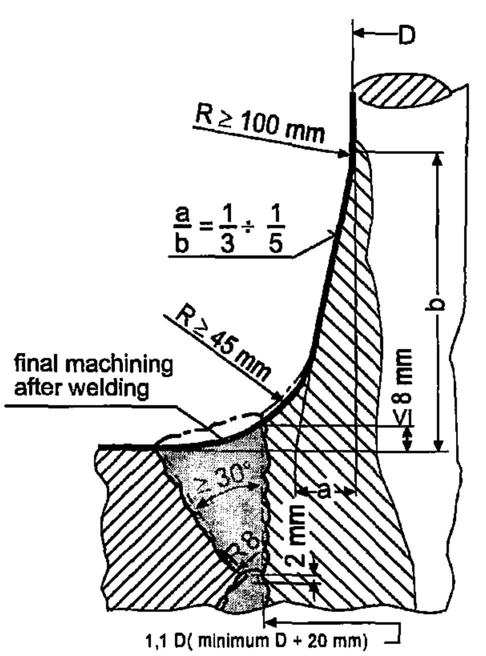


Fig. 19.21 **Welded joint between rudder stock and coupling flange**

C. Stress Analysis

1. General analysis of fillet weld stresses

1.1 Definition of stresses

For calculation purposes, the following stresses in a fillet weld are defined (see also Fig. 19.22):

$\sigma\perp$ = normal stresses acting vertically to the direction of the weld seam

$\tau\perp$ = shear stress acting vertically to the direction of the weld seam

$\tau_{||}$ = shear stress acting in the direction of the weld seam.

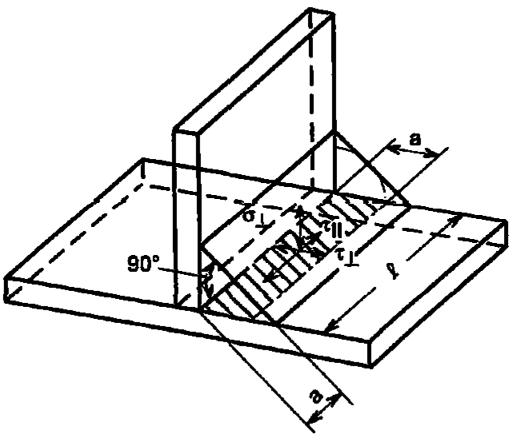


Fig. 19. 22

Normal stresses acting in the direction of the weld seam need not be considered.

For calculation purposes the weld seam area is $a \cdot \ell$

For reasons of equilibrium the following applies to the flank area vertical to the shaded weld seam area

$$\tau\perp = \sigma\perp$$

The equivalent stress is to be calculated by the following formula:

$$\sigma_v = \sqrt{\sigma_\perp^2 + \tau_\perp^2 + \tau_{||}^2}$$

1.2 Definitions

a = throat thickness in [mm]

ℓ = length of fillet weld in [mm]

P = single force in [N]

M = bending moment at the position considered in [Nm]

Q = shear force at the point considered in [N]

S = first moment of the cross sectional area of the flange connected by the weld to the web in relationship to the neutral beam axis in [cm^3]

I = moment of inertia of the girder section in [cm^4]

W = section modulus of the connected section in [cm^3].

2. Determination of stresses

2.1 Fillet welds stressed by normal and shear forces

Flank and frontal welds are regarded as being equal for the purposes of stress analysis. In view of this, normal and shear stresses are calculated as follows:

$$\sigma = \tau = \frac{P}{\Sigma\, a \cdot \ell} \quad [N/mm^2]$$

Joint as shown in Fig. 19.23:

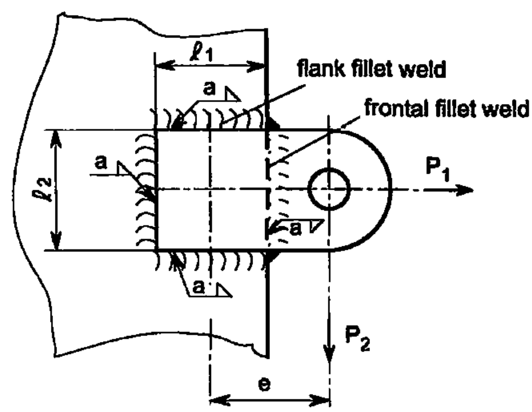


Fig. 19.23

- Stresses in frontal fillet welds:

$$\tau\perp = \frac{P_1}{2 \cdot a(\ell_1 + \ell_2)} \quad [N/mm^2]$$

$$\tau_{||} = \frac{P_2}{2 \cdot a\,(\ell_1 + \ell_2)} \pm \frac{P_2 \cdot e}{2 \cdot a \cdot F_t} \quad [N/mm^2]$$

$$F_t = (\ell_1 + a)\,(\ell_2 + a) \quad [mm^2]$$

- Stresses in flank fillet welds :

$$\tau\perp = \frac{P_2}{2 \cdot a\,(\ell_1 + \ell_2)} \quad [N/mm^2]$$

$$\tau_{||} = \frac{P_1}{2 \cdot a\,(\ell_1 + \ell_2)} \pm \frac{P_2 \cdot e}{2 \cdot a \cdot F_t} \quad [N/mm^2]$$

ℓ_1, ℓ_2, e in [mm]

- Equivalent stress for frontal and flank fillet welds:

$$\sigma_v = \sqrt{\tau_\perp^2 + \tau_{||}^2} \quad [N/mm^2]$$

Joint as shown in Fig. 19.24:

$$\tau\perp = \frac{P_2}{2 \cdot \ell \cdot a} + \frac{3 \cdot P_1 \cdot e}{\ell^2 \cdot a} \quad [N/mm^2]$$

$$\tau_{||} = \frac{P_1}{2 \cdot \ell \cdot a} \quad [N/mm^2]$$

- Equivalent stress :

$$\sigma_v = \sqrt{\tau_\perp^2 + \tau_\parallel^2} \qquad [N/mm^2]$$

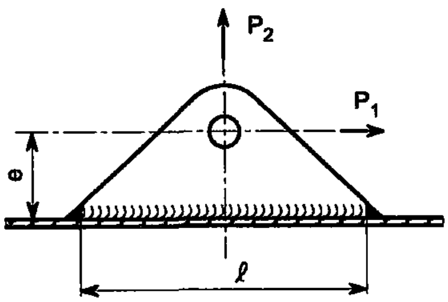


Fig. 19.24

2.2 Fillet weld joints stressed by bending moments and shear forces

The stresses at the fixing point of a girder are calculated as follows (in Fig. 19.25 a cantilever beam is given as an example) :

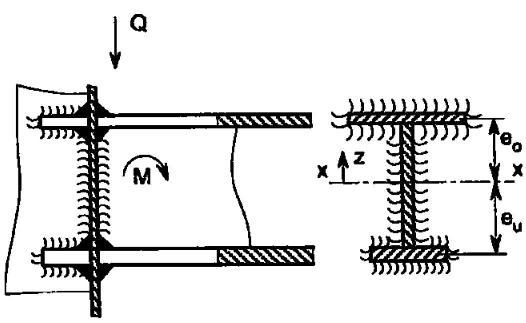


Fig. 19.25

.1 Normal stress due to bending moment:

$$\sigma\perp(z) = \frac{M}{I_s} z \; [N/mm^2]$$

$$\sigma\perp_{max} = \frac{M}{I_s} e_u \quad [N/mm^2], \text{ if } e_u > e_0$$

$$\sigma\perp_{max} = \frac{M}{I_s} e_0, \quad [N/mm^2], \text{ if } e_u < e_0$$

.2 Shear stress due to shear force:

$$\tau_\parallel(z) = \frac{Q \cdot S_s(z)}{10 \cdot I_s \cdot \Sigma a} \; [N/mm^2]$$

$$\tau_{\parallel max} = \frac{Q \cdot S_{smax}}{20 \cdot I_s \cdot a} \quad [N/mm^2]$$

I_s = moment of inertia of the welded joint related to the x-axis in [cm^4]

$S_s(z)$ = the first moment of the connected weld section at the point under consideration in [cm^3]

z = distance from the neutral axis in [cm].

.3 Equivalent stress :

It has to be proved that neither $\sigma\perp_{max}$ in the region of the flange nor $\tau_{\parallel max}$ in the region of the neutral axis nor the equivalent stress $\sigma_v = \sqrt{\tau_\perp^2 + \tau_\parallel^2}$ exceed the permitted limits given in 2.8 at any given point. The equivalent stress σ_v should always calculated at the web-flange connection.

2.3 Fillet welded joints stressed by bending and torsional moments and shear forces

Regarding the normal and shear stresses resulting from bending, see 2.2. Torsional stresses resulting from the torsional moment M_T are to be calculated:

$$\tau_T = \frac{M_T \cdot 10^3}{2 \cdot a \cdot A_m} \quad [N/mm^2]$$

M_T = torsional moment in [Nm]

A_m = sectional area in [mm^2] enclosed by the weld seam.

The equivalent stress composed of all three components (bending, shear and torsion) is calculated by means of the following formulae:

$$\sigma_v = \sqrt{\sigma_\perp^2 + \tau_\parallel^2 + \tau_T^2} \qquad [N/mm^2]$$

where $\tau_\parallel$ and τ_T have not the same direction

$$\sigma_v = \sqrt{\sigma_\perp^2 + (\tau_\parallel + \tau_T)^2} \quad [N/mm^2]$$

where $\tau_\parallel$ and τ_T have the same direction.

2.4 Continuous fillet welded joints between web and flange of bending girders

The stresses are to be calculated in way of maximum shear forces. Stresses in the weld's longitudinal direction need not to be considered. In the case of continuous double fillet weld connections the shear stress is to be calculated as follows:

$$\tau_\parallel = \frac{Q \cdot S}{20 \cdot I \cdot a} \qquad [N/mm^2]$$

The fillet weld thickness required is:

$$a_{req} = \frac{Q \cdot S}{20 \cdot I \cdot \tau_{perm}} \quad [N/mm^2]$$

2.5 Intermittent fillet welded joints between web and flange of bending girders

Shear stress :

$$\tau_\parallel = \frac{Q \cdot S \cdot \alpha}{20 \cdot I \cdot a}\left[\frac{b}{\ell}\right] \qquad [N/mm^2]$$

b = pitch

α = 1,1 stress concentration factor which takes into account increases in shear stress at the ends of the fillet weld seam "ℓ ".

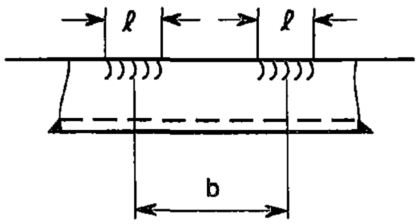


Fig. 19.26

The fillet weld thickness required is :

$$a_{req} = \frac{Q \cdot S \cdot 1{,}1}{20 \cdot I \cdot \tau_{perm}} \left[\frac{b}{\ell}\right] \quad [\text{mm}]$$

2.6 Fillet weld connections on overlapped profile joints

.1 Profiles joined by means of two flank fillet welds (see Fig. 19.27):

$$\tau_{\perp} = \frac{Q}{2 \cdot a \cdot d} \qquad [\text{N/mm}^2]$$

$$\tau_{||} = \frac{M \cdot 10^3}{2 \cdot a \cdot c \cdot d} \qquad [\text{N/mm}^2]$$

The equivalent stress is :

$$\sigma_v = \sqrt{\sigma_{\perp}^2 + \tau_{||}^2} \qquad [\text{N/mm}^2]$$

c, d, ℓ_1, ℓ_2, r in [mm] see Fig. 19.27

$$c = r + \frac{3\ell_1 - \ell_2}{4} \qquad [\text{mm}].$$

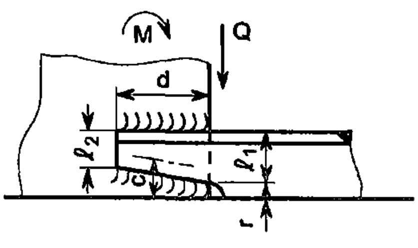


Fig. 19.27

As the influence of the shear force can generally be neglected, the required fillet weld thickness may be determined by the following formula :

$$a_{req} = \frac{W \cdot 10^3}{1{,}5 \cdot c \cdot d} \qquad [\text{mm}].$$

.2 Profiles joined by means of two flank and two frontal fillet welds (all round welding as shown in Fig. 19.28):

$$\tau_{\perp} = \frac{Q}{a\,(2d + \ell_1 + \ell_2)} \qquad [\text{N/mm}^2]$$

$$\tau_{||} = \frac{M \cdot 10^3}{a \cdot c\,(2d + \ell_1 + \ell_2)} \qquad [\text{N/mm}^2]$$

The equivalent stress is :

$$\sigma_v = \sqrt{\sigma_{\perp}^2 + \tau_{||}^2} \qquad [\text{N/mm}^2]$$

$$a_{req} = \frac{W \cdot 10^3}{1{,}5 \cdot c \cdot d\left[1 + \frac{\ell_1 + \ell_2}{2d}\right]} \qquad [\text{mm}].$$

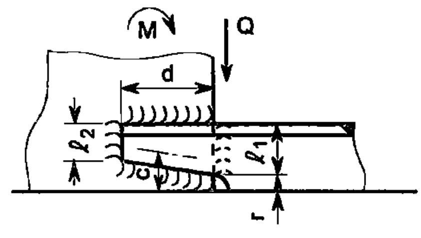


Fig. 19.28

2.7 Bracket joints

Where profiles are joined to brackets as shown in Fig. 19.29, the average shear stress is :

$$\tau = \frac{3 \cdot M \cdot 10^3}{4 \cdot a \cdot d^2} + \frac{Q}{2 \cdot a \cdot d} \quad [\text{N/mm}^2]$$

d = length of overlap in [mm].

The required fillet weld thickness is to be calculated from the section modulus of the profile as follows :

$$a_{req} = \frac{1000 \cdot W}{d^2} \quad [\text{mm}].$$

(The shear force Q has been neglected.)

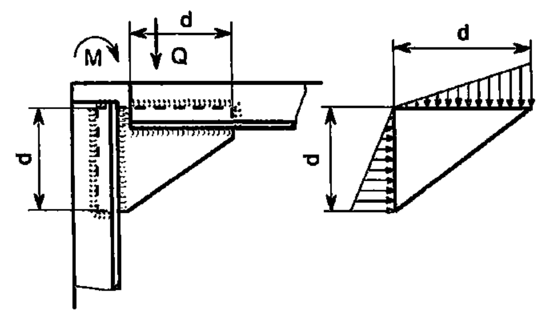


Fig. 19.29 A bracket joint with idealized stress distribution resulting from the moment M and shear force Q

2.8 Permissible stresses

The permissible stresses for various materials under mainly static loading conditions are given in Table 19.2. The values listed for high tensile steels, Austenitic stainless steels and aluminium alloys are based on the assumption that the strength values of the weld metal used are at least as high as those of the parent metal. If this is not the case, the "a" value calculated must be increased accordingly (see also B.3.3.2).

Table 19.2

Material		R_{eH} or $R_{p0,2}$ [N/mm²]	Permissible stresses [N/mm²] equivalent stress, shear stress σ_{vp}, τ_p
ordinary hull structrural steel	KI - A/B/D/E [1]	235	115
higher tensile structural steels	KI - A/D/E 27 S	265	125
	KI - A/D/E/F 32	315	145
	KI - A/D/E/F 36 [2]	355	160
	KI - A/D/E/F 40	390	175
high tensile steels	St E 460	460	200
	St E 690	685	290
austenitic and austenitic-ferritic stainless steels	1,4306/304 L	180	110
	1,4404/316 L	190	
	1,4435/316 L	190	
	1,4438/317 L	195	
	1,4541/321	205	
	1,4571/316 Ti	215	
	1,4406/316 LN	280	130
	1,4429/316 LN	295	
	1,4439/(316 LN)	285	
	1,4462/(318)	480	20 [5]
aluminium alloys	Al Mg 3	80 [3]	35 [5]
	Al Mg 4,5 Mn	125 [3]	56 [6]
	Al Mg Si 0,5	65 [4]	30 [7]
	Al Mg Si 1	110 [4]	45 [8]

1) Valid also for grade St 37 structural steel according to DIN-EN 10025

2) Valid also for grade St 52-3 structural steel according to DIN-EN 10025

3) Plates, soft condition

4) Sections, cold hardened

5) Welding consumables: S-Al Mg 3, S-Al Mg 5 or S-Al Mg 4,5 Mn

6) Welding consumables: S-Al Mg 4,5 Mn

7) Welding consumables: S-Al Mg 3, S-Al Mg 5, S-Al Mg 4,5 Mn or S-Al-Si 5

8) Welding consumables: S-Al Mg 5 or S-Al Mg 4,5 Mn

Table 19.3 Fillet Weld Connections

Structural parts to be connected	Basic thickness of fillet welds a / t_0 [1] for double continuous fillet welds [2]	Intermittent fillet welds permissible [3]
Bottom structures		
Transverse and longitudinal girders to each other	0,35	x
to shell and inner bottom	0,20	x
Centre girder to flat keel and inner bottom	0,40	
Transverse and longitudinal girders and stiffeners in way of bottom strengthening forward	0,30	
Machinery space		
- Transverse and longitudinal girders to each other	0,35	
- to shell and inner bottom	0,30	
- Inner bottom to shell	0,40	
Machinery foundation		
Longitudinal and transverse girders to each other and to the shell	0,40	
- to inner bottom and face plates	0,40	
- to top plates	0,50 [4]	
- in way of foundation bolts	0,70 [4]	
- to brackets and stiffeners	0,30	
longitudinal girders of thrust bearing to inner bottom	0,40	
Decks		
to shell (general)	0,40	
Deckstringer to sheerstrakes (see also Section 7, A.2)	0,50	
Frames, stiffeners, beams etc.		
general	0,15	x
in peak tanks	0,30	x
bilge keel to shell	0,15	
Transverse, longitudinal and transverse girders		
general	0,15	x
within 0,15 of span from supports.	0,25	
cantilevers	0,40	
pillars to decks.	0,40	
Bulkheads, tank boundaries, walls of superstructures and deckhouses.		
to decks, shell and walls.	0,40	
Hatch coamings		
to deck	0,40	
to longitudinal stiffeners	0,30	
Hatch covers		
general	0,15	x [5]
watertight or oiltight fillet welds.	0,30	
Rudder plating to webs	0,25	x
Stem plating to webs	0,25	x

1) t_0 = Thickness of the thinner plate.

2) In way of large shear forces larger throat thicknesses may be required on the bases of calculations according to C.

3) For intermittent welding in spaces liable to corrosion B.3.3.8 is to be observed.

4) For plate thicknesses exceeding 15 mm single or double bevel butt joints with, full penetration or with defined incomplete root penetration according to Fig. 19.9 to be applied.

5) Excepting hatch covers above holds provided for ballast water.

Section 20

Fatigue Strength

A. General

1. Definitions

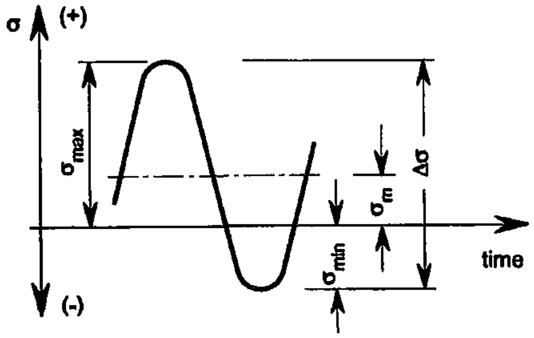


Fig. 20 1

$\Delta\sigma$ = applied stress range ($\sigma_{max} - \sigma_{min}$) in [N/mm²], see also Fig. 20.1

σ_{max} = maximum upper stress of a stress cycle in [N/mm²]

σ_{min} = maximum lower stress of a stress cycle in [N/mm²]

σ_m = mean stress ($\sigma_{max}/2 + \sigma_{min}/2$) in [N/mm²]

$\Delta\sigma_{max}$ = applied peak stress range within a stress range spectrum in [N/mm²]

$\Delta\sigma_p$ = permissible stress range in [N/mm²]

$\Delta\tau$ = corresponding range for shear stress in [N/mm²]

n = number of applied stress cycles

N = number of endured stress cycles according to S-N curve (= endured stress cycles under constant amplitude loading)

$\Delta\sigma_R$ = fatigue strength reference value of S-N curve at $2 \cdot 10^6$ cycles of stress range in [N/mm²] (= detail category number according to Table 20.3)

f_m = correction factor for material effect

f_R = correction factor for mean stress effect

f_w = correction factor for weld shape effect

f_i = correction factor for importance of structural element

f_s = additional correction factor for structural stress analysis

f_n = factor considering stress spectrum and number of cycles for calculation of permissible stress range.

$\Delta\sigma_{Rc}$ = corrected fatigue strength reference value of S-N curve at $2 \cdot 10^6$ stress cycles in [N/mm²]

D = cumulative damage ratio.

2. Scope

2.1 A fatigue strength analysis is to be performed for structures which are predominantly subjected to cyclic loads. Due consideration shall thereby be given to auxiliary structures such as e.g. fasteners. The notched details i. e. the welded joints as well as notches at free plate edges are to be considered individually. The fatigue strength assessment is to be carried out either on the basis of a permissible peak stress range for standard stress spectra (see B.2.1) or on the basis of a cumulative damage ratio (see B.2.2).

2.2 No fatigue strength analysis is required if the peak stress range due to dynamic loads in the seaway (stress spectrum A according to 2.4) and/or due to changing draught or loading conditions, respectively, fulfils the following conditions:

– peak stress range only due to seaway-induced dynamic loads:

$$\Delta\sigma_{max} \leq 2,5\ \Delta\sigma_R$$

– sum of the peak stress ranges due to seawayinduced dynamic loads and due to changes of draught or loading condition, respectively:

$$\Delta\sigma_{max} \leq 4,0\ \Delta\sigma_R$$

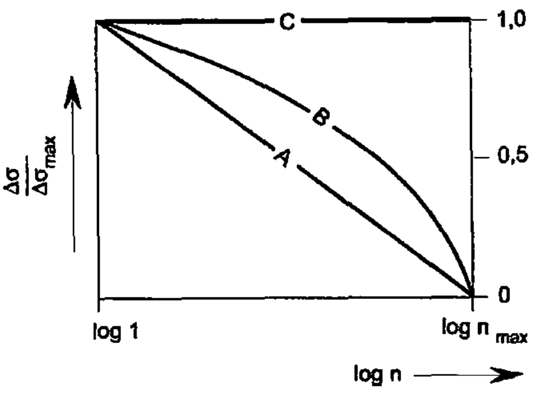
Guidance

For welded structures of detail category 80 or higher a fatigue strength analysis is required only in case of extraordinary high dynamic stresses.

2.3 The rules are applicable to constructions made of ordinary and higher-tensile hull structural steels according to Section 2, B.as well as aluminium alloys. Other materials such as cast steel can be treated in an analogous manner by using appropriate design S-N curves.

Low cycle fatigue problems in connection with extensive cyclic yielding have to be specially considered. When applying the following rules, the calculated nominal stress range should not exceed 1,5 times the minimum nominal upper yield point. In special cases the fatigue strength analysis may be performed by considering the local elasto-plastic stresses.

2.4 The stress ranges $\Delta\sigma$ which are to be expected during the service life of the ship or structural component, respectively, may be described by a stress range spectrum (long-term distribution of stress range). Fig. 20.2 shows three standard stress range spectra A, B and C, which differ from each other in regard to the distribution of stress range $\Delta\sigma$ as a function of the number of load cycles.



A : straight-line spectrum (typical stress range spectrum of seaway-induced stress ranges)

B : parabolic spectrum (approximated normal distribution of stress range $\Delta\sigma$)

C : rectangular spectrum (constant stress range within the whole spectrum; typical spectrum of engine- or propeller-excited stress ranges).

Fig. 20.2

In case of only seaway-induced stresses, normally the stress range spectrum A is to be assumed with a number of cycles $n_{max} = 5 \cdot 10^7$.

In this case the maximum and minimum stresses result from the maximum and minimum relevant seaway-induced load effects. The different load - effects have to be superimposed conservatively in a reasonable way. Table 20.1 shows examples for the individual loads which have to be considered in normal cases. Other significant fluctuating stresses, e.g. in longitudinals due to deflections of supporting transverses as well as additional stresses due to the application of non-symmetrical sections, have to be considered, see Section 3, L.

For ships of unconventional hull shape and for ships for which a special mission profile applies, a stress range spectrum deviating from spectrum A may be applied which may be evaluated by the spectral method.

2.5 Additional stress cycles resulting from changing mean stresses, e.g. due to changing loading conditions or draught, need generally not be considered as long as the seaway-induced stress ranges are determined for the loading condition being most critical with respect to fatigue strength and the maximum change in mean stress is less than the maximum seaway-induced stress range.

Larger changes in mean stress are to be included in the stress range spectrum by conservative superpositioning of the largest stress ranges (e.g. in accordance with the "rainflow counting method"). If nothing else is specified, 10^3 load cycles have to be assumed for changes in loading condition or draught.

2.6 The fatigue strength analysis is, depending on the detail considered, based on one of the following types of stress:

- For notches of free plate edges the notch stress σ_k, determined for linear - elastic material behaviour, is relevant, which can normally be calculated from a nominal stress σ_n and a theoretical stress concentration factor K_t. Values for K_t are given in Section 3, J., Figs. 3.8 and 3.9 for different types of cut-outs. The fatigue strength is determined by the detail category (or $\Delta\sigma_R$) according to Table 20.3, type 29 and 30.
- For welded joints the fatigue strength analysis is normally based on the nominal stress σ_n at the structural detail considered and on an appropriate detail classification as given in Table 20.3, which defines the detail category (or $\Delta\sigma_R$).
- For those welded joints, for which the detail classification is not possible or additional stresses occur, which are not or not adequately considered by the detail classification, the fatigue strength analysis may be performed on the basis of the structural stress σ_s in accordance with C.

3. Quality requirements (fabrication tolerances)

3.1 The detail classification of the different welded joints as given in Table 20.3 is based on the assumption that the fabrication of the structural detail or welded joint, respectively, corresponds in regard to external defects at least to quality group B according to DIN 8563 and in regard to internal defects at least to quality group C. Further information about the tolerances can also be found in several Shipbuilding Quality Standards accepted by **BKI**.

3.2 Relevant information have to be included in the manufacturing document for fabrication. If it is not possible to comply with the tolerances given in the standards this has to be accounted for when designing the structural details or welded joints, respectively. In special cases an improved manufacture as stated in 3.1 may be required, e.g. stricter tolerances or improved weld shapes, .see also B.3.2.4.

B. Fatigue Strength Analysis for Free Plate Edges and for Welded Joints Using Detail Classification

1. Definition of nominal stress and detail Classification for welded joints

1.1 Corresponding to their notch effect, welded joints are normally classified into detail categories considering particulars in geometry and fabrication, including subsequent quality control, and definition of nominal stress. Table 20.3 shows the detail classification based on recommendations of the International Institute of Welding (IIW) giving the detail category number (or $\Delta\sigma_R$) for structures made of steel or aluminium alloys (Al).

Table 20.1 Maximum and minimum value for seaway-induced cyclic loads

Load	Maximum load	Minimum load
Vertical longitudinal bending moments (Section 5, B.)[1]	$M_{SW} + 0{,}75\ M_{WV} + M_{BF}$	$M_{SW} - 0{,}75\ M_{WV} - M_{BF}$
Influence of horizontal wave bending moments [1, 5] (Section 5, F.3.2)	$M_{SW} + 0{,}5\ M_{WV} + M_{WH}$	$M_{SW} - 0{,}5\ M_{WV} - M_{WH}$
Loads on weather decks [2] Section 4, B.1.)	p_D	0
Loads on ship's sides [2, 4] – below LWL	$10\,(T - z) + p_0 \cdot c_F \left[1 + \frac{z}{T}\right]$	$10\,(T - z) - p_0 \cdot c_F \left[1 + \frac{z}{T}\right]$ but ≥ 0
– above LWL (Section 4, B.2.)	$p_0 \cdot c_F\ \frac{20}{10 + z - T}$	0
Loads on ship's bottom [2, 4] (Section 4, B.3.)	$10\,T + p_0 \cdot c_F$	$10\,T - p_0 \cdot c_F$
Liquid pressure in completely filled tanks [4] (Section 4, D.1.)	$9{,}81 \cdot h_1 \cdot \rho\,(1 + a_v) + 100\,p_v$ or $9{,}81 \cdot \rho\,[h_1 \cdot \cos\varphi + (0{,}3 \cdot b + y)\sin\varphi] + 100\,p_v$	$9{,}81 \cdot h_1 \cdot \rho\,(1 - a_v) + 100\,p_v$ or $9{,}81 \cdot \rho\,[h_1 \cdot \cos\varphi + (0{,}3 \cdot b - y)\sin\varphi] + 100\,p_v$ but $\geq 100\,p_v$
Loads due to cargo (Section 4, C.1.1 and E.1)	$p\,(1 + a_v)$ $p \cdot a_x \cdot 0{,}7$ $p \cdot a_y \cdot 0{,}7$	$p\,(1 - a_v)$ $-p \cdot a_x \cdot 0{,}7$ $-p \cdot a_y \cdot 0{,}7$
Loads due to friction forces [3] (Section 17, C.5.2.8)	P_h	$-P_h$

1) Maximum and minimum load are to be so determined that the largest applied stress range $\Delta\sigma$ as per Figure 20.1 is obtained having due regard to the sign (plus, minus) of M_{WV} and M_{BF}.

2) With following probability factor f for calculation p_0 according to Section 4, A.2.2.:
f = 1,0 in general for all structural components if no other cyclic load components are considered
f = 0,75 if different cyclic load components are assumed to act simultaneously.

3) In general the largest friction load is to be taken in connection with the load spectrum B without considering further cyclic loads.

4) Assumption of conservative superpositioning for the shell:
a) max./min. outer pressure together with mean inner pressure (if existing)
b) max./min. inner pressure with mean outer pressure.

5) For ships with large deck openings see Section 5, F.2., load cases 2 and 3 in Table 5.2.

It has to be noted that some influence parameters cannot be considered by the detail classification and that a large scatter of fatigue strength has therefore to be reckoned with.

1.2 Details which are not contained in Table 20.3 may be classified either on the basis of local stresses in accordance with C. or, else, by reference to published experimental work or by carrying out special fatigue tests, assuming a sufficiently high confidence level (see 3.1) and taking into account the correction factors as given in C.4.

1.3 Regarding the definition of nominal stress, the arrows in Table 20.3 indicate the location and direction of the stress for which the stress range is to be calculated. The potential crack location is also shown in Table 20.3. Depending on this crack location, the nominal stress range has to be determined by using either the cross sectional area of the parent metal or the weld throat thickness, respectively.

Bending stresses in plate and shell structures have to be incorporated into the nominal stress, taking the nominal bending stress acting at the location of crack initiation.

Note:

The factor K_s for the stress increase at transverse butt welds between plates of different thickness (see type 5 in Table 20.3) can be estimated in a first approximation as follows:

$$K_s = \frac{t_2}{t_1}$$

t_1 = *smaller plate thickness*

t_2 = *larger plate thickness*

Additional stress concentrations which are not characteristic of the detail category itself, e.g. due to cut-outs the neighbourhood of the detail, have also to be incorporated into the nominal stress.

1.4 In the case of combined normal and shear stress the relevant stress range may be taken as the range of the principal stress at the potential crack location which act approximately perpendicular to the crack front as shown in Table 20.3.

1.5 Where solely shear stresses are acting the largest principal stress $\sigma_1 = \tau$ may be used in combi-nation with the relevant detail category.

2. Permissible stress range for standard stress range spectra or calculation of the cumulative damage ratio

2.1 For standard stress range spectra according to Fig. 20.2, the permissible peak stress range can be calculated as follows:

$$\Delta\sigma_p = f_n \cdot \Delta\sigma_{Rc}$$

$\Delta\sigma_{Rc}$ = detail category or fatigue strength reference value, respectively, corrected according to 3.2

f_n = factor as given in Table 20.2.

The peak stress range of the spectrum must not exceed the permissible value, i.e.

$$\Delta\sigma_{max} \leq \Delta\sigma_p$$

2.2 If the fatigue strength analysis is based on the calculation of the cumulative damage ratio, the stress range spectrum expected during the envisaged service life is to be established (see A.2.4) and the cumulative damage ratio D is to be calculated as follows :

$$D = \sum_{i=1}^{I} \left(\frac{n_i}{N_i} \right)$$

I = total number of blocks of the stress range spectrum for summation (normally $I \geq 20$)

n_i = number of stress cycles in block i

N_i = number of endured stress cycles determined from the corrected design S-N curve (see 3.) taking $\Delta\sigma = \Delta\sigma_i$

$\Delta\sigma_i$ = stress range of block i.

To achieve an acceptable high fatigue life, the cumulative damage sum should not exceed D = 1.

If the expected stress range spectrum can be superimposed by two or more standard stress spectra according to A.2.4, the partial damage ratios D_i due to the individual stress range spectra can be derived from Table 20.2. In this case a linear relationship between number of load cycles and cumulative damage ratio may be assumed. The numbers of load cycles given in Table 20.2 apply for a cumulative damage ratio of D = 1.

3. Design S-N Curves

3.1 Description of the design S-N curves

3.1.1 The design S-N curves for the calculation of the cumulative damage ratio according to 2.2 are shown in Fig. 20.3 for welded joints and in Fig. 20.4 for notches at plate edges of steel plates.Fig. 20.4 for notches at plate edges of steel plates. For aluminium alloys (Al) corresponding S-N curves apply with reduced detail categories $D\sigma_R$ acc. to Table 20.3. The S-N curves represent the lower limit of the scatter band of 95 % of all test results available (corresponding to 97,5 % survival probability) considering further detrimental effects in large structures.

To account for different influence factors, the design S-N curves have to be corrected according to 3.2.

3.1.2 The S-N curves represent sectionwise linear relationships between log ($\Delta\sigma$) and log (N):

$$\log(N) = 6{,}69897 + m \cdot Q$$

Q = $\log(\Delta\sigma_R/\Delta\sigma) - 0{,}39794/m_0$

m = inverse slope of S-N curve

m_0 = inverse slope in the range $N \leq 5 \cdot 10^6$

m_0 = 3 for welded joints

m_0 = $3{,}5 \div 5$ for free plate edges. (see Fig. 20.4)

The S-N curve for detail category 160 forms the upper limit also for the S-N curves of free edges of steel plates with detail categories 100 – 140 in the range of low stress cycles, see Fig. 20.4.

The same applies accordingly to detail categories 71 or 80 of aluminium alloys, see type 28 in Table 20.3.

Table 20.2 Factor f_n for the determination of the permissible range for standard stress range spectra

Stress range spectrum	Welded Joints			Plates Edges								
	$(m_o = 3)$ n_{max} =			type 28 $(m_o = 5)$ n_{max} =			type 29 $(m_o = 4)$ n_{max} =			type 30 $(m_o = 3{,}5)$ n_{max} =		
	10^3	10^5	5×10^7	10^3	10^5	5×10^7	10^3	10^5	5×10^7	10^3	10^5	5×10^7
A		(17,2)	3,66		(8,1)	3,67		(11,0)	(3,76)		(13,5)	3,74
B		(9,2)	1,76	(9,5)	5,0	1,99	(15,0)	6,4	1,93		7,5	1,86
C	(12,6)	2,71	0,465 0,737 [1)]	4,57	1,82	0,645 0,833 [1)]	(6,7)	2,11	0,572 0,795 [1)]	(8,8)	2,35	0,525 0,770 [1)]

The values given in parentheses may be applied for interpolation.

For interpolation between any pair of values (n_{max1} ; f_{n1}) and (n_{max2} ; f_{n2}), the following formula may be applied in the case of stress spectrum A or B:

$$\log f_n = \log f_{n1} + \log\left(n_{max}/n_{max1}\right) \frac{\log\left(f_{n2}/f_{n1}\right)}{\log\left(n_{max2}/n_{max1}\right)}$$

For the stress spectrum C intermediate values may be calculated according to 3.1.2 by taking $N = n_{max}$ and $f_n = D\sigma/D\sigma_R$.

[1)] f_n for non-corrosive environment, see also 3.1.4.

3.1.3 For structures subjected to variable stress ranges, the S-N curves shown by the solid lines in Fig. 20.3 and Fig. 20.4 have to be applied (S-N curves of type "M"), i.e.

$$m = m_0 \quad \text{for } Q \le 0$$

$$m = 2 \cdot m_0 - 1 \quad \text{for } Q > 0.$$

3.1.4 For stress ranges of constant magnitude (stress range spectrum C) in non-corrosive environment the stress range given at $N = 5 \cdot 10^6$ cycles may be taken as fatigue limit (S-N curves of type "O" in Fig. 20.3 and 20.4), thus:

$$m = m_0 \quad \text{for } Q \le 0$$

$$m = \infty \quad \text{for } Q > 0$$

3.2 Correction of the reference value of the design S-N curve

3.2.1 A correction of the reference value of the S-N curve (or detail category) is required to account for additional influence factors on fatigue strength as follows:

$$\Delta\sigma_{Rc} = f_m \cdot f_R \cdot f_w \cdot f_i \cdot \Delta\sigma_R$$

f_m, f_R, f_w, f_i defined in 3.2.2 - 3.2.5.

In order to account for the plate thickness effect, application of an additional reduction factor may be required by BKI for welded connections oriented transversely to the direction of applied stress with larger plate thicknesses. For the description of the corrected design S-N curve, the formulae given in 3.1.2 may be used by replacing $\Delta\sigma_R$ by $\Delta\sigma_{Rc}$.

3.2.2 Material effect (f_m)

For welded joints it is generally assumed that the fatigue strength is independent of steel strength, i.e.:

$$f_m = 1{,}0.$$

For free edges at steel plates the effect of the material's yield point is accounted for as follows:

$$f_m = 1 + \frac{R_{eH} - 235}{1200}$$

R_{eH} = minimum nominal upper yield point of the steel [N/mm²].

For aluminium alloys, $f_m = 1$ generally applies.

3.2.3 Effect of mean stress (f_R)

The correction factor is calculated as follows:

- in the range of tensile pulsating stresses, i.e.

$$\sigma_m \ge \frac{\Delta\sigma_{max}}{2}$$

$$f_R = 1{,}0$$

- in the range or alternating stresses, i.e.

$$-\frac{\Delta\sigma_{max}}{2} \le \sigma_m \le \frac{\Delta\sigma_{max}}{2}$$

$$f_R = 1 + c\left[1 - \frac{2 \cdot \sigma_m}{\Delta\sigma_{max}}\right]$$

- in the range of compressive pulsating stresses, i.e.

$$\sigma_m \le -\frac{\Delta\sigma_{max}}{2}$$

$$f_R = 1 + 2 \cdot c$$

c = 0 for welded joints subjected to constant stress cycles (stress range spectrum C)

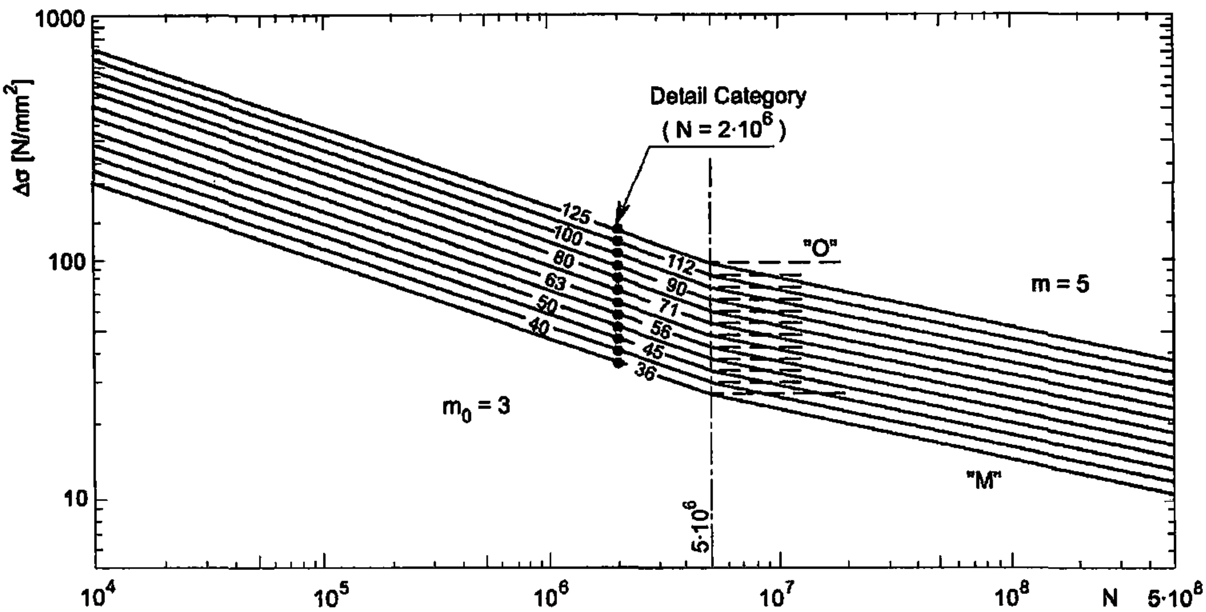


Fig. 20.3

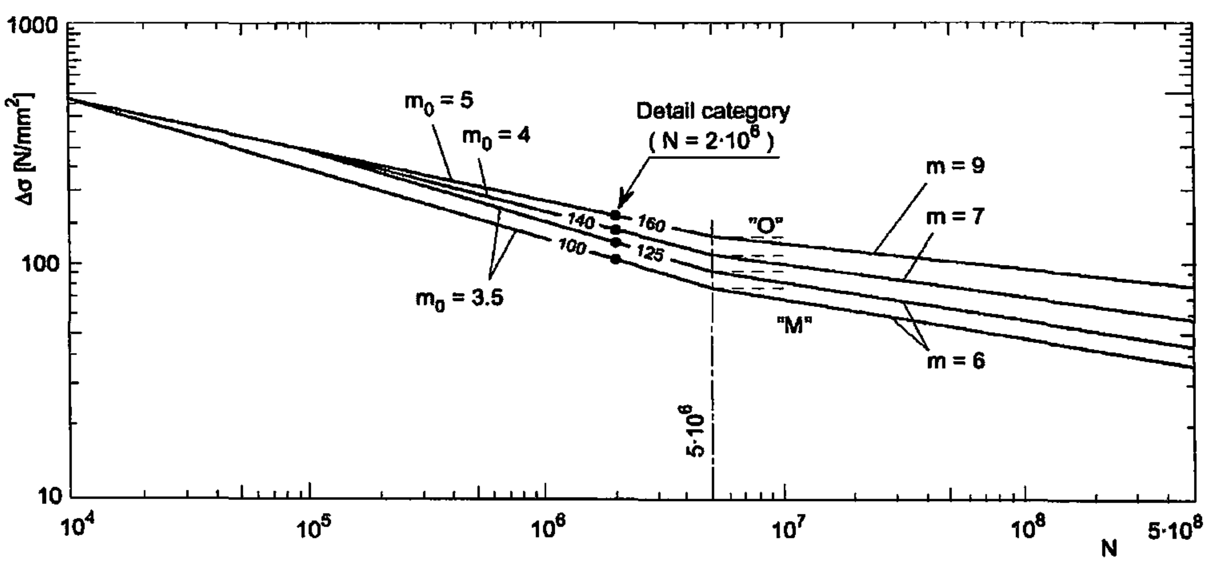


Fig. 20.4

c = 0,15 for welded joints subjected to variable stress cycles (corresponding to stress range spectrum A or B)

= 0,3 for free plate edges.

3.2.4 Effect of weld shape (f_w)

In normal cases:

f_w = 1,0.

A factor $f_w > 1,0$ applies for welds treated e.g. by grinding. By this surface defects such as slag inclusions, porosity and crack-like undercuts shall be removed and a smooth transition from the weld to the base material shall be achieved. Final grinding shall be performed transversely to the weld direction. The depth should be approx. 0,5 mm larger than that of visible undercuts. For ground weld toes of fillet and K- butt welds:

f_w = 1,15.

For butt welds ground flush either the corresponding detail category has to be chosen, e.g. type 1 in Table 20.3, or a weld shape factor

f_w = 1,25.

may be applied.

For endings of stiffeners or brackets, e.g. type 14 or 16 in Table 20.3, which have a full penetration weld and are completely ground flush to achieve a notch-free transition, the following factor applies:

f_w = 1,4.

The assessment of a local post-weld treatment of the weld surface and the weld toe by other methods has to be agreed on in each case.

3.2.5 Influence of importance of structural element (f_i)

In general the following applies:

$f_i = 1{,}0.$

For secondary structural elements failure of which may cause failure of larger structural areas, the correction factor f_i is to be taken as:

$f_i = 0{,}9.$

For notches at plate edges in general the following correction factor is to be taken which takes into account the radius of rounding:

$f_i = 0{,}9 + 5/r \leq 1{,}0.$

r = notch radius in [mm]; for elliptical roundings the mean value of the two main half axes may be taken.

C. Fatigue Strength Analysis for Welded Joints Based on Local Stresses

1. Alternatively to the procedure described in the preceding paragraphs, the fatigue strength analysis for welded joints may be performed on the basis of local stresses. For common plate and shell structures in ships the assessment based on the socalled structural (or hot-spot) stress σ_s is normally sufficient.

The structural stress is defined as the stress being extrapolated to the weld toe excluding the local stress concentration in the local vicinity of the weld, see Fig. 20.5.

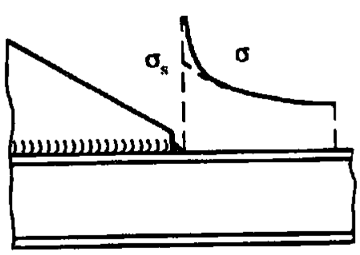


Fig. 20.5

2. The structural stress can be determined by measurements or numerically e.g. by the finite element method using shell or volumetric models under the assumption of linear stress distribution over the plate thickness. In some cases the structural stress can be calculated from the nominal stress σ_n and a structural stress concentration factor K_s, which has been derived from parametric investigations using the methods mentioned. Parametric equations should be used with due consideration of their inherent limitations and accuracy.

3. For the fatigue strength analysis based on structural stress, the S-N curves shown in Fig. 20.3 apply with the following reference values:

$\Delta\sigma_R$ = 100 (resp. 36 for Al)

for K-butt welds with fillet welded ends, e.g. type 21 in Table 20.3, and for fillet welds which carry no load or only part of the load of the attached plate, e.g. type 17 in Table 20.3

$\Delta\sigma_R$ = 90 (resp. 36 for Al)

for fillet welds, which carry the total load of the attached plate, e.g. types 22 in Table 20.3.

For butt welds the values given for types 1 to 6 in Table 20.3 apply. In special cases, where e.g. the structural stresses are obtained by non-linear extrapolation to the weld toe and where they contain a high bending portion, increased reference values of up to 15% can be allowed.

4. The reference value $\Delta\sigma_{Rc}$ of the corrected S-N curve is to be determined according to B.3.2, taking into account the following additional correction factor which describes further influencing parameters such as e.g. predeformations:

$$f_s = \frac{k^*_m}{k_m - \frac{\Delta\sigma_{s,b}}{\Delta\sigma_{s,max}}\left(k_m - 1\right)}$$

$\Delta\sigma_{s,max}$ = applied peak stress range within a stress range spectrum

$\Delta\sigma_{s,b}$ = bending portion of $\Delta\sigma_{s,max}$

k_m = stress increase factor due to predeformations under axial loading, at least:

= 1,3 for butt welds, transverse stiffeners or tee-joints (corresponding to types 1 – 6, 17 and 21 – 22 in Table 20.3)

= 1,45 for cruciform joints (corresponding to types 21 and 22 in Table 20.3)

= 1,0 in all other cases

k^*_m = stress increase factor already contained in the fatigue strength reference value $\Delta\sigma_R$:

= 1,3 for butt welds (corresponding to types 1 – 6 in Table 20.3)

= 1,0 in all other cases

For simplification, $f_s = k^*_m / k_m$ may be applied.

The permissible stress range or cumulative damage ratio, respectively, has to be determined according to B.2.

5. In addition to the assessment of the structural stress at the weld toe, the fatigue strength with regard to root failure has to be considered by analogous application of the respective detail category, e.g. type 23 of Table 20.3. In this case the relevant stress is the stress in the weld throat caused by the axial stress in the plate perpendicular to the weld.

Table 20.3 Catalogue of Details

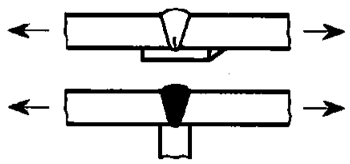
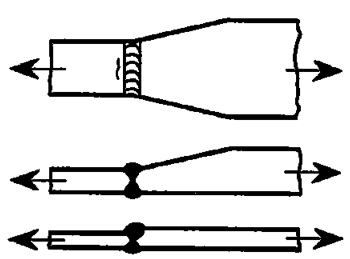
Type No	Joint configuration showing mode of fatigue cracking and stress σ considered	Description of joint	Detail category $\Delta\sigma_R$	
			Steel	Al
1		Transverse butt weld ground flush to plate, 100% NDT (Non Destructive Testing)	125	50
2		Transverse butt weld made in the shop in the flat position, max. weld reinforcement 1 mm + 0,1 x weld width, smooth transitions, NDT	100	40
3		Transverse butt welds not satisfying conditions for joint type No.2, NDT	80	32
4		Transverse butt weld on backing strip or three - plate connection with unloaded branch	71	25
5		Transverse butt welds between plates of different widths or thickness, NDT as for joint type No. 2, slope 1 : 5 as for joint type No. 2, slope 1 : 3 as for joint type No. 2, slope 1 : 2 as for joint type No.3, slope 1 : 5 as for joint type No.3, slope 1 : 3 as for joint type No.3, slope 1 : 2 For the third sketched case the slope results from the ratio of the difference in plate thicknesses to the breadth of the welded seam. Additional bending stress due to thickness change to be considered, see also B.1.3.	 100 90 80 80 71 63	 32 28 25 25 22 20
6		Transverse butt welds welded from one side without backing bar, full penetration root controlled by NDT not NDT For tubular profiles $\Delta\sigma_R$ may be lifted to the next higher detail category	 71 45	 28 18
7		Partial penetration butt weld; the stress is to be related to the weld throat sectional area, weld overfill not to be taken into account	45	16

Table 20.3 Catalogue of Details (Continued)

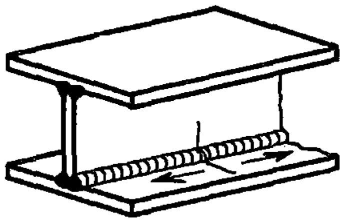
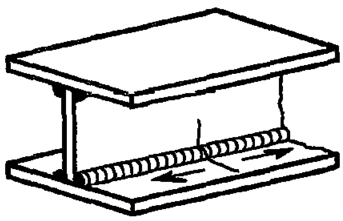
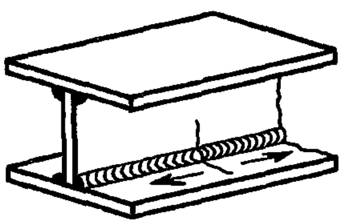
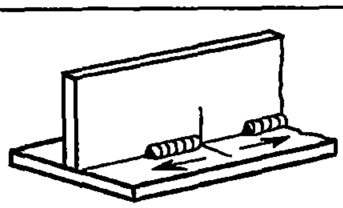
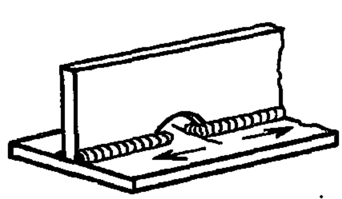
Type No	Joint configuration showing mode of fatigue cracking and stress σ considered	Description of joint	Detail category $\Delta\sigma_R$	
			Steel	Al
8		Continuous automatic longitudinal fully penetrated butt weld without stop/start positions (based on stress range in flange adjacent to weld)	125	50
9		Continuous automatic longitudinal fillet weld without stop / start positions (based on stress range in flange adjacent to weld)	100	40
10		Continuous manual longitudinal fillet or butt weld (based on stress range in flange adjacent to weld)	90	36
11		Intermittent longitudinal fillet weld (based on stress range in flange at weld ends) In presence of shear τ in the web, the detail category has to be reduced by the factor $(1 - \Delta\tau / \Delta\sigma)$, but not below 36 (steel) or 14 (Al).	80	32
12		Longitudinal butt weld, fillet weld or intermittent fillet weld with cut outs (based on stress range in fillet at weld ends) If cut outs is higher than 40% of web height In presence of shear τ in the web, the detail category has to be reduced by the factor $(1 - \Delta\tau / \Delta\sigma)$, but not below 36 (steel) or 14 (Al). *Remark* *For Ω-shaped scallops, an assessment based on local stresses is recommended.*	71 63	28 25

Table 20.3 Catalogue of Details (Continued)

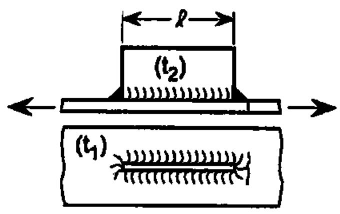
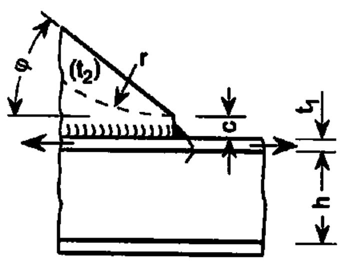
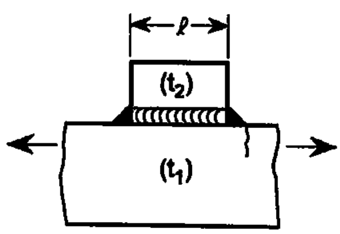
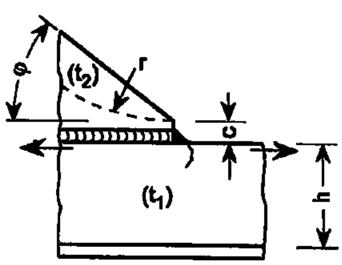
Type No	Joint configuration showing mode of fatigue cracking and stress σ considered	Description of joint	Detail category $\Delta\sigma_R$	
			Steel	Al
13		Longitudinal gusset welded on beam flange, bulb or plate : $\ell \le 50$ mm 50 mm $< \ell \le 150$ mm 150 mm $< \ell \le 300$ mm $\ell > 300$ mm For $t_2 \le 0{,}5\ t_1$, $\Delta\sigma_R$ may be increased by one category, but not over 80 (steel) or 28 (Al); not valid for bulb profiles. If the component below the gusset is subjected to bending, $\Delta\sigma_R$ has to be decreased by one category.	 80 71 63 56	 28 25 20 18
14		Gusset with smooth transition (sniped end or radius) welded on beam flange, bulb or plate; $c \le 2t_2$, max 25 mm. $r \ge 0{,}5$ h $r < 0{,}5$ h or $\varphi \le 20°$ $\varphi > 20°$ see joint type 13 For $t_2 \le 0{,}5\ t_1$, $\Delta\sigma_R$ may be increased by one category; not valid for bulb profiles.	 71 63	 25 20
15		Longitudinal flat side gusset welded on plate or beam flange edge $\ell \le 50$ mm 50 mm $< \ell \le 150$ mm 150 mm $< \ell \le 300$ mm $\ell > 300$ mm For $t_2 \le 0{,}7\ t_1$, $\Delta\sigma_R$ may be increased by one category, but not over 56 (steel) or 20 (Al). If the plate or beam flange is subjected to in-plane bending, $\Delta\sigma_R$ has to be decreased by one category.	 56 50 45 40	 20 18 16 14
16		Longitudinal flat side gusset welded on plate edge or beam flange edge, with smooth transition (sniped end or radius); $c \le 2\ t_2$, max. 25 mm $r \ge 0{,}5$ h $r < 0{,}5$ h or $\varphi \le 20°$ $\varphi > 20°$ see joint type 15 For $t_2 \le 0{,}7\ t_1$, $\Delta\sigma_R$ may be increased by one category.	 50 45	 18 16

Table 20.3 Catalogue of Details (Continued)

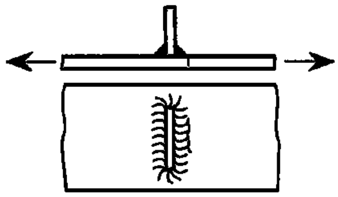
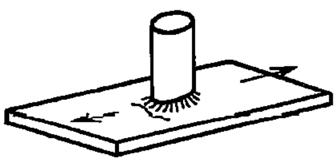
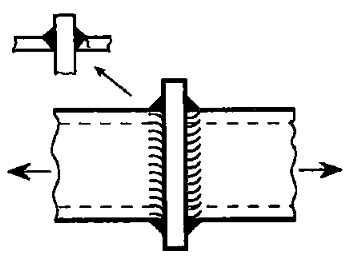
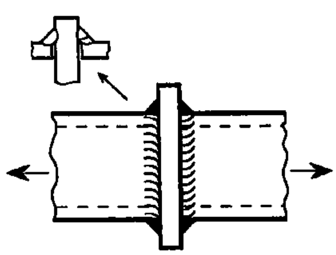
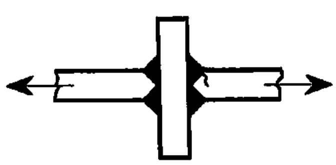
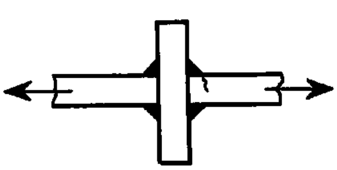
Type No	Joint configuration showing mode of fatigue cracking and stress σ considered	Description of joint	Detail category $\Delta\sigma_R$	
			Steel	Al
17		Transverse stiffener with fillet welds (applicable for short and long stiffeners).	80	28
18		Non-load-carrying shear connector	80	28
19		Full penetration weld at the connection between a hollow section (e.g. pillar) and a plate, for tubular section for rectangular hollow section	 56 50	 20 18
20		Fillet weld at the connection between a hollow section (e.g. pillar) and a plate, for tubular section for rectangular hollow section The stress is to be related to the weld sectional area.	 45 40	 16 14
21		Cruciform or tee - joint K-butt weld with full penetration or with defined incomplete root penetration according to Fig. 19.9 cruciform joint tee-joint	 71 80	 25 28
22		Cruciform or tee - joint transverse fillet weld, toe failure (root failure particularly for throat thickness a < 0,7 · t , see joint type 23) cruciform joint tee-joint	 63 71	 22 25

Table 20.3 Catalogue of Details (Continued)

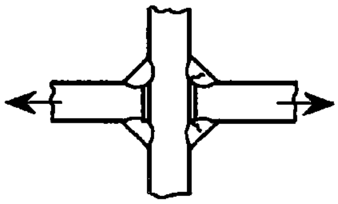
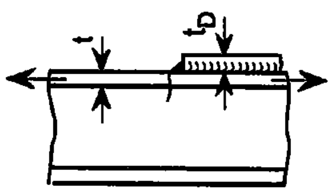
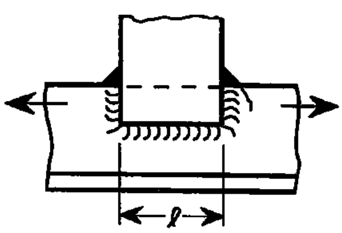
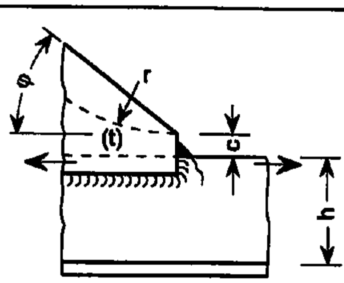
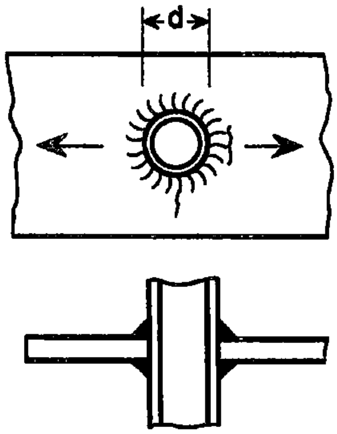
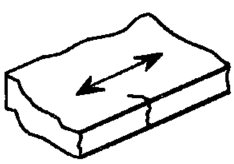
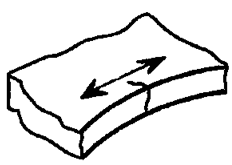
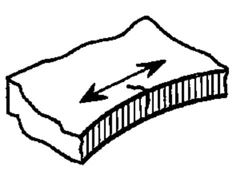
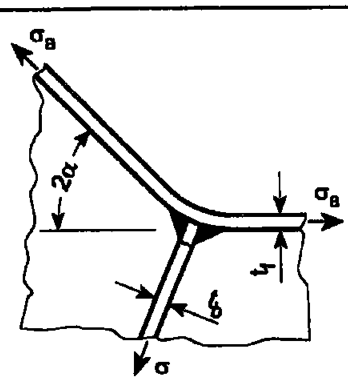
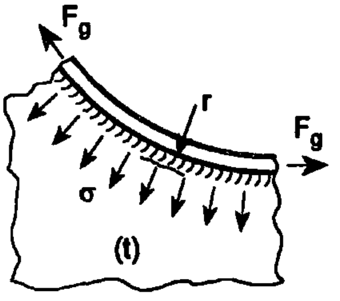
Type No	Joint configuration showing mode of fatigue cracking and stress σ considered	Description of joint	Detail category $\Delta\sigma_R$	
			Steel	Al
23		Welded metal in transverse load-carrying fillet weld at cruciform or tee - joint, root failure (based on stress range in weld throat). See also joint type 22.	45	16
24		End of long doubling plate on beam, welded ends (based on stress range in flange at weld toe) $t_D \le 0,8\,t$ $0,8\,t < t_D \le 1,5\,t$ $t_D > 1,5\,t$ The following features increase $\Delta\sigma_R$ by one category accordingly: - reinforced ends according to Fig. 19.4 - weld toe angle ≤ 30° - length of doubling ≤ 150 mm.	 56 50 45	 20 18 16
25		Fillet welded non-load-carrying lap joint welded to longitudinally stressed element – to bulb section or flat bar – to angle section For $\ell > 150$ mm, $\Delta\sigma_R$ has to be decreased by one category, while for $\ell \le 50$ mm, $\Delta\sigma_R$ may be increased by one category. If the component is subjected to bending, $\Delta\sigma_R$ has to be reduced by one category.	 56 50	 20 18
26		Fillet welded lap joint with smooth transition (sniped end the with $\varphi \le 20°$ or radius) welded to longitudinally stressed element – to bulb section – to angle section $c \le 2\,t$, max. 25 mm	 56 50	 20 18

Table 20.3 Catalogue of Details (Continued)

Type No	Joint configuration showing mode of fatigue cracking and stress σ considered	Description of joint	Detail category $\Delta\sigma_R$	
			Steel	Al
27		Continuous butt or fillet weld connecting a pipe penetrating through a plate $d \le 50$ mm $d > 50$ mm *Remark :* *For large diameters an assessment based on local stress is recommended.*	71 63	25 22
28		Rolled or extruded plates and sections as well as seamless pipes, no surface or rolling defects	160 ($m_0 = 5$)	71 ($m_0 = 5$)
29		Plate edge sheared or machined cut by any thermal process with surface free of cracks and notches, corners broken or rounded. Stress increase due to geometry of cut-outs to be considered.	140 ($m_0 = 4$)	40 ($m_0 = 4$)
30		Plate edge not meeting the requirements of type 29, but free from cracks and severe notches. Machine cut or sheared edge: Manually thermally cut: Stress increase due to geometry of cut-outs to be considered.	125 ($m_0 = 3{,}5$) 100 ($m_0 = 3{,}5$)	36 ($m_0 = 3{,}5$) 32 ($m_0 = 3{,}5$)
31		Joint at stiffened knuckle of a flange, to be assessed according to type 21, 22 or 23, depending on the type of joint. The stress in the stiffener at the knuckle can normally be calculated as follows: $\sigma = \sigma_a \frac{t_f}{t_b} 2 \sin\alpha$	—	—

Type No	Joint configuration showing mode of fatigue cracking and stress σ considered	Description of joint	Detail category $\Delta\sigma_R$	
			Steel	Al
32		Unstiffened flange to web joint, to be assessed according to type 21, 22 or 23, depending on the type of joint. The stress in the web is calculated using the force F_g in the flange as follows: $\sigma = \frac{F_g}{r \cdot t}$ Furthermore, the stress in longitudinal weld direction has to be assessed according to type 8 – 10. In case of additional shear or bending, also the highest principal stress may become relevant in the web, see B.1.4.	—	—

Section 21

Hull Outfit

A. Side Scuttles and Windows

1. Side scuttles and windows including their glasses in the shell plating and in the end bulkheads are to be of sufficient strength. The respective ISO or DIN Standards are considered as guidance. Other types are to be submitted for approval.

2. Below the bulkhead deck and in enclosed superstructures on the bulkhead deck, side scuttles of heavy or medium type are to be provided.

3. The lower edge of side scuttles in the shell plating shall be situated above a line parallel to the bulkhead deck the lowest point of which is located not less than 0,025**B** or 500 mm above the deepest load waterline.

4. Windows and side scuttles in deckhouses on the bulkhead deck forming the only protection of openings giving access to a space below, are to be provided with permanently attached deadlights.

B. Scuppers, Sanitary Discharges and Freeing Ports

1. Scuppers and sanitary discharges

1.1 Scuppers sufficient in number and size to provide effective drainage of water are to be fitted in the weather deck and in the bulkhead deck within weathertight closed superstructures and deckhouses. Decks within closed superstructures are to be drained to the bilge. Scuppers from superstructures and deck-houses which are not closed weathertight are to be led outside.

1.2 Scuppers draining spaces below the deepest load waterline, are to be connected to pipes, which are led to the bilges and are to be well protected.

1.3 Where scupper pipes are led outside from spaces below the bulkhead deck and from weathertight closed superstructures and deckhouses, they are to be fitted with non-return valves of automatic type, which can be operated from a position always accessible and above the bulkhead deck. Means showing whether the valves are open or closed (positive means of closing) are to be provided at the control position.

1.4 Where the vertical distance from the load waterline to the inboard end of the discharge pipe exceeds 0,01 $\mathbf{L_c}$, the discharge may have two automatic non-return valves without positive means of closing, provided that the inboard valve is always accessible for examination, i.e., the valve is to be situated above the deepest load waterline.

1.5 Where the vertical distance mentioned under 1.4 exceeds 0,02 $\mathbf{L_c}$, a single automatic non-return valve, without positive means of closing may be accepted.

1.6 Scuppers and discharge pipes originating at any level and penetrating the shell either more than 450 mm below the bulkhead deepest load water line are to be provided with a non-return valve at the shell. This valve, unless required by 1.3, may be omitted if a heavy gauge discharge pipe is fitted.

1.7 Except in unmanned machinery and auxiliary machinery spaces, sea inlets and discharges in connection with the operation of the machinery may be controlled locally. The controls shall be readily accessible and shall be provided with indicators showing whether the valves are open or closed.

1.8 All valves including the ship side valves required under 1.2 – 1.7 are to be of steel, bronze or other approved ductile material. Ordinary cast iron is not acceptable. Pipe lines are to be of steel or similar material.

1.9 Scuppers and sanitary discharges should not be fitted above the light waterline in way of lifeboat launching positions or means for preventing any discharge of water into the life boats are to be provided for. The location of scuppers and sanitary discharges is also to be taken into account when arranging gang-ways and pilot lifts.

2. Freeing ports

2.1 Where bulwarks on exposed portions of bulk-head and/or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of water.

2.2 Except as provided in 2.3 to 2.5 the minimum freeing port area (A) on each side of the ship for each well on the freeboard deck is to be given by the following formula in cases where the sheer in way of the well is standard or greater than standard:

$$A = 0{,}7 + 0{,}035\,\ell \quad [m^2] \quad \text{for } \ell \le 20 \text{ m}$$

$$A = 0{,}07\,\ell \quad [m^2] \quad \text{for } \ell > 20 \text{ m}$$

ℓ = length of bulwark in [m]
(ℓ need not be taken greater than 0,7 $\mathbf{L_c}$).

The minimum area for each well on superstructure decks shall be 50 % of the area obtained by the formula.

If the bulwark is more than 1,2 metres in average height the required area is to be increased by 0,004 square metres per metre of length of well for each 0,1 metre difference in height. If the bulwark is less than 0,9 metre in average height, the required area may be decreased accordingly.

2.3 In ships with no sheer, the area calculated according to 2.2 is to be increased by 50 %. Where the sheer is less than standard the percentage shall be obtained by linear interpolation.

2.4 Where a ship is fitted with a trunk on the exposed bulkhead deck, or where continuous or substantially continuous hatchway side coamings are fitted between detached superstructures the minimum area of the freeing port openings is to be calculated from Table 21.1:

Table 21.1

Breadth of hatchway or trunk in relation to B in [%]	**Area of freeing ports on each side in relation to the total area of the bulwark in [%]** [1]
40 or less	20
75 or more	10

[1] The area of freeing ports at intermediate breadth is to be obtained by linear interpolation

The area of freeing ports at intermediate breadths is to be obtained by linear interpolation.

2.5 In ships having open superstructures, adequate freeing ports are to be provided which guarantee proper drainage.

2.6 The lower edges of the freeing ports shall be as near to the deck as practicable. Two thirds of the freeing port area required shall be provided in the half of the well nearest to the lowest point of the sheer curve.

2.7 All such openings in the bulwarks shall be protected by rails or bars spaced approximately 230 mm apart. If shutters are fitted to freeing ports, ample clearance shall be provided to prevent jamming. Hinges shall have pins or bearings of non- corrodible material.

C. Facilities for Waste and Water Discharge, Bilge Wells

1. It has to be ensured that all kinds of refuse and water accumulating in the course of processing of the catch may be discharged or carried outboards without endangering the vessel. The bilge pumps are to have sufficient power.

2. Where the fish processing holds are located below the weather deck, the refuse and water accumulating in the course of processing are to be discharged outboards through suitable pumps or conveyor worms. The respective outlets at the shell shall be located as near as possible to the weather deck and are to be closeable by means of sluice valves. Where the discharge line is raised up to above the weather deck, a swing check valve may be fitted instead of a sluice valve. Where the pumps are sucking from outboard, a blocking device is required to prevent water from being pumped into the 'tween deck space.

3. Stone shoots in fish processing decks are to be fitted as high as practicable. The lowest point of the inner openings should not come to water at inclinations of less than 15°, ship fully loaded. In addition to the watertight covers of the stone shoots swell shutters are to be fitted at the shell.

4. Bilge wells (slush wells) of an increased capacity are to be arranged in fish holds. They are to be equipped with an arrangement for rinsing the bilge sections, which is to be secured against unintentional operation.

D. Airpipes, Overflow Pipes, Sounding Pipes

1. Each tank is to be fitted with air pipes, over-flow pipes and sounding pipes. The air pipes are in general to be led to above the exposed deck. The height from the deck of the point where the water may have access is to be at least 760 mm on the exposed bulkhead deck and 450 mm on a superstructure deck. Upon request the height of air pipe may be reduced to avoid interference with the fishing operation.

2. For tanks which can be pumped up or filled up through closed shore connections, the air pipes are to be considered also as overflow pipes. The free inner cross sectional area of these air pipes is to be at least 1,25 times the inner cross sectional area of the filling pipes.

3. Where such pipes lead through weather decks, bulkhead decks or watertight partitions, their thickness is to be sufficient to allow efficient welding and protection against mechanical damage. Special joining pieces may be used as leadthroughs.

The wall thicknesses of air, overflow and sounding pipes are to be determined according to Rules for Machinery Installations - Volume III, Section 11 , R.

4. Suitable closing appliances are to be provided for air pipes, overflow pipes and sounding pipes, (see also Rules for Machinery Installations - Volume III, Section 11 , R) and are to be readily accessible at all times.

5. Closely under the inner bottom or the tank top, holes are to be cut into floor plates and side girders as well as into beams, girders, etc., to give the air free access to the air pipes. All floor plates and side girders are to be provided with limbers to permit the water and oil to reach the pump suctions.

6. Sounding pipes are to be extended to directly above the tank bottom. The shell plating is to be strengthened by thicker plates or doubling plates under the sounding pipes.

7. The distance of sounding pipes of oil tanks from the shell plating is not to be less than 100 mm.

E. Fishing Gear

1. General

1.1 Mast, gantries, gallows, outriggers, blocks, shackles, ropes etc. used for fishing are not part of the classification of the vessel. The classification does however, include examining the design of the ship's hull in way of mast, gantries and gallows with regard to the forces induced thereby.

1.2 Derrick booms, cranes, trolleys, gins and other gear used for loading or discharging processed catch, fish meal, equipment etc. are to be regarded as cargo handling appliances and are not included in the scope of these rules.

1.3 Test, examination and certification of the fishing gear following installation on board and prior to being put into use as well as periodical tests and examinations will be carried out on special request only. In this case E.2 to E.4 apply.

2. Submission of documents

2.1 For fishing gear the following documents have to be submitted in 3-fold [1]:

- general arrangement
- strength calculations and force diagrams
- rigging plans
- drawings of mast, gantries, gallows and outriggers together with their fittings
- drawing of the substructures, showing the connections of mast, gantries and gallows with the ship's structures and the local strengthenings
- drawings of interchangeable components which are not manufactured to standards (e.g. trawl blocks)
- information on trawl warp
- information on the machinery equipment such as hoisting, slewing and luffing mechanisms design data and winches as well as circuit diagrams of the hydraulic, pneumatic or steam system.

2.2 The drawings for approval must contain dimensions and details of the materials and welding method used. Where necessary parts lists are to be submitted.

3. Design criteria

3.1 All fishing gear is to be designed for a defined load (load condition I). The design loads shall be specified completely in the drawings and calculations submitted. Allowance is to be made for possible oblique loading and the simultaneous loading of a supporting structure by more than one lifting or towing gear.

3.2 In case of gear used for towing nets, calculations shall take account of the following load conditions:

.1 Trawl warp acting in the longitudinal direction at an angle of 30° to the horizontal;

.2 Trawl warp acting at an angle of 45° to the longitudinal axis of the ship and at an angle of 30° to the horizontal.

3.3 When trawling the rope tension S is to be calculated by reference either to the holding force or slip torque of the trawl winch or to the installed propulsive power (load condition II). The smaller value may be applied.

The minimum breaking load of the rope has to be 2,5 x S.

3.4 The total trawling force F may be roughly calculated from the installed propulsion power as follows:

Propeller with nozzle $F = 245 \cdot P$ [N]

Propeller without nozzle $F = 160 \cdot P$ [N]

P = total engine output [kW]

3.5 Where a breakage of the trawl warp (e.g. in the event of the net becoming caught) cannot be prevented by suitable means (e.g. by the use of constant pull winches), the load bearing structures are to be designed for the minimum breaking load of the rope (load condition III).

3.6 If a fishing gear is designed to withstand the breaking of the trawl warp, all related interchangeable components life blocks, shackles, rings etc. are to have a nominal size at least equal to half the minimum breaking load of the trawl warp.

4. Permissible stresses

4.1 The permissible stresses as defined below pay due regard to dynamic effects caused by load handling and/or seaway conditions.

4.2 The permissible stresses for masts, gantries, gallows,

[1] For Indonesian flag ships in quadruplicate one of which intended for the Indonesian Government.

outriggers and other structural members are to be calculated to the formula.

$$\sigma_{perm} = \frac{235}{k \cdot \gamma} \quad [N/mm^2]$$

k = material factor $\frac{295}{R_{eH} + 60}$

R_{eH} = yield point of material [N/mm^2]

γ = safety coefficient as shown in Table 21.2:

Table 21.2

Type of stress	Load condition I	Load condition II	Load condition III
Compressive stress	2,3	1,6	1,4
Tensile stress	2,0	1,4	1,2
Shear stress	3,5	2,4	2,1
Equivalent stress	2,0	1,4	1,2

F. Ventilators

1. For the height of coamings see A.2.

2. Ventilators of cargo holds are not to have any connection with other spaces.

3. The thickness of the coaming plates is to be 7,5 mm where the clear opening sectional area of the ventilator coamings is 300 cm^2 or less, and 10 mm where the clear opening sectional area exceeds 1600 cm^2. Intermediate values are to be determined by interpolation. A thickness of 6 mm will generally be sufficient within not permanently closed superstructures.

4. The thickness of ventilator posts should be at least equal to the thickness of coaming as per 3.

5. The wall thickness of ventilator posts of a clear sectional area exceeding 1600 cm^2 is to be in-creased according to the expected loads.

6. Generally, the coamings and posts shall pass through the deck and shall be welded to the deck plating from above and below. Where coamings or posts are welded onto the deck plating, fillet welds of $a = 0{,}5 \cdot t_o$ should be adopted for welding inside and outside.

7. Coamings and posts particularly exposed to wash of sea are to be efficiently connected with the ship's structure.

8. Where the thickness of the deck plating is less than 10 mm, a doubling plate or insert plate of 10 mm thickness is to be fitted. Their side lengths are to be equal to twice the length or breadth of the coaming.

9. Where beams are pierced by ventilator coamings, carlings of adequate scantlings are to be fitted between the beams in order to maintain the strength of the deck.

10. The ventilators in machinery spaces are to be arranged in such a way that no gases can accumulate under the deck between deck beams.

11. The main inlet and exhaust openings of the ventilation systems are to be provided with easily accessible closing appliances, which can be closed weathertight against wash of the sea. In ships of not more than 100 m in length, the closing appliances are to be permanently attached. In ships exceeding 100 m in length, they may be conveniently stowed near the openings to which they belong.

12. For ventilator posts which exceed 4,5 m in height above decks in Position 1 and for ventilator posts exceeding 2,3 m in height above decks in Position 2 closing appliances are required in special cases only.

G. Life Saving Appliances and Launching Devices

1. It is assumed that regarding the arrangement and operation of lifeboats and other life saving appliances either the requirements of the "Torremolinos International Convention for the Safety of Fishing Vessels, 1977", the regulations of the 1974 SOLAS Convention or other regulations set forth by the competent authority are complied with.

2. The dimensioning and testing of life boats with their launching devices and of other life saving appliances are not part of classification.

However, approval of the hull structure in way of the launching devices taking into account the forces from the above appliances is part of classification.

Part of classification also is the survey of the life saving appliances and their launching devices with regard to their proper condition and functioning within the scope of the class renewal surveys.

Guidance

For ships for which BKI has been requested to approve the launching arrangements, the "Regulations for Life Saving Launching Appliances" will be applied.

Section 22

Structural Fire Protection

Guidance :

For structural fire protection of fishing vessels references are to be made to Chapter V of Torremolinos International Convention.

A. Material

1. The hull, decks, structural bulkheads, superstructures and deckhouses are to be of steel except where in special cases the use of others suitable material may be approved, having in mind the risk of fire.

2. Bulkheads and decks enclosing machinery spaces, cargo spaces, emergency generator rooms, galleys, pantries containing cooking appliances, store-rooms containing flammable liquids and workshops other than those forming part of the machinery spaces are to be of steel or equivalent material.

3. All stairways in accommodation and service spaces shall be of steel frame construction or equivalent material.

B. Exemptions

For small fishing vessels BKI may accept deviations from material requirements of A.1 and A.2.

C. Restricted Use of Combustible Materials

1. Paints, varnishes and other finishes used on exposed interior surfaces shall not be capable of producing excessive quantities of smoke and toxic products [1].

2. Primary deck coverings, if applied, within accommodation and service spaces and control stations, which are located above machinery spaces shall be of approved material which will not readily ignite, or give rise to toxic or explosive hazards at elevated temperatures [2].

D. Ventilation Systems

1. The main inlets and outlets of all ventilation systems shall be capable of being closed from outside the respective spaces in the event of a fire.

2. Where they pass through accommodation spaces or spaces containing combustible materials, the exhaust ducts from galley ranges shall be appropriately isolated.

E. Means of Escape

1. Stairways and ladders shall be so arranged as to provide, from all accommodation spaces and from spaces in which the crew is normally employed, other than machinery spaces, ready means of escape to the open deck and thence to the lifeboats and liferafts.

2. At all levels of accommodation there shall be provided at least two widely separated means of escape from each restricted space or group of spaces.

3. Dispense may be given with one of the means of escape, due regard being paid to the nature and location of spaces and to the numbers of persons who normally might be quartered or employed there.

4. No dead-end corridors having a length of more than 7 m shall be accepted. A dead-end corridor is a corridor or part of a corridor from which there is only one escape route.

5. Two means of escape shall be provide from the machinery space by two sets of steel ladders as widely separated as possible leading to doors in the upper part of the space similarly separated and from which access is provided to the appropriate lifeboat and liferaft embarkation decks.

6. For a ship of a gross tonnage less than 1000, may be dispensed with one of the means of escape, due regard being paid to the width and disposition of the upper part of the space; and a ship of a gross tonnage of 1000 and above, may be dispensed with one means of escape from any such space so long as either a door or a steel ladder provides a safe escape route to the embarkation deck, due regard being paid to the nature and location of the space and whether persons are normally employed in that space.

7. Lifts shall not be considered as forming one of the required means of escape.

---

[1] Reference is made to the Fire Test Procedure Code Part 2, adopted by IMO by Resolution MSC.61(67).

[2] Reference is made to the Fire Test Procedure Code Part 6, adopted by IMO by Resolution MSC.61(67).

Annex

Sectional Properties of Sections and Girders

1. Sectional moduli of Sections

The section moduli of frames, beams stiffeners and other parts made of sections as given in the Rules are valid for sections in conjunction with plating to which they are welded. For the determination of the required sections the following Tables can be applied for moduli from 5 to 2350 cm^3 without having to determine especially the effective width of plating.

The sections moduli of the sections are to be applied only in connection with these Rules. The section moduli given are based on the assumption of an effective width of plating of $40 \cdot t_w$ (t_w = web thickness of the section).

The given scantlings of the sections are valid only for angles according to DIN 1028 and 1029, bulb angles according to DIN 1020, bulb plates according to DIN 1019. Where sections are being used differ from those standards the exact dimension and moduli of these sections are to be submitted.

2. Scantlings of brackets

The scantlings of brackets given on pages A-2 through A-11 apply for the case that both brackets and attached sections are made of ordinary hull structural steel.

3. Sectional properties of built girders

The moment of inertia and section moduli of transverses, girders etc., determine according to the Rules, may be derived from the graphs on pages A-12 and A-13 of this Annex.

Modulus of sections in conjunction with plating

Modulus [cm^3]	Section in conjunction with plating in [mm] 			Scantlings of brackets in [mm]
5			– 50 x 5	
6			– 50 x 6	
7			– 50 x 7	
8				
9			– 65 x 6	
10			– 60 x 8	– 100 x 6,5
11		– 60 x 4	– 65 x 7	
12		– 60 x 5	– 75 x 6	
13			– 65 x 8	
14		– 60 x 6	– 75 x 7	
15			– 80 x 7	
16	– 60 x 40 x 5		– 75 x 8	
17				
18				
19	– 60 x 40 x 6		– 75 x 9	
20		– 80 x 5		
21	– 65 x 50 x 5		– 75 x 10	
22	– 60 x 40 x 7			
23		– 80 x 6	– 90 x 8	
24				– 100 x 6,5

Modulus of sections in conjunction with plating *(continued)*

Modulus [cm³]	Section in conjunction with plating in [mm] 			Scantlings of brackets in [mm]
25	– 75 x 50 x 5	– 80 x 7		– 110 x 6,5
26			– 90 x 9	
27	– 75 x 55 x 5		– 100 x 8	
28				
29	– 80 x 40 x 6 – 65 x 50 x 7		– 90 x 10	
30				
31			– 100 x 9	
32			– 110 x 8	– 120 X 6,5
33			– 90 x 11	
34		– 100 x 6		
35	– 75 x 50 x 7		– 100 x 10	
36			– 90 x 12	
37	– 65 x 50 x 9 – 75 x 55 x 7 – 80 x 40 x 8		– 110 x 9	
38		– 100 x 7	– 120 x 8	
39	– 80 x 65 x 6		– 100 x 11	
40				
41				
42		– 100 x 8	– 110 x 10	– 130 X 6.5
43	– 90 x 60 x 6			
44	– 75 x 50 x 9		– 120 x 9	

Modulus of sections in conjunction with plating *(continued)*

Modulus [cm³]	Section in conjunction with plating in [mm]			Scantlings of brackets in [mm]
				
45	– 100 x 50 x 6			
46				
47	– 75 x 55 x 9		– 110 x 11	
48				
49		– 120 x 6	– 120 x 10	– 140 x 6,5
50				
51				
52	– 80 x 65 x 8		– 110 x 12	
53				
54		– 120 x 7		
55			– 120 x 11	
56				
57	– 90 x 60 x 8		– 130 x 10	– 150 x 6,5
58			– 150 x 8	
59	– 90 x 75 x 7 – 100 x 50 x 8			
60		– 120 x 8	– 120 x 12	
61	– 100 x 65 x 7			
62				
63				

Modulus of sections in conjunction with plating *(continued)*

Modulus [cm³]	Section in conjunction with plating in [mm]			Scantlings of brackets	
				non-flanged	flanged
64	– 80 x 65 x 10		– 140 x 10	– 160 x 6,5	– 160 x 6,5
66	– 100 x 75 x 7	– 140 x 6			
68			– 120 x 13		
70					
72			– 140 x 11		
74	– 100 x 50 x 10	– 140 x 7	– 150 x 10	– 170 x 6,5	– 170 x 6,5
76			– 120 x 14		
78	– 100 x 65 x 9				
80			– 140 x 12		
82		– 140 x 8			
84			– 160 x 10		
86				– 180 x 7,0	– 180 x 6,5
88	– 100 x 75 x 9		– 140 x 13		
90					
92		– 140 x 9	– 150 x 12		Flange 50 mm
94					
96	– 100 x 65 x 11		– 140 x 14		
98					
100	– 130 x 65 x 8			– 190 x 7,0	– 190 x 6,5

Modulus of sections in conjunction with plating *(continued)*

Modulus [cm³]	Section in conjunction with plating in [mm]			Scantlings of brackets	
				non-flange	flange
105	– 100 x 75 x 11 – 120 x 80 x 8	– 160 x 7	– 160 x 12 – 180 x 10		
110	– 130 x 75 x 8	– 160 x 8			
115			– 160 x 13	– 200 x 7,5	– 200 x 6,5
120		– 160 x 9	– 140 x 16		
125	– 130 x 65 x 10		– 160 x 14		
130	– 120 x 80 x 10		– 180 x 12	– 210 x 7,5	– 210 x 6,5
135	– 130 x 75 x 10		– 160 x 15		
140			– 180 x 13		Flange 50 mm
145		– 180 x 8	– 160 x 16		
150	– 130 x 65 x 12 – 150 x 75 x 9			– 220 x 8,0	– 220 x 6,5
155	– 120 x 80 x 12 – 130 x 90 x 10		– 180 x 14		
160		– 180 x 9	– 160 x 17		
165	– 130 x 75 x 12		– 180 x 15	– 230 x 8,0	– 230 x 7,0
170			– 160 x 18		
175	– 120 x 80 x 14	– 180 x 10			
180	– 150 x 75 x 11 – 130 x 90 x 12		– 180 x 16		
185		– 180 x 11	– 200 x 14	– 240 x 8,5	– 240 x 7,0
190	– 150 x 90 x 10 – 160 x 80 x 10		– 180 x 17		
195					
200	– 150 x 100 x 10		– 200 x 15	– 245 x 8,5	–245 x 7,0

Modulus of sections in conjunction with plating *(continued)*

Modulus [cm³]	Section in conjunction with plating in [mm]			Scantlings of brackets	
				non-flanged	flanged
210		– 200 x 9	– 180 x 18	– 250 x 8,5	– 250 x 7,0
220		– 200 x 10	– 200 x 16 – 220 x 14		
230	– 150 x 90 x 12 – 160 x 80 x 12		– 200 x 17	– 260 x 9,0	– 260 x 7,5
240	– 150 x 100 x 12		– 220 x 15		Flange 50 mm
250	– 180 x 90 x 10	– 200 x 11,5	– 200 x 18		
260	– 160 x 80 x 14		– 220 x 16 – 240 x 14	– 270 x 9,0	– 270 x 7,5
270			– 200 x 19		
280	– 150 x 100 x 14	– 220 x 10	– 220 x 17 – 200 x 20 – 240 x 15	– 280 x 9,5	– 280 x 8,0
290	– 180 x 90 x 12				
300	– 200 x 100 x 10		– 220 x 18		
310		– 220 x 11,5	– 240 x 16 – 260 x 14	– 290 x 9,5	– 290 x 8,0
320			– 220 x 19		
330	– 180 x 90 x 14		– 240 x 17 – 260 x 15 – 220 x 20		
340		– 240 x 10			
350			– 240 x 18 – 260 x 16	– 300 x 10,0	– 300 x 8,0
360	– 200 x 100 x 12				Flange 55 mm
370		– 240 x 11	– 240 x 19		
380	– 250 x 90 x 10		– 260 x 17	– 310 x 10,5	– 310 x 8,5
390		– 240 x 12	– 240 x 20		
400			– 260 x 18	– 315 x 10,5	–315 x 8,5

Modulus of sections in conjunction with plating *(continued)*

Modulus [cm^3]	Section in conjunction with plating in [mm] 			Scantlings of brackets non-flanged	flanged
410	– 200 x 100 x 14		– 280 x 16		
420		– 260 x 10		– 320 x 10,5	– 320 x 8,5
430			– 260 x 19 – 280 x 17		Flange 55 mm
440					
450		– 260 x 11			
460	– 250 x 90 x 12		– 260 x 20 – 280 x 18	– 330 x 11,0	– 330 x 9,0
470	– 200 x 100 x 16	– 260 x 12			
480					
490			– 300 x 17 – 280 x 19	– 340 x 11,0	– 340 x 9,0
500		– 260 x 13			
510					Flange 60 mm
520			– 280 x 20 – 300 x 18		
530	– 250 x 90 x 14	– 280 x 11			
540				– 350 x 11,5	– 350 x 9,0
550			– 280 x 21		
560			– 300 x 19		
570		– 280 x 12			
580			– 280 x 22	– 360 x 11,5	– 360 x 9,5
590			– 300 x 20 – 320 x 18		
600	– 250 x 90 x 16	– 280 x 13			

Modulus of sections in conjunction with plating *(continued)*

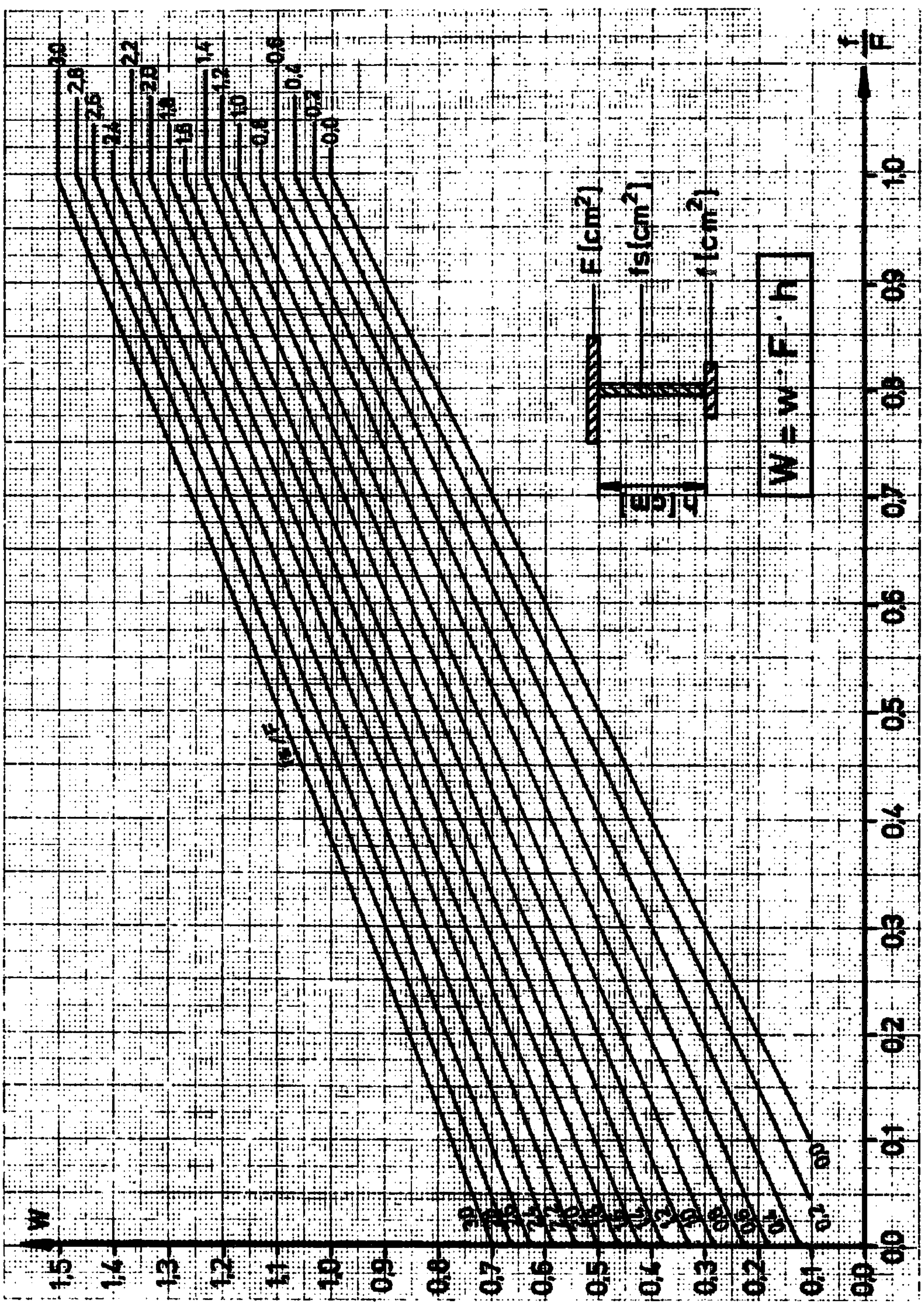
Modulus [cm^3]	Section in conjunction with plating in [mm] 		Scantlings of brackets non flanged	flanged
620			– 370 x 12,0	– 370 x 9,5
640	– 280 x 14 – 300 x 11	– 300 x 21 – 320 x 19		
660		– 300 x 22		
680	– 300 x 12	– 320 x 20	– 380 x 12,0	– 380 x 10,0
700	– 300 x 13	– 300 x 23		Flange 65 mm
720		– 320 x 21 – 340 x 19		
740	– 300 x 14	– 300 x 24 – 320 x 22	– 390 x 12,5	– 390 x 10,0
760		– 340 x 20		
780	– 300 x 15 – 320 x 12	– 320 x 23		
800		– 340 x 21	– 400 x 13,0	– 400 x 10,5
820	– 320 x 13	– 320 x 24		Flange 70 mm
840		– 340 x 22 – 360 x 20		
860	– 320 x 14		– 410 x 13,0	– 410 x 10,5
880		– 320 x 25 – 340 x 23		
900	– 340 x 12 – 320 x 15			
920		– 320 x 26 – 340 x 24	– 420 x 13,5	– 420 x 10,5
940	– 320 x 16	– 300 x 22		
960	– 340 x 13	– 340 x 25		Flange 75 mm
980			– 430 x 13,5	– 430 x 11,0
1000	– 340 x 14			

Modulus of sections in conjunction with plating *(continued)*

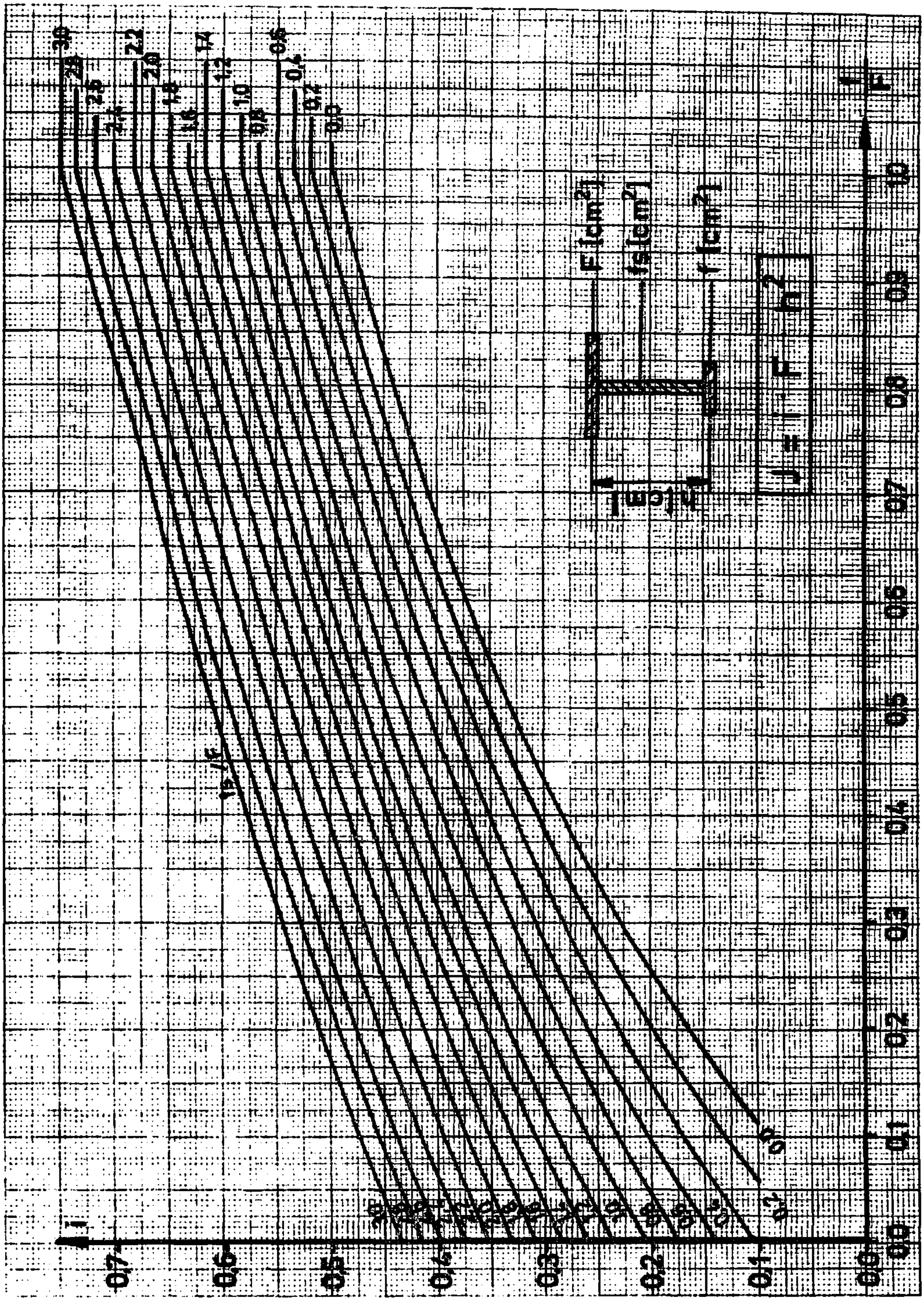
Modulus [cm³]	Section in conjunction with plating in [mm] (bulb)	Section in conjunction with plating in [mm] (T)	Scantlings of brackets: non flanged	Scantlings of brackets: flanged
1020		– 340 x 26 – 360 x 24		
1040	– 340 x 15	– 380 x 22		Flange 75 mm
1060			– 440 x 14,0	– 440 x 11,0
1080	– 340 x 16			
1100		– 340 x 28		
1120		– 360 x 26	– 450 x 14,0	– 450 x 11,5
1140		– 380 x 24		Flange 80 mm
1160				
1180	– 370 x 13			
1200			– 460 x 14,5	– 460 x 11,5
1220	– 370 x 14	– 360 x 28		
1240		– 380 x 26		
1260		– 400 x 24		
1280	– 370 x 15		– 470 x 15,0	– 470 x 12,0 Flange 85 mm
1300				
1320	– 370 x 16	– 360 x 30		
1340				
1360		– 380 x 28 – 400 x 26	– 480 x 15,0	– 480 x 12,0
1380	– 370 x 17	– 420 x 28		Flange 90 mm
1400				

Modulus of sections in conjunction with plating *(continued)*

Modulus [cm^3]	Section in conjunction with plating in [mm]		Scantlings of brackets	
			non flanged	flanged
1450	– 370 x 18		– 490 x 15,5	– 490 x 12,5
1500	– 400 x 14	– 380 x 30 – 400 x 28		
1550	– 400 x 15	– 420 x 26	– 500 x 16,0	– 500 x 12,5
1600	– 400 x 16	– 400 x 30	– 510 x 16,0	– 510 x 13,0
1650	– 400 x 17	– 420 x 28 – 440 x 26		
1700			– 520 x 16,5	– 520 x 13,0
1750	– 400 x 18	– 420 x 30		
1800	– 400 x 19	– 440 x 28		
1850	– 430 x 15		– 530 x 16,5	– 530 x 13,5
1900		– 420 x 32	– 540 x 17,0	– 540 x 13,5
1950	– 430 x 16	– 440 x 30 – 460 x 28		Flange 90 mm
2000	– 430 x 17			
2050			– 550 x 17,5	– 550 x 14,0
2100	– 430 x 18	– 440 x 32 – 460 x 30		
2150	– 430 x 19		– 560 x 17,5	– 560 x 14,0
2200				
2250	– 430 x 20		– 570 x 18,0	– 570 x 14,5
2300		– 460 x 32		
2350	– 430 x 21			
2400			– 580 x 18,0	– 580 x 14,5
2450			– 585 x 18,5	– 585 x 14,5



Smallest Section Modulus of I- and T- girder



Moment of Inertia of I- and T- girder