Rules for Classification and Construction

I Ship Technology

3 Special Craft

3 Yachts and Boats up to 24 m

Edition 2003

The following Rules come into force on October 1st, 2003

Alterations to the preceding Edition are marked by beams at the text margin.

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Published by: Germanischer Lloyd Aktiengesellschaft, Hamburg
Printed by: Gebrüder Braasch GmbH, Hamburg

Table of Contents

Annex A Series Construction Supervision of Pleasure Craft

Annex B Requirements for FRP Materials and Production

Annex C Excerpts from the Rules for Materials

Annex D Excerpt from the Rules for Welding

Annex E Workboats, Conversion Formulae

Annex F Notes and Tables

Annex G Cabins and Accommodation

Annex H Number of Persons and Freeboard

Section 1

Hull Structures

A. General Rules for the Hull

1. General, definitions

1.1 Application

These rules apply to pleasure craft of length **L** from 6 to 24 m and provided that the pleasure craft classed and approved in accordance therewith are at all times employed exclusively under the conditions for which they have been designed, constructed and approved and that they are in the sense of good seamanship correctly handled and equipped and operated at a speed adopted to the respective seaway conditions.

Commercial vessels according to 1.10.3 may also be dimensioned to these rules taken certain add-on factors into account.

1.2 Operating categories

1.2.1 The scantlings of hull primary structural members apply to operating category I without restriction.

Note

Definitions of Operating Categories I, II, III, IV and V see "Rules for Classification and Construction, I - Ship Technology, Part O – Classification and Surveys, Section 2, F.2.2".

1.2.2 Restricted operating categories

1.2.2.1 For craft intended to be classified only for one of the restricted operating categories II, III, IV and V the governing scantlings of the primary structural members of the hull may be reduced as follows:

Operating Category II:	by	5 %
Operating Category III:	by	10 %
Operating Category IV, V:	by	15 %

The reductions are effected by appropriate reduction factors to the design loads. Excluded from the reduction of the scantlings according to the regulations are:

– rudders

– propeller brackets

– watertight bulkheads

– tanks, masts and standing rigging

– keelbolts

1.2.2.2 The operating category of a pleasure craft to be classified may be restricted if closures according to Section 5, A. do not meet the requirements of the operating category applied for.

1.3 Equivalence

Pleasure craft of unusual type or which partly deviate from the construction rules may be assigned a class certificate if their structural members are considered equivalent to those for this class.

1.4 Accessibility

Hull equipment components such as sea cocks, through-hull fittings and connected pipelines shall be accessible for inspection and maintenance.

Inside the craft, good air circulation shall be ensured.

1.5 Definitions

1.5.1 Principal dimensions

Unless otherwise indicated, the following dimensions are to be substituted in the calculation formulae of the following sections with the dimensions in [m]. (For full detail see ISO 8666).

1.5.1.1 Length of the hull L_H

The length L_H in [m] of the hull is the horizontal distance between the foremost and the aftermost part of the craft. The length includes structural and integral parts of the craft.

1.5.1.2 Waterline length L_{WL}

The waterline length in [m] is the distance between the foremost and the aftermost intersections of the hull with the flotation plane.

1.5.1.3 Scantling length L

The scantling length is determined as follows:

$$L = \frac{L_H + L_{WL}}{2} \quad [m]$$

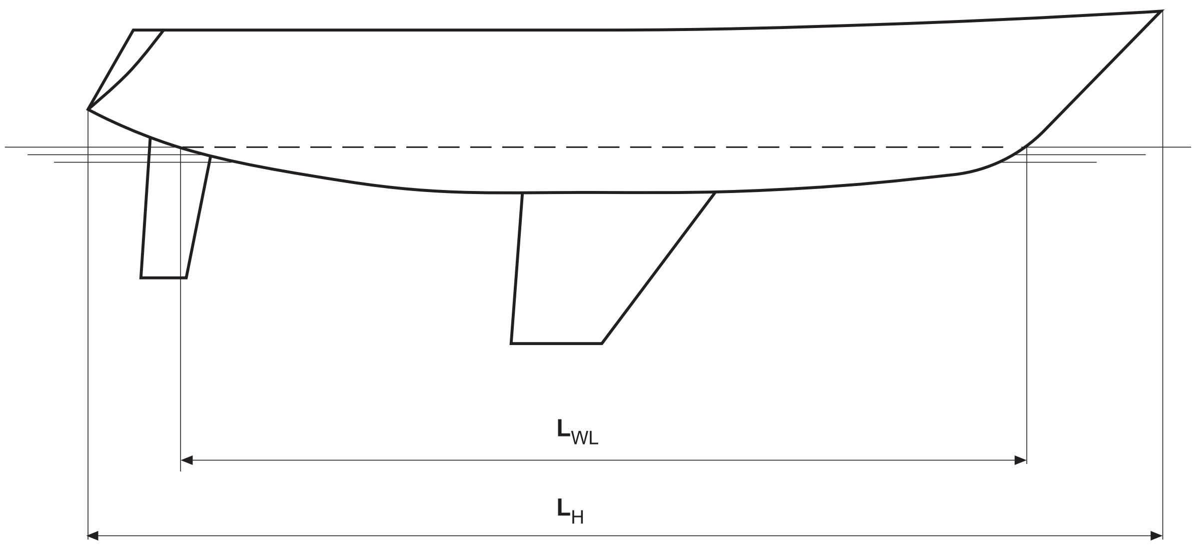


Fig. 1.1

1.5.1.4 Beam B

The beam **B** in [m] is the maximum breadth of the craft measured from one shell outer edge to the other, disregarding any rubbing strakes etc.

1.5.1.5 Depth H

The depth **H** in [m] is the vertical distance between the canoe body bottom and the top edge of the deck, measured at the side of the craft halfway along $\mathbf{L_{WL}}$, as in Figs. 1.1 and 1.2.

1.5.1.6 Depth H_1

The depth $\mathbf{H_1}$ in [m] is the depth **H** increased by 1/6 of the depth $\mathbf{H_k}$ of the keel, measured at the side of the craft halfway along $\mathbf{L_{WL}}$, as in Figs. 1.1 and 1.2.

1.5.1.7 Depth H_k of the keel

The depth of the keel in [m] is the distance measured amidships from the bottom edge of the keel to the lowest point of the hull, as in Figs. 1.1 and 1.2.

1.5.1.8 Draught T

The draught **T** in [m] is the vertical distance, measured halfway along $\mathbf{L_{WL}}$, between the flotation plane of the craft in the ready to operate condition and the bottom edge of the keel.

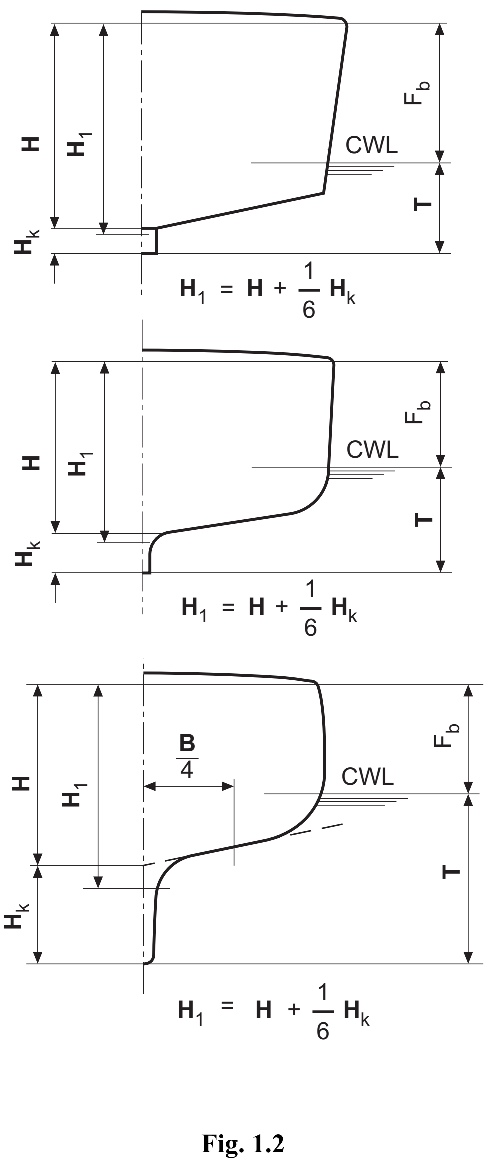


Fig. 1.2

1.5.1.9 Freeboard F_b

In the case of open or partially-decked craft, the freeboard is the minimum distance between the flotation plane and the upper edge of the gunwale or an opening in the hull without a watertight closure. For decked craft the freeboard is to be measured to the upper edge of the deck at its lowest point.

1.5.1.10 Frame spacing a

The spacing **a** in [m] of longitudinal and transverse frames is measured from moulding edge to moulding edge.

1.5.2 Speed v

The speed **v** is the expected maximum speed in knots [kn] of the craft in the ready to operate condition in smooth water.

1.5.3 Displacement D

The displacement weight **D** in [t] is the weight of the craft in the ready to operate condition, corresponding to the sum of the lightweight and the deadweight.

$$D = V \cdot \rho$$

ρ = density of the displaced water [t/m³]

V = immersed volume up to line of flotation [m³]

1.5.4 Distinction of vessels (tightness)

1.5.4.1 Open craft

Craft without any deck, max. permissible operating category: V.

1.5.4.2 Partially-decked craft

Craft with a foredeck whose length is at least 0,33 **L** and an after deck, otherwise open. Permissible operating categories: IV and V.

1.5.4.3 Decked craft

Craft with a continuous watertight deck from stern to stem, possibly interrupted by a self-bailing cockpit. Permissible operating categories I – V.

1.5.5 Types of vessels

1.5.5.1 Sailing dinghy

Sailing boat without a ballast keel, without cabin.

1.5.5.2 Cruising centreboarder

Sailing boat with cabin, but without ballast keel.

1.5.5.3 Keel boat

Sailing boat with ballast keel (with or without cabin).

1.5.5.4 Sailing yacht

Decked craft with cabin, fixed engine installation and ballast keel.

1.5.5.5 Motor boat

Open or partially-decked boat propelled by outboard motors or fixed engines.

1.5.5.6 Motor yacht

Decked craft with cabin and fixed engine installation.

1.5.5.7 Motorsailer

Decked craft with cabin, sail rig and fixed engine installation, suitable for main propulsion.

1.6 Materials

The materials of the structural members shall comply with the Rules for Classification and Construction, II – Materials and Welding, Part 1 – 3, excerpts of which are listed in Annex B, C, and D. Materials with qualities differing from these regulations may be used only if specifically approved.

1.7 Submission of documents

1.7.1 To ensure conformity with the regulations, drawings and documents in triplicate are to be submitted which clearly show the arrangement and scantlings of the components plus their material designations.

For the scope see Form F 146 in Annex F.

Other data which appear to be necessary, e.g. strength calculations, may be requested by GL.

Deviations from the approved construction drawings require approval before work commences.

1.7.2 Survey during construction will be based on the approved documentation which shall have been submitted before manufacturing starts.

1.8 Programmed construction rules GL-Yacht

For the dimensioning rules of the hull, an interactive computer program is available from Germanischer Lloyd. The program comprises of rules for hull of GRP, metallic material as well as cold-moulded wood laminates. It permits rapid dimensioning in accordance with the Germanischer Lloyd's rules and may be used for the optimisation of structures.

1.9 Basic principles for load determination

1.9.1 General

A. contains data concerning the design loads for the scantling determination of pleasure craft hull according to the dimensioning formulae of B., E. and F.

1.9.2 Hull loadings

Table 1.1

Hull area	**Motor craft**	**Sailing craft and motorsailers**
	Design loading [kN/m²]	
Shell bottom	P_{dBM}	P_{dBS}
≥ 0,4 **L** ÷ fore	$2{,}7\ \mathbf{L} + 3{,}29$	$3{,}29\ \mathbf{L} - 1{,}41$
< 0,4 **L** ÷ aft	$2{,}16\ \mathbf{L} + 2{,}63$	$2{,}63\ \mathbf{L} - 1{,}13$
Shell side	P_{dSM}	P_{dSS}
≥ 0,4 **L** ÷ fore	$1{,}88\ \mathbf{L} + 1{,}76$	$2{,}06\ \mathbf{L} - 2{,}94$
< 0,4 **L** ÷ aft	$1{,}5\ \mathbf{L} + 1{,}41$	$1{,}65\ \mathbf{L} - 2{,}35$

1.9.3 Correction factors for speed

Table 1.2

Loading area	**Correction factor**
Shell bottom	$F_{VB} = 0{,}34 \cdot \sqrt{\dfrac{\mathbf{v}}{\sqrt{\mathbf{L}_{WL}}}} + 0{,}355 \geq 1{,}0$
Shell side	$F_{VS} = \left(0{,}024 \cdot \dfrac{\mathbf{v}}{\sqrt{\mathbf{L}_{WL}}} + 0{,}91\right)\left(1{,}018 - 0{,}0024\,\mathbf{L}\right) \geq 1{,}0$
Internal structural members Floors	$F_{VF} = \left(0{,}78 \cdot \sqrt{\dfrac{\mathbf{v}}{\sqrt{\mathbf{L}_{WL}}}} - 0{,}48\right)\left(1{,}335 - 0{,}01\,\mathbf{L}\right) \geq 1{,}0$
Web frame at CL Bottom longitudinal frames	F_{VBW}, F_{VL} $= 0{,}075 \cdot \dfrac{\mathbf{v}}{\sqrt{\mathbf{L}_{WL}}} + 0{,}73 > 1{,}0$
Transverse frames Webs at side	F_{VSF}, F_{VSW} $= \left(0{,}1 \cdot \dfrac{\mathbf{v}}{\sqrt{\mathbf{L}_{WL}}} + 0{,}52\right)\left(1{,}19 - 0{,}01\,\mathbf{L}\right) > 1{,}0$
Side longitudinal frames	$F_{VSL} = \left(0{,}14 \cdot \dfrac{\mathbf{v}}{\sqrt{\mathbf{L}_{WL}}} + 0{,}47\right)\left(1{,}07 - 0{,}008\,\mathbf{L}\right) > 1{,}0$
$\mathbf{L}_{WL}$ and **v** see 1.5:	$v_{max} = 12 \cdot \sqrt[4]{\mathbf{L}}\ \ [kn]$

1.9.4 Deck and superstructure loadings

Table 1.3

Area			**Sailing- and motor craft** [3] **Design loads P_{dD} [kN/m²]**
Main deck			0,26 **L** + 8,24
Cabins	h ≤ 0,5 m	deck [1]	0,235 **L** + 7,42
		wall	0,26 **L** + 8,24
Deckhouses	h > 0,5 m	deck [1, 2]	(0,235 **L** + 7,42) (1 – h'/10)
		side wall [2]	(0,26 **L** + 8,24) (1 – h'/10)
		front wall	1,25 (0,26 **L** + 8,24) (1 – h'/10)

1 Minimum load for non-walk-on cabin decks P_{dD} min = 4,0 [kN/m²]
2 h' = 0,5 · h (h = superstructure height above main deck)
3 In the case of special-purpose craft such as fishing craft, the deck load may have to be corrected as appropriate for additional loads present.

1.10 General principles for scantling determination

1.10.1 The scantlings of structural members and components are to be determined by direct calculation if the craft is of unusual design or shape, or has unusual proportions, or if

– the speed **v** exceeds 35 knots or

– if $\frac{\mathbf{v}}{\sqrt{\mathbf{L}_{WL}}} \geq 10{,}8$ or

– $D > 0{,}094\left(\mathbf{L}^2 - 15{,}8\right)$

and at the same time

$$\frac{v}{\sqrt{\mathbf{L}_{WL}}} > 3{,}6$$

– materials are intended to be used other than those listed in Rules for Classification and Construction, II – Materials and Welding. Excerpts from these are listed in Annex B and C.

1.10.2 Hull of yachts intended for training or charter and strengthened on application by the owner or the building yard are assigned the type designation 'Training sailing/motor yacht' or 'Charter sailing/motor yacht' in their classification certificate.

1.10.3 Scantling determination for the following commercial craft

– fishing craft of GRP

– workboats of GRP or metallic material

is carried out with the aid of add-on factors for plate thickness and section moduli see B. (GRP) and F. (metal hull).

2. Bulkheads

2.1 Arrangement of bulkheads

2.1.1 Collision bulkhead

It is recommended that each pleasure craft be fitted with a collision bulkhead. Motor yachts with a length **L** exceeding 17 m and sailing yachts/motorsailers with a length **L** exceeding 20 m shall have a collision bulkhead. Collision bulkheads shall be extended up to the weather deck.

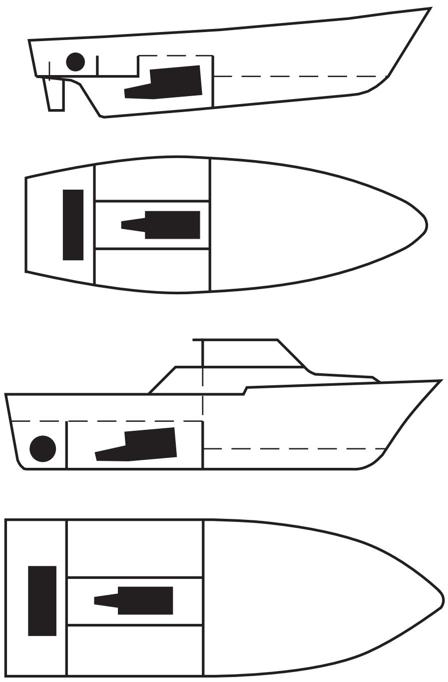
2.1.2 Other bulkheads and subdivisions

2.1.2.1 Motor yachts whose length **L** exceeds 17 m shall have watertight and fire-retardant bulkheads between the engine compartment(s) and other spaces. This also applies to sailing yachts and motorsailers whose length **L** exceeds 20 m. If these bulkheads cannot be extended up to the main deck, approval of equivalent technical solutions may be considered. If accommodation spaces are arranged above the engine compartment, the deck in this area shall be tight enough to prevent penetration by any gases or vapours from the engine compartment.

For smaller craft, engine compartment bulkheads corresponding to the above requirements are recommended as far as practicable.

2.1.2.2 Pleasure craft with petrol engines shall have gastight bulkheads between engine compartment(s) and the adjoining spaces, and independent supply and exhaust ventilation fitted to these compartments. Motor-driven fans must be ignition protected.

Petrol tanks shall be arranged in a space separate from all other spaces by gastight bulkheads and shall be ventilated overboard. Exceptionally, in the case of small yachts where this arrangement of the petrol tanks is not practicable because of lack of space, fitting of the intermediate bulkheads may be dispensed with.



2.1.2.3 It is recommended that the stern tube be installed in a watertight compartment.

2.2 Openings in bulkheads

2.2.1 Type and arrangement of doors, manholes, etc. in watertight bulkheads are subject to approval.

2.2.2 The collision bulkhead shall not have any openings below deck. In small boats, manholes may be fitted if it is not practicable to provide an access from the deck. A pipe for draining the forepeak may pass through the bulkhead if there is a shut-off device immediately at the bulkhead.

2.2.3 Watertight bulkheads (except for collision bulkheads) may have watertight trap doors or sliding doors. The door openings are to have rigid frames. The doors shall fit neatly to guarantee proper sealing. The doors shall be of proven design and capable of withstanding a water pressure up to the deck top edge from either side. The doors shall have rubber seals and at least 4 clips, or other proven means of closure which ensures adequate sealing pressure. The clips and means of closure must be operable from both sides of the bulkhead. The door hinges shall have elongated holes.

2.2.4 If cables, pipelines, etc. are passing through watertight bulkheads, this shall not impair their mechanical strength, watertightness and fire resistance.

2.2.5 Fireproof cable glands (including the sealing compound) shall be of non-combustible material.

3. Rudder and steering arrangements

3.1 General

3.1.1 Each pleasure craft shall be fitted with rudder and steering arrangements which provide adequate manoeuvrability.

3.1.2 The rudder- and steering arrangement comprises of all components necessary for manoeuvring the craft, from the rudder and the rudder operating gear to the steering position.

3.1.3 Rudder- and steering equipment shall be so arranged that checks and performance tests of all components are possible.

3.2 Rudder force and torsional moment

3.2.1 Rudder force

The rudder force to be used for determining the component scantlings is to be calculated in accordance with the following formula:

$$C_R = \kappa_1 \cdot \kappa_2 \cdot C_H \cdot \mathbf{v}_0^2 \cdot A \quad [N]$$

A = total surface area of rudder without that of skeg, in [m²] e.g. $A = A_1 + A_2$.

$\mathbf{v}_0$ = highest anticipated speed of the craft in knots [kn]

$\mathbf{v}_{0min} = 3 \cdot \sqrt{\mathbf{L}_{WL}}$ for sailing boats, sailing yachts [kn]

$= 2{,}4 \cdot \sqrt{\mathbf{L}_{WL}}$ for motorsailers and motor yachts [kn]

$\mathbf{v}_{0max} = 12 \cdot \sqrt[4]{\mathbf{L}}$

$\mathbf{L}_{WL}$ = in accordance with 1.5 in [m]

κ_1 = factor depending on aspect ratio of the effective rudder surface area A_0

$$\Lambda = \frac{b^2}{A_0}$$

b = mean height of rudder surface in [m]

A_0 = effective rudder surface [m^2]

= rudder surface plus effective part of skeg surface in accordance with Figs. 1.4 and 1.7

Table 1.4

Λ	κ_1
0,50	0,66
0,75	0,83
1,00	1,00
1,25	1,12
1,50	1,21
1,75	1,29
2,00	1,36
2,25	1,41
2,50	1,45
2,75	1,48
3,00	1,50
3,25	1,52
3,50	1,53

κ_2 = factor, depending on type of craft

Table 1.5

Type of craft	C_H	κ_2
Sailing dinghies Cruising centreboarders Motor boats Motor yachts Sailing yachts with flat afterbody	93 [1]	1,20
Motorsailers		1,10
Keel boats Keel and centreboard yachts Sailing yachts		1,00
Fishing craft Workboat	132	1,20

[1] for craft **L** > 20 m C_H = 100

3.2.2 Torsional moment

The torsional moment to be transmitted by the rudder operating gear is to be calculated in accordance with the following formula:

$$Q_R = C_R \cdot r \ [\text{Nm}]$$

r = $x_c - f$ [m], if the axis of rotation lies within the rudder

= $x_c + f$ [m], if the axis of rotation is forward of the rudder

x_c, f, r_{min} in [m] dependent on the type of rudder as in Figs. 1.3, 1.4, 1.5, 1.6 and 1.7.

$x_c = 0{,}3 \cdot c$

$r_{min} = 0{,}10 \cdot c$

$c = \frac{A_1}{b}$

$A_0 = A_1$

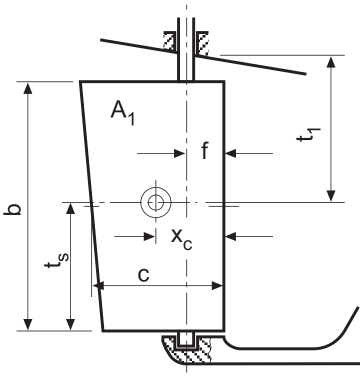


Fig. 1.3

$x_c = 0{,}5 \cdot c$

für $\frac{A_1}{A_3} \geq 2{,}0$

$r_{min} = 0{,}05 \cdot c$

$c = \frac{A_1 + A_3}{b}$

$A_0 = A_1 + A_3$

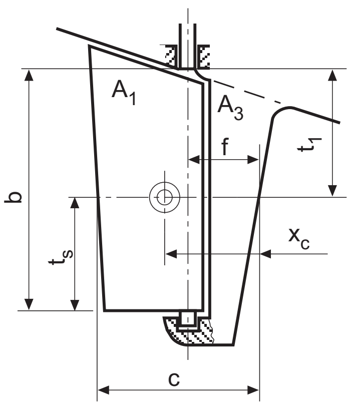


Fig. 1.4

$x_c = 0{,}25 \cdot c = r$

für $\frac{A_1}{A_3} < 2{,}0$

$r_{min} = 0{,}05 \cdot c$

$c = \frac{A_1}{b}$

$A_0 = A_1$

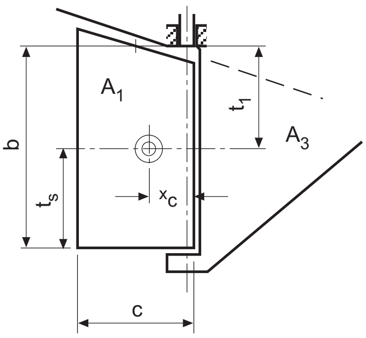


Fig. 1.5

$x_c = 0{,}3 \cdot c$

$r_{min} = 0{,}1 \cdot c$

$c = \frac{A_2}{b}$

$A_0 = A_2$

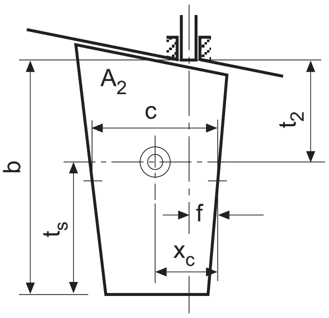


Fig. 1.6

$x_c = c\left[0{,}2 \cdot \frac{b_1}{b} + 0{,}3\right]$

$r_{min} = c\left[0{,}1 - 0{,}05 \cdot \frac{b_1}{b}\right]$

$c = \frac{A_1 + A_2 + A_3}{b}$

$A_0 = A_1 + A_2 + A_3$

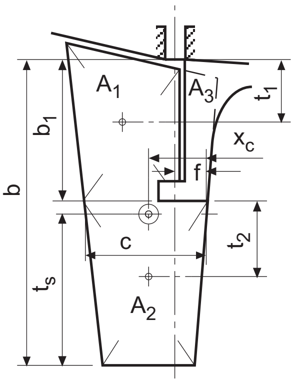


Fig. 1.7

3.3 Scantlings of the rudder arrangement

3.3.1 Rudder stock

The rudder stock diameter required for transmission of the torsional moment shall not be less than:

$$D_t = 3{,}8 \sqrt[3]{k \cdot Q_R} \quad [\text{mm}]$$

k = material factor according to F.3.3

Depending on their type of support, rudder stocks must additionally carry bending moments and are to be reinforced in accordance with the following formula:

$$D_v = D_t \cdot \kappa_3 \quad [\text{mm}]$$

κ_3 = factor depending on the type of rudder and support of rudder stock

For rudders according to Figs. 1.3, 1.4 and 1.5

$$\kappa_3 = \sqrt[6]{\frac{1}{12} \cdot \left(\frac{t_1}{r}\right)^2 + 1}$$

For rudders according to Fig. 1.6 (spade rudder)

$$\kappa_3 = \sqrt[6]{\frac{4}{3} \cdot \left(\frac{t_2}{r}\right)^2 + 1}$$

For rudders according to Fig. 1.7

$$\kappa_3 = \sqrt[6]{\frac{4}{3} \cdot \left(\frac{A_2}{A_1 + A_2}\right)^2 \cdot \left(\frac{t_2}{r}\right)^2 + 1}$$

For rudders according to Figs. 1.3, 1.4, 1.5 and 1.7

κ_3 = 1,0 if there is proof that the rudder stock is not subject to bending moments.

The rudder stock diameter D_v thus determined is to be maintained for at least 0,1 the distance between the lower main bearing and the next higher bearing above the lower bearing. The diameter may then be reduced to the diameter D_t necessary for the transmission of the torque at the tiller. Halfway along the shaft, the diameter may not be less than

$$D_m = \frac{D_v + D_t}{2} \cdot 1{,}15 \quad [\text{mm}]$$

for spade rudders according to Fig. 1.6;

$$D_m = \frac{D_v + D_t}{2} \cdot 1{,}0 \quad [\text{mm}]$$

for rudders according to Figs. 1.3, 1.4, 1.5 and 1.7.

The diameter necessary for transmission of the torque from the emergency tiller shall not be less than $0{,}9 \cdot D_t$.

Where the rudder stock enters the top of the rudder body it shall have the rule diameter D_v for at least 0,1 of its length; the diameter may then be reduced linearly towards the lower end.

Tubular rudder stocks shall have the same section modulus as solid stocks. The relation between the diameters of the tubular rudder stock can be calculated from the following formula:

$$D_v = \sqrt[3]{\frac{D_a^4 - D_i^4}{D_a}}$$

D_a = outer diameter of the tubular stock [mm]

D_i = inner diameter of the tubular stock [mm]

The minimum wall thickness of the tubular stock shall not be less than:

$$t_{min} = 0{,}1 \cdot D_a \quad [\text{mm}]$$

The stock is to be secured against axial movement. The amount of permissible axial play depends on the design of the steering gear and the supporting arrangements.

3.3.2 Rudder couplings

Design of the couplings must be such that they are capable of transmitting the full torque applied by the rudder stock.

3.3.2.1 Horizontal couplings

The diameter of the coupling bolts shall not be less than

$$d = 0{,}65 \cdot D_v \sqrt{\frac{235}{R_{eH} \cdot n}} \quad [mm]$$

D_v = shaft diameter according to 3.3.1 in [mm]

n = number of coupling bolts the minimum number of coupling bolts is 6

R_{eH} = yield strength of the bolt material in [N/mm²].

The yield strength of the coupling bolt material shall not be less than 235 N/mm².

Material with a yield strength above 650 N/mm² shall not be used.

The distance of the axis of the coupling bolts from the edges of the coupling flange shall not be less 1,2 times the bolt diameter. Where horizontal couplings are used at least two bolts must be forward of the shaft axis.

The coupling bolts are to be fitted. Nuts and bolts are to be securely fastened against inadvertent slacking-back, e.g. by tab washers in accordance with DIN 432.

The thickness of the coupling flange is to be determined in accordance with the above "Formula for the coupling bolt diameter". For R_{eH}, the yield strength of the coupling flange material used is to be inserted. In order to reduce the load on the bolts, the coupling flanges are to be provided with a fitting key in accordance with DIN 6885.

The key may be omitted if the coupling bolt diameter is increased by 10 %.

The coupling flanges are either to be forged onto the rudder stock or welded to a collar headed onto the stock. The collar diameter shall be 1,1 D_v (at least D_v + 10 mm) and its thickness shall be at least equal to that of the flange.

3.3.2.2 Conical couplings

Conical couplings without any special arrangement for tightening or undoing them are to be in the form of a cone k ≅ 1 : 8 to 1 : 12, as shown in Fig. 1.8:

$$k_k = \frac{d_0 - d_u}{\ell}$$

The coupling surfaces must be a perfect fit. Nut and pintle are to be reliably secured against unintentional slacking-back. The coupling between shaft and rudder is to have a fitting key.

3.3.3 Rudder construction

Rudder bodies may be made from FRP, steel or other metallic and non-metallic material. The body is to have horizontal and vertical stiffening members, to make it capable of withstanding bending- and torsional loads. Proof of adequate strength, either by calculation or by a performance test on the prototype, is required. The rudder scantlings of the plating is to be as for shell bottom plating.

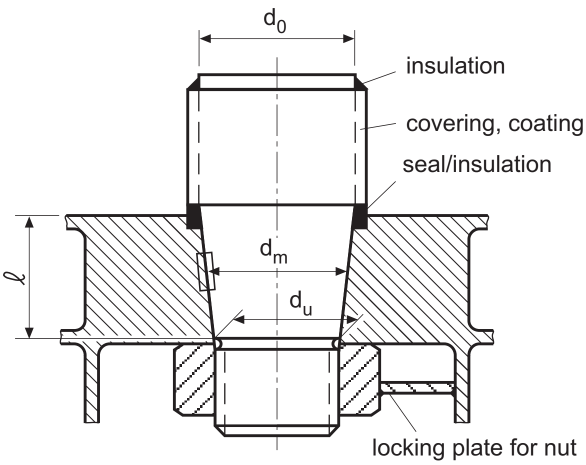


Fig. 1.8

3.3.4 Stoppers

The travel of the rudder quadrant or the tiller is to be limited in both directions by stoppers. The stoppers and their attachments to the hull are to be made so strong that the yield strength of the material used is not exceeded when the rudder stock reaches its yield bending moment.

3.3.5 Rudder heels

Rudder heels of semi balanced rudders and skegs according to Fig. 1.4, and sole pieces according to Fig. 1.9 shall be designed at the hull intersection in a way which ensures the moments and transverse forces arising to be transmitted without any problem.

3.3.5.1 The section modulus of the sole piece about the z-axis shall not be less than:

$$W_z = \frac{B_1 \cdot x \cdot k}{80} \quad [cm^3]$$

B_1 = reaction of support in [N]

Where the rudder is supported both ends the support reaction without taking into account the elasticity of the sole piece is $B_1 = C_R/2$.

x = distance of the respective cross-section from the rudder axis in [m]; no value less than x_{min} = 0,5 m may be inserted.

x_{max} = e

k = material factor according to F.3.3

3.3.5.2 The section modulus relative to the y-axis shall not be less than:

– where there is no rudder post or rudder stock

$$W_y = \frac{W_z}{2}$$

– where there is a rudder post or rudder stock

$$W_y = \frac{W_z}{3}$$

3.3.5.3 The cross-sectional area at x = e shall not be less than:

$$A_s = \frac{B_1}{48}\, k \quad \left[mm^2\right]$$

3.3.5.4 The equivalent stress from bending plus shear within the length e shall in no position be more than:

$$\sigma_v = \sqrt{\sigma_b^2 + 3\tau^2} = \frac{115}{k} \quad \left[N/mm^2\right]$$

$$\sigma_b = \frac{B_1 \cdot x}{W_z} \quad \left[N/mm^2\right]$$

$$\tau = \frac{B_1}{A_s} \quad \left[N/mm^2\right]$$

3.3.6 Rudder bearings

The rudder force C_R shall be distributed between the individual bearings according to the vertical position of the rudder's geometric centre of gravity.

The forces on the bearings are to be calculated as follows:

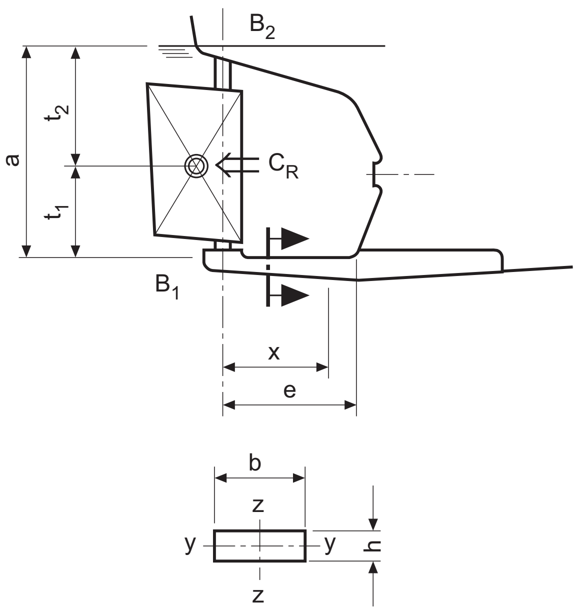


Fig. 1.9

Rudders with bearing in sole piece/skeg:

$$\text{Bearing force } B_1 = \frac{C_R \cdot t_2}{a} \quad [N]$$

$$\text{Bearing force } B_2 = \frac{C_R \cdot t_1}{a} \quad [N]$$

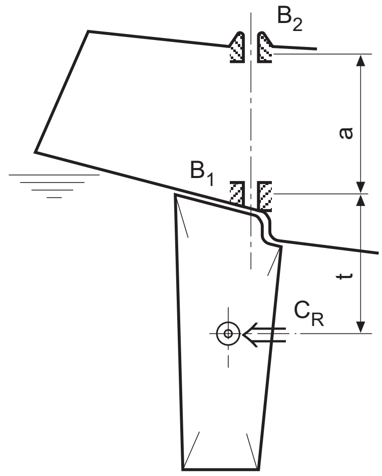


Fig. 1.10 Spade rudder

Bearings of spade rudders:

$$\text{Bearing force } B_1 = B_2 + C_R \quad [N]$$

$$\text{Bearing force } B_2 = \frac{C_R \cdot t}{a} \quad [N]$$

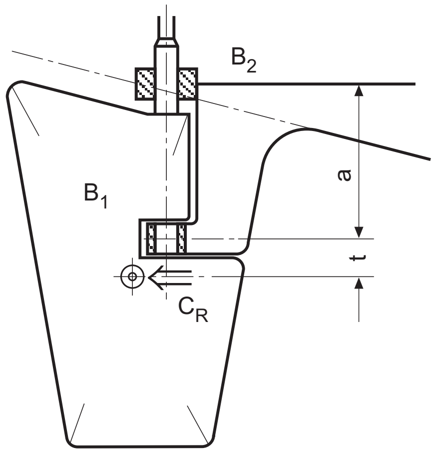


Fig. 1.11 Semi spade rudder

Bearings of semi spade rudders:

$$\text{Bearing force } B_1 = B_2 + C_R \quad [N]$$

$$\text{Bearing force } B_2 = \frac{C_R \cdot t}{a} \quad [N]$$

The mean surface pressure in the bearings shall not exceed the following values:

Table 1.6

Bearing material	**p [N/mm²]**
PTFE	2,5
PA PI	5,0
bronze steel Thordon XL	7,0
Trade names (selection):	
PTFE *(polytetrafluoroethylene)*:	Fluon, Hostaflon TF, Teflon
PA *(polyamide)*:	Degamid, Ultramid B, Durethan, Rilsan, Vestamid, Trogamid
PI *(polyimide)*:	Kapton, Vespel

The mean surface pressure is to be determined as follows:

$$p = \frac{P}{d \cdot h} \quad \left[N/mm^2\right]$$

P = bearing force (B_1 or B_2) in [N]

d = bearing diameter in [mm]

h = bearing height in [mm]

The bearing height shall be at least 1,2 · d.

3.3.7 Rudder tube

Rudder tubes are to be strong enough to withstand the loads which arise. They are to be adequately supported longitudinally and transversely and connected to the longitudinal and transverse structural members.

The minimum thickness S of the tube wall is to be determined according to the following formula:

for metallic materials:

$$S = 0{,}9 \sqrt{\mathbf{L}_{WL}} \cdot \sqrt{k}$$

$\mathbf{L}_{WL}$ in [m].

Fibre-reinforced plastic rudder tubes shall be of the same strength as the shell bottom laminate.

The tube is to extend up through the hull to the deck, or a stuffing box is to be fitted above the flotation plane of the craft in the ready to operate condition.

Hoses or hose-type sleeves of suitable material may be used 200 mm above the flotation plane.

3.4 Tiller and quadrant

If the hub of tiller or quadrant is shrunk onto the rudder stock or designed as a split hub or conical connection, this connection is to be additionally secured by a fitting key. The hub external diameter may not be less than:

$$d = 1{,}9\ D_t \cdot \sqrt{k} \quad [mm]$$

Split hubs must have at least two bolts on each side of the stock, whose total root diameter shall not be less than:

$$f = 0{,}22\ \frac{D_t^3}{e} \cdot 10^{-2} \quad \left[cm^2\right]$$

D_t = rudder stock diameter in [mm] according to 3.3.1

e = distance of bolt axis from stock centreline in [mm]

The arms of tiller and quadrant are to be so dimensioned that the equivalent stress from bending plus shear does not exceed 0,35 × times the material yield strength.

3.5 Cable-operated steering gear

The minimum breaking strength of the steering cables shall not be less than

$$P_s = \frac{Q_R \cdot 4}{e'} \quad [N]$$

Q_R = torsional moment according to 3.2.2 [Nm]

e' = distance of cable lead from rudder stock centreline [m]

The make of cables used is to be 6 × 19 DIN 3060 or equivalent.

3.6 Emergency steering gear

Mechanical or hydraulic rudder operating gear must be provided with emergency steering gear as a back up.

Emergency tillers must be operable from the open deck unless there is a non-powered means of communication between the bridge steering position and the rudder compartment.

To allow the emergency tiller to be connected, the rudder stock is at the top end to be provided with a square of the following dimensions:

width across flats = 0,87 D_t

height = 0,80 D_t

D_t according to 3.3.1.

For dimensioning the emergency tiller and its components, the torsional moment Q_R according to 3.2.2 reduced by 25 % is to be used as a basis.

4. Propeller brackets

4.1 Double arm brackets

The scantlings of full double arm propeller brackets of ordinary hull structural steel, based on the shaft diameter d are as follows:

strut thickness = $0{,}40\ d_p$ [mm]

strut cross-sectional area each arm = $0{,}40\ d_p^2$ [mm²]

length of boss = $2{,}70\ d_p$ [mm]

boss wall thickness = $0{,}25\ d_p$ [mm]

d_p = diameter [mm] of propeller shaft of non-stainless steel in accordance with Section 3, C.6.1

The scantlings apply to an arm length $L' = 11 \cdot d_p$. For longer arms, the cross-sectional areas are to be increased in proportion with the length.

4.2 Single arm propeller brackets

The section modulus of the arm of hull structural steel at its clamped support (without taking into account possible roundings) is to be determined according to the following formula:

$$W_1 = 0{,}0002 \cdot d_p^3 \cdot k \quad \left[cm^3\right]$$

k = material factor according to F.3.3

The section modulus at the boss, above any curvature, (W_2) may not be less than:

$$W_2 = 0{,}00014 \cdot d_p^3 \cdot k \quad \left[cm^3\right]$$

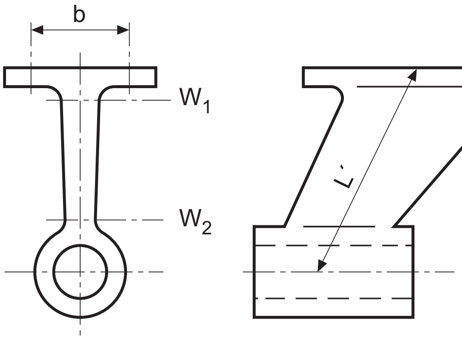


Fig. 1.12

The section moduli apply to an arm length $L' = 11 \cdot d_p$. For longer arms, the section modulus is to be increased in proportion with the length.

For final determination of the propeller bracket scantlings, GL reserve the right to request a stress analysis with the following dynamic loads: The pulsating force which arises assuming loss of one propeller blade and a propeller rotational speed of 0,75 × nominal rpm is to be determined. In these circumstances the following bending stress is not to be exceeded:

$$\sigma_{dzul} = 0{,}4 \cdot R_{eH} \quad \text{for} \quad R_{eH} = 235\ N/mm^2$$

$$= 0{,}35\ R_{eH} \quad \text{for} \quad R_{eH} = 335\ N/mm^2$$

R_{eH} = yield strength of the material used in [N/mm²]

4.3 Propeller bracket attachment

4.3.1 Screw connection of propeller bracket arms

The propeller brackets are to be carefully and directly fastened to floors and longitudinal bearers by means of flanges. The shell is to be reinforced in this area.

Number and diameter of screws of single-arm propeller brackets are to be taken from the following Table:

Table 1.7

Section modulus W_1 [cm³]	Spacing b of the two rows of bolts [mm]	Fixing bolts [1] Number	Fixing bolts [1] Diameter [mm]
2	85	6	M 12
4	100	6	M 12
6	115	6	M 12
8	125	6	M 12
10	135	6	M 12
25	140	6	M 16
45	150	6	M 16
60	150	6	M 20
80	155	6	M 22
100	160	6	M 24

[1] ordinary hull structural steel

The distance of the fixing bolts from the edge of the flange is to be at least 1,2 times the bolt diameter.

The flange thickness is to be at least equal to the diameter of the fixing bolts.

4.3.2 Casting-in propeller bracket arms

Propeller bracket arms can be cast-in to hull of FRP as shown in the following principle sketch, using fibre reinforced resin. Propeller bracket arms must be provided with anchors of sea-water-compatible material in the area where they are cast-in. Such principles of construction are subject to special tests. GL reserve the right to have performance tests conducted which can provide information about the fatigue strength of the bond, plus the vibration pattern under a variety of operating conditions.

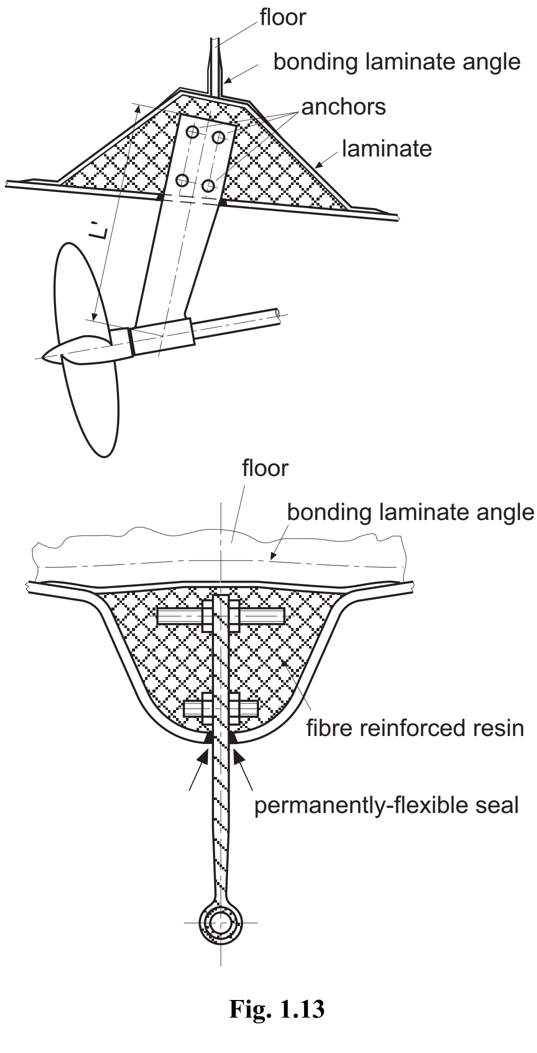


Fig. 1.13

5. Ballast keels

5.1 External ballast

5.1.1 The ballast keel may be of lead, cast iron, steel or other suitable material and is to be fastened to the adequately strengthened keel sole using keel bolts. The top surface of the keel must be flat to ensure a tight fit to the hull. The keel/hull interface is to be provided with a suitable durable seal.

5.1.2 Keel bolts

The diameters of keel bolts arranged in pairs are to be calculated using the following formula:

$$d_k = \sqrt{\frac{2 \cdot W_k \cdot h_k \cdot b_{max}}{R_{eH} \cdot \sum b_i^2}} \quad [\text{mm}]$$

d_{kmin} = 12,0 mm where R_{eH} = 235 [N/mm²]

d_k = keel bolt root diameter

W_k = ballast keel weight [N]

h_k = distance of keel CG from keel upper edge [mm] as in Fig. 1.14

b_{max} = maximum scantling width b_i [mm]

b_i = scantling width at each pair of keel bolts [mm]

= $0,5 \cdot b_{bi} + 0,4 \cdot b_{ki}$

R_{eH} = yield strength of bolt material [N/mm²]

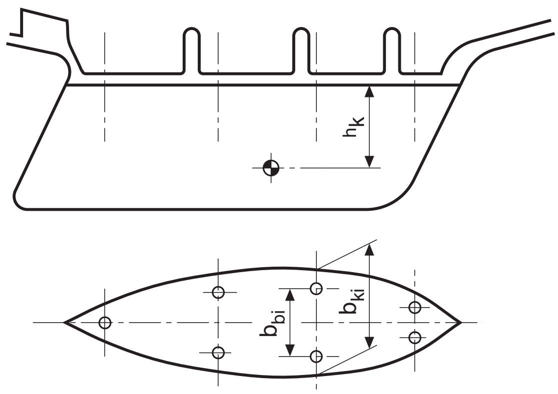


Fig. 1.14

Large washers with a diameter of 4 times and thickness of one quarter of the keel bolt diameter (d_k) are to be fitted under the head of each bolt. The thread must be long enough to allow fitting of lock nuts or other suitable locking devices.

Keel bolts must be made of material suitable for use in sea water. They are to be fastened in the ballast keel as required for the forces arising.

5.2 Internal ballast

Internal ballast must be accommodated in the hull securely fastened. It may be cast-in or inserted in blocks. It shall not stress the shell, but the load from it shall be transferred to keel, floors and other load-bearing structural members.

When casting-in lead ballast, suitable measures are to be taken to ensure that there is no adverse effect on the shell's grade of quality.

Voids resulting from inserting the ballast in form of blocks are to be filled with a suitable castable material.

In the case of FRP hull, the top surface of the internal ballast shall be covered with FRP laminate.

6. Water tanks and fuel tanks

6.1 General

Water and diesel fuel may be stored in integral or in detached tanks, securely fastened. Petrol may only be stored in detached separate tanks, provided with adequate supply and suction ventilation.

The fuel tanks must be so arranged that they cannot be unacceptably heated by the engine, the exhaust system or other sources of heat.

A coffer dam is to be provided between integral fresh water tanks and fuel/holding tanks, or other measures shall be taken to ensure that fuel cannot penetrate into the water tank.

The tanks are, as necessary, to be subdivided by internal wash plates so that the breadth of the liquid surface does not exceed 0,5 **B** or 1,0 m, whichever is the lesser. The wash plates need only be arranged halfway up the tank. For tanks more than 3,0 m long, transverse wash plates are recommended.

Wash plates are to be dimensioned in accordance with the prevailing forces; the total glass weight of their laminates must not be less than 2 400 g/m^2.

The tanks are to be provided with handholes. These must be large enough to allow all corners of the tanks to be reached for cleaning.

6.2 Scantlings

6.2.1 The plating thickness of flat-sided metallic tanks is calculated from:

$$s = 4 \cdot a \cdot \sqrt{h_1} \cdot F_p \cdot \sqrt{k} \quad [\text{mm}]$$

6.2.2 Stiffeners are to be fitted to stiffen the tank walls. The required section moduli of the stiffeners are calculated from:

$$W = a \cdot h_2 \cdot \ell^2 \cdot c_2 \cdot k \quad \left[\text{cm}^3\right]$$

a = stiffener spacing in [m]

h_1 = pressure head measured from plate bottom edge to top of filler tube in [m]

h_2 = pressure head measured from stiffener mid-length to top of filler tube in [m]

for the height of the filler tube above deck, the minimum values which shall be inserted are:

- 0,25 m for yachts up to **L** = 10 m
- 0,50 m for yachts up to **L** = 15 m
- 1,00 m for larger yachts

k = material factor according to F.3.3

ℓ = length of stiffener in [m]

F_p = $(0{,}54 + 0{,}23\ R) \le 1{,}0$

correction factor for the aspect ratio R of unsupported plate panels

R = $\dfrac{\ell}{a}$ aspect ratio

c_2 = 5,0 where the stiffener end fastenings do not have bracket plates

= 3,4 where the stiffener end fastenings have bracket plates

The calculated section moduli apply to the stiffeners in conjunction with the tank plating to which they are welded.

6.2.3 In the case of detached tanks with curved walls, the plate thicknesses and section moduli determined in accordance with 6.2.1 and 6.2.2 may be reduced, if adequate rigidity and tightness is proven by means of a water pressure test at elevated pressure. The test pressure head is to be 1,5 times the height from the floor of the tank to the top of the filler tube - at least 2 m.

6.2.4 Tanks more than 2 m wide or long shall be provided with a wash plate. Plate thickness- and stiffener calculations are to be in accordance with 6.2.1 and 6.2.2.

6.2.5 Larger water and diesel fuel tanks shall be equipped with handholes; very large ones with manholes. The handholes must be large enough to reach all corners of the tank. The diameters of the bolts for handhole and manhole covers shall at least be double the cover thickness; bolt spacing is not to exceed 8 to 9 times the plate thickness. Bolts are to have at least an M8 thread.

6.2.6 For fitting the tanks and containers with pipes, mountings, etc., see Section 3.

6.3 Vent pipes and filling arrangement

6.3.1 Each tank is to be provided with a vent pipe. This is to be extended above the open deck and so arranged that the tank can be filled completely.

6.3.2 It must be possible to fill water, diesel fuel and petrol tanks from the open deck. Filler caps, filler tubes, vent pipes and sounding tubes shall have watertight connection with the deck and shall be so located that neither fuel nor petrol vapour (heavier than air) can flow into the accommodation or other spaces such as the cockpit and cockpit lockers, anchor chain lockers, water tanks or the surrounding water.

6.3.3 Each tank is to have a sounding tube, lead close to the tank bottom. A doubling plate is to be welded to the tank bottom underneath the sounding tube. Electric tank-sounding devices of proven design may be accepted.

6.4 Testing for tightness

6.4.1 All tanks are to be water or air pressure tested for tightness. The minimum test level is a water column up to the highest point of the overflow/vent pipe.

The air pressure may not exceed 15 kPa (overpressure). The increased risk of accidents involved in testing with air pressure is to be taken into account.

6.4.2 The test is generally to be carried out ashore, before application of the first coat of paint. Should, for the passage of pipes or for other reasons, the tank wall be penetrated after the test, a second tightness-test must be carried out if requested by the responsible surveyor. This test may be carried out afloat.

7. Special equipment

All mountings, fittings, equipment and apparatus, not referred to in these rules, shall be suitable for the intended service in pleasure craft. They must not impair the safety of the craft and its crew. Where applicable, the relevant rules, regulations and guidelines of the responsible authorities and institutions are to be complied with.

B. Glass Fibre Reinforced Plastic Hulls

1. Scope

1.1 These rules apply to the scantling determination of GRP hulls with **L** from 6 m to 24 m built by the hand lay-up method in single skin construction from E-glass laminate consisting of chopped strand mat (CSM) layers or alternate layers of CSM and bidirectional woven roving.

If it is intended to use glass-fibre-resin spray-up moulding for the production of primary structural parts, the conditions according to 2.3 are to be complied with. This applies also to the intermediate layers of composite laminates. Use of this method is limited to components which by virtue of their design principle, or position and configuration of the mould allow for a satisfactory structuring of the laminate.

2. Basic principles for scantling determination

2.1 The scantling determination of the hull primary structural members of motor and sailing craft and motorsailers of conventional mono-hull form and proportions are to be determined in accordance with Tables 1.8 to 1.20, if laminates with mechanical properties in accordance with 3.1 are used.

2.2 Notes for scantling determination for craft used for commercial purposes, like:

– fishing craft

– workboats

The scantlings determined in accordance with Tables 1.8 to 1.20 are to be multiplied by the following factors: 1,2 for the glass weight and 1,44 for the section moduli. Deck loads are to be corrected as appropriate for the additional loads present.

Hulls of fishing craft, depending on the fishing method, shall be provided with local reinforcement in accordance with the Rules for Classification and Construction, I – Ship Technology, Part 1 – Seagoing Ships, Chapter 8 – Fishing Vessels.

2.2.1 For crafts of unusual construction and special conditions of operation following safety factors are proposed to be applied at RT or 23 °C:

1. static loads: $S = 1,1$

2. extreme loads: $S = 1,1$

3. statistical loads (sea loads): $S = 2,0$

$$\sigma_{zul} = \frac{R_m \cdot R_1 \cdot R_2 \cdot R_3 \cdot \ldots\ldots \cdot R_8}{S} \quad \left[N/mm^2\right]$$

R_m = tensile strength of laminate

Reduction factors for laminates	
statistical long-term loading (sea loads)	$R_1 < 0,75$
static long-term loading (tank walls)	$R_2 < 0,5$
raised temperature	$R_3 < 0,9$
ageing	$R_4 < 0,8$
manufacturing i.e. hand lay-up prepreg	 $R_5 = 0,9$ $R_5 = 1,0$
fatigue $N < 10^2$ $N < 10^3$ $N < 10^6$	 $R_6 = 1,0$ $R_6 = 0,8$ $R_6 = 0,4$
different material properties	$R_7 < 0,9$
moisture	$R_8 < 0,8$

N = number of load changes during life span of the structural member

2.3 Scantling determination for structural members of spray-up laminate may be determined in accordance with Tables 1.8 to 1.20 if the following conditions are fulfilled:

– the manufacturer shall provide proof of the suitability of its workshop, equipment and apparatus, plus the qualification of its personnel. Therefor a procedure test is to be carried out in the presence of the GL surveyor.

– The following mechanical properties relevant for scantling determination are to be verified as part of the procedure test:

Glass content		ISO 1172
Tensile strength	dry wet	EN ISO 527-4 EN ISO 527-4 [1, 2]
Young's modulus (tension)	dry	EN ISO 527-4
Flexural strength	dry wet	EN ISO 14125, Procedure A EN ISO 14125, Procedure A [1, 2]
Water absorption		DIN EN ISO 62 [3]

[1] No. of test pieces = 3

[2] Conditioning of 30 ± 1 days in distilled water at 23 °C. The conditioning period can be reduced by 50 % for each temperature increase of 10 °C. While conditioning, the dimensional stability temperature of the thermosetting resin shall not be exceeded.

[3] Total test duration 30 ± 1 days. Water absorption to be determined after 3 days, after 7 days and after 30 days.

– proof is to be obtained that the laminate minimum thicknesses as calculated are maintained on all parts of the structure. Since evenness of layer thickness depends on the skill of the sprayer doing the work, it is recommended that resin- and glass quantities each be exceeded by 10 % relative to the calculated values to ensure attainment of the minimum thicknesses.

– The requirements in accordance with the Rules for Classification and Construction, II – Materials and Welding, Part 2 – Non-metallic Materials, Chapter 1 are to be observed; excerpts are listed in Annex B.

3. Material properties

3.1 The values laid down in Tables 1.8 to 1.20 embody the following mechanical properties of the basic laminate which consists of CSM layers. The properties given are minimum values which must be achieved by the actual laminate.

Mechanical properties of basic laminate (minimum values)		$\frac{N}{mm^2}$
Tensile strength (fracture)	σ_{zB}	85
Young's modulus (tension)	E_Z	6350
Flexural strength (fracture)	σ_{bB}	152
Compressive strength (fracture)	σ_{dB}	117
Shear strength (fracture)	τ_B	62
Shear modulus	G	2750
Interlaminar shear strength	τ_{ib}	17
Specific thickness = 0,70 mm per 300 g/m² glass reinforcement		
Glass content by weight Ψ = 0,30		

3.2 If the glass content by weight of the actual laminate differs from the value of 30 % stated in 3.1, the mechanical properties are to be determined from the following formulae. This is generally the case if the laminate consists of CSM/woven roving combinations.

Tensile strength (fracture)

$$\sigma_{zB} = 1278 \cdot \Psi^2 - 510 \cdot \Psi + 123 \quad \left[N/mm^2\right]$$

Young's modulus (tension)

$$E_Z = (37 \cdot \Psi - 4{,}75) \cdot 10^3 \quad \left[N/mm^2\right]$$

Flexural strength (fracture)

$$\sigma_{bB} = 502 \cdot \Psi^2 + 106{,}8 \quad \left[N/mm^2\right]$$

Compressive strength (fracture)

$$\sigma_{dB} = 150 \cdot \Psi + 72 \quad \left[N/mm^2\right]$$

Shear strength (fracture)

$$\tau_B = 80 \cdot \Psi + 38 \quad \left[N/mm^2\right]$$

Shear modulus

$$G = (1{,}7 \cdot \Psi + 2{,}24) \cdot 10^3 \quad \left[N/mm^2\right]$$

Interlaminar shear strength

$$\tau_{iB} = 22{,}5 - 17{,}5\ \Psi \quad \left[N/mm^2\right]$$

Ψ = glass content of laminate by weight

3.3 The individual layer thickness can be determined from the following formula:

$$t = 0{,}001\ W \left(\frac{1}{\rho_F} + \frac{1-\Psi}{\Psi}\cdot\frac{1}{\rho_H}\right) \quad [\text{mm}]$$

W = weight per unit area of reinforcement fibre [g/m²]

ρ_F = density of fibre (2,6 [g/cm³] for E-glass as reinforcing material)

ρ_H = resin density (1,2 [g/cm³] for unsaturated polyester resin matrix)

Mass- and volume content of glass fibres is to be taken from the following Table.

	Fibre mass content	Fibre volume content
Mat laminate Sprayed laminate	$\Psi = 0{,}30$	$\varphi = 0{,}17$
Woven roving laminate	$\Psi = 0{,}50$	$\varphi = 0{,}32$

3.4 If the mechanical properties of laminates intended to be used do not achieve those determined according to 3.2, their properties and their glass content are to be determined by tests.

3.5 The test specimen for determination of properties and characteristic values in accordance with 3.4 are to be made using the same procedure and the same conditions, and given the same thermal treatment, as intended to be used for the construction of the hull. When determining the flexural strength, the gel coat side of the test specimen shall be stressed in tension. Proof of the properties and characteristic values is to be provided by means of test certificates from an official material testing institute.

3.6 The mechanical properties and characteristic values used for scantling determination of primary structural members and components must not exceed 90 % of the mean values determined by the tests under 3.5.

4. Conditions for scantling determination

4.1 The scantling determination of the primary structural members of pleasure craft hulls is based on the loads in accordance with A.

4.2 The weights of laminate reinforcement required by these rules represent the weight of the glass-fibre reinforcement material contained in 1 m² of laminate. The section moduli of the stiffeners apply to profiles in conjunction with the plate to which they are laminated. They apply to an effective plate width of 300 mm in accordance with 5.2 and 5.3.

4.3 Should the mechanical properties and/or the glass content by weight differ from the values stated in 3.1, the scantlings are to be adjusted in accordance with 4.4. and 4.5.

4.4 The required total weight of the laminate plus the corresponding nominal thickness are to be modified in accordance with the following criteria:

4.4.1 Laminate plates

The total weight of glass reinforcement determined according to Tables, 1.8, 1.9, 1.14, 1.15, 1,16 and 1.19 is to be multiplied by the factor K_w. This factor is to be calculated as follows:

4.4.1.1 If the flexural strength (fracture) σ_{bB} and the glass content by weight of the laminate plate have been determined by tests in accordance with 3.4 to 3.6, the factor is

$$K_w = \frac{5{,}27\cdot\Psi}{1{,}88-\Psi}\cdot\sqrt{\frac{152}{\sigma_{bB}}}$$

σ_{bB} = flexural strength (fracture) [N/mm²]

Ψ = glass content of laminate by weight

4.4.1.2 If the flexural strength (fracture) σ_{dB} and the glass content of the laminate plate have **not** been determined by tests in accordance with 3.4 to 3.6, the factor is

$$K_w = 2{,}8\cdot\Psi + 0{,}16$$

Ψ = glass content of laminate by weight.

4.4.2 The nominal thickness t of the laminate based on 0,70 mm per 300 g/m² weight of laminate reinforcement, determined in accordance with Tables 1.8, 1.9, 1.14, 1,15, 1,16 and 1.19, is to be multiplied by the factor K_t obtained as follows:

4.4.2.1 If the flexural strength (fracture) σ_{bB} of the laminate plate has been determined by tests in accordance with 3.4 to 3.6, that factor is:

$$K_t = \sqrt{\frac{152}{\sigma_{bB}}}$$

4.4.2.2 If the flexural strength (fracture) σ_{bB} of the laminate plate has **not** been determined by tests in accordance with 3.4 to 3.6, that factor is

$$K_t = \sqrt{\frac{1}{3{,}3 \cdot \Psi^2 + 0{,}703}}$$

Ψ = glass content of laminate by weight

4.4.2.3 Correction factor for aspect ratio R of unsupported plate panels

$$F_p = \left(0{,}54 + 0{,}23\,R\right) \leq 1{,}0$$

R = aspect ratio ≥ 1

4.4.2.4 Curved plate panels

When dimensioning the laminates of plate panels with simple convex curvature, the effect of the curvature is taken into account by the correction factor f_k.

The initial value for dimensioning is the total weight of glass required for the basic laminate. The relevant values are to be corrected by multiplying with the curvature factor f_k.

This factor is to be determined from the following Table:

h/s	f_k
0 – 0,03	1,0
0,03 – 0,1	$1{,}1 - 3 \cdot \frac{h}{s}$
≥ 0,1	0,8

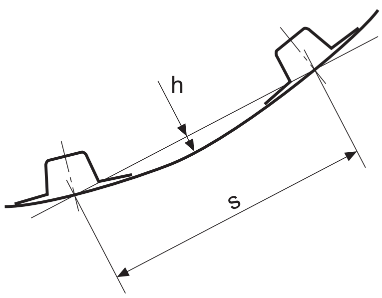


Fig. 1.15

The total weight of glass required, calculated using the factor f_k must not be less than the corresponding minimum value from the Tables 1.8, 1.9, 1.14, 1.15, 1.16 or 1.19.

Calculation of the corrected total weight of glass required respective the corrected nominal thickness required is to be in accordance with 4.4.1/4.4.2.

4.5 Stiffener sections

The section modulus determined from Tables 1.11, 1.12, 1.13, 1.14, 1.15, 1.17, 1.18 and 1.20 is to be multiplied by the factor K_Z, obtained as follows:

4.5.1 If the tensile strength (fracture) σ_{zB} of the laminate plate has been determined by tests in accordance with 3.4 to 3.6, that factor is:

$$K_Z = \frac{85}{\sigma_{zB}}$$

4.5.2 If the tensile strength (fracture) σ_{zB} of the laminate plate has **not** been determined by tests in accordance with 3.4 to 3.6, that factor is:

$$K_Z = \frac{1}{15\,\Psi^2 - 6\,\Psi + 1{,}45}$$

Ψ = glass content of laminate by weight

4.6 Each section modulus determined from Tables 1.11, 1.14, 1.15, 1.17 and 1.20 and corrected in accordance with 4.5 applies to a stiffener of the same material as the laminate plate.

5. Section moduli and geometric properties of the stiffeners

5.1 The section moduli of the stiffeners are to be calculated directly from the profile dimensions and the effective width of plating.

5.2 The effective width of the connected laminate plate is measured from centre to centre of the unsupported panels adjoining the stiffener. It shall not exceed 300 mm.

5.3 The section modulus of stiffener and connected laminate plate is calculated from the following formula:

$$W = \frac{f \cdot h}{10} + \frac{t_s \cdot h^2}{3000} \cdot \left(1 + \frac{100\,(F - f)}{100 \cdot F + t_s \cdot h}\right) \quad \left[cm^3\right]$$

t_s = thickness of an individual web [mm]

5.4 Where the glass content of laminate by weight is Ψ = 0,30, the minimum thickness of the web may not be less than:

$$t_{s\,min} = 0{,}025 \cdot h + 1{,}10 \quad [mm]$$

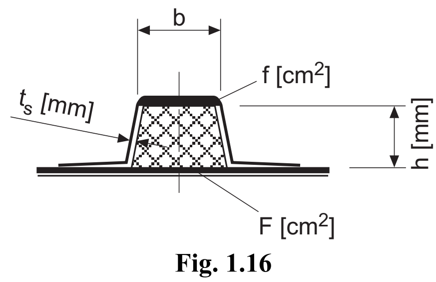


Fig. 1.16

5.5 Where the glass content by weight Ψ of the stiffener's web laminate differs from 0,30, the thickness determined from 5.4 is to be divided by the value K_S.

$$K_S = 1{,}30 \cdot \Psi + 0{,}61$$

5.6 Should the tensile properties of the materials in the stiffener differ from those of the laminate plate, the effective tensile modulus of the stiffener in conjunction with the laminate plate is to be determined by correction of the cross-sectional area and/or the width of the various laminate layers in the stiffener in the ratio of the tensile modulus of each of the materials in the stiffener to that of the laminate plate.

5.7 Calculation of the laminate thicknesses to determine the section modulus of a top-hat type profile and connected plate.

5.7.1 Thickness of the individual layer can be determined from the following formula:

$$t = 0{,}001\ W \left(\frac{1}{\rho_F} + \frac{1 - \Psi}{\Psi} \cdot \frac{1}{\rho_H} \right) \ [\text{mm}]$$

W = weight per unit area of the reinforcing fibre [g/m²]

ρ_F = fibre density (2,6 [g/cm³] for glass reinforcement material)

ρ_H = resin density (1,2 [g/cm³] for UP)

Ψ = glass content of laminate by weight

5.8 Frame spacing

The following frame spacing is recommended for design:

$$a = (350 + 5\,\mathbf{L}) \ [\text{mm}]$$

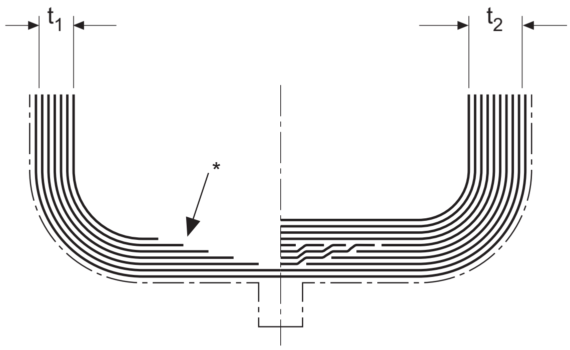
6. Shell laminate

6.1 General

6.1.1 It is recommended that fabrication of the shell be carried out in a single working cycle. If the hull is prefabricated in two halves, these are to be joined as shown in Fig. 1.17.

6.1.2 The outside of the hull shall be covered by a gel coat which shall have a thickness of 0,4 – 0,6 mm.

6.1.3 In the bilge and transom area and other comparable places, the individual layers are to be arranged as shown in Fig. 1.18 to act as a reinforcement.



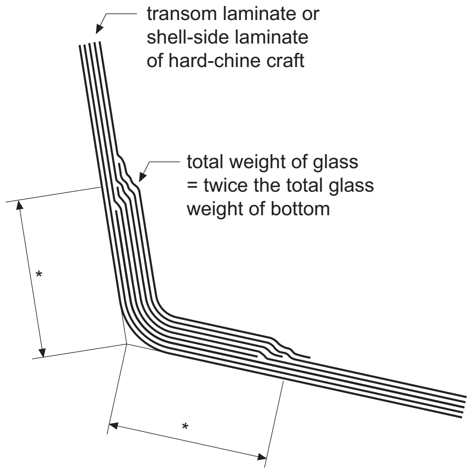
t_1 = laminate before joining the two prefabricated hull halves

t_2 = keel laminate

* = layers are to be stepped 25 mm per 600 g/m² glass fibre reinforcement.

Fig. 1.17 Joining-laminate

The reinforcement achieved by overlapping in Fig. 1.18 can also be achieved by the insertion of separate strips of reinforcement. The total weight of glass in the reinforced area must not be less than twice that in the shell side.



* Width of overlap = 25 mm per 600 g/m² glass fibre reinforcement

Fig. 1.18

6.1.4 The hull laminate is to be reinforced locally in the areas of force transfer from propeller bracket, rudder tube, bollards, etc. The reinforcement is to be stepped at a ratio of 25 mm per 600 g/m².

6.2 Motor craft

6.2.1 The total glass reinforcement weight of the shell laminate is to be determined from Table 1.8 (see also Fig. 1.19).

6.2.2 The nominal laminate thickness from Table 1.8 is calculated in accordance with 3.1 with 0,70 mm per 300 g/m² of reinforcement

6.2.3 The glass weight for the bottom determined in accordance with Table 1.8 applies over the entire length of the craft and is to be extended upwards to the chine or 150 mm above the flotation plane, whichever is higher.

6.2.4 The total glass weight of the keel laminate shall comply with the values stated in Table 1.8.

6.2.5 The minimum width of the keel laminate shall be:

$$(25 \cdot \mathbf{L} + 300) \quad [\text{mm}]$$

6.2.6 The keel laminate must extend from the stern/transom to the stem. Determination of the total glass weight shall be in accordance with 6.2.4. Reductions based on reduced frame spacing are not permitted (see also Figs. 1.19 and 1.20).

6.2.7 The stern or transom shall have the same glass weight as the shell side. In case of special propulsion systems (stern drives, "Aquamatic", etc.) reinforcement shall be provided as appropriate for the forces arising.

6.2.8 Chine and transom corners are to be built in accordance with 6.1.3.

6.2.9 Should the flexural strength and/or the glass content of weight of the laminate differ from that stated in 3.1, the total glass weight or nominal thicknesses determined above are to be multiplied by the factor K_W or K_t in accordance with 4.4. Whatever the type of reinforcement, the minimum thickness of laminate must not be less than 2,5 mm.

6.3 Sailing craft and motorsailers

6.3.1 The total glass weight of the shell laminate is to be determined from Table 1.9 (see also Fig. 1.21).

6.3.2 The nominal laminate thickness from Table 1.9 is calculated in accordance with 3.1 based on 0,70 mm per 300 g/m² of glass reinforcement.

6.3.3 The glass weight for the bottom determined in accordance with Table 1.9 is to be extended upwards to the chine or 150 mm above the flotation plane, whichever is higher.

The shell is to be reinforced in the area of the fin keel and tuck in accordance with Table 1.9.

6.3.4 The minimum reinforcement weight of the keel laminate in accordance with Table 1.9 applies to hulls with a single skin shell and shall have the following minimum width:

$$(25 \cdot \mathbf{L} + 230) \quad [\text{mm}]$$

6.3.5 The keel laminate shall extend from the stern/transom to the stem. Determination of the total glass weight shall be in accordance with Table 1.9. Reductions based on reduced frame spacing are not permitted (see also Fig. 1.21). The total glass weight of the keel laminate shall be at least 1,5 times the required reinforcement weight for the shell bottom (see also Figs. 1.21 and 1.22).

6.3.6 The total glass weight for fin keel and tuck obtained from Table 1.9 shall at least match that of the shell bottom; reductions based on reduced frame spacing are not permitted.

6.3.7 Design and construction of the gunwale must be such as to achieve an adequate rigidity (see 8.3).

6.3.8 Primary structural members of the hull are to be reinforced in those areas where forces from chain plates, masts and their foundations plus rudder tubes, etc. are applied.

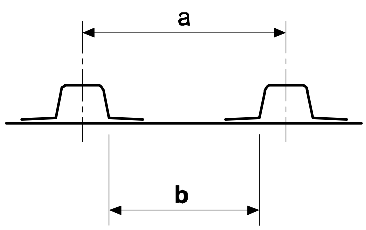
6.3.9 The total reinforcement weight for the stern or the transom must not be less than that for the shell side. Transoms are to be stiffened adequately. Additional reinforcement is required in accordance with 6.1.3.

6.3.10 Bottom reinforcement of sailing craft fitted with bilge keels is to be provided as per 6.3.6.

6.3.11 Should the flexural strength and/or the glass content of weight of the laminate differ from that stated in 3.1, the total glass weights or nominal thicknesses determined above are to be multiplied by the factor K_W or K_t in accordance with 4.4. Whatever the type of reinforcement, the minimum thickness of laminate must not be less than 2,5 mm.

Table 1.8

Total glass weight of motor craft shell laminate [g/m²]	
Shell bottom	$G_{WB} = 1{,}57 \cdot \mathbf{b} \cdot F_p \cdot F_{VB} \cdot \sqrt{P_{dBM}}$ $G_{WB(min)} = 1{,}10 \cdot (350 + 5\,\mathbf{L}) \cdot \sqrt{P_{dBM}}$ $G_{WB(min)} \geq G_{WS}$
Shell side	$G_{WS} = 1{,}57 \cdot \mathbf{b} \cdot F_p \cdot F_{VS} \cdot \sqrt{P_{dSM}}$ $G_{WS(min)} = 1{,}10 \cdot (350 + 5\,\mathbf{L}) \cdot \sqrt{P_{dSM}}$ $G_{WS(min)} \geq 1200$
Keel	$G_K = 2{,}35 \cdot (350 + 5\,\mathbf{L}) \cdot \sqrt{P_{dBM}}$



F_p = See 4.4.2.3
F_{VB} = See A.1.9.3
F_{VS} = See A.1.9.3
P_{dBM} = See A.1.9.2
P_{dSM} = See A.1.9.2

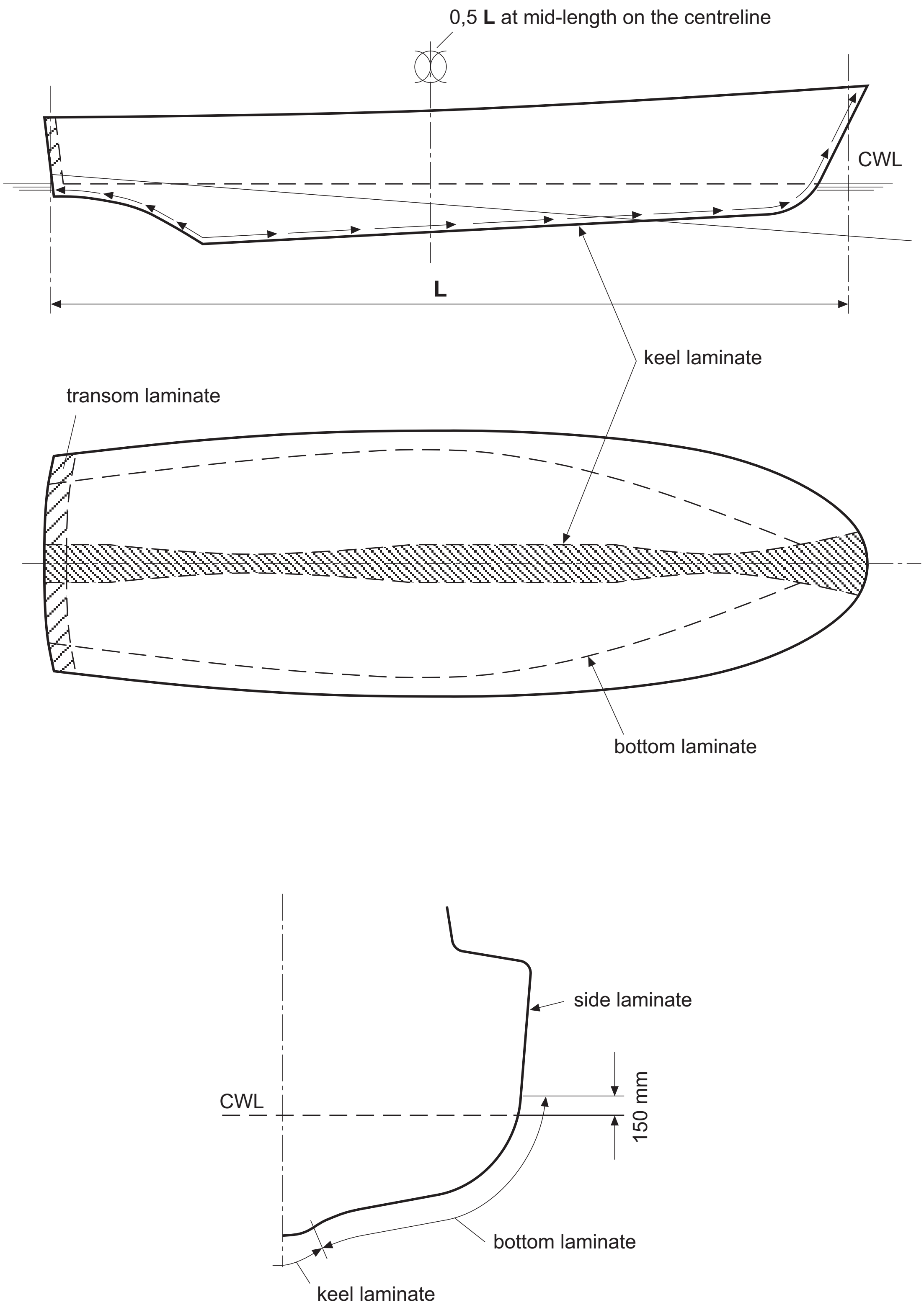
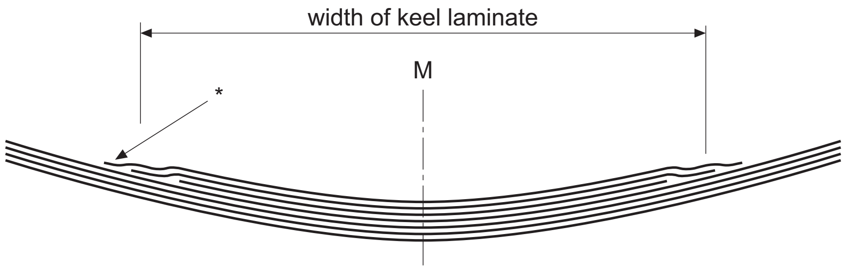
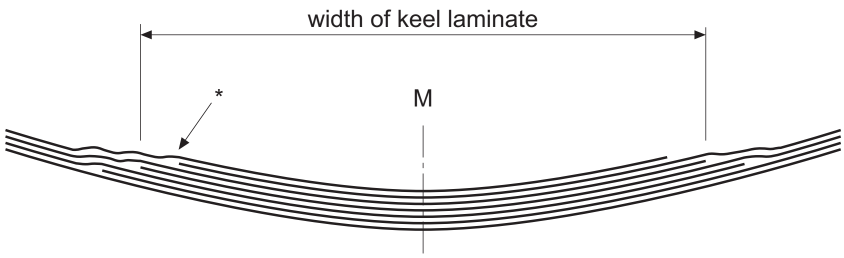

0,5 L at mid-length on the centreline
CWL
L
keel laminate
transom laminate
bottom laminate
side laminate
CWL
150 mm
bottom laminate
keel laminate

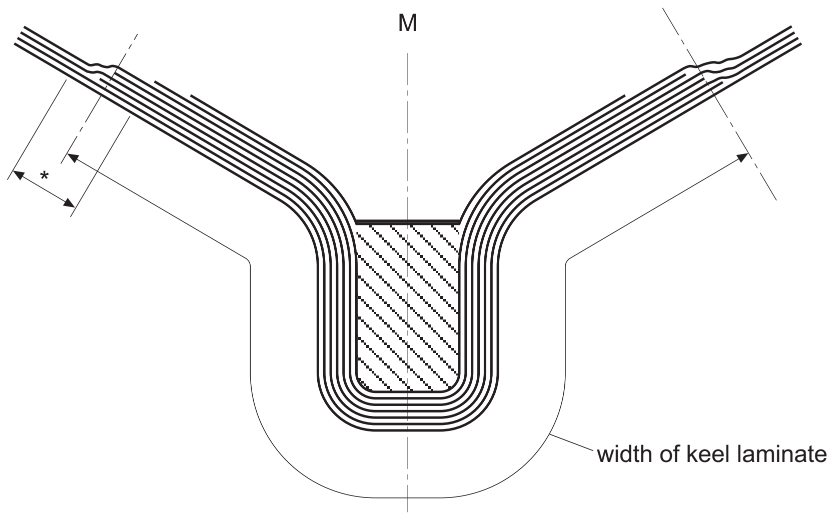
Fig. 1.19



special reinforcement layers form the keel laminate



pt and stbd glass reinforcement layers overlap and form the keel laminate



port and starboard glass reinforcement layers overlap and form the keel laminate

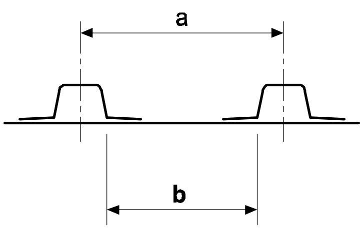
Fin keel may be filled and covered with laminate whose total glass weight must be at least 50 % of that of the shell bottom

* Width of overlap = 25 mm per 600 g/m2 glass fibre reinforcement

Fig. 1.20

Table 1.9

Total glass weight of shell laminate for sailing craft and motorsailers [g/m²]	
Shell bottom	$G_{WB} = 1{,}57 \cdot \mathbf{b} \cdot F_p \cdot \sqrt{P_{dBS}}$ $G_{WB(min)} = 1{,}10 \cdot (350 + 5\,\mathbf{L}) \cdot \sqrt{P_{dBS}}$ $G_{WB(min)} \geq G_{WS}$
Shell side	$G_{WS} = 1{,}57 \cdot \mathbf{b} \cdot F_p \cdot \sqrt{P_{dSS}}$ $G_{WS(min)} = 1{,}10 \cdot (350 + 5\,\mathbf{L}) \cdot \sqrt{P_{dSS}}$ $G_{WS(min)} \geq 1200$
Fin	$G_{WF} = 1{,}70 \cdot (350 + 5\,\mathbf{L}) \cdot \sqrt{2{,}4\,\mathbf{L} + 28}$
Keel and tuck	$G_{WK} = 1{,}70 \cdot (350 + 5\,\mathbf{L}) \cdot \sqrt{3{,}3\,\mathbf{L} + 66{,}5}$



F_p = see 4.4.2.3
P_{dBS} = see A.1.9.2
P_{dSS} = see A.1.9.2

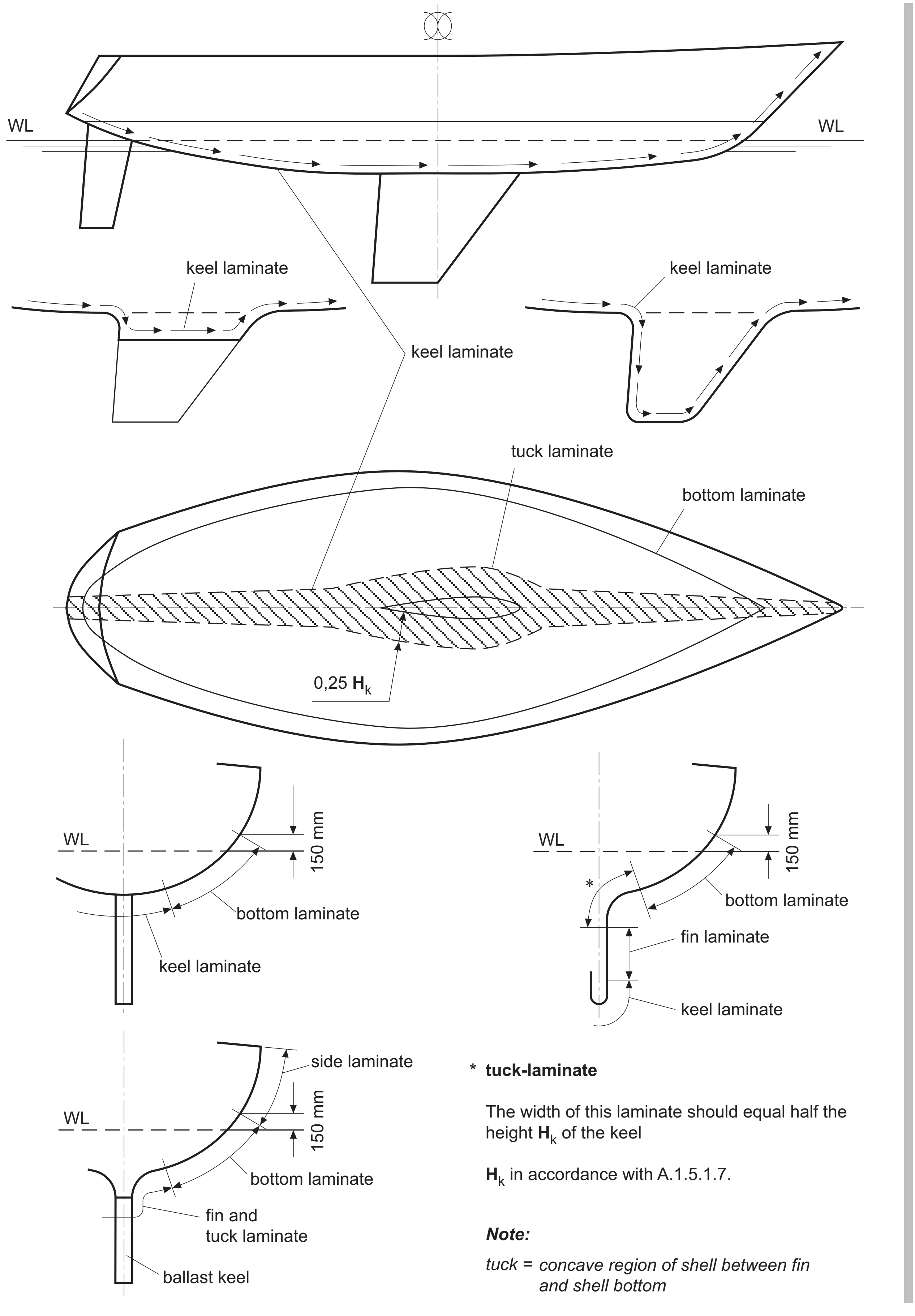
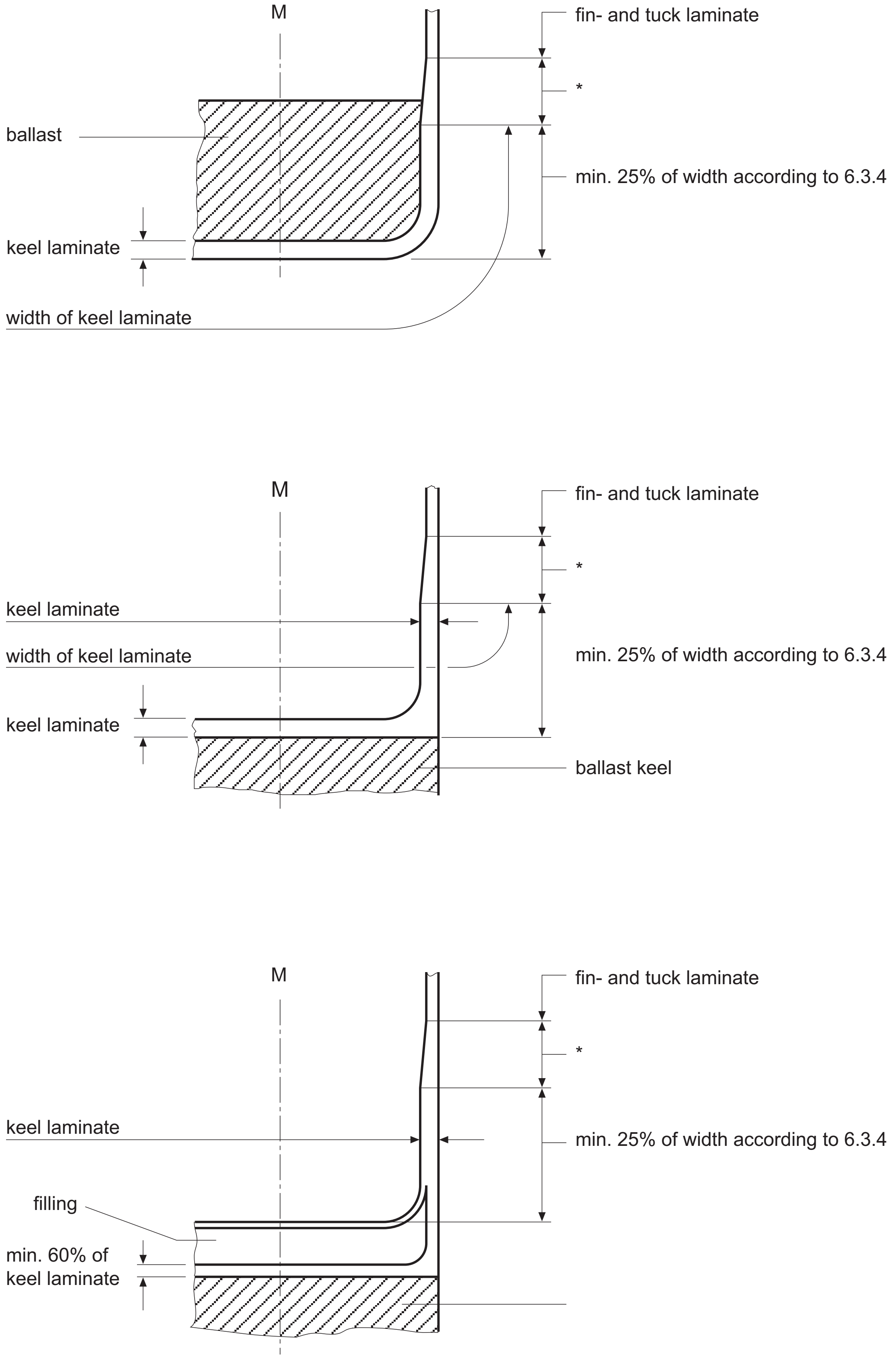

WL
WL
keel laminate
keel laminate
keel laminate
tuck laminate
bottom laminate
0,25 Hk
WL
150 mm
bottom laminate
keel laminate
WL
*
150 mm
bottom laminate
fin laminate
keel laminate
side laminate
WL
150 mm
bottom laminate
fin and
tuck laminate
ballast keel
* tuck-laminate
The width of this laminate should equal half the height Hk of the keel
Hk in accordance with A.1.5.1.7.
Note:
tuck = concave region of shell between fin and shell bottom

Fig. 1.21



* Width of overlap = 25 mm per 600 g/m^2 glass fibre reinforcement

Fig. 1.22

7. Internal structural members of the hull

7.1 General

7.1.1 The hull shall be fitted with an effective system of transverse and/or longitudinal frames supported by web frames, bulkheads, etc.

7.1.2 Frames may be arranged in transverse or longitudinal direction; the internal structural members may also comprise of a combination of the two frame systems. For pleasure craft with a speed $\mathbf{v} \geq 3{,}6\sqrt{\mathbf{L}_{WL}}$ in $[\text{kn}]$, longitudinal framing is recommended.

7.1.3 If certain parts of the accommodation shall be used for stiffening purposes, these must be of equivalent strength and structurally joined to the hull in accordance with 7.1.5. Proof of equivalent strength of integral inner shells/liners lies in the responsibility of the builder.

7.1.4 Where frames and stiffeners are of the top-hat type, the width of the flange connection to the laminate plate shall be 25 mm for the first reinforcement layer plus 12 mm for all subsequent 600 g/m² glass weight of the laminate – at least 50 mm total width.

7.1.5 Floors and bulkheads are to be bonded to the shell by laminate angles on both sides; the width of each flange must be 50 mm for the first reinforcement layer plus 25 mm for all subsequent 600 g/m² glass weight of the laminate.

7.1.6 Floors and bulkheads of solid GRP are to be bonded to the shell or laminate plate on both sides using laminate angles. The total glass weight of each laminate angle may not be less than 50 % of that of the component to be attached; it must not be less than 900 g/m².

7.1.7 Should floors, bulkheads and similar members be made of plywood (specification see Annex C, C.2.), the reinforcement weight of each laminate angle shall comply with the requirements according to Table 1.10.

7.1.8 Sailing craft and motorsailers shall have reinforced bulkheads or equivalent structures in way of mast(s) in order to achieve an adequate transverse rigidity.

7.1.9 Section modulus for floors of sailing yachts in way of ballast keel is to be:

$$W = W_B + W_K$$

$$W_K = \frac{w'_K \cdot h'_K}{\sigma_{bzul} \cdot n} \quad \left[\text{cm}^3\right]$$

W_B = see Table 1.11

w'_K = ballast keel weight in [N]

h'_K = distance between ballast keel's centre of grafity and mean keel floor height in [m]

$$\sigma_{bzul} = \frac{\left(502 \cdot \psi^2 + 106{,}8\right)}{4} \quad \text{in} \left[\text{N/mm}^2\right]$$

n = number of floors in way of ballast keel

Ψ = glass content of laminate by weight, see 3.2

7.1.10 For special bottom designs such as e.g. in sailing yachts with a swivelling ballast keel, proof of adequate strength is to be submitted to GL.

7.1.11 Limber holes in floors shall be arranged as midships as possible.

Note

For sailing yachts with short ballast keels, a reinforced floor at leading and trailing edge of the keel is recommended. The section modulus of these floors shall be at least 1,5 times the section modulus demanded under 1.9, depending on the length of the keel.

7.2 Transverse frames

7.2.1 The scantlings of transverse frames and floors shall be determined in accordance with Table 1.11.

7.2.2 The floors shall be continuous over the bottom of the craft; the section modulus at centre line may be gradually reduced to that of the side frame at bilge or chine.

7.2.3 Floors or equivalent stiffeners are to be fitted in the area of the ballast keel, bilge keels or the rudder heel or skeg, if applicable.

7.2.4 Watertight floors or floors forming the boundary of tank spaces shall also comply with 7.5.

7.2.5 If the tensile strength (fracture) of the shell laminate differs from that stated in 3.1, the section modulus determined is to be corrected in accordance with 4.5.

7.2.6 For determination of the section modulus, see 5.

Table 1.10

Laminate angles for connecting plywood structural members					
Scantling length L **Thickness of plywood (mm)**	**Flange widths (mm) and total glass weights [g/m²]**				
	Main bulkhead	**Forebody**		**Structural members behind main bulkhead**	
	both sides	**one side**	**both sides**	**one side**	**both sides**
up to 9 m 10 mm	50 1150	75 2250	50 1150	60 1800	50 900
up to 10 m 10 mm	50 1150	75 2250	50 1150	60 1800	50 900
up to 11 m 12 mm	60 1350	90 2700	60 1350	75 2250	50 1150
up to 12 m 15 mm	70 1700	105 3150	70 1700	90 2700	60 1350
up to 15 m 18 mm	90 2050	135 3800	90 2050	155 3250	75 1650
up to 17 m 20 mm	100 2350	150 4350	100 2350	130 3750	90 1900

7.2.7 Reduction for transverse frames

When dimensioning curved frames, the effect of the curvature is to be allowed-for by the factor f_{kw}.

h/s	f_{kw}
0 – 0,03	1,0
0,03 – 0,1	$1{,}15 - 5 \cdot \frac{h}{s}$
≥ 0,1	0,65

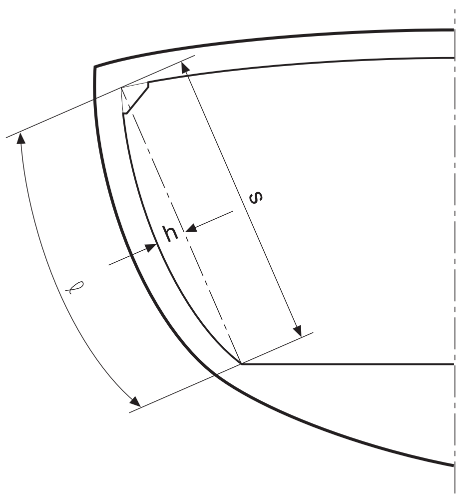


Fig. 1.23

The section modulus determined in accordance with 7.2.6 is to be multiplied by the factor f_{kw}.

The required section modulus calculated using the factor f_{kw} must not be less than the appropriate minimum value, to be taken from Table 1.11.

7.3 Longitudinal frames

7.3.1 The scantlings of longitudinal and web frames for bottom and sides shall comply with Tables 1.12 and 1.13. For dimensioning of curved web frames, see 7.2.7.

7.3.2 The longitudinal frames are to be supported by bulkheads or web frames.

7.3.3 Additional floors or transverse frames are to be arranged in way of engine foundations, rudder skegs, ballast and bilge keels and the bottom in the forebody. The scantlings of these floors must never be less than those required in accordance with Table 1.11.

7.3.4 If the tensile strength (fracture) of the shell laminate differs from that stated in 3.1, the section modulus determined is to be corrected in accordance with 4.5.

7.3.5 For determination of the section modulus, see 5.

7.4 Bottom girders, engine seatings

7.4.1 The engine seatings must be of sufficiently sturdy construction to suit power, weight and type of the engine(s).

7.4.2 The longitudinal girders forming the engine seatings must extend fore and aft as far as possible and are to be suitably supported by floors, transverse frames and/or brackets.

7.4.3 Additional centre and side girders may be required to be fitted to the shell bottom.

7.5 Fuel and water tanks

7.5.1 The scantlings of integral GRP tanks are to be determined in accordance with Table 1.14 (integral tanks are tanks whose walls also form part of the craft shell). For the purpose of these regulations, "fuel" means only gas oil or diesel oil with a flash point ≥ 55 °C.

Petrol may not be stored in integral GRP tanks.

Note

Depending on the operating category, drinking water should be stored in tanks and containers of the following number and type:

The quantity of drinking water depends on the number of persons permitted on board and the duration of the voyage, and should be at least 1,5 litres per person and day at sea.

Operating category	
I	*The water must be stored in two separate tanks.*
II	*At least half of the water reserves must be stored in a tank. The rest of the reserves may be stored in containers.*
III, IV, V	*The water must be stored in suitable containers.*

7.5.2 Should the flexural strength and/or the glass content of the laminate differ from the values stated in 3.1, the total glass weights or nominal thicknesses determined above in accordance with 4.4 are to be multiplied by the factor K_w or K_t. The minimum thickness of the laminate must not be less than 5,0 mm.

7.5.3 If the tensile strength (fracture) of the tank laminate differs from that stated in 3.1, the calculated section modulus is to be corrected in accordance with 4.5.

7.5.4 The section moduli of top-hat type stiffeners are to be determined in accordance with 5.

7.5.5 The internal surfaces of tanks must be suitable for the substances coming into contact with them and must not affect these adversely.

7.6 Bulkheads

7.6.1 Watertight bulkheads are to be provided in accordance with A.2. and shall be effectively joined to the hull in accordance with 7.1.5 to 7.1.7.

7.6.2 The scantlings of single skin GRP bulkheads must comply with Table 1.15.

7.6.3 Bulkheads not watertight or partial bulkheads supporting the longitudinal or transverse frames of the hull must have scantlings equivalent to those of the web frames in accordance with 7.3. The partial bulkheads are to be joined to the hull in accordance with 7.1.5 to 7.1.7.

7.6.4 Bulkheads or parts thereof forming tank boundaries must also comply with the requirements in accordance with 7.5.

7.6.5 The nominal laminate thickness from Table 1.15 is calculated in accordance with 3.1 with 0,70 mm per 300 g/m² of reinforcement.

7.6.6 Should the flexural strength and/or the glass content by weight of the laminate differ from the values as stated in 3.1, the total glass weights or nominal thicknesses determined above in accordance with 4.4 are to be multiplied by the factor K_w or K_t.

The minimum laminate thickness may not be less than 2,5 mm.

7.6.7 If the tensile strength (fracture) differs from that stated in 3.1, the section modulus determined is to be corrected in accordance with 4.5.

Table 1.11

Section moduli of floors and transverse frames of motor-, sailing crafts and motorsailers [cm³]		
Floors	Motor craft	$W_B = 3{,}21\ e\ \ell^2\ F_{VF} \cdot P_{dBM} \cdot 10^{-3}$ $W_{B(min)} = 3{,}21\ e\ k_4^2\ F_{VF} \cdot P_{dBM} \cdot 10^{-3} \geq W_S$
	Sailing craft and motorsailer	$W_B = 2{,}72\ e\ \ell^2\ P_{dBS} \cdot 10^{-3}$ $W_{B(min)} = 2{,}72\ e\ k_4^2 \cdot P_{dBS} \cdot 10^{-3} \geq W_S$
Transverse frames	Motor craft	$W_S = 2{,}18\ e\ \ell^2\ F_{VSF} \cdot P_{dSM} \cdot 10^{-3}$ $W_{S(min)} = 2{,}18\ e\ k_4^2\ F_{VSF} \cdot P_{dSM} \cdot 10^{-3} \geq \mathbf{L}$
	Sailing craft and motorsailer	$W_S = 2{,}26\ e\ \ell^2 \cdot P_{dSS} \cdot 10^{-3}$ $W_{S(min)} = 2{,}26\ e\ k_4^2 \cdot P_{dSS} \cdot 10^{-3} \geq \mathbf{L}$

e = distance of floors/transverse frames [mm]
ℓ = span (unsupported length of floor of frame) [m]
F_{VF} = see A.1.9.3
F_{VSF} = see A.1.9.3
k_4 = $0{,}045 \cdot \mathbf{L} + 0{,}10$ for motor craft [m] or 0,60 [m], the larger value to be used
= $0{,}065 \cdot \mathbf{L} + 0{,}30$ for sailing craft and motorsailers [m] or 0,60 [m], the larger value to be used
P_{dBM} = see A.1.9.2
P_{dBS} = see A.1.9.2
P_{dSM} = see A.1.9.2
P_{dSS} = see A.1.9.2

Table 1.12

Section moduli of the longitudinal frames of motor-, sailing crafts and motorsailers [cm³]		
Bottom longitudinal frames	Motor craft	$W_{BL} = 2{,}14 \ e \ \ell^2 \ F_{VL} \cdot P_{dBM} \cdot 10^{-3}$ $W_{BL(min)} = 2{,}14 \ e \ k_5^2 \ F_{VL} \cdot P_{dBM} \cdot 10^{-3} \geq \mathbf{L}$
	Sailing craft and motorsailer	$W_{BL} = 1{,}82 \ e \ \ell^2 \cdot P_{dBS} \cdot 10^{-3}$ $W_{BL(min)} = 1{,}82 \ e \ k_5^2 \cdot P_{dBS} \cdot 10^{-3} \geq \mathbf{L}$
Side longitudinal frames	Motor craft	$W_{SL} = 2{,}07 \ e \ \ell^2 \ F_{VSL} \cdot P_{dSM} \cdot 10^{-3} \geq \mathbf{L}$ $W_{SL(min)} = 2{,}07 \ e \ k_5^2 \ F_{VSL} \cdot P_{dSM} \cdot 10^{-3} \geq \mathbf{L}$
	Sailing craft and motorsailer	$W_{SL} = 2{,}16 \ e \ \ell^2 \cdot P_{dSS} \cdot 10^{-3}$ $W_{SL(min)} = 2{,}16 \ e \ k_5^2 \cdot P_{dSS} \cdot 10^{-3} \geq \mathbf{L}$
e = distance between longitudinal frames [mm] ℓ = span [m] F_{VF} = see A.1.9.3 F_{VSF} = see A.1.9.3 k_5 = (0,01 **L** + 0,7) or 0,75, the larger value to be used P_{dBM} = see A.1.9.2 P_{dBS} = see A.1.9.2 P_{dSM} = see A.1.9.2 P_{dSS} = see A.1.9.2		

7.6.8 Partial bulkheads of plywood may be used to stiffen the hull. The bulkhead minimum thickness may not be less than:

7.6.8.1 for sailing crafts and motorsailers

$$t = \frac{P_{dBS} \cdot 1{,}45 \cdot \ell}{\sigma_{dzul}} \quad [mm]$$

7.6.8.2 for motor crafts

$$t = \frac{P_{dBM} \cdot F_{VF} \cdot 1{,}45 \cdot \ell}{\sigma_{dzul}} \quad [mm]$$

ℓ = span (unsupported length) in [m]

F_{VF} = speed correction factor, see A.1.9.3

P_{dBM} = see A.1.9.2

P_{dBS} = see A.1.9.2

$$\sigma_{dzul} = \frac{\sigma_{dBruch}}{S}$$

see Table C.7. for durability groups and characteristic values of the wood types in Annex C

S = 5,5

8. Decks, deckhouses and cabins

8.1 Decks

8.1.1 The scantlings for a single skin construction deck are to be taken from Table 1.16. Scantlings of sandwich construction decks are dealt with in C.

8.1.2 The nominal laminate thickness from Table 1.16 is calculated in accordance with 3.1 at 0,70 mm per 300 g/m² of reinforcement.

8.1.3 Openings in the deck for access hatches, skylights, etc. are to be provided with an adequate frame; the coaming is to be effectively bonded to the deck structural members. Skylights and access hatches shall comply with the requirements in Section 5, A.

8.1.4 Supplementary reinforcement is to be provided in the area of bollards, chain plates, deck fittings, etc.

8.1.5 The walkways and working areas on deck and the cabin roof shall be finished with a non-skid surface.

8.1.6 Should the flexural strength and/or the glass content by weight of the laminate differ from the values stated in 3.1, the total glass weights or nominal thicknesses determined above in accordance with 4.4 are to be multiplied by the factor K_w or K_t. The minimum thickness of the laminate may not be less than 2,5 mm.

8.2 Deck supports and pillars

8.2.1 Decks are to be supported by a system of transverse and/or longitudinal stiffeners and pillars. The scantlings of the components are based on Tables 1.17 to 1.20; for steel pillars see F.9.

8.2.2 At the ends of large openings and in way of the mast deck transverses are to be arranged in-plane of the web frames.

8.2.3 The ends of supports and stiffeners are to be effectively anchored into the adjacent structure, or equivalent arrangements shall be provided.

8.2.4 Head and heel pieces of deck pillars plus supports shall be built appropriate for the forces to be transmitted and shall be joined to the strength members.

8.2.5 Stiffeners and supports of tank decks of water and fuel tanks must also meet the requirements of 7.5.

8.2.6 If the tensile strength (fracture) of the deck laminate differs from that stated in 3.1, the calculated section modulus is to be corrected in accordance with 4.5.

8.2.7 For calculation of the section modulus see 5.

8.3 Hull to deck joint

8.3.1 The connection between deck and hull must be made watertight, using laminate and/or mechanical fastenings. Design details are to be shown in the technical documentation submitted for approval.

8.3.2 Particular attention is to be given to the attachment of the chain plates and the forebody connections of fast motor craft.

8.3.3 The strength and watertightness of the hull must not be impaired by the attachment of rubbing strakes/rails, etc.

8.4 Cockpits

8.4.1 The scantlings of cockpit sides and bottom must be of equivalent strength to those for the deck in accordance with 8.1.

8.4.2 Cockpits must be provided with drain pipes in accordance with Section 5.

8.5 Deckhouses and cabins

8.5.1 The scantlings of single skin construction deckhouses and cabins are given in Tables 1.19 and 1.20.

8.5.2 The nominal laminate thickness from Tables 1.19 is calculated in accordance with 3.1 with 0,70 mm per 300 g/m^2 of reinforcement.

8.5.3 Should the flexural strength and/or the glass content of the laminate differ from the values as stated in 3.1, the total glass weights or nominal thicknesses determined above in accordance with 4.4 are to be multiplied by the factor K_w or K_t.

The minimum thickness of the laminate must not be less than 2,5 mm.

8.5.4 Web frames or partial/wing bulkheads are to be provided to ensure transverse rigidity in large deckhouses. The strength members are to be suitably reinforced in the area of masts and other load concentrations.

8.5.5 If the tensile strength (fracture) of the deck laminate differs from that stated in 3.1, the calculated section modulus is to be corrected in accordance with 7.5.

8.5.6 For calculation of the section modulus see 5.

8.5.7 Openings for doors and windows are to be provided with frames of adequate strength.

8.5.8 With reference to doors and windows, see Section 5.

Table 1.13

Section moduli of the web frames for motor-, sailing craft- and motorsailers [cm³]		
floor at centre	Motor craft	$W_{RM} = 3{,}21\ e\ \ell^2\ F_{VBW} \cdot P_{dBM}$ $W_{RM(min)} = 3{,}21\ e\ k_6^2\ F_{VBW} \cdot P_{dBM} \geq W_{RS}$
	Sailing craft and motorsailers	$W_{RM} = 2{,}72\ e\ \ell^2 \cdot P_{dBS}$ $W_{RM(min)} = 2{,}72\ e\ k_6^2 \cdot P_{dBS} \geq W_{RS}$
frame at side	Motor craft	$W_{RS} = 2{,}18\ e\ \ell^2\ F_{VSW} \cdot P_{dSM}$ $W_{RS(min)} = 2{,}18\ e\ k_6^2 \cdot F_{VSW} \cdot P_{dSM}$
	Sailing craft and motorsailers	$W_{RS} = 2{,}26\ e\ \ell^2 \cdot P_{dSS}$ $W_{RS(min)} = 2{,}26\ e\ k_6^2 \cdot P_{dSS} \geq \mathbf{L}$

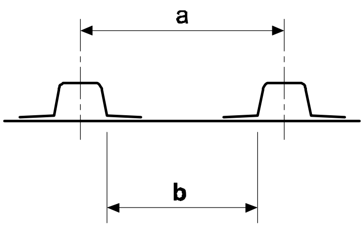
L = see A.1.5
e = web frame spacing [m]
ℓ = unsupported length (span) [m]
F_{VBW} = see A.1.9.3
F_{VSW} = see A.1.9.3
k_6 = $0{,}045 \cdot \mathbf{L} + 0{,}10$ for motor craft [m] or 0,60 [m], the larger value to be used
$0{,}065 \cdot \mathbf{L} + 0{,}30$ for sailing craft and motorsailers [m] to 0,60 [m], the larger value to be used
P_{dBM} = see A.1.9.2
P_{dBS} = see A.1.9.2
P_{dSM} = see A.1.9.2
P_{dSS} = see A.1.9.2

Table 1.14

Total glass weight for water- and fuel tank boundaries plus section moduli of water- and fuel tank wall stiffeners of motor, sailing craft and motorsailers	
Total glass weight [g/m²]	$G_W = 5{,}40 \cdot \mathbf{b} \cdot F_p \cdot \sqrt{h_1}$ $G_{W\,(min)} = 8{,}36 \cdot \mathbf{b} \cdot F_p \geq 2700$
Section modulus [cm³]	$W_T = 0{,}05 \cdot h_2 \cdot a \cdot \ell^2$ $W_{T\,(min)} = 0{,}037 \cdot a$

a = stiffener spacing [mm]

b = see below [mm]



ℓ = stiffener length [m]

F_p = see 4.4.2.3

h_1 = vertical distance from tank bulkhead bottom edge to filler tube [m]

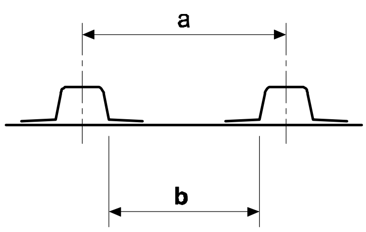
h_2 = vertical distance from the centre of the stiffener's unsupported length to the filler tube [m]

Table 1.15

Total glass weight for bulkheads plus section moduli of bulkhead stiffeners of motor-, sailing craft and motorsailers	
Total glass weight [g/m²]	$G_{WQ} = 5{,}4 \cdot a \cdot F_p \cdot \sqrt{h_3}$ $G_{WQ\,(min)} = 3{,}8\,(350 + 5\,\mathbf{L}) \cdot \sqrt{h_3} \geq 1200$
Section moduli vertical stiffeners [cm³]	$W_{QV} = 0{,}017 \cdot a \cdot \ell^2 \cdot F_{fv} \cdot \left(h' + \frac{\ell}{2}\right)$ $W_{QV\,(min)} = 6{,}0\,(350 + 5\,\mathbf{L}) \cdot F_{fV} \cdot 10^{-3}$
Section moduli horizontal stiffeners [cm³]	$W_{QH} = 0{,}03 \cdot \mathbf{b} \cdot \ell^2 \cdot F_{fH} \cdot h_4$ $W_{QH\,(min)} = 10{,}3\,(350 + 5\,\mathbf{L}) \cdot F_{fH} \cdot 10^{-3}$

a = stiffener spacing [mm]

b = see below [mm]



ℓ = stiffener length [m]

F_p = see 4.4.2.3

h_3 = vertical distance from bulkhead bottom edge to deck edge [m]

h_4 = height of deck at side above top of stiffeners [m]

h' = vertical distance from centre of stiffener to deck edge [m]

F_{fV} = 1,0 for stiffeners with free ends

$$0{,}80 - \frac{h'}{3{,}75\,(2h' + \ell)}$$

for stiffeners with bracket attachment at each end

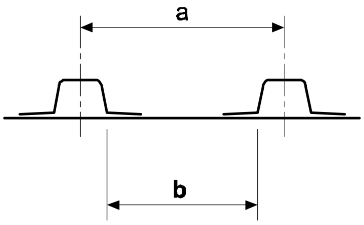
F_{fH} = 1,0 for stiffeners with free ends

0,667 for stiffeners with bracket attachment at each end

Table 1.16

Total glass weight for deck laminate of motor and sailing craft and motorsailers	
Total glass weight [g/m²]	$G_{WD} = 1{,}57 \cdot \mathbf{b} \cdot F_p \cdot \sqrt{P_{dD}}$ $G_{WD\,(min)} = 1{,}1\,(350 + 5\,\mathbf{L})\,\sqrt{P_{dD}}$ $G_{WD\,(min)} \geq 1200$

a = stiffener spacing [mm]
b = see below [mm]



F_p = see 4.4.2.3
P_{dD} = see A.1.9.4

Table 1.17

Section moduli of main deck beams for motor and sailing craft and motorsailers [cm³]	
Weather deck beams	$W_D = 20{,}38 \cdot P_{dD} \cdot a \cdot \ell^2 \cdot 10^{-4}$ $W_{D\,(min)} = 11{,}54 \cdot P_{dD}\,(350 + 5\,\mathbf{L}) \cdot 10^{-4}$ $W_{D\,(min)} \geq 3{,}0$
Beams within deckhouses	$W_{DI} = 20{,}38 \cdot k_8 \cdot a \cdot \ell^2\, P_{dD} \cdot 10^{-4}$ $W_{DI\,(min)} = 11{,}54 \cdot k_8\, P_{dD}\,(350 + 5\,\mathbf{L}) \cdot 10^{-4}$ $W_{DI\,(min)} \geq 3{,}0$

a = beam spacing [mm]
ℓ = unsupported length of beam [m]
P_{dD} = see A.1.9.4
k_8 = correction factor for craft whose length $\mathbf{L} \geq 10{,}0$ m

$$k_8 = 0{,}90 - 0{,}01\,\mathbf{L}$$

Table 1.18

Section moduli of main deck girders for motor and sailing craft and motorsailers [cm³]	
Weather deck girders	$W_{DU} = 2{,}04 \cdot e \cdot \ell^2 \, P_{dD}$ $W_{DU\,(min)} = 1{,}65 \cdot e \, P_{dD}$
Girders within deckhouses	$W_{DUI} = 2{,}04 \cdot k_8 \cdot e \cdot \ell^2 \, P_{dD}$ $W_{DUI\,(min)} = 1{,}65 \cdot k_8 \cdot e \, P_{dD}$
e = distance of girders [m] ℓ = unsupported length of girder [m] k_8 = correction factor for craft whose length **L** ≥ 10,0 m $k_8 = 0{,}90 - 0{,}01\,\mathbf{L}$ P_{dD} = see A.1.9.4	

Table 1.19

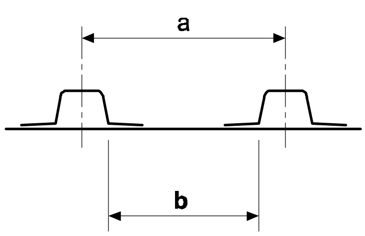
Total glass weight of deckhouse and cabin laminates of motor, sailing craft and motorsailers	
Total glass weight [g/m²]	$G_{WD} = 1{,}57 \cdot \mathbf{b} \cdot F_p \cdot \sqrt{P_{dD}}$ $G_{WD\,(min)} = 1{,}1\left(350 + 5\,\mathbf{L}\right) \cdot \sqrt{P_{dD}}$ $G_{WD\,(min)} = 1200$
 F_p = see 4.4.2.3 P_{dD} = see A.1.9.4	

Table 1.20

Section moduli of the deckhouse- and cabin wall stiffeners for motor and sailing craft and motorsailers [cm³]	
Deckhouse	$W_{SDH} = 6{,}92 \cdot a \cdot \ell^2 \cdot P_{dD} \cdot 10^{-4}$ $W_{SDH\,(min)} = P_{dD}\,(350 + 5\,\mathbf{L}) \cdot 10^{-4}$ $W_{SDH\,(min)} = 3{,}0$
Cabins	$W_{SK} = 10{,}38 \cdot P_{dD} \cdot a \cdot \ell^2 \cdot 10^{-4}$ $W_{SK\,(min)} = 5{,}77 \cdot P_{dD} \cdot (350 + 5\,\mathbf{L}) \cdot 10^{-4}$ $W_{SK\,(min)} = 3{,}0$
a = stiffener spacing [mm] ℓ = stiffener length [m] P_{dD} = see A.1.9.4	

C. Advanced Composite Structures

1. General

1.1 The term "advanced" refers to FRP (fibre reinforced plastic) construction not limited to standard single-skin E-Glass laminates in terms of B., i.e. combinations of chopped strand mats and woven roving layers.

Rather the following applies to FRP structures where various fibre types and fibre arrangements may be utilised. Fibre types besides E-glass are e.g. carbon and aramid. Combinations of different fibres i.e. hybrid layers are also possible. Examples for fibre arrangements are unidirectional, multi-axial or woven fabrics.

1.2 Resins are to be appropriate for the chosen reinforcing layers and capable of withstanding ageing in marine environments.

1.3 Different lamination techniques besides wet hand lay-up can be applied, e.g. prepreg lamination where the laminate is built up from reinforcing material which is pre-impregnated with a thermosetting resin and can be processed without any further addition of resin or hardener.

1.4 Different fibres and the multitude of fabrics give rise to sophisticated laminate lay-ups of components specifically designed to the loads expected. Strength and stiffness calculation of such lay-ups requires careful analysis.

1.5 Mechanical properties of the laminate, nominal thickness and weight, type and fibre content of the individual reinforcing-materials used shall be specified on the design drawings.

2. Sandwich

2.1 The sandwich generally consists of two FRP skins and a core of lightweight material. In case of flexural loading the skins mainly absorb tension and compression stresses, whereas the core mainly absorbs shear stresses.

2.2 Flexural strength requirements can be usually achieved even with skins of reduced thickness, particularly if high-strength fibres are used. Therefore, when dimensioning sandwich structures, additional failure modes must be considered which can occur before ultimate stress of the skins is attained. Among these are:

– shear failure of the core material

– failure of skin/core bonding

– wrinkling

– core failure under point load

3. Sandwich core materials

– Rigid foam materials of a closed-cell type with a minimum apparent density of 60 kg/m³

– End-grained balsa wood

– Honeycomb materials

Note

Regarding FRP and core materials our Rules for Classification and Construction, II – Materials and Welding, Part 2 – Non-metallic Materials, Chapter 1– Fibre Reinforced Plastics and Bonding are to be observed. Excerpts are to be found in Annex B.

4. Non-sandwich areas

The following areas are to be of single skin construction

– keel root area

– major penetrations of the hull (e.g. for "Sail-drive" propulsion units)

5. Transitions from single-skin laminate to sandwich

In panels where there is a change from sandwich to single skin laminate (e.g. in hull to deck joints), the required single skin laminate is to be determined by the scantlings for the whole panel.

6. Design pressures

In the following design pressure formulae will be specified. The formulae are in the style of ISO/CD 12215-5 (draft international standard, 2000-06-30). Design pressure values obtained from these formulae serve to determine scantlings for FRP structures in terms of this section. Related allowable stresses are given in 7. and 8.

6.1 Bottom design pressure P_b

The bottom design pressure P_b is to be applied up to 150 mm above WL and is to be the greater of the bottom impact pressure P_{b1} or the bottom pressure for displacement mode P_{b2}. The former will be generally dominant for planing motor craft whereas the latter will dominate for sailing yachts in most cases.

6.1.1 Bottom impact pressure P_{b1} in [kPa]

$$P_{b1} = \frac{100 \cdot D}{L_{WL} \cdot B_{WL}} \cdot \left(1 + n_{cg}\right) \cdot k_L \cdot k_{ar}$$

D, L_{WL} = see A.1.

B_{WL} = max. beam at waterline in [m]

6.1.2 Dynamic load factor n_{cg} in units of [g]

$$n_{cg} = 0{,}00013 \cdot \left(\frac{f_{oc} \cdot L_{WL}}{10 \cdot B_{WL}} + 0{,}084\right) \cdot (50 - \beta) \cdot \frac{v^2 \cdot B_{WL}^2}{D}$$

v = max. speed in calm water in [kn]. For sailing yacht no lesser value than

$$3 \cdot \sqrt{L_{WL}}$$

shall be assumed.

ß = deadrise angle to be taken between 10° and 30°

f_{oc} = is the operating category factor. Its values are according to the following Table 1.21.

Table 1.21

Operating category	I	II	III	IV and V
f_{oc}	1,0	0,95	0,85	0,7

n_{cg} = shall not exceed a value of 4.

6.1.3 Longitudinal distribution factor k_L

$$k_L = 0{,}13 \left[1{,}4 \cdot x_L \cdot \left(10 - \frac{v}{\sqrt{L_{WL}}}\right) + 0{,}706 \cdot \frac{v}{\sqrt{L_{WL}}} + 0{,}64\right]$$

$$x_L = \frac{x}{L_{WL}}$$

is the position ratio where x in [m] is the distance from the aft end of WL

$$k_{L,\,min} = 0{,}13 \cdot \left(0{,}35 \cdot \frac{v}{\sqrt{L_{WL}}} + 4{,}14\right)$$

$$k_{L\,max} = 1{,}0$$

6.1.4 Design area reduction factor k_{ar}

Sailing craft:

$$k_{ar} = 0{,}673 - 0{,}52 \cdot \frac{u^{0,75} - 1{,}7}{u^{0,75} + 1{,}7}$$

Motor craft:

$$k_{ar} = 0{,}455 - 0{,}35 \cdot \frac{u^{0,75} - 1{,}7}{u^{0,75} + 1{,}7}$$

Sailing and motor craft:

$k_{ar,\,min}$ = 0,4

$$u = 100 \cdot \frac{A_d}{A_r}$$

6.1.5 Reference area A_r

$$A_r = 0{,}45 \cdot L_{WL} \cdot B_{WL} \quad \text{in} \left[m^2\right]$$

6.1.6 Design area A_d in [m²]

– for plating it is the area of the panel not to be taken greater than 2,5 times b^2 where b is the short panel span

– for stiffeners it is the stiffener length ℓ times the stiffener spacing not to be taken less than 0,33 times ℓ^2

6.2 Bottom pressure for displacement mode P_{b2} in [kPa]

$$P_{b2} = 11{,}76 \cdot \left(3 \cdot T_c + 0{,}23 \cdot L_{WL}\right) \cdot k_{ar} \cdot k_L \cdot f_{oc}$$

$P_{b2,min}$ = $10 \cdot H$

H = see A.1.

k_{ar}, k_L, f_{oc}, = see 6.1.2, 6.1.3, 6.1.4

T_c = canoe body draught in [m] not to be taken less than

$$T_c = 0{,}062 \cdot L_{WL} - 0{,}26$$

6.3 Side design pressure for sailing craft P_{sS} in [kPa]

$$P_{sS} = 7{,}14 \cdot (2 \cdot T_c + 0{,}23 \cdot L_{WL}) \cdot k_{ar} \cdot k_L \cdot f_{oc}$$

$P_{sS,min}$ = $5 \cdot H$

T_c = canoe body draught in [m] not to be taken less than

$$T_c = 0{,}062 \cdot L_{WL} - 0{,}26$$

6.4 Side design pressure for motor craft P_{sM} in [kPa]

$$P_{sM} = \left(f_{oc} \cdot 10 \cdot H + 0{,}24 \cdot P_{b1,base}\right) \cdot k_{ar} \cdot k_L \cdot k_v$$

$P_{sM,min}$ = $f_{oc} \cdot (0{,}18 \cdot L_{WL} + 2{,}37)$

with

$$P_{b1,base} = \frac{100 \cdot D}{L_{WL} \cdot B_{WL}} \cdot \left(1 + n_{cg}\right)$$

6.4.1 Vertical pressure distribution factor k_v

$$k_v = \frac{H - T_c - 0{,}15\,m - z}{H - T_c - 0{,}15\,m}$$

where z in [m] is the height of panel or stiffener centre above the limit between bottom and side pressure, i.e. 150 mm above the waterline.

6.5 Deck design pressure P_d in [kPa]

$$P_d = f_{oc} \cdot \left(0{,}11 \cdot L_{WL} + 5{,}35\right)$$

For superstructures the deck design pressure may be reduced except for frontwalls by considering the influence of height above the weather deck. A minimum pressure of 4,0 kPa must always be complied with.

6.6 Design pressure for watertight bulkheads p_{bh} in [kPa]

$$p_{bh} = 10 \cdot h_z$$

h_z = vertical distance from centre of bulkhead plate or stiffener to the top of the bulkhead in [m]

6.6.1 Design pressure for integral tanks p_t in [kPa]

$$p_t = 10 \cdot \left(h_d + h_{ft}\right)$$

where:

h_d = vertical distance from centre of tank boundary plate or stiffener to the deck [m]

h_{ft} = height of filler tube above the deck in [m]. No lesser values than the following shall be inserted:

– 0,25 m for craft with L < 10 m

– 0,50 m for craft with 10 ≥ L ≤ 15 m

– 1,00 m for craft with L > 15 m

7. Procedure for panel scantling determination

7.1 Laminate lay-up

The following is to be specified for each FRP layer:

– fibre orientation relative to appropriately defined coordinates

– cured ply thickness

– modulus of elasticity in short and long span direction
– shear modulus

In case of sandwich construction also

– core material thickness
– shear strength

7.2 Geometric panel data

– short and long span of panel
– curvature if applicable

7.3 Applicable design pressure

Depending on:

– whether the panel is part of hull, deck, bulkhead, tank boundary or superstructure
– other parameters as specified in 6.

7.4 Results of calculation

– strain of each individual FRP layer
– shear stress of core in case of sandwich construction
– deflection of panel

7.5 Required factors of safety (FoS)

– the FoS between ultimate strain and calculated strain of each FRP layer according to the ply analysis must be at least 4,0
– in case of sandwich construction the FoS against core shear failure must be at least 2,0
– standard values for max. panel deflection are 1,5 % of the panel's short span in case of single-skin laminate and 1 % for a sandwich panel.

8. Procedure for stiffener scantling determination

8.1 Specification of FRP stiffener lay-up and attached FRP plate

– fibre orientation parallel and perpendicular to stiffener
– cured ply thickness
– modulus of elasticity
– shear modulus

8.2 Geometric stiffener data

– stiffener core height
– stiffener core width
– bonding width
– unsupported length of stiffener
– support conditions
– curvature if applicable
– stiffener spacing

8.3 Applicable design pressure

Depending on:

– whether the stiffener is attached to the hull, deck, bulkhead, tank boundary or superstructure
– other parameters as specified in 6.

8.4 Results of calculation

– bending moment and shear force due to design pressure and support conditions
– effective width of plating
– strain of FRP layers in stiffener capping due to bending
– strain of FRP layers in attached plating according to effective width
– shear stress in stiffener webs
– deflection of stiffener

8.5 Required factors of safety (FoS)

– the FoS between ultimate strain and calculated strain of each FRP layer due to stiffener's bending must be at least 4,0
– the FoS against ultimate shear stress in stiffener webs must be also at least 4,0
– the standard value for max. deflection of stiffeners is 0,5 % of their unsupported length. In case of engine foundations a 0,3 % limit shall be kept.

D. Wooden Hulls

1. General

1.1 Scope

These rules apply to the scantling determination of the structure of sailing craft, motorsailers and motor yachts of normal monohull form, traditionally carvel or clinker built on transverse frames.

1.2 Basic principles for scantling determination

1.2.1 Determination of the component scantlings of structural members shall be carried out in accordance with the Tables 1.22 – 1.36 respecting the scantling numerals **B**/3 + $\mathbf{H}_1$or **L** (**B**/3 + $\mathbf{H}_1$). Structural members of hulls with larger dimensions or unusual proportions shall have the scantlings determined by individual calculations.

The scantlings given in Tables 1.22 – 1.36 for the structural members listed below apply to timber with a bulk density of:

Structural member	Standard bulk density [g/cm³] [1]
Keel Stem Floors Frames Transom beams	0,70
Shell Sheer plank Reinforced deck beams Beam knees Carlines Engine seatings Deadwood	0,56
Decks Deck beams Planks, shelves	0,45

[1] In standard atmosphere condition with a moisture content (according to "VG") of 12 %.

1.2.2 If the bulk density of the wood intended to be used differs from the values in the above Table, the scantlings/section moduli listed in the Tables are to be increased/decreased proportionally with the bulk density ratio $\rho_{standard}/\rho_{actual}$.

1.2.3 Keel, stem/sternpost and other hull structural members may be lamellated. Scantlings are to be calculated in accordance with E.

1.3 Types of wood and materials

1.3.1 Wood

Timbers for load bearing components shall be best quality, adequately dried, sound, free from sap, knots and detrimental flaws. Twisted timber shall not to be used. Requirements in accordance with E.2. are to be observed.

Timber in durability groups 1, 2 and 3 in accordance with C.7., Annex C. is preferably to be used. Timber in groups 4 and 5 requires special approval from GL.

For non-load-bearing components, e.g. interior parts, no particular types of wood are specified.

1.3.2 Plywood

Structural members from plywood exposed to the weather, such as decks, superstructures, deckhouses, etc. shall comply with the Rules for Classification and Construction, II – Materials and Welding, Part 2 – Non-metallic Materials, Chapter 2.

1.4 Workshop requirements and quality assurance

Requirements in accordance with E.5. are to be observed.

2. Shell

2.1 Shell planks shall be quartersawn (riftsawn). Thickness and width are listed in Tables 1.22 and 1.23. Planks around the bilge should be narrower than those for other areas. Plank thicknesses are the ones after shaping. If the frame spacing is increased compared with Table values, plank thickness is to be increased in proportion, a reduction of plank thickness is permissible if frame spacing is reduced.

2.2 For double-planked yachts whose scantling numeral **L**(**B**/3 + $\mathbf{H}_1$) is greater than 28, the total thickness of the shell may be reduced by 10% in accordance with Table 1.22.

Spacing of butts in shell planking			
	Plank thickness		
	under 20 mm	20 – 33 mm	over 33 mm
if strakes adjoin	1,00 m	1,20 m	1,50 m
if there is one intermediate strake	0,70 m	0,90 m	1,20 m
if there are two intermediate strakes	0,40 m	0,60 m	0,90 m

2.3 Shell planking is to be fitted in as long lengths as possible. Planks in one strake may however be joined by glued joints or butt straps.

Where there are joints in two neighbouring strakes of planking, these must be at least three frame spaces apart. If there is one strake in between, they must be two frame spaces apart; if two, one frame space.

2.4 If the shell planking does not have glued joints, the planks are to be connected by butt straps. The distances between butts are to be taken from the Table below:

Plank butts in the plane of the same frame are only permitted if there are three intermediate strakes.

2.5 The butts in the shell planking are to be so arranged that they are not in the same plane as those of the beam shelf, the keel and the sheer plank.

2.6 Butt straps of wood or sea-water-compatible metal are to be arranged in between frames with drainage at both ends. They should be wide enough to overlap adjoining strakes by at least 10 mm. Wooden straps should be of the same thickness as the shell; metal ones are to have an equivalent strength. For arrangement details of butt straps see Fig. 1.24.

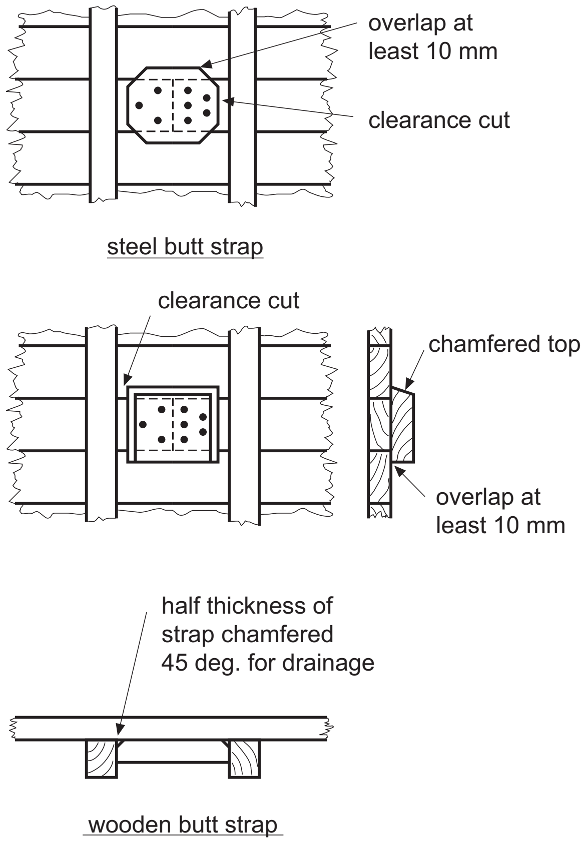


Fig. 1.24

2.7 Planks and butt straps are to be joined by means of threaded bolts, as follows:

Width of plank [mm]	Number of bolts in each plank end
up to 100	3
100 up to 200	4
200 up to 250	5

3. Bulkheads

3.1 Bulkhead plating

The thickness of the bulkhead plating shall not be less than:

$$s = a \cdot \sqrt{h_1 \cdot k} \cdot C \quad [mm]$$

a = stiffener spacing in [m]

h_1 = pressure head in [m] measured from bulkhead bottom edge to bulkhead deck

k = 12 as standard value for teak, kambala, oak, sipo-mahogany

= 16 as standard value for less firm wood, e. g. khaya-mahogany, sound pine

C = 4,0 in case of collision bulkhead

= 2,9 for other bulkheads

The bulkhead plating need not be thicker than the shell if frame spacing and stiffener spacing correspond.

3.2 Bulkhead stiffeners

The section moduli of the stiffeners shall not be less than:

$$W = k \cdot C \cdot a \left(h_2 + 0{,}5\right) \cdot \ell^2 \quad \left[cm^3\right]$$

h_2 = pressure head in [m] measured from the center of the stiffener up to the bulkhead deck

ℓ = length of stiffener in [m]

k = 12 for stiffeners of teak, kambala, oak, sipo-mahogany and laminated stiffeners

= 16 for stiffeners of less firm wood, e. g. khaya-mahogany, sound pine.

3.3 Non-watertight bulkheads

Components of non-watertight transverse or longitudinal bulkheads, wing bulkheads or such which serve to stiffen the hull are to be dimensioned in accordance with the same formulae.

4. Floors

4.1 Floors shall be fitted over 0,75 $\mathbf{L}_{WL}$ of the mid-body of the craft at each frame; see Fig. 1.25. In the case of yachts with curved or lamellated frames, whose scantling numeral **L** (**B** /3 + $\mathbf{H}_1$) is less than 20, floors may be spaced 1½ frames apart within 0,75 $\mathbf{L}_{WL}$ in accordance with Table 1.22; under the mast tabernacle however floors are required at each frame.

4.2 In the afterbody, a spacing of two frames suffices beyond 0,75 $\mathbf{L}_{WL}$, a spacing of three frames beyond $\mathbf{L}_{WL}$; in the forebody beyond $\mathbf{L}_{WL}$ a spacing of two frames. Where sterns hang over, as with conventional yacht sterns and retracted transoms, no floors are needed in the overhang beyond $\mathbf{L}_{WL}$ provided the frames are carried continuously from one side to the other.

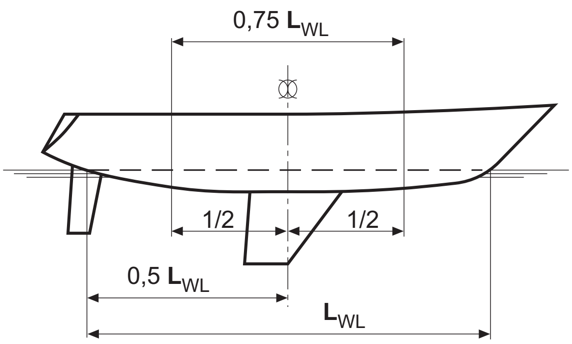


Fig. 1.25

4.3 Floors may be in the form of flat bar steel, angle bar steel and wood, steel plates or wooden planks. In place of steel flat bar, angle bar or plate floors, floors of the same strength of other metal may be fitted. Wooden floors shall be sawn from knee timber; the grain shall substantially run parallel with the shell. The grain of wooden plank floors runs horizontally.

4.4 For yachts where the scantling numeral **L** (**B**/3 + $\mathbf{H}_1$) is more than 25, wooden floors, steel plate floors or wooden plank floors shall be fitted in the area of the fin keel.

4.5 Steel plate or wooden plank floors shall be fitted underneath the mast, and underneath the seatings of more powerful propulsion engines.

4.6 Floor scantlings are given in Tables 1.24 and 1.25 based on the scantling numeral **B**/3 + $\mathbf{H}_1$ and floor spacing, for the mid-body area of 0,75 $\mathbf{L}_{WL}$. If the spacing is greater than that in the Table, the floor scantlings are to be increased in the same proportion. For the floors beyond 0,75 $\mathbf{L}_{WL}$ whose spacing is increased in accordance with 4.2, increase in scantlings is not required.

4.7 Beyond $\mathbf{L}_{WL}$, arm lengths may be reduced to 1/3 of the associated frame lengths.

4.8 Steel flat and angle bar floors may be fitted on top of or alongside the frames.

4.9 Angle bar floors fitted alongside the frames are to be bolted to the frame and the shell.

4.10 The arms of flat bar steel floors may be tapered off to the scantlings given in Table 1.25 for arm ends, from the first third onwards. Similarly, the projecting leg of angle bar floors may be tapered off to leg thickness from the first third of the arm length onwards.

4.11 The scantlings for wooden floors given in Tables 1.24 and 1.25 apply to the centre of the floor. Towards the ends of the arms, the height may gradually be reduced to that of the frame.

If ballast keel bolts are taken through wooden floors, the floor width is to be increased by half a bolt diameter.

4.12 The heights given in Table 1.24 for steel plate or wooden plank floors are the heights above the top edge of the wood keel. Beyond $\mathbf{L}_{WL}$, the height may gradually be reduced to twice that stated for naturally grown frames. The floors are to be extended high enough for the associated frames to be rigidly joined to them.

4.13 If ballast keel bolts are taken through the wooden plank floors, the thickness of the floors is to be increased correspondingly. It is to equal four times the bolt diameter.

4.14 Steel plate floors are to be joined to the wood keel and the shell by angle bars of the shape of the stipulated steel frames. However the profile flanges in contact with the keel must be wide enough to be at least 1/3 of the flange width between bolt hole and profile edge. The upper edges of plate floors are to be flanged. Plate floors may in the region of 0,6 **B** amidships have lightening holes no greater in height than half the local web height and not exceeding the local web height in length.

5. Frames

5.1 Frames may either be prebent, bent-in, lamellated grown, of metal or made by a combination of these. Frame spacing is given in Table 1.22. Frame spacing may be altered if the thickness of shell planking is increased (see 2.1). Frame scantlings are to be determined from Tables 1.26 and 1.27 based on the scantling numeral $\mathbf{B}/3 + \mathbf{H}_1$ and the frame spacing chosen.

5.2 Forward and aft of the length $\mathbf{L}_{WL}$, the section modulus of bent, lamellated or steel frames may be reduced by 15 %; that of grown frames by 20 %.

5.3 Where bent frames have sharp bends, it is recommended that metal strips be fitted.

5.4 The cross section of bent and lamellated frames shall be the same from keel to deck. They are to be made of a single piece.

5.5 Grown frames shall have the same width from keel to deck, the height on the other hand may be gradually reduced from the top edge of the floor to the deck, down to the frame height shown in Table 1.27.

5.6 For grown frames, timber shall be used whose grain follows the shape of the frame. If such timber is not available in adequate lengths, the frames may be strapped. The following straps are permitted: the two ends overlap by at least 3,5 times the frame width, or the two parts butt and are joined along the sides by a strap with a cross section equal to the frame's and with a length 7 times the frame width.

5.7 Metal frames shall be welded to floor plates and beam knees.

Sailing yachts with an $\mathbf{L}\,(\mathbf{B}/3 + \mathbf{H}_1)$ up to 14 shall have two reinforced frames in way of the mast; larger ones at least three. In place of the reinforced frames, intermediate ones may be fitted which have the same cross section as the neighbouring ones.

5.8 For yachts with an $\mathbf{L}\,(\mathbf{B}/3 + \mathbf{H}_1)$ greater than 26, reinforced or intermediate frames are additionally to be provided at the ends and in the middle of longer deck openings. The minimum number of reinforced or intermediate frames is to be taken from the following Table.

$\mathbf{L}\,(\mathbf{B}/3 + \mathbf{H}_1)$	**Number of reinforced or intermediate frames**
> 26	4
> 35	5
> 47	6
> 62	7
> 80	8
> 115	9

Bulkheads or partial bulkheads of adequate strength may replace the reinforced frames.

The section modulus of the reinforced frames is to be at least 30 % greater than that of normal frames. In the area of the beam shelves, the height of the reinforced frames may be reduced to that of the other grown frames.

5.9 If possible the reinforced frames shall be fitted in conjunction with reinforced deck beams, with which they are to be connected by hanging knees.

5.10 In the case of yachts with an $\mathbf{L}\,(\mathbf{B}/3 + \mathbf{H}_1)$ greater than 62, one of the reinforced frames in way of the mast shall be a web frame; where $\mathbf{L}\,(\mathbf{B}/3 + \mathbf{H}_1)$ exceeds 78, at least two must be in the form of web frames. Metal web frames comprise of a metal floor, a web plate and a reverse frame or a flange located at the inner edge of the web frame.

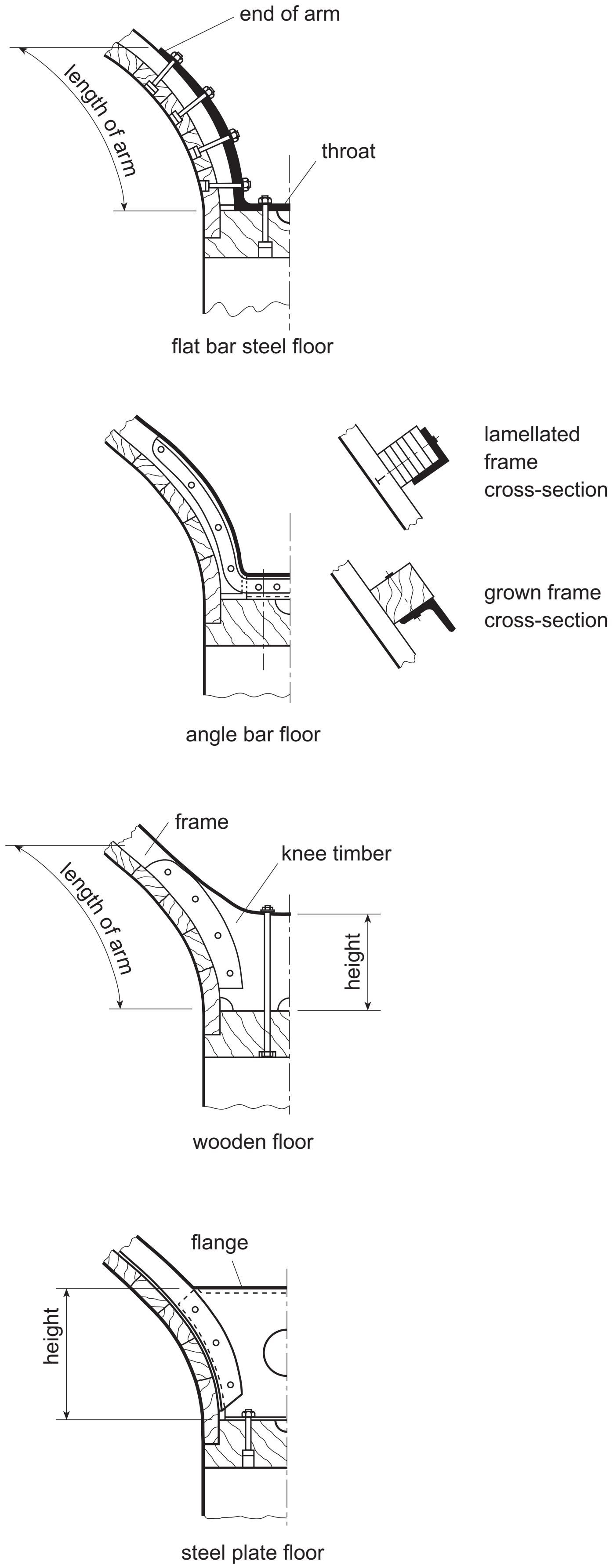

end of arm
length of arm
throat
flat bar steel floor
lamellated
frame
cross-section
grown frame
cross-section
angle bar floor
frame
knee timber
length of arm
height
wooden floor
flange
height
steel plate floor

Fig. 1.26

5.11 Steel web frames shall comply with the following Table:

L (B/3 + H_1)	Web plate
m^2	mm
over 62	200 · 4
over 70	220 · 4
over 78	230 · 5
over 88	250 · 5

The web plates may have round lightening holes with a diameter of 1/3 of the web height. Hole edges shall be at least 1/4 of the web height apart.

5.12 The web frames are to be firmly welded to the floors and connected to the reinforced deck beams by hanging knees.

5.13 In lieu of steel web frames, wooden web frames of the same strength and also bulkheads or partial bulkheads of adequate strength are permitted.

6. Beam shelves and bilge planks

6.1 The cross sections required for the beam shelves and bilge planks on each side of the hull are given in Table 1.22. The shelves/planks shall extend from the stem to the transom. Beyond 0,75 $\mathbf{L}_{WL}$ towards the ends, their cross section may gradually be reduced to 75 %. They shall be fitted in the maximum possible lengths. If they are butt joined or scarified, the butt length shall be at least six times the height of the shelf/plank. Butts shall not be located in way of the mast, the chain plates or other areas where forces are introduced into the structure. The port and starboard beam shelves shall be linked by bow pointers or stem knees at the stem and shall be connected to the transom by knees.

6.2 The beam shelves may be all in one piece or divided into a primary and a minor or secondary shelf, in which case the cross section of the primary shelf is to be about 65 % of the total given.

6.3 Preferably the deck beams shall not be embedded in the beam shelves. If they nevertheless are, the cross section according to the Table must remain unimpaired underneath the beams.

6.4 In way of the mast and the chain plates, secondary shelves shall be additionally fitted whose cross section is 75 % of that of the shelf in accordance with Table 1.22. The length of these secondary shelves shall be at least 0,3 $\mathbf{L}_{WL}$. If the shelves have been subdivided into primary and secondary ones, half the beam shelf cross section is sufficient for the additional secondary shelves near the mast. Yachts with plywood decks do not require the additional secondary shelves near the mast, nor are they needed where there are plywood decks on which strip planking has been laid if the thickness of the plywood is at least 50 % of the deck plank thickness in accordance with Table 1.22.

7. Deck structure

7.1 Decks

7.1.1 Deck planks must be quartersawn (riftsawn) planks. Plank thickness is given in Table 1.22.

7.1.2 The widths of strip planking planks shall approximately match with the requirements of Table 1.23.

7.1.3 Plywood decks are permitted. The thickness of the plywood panels must be at least 65 % of the thickness given in Table 1.22 for deck planks. Joints in the plywood deck are to be scarified. Scarfs in plywood must be at least ten panel thicknesses long.

7.1.4 Decks are to have a hardwood (mahogany, oak, teak or similar) plank sheer/gunwale capping plank around the outboard edge, at least as thick as the shell according to the Table and at least 3 to 5 times as wide as it is thick. In the case of plywood decks this plank of solid wood is only required for yachts with a scantling numeral **L** (**B**/3 + $\mathbf{H}_1$) greater than 25. The outer cut edges of plywood decks must be protected by means of fillets.

7.2 Deck beams and beam knees

7.2.1 Deck beam scantlings are to be determined in accordance with Table 1.28, based on their respective length and the beam spacing. The relevant beam length is that between the outer edges of the beam shelves. In the case of half beams or supported beams the relevant length is that between the shelf outer edge and the cabin or hatch longitudinal coaming or the support. The minimum length to be inserted is 0,5 **B**.

Note

The deck loads given in Table 1.28 are empirical values and have no connection with the deck loads in B., C., E., and F.

7.2.2 Beam spacing may be increased to about 1,25 times the frame spacing in accordance with Table 1.22; in very large yachts even up to 1,4 times. The beam section modulus is to be determined based on the actual spacing.

7.2.3 The heights of the deck beam cross sections determined in accordance with 7.2.2 may be reduced to 75 % towards the beam ends.

7.2.4 The end beams of deck openings whose length exceeds one space between beams shall be reinforced. For determining their scantlings, the length of deck to be supported by these beams is to be inserted as the beam spacing.

7.2.5 The continuous deck beams in way of the mast and the beams at the ends of large deck openings, e.g those at the forward edge of the cabin and the after edge of the cockpit, are to be reinforced. If the beams are supported by bulkheads, their section modulus shall be increased by 50 %; if they are unsupported, by 150 %. For calculating the section modulus of the deck beams at the ends of the cabin, the beam spacing inserted is to be equal to the frame spacing in accordance with Table 1.22.

7.2.6 Beams underneath anchor winches and deckhouses may be reduced at the ends to the height of adjacent beams to avoid weakening the beam shelves.

7.2.7 The height of reinforced deck beams may be reduced at the ends to the height of adjacent beams to avoid weakening the beam shelves.

7.2.8 The reinforced deck beams shall butt against the frames if possible. They are to be joined to these, or to sole pieces, by hanging knees.

7.2.9 The minimum number of hanging knees is given in Table 1.29, their arm lengths and scantlings in Table 1.30. In lieu of hanging knees, adequately strong bulkheads of partial bulkheads are also permitted.

7.2.10 The cross section of flat bar steel hanging knees may be gradually reduced to 40 % beyond the first third of the arm length of the neck cross section. Similarly the projecting legs of angle bars may be tapered off beyond the first third of the arm length to leg thickness at the ends. Beyond $\mathbf{L}_{WL}$, the arm length of the hanging knees need not be more than 1/3 of the frame or beam length.

7.2.11 At the ends of larger deck openings, horizontal wooden knees are to be fitted between deck beams and beam shelves at the corners. These knees are not needed in the case of plywood decks.

7.2.12 Floor beam scantlings may be determined in accordance with Table 1.28. Based on their length and spacing their section modulus may be reduced up to 75 %.

7.3 Diagonal braces

7.3.1 Sailing craft and motorsailers with an $\mathbf{L}$ ($\mathbf{B}$/3 + $\mathbf{H}_1$) greater than 35, diagonal braces shall be arranged on the frames in way of the mast which are to end at the futtock chain plates. The futtock chain plates are to be extended to the frames forward and aft of the shroud chain plates. Their width is to be about 1,4 times the frame spacing.

7.3.2 In the case of sailing craft and motorsailers with an $\mathbf{L}$ ($\mathbf{B}$/3 + $\mathbf{H}_1$) greater than 70, the deck beam in way of the mast is to be provided with a cross of diagonal braces. Such braces are not needed in the case of plywood decks.

7.3.3 The scantlings of diagonal braces are given in Table 1.29.

8. Keel

8.1 Height and width of the wood keel halfway along $\mathbf{L}_{WL}$ are given based on the scantling numeral $\mathbf{L}$ ($\mathbf{B}$/3 + $\mathbf{H}_1$). The height applies to the full length of the wooden keel; the width may be tapered off towards the ends, down to stem/sternpost width. In the case of centreboard yachts, the cross section of the wooden keel in way of the centreboard case is to be increased by 10 %. The height of lamellated wooden keels may be 5 % less than that of solid ones.

8.2 The frames are not to be embedded in the wood keel or the stem/ sternpost.

8.3 The width of the keel rabbet shall be at least equal to half the tabular height of the wood keel, but anyway it shall be wide enough for the screws to be staggered (zig-zag).

8.4 The wooden keel shall consist of a single piece, if ever possible.

8.5 For yachts whose $\mathbf{L}$ ($\mathbf{B}$/3 + $\mathbf{H}_1$) is less than 35, the wooden keel shall be one piece. Yachts with an $\mathbf{L}$ ($\mathbf{B}$/3 + $\mathbf{H}_1$) of 35 to 100 may have a two-piece wooden keel with a scarf joint; even larger yachts, a three-piece keel with scarf joints. The scarfs shall be in the area of the metal fin, if ever possible.

8.6 The scarfs are to take the form of hook scarfs or in the case of larger yachts double-hook scarfs. The scarf length shall be at least six times the keel height. The keel scarfs shall have softwood stopwaters in the rabbet, see 11. and Fig. 1.27.

8.7 The wooden keel may be built up by glueing together separate laminated planks running horizontally.

8.8 If the mast stands on the stem-keel scarf or in the vicinity of this, a mast stool shall be provided on the floors. In smaller yachts this stool should at least extend over 3 floors; in larger ones, over 5 or 6. Mast steps must not be cut directly into the keel or keel scarfs.

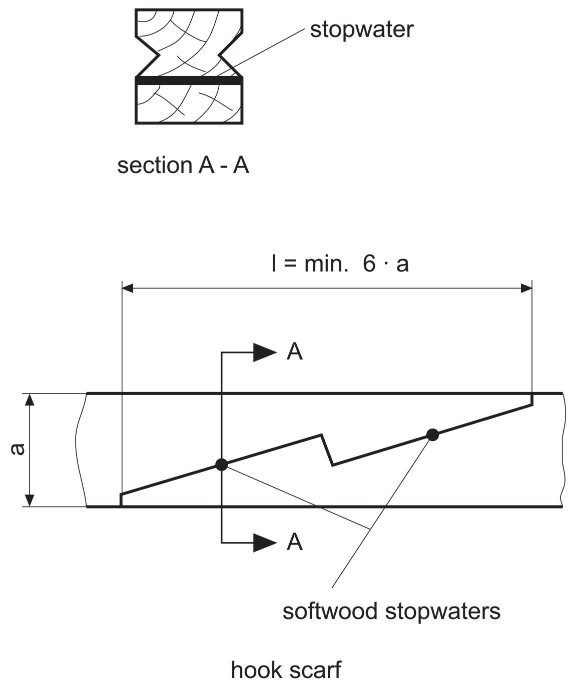


Fig. 1.27

9. Stem/sternpost and transom beam

9.1 The height of the stem on the design waterline must be at least 1,2 times the height of the wooden keel in accordance with Table 1.31. Between the rabbets the thickness of the stem shall be at least twice that of the shell planking. The width of the rabbet shall be at least 1,5 times the shell planking thickness. The leading edge of the stem and the trailing edge of the sternpost may be tapered.

9.2 The stem scarfs shall be made as hook scarfs or glued joints. The length of the scarf shall equal 6 times the stem height. In way of the rabbets, softwood stopwaters shall be fitted in the stem scarfs and the scarfs between stem and keel sole.

9.3 If the mast stands on the stem, this shall to be reinforced in particular regarding its height; additionally a mast stool shall be provided. Mast steps may not be cut into the stem.

9.4 If shafting is led through the sternpost, this shall be widened so as to leave at least 0,4 of the tabular sternpost width either side of the stern tube where this is taken through.

9.5 Stems/sternposts may be glued together from separate lamellated planks.

9.6 The transom beam shall be rigidly connected to the sternpost. The cross section of the transom beam at the forward end and in the area where the rudder stock/tube is taken through must at least equal the square of the height of the stem in accordance with with 9.1. Towards the after end the cross section may be reduced to 75 %. The height of the transom beam shall be at least 2,5 times the height of the bent-in frames. The seat of the transom beam must be of adequate length. Care is to be taken to make sure that the bolting is adequate (recessed bolts if appropriate).

10. Coachroofs, deckhouses

10.1 Apertures in the deck shall be bordered by frames consisting of hatch end beams and deck carlines.

10.2 The scantlings of deck beams at the ends of superstructure, hatches and cockpits shall be determined in accordance with 6.2.

10.3 The cross sections of the deck carlines shall approximately match the data in Table 1.32; the height of the deck carlines shall be about half the height of the beams and their width shall be 4,5 times the thickness.

10.4 The thickness of side walls and deck planking of the superstructure is given in Table 1.32.

10.5 Superstructure side walls with extra large windows are to be strengthened.

10.6 The spacing of the superstructure deck beams (cabin beams) shall be about 25 % less than the frame spacing in accordance with Table 1.22; in the case of plywood decks however the beam spacing may be increased depending on the thickness of the deck and the camber of the cabin beam. The cabin beam scantlings are to be determined in accordance with Table 1.28, based on their spacing and their length, but their section modulus may be 20 % less.

10.7 Deck beams at the ends of apertures in the cabin deck shall be reinforced or supported as appropriate to the length of the aperture.

10.8 Hatch coamings shall be of adequate strength.

11. Bolting connection of structural members

11.1 General

11.1.1 The necessary data about interconnection of the individual members are given in Tables 1.33 to 1.36.

11.1.2 The bolts used shall be of sea water resistant materials.

11.1.3 Nuts shall be of the same material as the bolts, if possible. Washer diameters shall be about three times the bolt diameter; washer thickness about 25 % of the bolt diameter.

11.2 Floors

11.2.1 Number and diameter of the bolts connecting the floors to shell and keel are given in Table 1.34.

11.2.2 Floors fitted alongside the frames shall be fastened to the shell and the frames. They shall be fastened to each shell plank by one bolt and to the frames by at least 3 or 4 bolts.

11.2.3 Steel floor plates shall be welded to the steel frames.

11.2.4 Frames in the afterbody extending from one side of the yacht to the other without any floors shall be fastened to the transom beam by bolts in accordance with Table 1.34.

11.3 Shell and frames

11.3.1 Each shell plank shall be fastened to each frame by at least 2 screws. The screws are to be staggered (zig-zag) to prevent the frames from splitting. Screw diameters are given in Table 1.35.

11.3.2 The length of the wood screws shall be at least 2 to 2,5 times the thickness of the shell planks.

11.3.3 The butt straps are to be fastened to each of the planks by screws of the same diameter as those for shell-to-frame connection in accordance with Table 1.35.

11.3.4 If grown frames have butt-strapped joints, the straps shall be fastened to each frame part by 3 bolts in the case of scantling numerals $\mathbf{B}/3 + \mathbf{H}_1$ up to 2; by at least 4 bolts in the case of larger scantling numerals.

11.3.5 The shell planking shall be fastened to the wooden keel and the stem/sternpost by wood screws. These screws shall be at least of the same diameter and length as those between shell and frames. The distance between adjacent screws shall not be more than 12 screw diameters. The screws are to be staggered to avoid the wood splitting.

11.3.6 Screws through the shell may be countersunk if they are capped with a plug whose height equals the screw shank diameter.

11.4 Deck beams, hanging knees and beam shelves

11.4.1 Each deck beam is to be joined to the beam shelf; the half deck beams also to the carlines. In yachts up to an $\mathbf{L}\ (\mathbf{B}/3 + \mathbf{H}_1) = 60$, wood screws shall be used; in those with higher scantling numerals, bolts and nuts shall be used.

11.4.2 The hanging knees shall be fastened to the frames and deck beams by rivets or wood screws in accordance with Table 1.36.

11.4.3 If hanging knees are replaced by bulkheads, the connection of these to frame, shell, deck beam and deck shall be of the same strength as would be that with hanging knees.

11.4.4 The beam shelves shall be screwed to every frame.

11.5 Deck beams

11.5.1 The gunwale/covering board is to be screwed to the shell. The diameters of the wood screws are given in Table 1.35. The length of the screws shall be at least twice the thickness of the planks and the distance between screws equal to twelve screw diameters. The gunwale/covering board shall be fastened to every deck beam.

11.5.2 The deck planks shall be fastened to each deck beam by screws or hidden nails. If the latter solution is used, and if the deck beam spacing is greater than the tabular frame spacing, the planks shall additionally be fastened to one another sideways between the beams by a sea water resistant nail. The ends of the deck planks shall have an adequate supporting surface.

11.5.3 Deck margin planks shall be screwed to the carlines/ledges and the deck beams.

11.5.4 The screw diameters are given in Table 1.35.

11.5.5 The length of wood screws in solid wood decks is to be at least twice the plank thickness. Screws in plywood decks may be shorter in line with the reduced thickness of the deck.

11.6 Diagonal braces

Diagonal braces shall be fastened to the frames/deck beams and each shell or deck plank by at least one screw in accordance with Table 1.35.

12. Workmanship

12.1 The workshops for building wooden yachts shall be fully enclosed spaces with heating as well as supply and exhaust ventilation. If load bearing structural members of a yacht hull shall be glued or laminated, the requirements of E.3., E.4., E.5., E.6. and E.7. shall be observed.

12.2 The scantlings given in the Tables are minimum values. If required to guarantee the adequate strength of a screwed/bolted or riveted connection between individual members, the component scantlings may have to be increased - e.g. for the connection of the shell to the stem and the sternpost, where a rabbet of adequate width shall be provided.

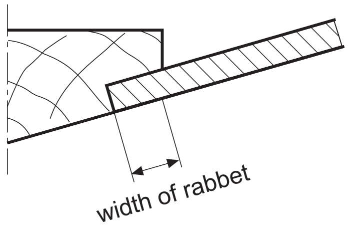


Fig. 1.28

12.3 Load bearing structural members of a yacht shall be made with an adequate accuracy of fit. They are to be preserved to prevent water penetration.

12.4 Holes for wood screws shall be drilled with a conical drill.

Maximum attention shall be paid to the watertightness of hull and superstructure. It is therefore necessary to take into consideration the properties of the wood, in particular its swelling and shrinkage properties which vary in the three dimensions, even when cutting the component to size. As wood - in particular hardwood - swells and shrinks tangentially much more than radially, deck and shell planking, and that of watertight bulkheads, shall consist of quartersawn (riftsawn) planks. It is advised to cut deadwood tangentially.

12.5 To guarantee watertightness between the scarfs of keel and stem/sternpost, stopwaters shall be provided where the rabbet crosses the scarf or a stop of the keel or stem/sternpost. Stopwaters should be of softwood, which does not rot much nor becomes brittle when air is excluded from it. Spruce or pine are suitable. Stopwaters shall have a diameter of at least 10 mm in small yachts; up to a maximum of 22 mm in large ones. They shall have a press fit, hammered in at totally dry state into clean holes cut with a sharp drill.

12.6 To allow for proper drainage of water to the bilges, and to prevent dirt accumulating in corners, care shall be taken to assure that any condensation or leakage water can run down to the lowest point of the bilges, to the strum box. This means that limberholes shall be provided in the floors, large enough to be easily cleaned.

12.7 Inside the yacht, good circulation of air through any areas and corners with a plank lining is to be ensured by means of ventilation openings, fingerholes and by making clearance cuts. It is recommended that all joinery such as lockers, cupboards, etc. be installed removable to permit subsequent conservation of the parts they conceal.

12.8 The connection between superstructure sidewalls and deck shall be made with special care and using proven methods, to avoid any leaks.

Table 1.22 Beam shelves, bilge planks, shell and deck

$L(B/3 + H_1)$	Frame spacing	Beam shelves	Bilge planks	Shell	Deck
m²	mm	cm²	cm²	mm	mm
7	120	17	—	11	18
8,5	130	19	—	12	18
10	140	21	—	13	18
11,5	150	24	—	14	18
13	160	28	—	15	18
14,5	170	31	—	16	18
16	180	34	—	17	18
17,5	190	37	—	18	18
19	200	40	—	19	18
20,5	210	43	—	20	19
22	220	46	—	21	20
23,5	230	49	—	22	21
25	240	52	—	23	22
27	250	56	—	24	23
29	260	60	—	25	24
31	270	64	—	26	25
33	280	69	—	27	26
35	285	73	—	28	27
37	295	77	59	29	28
39	305	80	62	30	29
41	310	84	64	31	30
43	320	88	67	32	30
46	330	94	70	33	31
49	340	100	73	34	32
52	345	106	76	35	33
55	355	112	80	36	34
58	360	117	84	37	35
61	370	123	87	38	36
64	380	129	90	39	37
67	385	135	93	40	38
75	405	149	102	42	40
85	420	167	112	44	42
96	440	185	123	46	44
108	455	204	134	48	46
122	475	225	147	50	48
140	495	250	162	52	50

If the frame spacing is increased, the thickness of the shell planking and the deck is to be increased in the same ratio. A reduction of plank thickness and the deck are permissible if the frame spacing is reduced. The spacing given is for carvel built yachts.

The frame spacing of clinker built yachts may be increased by 65 % whilst keeping the shell plank thickness at the value given in column 5.

Table 1.23 Widths of shell- and strip deck planks

Plank thickness	Max. widths of planks	
	Shell	Deck
mm	mm	mm
12	75 to 85	40
16	85 to 100	42
20	100 to 110	46
25	110 to 120	50
30	120 to 135	54
36	130 to 150	57
41	140 to 160	60
46	150 to 170	62
52	160 to 180	64

Table 1.24 Floors

$B/3 + H_1$	Frame spacing	Steel plate floors		Wooden plank-floors	
		Height	Thickness	Height	Thickness
m	mm	mm	mm	mm	mm
1,4	115	140	2,5	140	24
1,4	170	145	2,5	145	30
1,5	130	145	2,5	145	24
1,5	195	150	3	150	30
1,6	140	150	3	150	24
1,6	210	155	3	155	32
1,7	145	155	3	155	26
1,7	220	160	3,5	160	34
1,8	155	160	3,5	160	27
1,8	230	165	3,5	165	35
1,9	165	170	3,5	170	28
1,9	250	175	3,5	175	37
2,0	180	175	3,5	175	30
2,0	270	180	4	180	40
2,2	200	190	4	190	32
2,4	220	200	4	200	35
2,6	240	210	4	210	38
2,8	260	220	4	220	41
3,0	275	235	4	235	44
3,2	290	245	4	245	47
3,4	305	255	4	255	49
3,6	320	270	4,5	270	52
3,8	340	280	4,5	280	55
4,0	360	290	4,5	290	57
4,4	385	320	5	320	63
4,8	415	345	5	345	69
5,2	425	375	5	375	75
5,6	435	400	5,5	400	80
If the frame spacing is changed, the thickness of the floors is to be altered in the same ratio.					

Table 1.25 Floors

$B/3 + H_1$	Frame spacing	Arm length	Flat bar steel floors		Angle bar floors	Wooden floors	
			Throat	Arm end	W	Height	Thickness
m	mm	mm	mm	mm	cm³	mm	mm
1,4	115	175	22 · 5	17 · 4	0,60	37	15
1,4	170	175	23 · 7	20 · 5	0,85	48	18
1,5	130	180	20 · 7	17 · 5	0,92	46	17
1,5	195	180	25 · 8	24 · 5	1,37	53	23
1,6	140	190	21 · 8	20 · 5	1,27	50	20
1,6	210	190	26 · 10	22 · 7	1,90	58	28
1,7	145	200	26 · 7	22 · 5	1,54	53	23
1,7	220	200	28 · 10	24 · 7	2,30	68	27
1,8	155	210	26 · 8	21 · 6	1,95	58	25
1,8	230	210	31 · 10	28 · 7	2,90	77	28
1,9	165	225	30 · 8	24 · 6	2,38	63	27
1,9	250	225	36 · 10	31 · 7	3,60	82	31
2,0	180	235	26 · 10	22 · 7	2,88	69	29
2,0	270	235	36 · 12	32 · 8	4,35	89	33
2,2	200	260	33 · 10	28 · 7	3,92	82	32
2,4	220	280	37 · 12	33 · 8	4,65	91	37
2,6	240	300	38 · 14	31 · 10	6,02	98	44
2,8	260	320	44 · 14	37 · 10	7,40	100	50
3,0	275	340	47 · 15	35 · 12	8,66	109	54
3,2	290	360			9,91	118	58
3,4	305	380			11,40	125	62
3,6	320	400			13,20	131	67
3,8	340	420			14,60	141	71
4,0	360	440			17,70	150	75
4,4	385	480			21,00	167	84
4,8	415	520			24,40	180	93
5,2	425	560			27,50	195	99
5,6	435	600			29,80	209	101

If the frame spacing is changed, the thickness of the floors or the section moduli for steel angle bar floors given in column 6 are to be altered in the same ratio.

Table 1.26 Frames: Section moduli without effective width of plate

$B/3 + H_1$	**Section moduli referred to a basic frame spacing of 100 mm**			
	Curved	**Laminated**	**Naturallygrown**	**Steel profiles**
	W_{100}	**W_{100}**	**W_{100}**	**W_{100}**
m	**cm^3**	**cm^3**	**cm^3**	**cm^3**
1,4	0,70	0,68	2,0	0,105
1,5	0,85	0,83	2,5	0,127
1,6	1,02	0,99	3,1	0,150
1,7	1,20	1,17	3,7	0,177
1,8	1,39	1,36	4,3	0,206
1,9	1,59	1,55	4,9	0,236
2,0	1,81	1,75	5,6	0,266
2,1	2,04	1,97	6,2	0,300
2,2	2,29	2,19	7,0	0,334
2,3	2,56	2,42	7,8	0,370
2,4	2,85	2,66	8,6	0,409
2,5	3,17	2,94	9,5	0,453
2,6	3,51	3,25	10,4	0,502
2,7	3,88	3,58	11,4	0,555
2,8	4,27	3,94	12,5	0,606
2,9	4,70	4,32	13,7	0,671
3,0	5,16	4,74	14,9	0,739
3,1	5,65	5,17	16,2	0,807
3,2	6,18	5,65	17,6	0,884
3,3	6,75	6,15	19,2	0,965
3,4	7,37	6,71	20,8	1,055
3,6	8,75	7,93	24,5	1,25
3,8	10,32	9,30	28,8	1,48
4,0	12,09	10,82	33,6	1,73
4,2	14,06	12,57	39,0	2,01
4,4	16,32	14,43	45,0	2,32
4,6	18,60	16,49	51,6	2,66
4,8	21,17	18,61	58,8	3,02
5,0	23,95	21,00	66,8	3,43
5,2	26,97	23,55	75,5	3,84
5,4	30,23	26,30	84,9	4,32
5,6	33,71	28,20	94,9	4,82
5,8	37,43	32,30	105,5	5,35
The frame section moduli are given for a basic spacing of 100 mm. If the spacing selected differs from that, the section moduli are to be increased in the same ratio.				

Table 1.27 Grown frames: section moduli and cross sections

W	Breadth × Height
cm³	mm
3,00	23 · 28 / 23
3,60	24 · 30 / 24
4,44	26 · 32 / 26
5,23	27 · 34 / 27
6,05	28 · 36 / 28
7,21	30 · 38 / 30
8,54	32 · 40 / 32
9,97	33 · 42 / 33
11,20	35 · 44 / 35
12,86	36 · 46 / 36
14,60	38 · 48 / 38
16,69	40 · 50 / 40
18,50	41 · 52 / 41
20,9	43 · 54 / 43
23,0	44 · 56 / 44
25,2	45 · 58 / 45
28,2	47 · 60 / 47
32,4	49 · 63 / 49
37,0	51 · 66 / 51
42,9	54 · 69 / 54
48,5	56 · 72 / 56
54,3	58 · 75 / 58
61,0	60 · 78 / 60
68,0	62 · 81 / 62
75,4	64 · 84 / 64
84,5	67 · 87 / 67
93,0	69 · 90 / 69
106	72 · 94 / 72
120	75 · 98 / 75
135	78 · 102 / 78
149	80 · 106 / 80
167	83 · 110 / 83
186	86 · 114 / 86
209	90 · 118 / 90
232	93 · 122 / 93
254	95 · 126 / 95
276	98 · 130 / 98
303	101 · 134 / 101
328	103 · 138 / 103
358	106 · 142 / 106
The first height given for naturally grown frames is that in way of the floors, which may be gradually reduced to the second height towards the deck.	

Table 1.28 Deck beams, section moduli without effective width of plate

Beam length	Section moduli referred to a basic beam spacing of 100 mm			
	Wooden beams	Laminated beams	Steel sections	Deck load
	W_{100}	W_{100}	W_{100}	p
m	cm^3	cm^3	cm^3	kN/m^2
0,8	0,52	0,47	0,081	1,84
1,0	0,86	0,78	0,132	1,93
1,2	1,28	1,15	0,18	2,02
1,4	1,84	1,66	0,248	2,11
1,6	2,84	2,23	0,335	2,20
1,8	3,30	2,97	0,446	2,29
2,0	4,20	3,78	0,568	2,38
2,2	5,27	4,75	0,712	2,48
2,4	6,52	5,87	0,882	2,57
2,6	7,90	7,10	1,068	2,67
2,8	9,51	8,56	1,29	2,75
3,0	11,25	10,25	1,52	2,84
3,2	13,25	11,92	1,79	2,94
3,4	15,44	13,90	2,09	3,04
3,6	17,80	16,00	2,41	3,12
3,8	20,40	18,35	2,76	3,22
4,0	23,30	20,95	3,15	3,30
4,2	26,40	23,75	3,57	3,40
4,4	29,75	26,80	4,02	3,49
4,6	33,30	30,00	4,50	3,59
4,8	37,20	33,50	5,03	3,67
5,0	41,40	37,30	5,60	3,76
5,2	45,70	41,10	6,18	3,85
5,4	50,50	45,40	6,82	3,95
5,6	55,60	50,00	7,51	4,05
5,8	61,20	55,00	8,27	4,13
6,0	67,30	60,50	9,10	4,23
6,2	73,50	66,00	9,94	4,33
6,4	79,70	71,60	10,79	4,42
6,6	86,50	77,80	11,63	4,52

For each beam the section moduli may be determined on the basis of its specific length, but lengths less than half the breadth of the craft should not be inserted.

The section moduli are given for a basic beam spacing of 100 mm; they shall be increased in the ratio of the selected spacing to the basic spacing. Additionally, for beams shorter than the craft breadth **B** the section moduli shall be multiplied by the deck loading p_1 corresponding to the breadth **B** and be divided by the deck load p_2 corresponding to the beam length in question.

Example:
Beam length = 2,40 m
Breadth **B** = 4,00 m
Beam spacing = 370 mm

W_{100} = 6,52 cm^3
p_1 = 3,30 kN/m^2
p_2 = 2,57 kN/m^2

$$W = 6{,}52 \cdot 3{,}7 \frac{3{,}30}{2{,}57} = 31\,cm^3$$

Table 1.29 Diagonal braces and number of hanging knees

$L\ (B/3 + H_1)$	Diagonal braces	Hanging knees
m^2	mm	number
to 13	—	3
to 20	—	4
to 27	—	5
to 30	—	6
to 35	50 · 4	6
to 40	50 · 4	6
to 45	60 · 4	6
to 50	50 · 4,5	7
60	80 · 4,5	7
70	90 · 5	8
80	100 · 5	8
90	100 · 6	9
100	110 · 6	9
110	120 · 6	10
120	130 · 6	10
130	145 · 6	11

Table 1.30 Scantlings of hanging knees

$B/3 + H_1$	Flat bar steel knee [1] Width × Thickness	Angle bar W	Arm length	Bracket Thickness	Wooden Leg Thickness	Knee length
m	mm	cm^3	mm	mm	mm	mm
1,60	19 · 7	0,8	290	2,5	16	85
1,75	19 · 8	0,9	300	2,5	18	95
1,90	22 · 8	1,0	310	2,5	20	105
2,10	25 · 9	1,3	325	3	22	115
2,30	26 · 11	1,6	340	3	26	130
2,50	28 · 12	1,8	360	3,5	28	145
2,70	30 · 13	2,1	380	3,5	30	160
2,90	30 · 15	2,4	400	3,5	32	175
3,15	33 · 16	2,8	420	4	35	190
3,40	37 · 17	3,3	440	4	38	205
3,65	40 · 18	3,7	460	4	41	220
3,90	44 · 19	4,1	480	4	44	235
4,15	47 · 21	4,7	500	5	47	250
4,40	49 · 23	5,3	520	5	50	265
4,65	53 · 24	5,8	540	5	53	280
4,90	55 · 26	6,5	560	5	56	300
5,20	60 · 27	7,3	580	6	59	320
5,50	65 · 28	8,2	600	6	62	340
5,80	66 · 30	9,0	620	6	65	360

[1] Width and height apply to the throat of the flat bar knee. The cross section may be gradually reduced to 40 % of the cross section at the throat, from the first third of the length onwards towards the end.

Table 1.31 Wooden keel and stem/sternpost

L (B/3 + H_1)	Sailing yachts	Wooden keel amidships	Motor yachts
	width	height [1]	width
m^2	mm	mm	mm
7	123	57	123
8	131	59	131
9	139	61	139
10	145	64	145
11	152	66	152
12	159	68	159
13	165	70	165
14,5	175	74	172
16	185	77	178
17,5	195	81	182
19	205	84	185
20,5	214	87	187
22	223	90	189
23,5	232	93	191
25	241	96	193
26,5	248	99	195
28	255	102	196
29,5	262	105	197
31	269	108	198
32,5	275	111	199
34	282	114	200
35,5	288	117	201
37	294	119	202
39	301	122	203
41	309	125	204
43	315	128	205
45	323	131	206
47	330	134	207
49	337	137	208
51	342	140	209
54	350	144	210
57	358	147	212
60	366	151	213
63	374	155	214
66	381	158	215
69	387	161	216
72	394	164	217
76	401	168	218
80	409	171	219
84	416	175	220
88	424	179	222

Table 1.31 Wooden keel and stem/sternpost *(continued)*

L (B/3 + H_1)	Sailing yachts	Wooden keel amidships	Motor yachts
	width	height [1]	width
m^2	mm	mm	mm
92	431	182	224
96	439	185	226
100	446	188	228
105	454	192	230
110	461	195	233
115	469	198	236
120	476	201	239
125	483	204	242
130	490	207	245
135	497	210	248
140	505	213	251

Towards the ends, the width of the wooden keel may be tapered off to that of the stem/sternpost.
The height of laminated wooden keels may be reduced by 5 %.

[1] Applies to sailing and motor yachts.

Table 1.32 Superstructure, carlines

L (B/3 + H_1)	Superstructure side walls		Superstructure deck		Carlines
	Solid wood	Plywood	Solid wood	Plywood	
m^2	mm	mm	mm	mm	cm^2
7	18	9	8	6	7
8,5	18	10	8	6	7
10	19	11	9	6	9
11,5	19	12	9	6	11
13	20	13	10	6	12
14,5	20	13	10	7	13
16	21	14	11	7	14
17,5	21	14	12	8	15
19	22	15	12	8	16
20,5	22	15	13	8	17
22	23	15	14	9	18
23,5	23	15	14	9	19
25	23	15	15	10	20
27	24	16	15	10	21
29	24	16	16	10	22
31	24	16	16	11	23
33	24	16	17	11	24
35	24	18	17	11	25
37	25	18	18	11	26
39	25		18	12	26
41	25		19	12	27
43	25		19	12	28
46	25		20	13	29
49	26		20	13	30
52	26		21	13	31
55	26		21	13	32
58	27		21	14	33
61	27		22	14	34
64	27		22	14	35
67	27		23	15	36
71	28		23	15	37
75	28		24	15	38
80	29		24	15	39
85	29		24	16	40
90	30		25	16	41
96	30		25	16	42
102	31		25	16	43
108	31		26	16	44
115	32		26	17	45
122	33		27	17	45
130	34		27	17	46
140	35		27	17	47

Table 1.33 Bolting-up keel, stem/sternpost, deadwood, transom beam, etc.

L (B/3 + H_1)	Keel, stem/sternpost, deadwood, transom beam	Horizontal knee
m^2	Bolt diameter in mm ∅	
to 10	9	6
10 to 12	10	6
12 to 15	11	6
15 to 19	12	6
19 to 23	13	8
23 to 28	14	8
28 to 32	15	8
32 to 37	16	8
37 to 41	17	8
41 to 46	18	8
46 to 60	20	10
60 to 75	22	10
75 to 140	25	10

Table 1.34 Connecting floors with keel and shell and frames

$B/3 + H_1$	Bolts		Bolts			
	In the arms		In the throat			
			for 0,8 L_{WL}		at the ends of the yacht	
	Number	mm ∅	Number	mm ∅	Number	mm ∅
to 1,5	3	5,5	1	8	1	8
1,5 to 1,75	3	5,5	2	8	1	8
1,75 to 1,9	3	6	2	8	1	9
1,9 to 2,1	3	6	2	9	1	9
2,1 to 2,3	4	6	2	9	1	10
2,3 to 2,5	4	6,5	2 3	10 9	1 2	10 7
2,5 to 2,7	4	7	2 3	11 10	1 2	11 8
2,7 to 2,9	4	8	2 3	11 10	1 2	11 8
2,9 to 3,15	4	9	2 3	12 11	1 2	12 9
3,15 to 3,4	4	9	2 3	12 11	1 2	12 9
3,4 to 3,65	5	10	2 3	13 12	1 2	13 9
3,65 to 3,9	5	10	2 3	14 13	1 2	14 10
3,9 to 4,15	5	11	2 3	15 14	1 2	15 11
4,15 to 4,4	5	11	3	15	2	12
4,4 to 4,65	5	12	3	16	2	13
4,65 to 4,9	5	12	3	17	2	14
4,9 to 5,2	5	13	3	18	2	15
5,2 to 5,5	5	14	3	19	2	16
5,5 to 5,8	5	15	3	20	2	17

Table 1.35 Screws in shell and deck

Plank thickness	**Shell with frames Screws**	**Deck planks to deck and shell beams screws**
mm	**mm ∅**	**mm ∅**
to 15	4	4
15 to 17	4	4
17 to 19	4,5	4
19 to 23	5	4,5
23 to 26	5,5	5
26 to 29	6	5,5
29 to 32	6,5	6
32 to 35	7,5	7
35 to 38	8	7,5
38 to 41	8,5	8
41 to 44	9	8,5
44 to 47	10	9
47 to 50	10,5	9,5
50 to 53	11	10

Table 1.36 Screwing hanging knees and shelves to frames and deck beams

$B/3 + H_1$	**Number**	**Screws**
m		**mm ∅**
to 1,5	3	4,5
1,5 to 1,75	3	5
1,75 to 1,9	3	5,5
1,9 to 2,1	3	6
2,1 to 2,3	3	7
2,3 to 2,5	4	8
2,5 to 2,7	4	8
2,7 to 2,9	4	9
2,9 to 3,15	4	10
3,15 to 3,4	4	10
3,4 to 3,65	5	11
3,65 to 3,9	5	11
3,9 to 4,15	5	12
4,15 to 4,4	5	12
4,4 to 4,65	6	13
4,65 to 4,9	6	13
4,9 to 5,2	6	14
5,2 to 5,5	6	15
5,5 to 5,8	6	16

E. Cold-Moulded Wood Construction

1. General

A cold moulded wood laminate consists of at least three layers of veneer/lamellae of the same wood or of timber with similar mechanical properties. The plies are glued together in layers on a mould, or on a core or a wooden frame/bulkhead system integral with the strength structure, the fibres in successive layers lying at an angle of 45 – 90° to one another. Side and/or edge surfaces of the individual strips of veneer are additionally glued to one another. Internal structural members with larger cross sectional dimensions such as keel, beam shelves, frames or stringers and deck beams are made up of lamellae of wood, glued together.

2. Wood

Any of the timbers suitable for boat building may be used. Their bulk density should be greater than 0,56 g/cm^3 with a moisture content of 12 %.

Timber envisaged for use in this type of construction is to be cut in such a way that the inclination of the annual rings is no less than 30°, i.e. the angle between the flattest annual ring/its chord, and the face of a lamella or strip of veneer must not be less than 30°. The fibres shall be oriented parallel to the edge of a lamella, if possible. Veneers for making plating may be sliced or sawn.

The timber shall be free from unacceptable characteristics or defects that might impair the quality.

Unacceptable defects in the wood are:

– blueing
– brittleness
– rot
– cracks, except for natural (air) cracks in the inner layers of multi-ply wood or plywood, provided their depth does not exceed 2/3 of the thickness of the veneer.
– sapwood

Wood with defects and growth damage which shows up during cutting to size must not be used for load bearing structural members.
Conditionally acceptable defects in the wood are branches/knots if:

– their maximum cross sectional extent (visible extent) does not exceed 10 mm,
– they are firmly growth-bonded to the surrounding wood (loose knots are to be replaced by plugs),
– their distance from each other is no less than 500 mm,
– their distance from the edge of the component or veneer is not less than their maximum cross sectional dimension. No consideration need be given to branches/knots whose maximum diameter is less than 5 mm if they are firmly growth-bonded to the surrounding wood.

3. Glues and adhesives

3.1 Requirements

Only mixed adhesives (phenolic and epoxy resins) and glues tested and approved by GL may be used. Adhesives and glues shall have passed the tests in accordance with section 2 of DIN 68141 - "Prüfung von Leimen und Leimverbindungen für tragende Holzbauteile" (Testing of glues and adhesive combinations for load bearing wooden components). Relevant confirmation and/or test certificates are to be submitted to GL.

In accordance with current practice, mixed adhesives will hereinafter also be referred to as glues.

3.2 Storage, application

The rules of the producers of the glue regarding storage and use of the glues and hardeners shall be observed.

Glues and hardeners are to be stored in their original containers well sealed in a cool, dry place. The indicated shelf life must not be surpassed.

4. Principles for making glued wood joints

4.1 Preparation of the components

4.1.1 The moisture content of the components to be glued must meet the following requirements:

When being glued the wood moisture content must not be less than 8 % and not more than 14 %.

The moisture content of components to be glued together is to be roughly equal; the difference may not exceed 4 %.

The final moisture content of the timber shall always be controlled before any further working/glueing.

4.1.2 Temperature of the wood

The temperature of the surfaces to be glued must match that of the environment; this must not be less than 15 °C.

4.1.3 Condition of the surfaces to be glued

Surfaces to be glued must be free from any kind of foreign substance or contamination (e.g. grease, oil, paint, dirt, dust, wood or metal chips).

Components to be glued shall be free from wood preservatives. In exceptional cases, i.e. if the components are treated with preservatives before glueing, the compatibility of these preservatives with the glue to be used shall be demonstrated to GL by a procedure test.

Note:

Tests are to be carried out in accordance with DIN 52179. A list of adhesives and wood preservatives which have passed this test can be obtained from the FMPA Baden-Würtemberg, Stuttgart.

4.2 Environmental conditions

The ambient air temperature must not drop below 15 °C during glueing and curing. The air humidity shall be at least 45 %.

4.3 Preparation of the glue and glueing

The glue is to be made up in accordance with the mamufacturer's instructions and the usage guidelines shall be observed.

4.4 Applying the glue, surplus glue, joint

The glue ready for use is applied evenly with (e.g.) a roller or paint brush or other means to both surfaces to be joined. Sufficient glue is to be applied for a little surplus to be squeezed out of the joint when this is subject to pressure. The aim should be a thin joint; joints more than 1 mm thick are not permitted. During the time under pressure, care shall be taken to assure that the pressure on the veneers to be joined is adequate.

5. Works prerequisites and quality assurance

Companies producing wooden hulls and components cold moulded by glueing shall be qualified for the work to be carried out regarding their workshop equipment, internal quality control, manufacturing process as well as the training and qualification of the personnel carrying out and supervising the work. Providing the prerequisites for approval have been met, suitability will be certified for the works on application by a GL shop approval.

6. Construction

6.1 Lamellated panels

Shell, deck and cabin/superstructure panels shall meet the following requirements:

The thickness of a layer of veneer should not be more than 1/3 of the thickness of the laminated component.

In the case of three layer laminated panels, the following directions of the veneer layers referred to the longitudinal axis of the hull are recommended:

1st layer: 45°

2nd layer: 90° to 1st layer

3rd layer: 90° to previous layer or in line with hull axis

In the case of planking of greater thickness, the layers of veneer after the 2nd one are glued onto the mould each 90° out from the previous one.

6.2 Lamellated internal structural members

The thickness of individual layers depends on the size and shape of the component and lies between 5 and 25 mm.

6.3 Bending radii

The bending radius of an individual veneer or ply/layer must not be lower than the following value:

$$r = t \cdot 110 \quad [\mathrm{mm}]$$

t = thickness of the individual veneer

6.4 Component connections

The length of spliced/scarified joints must be at least 8 times the height.

Unidirectional components or laminae may be glued together using interlocking wedge shaped dovetails with the same pitch and profile. In doing so, the following principles shall be observed:

– dovetail profiles must correspond to the stress group I according to DIN 68140.
– Only width dovetailing may be used.
– Dovetail joints of successive laminae shall be staggered by at least 20 dovetail lengths; these must not be used in outer layers of shell and deck nor in inner layers of the shell around the bilges.

Load carrying components shall be glued at the corners with the aid of beads or clips.

The area of the surfaces to be glued depends on the binding strength τ_B (DIN 68141) of the glue and on the load.

Component connections of novel design about which there is not sufficient practical experience require special proof of their strength. Such proof may be provided mathematically or by the results of a procedure test carried out in the presence of the GL surveyor or by an official material testing establishment.

7. Details of design and construction

In areas where concentrated forces are introduced into the structure from rig, rudder, fin keel, propulsion units, etc. hulls shall be designed as appropriate for the forces arising and shall be locally reinforced, if necessary.

In the case of special designs GL reserves the right to call for mathematical proof of adequate structural safety. Materials suitable for sea water shall be used for screwed and bolted joints.

8. Determination of component scantlings

8.1 Principles

The tabular scantlings of keel, stem/sternpost and beam shelves apply to lamellated and solid wood constructions using timber with a density of 0,56 g/cm³. If it is intended to use timber of a different density, the cross sectional areas of the components are to be multiplied by the following factor:

$$k_s = \frac{0,56}{\rho}$$

ρ = density of the wood intended to be used [g/cm³]

Data concerning the density of wood with reference to the determination of component scantlings apply for a moisture content of 12 – 15 % in accordance with DIN 52183.

8.2 Keel and stem/sternpost

The scantlings are to be determined in accordance with the following Tables:

Scantling length L [m]	Keel: Sailing yachts amidships height [mm]	Keel: Sailing yachts amidships width [mm]	Keel: Motor yachts amidships height [mm]	Keel: Motor yachts amidships cross-section [1] [cm²]
6	75	150	70	80
8	90	185	80	130
10	110	220	90	190
12	125	255	105	250
14	140	285	115	310
16	160	320	125	380
18	175	355	140	450
20	195	385	150	520
22	210	410	165	600
24	230	435	180	690
26	245	455	190	770
28	260	470	205	860
30	280	480	220	950

[1] Applies to internal and external keels.

Scantling length L [m]	Stem foot heights and widths [1]: Sailing yachts [mm]	Stem foot heights and widths [1]: Motor yachts [mm]	Stem head and sternpost heights and widths [1]: Sailing yachts [mm]	Stem head and sternpost heights and widths [1]: Motor yachts [cm²]
6	90	75	75	75
8	105	90	90	85
10	120	110	100	95
12	140	125	115	105
14	155	140	125	115
16	170	160	140	125
18	190	175	150	140
20	205	195	165	150
22	220	210	175	160
24	240	230	190	170
26	255	245	200	180
28	270	260	215	190
30	290	280	230	200

[1] Widths are to be measured halfway up the profile

Note regarding keel scantlings

In the case of motor yachts the width of the keel must not be less than its height. The height of the external keel necessary shall be at least twice the shell thickness.

The scantlings apply to laminated and solid wood construction using timber with a density of 0,56 g/cm³.

The tabular height of the keel applies over its entire length; its width may be tapered off towards the ends to that of the stem/sternpost.

In the case of keel/centreboard yachts the cross section in way of the centreboard case shall be increased so that the structural member is not weakened. This also applies where propeller shafts, rudder stocks, etc. are passing through a structural member.

8.3 Beam shelves

The scantlings are recommended to be in accordance with the following Table:

Scantling length L [m]	Beam shelf cross section	
	Sailing yachts [cm²]	Motor yachts [cm²]
6	29	32
8	40	40
10	50	50
12	70	60
14	90	80
16	110	100
18	130	110
20	150	130
22	170	150
24	190	170
26	220	190
28	250	210
30	280	240

With decks of scarified plywood the cross section of the beam shelf's may be reduced in consultation with GL.

8.4 Shell, deck, bulkheads

8.4.1 Scantling determination with ultimate bending stress determined by experiment

Thickness of plating must not be less than

$$t = 0{,}0452 \cdot f_k \cdot \mathbf{b} \cdot \sqrt{\frac{P_d}{\sigma_{Rm}}} \quad [\text{mm}]$$

f_k = factor for curved plate panels in accordance with B.4.4.2.4

P_d = loading of component in question in accordance with A.1.9

Definition of the components logically as in Figs. 1.19 and 1.21.

σ_{Rm} = ultimate bending strength of wood composite [N/mm²] determined by experiment

8.4.2 Scantling determination by mathematical proof

Mathematical proof of the permissible bending stresses of individual layers of veneer of the shell may be provided using the following formula:

$$\sigma_k \le \sigma_{zul}$$

σ_{zul} = $0{,}25 \cdot \sigma_{Rm}$

σ_{Rm} = average breaking strength for tension/compression in accordance with Table C.7. in Annex C

σ_k = stress in the individual layer

$$= \frac{P_d \cdot b^2 \cdot z_k \cdot E_k}{\Sigma\, E_k \cdot I_k} \cdot 8{,}33 \cdot 10^{-5} \quad \left[N/mm^2\right]$$

P_d = shell loading in accordance with A.1.9

b = principal unsupported panel dimension

The principal unsupported panel dimension is defined as the dimension [mm] of the panel in the direction of greater bending stiffness.

z_k = distance of the individual layer from the neutral fibre

E_k = Young's modulus of the individual layer in the direction of the unsupported panel dimension b

$$= \frac{E_L}{\cos^4(\varphi) + \frac{E_L}{E_{Tc}}\sin^4(\varphi) + \frac{1}{4}\left[\frac{E_L}{G_{LT}} - 2\mu_{TL}\right]\sin^2(2\varphi)} \quad \left[N/mm^2\right]$$

I_k = moment of inertia of the individual layer, referred to the neutral fibre

$$I_k = \frac{t_k^3}{12} + \left(z_k - \frac{t_k}{2}\right)^2 \cdot t_k \quad \left[mm^4\right]$$

E_L = Young's modulus parallel to the direction of the fibres [N/mm²] in accordance with Table C.7. in Annex C

E_{Tc} = $0{,}8 \cdot E_T$ [N/mm²]

E_T = Young's modulus perpendicular to the direction of the fibres [N/mm²] in accordance with Table C.7. in Annex C

G_{LT} = shear modulus in accordance with Table C.7. in Annex C

μ_{TL} = transverse contraction with Table C.7. in Annex C

φ = angle [°] of the veneer referred to the direction of the unsupported panel dimension b

$$S_n = \frac{\Sigma\, t_k \cdot E_k \cdot S_k}{\Sigma\, t_k \cdot E_k} \quad [\text{mm}]$$

S_k = span [mm] between center of individual layer and basis

S_n = span [mm] between neutral fibre and basis

t_k = thickness of the individual layer of veneer [mm]

Shell plating is to be stiffened by a system of longitudinal frames and transverse bulkheads or web frames. Decks are stiffened in accordance with the transverse and/or longitudinal framing method.

8.5 Floors, frames and bulkhead stiffeners

The section moduli are to be determined from Tables 1.11, 1.12, 1.13, 1.15 and 1.18 and multiplied by the material characteristic k_{10}.

$$k_{10} = \frac{152}{\sigma_{RM}}$$

σ_{Rm} = ultimate stress of wood laminate $\left[N/mm^2\right]$

These calculated section moduli apply to lamellated constructions.

If the mast stands on the keel, a keelson or mast stool shall be provided so that the pressure from the mast is transmitted to the keel via several floors. This applies in principle also to masts mounted on the deck, whose supports shall be given appropriate rests. For sailing yachts with ballast keel the floors shall be reinforced in way of keel in accordance with B.7.1.9.

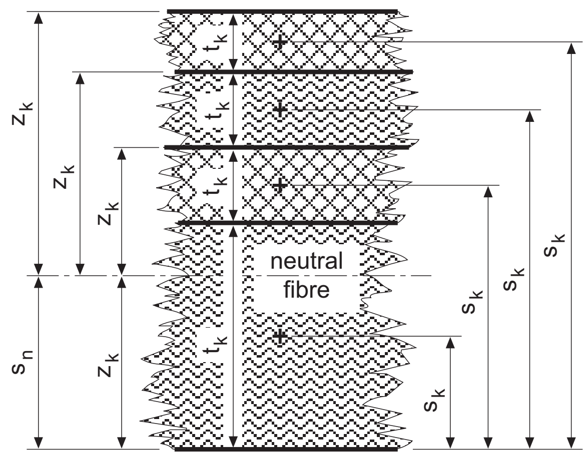


Fig. 1.29

F. Metal Hulls

1. Scope

1.1 In addition to pleasure craft hulls with **L** between 6 m and 24 m these rules may also be used to determine the hull scantlings of workboats up to 15 m in length, provided supplementary factors in accordance with 2.4 are applied.

2. Principles of scantling determination

2.1 The scantling determination of the principal structural members of pleasure craft hulls is based on the main dimensions and loads in accordance with A.

2.2 Determination of component scantlings of the principal structural members of the hull is to be based on the formulae in accordance with Tables 1.37 – 1.51.

2.3 For dimensioning rudders, shaft brackets, ballast keel bolts and tanks, see A.

2.4 Notes for scantling determination of the hulls of workboats up to **L** = 15 m. The scantlings determined are to be multiplied by the following supplementary factors:

1,20 for plate thicknesses

1,44 for section moduli.

2.5 Permissible stresses

If structural members of a metallic vessel's hull are to be determined by direct calculation, the stresses shall not exceed the following values.

2.6 The scantlings of structural members and components are to be determined by direct calculation if the craft is of unusual design or has principal scantlings of unusual proportions.

2.7 Rounding off tolerances

If dimensions other than round millimetres or half millimetres are arrived at in determining the scantlings of components, these may up to 0,2 or 0,7 be rounded off to millimetres/half millimetres; beyond 0,2/0,7 they shall be rounded up.

Table 1.37

Member	Permissible stresses [N/mm²]		
	σ_b	τ	σ_v [1]
Bottom long. frames; Side long. frames Long. girders	$\frac{150}{k}$	$\frac{100}{k}$	$\frac{180}{k}$
Floors Bottom transverses			$\frac{230}{k}$
Web frames	$\frac{150}{k}$	$\frac{100}{k}$	$\frac{180}{k}$
Transverse frames	$\frac{180}{k}$	$\frac{110}{k}$	$\frac{200}{k}$
Deck transverses Deck beams Deck girders	$\frac{150}{k}$	$\frac{100}{k}$	$\frac{180}{k}$
[1] Equivalent stress: $\sigma_v = \sqrt{\sigma_b^2 + 3\tau^2}$			
k = Material factor acc. to 3.3			

3. Properties of materials

3.1 The formulae for calculating component scantlings embody the mechanical characteristics of ordinary hull structural steel.

3.2 Ordinary hull structural steel is taken to mean steel whose yield strength R_{eH} is at least 235 N/mm² and whose ultimate tensile strength R_m is 400 N/mm².

3.3 Material factor

3.3.1 The material factor k in the formulae of the subsequent sections is to be entered at 1,0 if ordinary hull structural steel is used, according to 3.2.

3.3.2 If materials with comparatively higher or lower mechanical properties are intended to be used and the material factor k is not already taken into account with the corresponding formulae, component thicknesses, section moduli or diameters are to be multiplied by the coefficient k as follows:

Plate thicknesses:

$$t_2 = t_1 \cdot \sqrt{k} \quad [mm]$$

Section moduli:

$$W_2 = W_1 \cdot k \quad [cm^3]$$

Diameter:

$$d_2 = d_1 \cdot \sqrt{k} \quad [mm]$$

for round bar under tensile stress.

$$d_3 = d_1 \cdot \sqrt[3]{k} \quad [mm]$$

for rudder stocks and round bar under bending stress where:

$$k = \frac{635}{R_{eH} + R_m}$$

R_{eH} = yield strength of material used in [N/mm²]

R_m = ultimate tensile strength of material used in [N/mm²]

3.3.3 If the sea water resistant aluminium alloys listed in the materials regulations are used for hull members, the material factor k shall be calculated using the following formula:

$$k = \frac{635}{R_{p0,2} + R_m}$$

$R_{p0,2}$ = 0,2 % yield strength of the aluminium alloy in [N/mm²]

R_m = ultimate tensile strength of the aluminium alloy in [N/mm²]

In the case of welded connections, the appropriate mechanical properties of the welded condition are to be inserted (see Table 1.38). If these values are not available, the properties of the material's "soft"-condition are to be inserted.

4. Welding

The materials for the components indicated shall comply with the Rules for Classification and Construction, II – Materials and Welding, Part 1 and 3. Excerpts from these are listed in Annex B to D. Materials whose properties differ from those in these rules may only be used if specially approved.

5. Bulkheads

5.1 Bulkhead plating

The thickness of the bulkhead plating shall not be less than

$$s = a \cdot \sqrt{h_1 \cdot k} \cdot C \quad [mm]$$

a = stiffener spacing in [m]

h_1 = pressure head in [m] measured from bulkhead bottom edge up to bulkhead deck

k = material factor

The following values for C apply:

	Collision bulkhead	Other bulkheads
Stiffeners simply supported both sides	4,00	2,90
Stiffeners fixed both sides by bracket plates	2,03	1,45

The bulkhead plating need not be thicker than the shell if frame spacing and stiffener spacing correspond.

5.2 Bulkhead stiffeners

The section moduli of the stiffeners shall not be less than

$$W = k \cdot C \cdot a \left(h_2 + 0{,}5\right) \cdot \ell^2 \quad \left[\text{cm}^3\right]$$

h_2 = pressure head in [m] measured from the center of the stiffener up to the bulkhead deck

ℓ = length of stiffener in [m].

The section moduli of stiffeners applies in conjunction with the effective width of plating.

5.2.1 If bulkhead stiffeners are fixed by end brackets, the vertical leg of the bracket shall be at least 1,5 times the stiffener depth. The horizontal leg shall be extended to appox. 15 mm of the nearest floor/deck beam. Bracket thickness shall equal stiffener thickness.

5.2.2 Bulkhead stiffeners without brackets are to be considered simply supported. Such stiffeners are to be extended to approx. 15 mm to the deck or shell respectively.

5.2.3 If longitudinal bottom frames and deck beams are used, the bulkhead stiffeners shall be arranged in the same plane as these and shall be connected to them by brackets.

5.2.4 Stiffeners interrupted by watertight doors etc. are to be supported by carlings or transverse stiffeners.

5.2.5 Bulkhead stiffeners underneath deck girders or subject to large individual loads are to be dimensioned like pillars in accordance with 10.6.

5.3 Non-watertight bulkheads

Components of non-watertight transverse or longitudinal bulkheads, wing bulkheads or such which serve to stiffen the hull are to be dimensioned in accordance with the same formulae.

6. Shell

6.1 The thickness of side and bottom plating is to be determined in accordance with Table 1.39.

6.2 Bottom plating extends up to 150 mm above the waterline.

In the case of hard chine hulls, the bottom plating extends to the chine or to 150 mm above the waterline, whichever is the higher.

6.3 Curved plate panels

When dimensioning plate panels with simple convex curvature, the effect of the curvature may be taken into account by the correction factor f_k.

The basic value for the scantling determination is the thickness required in accordance with Table 1.39.

The shell thicknesses are to be corrected by multiplying by the curvature factor f_k.

This factor shall be taken from the following Table.

h/s	f_k
0 – 0,03	1,0
0,03 – 0,1	$1{,}1 - 3 \cdot \frac{h}{s}$
≥ 0,1	0,8

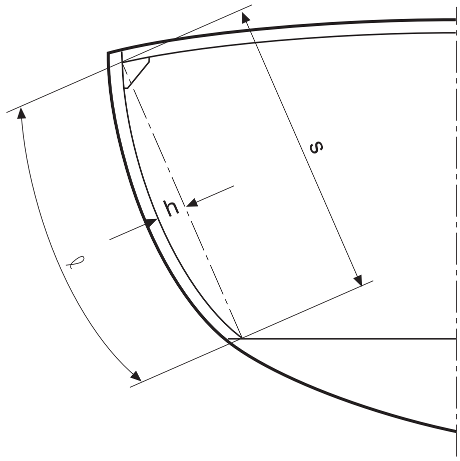


Fig. 1.30

6.4 Rubbing strake, rub rail

It is recommended that a rubbing strake be provided at the level where the shell is broadest. Craft which on account of their special purpose have to go alongside frequently (workboats) should be given adequately dimensioned rub rails.

Table 1.38

Strengths (minimum values) of inert-gas welded aluminium sheets and profiles (MIG)					
Component			R_m N/mm²	$R_{p0,2}$ N/mm²	k
Sheets	Al Mg 3	all conditions	190	80	2,35
	Al Mg 4,5 Mn	all conditions	275	125	1,59
Profiles	Al Mg 3	F 18	190	80	2,35
	Al Mg 4,5 Mn	F 27	275	125	1,59
	Al Mg Si 0,5	F 22 – 25	110	70	3,53
	Al Mg Si 1	F 28 – 31	185	125	2,05

6.5 Reinforcements

6.5.1 In way of sternpost, shaft brackets and stabilisers heavier plating shall be fitted, 1,5 times as thick as the bottom plating.

6.5.2 In the case of flat bottomed motor craft, the area of the plating panels above and forward of the propellers is to be reduced by fitting intercostal carlines.

6.5.3 The sea chests plating must be 2 mm thicker than the shell bottom plating.

6.6 Apertures in the shell

If apertures for windows, hawsepipes, discharges, sea cocks, etc. are cut into the shell, any corners have to be rounded carefully.

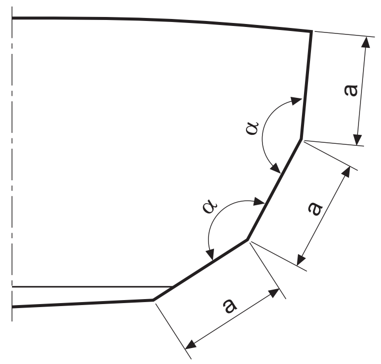
6.7 Shell plating of hard chined hulls

In hard chined construction, the chine may be considered as load bearing provided the plate thicknesses are arrived at as follows:

$$t_{korr} = t \cdot k_w \quad [\text{mm}]$$

t = plate thickness in accordance with Table 1.39 [mm]

k_w = hard chine correction factor in accordance with Fig. 1.31 for equidistant chines



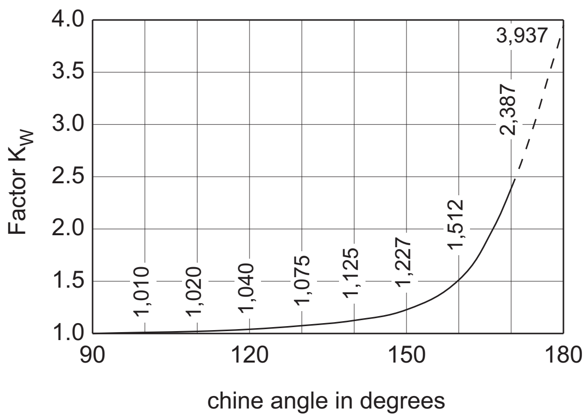


Fig. 1.31

7. Bulwarks

7.1 The bulwarks may not be thinner than the shell side plating in accordance with Table 1.39.

Superstructure bulwarks may be 0,5 mm thinner.

7.2 The bulwarks shall have a bulwark profile on top.

7.3 The bulwarks must be given a support at every second frame. The supports are to be arranged on top of deck beams, frame knees or carlines.

7.4 The supports are to be dimensioned on the basis of strength calculations, the loads being determined as follows:

Member	Loading $[kN/m^2]$	
	≥ 0,75 L ÷ forward	0,75 L ÷ aft
Main deck	P_d	$0{,}75 \cdot P_d$
Deckhouse Wheelhouse top	P_{dD}	
P_d = shell side load in accordance with A.		
P_{dD} = deck loading depending on type of craft		

The stress values in accordance with 2.5 must not be exceeded.

8. Bottom structure

8.1 General

8.1.1 The structural members may be arranged either on the transverse frame principle or the longitudinal frame principle, or on a mixture of the two.

8.1.2 The bottom structure shall have limberholes to permit uninterrupted flow of the bilge water to the bilge pumps.

Bilges in way of the engine shall be made oiltight. Regarding oil recovery equipment in machinery spaces see Section 3, A.3.5.

8.2 Floors

8.2.1 In the case of transverse frame construction, floors are to be arranged at every frame.

8.2.2 The section modulus of the floors is to be determined using Table 1.40. In case of sailing yachts the section modulus of the floors in way of the ballast keel must be increased by

$$W_k = \frac{G \cdot h}{(150/k) \cdot n}$$

G = weight of ballast keel [N]

h = distance keel floor to the keel's centre of gravity [m]

n = number of floors in way of ballast keel

k = material factor

8.2.3 Where there is a sharp deadrise, the required section modulus W shall still be present at a distance of b/4 from the centreline where b is the distance between port and starboard edge of the respective floor.

8.2.4 The thickness t of the floor web is not to be less than

$$t = 1{,}1 \cdot \sqrt{\mathbf{L}} \cdot \sqrt{k} + 1 \quad [mm]$$

t_{min} = 4 mm

8.2.5 Floors, bottom longitudinal and bottom transverse girders shall have a top chord if their length is greater than 100 times the plate thickness. If this is a flange, its width is to be 10 times the thickness of the web.

8.2.6 The floor chords/flanges shall be continuous over the unsupported length. If they are interrupted at the centreline girder, they shall be joined to the flange of that girder with a continuous weld.

8.2.7 The connection of the frames to the floors and bracket plates shall be made in accordance with the construction sketches, and using the dimensional data, displayed in Fig. 1.32.

8.2.8 Within 0,6 **B** midships, floors may have lightening holes no greater in height than 50 %, and no greater in length than 100 % of the web height of the particular floor.

8.2.9 Floors are to be continuous from one side to the other.

8.3 Bottom transverse girders

8.3.1 If the bottom of the craft is stiffened by longitudinal frames, these are to be braced by bottom transverse girders in accordance with Table 1.40.

8.3.2 If side frames join onto the bottom transverse girders, the section modulus of the frames must not be less than evaluated acc. to Table 1.42.

8.4 Centreline girder

8.4.1 All craft whose length exceeds 15 m shall have a centreline girder. Centreline girders shall be extended forward and aft as far as possible.

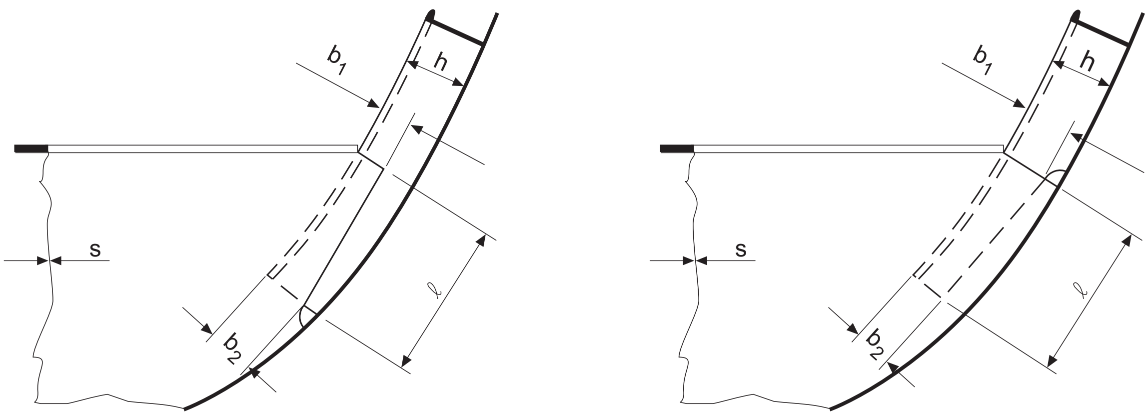
Centreline girders may be omitted in way of motor craft box keels and fins of sailing craft and motorsailers.

8.4.2 The centreline girder's scantlings are to match those of the floors in accordance with Table 1.40.

Table 1.39

	Shell plating for motor craft	**Shell plating for saling craft and motorsailers**
	plate thickness [mm]	**plate thickness [mm]**
Shell bottom	$t = 1{,}62 \cdot \mathbf{a} \cdot F_{VB} \cdot \sqrt{P_{dBM} \cdot k}$	$t = 1{,}62 \cdot \mathbf{a} \cdot \sqrt{P_{dBS} \cdot k}$
Shell side	$t = 1{,}62 \cdot \mathbf{a} \cdot F_{VS} \cdot \sqrt{P_{dSM} \cdot k}$	$t = 1{,}62 \cdot \mathbf{a} \cdot \sqrt{P_{dSS} \cdot k}$
Min. thickness	$t_{min} = 0{,}9 \cdot \sqrt{\mathbf{L} \cdot k}$	

a = frame spacing [m]
k = material factor in accordance with 3.3
F_{VB} = see A.1.9.3
F_{VS} = see A.1.9.3
P_{dBM} = see A.1.9.2
P_{dSM} = see A.1.9.2



$\ell \geq 1{,}5\ h$
$b_1 \geq 0{,}5\ h$
$b_2 \geq 0{,}75\ h$

$\ell \geq 1{,}5\ h$
$b_1 \geq 0{,}5\ h$
$b_2 \geq 0{,}75\ h$

Fig. 1.32

Table 1.40

Required section moduli of floors and bottom transverse girders for motor craft, sailing craft and motorsailers [cm³]		
Floors	Motor craft	$W = 0{,}43\ \mathbf{a}\ \ell^2\ F_{VF} \cdot P_{dBM} \cdot k$
	Sailing craft and motorsailers	$W = 0{,}37\ \mathbf{a}\ \ell^2 \cdot P_{dBS} \cdot k$
Bottom transverse girders	Motor craft	$W = 0{,}43\ \mathbf{a}\ \ell^2\ F_{VBW} \cdot P_{dBM} \cdot k$
	Sailing craft and motorsailers	$W = 0{,}37\ \mathbf{a}\ \ell^2 \cdot P_{dBS} \cdot k$

ℓ = unsupported length of floor or transverse girder [m] as in Fig.
F_{VF} = see A.1.9.3
F_{VBW} = see A.1.9.3
k = material factor in accordance with 3.3
a = floor respectively girder spacing [m]

Floors:

ℓ_{min} = $0{,}045 \cdot \mathbf{L} + 0{,}10$ for motor craft [m] or 0,60 [m], the larger value to be used.
ℓ_{min} = $0{,}065 \cdot \mathbf{L} + 0{,}30$ for sailing craft and motorsailers [m] or 0,60 [m], the larger value to be used.

Bottom transverse girders:

ℓ_{min} = $0{,}01 \cdot \mathbf{L} + 0{,}70$ or 0,75 [m], the larger value to be used
P_{dBM} = see A.1.9.2
P_{dBS} = see A.1.9.2

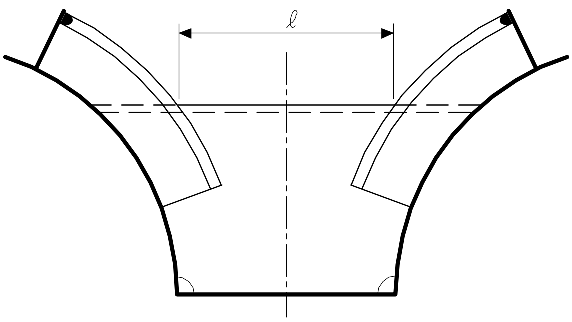


Table 1.41

Req. section moduli of bottom longitudinal frames of motor craft, sailing craft and motorsailers [cm³]		
Bottom longitudinal frames	Motor craft	$W = 0{,}49\ \mathbf{a}\ \ell^2\ F_{VL} \cdot P_{dBM} \cdot k$
	Sailing craft and motorsailers	$W = 0{,}37\ \mathbf{a}\ \ell^2 \cdot P_{dBS} \cdot k$

a = longitudinal frame spacing [m]
ℓ = unsupported length [m]
F_{VL} = see A.1.9.3
k = material factor in accordance with 3.3
ℓ_{min} = $0{,}01\ \mathbf{L} + 0{,}70$ or 0,75 [m], the larger value to be used
P_{dBM} = see A.1.9.2
P_{dBS} = see A.1.9.2

8.4.3 In the case of sailing craft and motorsailers a centreline girder extending over at least three frame spaces is to be arranged in way of the mast.

8.5 Bottom longitudinal frames

8.5.1 The section moduli of bottom longitudinal frames shall be calculated in accordance with the formulae in Table 1.41.

8.5.2 Bottom longitudinal frames shall be arranged in a continous line. They may be interrupted at watertight bulkheads, to be fastened to these by bracket plates on both sides.

8.5.3 It is recommended to connect interrupted longitudinal frames by continuous brackets positioned through the transverse bulkhead. As a minimum brackets on both sides of the bulkhead must be strictly aligned.

8.6 Engine seatings

8.6.1 General

The subsequent rules apply to the seatings of high speed engines whose revolutions $n > 1000\ \text{min}^{-1}$, made from ordinary hull structural steel. If it is intended to use sea water resistant aluminium alloys, proof of equivalent strength/rigidity is to be provided for the dimensions chosen. The web thickness of the longitudinal girders and cross sectional areas of the top plates calculated on this basis are standard values, as they depend not only on the power of the engine but also on weight and size of the engine including gearbox and thrust bearing, and on the type of construction of the hull. Furthermore the number of cylinders, engine revolutions, shape of the craft's bottom and design of the seating are to be taken into consideration.

8.6.2 Engines shall be mounted on the floors via longitudinal engine girders. Low power engines may be mounted directly on the reinforced floors, but generally it will be necessary to fit longitudinal engine girders.

8.6.3 Higher longitudinal girders of high-propulsion-power engines shall at least be long enough to carry the engine, the gearbox and the thrust block, to transfer the forces arising to as large an area of the shell as possible. Longitudinal girders of seatings shall be connected to the machinery space end bulkheads.

8.6.4 For continuous operation, care is to be taken to avoid the occurrence of resonant vibrations with unacceptably large amplitudes over the whole speed range of the main propulsion unit. GL reserve the right to call for a vibration calculation and possibly vibration measurements.

8.7 Seating longitudinal girders

8.7.1 Web thickness of the longitudinal girders must not be less than:

$$t = \sqrt{\frac{N}{200}} + 2 \quad [\text{mm}]$$

N = power of individual engine in [kW]

8.7.2 The top plate scantlings (width, thickness) to be chosen have to assure a propper support and mounting of the engine as well as adequate transverse rigidity.

The cross section of the top plate must not be less than:

$$F_T = \frac{N}{40} + 14 \left[\text{cm}^2\right] \quad \text{for} \quad N \leq 750\ \text{kW}$$

$$F_T = \frac{N}{200} + 29 \left[\text{cm}^2\right] \quad \text{for} \quad N > 750\ \text{kW}$$

8.7.3 The seating longitudinal girders shall be adequately supported athwartships by web frames. The web frames shall be in accordance with 9.3.

9. Frames

9.1 Transverse frames

9.1.1 The frame section moduli shall be calculated in accordance with the formulae in Table 1.42.

9.1.2 In the case of curved frames, the influence of curvature can be taken into account by the factor f_k when determining scantlings as follows.

The section modulus determined in accordance with 9.1.1 is to be multiplied by the factor f_k.

h/s	f_k
0 – 0,03	1,0
0,03 – 0,1	$1{,}15 - 5 \cdot \frac{h}{s}$
≥ 0,1	0,65

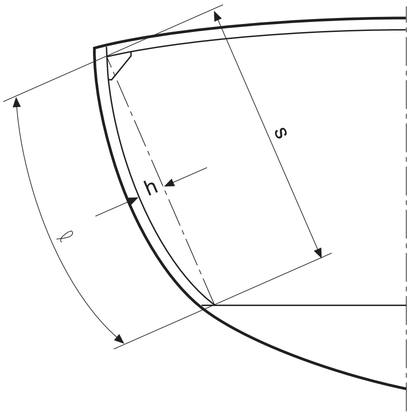


Fig. 1.33

The required section modulus calculated by using the factor f_k, must not be less than the minimum value from Table 1.42, evaluated by using ℓ_{min}.

9.1.3 For hard chine construction the chine may be considered as load bearing if the frames are dimensioned as follows:

$$W_{korr} = W \cdot k_w \quad \left[cm^3\right]$$

W = frame section modulus in accordance with Table 1.42 [cm^3]

k_w = hard chine correction factor in accordance with 6.7

9.1.4 In sailing craft and motorsailers with **L** < 15 m, a reinforced transverse frame with a section modulus increased by 50 % is to be fitted in way of the mast; if **L** ≥ 15 m, at least two frames shall be reinforced. The increase in section moduli may be spread over several frames in way of the mast. Bulkheads or transverse partitions can be accepted as reinforcement.

9.2 Longitudinal side frames

The section moduli of the longitudinal side frames shall be calculated in accordance with the formulae in Table 1.43.

9.3 Web frames

9.3.1 When arranging longitudinal side frames, these shall be supported by web frames. At the level of the bottom transverse girder top edge, the web frames shall have at least half the section modulus of the bottom transverse girders in accordance with 8.3. At the level of the deck transverses, the section modulus must not be less than that of the deck transverse in accordance with 10.2. Under no circumstances the section modulus of the web frame may be less than according to Table 1.44.

For curved web frames, the section modulus may be multiplied by the factor f_k in accordance with 9.1.2.

9.4 Web frames in the machinery space

9.4.1 In the case of propulsion units up to 400 kW, the web frames shall be arranged at the forward and after end of the engine.

Propulsion units exceeding 400 kW shall have an additional web frame.

9.4.2 In hulls built on the transverse framing principle with propulsion power units up to 400 kW, the section modulus of the web frame shall be 5 times that of the transverse frame in accordance with 9.1.1.

In hulls built on the longitudinal framing principle, the section modulus shall meet the requirements of 9.3.1.

9.4.3 In hulls built on a combined transverse/ longitudinal framing principle with propulsion units exceeding 400 kW, the section modulus shall meet the requirements of 9.3.1.

10. Deck structure

10.1 Deck plating

10.1.1 The thickness of the main deck plating shall be calculated in accordance with the formulae in Table 1.45.

In way of scuppers, a 10 % increase in plate thickness is recommended.

10.1.2 If a steel deck is covered with wood, the thickness established in accordance with 10.1.1 may be reduced by 15 %, but this reduced thickness shall not be less than:

$$t_{min} = 0{,}75 \cdot \sqrt{\mathbf{L}} \cdot \sqrt{k} \quad [mm]$$

10.2 Deck beams

10.2.1 The section modulus of the main deck transverse and longitudinal deck beams is to be calculated in accordance with the formulae in Table 1.46.

10.2.2 The transverse deck beams shall be joined to the frames by bracket plates, see Fig. 1.34.

The thickness of the bracket plates is to be midway between the web thickness of deck beam and frame.

10.3 Reinforced deck beams for sailing craft and motorsailers

The section moduli of the deck beams in way of the mast shall be doubled, whether or not the mast is taken through the deck.

Deck beams underneath winches, masts, etc. must be reinforced or propped as appropriate for the increased stress.

Table 1.42

Required section moduli of transverse frames for motor craft, sailing craft and motorsailers [cm³]		
Transverse frames	Motor craft	$W = 0{,}35\ \mathbf{a}\ \ell^2\ F_{VSF} \cdot P_{dSM} \cdot k$
	Sailing craft and motorsailers	$W = 0{,}32\ \mathbf{a}\ \ell^2 \cdot P_{dSS} \cdot k$

a = transverse frame spacing [m]
ℓ = unsupported length of frame [m]
F_{VSF} = see A.1.9.3
k = material factor in accordance with 3.3.
ℓ_{min} = $0{,}045 \cdot \mathbf{L} + 0{,}10$ for motor craft or 0,60 [m], the larger value to be used
ℓ_{min} = $0{,}065 \cdot \mathbf{L} + 0{,}30$ for sailing craft and motorsailers or 0,60 [m], the larger value to be used
P_{dSM} = see A.1.9.2
P_{dSS} = see A.1.9.2

Table 1.43

Required section moduli of side longitudinal frames of motor craft, sailing craft and motorsailers [cm³]		
Longitudinal frames	Motor craft	$W = 0{,}31\ \mathbf{a}\ \ell^2\ F_{VSL} \cdot P_{dSM} \cdot k$
	Sailing craft and motorsailers	$W = 0{,}33\ \mathbf{a}\ \ell^2 \cdot P_{dSS} \cdot k$

a = longitudinal frame spacing [m]
ℓ = unsupported length [m]
F_{VSL} = see A.1.9.3
k = material factor in accordance with 3.3.
ℓ_{min} = $0{,}01\ \mathbf{L} + 0{,}70$ or 0,75 [m], the larger value to be used
P_{dSM} = see A.1.9.2
P_{dSS} = see A.1.9.2

Table 1.44

Required section moduli of web frames for motor craft, sailing craft and motorsailers [cm³]		
Web frames	Motor craft	$W = 0{,}31\ e\ \ell^2\ F_{VSW} \cdot P_{dSM} \cdot k$
	Sailing craft and motorsailers	$W = 0{,}32\ e\ \ell^2 \cdot P_{dSS} \cdot k$

e = web frame spacing [m]
ℓ = unsupported length of web frame, measured from the turn of the bilge or the chine to where it is attached to the deck side or the gunwale [m]
F_{VSW} = see A.1.9.3
ℓ_{min} = $0{,}01\ \mathbf{L} + 0{,}70$ or 0,75 [m], the larger value to be used
k = material factor in accordance with 3.3
P_{dSM} = see A.1.9.2
P_{dSS} = see A.1.9.2

Table 1.45

Deck plating for motor craft, sailing craft and motorsailers [mm]
$t = 1,65 \cdot a \cdot \sqrt{P_{dD} \cdot k}$
a = deck beam spacing [m] k = material factor in accordance with 3.3 P_{dD} = see A.1.9.4 $t_{min} = 0,75 \cdot \sqrt{\mathbf{L} \cdot k}$

Table 1.46

Required section moduli of transverse and longitudinal deck beams of motor craft, sailing craft and motorsailers [cm³]	
Beams of main deck	$W = n \cdot P_{dD} \cdot a \cdot \ell^2 \cdot k$
Beams inside deckhouses	$W = n \cdot P_{dD} \cdot k_8 \cdot a \cdot \ell^2 \cdot k$
a = beam spacing [m] ℓ = unsupported length of beam [m] ℓ_{min} = B/6 or 1,0 [m], the larger value to be used P_{dD} = see A.1.9.4 k = material factor in accordance with 3.3 k_8 = correction factor for craft whose $\mathbf{L} \geq 10,0$ m $k_8 = 0,90 - 0,01\,\mathbf{L}$ n = 0,277 for transverse deck beams n = 0,346 for longitudinal deck beams	

10.4 Deck girders

10.4.1 The section modulus of deck girders is to be determined in accordance with the formulae in Table 1.47.

Web height is not to be less than 1/25 of the unsupported length of the girder. Girders with notches for deck beams passing through shall be at least 1,5 times as high as the deck beams.

10.4.2 If a girder is not given the same section modulus throughout, the greater scantlings are to be retained at the supports with gradual reduction to the lesser dimensions.

10.4.3 If girders are subject to special loadings, as for instance by pillars not vertically in line, suspended loads, etc., the section moduli are to be so calculated that the bending stress does not exceed (150/k) N/mm².

10.4.4 The intermediate and end fastenings of the girders to bulkheads must be appropriate for withstanding the bending moments and transverse forces. Deck girders shall be supported by bulkhead stiffeners capable of withstanding the reaction.

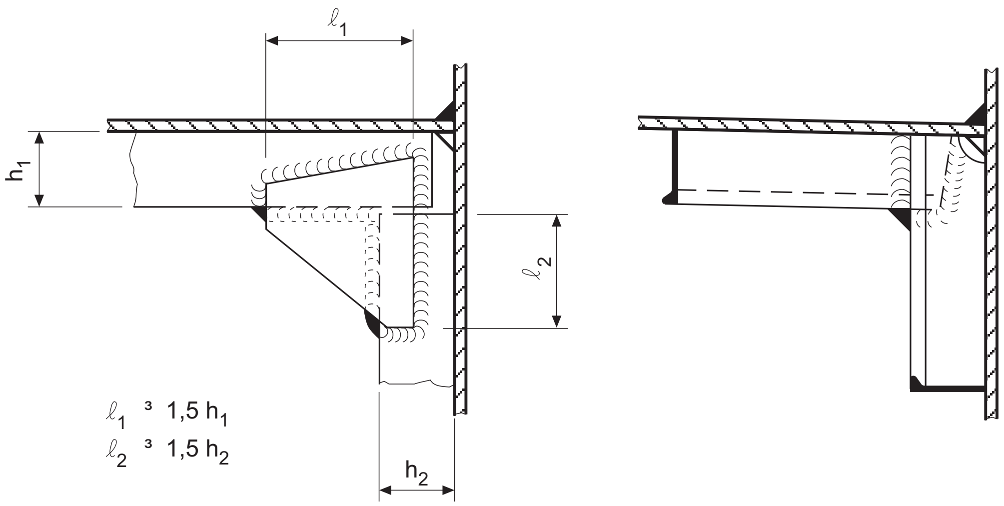


Fig. 1.34

Table 1.47

Required section moduli of deck girders of motor craft, sailing craft and motorsailers [cm³]	
Deck girders of open deck	$W = 0{,}227 \cdot e \cdot \ell^2 \; P_{dD} \cdot c \cdot k$
Deck girders within deckhouses	$W = 0{,}227 \cdot k_8 \cdot e \cdot \ell^2 \; P_{dD} \cdot c \cdot k$

e = spacing of deck girders [m]

ℓ = unsupported length of deck girder [m]

k = material factor in accordance with 3.3

k_8 = correction factor for craft whose **L** ≥ 10,0 m

$$k_8 = 0{,}90 - 0{,}01\,\mathbf{L}$$

c = 1,0 for deck girders where both ends are considered constrained

c = 1,33 for deck girders where one or both ends are to be considered simply supported

P_{dD} = see A.1.9.4

Table 1.48

Deckhouse and cabin plating of motor craft, sailing craft and motorsailers
$t = 1{,}56 \cdot \mathbf{a} \cdot \sqrt{P_{dD} \cdot k}$

a = stiffener spacing [m]

k = material factor in accordance with 3.3

P_{dD} = see A.1.9.4

10.4.5 At every second deck beam the flanges are to be stiffened by web plates. In the case of symmetrical girders they are to be arranged alternately on both sides of the web.

10.4.6 For 0,6 **L** amidships, in extension of superstructures and deckhouses, girders shall be arranged under the main deck extending at least three frame spaces beyond the ends of the longitudinal walls. These girders shall overlap the longitudinal walls by at least two frame spaces.

10.5 Deck transverses

Deck transverses shall be dimensioned like deck girders, in accordance with 10.4.

10.6 Deck pillars

10.6.1 The cross section of pillars may not be less than:

$$A = \frac{10 \cdot P}{\sigma_p} \quad [cm^2]$$

σ_p = permissible compression stress in accordance with Table 1.49

Table 1.49

Degree of slenderness λ	Permissible compressive stress σ_p [N/mm²] for pillars in accommodation	other pillars
$\le$ 100	$140 - 0{,}0067 \cdot \lambda^2$	$117 - 0{,}0056 \cdot \lambda^2$
> 100	$\frac{7{,}3 \cdot 10^5}{\lambda^2}$	$\frac{6{,}1 \cdot 10^5}{\lambda^2}$

P = load in [kN]. This is calculated from the specific deck load P_{dD} in accordance with A.1.9.4 multiplied by the area of deck supported by the pillar, extending lengthways from centre to centre of the deck girder fields on either side, sideways from centre to centre of the adjoining beam fields. Isolated loads and loads from pillars above shall be added to the calculation depending on their arrangement.

$\lambda = \frac{\ell}{i}$ degree of slenderness of pillars

ℓ = length of pillar in [cm]

i = radius of gyration of pillar

$$i = \sqrt{\frac{J}{f}}, \text{ in [cm]}$$

J = moment of inertia of pillar cross section in [cm⁴]

f = cross section of pillar in [cm²]

In the case of mast support pillars of sailing craft and motorsailers, the load from the mast

$$P = 3 \cdot \frac{RM\ 30°}{b}$$

shall be inserted.

RM 30° = righting moment at 30° heel

b = distance between mast and chainplate

10.6.2 Components at the top and bottom ends shall be made to match the forces to be transmitted.

10.6.3 The pillars shall rest on girders, floors, other pillars or carlines.

10.6.4 Mast support pillars in sailing craft and motorsailers shall be provided with supporting structures in accordance with 8.4.3.

10.7 Supporting structures for anchor winches

10.7.1 The scantlings of supporting structures for anchor winches and chain stoppers shall limit bending stress to 200/k N/mm² and shear stress in the web to 120/k N/mm². To determine the forces acting on the anchor winches, 80 % of the rated breaking strength of the anchor cable is to be used as the basis. If there is a chain stopper, 45 % of that breaking strength shall be used. For the forces acting on the chain stopper, 80 % of the rated breaking strength shall be used as the basis.

10.7.2 The scantling of beams and girders underneath large isolated loads, e.g. underneath pillars, shall limit bending stress to 150/k N/mm² and shear stress to 80/k N/mm².

11. Superstructures and deckhouses

11.1 Plate thickness of side and front walls shall be calculated in accordance with the formulae in Table 1.48.

11.2 The plate thickness of superstructure decks and accommodation decks are to be calculated in accordance with the formulae in Table 1.45.

11.3 The section moduli of the deckhouse side and front wall stiffeners shall be calculated in accordance with the formulae in Table 1.50.

11.4 The section moduli of the deck beams of superstructures and deckhouses shall be calculated in accordance with the formulae in Table 1.50.

The section moduli of the beams of accommodation decks within the deckhouses shall be calculated in accordance with the formulae in Table 1.46.

12. Keel and stem/sternpost

12.1 Keel

12.1.1 Bar keel

The bar keel scantlings are to be calculated in accordance with the following formulae:

$$h = (65 + 1{,}6\,\mathbf{L}) \cdot \sqrt{k} \quad [mm]$$

$$t = (6{,}5 + 0{,}5\,\mathbf{L}) \cdot \sqrt{k} \quad [mm]$$

k = material factor in accordance with 3.3

12.1.2 Flat keel

The scantlings of the flat keel are not to be less than:

$$b = (530 + 5\,\mathbf{L}) \cdot \sqrt{k} \quad [mm]$$

$$t = (3{,}3 + 0{,}5\,\mathbf{L}) \cdot \sqrt{k} \quad [mm]$$

Provided the cross sectional area remains constant, the width of the flat keel may be reduced.

12.2 Fins of sailing craft and motorsailers

The thickness t of the fin side plating must not be less than:

$$t = \left(\sqrt{\mathbf{L}} + 0{,}8 + f\right) \cdot \sqrt{k} \quad [mm]$$

$$f = (4{,}25\,\mathbf{L} + a - 355) \cdot 10^{-2}$$

k = material factor in accordance with 3.3

a = spacing of floors [mm]

The thickness of the keel sole shall not be less than:

$$t = (3 + 0{,}5 \cdot \mathbf{L}) \cdot \sqrt{k} \quad [mm]$$

12.3 Rectangular stem

12.3.1 The height h and thickness t of a stem of full rectangular section must not be less than:

$$h = (50 + 2\,\mathbf{L}) \cdot \sqrt{k} \quad [mm]$$

$$t = (3{,}5 + 0{,}55\,\mathbf{L}) \cdot \sqrt{k} \quad [mm]$$

12.3.2 The rectangular stem shall be welded to the centre girder in accordance with 8.4.

Table 1.50

Required section moduli of the stiffeners of deckhouse and cabin walls for motor craft, sailing craft and motorsailers [cm³]	
Deckhouse	$W_{SDH} = 1{,}346 \cdot a \cdot \ell^2 \cdot P_{dD} \cdot 10^{-4} \cdot k$ $W_{SDH(min)} = \left(0{,}1\,\mathbf{L}^2 + 10{,}1\,\mathbf{L} + 220\right) \cdot 10^{-3} \cdot k$
Cabins	$W_{SK} = 1{,}92 \cdot a \cdot \ell^2 \cdot P_{dD} \cdot 10^{-4} \cdot k$ $W_{SK(min)} = \left(0{,}142\,\mathbf{L}^2 + 14{,}4\,\mathbf{L} + 315\right) \cdot 10^{-3} \cdot k$
a = stiffener spacing [mm] ℓ = stiffener length [m] k = material factor in accordance with 3.3 P_{dD} = see A.1.9.4	

12.3.3 Stems shall be stiffened by horizontal webs whose thickness is to correspond to that of the shell plating, at intervals of no more than 900 mm. Where transverse frames are arranged, these webs shall extend to the foremost side frame and be joined to this. If there is an arrangement of longitudinal side frames, the webs shall be joined to these.

12.3.4 From the waterline upwards to the top end, the cross section of the rectangular stem may gradually be reduced to 75 % of the value required under 12.3.1.

12.4 Sternpost

12.4.1 The height h and thickness t of a propeller post of full rectangular cross section must not be less than the scantlings required for a rectangular stem in 12.3.1. The thickness shall not be less than 13 mm.

Sternposts will get the same scantlings.

13. Cathodic corrosion protection

13.1 Non sea water resistant metal components or coated sea water resistant alloys below water shall be protected against corrosion by zinc galvanic anodes.

13.2 Such components shall be connected to each other and to the anodes by electrical conductors; if possible, flexible insulated copper conductors with a minimum cross section of 4 mm^2. Contacts shall be made particularly carefully.

13.3 Contact between the anode and the component to be protected should only exceptionally be made by bolting-on.

13.4 The propeller is to be protected by a zinc anode.

13.5 Underwater coatings must be resistant against cathodic protection.

14. Corrosion additions

14.1 The rules for the scantling determination of metal hulls and components embody the following additions t_k for corrosion:

Table 1.51

Thickness t' [mm]	Addition t_k [mm]
≤ 10	0,5
> 10	0,3 t' + 0,2 max. 1,0 mm

14.2 Stainless steel components:

$$t_k = 0$$

14.3 Aluminium components do not need any allowances for corrosion. It is assumed that these components will be adequately protected against corrosion by a coating.

Note

Complete thickness measurements of steel structural members and anchor chains are to be carried out at Class Renewal Survey II (age of craft 8 to 10 years) and every subsequent one.

If these measurements demonstrate a greater degree of corrosion allowance than is indicated under14.1, the structural members concerned are to be renewed.

G. Anchoring, Towing and Warping Gear

1. Anchoring gear

1.1 General

Pleasure craft shall be equipped with anchoring gear which assures swift and safe laying out and heaving up of the stipulated anchors in all foreseeable situations, and which hold the craft at anchor. The anchoring gear comprises of anchors, anchor chains or cables and possibly anchor winches or other equivalent equipment for laying out and heaving up the anchors and for keeping the craft at anchor.

1.2 Equipment numeral

1.2.1 The required equipment with anchors, chains and cables shall be determined in accordance with Table F.1., F.2. in Annex F according to the equipment numeral Z. The equipment numeral is obtained from the following formula:

$$Z = 0{,}6 \cdot \mathbf{L} \cdot \mathbf{B} \cdot \mathbf{H}_1 + A$$

$\mathbf{L}$, $\mathbf{B}$, $\mathbf{H}_1$ in accordance with A.1.5

A = 0,5 times the volume of the superstructures [m^3]
(Superstructures and deckhouses whose width is less than **B**/4 may be disregarded.)

1.2.2 In the case of small pleasure craft whose displacement is less than 1,5 t, the equipment is to be based on the displacement.

1.3 Anchors

1.3.1 The anchor weights listed in Tables F.1., F.2. apply to "High holding power" anchors.

The following types of anchor have so far been accepted as anchors with high holding power:

BRUCE anchor

CQR (plough) anchor

Danforth anchor

D'Hone anchor

Heuss special anchor

Pool anchor

Kaczirek bar anchor

A stock anchor may be used if its weight is 1,33 times that in the Table.

Other types of anchor require special approval. Procedure tests and holding trials shall be carried out in accordance with the Rules for Classification and Construction, II – Materials and Welding, Part 1 – Metallic Materials.

1.3.2 The weight of each individual anchor may deviate up to ± 7 % from the stipulated value, provided the combined weight of the two anchors is not less than the sum of the stipulated weights.

1.3.3 Materials for anchors must comply with the Rules for Classification and Construction, II – Materials and Weding, Part 1 – Metallic Materials. Anchors weighing more than 75 kg must be tested on a GL approved tensile testing machine in the presence of a surveyor. For anchors below 75 kg and those intended for pleasure craft with a restricted operating category (II – V), proof is sufficient that anchors and chains have been reliably tested.

1.4 Cables and chains

1.4.1 Towing line

Each pleasure craft shall be equipped with a towing line in accordance with Table F.1. or F.2. in Annex F.

1.4.2 Anchor lines/cables and chains

1.4.2.1 On craft with a displacement ≤ 1,5 t, the towing line may be used as anchor line.

If the displacement is ≥ 1,0 t, at least 3,0 m chain with 6,0 mm nominal thickness is to be shackled between anchor and line.

1.4.2.2 On pleasure craft with a displacement ≥ 1,5 t whose $\mathbf{L_{WL}}$ is ≤ 15 m, both anchors may be on chains or on lines with chain outboard shot.

Anchor chains shall be determined in accordance with columns 5 and 6 of Table F.1. or F.2. in Annex F.

Synthetic fibre anchor lines shall be 1,5 times as long as the stipulated anchor chain and fitted with a spliced-in thimble at one end. They shall have the same maximum tensile strength as the towing line. Regarding notes for the selection of other ropes, see Table F.3. in Annex F.

1.4.2.3 Between line and anchor a chain outboard shot is to be shackled whose nominal thickness is determined in accordance with column 6 of Table F.1. or F.2. and whose length is obtained from the following Table:

Nominal thickness of chain outboard shot [1] [mm]	Length of chain outboard shot [m]
6 – 8	6,0
9 – 15	12,5
[1] ISO 4565 EN 24565 DIN 766	

Anchor chains and chain outboard shots must have reinforced links at the ends. A swivel is to be provided between anchor and cable.

1.4.2.4 The chain end fastening to the hull must be so made that in the event of danger the chains can be slipped at any time from a readily accessible position without endangering the crew. As regards strength, the end fastening is to be designed for at least 15 % but not more than 30 % of the nominal breaking load of the chain.

1.5 Anchor winches

1.5.1 For anchors weighing 30 – 50 kg, anchor winches are recommended. For sailing yachts, sheet winches are suitable for breaking-out and heaving-in these anchors.

1.5.2 For anchors weighing more than 50 kg, winches are obligatory.

1.5.3 The winches shall correspond to Section 3, I. If anchors weighing more than 50 kg are to be worked by means of lines, the winch must be fitted with rope drums allowing rapid letting-go of the gear in all foreseeable situations. Practical proof of handling safety is to be provided.

1.6 Chain locker

1.6.1 Size and height of the chain locker shall be such that a direct and unimpeded lead of the chain to the navel pipes is guaranteed even with the entire chain stowed. A wall in the locker shall separate the port and starboard chains.

1.6.2 Precautions are to be taken to prevent flooding of adjoining spaces if the chain locker is flooded via the navel pipes.

2. Towing and warping gear

2.1 Towing bollard

2.1.1 Each pleasure craft shall be provided with a device suitable for fastening the towing line to at or near the stem. Suitable devices are:

– eyebolts fastened to the stem of small boats

– two belaying cleats either side on the foredeck

– a bollard mounted amidships on the foredeck

2.1.2 Towing bollards and cleats, plus any stem fittings, must not have any sharp edges.

2.1.3 The design strength of the connections to the deck and the substructure is to be at least 120 % of the maximum tensile strength of the rope.

2.2 Warping gear

2.2.1 Each pleasure craft shall be fitted with suitable equipment for mooring (bollards, cleats, eyes) forward and aft - and if appropriate for larger craft, along the sides.

2.2.2 The size of the bollards or belaying cleats depends on the recommended rope diameter according to the Table below, each bollard or cleat being intended for belaying two ropes securely. Bollards, cleats and eyes are to be positively joined to the hull.

2.2.3 It is recommended that each pleasure craft be equipped with 4 securing lines, i.e.

2 lines of 1,5 · **L** [m] each and

2 lines of 1,0 · **L** [m] each

The nominal rope diameter can be derived from the following Table.

Deplacement [t]	**Nominal rope diameter d_2** [1] [mm]
to 0,2	10
0,6	12
1,0	14
2,0	14
6,0	16
12,5	18
25,0	20
50,0	22
75,0	24
100,0	26

1 Three-strand hawser-lay polyamide rope in accordance with DIN 83330

For notes concerning the choice of other ropes see Table F.3. in Annex F.

Section 2

Mast and Rig

A. General

1. Examination

1.1 According to the development of computation methods GL examines mast and rig dimensioning through geometric non-linear finite element analysis (FEA).

1.2 Load levels of standing rigging and factors of safety (FoS) respectively against breaking loads will be determined as well as compression levels in the mast allowing assessment of global and local stiffness.

1.3 Setup of the finite element model (FEM), computation prerequisites and load cases are described in the following.

1.4 Calculations following the same outline may be submitted. GL reserve the right to verify such results.

B. Basis for Calculation

1. Finite element model setup and prerequisites

1.1 The FE model must correctly reflect the geometry of the rig as specified in the sailplan.

1.2 The mast is generated from beam elements with assigned properties according to the mast section, i.e. moments of inertia and modulus of elasticity.

1.3 Spreaders and jumpers are setup analogously.

1.4 Standing rigging will be assembled from truss elements according to material and diameter of shrouds and stays, for example 1 × 19 steel wire, dyform or rod.

1.5 There will be no prestressing of the rig in the FE-model. Consequently, the calculated axial loads in standing rigging do not include the contribution of prestressing. This fact is covered by the required FoS against breaking loads.

2. Load cases and determination of loads

2.1 Normally, four sailing conditions upwind and one spinnaker case are considered, all at 30° heeling angle of the yacht according to the following specifications.

Upwind condition 1: Full main sail plus max. genoa

Upwind condition 2: First reef plus 100 % genoa

Upwind condition 3: Second reef plus 100 % genoa

Upwind condition 4: Third reef in main without headsail

Spinnaker case: Here it is assumed that only the spinnaker is set by an apparent wind angle of 90°.

2.2 Transverse rig loads according to all five sailing conditions are determined based on the yacht's righting moment at 30° heeling angle.

2.3 Under the simplifying assumption that 3/7 of the sail force act at the head and 2/7 each at tack and clew these forces can be determined if it is additionally assumed that the ratio between main sail force and genoa force is the same as between their sail areas.

2.4 The products of each transverse force multiplied by its distance from the centre of effort of the underwater body are summed up to obtain the heeling moment. The result must equal the righting moment.

2.5 According to this distribution the FE-model is to be loaded with the relevant forces at mainsail and genoa head and at the gooseneck.

2.6 In the spinnaker case the procedure for transverse force determination is analogous except for the percentages which are here 4/10 at the head and 3/10 each at the clews. The FE-model is to be loaded with the spinnaker head force only.

C. Assessment Criteria

1. Requirements for shrouds

1.1 Among others results of the FE-calculation are axial loads in transverse standing rigging for each load case.

For each shroud the highest calculated load of all five load cases must have a minimum FoS of 3,3 against breaking load.

2. Requirements for longitudinal stays

2.1 Headstay dimensioning

The headstay's axial load F_{hs} can be calculated analytically by the formula

$$F_{hs} = \frac{F_g}{8 \cdot s}$$

from the genoa sail force F_g and a given relative sag

$$s = \frac{sag}{headstay\ length}$$

F_g is to be determined from the righting moment at 30° heel as outlined in B.

The relative sag s is not to exceed 1,5 %

The headstay load calculated with this input must not exceed half of its breaking load.

2.2 The backstay (or runner) must be capable to oppose the headstay while meeting the same FoS requirement.

3. Stiffness requirements

3.1 FE-calculation also enables assessment of mast stiffness by determining the compression levels of the mast for each load case.

3.2 Loads in longitudinal stays and halyards also contribute to mast compression. As a general approach this contribution to mast compression will be brought into account by 85 % of the maximum load at the mast step of the four upwind cases and is to be added accordingly to give the maximum total load.

3.3 Buckling load will be calculated observing the contribution described under 3.2. As a requirement for sufficient stiffness buckling load must be at least a factor 2,6 above the maximum total load.

D. Construction Notes and Chainplates

1. Notes regarding construction of the rig

1.1 Forces from shrouds and stays shall be applied to the mast profile free from any moments. This necessitates the use of suitable fittings.

1.2 Rigging screws shall be freely movable longitudinally and transversely in the chainplates.

1.3 Bolts and other detachable parts shall be durably secured.

1.4 Where fittings are of different materials, electrolytic corrosion shall be prevented by suitable insulation.

1.5 Wire ropes plus associated terminals, thimbles, shackles, and rigging screws shall be of sea water resistant material and of a proven type.

1.6 Halyard sheaves are to be fitted into their housings with such small tolerances, and to be made in such a way, that the ropes of the running rigging cannot jam between sheave and housing.

2. Chainplate scantlings

2.1 Generally, for all metal parts of the chainplate construction dimensioning load is the breaking load of the attached shroud or stay.

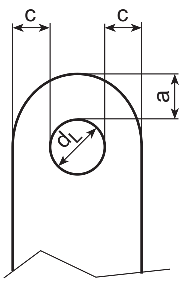
2.2 Permissible stress is the applicable yield stress with the exception of bearing stress for which the arithmetic mean of yield and ultimate stress is the allowable limit.

2.3 Generally, for FRP substructure and interfaces with metal parts of the chainplate construction dimensioning load is 1,6 times breaking load of the attached shroud or stay.

2.4 Permissible stress is the applicable FRP's ultimate stress.

2.5 If two shrouds are attached to one chainplate fitting then the breaking load of the stronger shroud and half of the breaking load of the lighter shroud are to be added for dimensioning purpose.

2.6 In case of chainplate fittings according to the following sketch having a thickness t and pin hole diameter d_l minimum edge distances a and c as given by the formulae below must be provided for:



$$a_{min} = \frac{F}{2 \cdot t \cdot \sigma_{all}} + \frac{2}{3} \cdot d_L \quad \text{and}$$

$$c_{min} = \frac{F}{2 \cdot t \cdot \sigma_{all}} + \frac{1}{3} \cdot d_L$$

Fig. 2.1

Therein F is the breaking load of the attached shroud or stay and σ_{all} the yield stress of the fitting material.

Pin hole bearing stress is not to exceed the arithmetic mean of yield and ultimate strength.

3. Attachment of chainplates to FRP structure

3.1 If fittings are bolted to FRP-reinforced bulkheads or webs FRP bearing stress in way of bolts is to be calculated on the basis of 1,6 times breaking load of the attached shroud or stay and must not exceed the GRP's ultimate compressive strength.

3.2 Bolt holes shall have a minimum distance of 3 times hole diameter from one another, measured from edge to edge.

3.3 For shear loading in bulkheads and webs due to chainplate attachment and secondary bonding respectively an analogous approach applies, i.e. relevant ultimate GRP mechanical properties are not to be exceeded if 1,6 times breaking load of attached shroud or stay is applied.

Note

If provision is made for a composite chainplate attachment or other solutions special consideration is required.

3.4 Chainplate arrangements may be load tested to prove sufficient strength.

Section 3

Machinery Installations

A. General Rules and Notes

1. General

1.1 These rules apply to the machinery of pleasure craft up to a length (**L**) [1] of 24 m in following operating categories [2]:

– sailing yachts:	operating categories	I to V
– auxiliary yachts:	operating categories	I to V
– motor yachts:	operating categories	III to V

If the length of 24 m, or the operating category, is exceeded, the Rules for Classification and Construction, I – Ship Technology, Part 1 – Seagoing Ships, Chapter 2 – Machinery Installations, apply.

1.2 Installations deviating from the rules may be accepted if they have been assessed by GL for their suitability and have been approved as equivalent.

1.3 For machinery and technical installations not included in these rules, GL may set special stipulations based on relevant rules and technical regulations if deemed necessary for the safety of the craft.

Furthermore GL reserve the right for all types of installations to state requirements beyond these rules, if deemed necessary due to newly-acquired knowledge or operating experience.

1.4 Deviations necessitated by design or intended service in case of special craft ("Fast Motor Yacht", "Special Sailing Yacht", "Special Motor Yacht", "Racing Sailing Yacht") may be accepted following consideration by GL.

In such cases GL reserve the right of restrictive entries in the certificate regarding the operation of the craft (e.g. operating category, weather clause).

1.5 National and regional rules and regulations beyond the requirements of these Rules remain unaffected. This in particular applies to craft used for commercial purposes.

1 Definition see Section 1, A.

2 Definition of operating categories see Rules for Classification and Construction, I – Ship Technology, Part 0 – Classification and Surveys, Section 2, F.2.2.

2. Documents for examination

2.1 For checking compliance with these Rules, drawings and documentation giving clear indication of the arrangement and dimensions of the components are to be submitted in triplicate. If necessary these are to be supplemented by descriptions and data sheets.

The scope of the documentation to be submitted is based on Form F 146 (Ref: Annex F to these Rules.)

Supervision of construction is based on the approved documentation which shall be submitted before commencing construction.

2.2 The approved documentation is binding. Any subsequent changes shall have GL approval.

3. Construction of machinery installations

3.1 Scantlings of structural parts and components; materials and welding

All parts shall be able to withstand the specific stresses due to the vessel's motion, heel, trim, vibration, increased corrosive action and, if applicable, also slamming. Where rules for the scantling of components are not available, acknowledged engineering rules shall be applied.

Materials for components as well as for the fabrication of welded components subject to the rules in Section 1 shall comply with Annex D.

3.2 Environmental conditions

3.2.1 Heel and trim

Unimpaired operation of the machinery installation is to be safeguarded for

– continuous heel	of up to 15° (static)
– short-term heel	of up to 30° (dynamic)
– short-term trim	of up to 20° (dynamic)

In the case of sailing craft, immediate starting of the machinery shall be safeguarded, even after the craft has been under sail at heeling angles exceeding the limits stated above.

3.2.2 Temperatures

Design of the machinery installation shall be subject to the following conditions:

– outside air temperature 45 °C

– outside water temperature 32 °C

– the ambient temperature during operation in the vicinity of internal combustion (IC) engines shall not exceed 60 °C.

3.2.3 Other environmental conditions

Basic assumptions for all compartments shall be salt-laden air and a relative humidity of up to 100 % at a reference temperature of 45 °C, plus the occurrence of condensation. Oil vapours have to be taken into account additionally in engine spaces.

Equipment on the open deck shall be resistant against saltwater spray and short-term immersion in sea water.

3.3 Arrangement

3.3.1 Machinery installations shall be arranged with adequate access for operation, checking and routine maintenance.

3.3.2 In the case of IC engines which can also be started manually, the cranking position is to be arranged with sufficient space and ergonomically favourable.

3.3.3 IC engines shall be installed separate from other spaces of the craft. Compartments for gasoline fuelled engines shall be gastight against accommodation spaces.

3.4 Foundations

Machinery installations shall be securely fastened to the craft, taking into account the loads to be expected. Foundations and seatings shall be properly integrated into the structure of the hull.

3.5 Bilges

3.5.1 Where oil or fuel leakage is likely to occur, the bilges are to be designed as to prevent such leakages from spreading to other parts of the craft. Drip trays are to be provided as appropriate

3.5.2 Means for collecting oil leakages, or parts of the craft where oil- or fuel leakage may occur, may not be connected to the common bilge system. Suitable equipment is to be provided for the environmentally-safe disposal of oil or oily water.

3.6 Ventilation

Adequate ventilation shall be provided in spaces where machinery is installed, taking appropriate account of the air required for combustion and cooling.

As regards the ventilation of spaces where gasoline engines and tanks are installed Section 4, C.3.1.1 is to be observed in addition.

3.7 Protective equipment, insulation

3.7.1 Machinery installations shall be such that the risk of accidents is substantially excluded.

Exposed moving parts and rotating shafts are to be protected by means of suitable guards. This may be dispensed with if moving parts and rotating shafts are adequately protected by other permanently installed equipment.

3.7.2 Crank handles of IC engines which can also be crank-started are to disengage automatically when the engine starts and to be kick-back proof.

3.7.3 Insulating material for machinery installations at least shall be not readily ignitable, e.g. acc. to DIN 4102 or equivalent. The insulation shall be suitably protected against penetration by moisture and leaking oil. It is to be so applied that

– maintenance can be carried out without damaging the insulation, or

– the insulation can be easily removed for maintenance or repairs and properly replaced on completion of the work.

3.7.4 Components of the installation having a high surface temperature (> 80 °C), such as exhaust lines, are to be fully insulated.

3.8 Painting

Only fire retardant paints are to be used on machinery and in areas where machinery is installed.

4. Operating and monitoring equipment

4.1 General

Operating and monitoring equipment is to be arranged suitably and distinct, and be provided with permanent identification.

4.2 Means of reversing

Craft with propulsive power ≥ 5 kW are to be equipped with means of reversing the direction of travel. Reversing levers are to be so arranged that their operating direction matches the desired direction of travel.

4.3 Scope of monitoring equipment

For permanently installed engines with propulsive power ≥ 5 kW, the control position is to be provided at least with optical/acoustic warning devices for oil pressure and cooling water temperature. The alarm thresholds are to be set in accordance with the engine manufacturers' instructions.

Motor- and auxiliary yacht propulsion engine control positions are additionally to be provided with revolution indicators.

For other permanently installed machinery, e.g. diesel generators, warning devices are to be provided analogously, unless dangerous operating conditions are prevented by automatic shut-down arrangements.

4.4 Emergency cut-offs

If power-driven machinery space ventilators and fuel transfer or -supply pumps are fitted, they are to be provided with an emergency cut-off at the control position. However, this does not apply to the ventilator required according to Section 4, C.3.1.1.

4.5 Craft with more than one steering position

Where craft have more than one steering position, safe operation of the craft under engine power shall be possible from each of the positions.

The minimum requirements stated under 4.1 to 4.4 are to be met at each steering position.

5. Trials

Trials of the completed machinery installation are carried out in accordance with the Rules for Classification and Construction, I – Ship Technology, Part 0 – Classification and Surveys.

B. Internal Combustion Engines

1. General

Inboard engines [3] for main propulsion or auxiliary propulsion, or prime movers of essential auxiliaries shall be approved for use with pleasure craft in accordance with these Rules. The rated power at associated rated revolutions declared by the engine manufacturers shall be the continuous power.

For the dimensioning of major engine components, the Rules for Classification and Construction, I – Ship Technology, Part 1 – Seagoing Ships, Chapter 2 – Machinery Installations, are to be applied analogously.

Main and auxiliary propulsion engines of ≥ 400 kW are subject to tests in accordance with B.6.

2. Foundations

2.1 Inboard engines

2.1.1 Inboard engines should be flexibly mounted on their foundations/seatings. The recommendations for installation given by the engine manufacturers shall be observed.

2.1.2 If the mounting is flexible, the connections for fuel, cables plus operating and monitoring equipment are to be made flexible.

2.1.3 Oil proof elastic mounts shall be used.

2.2 The fastening of outboard motors to the hull is to be flexible, unless this has already been incorporated in the design of the motor.

3. Safety devices on the engine

3.1 Each diesel engine is to be equipped with a safety or speed regulator which prevents the engine's rated rotational speed being exceeded by more than 15 %.

3.2 In the case of diaphragm-type fuel supply pumps, the installation has to ensure that fuel cannot either leak or get into the engine lubricating oil circuit if the diaphragm is damaged.

3.3 Regarding monitoring devices, see A.4.3.

4. Equipment

4.1 For the routing and securing of pipe and hose connections to the engine E. is to be applied analogously.

4.2 Only pipe connectors with metallic sealing shall be used in diesel engine fuel injection pipes.

4.3 For outboard motors, instantaneous fuel couplings may be used. These shall be so designed that fuel cannot leak when connecting or disconnecting.

4.4 Filters

4.4.1 Filters are to be fitted in fuel supply lines and on the discharge side of lubricating oil pumps. Propulsion engines ≥ 400 kW shall be fitted with double or automatic filters fitted in the supply lines to the fuel injection pumps.

In lubricating oil lines of these engines, switch-over double filters, automatic filters or equivalent devices of an approved type, which can be cleaned without interrupting operation, are to be fitted in the main oil flow downstream of the pumps.

4.4.2 Casings of filters fixed to the engine shall be of suitable metallic material.

Filters in the fuel system screwed-on from underneath shall be secured against becoming unscrewed.

4.5 Cooling system

4.5.1 To prevent deposits in the coolant passages in raw-water-cooled engines, the outlet temperature of the cooling water is to be limited to 55 °C.

4.5.2 In case of fresh-water-cooled engines, data and recommendations supplied by the engine manufacturers are to be observed for dimensioning the heat exchanger.

[3] Permanently-fitted outboards of motor yachts are also regarded as permanently installed engines. These rules do not apply to outboard motors used as auxiliary propulsion units in sailing yachts.

Fresh cooling water lines to and from keel coolers, or alike, shall be fitted with shut-off devices.

4.5.3 The discharged air from air-cooled engines shall not cause any unacceptable heating of the machinery space. If appropriate, the discharge is to be led directly into the open.

4.5.4 Air duct outlets are to be made spray-water proof.

4.6 For spaces where petrol engines are installed, safety equipment in accordance with Section 4, C.3. is to be provided. The exhaust-ventilation ducts shall be arranged such as to provide the removal of any petrol vapours from as low as possible in the engine compartment.

4.7 Regarding exhaust lines, see E.

5. Starters

5.1 Starters shall be reliable and safe to operate.

5.2 Small IC engines with electric starters should also be provided with alternative manual starting arrangements as far as practicable.

5.3 Engines which can only be started electrically are to be equipped with electric generators to provide automatic charging of the starter batteries.

It is recommended that the starter batteries be dedicated and be separated from electrical circuits other than the motor circuits.

5.4 The total capacity of the starter batteries depends on the size of the engine and shall be sufficient for at least six successive starts without recharging, at an ambient temperature of 5 °C.

6. Tests and trials

6.1 Tests of materials

For crankshafts and con-rods, proof of material quality is to be provided by acceptance test certificates in accordance with DIN 50049 3.1.B.

6.2 Pressure tests

The individual components of IC engines are to be subjected to pressure tests in accordance with the Rules for Classification and Construction, I – Ship Technology, Part 1 – Seagoing Ships, Chapter 2 – Machinery Installations, supervised by the engine manufacturer.

6.3 Trials at the manufacturer's

Engines are to be subjected to a GL-supervised bench trial at the manufacturers in accordance with the conditions laid down in the Rules for Classification and Construction, I – Ship Technology, Part 1 – Seagoing Ships, Chapter 2 – Machinery Installations.

C. Propeller Shafts, Propellers, Gearing, Couplings

1. General

The following applies to permanently installed propeller shaft arrangements including propellers, reduction gear and flexible couplings, to pivoted "Z"-drives of outboard motors and to "Z"-drives of permanently installed propulsion engines.

2. Propeller shaft

2.1 The propeller shaft in terms of these rules is the shaft linking propeller and gear, flexible coupling or cardan shaft. In the case of outboard-mounted "Z"-drives, the propeller shaft is identical with the output shaft from that drive.

2.2 Standard values for the propeller shaft diameter may be determined from 6.1.

Regarding permissible torsional vibration stresses in the propeller shaft, see 6.3.1.

2.3 Cardan shafts or ball-joint couplings are considered adequately dimensioned if they comply with the manufacturers' recommendations for the given propulsion and installation conditions. If these shafts or couplings have not been GL type approved, GL reserve the right to require proof of adequate dimensioning from the manufacturers.

It is to be ensured that bearings or equipment driven by the cardan shaft can safely take up the forces exerted by the shaft.

2.4 Propeller shafts permanently installed in the hull are to be so supported that displacement of individual bearings caused by flexing of the hull does not cause excessive bearing pressures in the adjoining bearings or in the gear bearings. Bearings should be as wide apart as practicable. As a guidance for the maximum distances between bearings the following may be applied:

$$\ell_{max} = C \cdot \sqrt{\frac{d}{n}} \quad [mm]$$

ℓ_{max} = maximum distance between bearings

d = shaft diameter [mm]

n = shaft revs. [min^{-1}]

C = 12 000 for steel shafts

C = 8 000 for bronze shafts

Where engine and gear are flexibly mounted and with the stern tube bearings of rubber, the C-value in above formula should be at least C = 6000 if the propeller shaft is led directly from the gear output flange to the propeller. In such cases flexible mounting of the stern seal to the stern tube is to be applied.

2.5 Guidance for permissible values of bearing pressures p_{max}, peripheral speeds v_{max} and bearing clearance s_L in stern tube bearings:

Type of bearing	p_{max} [N/mm²]	v_{max} [m/s]	s_L [mm]
Grey cast iron or bronze bearing, grease lubricated	0,5	2,5 – 5	~ 0,6
Rubber bearing, water lubricated	0,2	6	~ 0,5
White metal bearing, oil lubricated	0,8	> 6	~ 0,4

2.6 If the material of the propeller shaft is not corrosion-resistant, the propeller hub shall be suitably sealed against entry of water.

3. Propellers

3.1 Fixed-pitch propellers for pleasure craft should be of an established design. Any design differing from these shall be approved by GL.

3.2 Propellers should preferably be made of a cast copper alloy suitable for use in sea water. For propellers in units with outboard motors and with "Z"-drives, aluminium alloys suitable for use in sea water may also be chosen.

Propellers should in general be fastened to the propeller shaft taper by means of a key and cap nut. The cap nut shall be suitably secured. For lower powers and in particular in case of outboard motors and "Z"-drives, the propeller may also be fastened by another proven method.

3.3 For the dimensioning of the blades of fixed and variable pitch propellers 6.2 applies.

4. Gearing

4.1 The design of gearing for the propulsion of pleasure craft is considered to be suitable, if among other things:

– the toothing is adequately dimensioned in accordance with the Rules for Classification and Construction, I – Ship Technology, Part 1 – Seagoing Ships, Chapter 2 – Machinery Installations, Section 5, or DIN 3990/ISO 6336,

– gearing shafting is designed fatigue-resistant in accordance with standard engineering practice,

– roller bearings are designed for a rated working life of at least 1000 hours at full load for small craft with outboards - operating category IV – V - and sailing yachts, and at least 5 000 hours at full load for larger craft in operating category III,

– the lubricating oil bulk temperature does not exceed 90 °C with a water temperature of 32 °C and operating at full load,

– in case of hydraulically controlled reversing gears, a single emergency manoeuvre from "full ahead" to "full astern" does not cause damage to toothing, clutches, shafts and other components of the gearing.

4.2 As regards additional stress due to torsional vibrations, reference is made to 6.

5. Flexible couplings

Flexible couplings between engine and gearing or between the flexibly mounted engine plus gearbox and the propeller shaft shall be of a proven type. The permissible loads recommended by the manufacturers of the coupling shall not be exceeded.

6. Calculations and guidance for permissible stresses

6.1 Propeller shaft diameter

The propeller shaft diameter d_p can be determined as a guidance as follows:

$$d_p = k \cdot \sqrt[3]{\frac{P}{n_2} \cdot C} \quad [\text{mm}]$$

P = propulsive power [kW]

n_2 = propeller shaft revs. [min⁻¹]

k = 100 for shafts of non-corrosion-resistant steel not protected against seawater

= 90 for shafts of corrosion-resistant steel [4], wrought copper alloys [5], nickel alloys (Monel) [6] or for non-corrosion resistant steel if the shaft is protected against contact with seawater

= 75 for shafts of high-tensile wrought nickel alloys [7]

4 Preferably austenitic steels with 18 % chrome and 8 % nickel

5 e.g. wrought copper-nickel zinc alloy Cu Zn 35 Ni in acc. with DIN 1766

6 Nickel content > 60 %, tensile strength $\sigma_B > 400$ N/mm²

7 e.g. "Monel alloy K-500", tensile strength $\sigma_B > 900$ N/mm²

C = 1,2 for craft in operating category III [8] with one propulsion line

= 1,0 for craft with two propulsion units and operating category III [5]

= 0,8 for craft in operating categories IV and V

6.2 Thickness of propeller blades

Standard values for the thickness $t_{0,25}$ of propeller blades at a radius of 0,25 R can be determined as follows:

$$t_{0,25} = k \cdot \sqrt{\frac{P \cdot 10^3}{n_2 \cdot B \cdot z} \cdot C} \quad [mm]$$

P = propulsive power [kW]

n_2 = propeller revs. [min^{-1}]

B = width of blade at 0,25 R [mm]

z = number of blades

k = 50 for propellers of high-tensile cast brass

= 46 for propellers of corrosion-resistant austenitic steel

= 42 for propellers of high-tensile nickel-aluminium-bronze

= 75 for propellers of an aluminium alloy (cast in chill mould)

= 100 – 120 for propellers of synthetic material

C = 1,2 for craft in operating category III

= 0,8 for craft in operating categories IV and V

Controllable pitch propellers for motor yachts in operating category III shall be of a GL-approved type.

6.3 Torsional-vibration stresses

To check the torsional-vibration behaviour of the propulsion plant, a torsional-vibration calculation shall be carried out.

6.3.1 Standard values for permissible torsional-vibration stresses in the propeller shaft

The torsional-vibration stresses τ_W permissible in the propeller shaft are calculated in accordance with the following formula:

$$\tau_W = (59 - 39 \cdot \lambda) \cdot C_K \quad \left[N/mm^2\right]$$

λ = partial load/full load rotational speed ratio

C_K = coefficient of influence for the fatigue strength of the shaft in the area between the aft stern tube bearing and the propeller

= 1,0 for propeller shafts of corrosion-resistant material if the hub is protected against the entry of water; otherwise such shafts are to be given C_K = 0,8.

= 0,8 for other than corrosion-resistant propeller shafts if the shaft and the hub are suitably sealed against the entry of water

= 0,6 for other than corrosion-resistant propeller shafts not protected against the contact with seawater

6.3.2 Standard values for permissible torsional-vibration stresses in gearing

In the higher speed range the torsional-vibration stresses with gearing are not to exceed 30 % of the rated transmitted torque of the respective stage.

There shall not be any lifting of the toothing (load change) with the propeller clutched-in.

6.3.3 Permissible torsional-vibration stresses in flexible couplings

Flexible couplings in the propulsion plant shall be designed to withstand the alternating torques arising with the associated frequencies, over the entire range of rotational speeds.

D. Storage of Liquid Fuels

1. General

1.1 Fuel tanks shall be made of a suitable corrosion-resistant material, if necessary fitted with wash plates and securely fastened to the craft.

1.2 Portable fuel tanks are to be securely fixed.

1.3 Galvanised steel shall not be used for diesel fuel tanks.

1.4 Only metal tanks are permissible for gasoline.

1.5 Special approval is required for fuel tanks of plastics.

2. Arrangement of fuel tanks

2.1 Fuel tank shall be arranged such that unacceptable heating is avoided.

2.2 Gasoline tanks are to be separated from machinery spaces and living quarters by gastight partitions. Section 4, C.3. is to be observed.

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8 Sailing yachts with auxiliary propulsion engine(s) and auxiliary yachts also in operating categories I and II.

3. Fuel tank equipment

3.1 General

3.1.1 Pipe connections are preferably to be arranged in the tank top. They shall not weaken the tank; welded doubles are to be provided if necessary. Through-bolts are not permitted in tank boundaries.

3.1.2 Appliances which are not part of the tank equipment may be attached to the tank only via intermediate supports. In this case, the tank boundaries are to be adequately strengthened.

3.1.3 Diesel fuel tanks shall be provided with hand holes for cleaning. In the case of small tanks which can easily be removed and flushed such hand holes can be dispensed with.

3.1.4 Regarding hoses for filling- and vent lines plus hose connections, see E.2.2.2.

3.1.5 Tanks and filler necks are to be earthed with a bonding wire of at least 4 mm^2.

3.2 Filling arrangements

3.2.1 Fuel tanks shall be filled from the deck through a permanently installed filling line of at least NB 40. Filler necks are to be so arranged that in the event of an overflow fuel cannot get into the inside of the boat. The filler neck is to be clearly marked with the type of liquid.

3.2.2 The filling line shall terminate inside the tank at not less than 1/3 tank height.

3.3 Tank vent line

3.3.1 Each fuel tank is to be equipped with a fixed vent line led to the open. The vent line shall be run such that fuel cannot be trapped.

3.3.2 The cross-sectional area of the vent line depends on the method of fuelling:

– 10 mm for open filling through filler neck

– 1,25 times the filling line cross-sectional area for filling via a fixed connection

In case of fuel systems with more than one tank and transfer pump(s), also the discharge pipe diameter of the transfer pump shall be considered for the determination of the vent line diameter as appropriate.

3.3.3 Ingress of water and the spillage of fuel when heeled shall be prevented by suitable routing of the lines. For air pipes of 32 mm in diameter and above, automatic closures are to be provided.

3.3.4 Vent lines of gasoline tanks are to be equipped with suitable flame arrestors.

3.4 Fuel extraction lines and spill lines

3.4.1 The suction of the extraction line is to be arranged sufficiently high above the tank bottom to prevent dirt and water being sucked in.

3.4.2 Spill lines are to be connected to the tank at the tank top.

3.5 Tank drainage

3.5.1 Diesel storage and supply tanks are to be provided with suitable drainage arrangements.

On diesel supply tanks drainage arrangements may be omitted if an adequately sized water separator is fitted in the extraction line.

3.5.2 Tank drainage fittings are not permissible in gasoline tanks.

3.5.3 Drainage fittings near the tank bottom shall be equipped with a self-closing valve which additionally is to be provided with a cap or plug.

3.5.4 Tank drainage may also be facilitated via a line introduced into the tank from the tank top, using a suitable pump (e.g hand pump with appropriate connections, also transportable).

3.5.5 All drainage arrangements shall be easily accessible and located conveniently to allow safe drainage into a collecting receptacle.

3.6 Tank sounding equipment

Each fuel tank is to be provided with means for hand-sounding from the deck or with a proven remote level indicator.

Gauge glasses, sightglasses or float indicators with mechanical transmission are not permitted.

4. Tests

Fuel tanks including all connections shall be subjected to pressure testing with the hydrostatic pressure corresponding to the height of 2 000 mm above the overflow level of the tank.

E. Piping, Fittings, Pumps

1. General

These rules apply to piping systems, including pumps and fittings, for the operation of the machinery; as well as for the operation of the craft insofar as its safety is concerned.

These rules are also to be applied to piping systems referred to in other parts of this Section.

2. Materials

2.1 General

2.1.1 Materials for piping and fittings shall be suitable for their purpose. Regarding welding of pipes and fittings, see Annex D.

2.1.2 Piping and fittings are preferably to be made of metal. Where plastic pipes or hoses are used due to the installation conditions, the special requirements stated under 2.2 are to be observed.

2.2 Plastic pipes and hoses

2.2.1 Plastic pipes

2.2.1.1 The use of plastic pipes is restricted to systems conveying water, like drinking water, seawater, bilge water, waste water/sewage.

2.2.1.2 Plastic pipes are not allowed for piping leading to overboard without shut-off at the shell or for bilge piping lines within machinery spaces. In FRP hulls, however, cockpit drains without shut-off may be of a material corresponding to that of the hull.

2.2.1.3 Plastic pipes and pipe fittings shall comply with an acknowledged standard. The limiting operating pressures and temperatures stated in the standard are to be adhered to.

2.2.1.4 For pipes made of rigid PVC with glued joints and pipe fittings, DIN 86012 or equivalent applies. Processing and pipe laying shall be carried out in accordance with DIN 86015 or equivalent.

2.2.1.5 When laying plastic pipes, attention shall be paid to providing adequate and proper fastening devices, and protection against unacceptable external heating.

2.2.2 Flexible hoses

2.2.2.1 Hoses shall be suitable for the media envisaged to be conveyed, operating pressures and temperatures.

For hoses not complying with any standard, proof of suitability is to be provided. Such hoses shall have continuous marking which allows for identification even of short lengths.

2.2.2.2 Only hoses with a textile or wire-mesh intermediate layer may be used.

2.2.2.3 Hoses for drinking water shall be of a quality suitable for handling foodstuff.

2.2.2.4 For hoses connecting to overboard without seacock, such as cockpit drains, hoses with a textile or wire-mesh intermediate layer in accordance with DIN series 20018, 20021, 20022 or equivalent are to be used. If passing through a machinery space, type approved fire resistant hoses are to be used or else a rigid standpipe extending at least 100 mm above the waterline shall be provided. This standpipe shall at least match the strength and fire resistance of the shell in the area of the outlet opening.

2.2.2.5 Hoses for exhaust lines with water injection are to have a wire-mesh intermediate layer in accordance with DIN series 20022 or be of equivalent quality.

2.2.2.6 For liquid fuels, lubricating oil or hydraulic oil, only type-approved fire resistant hoses are permissible [9].

2.2.2.7 In gasoline piping, only short lengths of hose for connection to the consumer are permitted.

2.2.2.8 For connection to consumers, fittings, pipes, etc., hoses with fixed end fittings are to be used [1].

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9 Except for gasoline, not applicable to tank filling lines and vent lines.

2.2.2.9 Hose connections in systems conveying water may also be made using standard hose fitting ends or to suitably-shaped pipe ends. Fastenings to raw pipe ends are not permissible. Proven stainless steel hose clamps are to be used for fastening.

Hoses in systems connecting to overboard are to be fastened to the fitting ends by double clamps.

2.2.2.10 Hose lines are to be so routed and fastened that movement due to vibration or motion of the vessel, chafing and unacceptable heating is avoided and so that visual checking is possible at any time.

Hoses runs piercing structural components are to be suitably protected in way of the penetration.

2.2.2.11 Hoses may be taken through watertight or gastight bulkheads only by means of suitable bulkhead penetration fittings.

3. Hull fittings

3.1 Except for cockpit drains, all connections to the hull below or near the waterline are to be provided with seacocks.

3.2 Seacocks shall be easy to reach; if necessary, extension rods are to be provided.

3.3 If the seacock is not fitted directly to the shell, the pipe between the shell and the seacock shall at least match the strength and fire resistance of the shell in the area of the outlet opening.

3.4 Seacocks and through hull fittings shall be of ductile metallic material.

Other materials, e.g. fibre reinforced plastics, may be allowed if proof of adequate strength and fire resistance at least equal to that of the hull has been provided.

4. Pumps

4.1 Pumps are to be located accessibly and securely fixed.

4.2 Power pumps of the displacement type are to be fitted with means of overpressure protection if there are valves or cocks fitted in the piping system on the discharge side of the pump.

4.3 Centrifugal pumps shall not be damaged if operated with a closed shut-off fitting over a lengthy period of time.

5. Fuel lines

5.1 Fuel lines are generally to be made of corrosion-resistant metal with as few disconnectable pipe connections as practicable. Pipe joints may be made by welding or brazing. Brazed joints are to be made using fittings and hard solder.

The number of breakable connections shall be kept to a minimum, respective of the particular arrangement.

5.2 Only metal-to-metal screwed connections are permissible. Threaded sleeve joints requiring hemp, sealing strip, etc. in order to safeguard tightness may not be used.

5.3 As a general rule the use of hoses is only permitted for the connection of consumers to rigid piping. The use of hoses is to be limited to short lengths. 2.2.2 is to be observed.

5.4 Fuel lines are to be securely fastened and be arranged protected against damage.

5.5 The arrangement of fuel lines in the vicinity of machinery parts with high surface temperatures and of electrical appliances is to be avoided.

5.6 Extraction pipes are to be fitted with a valve or cock directly at the tank. Such valve or cock shall be capable of being closed from deck or the steering position. This also applies to other tank connections which if damaged would release the contents of the tank, e.g. equalising- or transfer lines.

5.7 The valve or cock may be omitted if the connection and piping is arranged such that fuel cannot be released from the tank in the event of damage to the piping. Siphoning action of the connected piping is to be considered if applicable.

5.8 Spill lines are to be connected at the tank top of the service tank. Means of closure may not be fitted in the spill line.

If the spill is connected to more than one tank, changeover valves are to be fitted, which also in the intermediate position safeguard that at least one way is always open.

5.9 Casings of fuel filters or water separators are to be of metal. Glass casings may be used only for diesel fuel.

If so, the arrangement shall be protected and easily visible.

5.10 If power-driven transfer pumps are fitted in fuel systems with more than one tank, suitable means are to be provided to prevent overfilling of service or storage tanks (e.g. overflow systems, high level alarm and automatic stop of the pump).

High level alarms shall trigger an acoustic signal a suitable period of time before an unacceptably high level is reached. The signal shall be audible under all conditions of operation.

5.11 In fuel systems with power-driven transfer pumps, it shall be possible to maintain the full fuel supply to the engines also in case of failure of a transfer pump. In systems with only one power-driven pump, this requirement is considered to be met if fuel can also be supplied to the engines directly from all the storage tanks fitted, or if additionally there is a hand pump for topping-up the supply tank.

6. Exhaust lines

6.1 Engine exhaust lines are to be led to the open separately and so insulated and run that combustible material cannot catch fire on the pipes and no detrimental heating effect on the environment can arise.

Temperatures of brackets and of bulkhead/deck/shell penetrations shall not exceed 80 °C.

6.2 Thermal expansion is to be compensated.

6.3 If exhaust lines terminate near the waterline, measures shall be taken to prevent water from entering the engine(s).

6.4 In metal exhaust lines, means of draining fittings are to be provided at the lowest points.

Cooling jackets of exhaust lines shall be capable of being drained completely.

6.5 Main- and auxiliary engine exhaust lines shall have effective silencers fitted. Depending on the type of silencer, means for cleaning and draining are to be provided.

6.6 For hoses in exhaust lines 2.2.2.5 shall be observed.

6.7 Thermoplastic components may be used in exhaust lines with water injection only and on condition of monitoring of the cooling water flow or the temperature in the exhaust line immediately downstream of the point of water injection.

7. Cooling water lines (raw water)

7.1 A filter is to be fitted in the raw-water supply line. For small auxiliary engines an inlet strainer on the hull is sufficient.

7.2 Drain fittings are to be arranged as necessary. It shall be possible to drain the entire raw-water system.

7.3 Shell or keel coolers are to be fitted with vent valves at the highest point.

7.4 For the cooling water supply to the engines, one cooling water pump per engine is sufficient, unless in accordance with A.1.1 the Rules for Classification and Construction, I – Ship Technology, Part 1 – Seagoing Ships, Chapter 2 – Machinery Installations are to be applied analogously.

7.5 If the installation is such that the bilge pump is also used as reserve cooling water pump for the engine and can take suction from overboard, the bilge suction lines shall be so connected to the pump that ingress of water from overboard into the bilge system is prevented.

7.6 Use of copper alloy pipes suitable for sea water is recommended. Steel pipes shall be internally galvanised or provided with other suitable corrosion protection.

As regards the use of hoses, 2.2.2 is to be observed.

7.7 In the case of engines with cooling water injection into the exhaust line, measures are to be taken to prevent that, after the engine has stopped, cooling water can enter the cylinders of the engine via the water inlet and the exhaust line. Siphoning shall be prevented by providing an automatic vacuum-breaker as appropriate. The vacuum breaker is to be arranged at the highest point at the pressure side of the cooling water line, raised above the water line.

8. Bilge pumping arrangements

8.1 Scope

8.1.1 Each craft is to be equipped with a bailer.

8.1.2 Craft within operating categories IV and V and with a length **L** of 6 m or more are to be provided with at least one fixed manual bilge pump in accordance with Table 3.1.

The nominal flow rate of manual bilge pumps shall be based on 45 strokes per minute.

Table 3.1 Bilge pumps

Length L (m)	Hand pump flow rate (m^3/h)	Power pump flow rate (m^3/h)	Bilge pipe NB (mm)	
			main pipe	branch pipe
< 8	3	5	32	
< 10	5	6	32	
< 15	5	7,5	40	
< 20	6	9	50	40
≤ 24	6	10,5	50	40

8.1.3 For craft in operating categories extending beyond those listed in 8.1.2, a power-driven bilge pump with at least the flow rate specified in Table 3.1 shall be installed in addition.

For sailing yachts without power (auxiliary) propulsion or power-driven electric generator(s), installation of a second manual bilge pump is sufficient. The rate of flow shall at least match that of the manual pump required in accordance with the Table.

8.1.4 The power-driven bilge pump may also be coupled to the main or auxiliary propulsion engine.

8.2 Bilge piping, bilge suctions

8.2.1 Bilge piping are to be so arranged that also with unfavourable trim the bilges can be drained completely.

8.2.2 In craft with watertight subdivisions or subdivided bilges, every bilge pump shall be capable of taking suction from every compartment aft of the forepeak bulkhead.

The pumps are to be connected to a bilge main with branch pipes leading to the compartments. The branch pipes are to be connected to the main via closable non-return valves or equivalent.

8.2.3 The forepeak shall not be connected to the common bilge system. For larger craft, the forepeak should be connected to a suitable power pump which shall not have any direct connection with the common bilge system, e.g. the raw-water or the fire pump. Alternatively the forepeak may be drained to the adjoining compartment aft, through a self-closing valve fitted to the forepeak bulkhead, or by means of a separate hand pump.

8.2.4 If several bilge pumps are connected to a common discharge line, a closable non-return valve or a combination of shut-off fitting and non-return valve is to be provided on the discharge side of each pump.

8.2.5 If several power-driven bilge pumps are fitted, one of these is to have a direct bilge suction device from the machinery space.

8.2.6 Plastic bilge piping is not permitted in machinery spaces. Regarding use of hoses see 2.2.2.

8.2.7 In the arrangement of bilge suction devices the following is to receive attention:

– free access for the bilge water,

– each suction device to have a strainer,

– accessibility for checking and maintenance.

8.3 Overboard connections

8.3.1 It shall be warranted that water cannot enter the craft through the bilge pumping line - even in the event of maloperation. The outlet from the line is to be arranged as high above the waterline as possible and the line is to be run to this via a pipe bend taken up to the deck. If that arrangement is not possible, two non-return devices shall be fitted between the outlet and the inlet (bilge suction). At least one of these devices is to be mounted at the hull.

The outlet at the vessel's side, however, shall always be closable. (See also 3.).

8.3.2 In the case of pumps which can also take a suction from the sea, the impossibility of seawater entering the craft is to be guaranteed by the installation of three-way cocks with L-plugs, angle cocks or similar, into the suction line.

8.4 Arrangement of bilge pumps

The manual bilge pump is to be operable from the steering position/the cockpit. In larger craft the power-driven pump may be operable from the steering position alternatively, if the height of installation of the manual pump would reduce the required output.

9. Fresh water, sanitary installations

9.1 Fresh water system

9.1.1 Walls of tanks for fresh water shall not be walls of fuel or sewage tanks.

9.1.2 If the storage tank is filled via a fixed connection, the bore of the filling pipe is to be used for dimensioning the vent line. If filling is not under pressure, a vent pipe with a nominal bore of 10 mm is sufficient.

9.1.3 Filling connections are to be identified unmistakably.

9.2 Sanitary equipment

9.2.1 General

9.2.1.1 When installing sanitary equipment, the official regulations applicable to the area of operation are to be observed.

9.2.1.2 Sewage discharge lines are to be so arranged or equipped that it is impossible for water to enter the craft from outboard. See also 3.

9.2.1.3 Each sanitary discharge is to have a gate valve or sea cock at the hull penetration. See also 3.

9.2.2 Sewage tanks

9.2.2.1 Vent lines are to be taken out into the open.

9.2.2.2 For the discharge ashore of dirty water and sewage, a discharge line with a threaded deck connection in accordance with ISO 4567 shall be provided.

9.2.2.3 For the discharge lines overboard, 9.2.1 is to be observed.

F. Cooking, Baking and Heating Appliances

1. General

1.1 Galley stoves or cookers operating with liquid fuels shall be provided with save-walls of non-combustible materials. Measures are to be taken to prevent any leaking fuel to spread through the craft.

1.2 Stoves, cookers and heating appliances are to be so installed that undue heating of adjacent structures will not occur.

1.3 For the operation of galley stoves and cookers using liquid fuels, there shall be adequately sized ventilation openings. If such openings are closable a notice shall be fitted at the appliance:

"Ventilation openings are to be kept
open during the use of the stove/cooker!"

2. Heaters burning liquid fuels

2.1 Only fuels with a flash point ≥ 55 °C may be used, unless specially approved by GL.

2.2 Only heaters with closed combustion chamber and air supply and exhaust gas lines tight against the interior of the craft are permitted.

2.3 Heaters which do not fully meet the requirements regarding safety time margin of the DIN standard may be approved if safety of operation is proved in some other way, e.g. explosion-proof design of the combustion chamber and the exhaust gas ducts.

3. Liquefied gas for cooking, heating and cooling appliances

The installation of liquefied gas systems has to be carried out in accordance with ISO 10239. Prospective surveys for acceptance and revisions are subject to national regulations.

For classification purposes the surveys for acceptance as well as the revisions, at intervals not exceeding a period of 2 years, are performed in compliance with GL Rules for Classification.

Surveys, carried out by experts of DVFG [10], will be accepted by GL.

G. Fire Extinguishing Equipment

1. General

1.1 Pleasure craft with accommodation or permanently installed IC engines are to be equipped with portable fire extinguishers suitable for A, B and C class fires according Table 3.2.

[10] Deutscher Verband Flüssiggas

Table 3.2 Classification of extinguishing media

Fire class	Nature of burning material	Extinguishing media
A	Solid combustible materials or organic nature (e.g. wood, coal, fibre materials)	Water, dry powder, foam
B	Inflammable liquids (e.g. oils, tars petrol)	Dry powder, foam, carbon dioxide
C	Gases (e.g. acety-lene, propane)	Dry power, carbon dioxide

Preferably only dry chemical powder extinguishers should be used (see "Note" at the end of G.).

For machinery spaces CO_2 extinguishers are also acceptable. These shall however be stored in a space which shall be gastight against accommodation spaces.

1.2 The charge of an extinguisher shall be at least 2 kg and is not to exceed 6 kg.

1.3 The extinguishers are to be arranged conveniently and with suitable brackets.

1.4 Fire extinguishers are to be checked by an acknowledged expert every 2 years.

1.5 For fighting a fire in the machinery space, a closable inlet opening is to be provided allowing the application of the extinguishing agent without prior removal or opening of parts of the machinery space casing.

1.6 Machinery spaces with IC engines with a total installed power of 375 kW or more are additionally to be equipped with a fixed fire extinguishing system in accordance with 4. The inlet opening required under 1.5 may be omitted in this case.

1.7 For machinery spaces with IC engines up to a total installed power of 375 kW the amount of extinguishing agent determined in accordance with Table 3.2 for permanently installed engines may be reduced by up to 6 kg if a fixed fire extinguishing system in accordance with 4. is fitted.

1.8 Craft with a length **L** of 15 m or more are to be provided with a water fire extinguishing installation in accordance with 3.

1.9 All craft are additionally to be provided with:

– craft up to 15 m: at least one draw bucket

– craft of 15 m and upwards: at least 2 draw buckets

2. Number of fire extinguishers

The number of extinguishers required is to be selected based on the total weight of extinguishing agent, to be determined from the Table 3.3.

Table 3.3

Application	Minimum weight of extinguishing agent [kg]
Inboard engines	
– up to 50 kW	2
– up to 100 kW	4
– over 100 kW	
per extra 100 kW or part thereof	an additional 2
Additionally for craft with accommodation	
– up to 10 m	2
– up to 15 m	4
– up to 20 m	8
– up to 24 m	12

3. Water fire extinguishing installation

3.1 The water fire extinguishing installation is to be so designed that a solid jet of water can be directed to every part of the craft.

3.2 A suitable permanently installed manual pump is to be provided, which with its associated lines and the sea-suction is to be located outside the machinery space.

3.3 Motor yachts are additionally to be equipped with a power-driven fire pump which shall meet the requirements in accordance with 3.1. This pump with its associated lines and the sea-suction may be located in the machinery space. Pumps serving also other water services, e.g. a bilge pump, may be used for this purpose.

If the manual and the power-driven pump are supplying to a common fire main, a closable non-return valve is to be fitted on the discharge side of each connected pump.

3.4 A suitable fire hose of NB 25 with a nozzle of at least 6 mm nozzle diameter and suitable couplings is to be provided. The length of the hose is to be approx. 2/3 of the length of the craft, but not more than 15 m.

3.5 In case of a power-driven pump, the fire main is to be fitted with at least one closable valve with hose coupling fitting the fire hose (fire hydrant) which shall be located on deck.

4. Fixed fire extinguishing systems

4.1 For fixed installations, dry powder or CO_2 may be used as extinguishing agents (see "Note" at the end of G.).

4.2 The quantity of extinguishing agent required to be stored is to be determined as follows, taking into account the size of the space to be protected.

Dry powder:

$$Q = 1{,}0 \cdot V_B \quad [kg]$$

CO_2:

$$Q = 0{,}8 \cdot V_B \quad [kg]$$

Q = quantity of extinguishing agent [kg]

V_B = gross volume of space [m^3]

4.3 Manual release of fixed fire extinguishing systems shall be activated from outside the machinery space.

4.4 Fixed piping with suitable nozzles is to be provided for conveying the extinguishing agent. The nozzles are to be so arranged as to ensure even distribution of the extinguishing agent.

4.5 CO_2 fire extinguishing system

4.5.1 CO_2 cylinders are to be installed with gastight separation from accommodation and accessible machinery spaces.

4.5.2 Automatic release of CO_2 systems is not permitted.

4.5.3 The CO_2 line to the machinery space is to be fitted with a shut-off valve in addition to the cylinder valve. The line between CO_2 cylinder and shut-off valve is to be designed for an operating pressure of $8 \cdot 10^6$ [Pa].

4.5.4 The release arrangement is to be suitably safeguarded against unintentional operation, taking also into account the presence of children on board.

A notice is to be provided at the release position:

"CO_2 fire extinguishing system for machinery space. Before releasing, make sure no one is in the space and all openings are closed."

This text is to be supplemented by brief operating instructions.

4.5.5 A warning notice is to be fixed to the access to accessible machinery spaces:

"This space is protected by a CO_2 fire extinguishing plant. If CO_2 is released there is danger of suffocation; leave space immediately. The space may only be re-entered after it has been thoroughly ventilated."

4.5.6 For larger accessible machinery spaces, provision of an acoustic alarm is recommended which should be activated before the CO_2 system is released.

4.5.7 The system is to be checked by an expert company at intervals not exceeding two years.

Note:

The use of extinguishers containing Halon and the installation of Halon fire-extinguishing systems is no longer permitted.

H. Steering Gear

1. Scope

The following applies to steering gear. This comprises of the steering engine and all elements of the transmission from the steering position to that engine.

2. Design

2.1 Modes of drive

Both, power and manual, drive may be applied. Means of emergency steering are to be provided, e.g. emergency tiller (see also Section 1, A.3.)

Emergency steering drive shall be such as to be readily available. In the case of power steering , it is to be ensured that in the event of failure of the power steering the emergency steering remains operable.

2.2 Steering gear for outboard motors

The outboard motor is to be fitted with a suitable tiller arm for connecting to the steering gear. Twin-engine plants are to have the two engines positively connected.

2.3 Steering gear for "Z"-drives and jet drives

The design of steering gear for these drives is to be agreed with GL.

2.4 Protection against overloading

2.4.1 Power-driven and manual-hydraulic steering gear shall be protected against overload (slipping clutch, safety valve) limiting the torque applied by the drive.

2.4.2 In the case of hydraulic steering gear, also inadmissible torques caused e.g. by grounding of the rudder, etc. are to be limited by safety valves. Safety valves which simultaneously are effective for both the driving and the driven end are permitted.

2.5 Rudder position indication

The midship position of the rudder shall be distinguishable at all times. Power driven steering gear is to be provided with a rudder position indicator.

2.6 Rudder angles

2.6.1 Power steering gear are to be provided with suitable devices (e.g. limit switches) limiting the possible travel such that the admissible rudder angle cannot be exceeded.

2.6.2 Regarding end stops for tillers, quadrants, etc., see Section 1, A.3.

3. Power and dimensioning

3.1 Power

The steering gear is to be so designed that, with the craft at full ahead, "Z"-drives and jet drives can be put from hard-over to hard-over to either side without undue effort.

The time taken for this shall as a rule not exceed 35 s.

3.2 Dimensioning of transmission elements

3.2.1 The stresses arising in the transmission elements shall lie below the yield strength of the materials employed.

3.2.2 For the dimensioning of tillers and quadrants, Section 1, A.3. is to be observed.

4. Testing

4.1 After installation the steering gear is to be submitted to a final survey and performance test.

4.2 In case of hydraulic gear a pressure test at 1,5 times the pressure setting of the safety valve is to be carried out.

I. Anchor Windlasses

1. Scope

The following applies to anchor windlasses required in accordance with Section 1, G.

2. Design

2.1 Driving mode

2.1.1 Manual drive is permissible as primary drive. Hand cranks shall be kick-back proof.

2.1.2 For power-driven windlasses, an emergency drive independent of the primary drive is recommended. If the emergency drive is to be manual, this is to be so arranged that switching-on the power drive cannot cause any danger.

2.2 Overload protection

An overload protection device is to be provided to limit the moment of the driving unit.

2.3 Clutches

Windlasses are to have clutches between chain sprocket and drive shaft.

2.4 Brakes

Windlasses shall be fitted with chain sprocket brakes which guarantee safe braking action and holding power of anchor and chain when the sprocket is unclutched. Furthermore in the case of non-self-locking gear, means are to be provided which prevent the chain from running out, if the drive fails with the chain sprocket clutched.

2.5 Chain sprockets

Chain sprockets shall have at least 5 teeth.

3. Power and dimensioning

3.1 It shall be possible to raise the threefold weight of the anchor at a mean speed of 3 m/min. In the case of manually driven windlasses, a manual force of 15 kg at a crank radius of about 35 cm and a cranking rate of about 30 rev./min is not to be exceeded.

3.2 The drive's capability of delivering a short-duration overload for breaking-out the anchor is to be ensured.

3.3 The dimensioning of the transmission elements is to be carried out in accordance with standard engineering practice.

J. Operating Instructions, Tools, Spare Parts

1. Operating instructions

The necessary operating and maintenance instructions for machinery and ancillary equipment shall be available on board.

2. Tools

Sufficient tools are to be carried to allow for simple repair or maintenance work to be carried out as described in the operating and maintenance instructions.

3. Spare parts

3.1 Craft of operating categories III and IV and beyond are to carry at least hose clips, V-belts and half a charge of engine lubricating oil as spares.

3.2 If extended voyages are intended, the operator is additionally obliged to supply tools, accessories, consumables and spares on board in accordance with requirements.

The recommendations of component manufacturers are to be taken into account.

Section 4

Electrical Installations

A. General

1. Scope

1.1 These construction rules apply to the craft's wiring systems up to an operating voltage of 50 V, whatever the class or type of craft.

GL reserve the right to permit deviations from these rules on an individual case basis, or to make special demands in the case of novel installations or equipment.

1.2 If the rated voltage of the installation is more than 50 V or parts of the electrical installation are operated at a voltage higher than 50 V, the current Rules for Classification and Construction, I – Ship Technology, Part 2 – Inland Waterway Vessels, Chapter 3, are to be applied as appropriate. As regards the shore connection for shoreside voltages exceeding 50 V, reference is made to F.6.

1.3 These rules apply to permanently installed electrical systems and equipment.

2. Rules and standards

Where specifications for electrical installations and equipment are not provided in these rules, the application of other rules and standards will be agreed if appropriate. Amongst these are (e.g.) the publications of the IEC, particularly all IEC-92 publications.

As well as the GL Rules, existing national rules and regulations are to be observed.

3. Principle requirements

3.1 Dimensioning of components

All parts shall be designed to meet the special operating stresses due to (e.g.) craft motion, heel, trim, vibration and be protected against moisture and corrosion.

3.2 Environmental conditions

Trouble-free operation of the electrical installation is to be ensured under:

– continuous heel of up to 15°

– short time heel of up to 30°

– short time longitudinal inclinations of up to 20°

– ambient temperature up to 45 °C

For pleasure craft intended to operate only in restricted areas, GL may permit deviating conditions.

B. Approval Documentation

The documentation listed below is to be submitted in triplicate for approval before construction starts:

1. Form F 145

Information about extent and type of the electrical installation on Form F 145 (the form can be obtained from GL).

2. General circuit diagram

A general circuit diagram of the electrical installations showing the basic systems for power generation, energy storage and distribution with output data for generators, storage batteries, users including their fuses and the associated cable types and cross sections.

Any non-standard symbols used are to be explained in a key.

All documents are to be indicated with the hull number and the name of the shipyard.

C. Protective Measures

1. General

1.1 Materials for electrical machinery, cables and other electrical components must be capable of withstanding humid air and sea water mist, sea water and oil vapour. They must not be hygroscopic; shall be hard to ignite and self-extinguishing.

For areas where sea air need not be taken into account, appliances designed to Industrial Standards may be used.

2. Protection against foreign bodies and water

2.1 The grade of protection of electrical components against foreign bodies and water shall be suitable for the location where they are installed.

2.2 In the compartments listed below, the minimum grade of protection considered for electrical components shall be:

– machinery spaces, operating spaces: IP 23

– below deck, living spaces, cabins: IP 20

– enclosed steering position: IP 23

– open deck, open steering positions: IP 55

– appliances which may be flooded: IP 56

– ventilation fan shafts to the open deck: IP 44

– storage battery spaces; lockers; boxes: IP 44

2.3 The grades of protection are to be ensured by the appliances directly or by appropriate constructional measures when installing them.

2.4 Regarding protective systems for appliances in spaces where an explosive atmosphere may build up, see 3.

3. Explosion protection

3.1 In enclosed or semi-enclosed spaces housing petrol engines or petrol containers, all electrical equipment shall be ignition protected (Explosion-group IIA, temperature class T 3) if their installation there cannot be avoided. This includes electric starters and generators; excluded are outboard motors in well-ventilated trunks.

3.1.1 If it is not possible to use fully ignition protected appliances, the machinery space is to be pre-ventilated using electric-motor driven ventilation fans. The fan output is to be such as to ensure at least a five times air exchange. Only after that the petrol engine may be started.

Preferably an interlock is to be provided between the fan motor and the petrol engine starter, which ensures that the latter can only be operated once the above-mentioned condition for the pre-ventilation of the machinery space has been fulfilled. Alternatively a plate shall be displayed in a clearly visible place, e.g. the engine control position, with the inscription:

> **ATTENTION! EXPLOSION HAZARD!**
>
> **Before starting the engine, the machinery space is to be ventilated for at least ..... minutes!**

The length of ventilation time to be inserted in the above text shall be calculated from the machinery space volume and the fan output.

In installations where pre-ventilation is obligatory, it shall be ensured that after a short interruption (possibly reversing) the propulsion engines of the craft can be started again without delay.

3.1.2 If the ventilation fans described under 3.1.1 above are installed in the machinery space, they must be ignition protected. Fans whose electric motor is not ignition protected shall be fitted outside the machinery space and outside the ventilation duct.

3.2 Electrical components must not be fitted in stowage spaces for gas cylinders for heating and cooking.

4. Protection against lightning

It is recommended that a lightning protection system be fitted.

For notes regarding design and construction see Annex F.

D. Electrical Machinery

1. General

1.1 All motors and generators must meet a standard accepted by GL, provided no special data are contained in the rules that follow.

1.2 Terminals must be located in an easily accessible position and dimensioned in accordance with the cross-section of the cable to be connected. The terminals are to be clearly identified.

1.3 Each generator and motor is to have a manufacturer's name- and capacity plate fitted which contains all important operating data as well as the manufacturing number.

E. Storage Batteries

1. General

1.1 These rules apply to permanently installed storage batteries.

1.2 Storage batteries shall be so made that they retain their rated capacity up to an inclination of 22,5° and leakage of electrolyte is prevented up to 40° of inclination (50° in the case of sailing yachts). Cells without covers are not permitted.

1.3 Storage battery ratings are to be shown on a rating plate.

2. Location

2.1 Storage batteries are to be so located that escaping gases or electrolyte can neither endanger persons nor damage equipment.

2.2 Storage batteries must not be located where they are exposed to unacceptably high, or also low, temperatures, spray or other influences which might impair their ability to function or reduce their service life. The minimum protective grade to be provided is IP 12.

2.3 When locating the storage batteries, the output of the associated chargers is to be taken into account. The charging capacity of the batteries is to be calculated from the charger maximum current and the battery rated voltage.

Depending on operating mode, service and utilisation of the storage battery to be charged and the nature of the charging process (charger characteristic), following agreement with GL, the maximum current may be deviated from as the basis for calculation of the charging capacity.

If several storage batteries are assembled in one place, the sum of their charging capacities is to be used as the basis.

2.4 Storage batteries with a charging capacity of up to 2 kW may be located below deck, open in a well-ventilated locker or housing.

2.5 Storage batteries with a charging capacity of more than 2 kW, if located below deck, are to be housed in an enclosed locker/housing or compartment, with ventilation supply and -extraction to the open deck (see also 4.4.).

2.6 Storage batteries shall be safeguarded against slipping. Straps or supports must not impair ventilation.

3. Equipment in battery compartments

3.1 Lights, ventilation fan motors and space heaters in battery compartments shall be ignition protected. The following minimum requirements are to be met:

– Explosion Group II C

– Temperature Class T 1

3.2 The internal walls of battery compartments, boxes and lockers including all supports, troughs, containers and racks shall be protected against the damaging effect of the electrolyte, should an escape of electrolyte be possible.

4. Ventilation

4.1 All battery compartments, lockers and boxes must be so constructed and ventilated that any build-up of ignitable gas mixtures is prevented.

4.2 The ventilation supply and exhaust openings are to be so arranged that there is a flow of fresh air over the entire battery.

4.3 Fittings impeding the free passage of air, such as flame arrestors and Davy screens must not be installed in battery compartment air supply and exhaust ducts.

4.4 If batteries are operated exclusively in parallel or switch-selected with the supply system, battery compartments, containers or lockers may be naturally ventilated provided the charging capacity does not exceed:

– 3 kW in the case of lead-acid batteries

– 2 kW in the case of nickel-cadmium batteries

even under boost charging conditions.

If that charging capacity is exceeded, forced ventilation is to be provided.

4.5 The minimum volume of air to be extracted is

$$Q = 0{,}11 \cdot I \cdot n$$

Q = the volume of air extracted in [m^3/h]

I = strength of current according to charger characteristic, but at least 1/4 of the maximum current of the charging system or of the charging current reduced in accordance with 2.3.

n = number of cells in the battery.

4.6 In case of natural ventilation, the conditions of 4.5. are considered being met if ducts are rated as set out below, where an air velocity of 0,5 m/sec is used as a basis.

The slope of the ducts must not exceed 45° to the vertical.

4.7 For forced ventilation, a suction fan is to be used preferably. The fan motors shall either be ignition protected (see 3.1.) and electrolyte-proof, or be located outside the area of danger (preferred solution).

The fan impellers shall be of a material which does not create sparks if it touches the casing, and which does not conduct any static charges.

The ventilation systems shall be independent of those of other compartments.

4.8 Where battery charging and switching-on of the ventilation fan are automatic when charging starts, continued ventilation is to be ensured for at least one hour after charging has ended.

Table 4.1 Cross-section of extraction air ducts

Charging capacity P [Watts]	Cross section of extraction air ducts [cm²]	
	Lead batt.	Ni-cad batt.
P < 1000	80	120
1000 ≤ P ≤ 1500	120	180
1500 < P ≤ 2000	160	240
2000 < P ≤ 3000	240	Forced ventilation
P > 3000	Forced ventilation	

4.9 Where sealed-cell batteries with internal oxygen consumption are used exclusively, the outgoing air duct cross sections may be reduced by half.

5. Miscellaneous

5.1 Charging devices have to be provided which are able to charge the batteries within 10 hours up to 80 % of the battery capacity.

5.2 Storage batteries are to be protected against discharge by reverse current by suitable means in the charging system, and against short circuits by fuses nearby. The fuses must however not be fitted in the battery container or compartment itself. Regarding battery switches see F.3.

5.3 Installation of the appropriate measuring instruments for indicating battery voltage and charging and discharging current is recommended.

The functioning of generators is to be monitored.

5.4 The battery capacity must be designed to be sufficient to supply important users (e.g. navigation lights) for at least 8 hours without a boosting charge.

5.5 Where IC engines are fitted which cannot be started manually, provision of separate batteries for starting and for general use is recommended.

F. Distribution Systems

1. General

1.1 Only those systems are permitted in which all operationally current-carrying conductors are laid insulated. Hull-return systems are only allowed for locally restricted installations, e.g. the electrical equipment of IC engines.

1.1.1 If it is intended to earth the on-board mains, the negative pole of the power supply is to be earthed centrally and open to checking.

Possible earths are the metal hull of the craft, a metal ballast keel not laminated-in or an earthing plate located submerged.

In this context, notes regarding the corrosion protection required for metal components located on the submerged part of the hull (Section 1, F.) are to be observed.

1.1.2 The standardised voltages 12 and 24 V are preferably to be used for the general on-board mains.

2. Switchboards and switchgear

2.1 Switchboards and switchgear locations are to be easily accessible.

2.2 Switchboard housings are to be made of metal or of a hard-to-ignite and self extinguishing material.

3. Fuses and switches

3.1 A main switch for disconnecting the on-board mains batteries is to be provided close to these. The length of cable between batteries and main switch shall be as short as possible.

3.2 Each generator shall be provided with short-circuit and overload protection.

Deviations are permissible for small installations, comprising of a dynamo and associated governor.

3.3 Fuses acting as overload and short-circuit protection are to be provided in the main switchboard or the distribution boards on the positive pole for each consuming device or user group and in pleasure craft with metal hulls in each non-earthed conductor. Provision of a switch to disconnect the mains is recommended for every user outlet protected by fuses. Fuses are to have an enclosed fuse link.

For non-fused battery outlets, e.g. starter cables, see 4.7.

3.4 Operationally important users are to be individually fused in principle, and if necessary individually switched.

3.5 Position lights and other lights significant for navigation shall be fused and able to be switched independently from other users, at least as a separate group.

4. Cables, lines and laying them

4.1 Cables and insulated lines shall be of a GL-approved make. Examples of such are:

a) cables and lines according to IEC-92 or DIN 89150 and made in accordance with the standards and rules quoted in these.

b) VDE- and DIN types of lines, e.g.:
   - HO7 RN-F in accordance with DIN 57282 VDE 0282
   - HO5 VV-F in accordance with DIN 57281 VDE 0281
   - HO7 V-K in accordance with DIN 57281 VDE 0281
   - YSLY or NYSLY
   - YSLYCY or NYSLYCYÖ

The conductors in the cables must be of electrolytic copper and multi or fine stranded.

4.2 Cables and lines must not be loaded and fused above the values given in Table 4.2.

In the case of lengthier cable runs, permissible voltage-drops are to be taken into account.

Permanently installed power cables shall have a minimum cross sectional area of 1,5 mm^2; control cables of 0,75 mm^2.

Table 4.2 Conductor cross-sectional area, allowable continuous current and stranding

Cross-sectional area mm^2	Maximum current, in amperes, for single conductors at insulation temperature ratings						Minimum number of strands	
	60 °C	70 °C	85 °C to 90 °C	105 °C	125 °C	200 °C	Type 1 [1]	Type 2 [1]
0,75	8	10	12	16	20	25	16	—
1	12	14	18	20	25	35	16	—
1,5	16	18	21	25	30	40	19	26
2,5	20	25	30	35	40	45	19	41
4	30	35	40	45	50	55	19	65
6	40	45	50	60	70	75	19	105
10	60	65	70	90	100	120	19	168
16	80	90	100	130	150	170	37	266
25	110	120	140	170	185	200	49	420
35	140	160	185	210	225	240	127	665
50	180	210	230	270	300	325	127	1 064
70	220	265	285	330	360	375	127	1 323
95	260	310	330	390	410	430	259	1 666
120	300	360	400	450	480	520	418	2 107
150	350	380	430	475	520	560	418	2 107

[1] Conductors with at least type 1 stranding shall be used for general craft wiring. Conductors with type 2 stranding shall be used for any wiring where frequent flexing is involved in use.

4.3 Cable cross sections for the electric starters of IC engines are to be dimensioned in accordance with the data furnished by the engine manufacturer.

Table 4.2 gives allowable continuous current ratings in amperes determined for 30 °C ambient temperature.

For conductors in engine rooms (60 °C ambient), the maximum current rating in Table 4.2 shall be derated by the factor below:

Table 4.3

Temperature rating of conductor insulation °C	Multiply maximum current by
70	0,75
85 to 90	0,82
105	0,86
125	0,89
200	1

4.4 The voltage drop between power source and consuming device must not exceed 7 %; for navigation lights 5 % respectively.

4.5 Cables and lines are to be so laid and fastened that the movements of the craft cannot cause them to shift, and that they are not exposed to unacceptable ambient temperatures.

They are to be laid at a safe distance from exhaust ducts and other sources of heat.

4.6 Non-fused cables, e.g. battery cables, are to be laid safe from short circuits, i.e. they must be laid in such a way that the possibility of a short circuit can be excluded even if the insulation should fail.

4.7 Multi-core cables or lines are preferably to be used.

4.8 Cables and lines must be hard-to-ignite and self-extinguishing.

5. Cable accessories and installation material

5.1 Cable and line connections shall, in principle, be made by using terminals with core protection, or via screwed connections by means of crimped lugs. Soldered connections must not be used.

5.2 Cable feed-throughs passing decks and watertight bulkheads shall have stuffing boxes or be sealed by means of a GL-approved pourable sealing compound.

6. Shore connection

6.1 Shore connection voltage ≤ 50 V

On-board mains voltage ≤ 50 V

The connection on board is to be made via a plug and socket. Protection shall be in accordance with C.2. but at least IP 23.

An information plate is to be fitted with data on permissible supply voltages, frequencies, current type and amperage.

The shore connection is to have overload and short circuit protection. There must be an indication whether the connection is live.

6.2 Shore connection voltage > 50 V

On-board mains voltage ≤ 50 V

Additionally to 6.1, a galvanic separation is to be fitted between shore and on-board mains, and the plug and socket shall have an earthing contact.

6.2.1 If individual users are fed at voltages exceeding 50 V via the shore connection, an earth-leakage circuit breaker shall be provided between the on-board plug and socket and the downstream users. The fault earth-leakage circuit breaker shall switch off the entire system if a rated fault current $I_{\Delta n} \leq 30$ mA is reached.

G. Spares

1. Spares

It is recommended that the following spares be taken on board:

1 set of electric bulbs for navigation lights

1 set of fuses unless all appliances are protected by automatic cut-outs.

Section 5

Safety Requirements

A. Technical Requirements for Ship Safety

1. General

1.1 The requirements defined hereinafter are to be checked by calculation and/or by trials with the prototype craft in the fully loaded ready for use condition. Trials are to be carried out under the supervision of a GL surveyor.

Details regarding the execution of the trials are laid down by GL Head Office.

1.2 Requirements/instructions in other Sections of these Rules based on the Operating Category are to be observed.

2. Maximum dead-weight

For all sorts and types of craft and in all Operating Categories, the maximum dead-weight "Z_{max}" derives from the displacement "D" at minimum freeboard subtracting the craft's lightweight "E":

3. Number of persons

There is a recommendation in Annex H for the number of persons in relation to the space available on board.

4. Freeboard

The freeboard derives from the maximum draught for which the stability of the craft has been proven. A relevant recommendation is listed in Annex H.

5. Closure condition

5.1 All openings, cut-outs, passages, etc. in the shell must be designed to be closed by means of suitable devices, fittings, etc. that no water can enter the inside of the craft. This does not apply to cockpit drain pipes.

5.2 Doors, hatch and ventilation duct covers plus their hinges, lock tumblers and securing arrangements must be adequately dimensioned. Details are to be submitted for approval.

5.3 All doors and escape hatches [1] must be operable from both sides.

5.4 Regarding in- and outlet fittings on the shell for the cooling- and bilge water and sewage lines, see Section 3, E.3.

5.5 A closure plan report in accordance with GL Form F 434, showing all openings, cut-outs, passages, etc. in deck and shell is to be submitted in triplicate for approval before the start of construction.

6. Openings and closures in hull, deck, cockpit and superstructure

The following is required:

Component	Requirements	
	Operating Category I, II	Operating Category III, IV, V
Deck hatches	[1] [3]	[2] [3]
Cockpit hatches	[1]	[2] [3]
Sliding covers	[2] [3] [9]	[2] [3]
Cabin access	[2] [5]	[2] [4]
Ventilation ducts for accommodation	[2] [7]	[2] [3]
Ventilation ducts for Machinery space	[2] [3] [6] [7]	[2] [3] [6]
Air pipes	[2] [3] [6]	[2] [3] [6]
Centreboard case	[1]	[2] [8]
Hawsepipe	[2]	[2]

[1] Weathertight closure

"Weathertight" means that whatever condition of the sea arises, no water can penetrate into the craft. Weatherthightness is to be checked by spraying the closure from outside using a conventional water hose, from a distance of about 2,0 m (minimum jet pressure 1 bar).

1 Regarding arrangement and size of escape hatches see B.5.3.

[2] Spraytight closure

"Spraytight" means that no major quantities of water can penetrate into the craft as a result of short-time immersion. Spraytightness is to be proven by shooting water from a bucket onto the closure from a distance of about 2 m.

[3] Craft unable to use sails or sail-like means for propulsion:

– all openings liable to become submerged over a heeling range from 0 to 50° shall, if the situation requires, be made weathertight to ensure a stability range up to 50°

– craft with a stability range of less than 50° are not excluded from this measure.

Craft able to use sails or sail-like means for propulsion:

– all openings liable to become submerged over a heeling range from 0 to 90° shall, if the situation requires, be made weathertight to ensure a stability range up to 90°

– craft with a stability range of less than 90° are not excluded from this measure.

"Sails or sail-like means"

Aerodynamic means of propulsion which as a rule cause significant heeling moments which must be taken into account for stability and its assessment.

[4] Height of coaming at least 50 mm.

Removable coamings of craft in Operating Category III must meet the requirements under [5].

[5] The heights of the coamings of the doors leading to the spaces below decks must not be less than the following values.

Position	**Motor craft** **Coaming height [mm]**	**Sailing craft and motorsailer** **Coaming height [mm]**
In side- and back walls, accessible from main deck	150	150
In back walls, accessible from cockpit	380 above cockpit floor	460 above cockpit floor
anywhere if this access leads directly into the spaces	460	460

Removable coamings in door openings are to be capable of being secured in place.

[6] May only be located above the main deck in a sheltered place, so that even in bad weather the engines can be kept going for as long as possible.

[7] Shall be capable of being closed weathertight (e.g. canvas cover) in the event of heavy weather.

[8] The safety gap from the flotation plane to the lowest point not watertight shall be at least 100 mm. Parts of the centreboard case above that level are to be made spraytight.

[9] May only be located on a superstructure or deckhouse.

Hatches with sliding covers in the forward part of the craft shall have a coaming height of 150 mm above the superstructure

7. Windows, skylights and port lights

7.1 In any case windows opening into enclosed spaces shall be watertight and adequately dimensioned for the intended Operating Category.

Machinery space windows must be fixed ones.

7.2 Windows in the hull which can be opened must be kept closed when at sea. Where the craft is used for commercial purposes or for public use, this must be suitably ensured.

The bottom edge of windows in the hull shall be at least 500 mm above the flotation plane.

Windows in the hull are not permitted in machinery spaces.

7.3 Deadlights are to be carried on board for all windows in the hull, windows in walls facing forward and those whose surface area exceeds 0,20 m^2. If there are windows of the same size on the port and the starboard side, deadlights are only needed for one side.

Deadlights may be dispensed with if:

– glass thickness is twice that required under 7.7, or

– the craft is due to operate in category IV and the windows are above the weather deck, or

– the craft is due to operate in category V.

7.4 Window panes shall preferably be made of toughened or tempered safety glass ("ESG"), but laminated glass ("MSG"), acrylic and polycarbonate sheet material or equivalent material may also be used.

Machinery space window panes in deckhouses must be of toughened/tempered safety glass; if not, an external deadlight shall be provided.

In Operating Categories I and II, plastic panes shall be UV-stabilised.

7.5 Hull windows with silicate glass ("ESG", "MSG") panes shall have metal frames which can be tightly bolted to the shell. The bearing width of the glass against the frame must be at least 6,0 mm.

Panes of acrylic or polycarbonate sheet material are to be fixed by frames. They may also be bolted directly to the shell or external wall, provided the bolting is capable of resisting the stresses arising and guarantees lasting water-tightness. The bearing width of the glass is to be 3 % of whichever is the shortest side of the pane, but at least 20 mm.

Designs offering equivalent safety are permitted. The strength is to be proven by tests and/or calculation.

7.6 Rubber clamping sections may be used only in Operating Categories IV and V, provided the shorter side of the window is no longer than 300 mm and the corner radius is at least 50 mm.

7.7 The window glass thicknesses are to be determined as follows:

$$t = n \sqrt{\frac{F \cdot F_b}{y}} \quad [mm]$$

F = surface area of pane in [m²]

F_b = freeboard in accordance with Annex H in [m]

y = height of window centre above flotation plane in [m]

n = factor in accordance with Table below

t_{min} = minimum thickness, see Table below

7.8 Only acrylic or polycarbonate sheet material may be used for skylights and hatches. The thickness of the panes in these must be 25 % greater than that of the shell windows or forward facing windows in accordance with 7.7, but at least 7,0 mm.

7.9 Port holes are treated like windows.

8. Cockpit

8.1 Cockpit floor plus longitudinal and transverse walls count as primary structural members, the scantling of which shall be in accordance with Section 1. Cockpits shall be watertight to the inside of the craft.

8.2 Regarding closures and coaming heights of hatches and doors of adjoining storage and living spaces, see 5. and 6.

8.3 The cockpit floor must be sufficiently high above the flotation plane to drain water that has entered immediately through drain pipes or clearing ports under all foreseeable states of heel and trim of the craft.

8.4 Each cockpit shall be provided with at least one drain pipe each side. The total cross section of the pipes on both sides shall be determined as follows:

V = cockpit volume in [m³] measured to top edge of cockpit coaming at its lowest point.

The total cross section of all drain pipes may not be less than:

f_{min} = 25,0 cm² in Operating Category I

f_{min} = 12,5 cm² in Operating Categories II and III

f_{min} = 10,0 cm² in Operating Categories IV and V

The cross section values determined are also required in the area of any strainers that may be present.

Window type and position	**Pane material**	**n**		**t_{min} [mm]**
		Operating Category I, II, III	**Operating Category IV, V**	
Hull- and forward facing windows of cabins and superstructure	"ESG"	12,0	11,0	6
	Polycarbonate	15,6	14,0	5
	Acrylic "MSG"	18,0	16,0	5
Windows in rear walls or recessed sidewalls of cabin and superstructure	"ESG"	9,6	8,6	4
	Polycarbonate	12,5	11,0	5
	Acrylic "MSG"	14,4	13,0	5

8.5 Cockpits extending all the way across the craft must have clearing ports or drain pipe cross sections in accordance with 9.2.

8.6 Cockpit drain pipes shall be equal in strength to the surrounding hull.

Cockpit drain pipes may only be replaced by hoses with special permission.

Valves in cockpit drain pipes must be kept permanently open.

8.7 Short hose sleeves are permissible under the following conditions:

– the distance between sleeve and waterline shall be at least 100 mm.

– The sleeve shall still be above the waterline with the craft heeled 15°.

– The hose used shall be in accordance with DIN 20022.

– Two corrosion resistant clips are to be fitted at each end of the sleeve.

9. Deck drainage

9.1 An adequate number of outlets or scuppers shall be fitted to allow water to drain from the weather deck(s).

9.2 If a bulwark is envisaged, this must have sufficient clearing ports of adequate size. The clear opening A of all the ports on one side of the craft is to be determined in accordance with the following formula:

ℓ = length of bulwark in [m] of one ship's side

h = height of bulwark in [m]

9.3 The clear opening of the clearing ports in a superstructure bulwark shall not be less than 50 % of the opening determined in accordance with 9.2.

9.4 The bottom edges of the clearing ports and bulwark cut-outs are to be as close to the deck as possible. If the clear height of a port or cut-out is more than 230 mm, a rail is recommended as protection against falling overboard.

9.5 Deck drain pipes shall match the surrounding hull in strength.

Deck drain pipes may only be replaced by hoses with special permission.

Valves are not permitted in deck drain pipes.

9.6 Short hose sleeves are permitted. The conditions in accordance with 8.7. are to be observed.

10. Guardrails, guardrail stanchions, bow and stern pulpits

10.1 Specification

Depending on Operating Category and craft size, each craft shall be fitted with guardrails meeting the following specification:

Operating Category	**Guardrail height [mm]**	**Specification and remarks**
I II, III, IV	600	for craft whose **L** ≥ 8,0 m [1] [2] [3] [4] [5]
I II, III, IV	450	for craft whose **L** < 8,0 m [1] [2] [4]
V	450	for decked craft with cabins & superstructures with **L** ≥ 6,0 m [2] [4] [6]

[1] Guardrails plus bow and stern pulpits provide the required degree of safety only if the adjoining surfaces are also safe to walk on in all foreseeable situations.

On each side of the craft there shall be a passageway of sufficient width and with a non skid surface, plus a toerail at least 20 mm high along the deck edge.

[2] Guardrail stanchions must not be more than 2,15 m apart.

[3] The distance between rails, and from rails to deck, must not exceed 300 mm.

On each side of the craft, the rails in way of the cockpit shall have slipping arrangements, adequately sized and simple to operate.

If a stern pulpit is not needed, the rails in a sailing craft shall run from the bow pulpit to the cockpit after edge and around the back of the cockpit.

[4] Bow pulpit required

[5] Stern pulpit required

[6] Guardrails are not needed if other safety arrangements appropriate to the craft type are provided. These include handrails and handholds on the cabins.

10.2 Required component dimensions

Guardrails shall consist of multi strand steel wire. The minimum thickness of the top rail shall be at least 4 mm. The thickness of the lower rails may be reduced by 40 % but must not be less than 3 mm dia.

Guardrail stanchions and pulpits shall have the following minimum section modulus at the foot:

$$W = c \cdot \frac{h}{R_{eH}} \left[cm^3\right]$$

c = 300 a + 100

c_{min} = 400

a = stanchion spacing in [m]

h = stanchion height in [m]

R_{eH} = yield stress of material in [N/mm²]

Stanchion feet and pulpits must be bolted through or welded down.

'Plug-in' stanchions and pulpits shall have the feet secured.

11. Flotability, reserve buoyancy

11.1 Open and partially decked craft shall be capable of remaining afloat with max. deadweight when swamped, and have enough reserve buoyancy to serve as flotation aid for the occupants. A reserve buoyancy in the swamped condition of at least 15 kg per person is to be provided.

11.2 The buoyant chambers necessary to provide the reserve buoyancy shall be permanently installed and should be foam filled. If not foam filled, they shall comprise of at least two separate cells and shall demonstrate watertightness.

12. Required and permissible engine power

12.1 The safe handling of pleasure craft presupposes a certain minimum power of the propulsion engines. For craft with inboard engines and fixed pitch propellers, the following minimum powers are recommended:

Type of craft	Minimum power in kW per 1,0 m³ of displacement
Sailing craft with V ≤ 2,25 m³	2,20 + (2,25 – V) 1,65
Sailing craft with V > 2,25 m³	2,2
Motorsailers with V ≥ 2,25 m³	3,0
Motor yachts	4,50
V = in accordance with Section 1, A.1.	

12.2 A maximum permissible engine power may be stated for motor yachts and motor boats if this is necessary for the safety of the craft.

B. Fire Protection

1. General

1.1 To prevent a fire from starting as well as from spreading, preventive measures shall be taken in the area of possible sources of fire.

Possible sources of fire are

- machinery
- electrical installations and appliances
- heating and cooking appliances

1.2 Installation of the machinery and the electrical gear in accordance with Sections 3 and 4 of these Rules already provides a certain basic level of required fire protection measures.

1.3 Compliance with the GL Rules which follow, preventive maintenance of the appliances and installations by the owner and the operator of the craft, plus the latter's prudent behaviour and regular checks will contribute to reduce the risk of a fire to a minimum.

2. Paintwork, insulation, etc.

2.1 Paintwork/topcoats in machinery spaces must be hard-to-ignite, e.g. in accordance with DIN 4102.

2.2 Material used for the insulation of machinery spaces shall be at least hard-to-ignite. The surface of the insulation towards the machinery space shall be oil repellent.

2.3 In motor yachts whose propulsion power > 400 kW, incombustible material - e.g. in accordance with DIN 4102 (A) - is to be used for insulating the surfaces of the principal partitions, which should in its effect correspond to a B-15 insulation in accordance with Reg. 3, Chapter II-2, **SOLAS 74**.

Principal partitions shall be gastight in addition.

Note

A principal partition is the partition (bulkhead or deck) between machinery space on one hand and the steering position or cabin above or adjoining on the other.

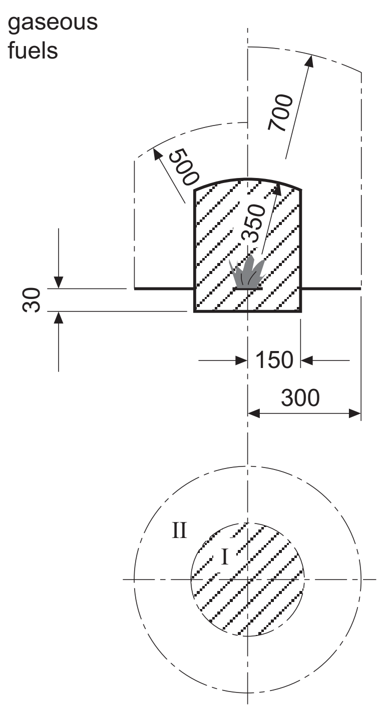
3. Ventilation systems

3.1 In craft whose propulsive power > 400 kW, all machinery space ventilation inlets and outlets shall be able to be closed from the outside.

3.2 If machinery space fans are power driven, it must be possible to switch them off from outside the space.

4. Open flame cooking appliances

4.1 Materials and surfaces of components in the vicinity of an open flame cooking appliance must meet the requirements of the illustration below.



Dimensions in [mm]

I. Incombustible material

II. Approved surface material with low flame-spread

4.2 Drip trays shall be arranged underneath open flame cooking appliances using liquid fuel.

4.3 Self extinguishing materials are to be used for net curtains and other curtains.

4.4 Cooking and heating appliances shall be mounted so as to be safe under the loads arising from sea motion. They may be gimballed or semi-gimbal mounted.

4.5 Cooking and heating appliances in which gas for domestic purposes is used (e.g. propane, butane), liquefied under pressure, shall comply with the regulations in Section 3, F. of these Rules.

5. Escape routes and emergency exits

5.1 Cabins or deckhouses of craft whose **L** ≥ 7,5 m shall have at least two escape routes, if this is practicable.

5.2 For craft whose length **L** is less than 7,50 m, emergency exits are recommended.

5.3 Emergency exits shall lead to the open deck and shall meet the following requirements:

– minimum size 400 × 400 mm clear width

– closures on hatches or on the skylights or side windows unable as emergency exits must be operable from both sides.

C. Stability

1. Stability

1.1 Adequate stability of the craft shall be proven. Insofar as rig, craft type and propulsive installation do not demonstrate any unusual characteristics, the criteria listed below are used for determining stability. Legal national regulations beyond these may also have to be complied with. Craft whose scantling length **L** ≥ 10,00 m shall have their proof of stability based on an inclining experiment; the test is to be supervised by a GL surveyor.

Note

Smaller boats in particular may have their stability endangered under unfavourable circumstances in spite of remaining within the stated limiting values for stability. Good seamanship is therefore an essential prerequisite for a stability secure craft.

1.2 Criteria to be used

1.2.1 Craft with a scantling length L < 10,00 m also open craft

1.2.1.1 Motor craft

An angle of heel of 12° shall not be exceeded with the craft under the combined influence of the centrifugal moment from a turning circle manoeuvre and a personnel moment, in accordance with the following formula:

$$M = 0{,}25\,\mathbf{D}\cdot\frac{v^2}{\mathbf{L}}\cdot(0{,}7\,\mathbf{H}-0{,}5\,\mathbf{T})+n\,(0{,}2\cdot\mathbf{B}+0{,}10)\quad[\text{kN}\cdot\text{m}]$$

v = speed in [m/s]

n = number of persons on board

D, L, H and **T** in accordance with Section 1, A.1.5.

1.2.1.2 Sailing craft (including motorsailers) without ballast keel

An angle of heel of 30° shall not be exceeded when the craft is exposed to a heeling moment due to lateral wind pressure in accordance with the following formulae:

$$M = 0{,}07\cdot S\cdot z - 0{,}35\cdot n'\cdot\mathbf{B}\quad[\text{kN}\cdot\text{m}]$$

$$S = 0{,}5\,(I\cdot J + P\cdot E)\quad[\text{m}^2]$$

S = sail area [m²]

I = height of foresail triangle [m]

J = base of foresail triangle [m]

P = length of mainsail luff [m]

E = length of main boom [m]

z = distance between centre of lateral resistance and centre of effort of sails [m], see Fig. 5.1

n' = $2\cdot n_{Luv} - n$

n_{Luv} = maximum number of persons for whom there is space on the windward side, but not more than n

n = number of persons on board

In the case of other types of rigs or sail plans the sail area is to be calculated as appropriate.

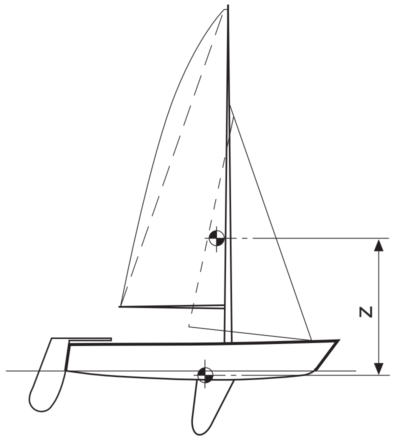


Fig. 5.1

If water can penetrate into the craft through unprotected openings at an angle of heel < 30°, the permissible angle shall be reduced appropriately.

If there are devices - e.g. a trapeze - permitting a reduction in the resultant heeling moment beyond what is already allowed for in the second part of the formula, this may be taken into consideration.

1.2.1.3 Sailing craft (including motorsailers) with a ballast keel

An angle of heel of 30° shall not be exceeded when the craft is exposed to a heeling moment due to lateral wind pressure in accordance with the following formula:

For S, z see Fig. 5.2 and 1.2.1.2.

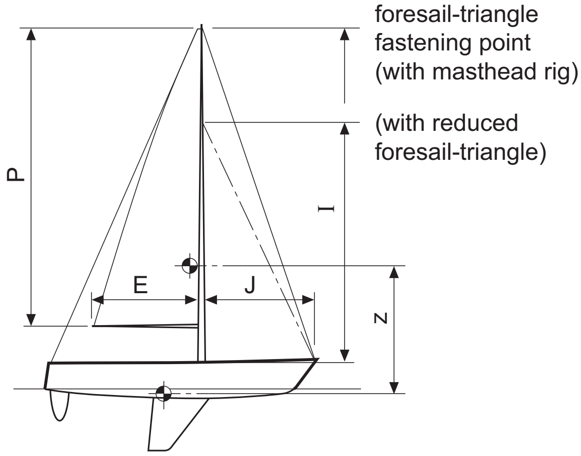


Fig. 5.2

The righting moment of the craft in the ready for use condition without personnel at 90° of inclination shall not be less than:

D = displacement in [t]

1.2.1.4 For craft with a scantling length **L** < 10,00 m, the proof of adequate stability may be provided by calculation or by experiment.

1.2.2 Craft with scantling length L ≥ 10,00 m, decked craft

1.2.2.1 Motor craft

– GM ≥ 0,35 m

– righting lever at 30° inclination ≥ 0,20 m

– stability range ≥ 60° (not for multi hull craft)

– area under lever arm curve up to 30° inclination ≥ 0,055 m · rad

– turning circle angle of heel ≤ 12°, to be determined by turning trials

During the trials the speed is to be increased in steps until either the turning circle angle of heel reaches 12° or the maximum speed is attained.

The proof of adequate stability shall be provided for the craft in the fully loaded ready for use condition with

– full crew

– full set of stores and

– residual stores

1.2.2.2 Sailing craft (including motorsailers)

– GM ≥ 0,60 m

– stability range ≥ 60° for craft without ballast keel

– stability range ≥ 90° for craft with ballast keel

– righting lever at the maximum of the lever arm curve ≥ 0,30 m

– static angle of heel under sail ≤ 20°, but not more than deck edge to water

– areas B + C ≥ 1,4 · (A + B), see Fig. 5.3

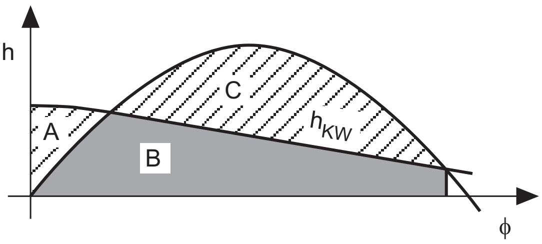


Fig. 5.3 Lever arm curve

h_{KW} = curve of heeling levers due to lateral wind pressure

If any of these criteria are not complied with, this may be accepted by GL if proof of equivalent safety is provided.

For multi hull sailing craft, stability ranges < 60° are permitted.

The proof of adequate stability shall be provided for the craft at least under the following conditions:

– all sails set

– half the sail area

– storm sails

– sails struck

the wind speed or strength in each case being determined at which the limit of stability set by the criteria is reached. With the sails struck, a lateral wind pressure equivalent to Beaufort 12 (32,7 to 36,9 m/s) must be tolerable.

1.2.2.3 In exceptional cases, GL may dispense with proof of stability in accordance with 1.2.2 for craft with a scantling length **L** of

$$10{,}00\ \text{m} \le \mathbf{L} < 15{,}00\ \text{m}$$

The proof is then to be provided in accordance with 1.2.1.

Other methods of determining the stability are acceptable provided they permit assessment of the stability with certainty.

Table 5.1 Stability

Range of service	Type of vessel	Type of propulsion	Requirements	
V	open and partial decked vessel	without propulsion	A.11.1 and A.11.2	C.1.2.1.1 only the second addend of the formula and a maximum inclination of 10° shall not be exceeded.
		motor vessel	A.11.1 and A.11.2	C.1.2.1.1
		sailing vessel (including motor sailing vessel)	A.11.1 and A.11.2	C.1.2.1.1 and C.1.2.1.2
IV	decked vessel	motor vessel	C.1.2.1.1	
		sailing vessel	C.1.2.1.3	
III II I	decked vessel	motor vessel	C.1.2.2.1 alternatively C.1.2.2.3	
		sailing vessel (including motor sailing vessel)	C.1.2.2.2 alternatively C.1.2.2.3	

A.11.1 and A.11.2: "Flotability, Reverse Buoyancy → cap sized"

C.1.2.1.1: Second summand: $M = n\,(0{,}2 \times B + 0{,}1)$ with $\varphi < 10°$

C.1.2.1.1: $M = 0{,}25\,D\,\frac{v^2}{L}\left(0{,}7\,H - 0{,}5\,T\right) + n\left(0{,}2 \cdot B + 0{,}1\right)$ with $\varphi > 12°$

Annex A

Series Construction Supervision of Pleasure Craft

A. General

1. The requirements below apply to the supervision of series construction of FRP hulls which are produced in large numbers.

The procedure controls in accordance with these rules are also used for craft with metal hulls whose series construction is monitored.

2. Supervision of series construction of small recreational craft by GL covers proving of the design documentation, testing of the prototype and supervision of the series construction.

It is a presupposition that the prototype of the series was built and tested under classification supervision.

2.1 Series construction supervision covers:

– primary structural members of the hull including deck, superstructure and transverse bulkheads

– fuel and water tanks if these are integral with the structure

– zones of the hull where forces are transmitted to it from mast and rigging

– the fastening of the ballast keel

– engine foundations/seatings

– rudder, including stock and bearings

– closing appliances

2.1.1 If specially applied for, examination of masts, spars and standing rigging can be included in the series construction supervision.

2.1.2 Not subject to proving are:

– sails and running rigging

– appliances on and below deck such as cooking, domestic and heating appliances

– equipment and loose gear

3. If applied for, the scope of series construction supervision can be extended to that for classification. The extended series construction supervision supplementing 2.1 then includes:

– rig (masts, spars and standing rigging)

– stability and closures

– steering gear

– auxiliary engines

– electrical installation

4. GL issues a certificate covering the results of the checks. Proof of the checks on board the recreational craft itself is provided by a permanently affixed plate.

B. Approval of Manufacturer

1. The manufacturing facilities of companies producing recreational craft of fibre reinforced plastics shall be suitable for the work to be carried out as regards workshop equipment (see Rules for Classification and Construction, II – Materials and Welding, Part 2 – Non-metallic Materials, Chapter 1 – Fibre Reinforced Plastics and Bonding), quality control, production procedures and the craftmanship of their personnel. The suitability is certified to the company by an approval certificate.

2. The application for approval, to be made by the company, must contain data about scale of production, organisation, technical equipment and production procedures, and the qualification of the staff executing the work.

3. A member of the management and his deputy are to be named to GL. This supervisory personnel is responsible for compliance with the approval conditions and for supervision of the production.

4. The applicant is responsible for compliance with the applicable laws and regulations, the processing guidelines of the producers of the materials, plus the codes of practice and accident prevention regulations of the responsible professional organisations, e.g of the chemical industry.

5. Following proving of the application and inspection of the manufacturing premises, approval may be given initially for a period of 2 years; providing the prerequisites for approval still exist, a 4-year extension may be granted.

6. GL shall be informed immediately of any kind of change if it affects the prerequisites for the approval of the manufacturing premises, such as:

– production equipment

– production procedures

– supervisory personnel

The introduction of new working procedures shall be reported to GL in good time before they are put into effect.

C. Series Construction Supervision

1. General

1.1 For fibre reinforced/resin matrix craft produced in series and not intended for classification, series construction certificates are issued on the basis of prototype tests and systematic supervision of production.

A presupposition is, that all craft of a series are produced under GL supervision.

1.2 There shall be GL approval for the materials used.

1.3 The craft tested under the terms of this series production supervision are not subject to any subsequent inspections in the form of periodic surveys during later operation; all that is certified is their as-built condition.

2. Prototype testing

2.1 Following approval of the manufacturing premises, construction of the first craft of a series ("prototype") shall be carried out based on GL approved technical documentation, under GL supervision - in accordance with classificatory requirements.

2.2 The prototype built under series construction supervision in accordance with A.2. is subject of comprehensive tests during completion, to be carried out in the presence of the GL surveyor. The tests cover all constructional and safety related details in accordance with the stipulations of these Rules.

2.3 The prototype built under extended series construction supervision in accordance with A.3. is subject of comprehensive tests during completion, to be carried out in the presence of the GL surveyor. The tests cover all constructional and safety related details of the hull, the machinery and electrical installations plus the rig and the closures in accordance with the stipulations of these Rules.

2.4 Repeated tests on the same scale as the prototype test are required if there is some change in the production, some significant design alterations or a lengthy interruption of the production of a series.

3. Testing during series production

3.1 Through its surveyors GL carries out regular checks matched to the production process to confirm that all craft of the current series conform to the tested prototype with regard to their technical characteristics and the constructional demands on the workmanship.

3.2 The frequency of these checks depends on the nature and intensity of the manufacturer's internal manufacturing quality control, type and size of the craft plus the number produced per year and the regularity of production.

The GL surveyor is to be given access at any time to the internal manufacturing quality control documentation.

3.3 As well as the above mentioned checks, strength and performance tests may be necessary. Nature and frequency of these depend on the type of craft and the number produced in the series.

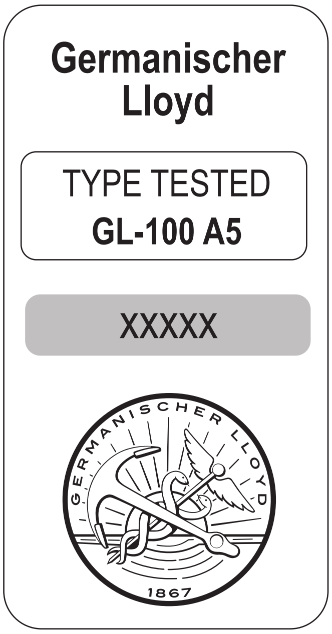
D. Identification, Documentation

1. Identification

Pleasure craft which have been tested in accordance with these Rules are identified by a plaque as in the illustration below:

1.1 Series construction supervision

1.2 Extended series construction supervision



1.3 Only GL issues plaques. They refer to the scope of supervision of the pleasure craft.

1.4 Issuing a new plaque (e.g. after repairs) is permitted only with GL approval.

2. Documentation

The series construction certificate contains data concerning:

– type and model of craft

– building yard

– yard series number

– year built

– Operating Category

– scope of tests carried out

E. Documentation for Approval

1. Drawings and documentation clearly showing the arrangement and scantlings of the structural members and components are to be submitted in triplicate for proving compliance with the Rules for Construction.

The scope is based on Form F 146 in Annex F.

2. The supervision of construction is based on approved documentation which must be available before production starts.

Annex B

Requirements for FRP Materials and Production

A. Definitions

1. Fibre reinforced plastics (FRP)

Heterogeneous materials, consisting of a thermosetting resin as the matrix and an embedded reinforcing material.

2. Thermosetting resin

Two-component mixture consisting of resin and hardener as well as possible additives.

3. Reinforcing materials

Materials generally in the form of fibre products which are embedded in a matrix in order to improve certain properties. In doing so, fibres of different materials displaying isotropic or anisotropic properties are processed in the form of semi-finished textile products (mats, rovings, fabrics, non-wovens). For special requirements, mixtures of different fibre materials are also used (hybrids).

4. Prepreg

Reinforcing material which is pre-impregnated with a thermosetting resin which can be processed without any further addition of resin or hardener.

5. Laminate

A moulded part which is manufactured by placing layers of reinforcing material on top of each other together with the thermosetting resin.

6. Sandwich laminate

Two laminate layers connected together by means of an intermediate core of a lighter material.

B. Materials

1. Thermosetting resin

Depending on the purpose, and consequently the requirement, a distinction is made between laminating resin and coating resin. Compatibility shall be demonstrated for the combination of gelcoat and laminating resin if the basic formulation of the resins are not the same.

1.1 Gelcoat and Topcoat resin

Gelcoat and topcoat resins shall protect the surface of the laminate from mechanical damage and environmental influences. Therefore, in a cured stage, the resin is to have a high resistance to existing media (e.g. fuel, river and sea water), to maritime and industrial environments), and to abrasion, in addition to low water absorption capabilities. Thixotropic agents and colouring pigments are the only permitted additives for gelcoat resins. In topcoat resins, additives for low styrene evaporation are also permitted.

1.2 Laminating resin

Laminating resins shall have good impregnation characteristics when being processed. In a cured stage, they shall be resistant to fuels, river and sea water, and shall exhibit a high resistance to ageing. Furthermore, adequate resistance to hydrolysis shall be ensured when used with permissible additives and filling materials. When using unsaturated polyesters (UP) as the resin, the resistance to hydrolysis shall be significantly higher than that of standard UP resin (for example through the use of a resin with an isophtalic acid basis).

1.3 Additives

1.3.1 All additives (catalysts, accelerators, filling materials, colouring pigments etc.) shall be suitable for the thermosetting resin and shall be compatible with it as well as the other additives, such that a complete curing of the resin can be ensured. The additives shall be dispersed carefully throughout the resin, in accordance with the guidelines of the manufacturer.

1.3.2 Catalysts, which initiate the hardening process, and accelerators, which control the working time (pot life, gel-time) and the cure time, shall be used in accordance with the processing guidelines provided by the manufacturer. For cold-setting systems, catalysts shall be proportioned in such a way that complete curing is ensured between temperatures of 16 °C and 25 °C. Cold-setting systems that are to cure at temperatures outside of this range, as well as warm-curing systems, may be used after consultation with GL Head Office (GL-HO).

1.3.3 Filling materials shall not significantly impair the properties of the cured resin. The type and quantity of the filling materials shall be approved by GL-HO and shall not lead to non-compliance with the minimum properties of the resin. In general, the proportion of filling materials in the laminating resin compound shall not exceed 12 % by weight (including a maximum of 1,5 % by weight of the thixotropic agent). If a smaller value is specified by the manufacturer, this value shall apply. The proportion of thixotropic agent in the gelcoat resin compound shall not exceed 3 % by weight. Laminates used for fuel and water tanks shall not contain filling materials.

1.3.4 Colouring pigments shall be climate-proof and consist of inorganic or non-fading organic dyes. The maximum permissible proportion shall not exceed the value specified by the manufacturer; if no value is specified, then it shall not exceed 5 % by weight.

2. Reinforcing materials

2.1 Various types of reinforcing materials with filaments of glass, carbon and aramide are available:

Roving:	A large number of parallel filaments placed together with or without twisting.
Mat:	Irregular layering of continuous filaments (fleeces), or chopped rovings (minimum 50 mm long) which are joined together by means of a binder.
Fabric:	Rovings woven together by means of the weaving techniques used in the textile industry, such as binding cloth, satin, body, atlas etc. Different materials and/or filament thicknesses are possible for warp and weft.
Non-woven fabric:	Unidirectional layers of fibres which are laid on each other in an arbitrary manner. The layers are fixed by thin fibre strands, either together or on mats. Different materials and/or filament thicknesses are possible in the individual layers.

2.2 Fibre surface treatment with sizing, coupling agents or finish shall be matched to the thermosetting resin, in order to ensure adequate material properties, also under the influence of media.

2.3 Only low-alkaline aluminium boron silicate glass may be used for glass fibres (alkali oxide content ≤ 1%), e.g. E-glass in accordance with VDE 0334/Part 1, 9.72, Section 4.

3. Core materials for sandwich construction

3.1 It shall be demonstrated that the core materials used are suitable for the intended purpose. They shall not impair the curing of the laminating resin.

3.2 The joining surfaces of local reinforcements made of metallic materials (e.g. inlets, connections) shall be cleaned in the same manner as for a gluing process, in order to ensure optimal bonding (cf. DIN 53281, Part 1).

3.3 Core materials other than those listed below may be used, provided that they are suitable for the intended purpose and that this is accepted by GL-HO by beforehand.

3.4 Rigid foam materials

Rigid foam materials which are used as core material for sandwich laminates, or as shear webs, shall be of a closed-cell type and have high resistance against the laminating resin or the adhesive, as well as against ageing, fuels, river and sea water. A low water absorption capability is required, together with a minimum apparent density of 60 kg/m³.

It shall be ensured that the allowable temperature of foam material is not exceeded during the curing reaction (exothermic reaction).

3.5 End-grained balsa wood

End-grained balsa wood used as core material for sandwich laminates shall fulfil the following requirements. It shall

- have immediately been treated after felling against attack by fungi and insects,
- be sterilized and homogenized,
- be kiln-dried within 10 days after felling, and
- have an average moisture content of maximum 12 %.

4. Prepregs

Fibre reinforcements pre-impregnated with laminating resin shall satisfy the requirements placed on their components. In addition, a minimum resin volumen content of 35 % by volume shall be ensured, as well as adequate tack at the processing temperature.

5. Adhesives

5.1 When bonding fibre-reinforced plastics together, or with other materials, only solvent-free adhesives shall be used. Preference shall be given to two-component reaction adhesives, if possible with the same basis as the laminating resin.

5.2 Laminates shall only be bonded in the cured state. Hot-setting adhesives generally attain a higher strength; however, the maximum allowable temperature of the materials to be bonded shall not be exceeded. This applies especially when using single-component hot-melt adhesive.

5.3 The adhesives shall be used in accordance with the processing guidelines issued by the manufacturer. They shall not affect the materials to be bonded and shall exhibit a high resistance to humidity and ageing. The influence of the operating temperature on the adhesive strength shall be small.

5.4 Adhesives shall be usable within a minimum temperature range of – 20 ° to + 60 °C.

C. Approval of Materials

1. All materials to be used during production of components from FRP shall first be assessed and approved by GL. Approval by other organizations can be recognized following agreement by GL, provided that the tests required for approval are in accordance with GL requirements.

2. The manufacturer and/or supplier of the material shall apply to GL-HO for approval.

3. Approval is granted if the material fulfils the requirements of GL. For this purpose, specific tests are necessary, and they shall either be carried out under supervision of GL or the results shall be documented in the report of a recognized testing institute.

4. Before production starts, the required material approvals shall be submitted to GL-HO and/or the responsible GL inspection office. If no approvals, or not all required approvals have been obtained, then as an exception and following agreement with GL-HO, proof of the properties of the basic material can be demonstrated as part of material testing of the component laminate.

5. The packaging or wrapping material shall bear a reference to the approval.

D. Requirements Regarding Manufacturing Equipment

1. General

1.1 All manufacturing facilities, store-rooms and their operational equipment shall fulfil the requirements of the responsible safety authorities and professional employers liability insurance associations. The manufacturer is exclusively responsible for compliance with these requirements.

1.2 The danger of contamination of laminating materials shall be minimized through separation of production facilities from store-rooms.

1.3 During laminating and bonding in the laminating shop, no dust-generating machinery shall be operated nor any painting or spraying operations carried out. As a matter of principle, such work shall take place in separate rooms.

2. Laminating workshops

2.1 Laminating workshops shall be closed spaces capable of being heated and having supply and exhaust ventilation. During laminating and curing, a room temperature of between 16 °C and 25 °C and a maximum relative humidity of 70 % shall be maintained, provided that the manufacturer of the laminating resin compound does not specify otherwise.

2.2 In order to control the climatic conditions, thermographs and hydrographs shall be provided. The equipment shall be set up following agreement with GL, their number and arrangement depending on operational conditions. The equipment shall be calibrated in accordance with statutory regulations. The recordings shall be kept for at least 10 years and submitted to GL on request.

2.3 Ventilation facilities shall be arranged in such a manner that no inadmissible amounts of solvents are removed from the laminate, and also that no inadmissible workplace concentrations (MAK values) occur.

2.4 The workplaces shall be illuminated adequately and suitably, but at the same time precautionary measures shall be taken to ensure that the controlled curing of the laminating resin compound is neither impaired through sunlight nor lighting equipment.

3. Storage-rooms

3.1 Laminating resins shall be stored in accordance with the manufacturer's instructions. If no such instructions are provided, then they shall be stored in dark, dry rooms at a temperature between 10 °C and 18 °C. The temperature of the storage-rooms shall be recorded continuously by means of thermographs.

3.2 Prepregs shall be stored in special cold-storage rooms in accordance with the manufacturer's instructions. The temperature in general shall not exceed – 22 °C.

3.3 Hardeners, catalysts and accelerators shall be stored separately in well-ventilated rooms in accordance with the manufacturer's instructions. If no instructions are provided, they shall be stored in dark, dry rooms at temperatures between 10 °C and 18 °C.

3.4 Reinforcing materials, fillers and additives shall be stored in closed containers, in dry and dust-free conditions.

3.5 Storage shall be arranged in such a way that the identification of the materials, their storage conditions and maximum period of storage (expiry date) as prescribed by the manufacturer are clearly visible. Materials whose duration of storage exceeds the expiry date shall be removed immediately from the stores.

3.6 Quantities of materials due to be processed shall be brought to the production shops as early as possible to ensure complete adjustment to the processing temperature ($\Delta T \leq 2°$ C), with the containers remaining closed.

3.7 Materials taken from the stores and partially used shall only be replaced in the stores in special cases (e.g. hot-curing prepregs) and with the consent of GL.

E. Regulations for Processing

1. General

1.1 As a matter of principle, only materials approved by GL shall be used. In addition to the choice of suitable and approved materials, special care shall be taken when working with them because of the great influence on the properties of the product.

1.2 For the preparation and processing of the resin compounds and reinforcing material, these Rules, the instructions issued by the material manufacturers and the regulations of the local authorities shall also be observed.

1.3 Resin, hardener and resin additives shall be mixed in such a way as to ensure a uniform distribution and to minimize the amount of air introduced into the mixture as far as possible. A degassing of the resin compound may be necessary in individual cases.

1.4 During lamination, the processing time of the prepared resin compound specified by the manufacturer shall not be exceeded. If such a time is not specified, the pot-life shall be determined by means of a preliminary test and the processing time then established in consultation with GL.

1.5 It is not possible to cover all types of moulds and processing methods in detail. Deviations are therefore possible for special cases with the consent of GL.

2. Requirements for moulds

2.1 The moulds shall be made of a suitable material that, on the one hand, has adequate stiffness to prevent inadmissible deformations while laminating or curing, and on the other hand has no influence on the curing of the laminate. Moulds made of FRP may be used only after complete curing and subsequent tempering.

2.2 In the case of moulds for products which are made using vacuum bags, absolute air tightness of the mould shall additionally be ensured.

2.3 The surface of the moulds shall be as smooth as possible and shall have no sharp edges. The mould shall be designed in such a way as to permit flawless removal of the product from the mould.

2.4 Before commencing with the laminating, the surface of the components shall be treated with a sufficient quantity of a suitable release agent and brought up to the temperature required for lamination. The surfaces shall be dry and free of dust. It is not permissible to use release agents with a silicon base.

3. Building up the laminate

3.1 If the surface protection is to be achieved by providing a gelcoat, then the gelcoat resin compound shall be applied with a uniform thickness of between 0,4 and 0,6 mm, using a suitable process.

3.2 The first laminate layer shall be applied as soon as possible after application of the gelcoat. A fibre mat or fabric with low weight per unit area and a high resin content shall be used (e.g. for glass fibres: a maximum of 450 g/m² and a maximum of 30 % glass by weight).

3.3 The laminate shall be built up in accordance with the approved technical documentation, whereby GL shall be consulted about the method. Air shall be adequately removed from the reinforcing layers and these layers shall be compacted in such a manner to ensure that the required proportion of resin is achieved. Resin enrichment shall be avoided.

3.4 The maximum thickness of the material that can be cured at one time is determined by the maximum permissible heat development. In the case of vacuum bagging, as a rule, the decisive factor is the maximum number of layers from which air can still be totally removed.

3.5 If a laminating process is interrupted for a period causing the base laminate resin to exceed the point of gelation, a test is to be performed to verify adhesion between the base laminate and the top laminate. For each resin system, under the given processing conditions, the permissible period of interruption of the laminating process is to be determined. In the event of this period being exceeded, the laminate shall be thoroughly ground in order to provide a surface exhibiting adequate adhesion properties after removal of the dust. For UP resins on an orthophthalic acid and standard glycol basis not containing any skin-forming agents a 48 h interruption on the laminating process may, without any further proof being furnished, be considered uncritical with respect to lamination.

3.6 When grinding laminates containing resins with low styrene evaporation as the matrix system, the surface shall be removed down to the mat layer. In order to ensure that no skin-forming agent elements (e.g. paraffins) will be left on the surface, the surface shall finally be polished using new abrasive paper. The same procedure shall also be applied when treating the surfaces of materials to be bonded (see E.6.2.3).

3.7 Transitions between different thicknesses of laminate shall be made gradually. A minimum value (for glass fabric in the fibre direction) of 25 mm per 600 g/m² reinforcing material can be used. In the transition region from a sandwich construction to a solid laminate, the core material shall be tapered with a gradient of not more than 1 : 2.

3.8 If cutting of reinforcing layers is unavoidable in the case of complicated mouldings, then the cut edges shall overlap, or reinforcement strips shall be provided. In the butt or seam region of laminates, every reinforcing layer shall overlap by at least 25 mm per 600 g/m².

3.9 Different components may be laminated together only while they are not fully cured. Special attention shall be paid to crossings of laminates.

3.10 Parallel or insert linings shall be free of all moisture and pollution (dirt). Their bonding surfaces with the laminate shall be prepared in a suitable manner (roughening, coupling agent or similar).

4. Glass-fibre resin spraying

Glass-fibre resin spraying, a partly mechanical method of lamination by hand, requires fulfilment of the following specific requirements:

4.1 The equipment to be used shall be demonstrated before use and its suitability proven.

4.2 The qualification of the fibre-resin sprayer, and where appropriate his assistant, shall be demonstrated to GL by means of procedure test.

4.3 The equipment shall be calibrated in accordance with the guidelines of the manufacturer. Calibration shall be checked regularly before fibre-resin spraying, but the very least at the beginning of every production day.

4.4 The length of a roving cut shall be between 25 mm and 50 mm.

4.5 A powder-bound textile glass mat of maximum 450 g/m² shall be used for the first laminate layer. The glass part of this layer (to be applied manually) shall be less than 30 % by weight.

4.6 The glass weight per unit area of the spray laminate layer of a combined laminate shall not exceed 1150 g/m².

4.7 After a maximum of 1150 g/m² of fibres have been sprayed, air shall be removed and the composite shall be compacted.

4.8 Tests shall be performed on a regular basis to check whether a uniform laying up of the reinforced layers as well as a uniform distribution of percentage glass weight has been achieved. GL reserve the right to demand test pieces to check the resulting mechanical properties.

5. Curing and tempering

5.1 Completed components may only be taken from the moulds after adequate curing of the thermosetting resin compounds. The required cure time generally depends on the manufacturer's instructions. Otherwise, a minimum cure time of 12 hours shall be observed for cold-setting systems.

5.2 Resin systems which cure under pressure, UV radiation and/or increased temperature shall be treated in accordance with the manufacturer's instructions.

5.3 Immediately after curing, the components should receive post-treatment at increased temperature (tempering). The tempering time depends on the resin in question and the temperature attained within the component during tempering, whereby this shall be below the temperature for dimensional stability under heat and shall be agreed on with GL. Cold-setting systems which are not subsequently tempered shall be stored for 30 days at a temperature of 16 °C, and for correspondingly shorter periods at temperatures up to 25 °C. This period can be shortened with the consent of GL, provided the relevant manufacturer's specifications regarding post-curing are available, or post-curing values exist which are supported by experimental results. If such values are not available, then in general the following tempering conditions can be used (polyester/epoxy resin):

at least 16 h at 40 °C / 50 °C or

at least 9 h at 50 °C / 60 °C

6. Bonding

6.1 General

6.1.1 Bonded joints for load-bearing parts shall in general be verified using a procedure test to be agreed on for each individual case. The scope of the required tests shall be determined in agreement with GL.

6.1.2 For bonding of composite fibre materials, only adhesives approved by GL shall be used.

6.1.3 The adhesives shall not have any negative effects on the materials to be bonded.

6.1.4 The application limits for the adhesive, as specified by the manufacturer, shall be adhered to. A bonding-suitable design which as far as possible avoids peeling moments and forces shall be used, and the thickness of the adhesive layer shall be kept as thin as possible.

The joining surfaces shall be kept as large as possible, and forces shall be applied over a large area.

6.2 Surface pre-treatment

6.2.1 The different surface pre-treatments are listed in VDI (Association of German Engineers) guidelines 2229 and 3821.

6.2.2 The surfaces of the materials to be bonded shall be dry and free of grease, dust and solvents. Particularly when degreasing, attention shall be paid to compatibility of the solvent with the materials.

6.2.3 In the case of smooth surfaces, they shall be roughened e.g. mechanically by grinding or sand blasting, or chemically through pickling. This is absolutely necessary when there are coatings on the surfaces of the materials to be bonded which impair adhesion (e.g. skin-forming agents in polyester resins; see E.3.6).

6.2.4 In most cases, an increase of the adhesive strength is achieved by the application of specially matched primers, in particular, the use of primers recommended for bonding which is subsequently subjected to negative environmental influences.

6.3 Processing

6.3.1 The adhesive shall be used in accordance with the instructions issued by the manufacturer, whereby the proportion of filling materials shall not exceed the permissible value.

6.3.2 The adhesive shall be applied uniformly, free of voids and not too thickly onto the materials to be bonded.

6.3.3 If, for special reasons, gluing joints of 5 mm or more cannot be avoided, then the materials to be bonded shall be first provided with a thin coating of pure adhesive resin.

6.3.4 It is not permissible to apply loads to the gluing before complete curing of the adhesive.

6.3.5 In the case of cold-setting thermosetting resin adhesives, a subsequent tempering of the gluing is recommended.

6.3.6 The edges of the area treated with adhesives shall be protected by means of suitable measures against penetration of extraneous media (e.g. humidity).

7. Sealing

7.1 Laminate surfaces without surface protection shall be sealed after curing or tempering, using suitable agents. In particular, edges of cut-outs and bondings shall be protected carefully against the penetration of extraneous media (moisture).

7.2 The sealing materials used shall not impair the properties of the laminate or of the bonding. Furthermore, they shall be appropriate for the purpose of the component.

F. Manufacturing Surveillance

1. General

1.1 For components made of FRP, manufacturing surveillance consists of the quality control of the basic materials, production surveillance and the quality inspection of the finished components.

1.2 In the case of manufacturing surveillance, a distinction is made between internal and third-party (external) surveillance. In the sense of these rules, third-party surveillance means periodic and random checks by GL of the internal surveillance as well as of the component quality.

1.3 GL reserve the right to carry out inspections in the production facilities without giving prior notice. The manufacturer shall grant inspectors access to all areas used for production, storage and testing and shall present all documentation concerning records and tests carried out.

1.4 The scope of third-party surveillance can be reduced in the case of production facilities that have a certified quality management system.

2. Incoming inspection

2.1 Characteristic values and mechanical properties specified in the material approval shall be confirmed by the manufacturer, at least by a test report (DIN EN 10204-2.2). On arrival of the product, a check shall be carried out to ascertain whether it corresponds to the requirements. Material properties shall be checked by random sampling.

2.2 The products shall be listed in the inventory file and shall be stored in accordance with the requirements of these rules.

3. Production surveillance

3.1 Details of production shall be stipulated by means of check lists and routing cards which accompany each stage of the production and are signed by the employees in charge.

3.2 Production surveillance shall be carried out constantly by the internal quality department. The scope shall be stipulated in an inspection and test plan and signed by the employees in charge.

3.3 Employees involved in production shall be suitably trained and shall work under professionally qualified supervision.

3.4 The materials used in the production shall be documented in a clear and comprehensive manner. Parameters relevant for the quality (temperature, humidity etc.) shall also be recorded in the production documentation.

3.5 Details (including the direction) of reinforcing layers in the laminate shall be checked off immediately during the production process.

3.6 A sample shall be taken from each batch of thermosetting resin compound that is mixed, and this shall be labelled, cured and stored. These samples shall be subjected to random testing of the degree of their curing and the results shall be documented.

3.7 During production, laminate samples shall be prepared and shall be used for checking the characteristic values and the mechanical properties. The material strength values shall conform with the specified values. If no adequately-sized laminate samples can be obtained from cuttings or sections, then reference laminates produced in parallel with dimensions of approximately 50×50 cm^2 shall be prepared. Their quantity depends either on the number of the components, or the number of production days (the lower number can be chosen).

4. Structural tests

4.1 During production and on completion of production, the component shall be subjected to visual inspections. In particular, attention shall be paid to voids, delamination, warping, discoloration, damage etc. In addition, the general quality, e. g. surface finish, shall be assessed.

4.2 By means of suitable testing procedures, the quality of the components shall be determined, if possible during production, and at the latest on completion of production. Special attention shall be paid to the bonding and to the degree of curing of the component.

4.3 Following agreement with GL, individual or random tests shall be carried out on finished components under static and/or dynamic loads.

4.4 GL shall be informed about repairs of any faults relevant to the strength of the component, and the procedure used to carry out the repair shall be in accordance with the Rules for Classification and Construction, II – Materials and Welding, Part 2 – Non-metallic Materials, Chapter 1 – Fibre Reinforced Plastics and Bonding, Section 3.

Annex C

Excerpts from the Rules for Materials

A. General

1. Materials for the structural and equipment components dealt with in these Rules for Classification and Construction, I – Ship Technology, Part 3 – Special Craft, Chapter 3 – Yachts and Boats up to 24 m, shall comply with the latest version of the Rules for Classification and Construction, II – Materials and Welding, Part 1 and 2). Excerpts are given here.

The materials must satisfy the requirements which follow, and be tested in accordance with D. and approved. Materials whose properties differ from those in these rules may only be used with special permission.

2. Materials complying with national or international standards and manufacturers' requirements may be used if their properties are equivalent to those in these rules and GL approves their use.

3. GL reserve the right to extend the scope of testing, and to subject to it even materials or components for which testing is not specifically required in these rules.

4. By carrying out tests, GL does not provide any guarantee that a consignment which has only been checked by random sampling or workpieces tested in a prescribed place will comply in all parts with the GL rules and guidelines, or the delivery conditions.

Materials or components which during the subsequent processing turn out to be defective may be rejected even if they have passed an earlier test satisfactorily.

5. The maintenance of the dimensions, qualitative and other requirements of these Rules is the responsibility of the manufacturer. This applies even if GL carries out tests.

6. Each product shall be provided with a material schedule from which all data needed for identification of the material may be obtained, such as type of material, method of manufacture and maker's number, number, delivery form, dimensions, etc., and in which the manufacturer and/or supplier confirms that the material has as far as necessary been produced in accordance with an approved procedure and complies with the GL Rules.

7. Materials or components shall be so labelled that the surveyor can check their compliance with the material schedule.

B. Steels and Non-Ferrous Metals

1. Selection of material

1.1 Steel and non-ferrous metals recommended for use are those suitable for sea water without special corrosion protection. This includes stainless steels with a pitting resistance equivalent (W) exceeding 25 ($W = \% Cr + 3{,}3 \% Mo$) and some non-ferrous, copper and nickel based metals. These materials are sensitive to crevice corrosion and pitting and must not be coated without cathodic protection.

Ship steels, general purpose structural steel, aluminium alloys and most copper and nickel alloys must be provided with suitable corrosion protection. Maintenance of this protection is in the responsibility of the owner of the craft.

1.2 The materials used for welded structures shall be suitable for welding, and the welding fillers must match the base material in accordance with the manufacturer's instructions. In scantling determination, account shall be taken of the possibility that the mechanical properties of some materials are impaired by welding.

1.3 Combination of materials shall be chosen to minimise the potential difference, so that contact corrosion is avoided. The stated potential values are only for reference, as changes in environmental conditions, heat treatment, welding and deformation can change them. The rate of corrosion amongst other things depends on the surface conditions and the possible formation of a protective layer. Contact corrosion can be prevented by cathodic protection.

1.4 In the case of metallic structural components and equipment items, such as shaft brackets, rudder stocks of FRP hulls and wood in FRP craft crevice corrosion in particular must be prevented, i.e. the penetration of moisture into the gap between metal and FRP is to be prevented. The parts are to be assembled using permanently elastic sealant.

Table C.1 Ship steel and comparable structural steel (specification excerpts) [1]

<table>
<tr><th colspan="3">Ship steel [1]</th><th colspan="4">Comparable structural steel to EN 10025
or Steel-Iron Material leaflet 089-70</th></tr>
<tr><th rowspan="2">Quality</th><th rowspan="2">Minimum yield strength [N/mm²]</th><th rowspan="2">Tensile strength [N/mm²]</th><th rowspan="2">Steel type</th><th colspan="2">Yield strength R_{eH} [N/mm²]</th><th>Tensile strength R_m</th></tr>
<tr><th>t ≤ 16 mm</th><th>16 < t ≤ 40 mm</th><th>[N/mm²]</th></tr>
<tr><td>GL–A
GL–B</td><td rowspan="3">235</td><td rowspan="3">400 – 490</td><td>Fe 430 B
Fe 360 B</td><td rowspan="2">275
235</td><td rowspan="2">265
225</td><td rowspan="2">410 – 540
340 – 470</td></tr>
<tr><td>GL–D</td><td>Fe 430 C
Fe 360 C</td></tr>
<tr><td>GL–E</td><td>(TT) StE 285
(TT) StE 255</td><td colspan="2">285 [2]
255 [2]</td><td>390 – 510
360 – 480</td></tr>
<tr><td colspan="7">1 The various quality grades of ship steel within a strength group differ mainly by their specified toughness, see also GL Materials Rules. In general, 'A' quality steels are used for building yachts.
For welded components more than 30 mm thick subject to increased stress at low operating temperatures, tougher 'B', 'D' and 'E' quality steels are to be used as a safeguard against brittle fracture.
2 Product thickness t ≤ 35 mm</td></tr>
</table>

Table C.2 Mechanical properties of austenitic stainless steels (specification excerpts)

Material No.	Designation according to DIN 17440	Tensile strength R_m [N/mm²]	Yield strength $R_{p0,2}$ [N/mm²]
1.4306	X2CrNi1911	450 – 700	215
1.4404	X2CrNiMo17132	450 – 700	235
1.4435	X2CrNiMo18143	450 – 700	235
1.4438	X2CrNiMo18164	500 – 700	235
1.4439	X3CrNiMoN17135	600 – 800	315
1.4541	X6CrNiTi1810	500 – 750	245
1.4462	X2CrNiMoN22	680 – 880	480
1.4571	X6CrNiMoTi17122	520 – 670	220
The materials listed are suitable for service under the influence of sea water or marine atmosphere			

Table C.3

Material No.	Designation according to DIN 17440	Sweden SS	USA AISI / SAE
1.4306	X2CrNi1911	2333	340 L
1.4404	X2CrNiMo17132	2348	316 L
1.4435	X2CrNiMo18143	2353	316 L
1.4438	X2CrNiMo18164	2367	317 L
1.4439	X3CrNiMoN17135		
1.4541	X6CrNiTi1810	2337	321
1.4462	X2CrNiMoN225	2324	329
1.4571	X6CrNiMoTi17122	2350	316 Ti

Table C.4 Material condition and mechanical properties of sheet aluminium

Material designation according to		Condition	Thickness range [mm]		Tensile strength R_m min. [N/mm²]	Yield point $R_{p0,2}$ min. [N/mm²]	Elongation at fracture min. [%]	Hardness HB 2,5/62,5
DIN 1725 Part 1	ISO R 209		over	up to				
Al Mg 3	AlMg3	cold rolled (¼ hard)		6,0	220	165	9	65
		hot rolled [1]	6,0	10,0	210	140	12	60
		hot rolled [1]	25,0	50,0	190	80	12	50
AlMg4,5Mn	AlMg4, 5Mn	soft	—	50,0	270	125	17	70
		hot rolled [1]	2,0	30,0	275	125	12	70
		heat treated (¼ hard)	2,0	40,0	310	205	10	85
AlMgSi1	AlSi1MgMn	cold age hardened	3,0	20,0	205	110	14	65
		heat treated	3,0	20,0	275	200	12	85
		heat treated	10,0	20,0	295	245	9	95

[1] Hot rolled may contain a lower cold working proportion

Table C.5 Mechanical properties of extruded aluminium sections suitable for sea water

Symbol [1]	**Material number** [1]	**Material condition**	**Wall thickness [mm]**	**Tensile strength R_m min. [N/mm²]**	**Yield strength $R_{p0,2}$ min. [N/mm²]**	**Elongation at break min. [%]**
3.3535.08	AlMg3F18	extruded	any	180	80	14
3.3547.08	AlMg4,5MnF27	extruded	any	270	140	12
3.3206.71	AlMgSi0,5F22	heat treated	any	215	160	12
3.2315.81	AlMgSi1,F28	heat treated	up to 10	275	200	12
3.2315.72	AlMgSi1,F31	heat treated	up to 20	310	260	8

[1] In accordance with DIN 1748, Part 1 or DIN 1746, Part 1.

Table C.6 Material designation

Type	**Ing. Leg. Register**	**ISO**	**D DIN**	**E UNE**	**F NF**	**GB BS**	**I UNI**	**S. SIS-MNC**
AlMgSi0,5	6060	AlMgSi	AlMgSi0,5	L–3442	6060	—	9006/1	144103
AlSi1MgMn	6082	AlSi1MgMn	AlMgSi1	L–3453	6082	6082	9006/4	144212
AlMg3	5754	AlMg3	AlMg3	L–3390	5754	—	—	—
AlMg4,5Mn	5083	AlMg4,5Mn0,7	AlMg4,5Mn	L–3321	5083	5083	9005/5	144140

Table C.7 Timber durability groups and characteristic values in accordance with DIN 68364

Wood type	Durability Group [1]	Bulk density [2] [g/cm³]	Mean breaking strengths [3] Tension [N/mm²]	Com-pression [N/mm²]	Bending [N/mm²]	Young's modulus E_L long. [N/mm²]	E_T rad. [N/mm²]	Shear modulus G_{LT} [3] [N/mm²]	Trans-verse contrac-tion μ_{TL}
Coniferous									
European spruce	4	0,47	80	40	68	10000	800	600	0,33
Fir	4	0,47	80	40	68	10000			
Pine	3 – 4	0,52	100	45	80	11000	1000		0,30
Oregon pine	3	0,54	100	50	80	12000	900	800	0,46
Larch	3	0,59	105	48	93	12000			
Spruce	4	0,47	85	35	65	9500	870	680	0,34
Deciduous									
Khaya-Mahogany	3	0,50	75	43	75	9500	1040	830	0,59
True-Mahogany	2	0,54	100	45	80	9500	990	770	0,44
Sapele-Mahogany	3	0,64	85	57	69	9800			
Sipo-Mahogany (Utile)	2	0,59	100	58	100	11000	1300	1140	0,53
Meranti, red	3	0,59	129	53	105	13000	1250		
Iroko	1 – 2	0,63	79	55	95	13000	1450	1080	0,59
Makore	1 – 2	0,66	85	53	103	11000	1390	1160	0,42
Oak	2	0,67	110	52	95	13000	1580	1150	
Beech	5	0,69	135	60	120	14000	2280	1640	0,52
Birch	5	0,65	137	60	120	14000	1130	1200	0,36
Ash	5	0,69	130	50	105	13000	1500	880	0,55
Teak	1	0,69	115	58	100	13000	1490	1040	0,55
Yang	3	0,76	140	70	125	16000	1850		

[1] Criterion for the durability group is the service life and the resistance of the wood against fungi and animal pests (but not the marine borer, teredo navalis) in contact with soil under central European conditions; the meanings are:

1 = high resistance
2 = resistance
3 = moderate resistance
4 = little resistance
5 = no resistance

[2] Bulk density in reference atmosphere standardised condition with 12 % moisture content in accordance with DIN 52183.

[3] In the radial plane.

C. Wood and Timber Products

Timber products for structural members shall meet the following requirements.

Wood and timber products that shall be integral with FRP laminate as load bearing components or be embedded as local reinforcement are subject to individual testing (swelling, shrinkage and durability).

1. Solid wood

1.1 Only timber in durability groups 1, 2 or 3 of Table C.7 may be used for primary structural members and load bearing components of the hull.

1.2 The timbers to be used must be long fibred and of best quality (free from sap, shakes, harmful knots and other defects).

1.3 For components not exposed to water or weather, and without demands on their strength, timber of lower durability may be used.

1.4 Wooden structures must be so designed that the direction of principal stress is also that of maximum mechanical strength of the wood.

1.5 The timber used is to be radially cut(quarter sawn), the angle of the annular rings to the lower cut edge to be not less than 45°.

1.6 When choosing timber, the fact that swelling and shrinkage differ in different directions must be taken into account to prevent components becoming loose and leaks developing at seams or butts.

1.7 Timber differing from that specified in Table C.7 may be used if it can demonstrate equivalent durability.

2. Plywood

2.1 Only GL approved marine plywood (exterior ply) may be used for primary structural members of the hull exposed to atmospheric influence without protection, e.g. decks,.

In accordance with GL test specifications for marine plywood, the following varieties of timber shall be used:

Teak	Tectona grandis
Makoré	Dumoria hekelii
Douka	Dumoria africana
Sipo-Mahogany (Utile)	Entandrophragma utile
Sapele Mahogany	Entandrophragma cylindricum
Oak	Quercus sp.
True Mahogany	Switenia Mahagonimacrophylla
Khaya-Mahogany	Khaja ivorensis
Okumé (Gabun)	Aucoumea Klaineana

2.2 For load bearing internal structural members of FRP hulls, plywood made from timber varieties other than those listed in 2.1 may be used provided it is bonded in accordance with DIN 68705-BFU 100. Timber not in durability groups 1, 2 or 3 according to DIN 68364 shall be bonded according to DIN 68705-BFU 100 G.

Timber in bilges and other wet areas must be permanently protected against moisture.

The mechanical properties and safety factors to be taken into account for scantling determination of internally used plywood shall be agreed with GL.

D. Testing Materials

1. The stipulated tests are carried out on application by the manufacturer of the material; they must be carried out in the manufacturer's premises before delivery. They may be carried out under GL supervision at the manufacurer's or by a test institute recognised by GL (e.g. an official materials testing house).

2. GL may require follow-up tests on the consignment, under its supervision, if the material verification provided for the materials or components is inadequate or they cannot be properly identified.

3. The tests are based on Table C.8.

Table C.8 Scope of materials tests

Type of material	Scope of tests	Type of certificate
Polyester, cold curing	GL-Form F 510	GL material test certificate [1]
Epoxy resin systems, cold curing	GL-Form F 511	
Woven Roving	GL-Form F 516	
Spray roving	GL-Form F 517	
Chopped strand mat	GL-Form F 518	
Woven fabric	GL-Form F 519	
Non woven fabric	GL-Form F 520	
Rigid expanded plastics and other core materials for sandwich construction	GL-Form F 515 [2]	
Ferrous Materials Non-Ferrous Metals	[3]	Acceptance test certificate B to DIN EN 10204-3.1 B
Plywood (exterior ply)	according to GL test rules for Non-metallic materials / Wood, latest version	GL material test certificate [1]
Plywood (interior ply)	[4]	Workshop test certificate DIN EN 10204-2.3

[1] These certificates are issued if tests under GL supervision have proven that the material meets all requirements of these Rules. It is up to the manufacturers of the materials to apply to GL Head Office for approval of their products.

[2] Tests to be agreed with GL Head Office.

[3] Is determined together with approval of the technical construction documentation, taking account of the type of material and its purpose.

[4] Test scope is based on DIN 68705. Tests are to be carried out by an officially approved material test establishment as part of external supervision.

Test standards:

BFU 100: weatherproof bonding for durability-groups I, II or III timber in accordance with DIN 68464.

BFU 100 G: weatherproof bonding with an agent to resist xylophagous fungi added during panel manufacture, for timber not in durability-groups I, II or III in accordance with DIN 68364

Annex D

Excerpt from the Rules for Welding

A. General Rules

1. General

This Annex by way of excerpts contains the most important requirements and data to ensure a high quality of welding work on metallic materials from the Rules for Classification and Construction, II – Materials and Welding, Part 3 – Welding, called "Rules for Welding" hereinafter - of GL. As far as necessary, the Rules were adapted to the special requirements of yacht construction. If requirements, other than those stated, have to be fulfilled, the GL Rules mentioned above shall be applied as appropriate.

2. Scope

These Rules apply to all welding work on the structure of the hull and on parts of the equipment, including masts and booms/spars with their associated fittings, plus on parts of the machinery, insofar as these components are covered by the abovementioned rules for construction and dimensioning (e.g. tanks, pipelines, etc.). GL may stipulate the application of these Rules also beyond that to other components, or logically to other joining procedures such as for example soldering/brazing.

3. Other rules and standards applicable at the same time

The rules, standards or other technical regulations quoted hereinafter count as part of these Rules. The application of further standards, etc., requires GL approval. Where there are differences in the requirements of standards etc. and rules, those in the GL Rules take precedence.

4. Data in the design documentation

4.1 The drawings and documentation to be submitted for approval in accordance with Form F 146 shall contain data concerning the materials, configuration of seams and dimensions plus any post treatment of the seams (e.g. grinding out notches) that might be needed. If non destructive testing of the weld seam is envisaged or required (see D.6.3), type and scope of the tests is to be indicated, plus some specific quality of seam (e.g. to DIN 8563, Part 3 or DIN-EN 25817) required on strength reasons, if relevant.

4.2 Symbols or letter symbols identifying materials or welded connections are to be explained if the definitions or symbols used are other than those in the standards. Insofar as seam preparation (in conjunction with approved welding procedures) complies with standard shipbuilding practice and these Rules or accepted standards, special depiction is not required.

4.3 In special cases (e.g. use of special materials) additionally data are to be provided about the envisaged welding procedure, the fillers and auxiliary materials, if applicable preheating and heat control during welding, seam preparation, build up of the seam and the root preparation, plus any other details affecting the quality of the welded joint.

5. Quality control, responsibility of the company

5.1 The company shall ensure by their own regular quality control during the course of fabrication, and on completion, that all welding work is carried out in accordance with these Rules and the approved design documentation as well as any instructions given in the course of approval and in accordance with sound engineering practice and shipbuilding. The responsibility for effecting the above mentioned quality control rests with the company.

5.2 When issuing subcontracts to suppliers, the company issuing the contract shall assure that the supplier undertakes to comply with these Rules (see also under B.1.1). The issuing is to be reported to GL; the suppliers are to be named to GL. Depending on the components to be supplied by the subcontractor, i.e. their significance (for safety) and stressing, GL may require certain tests and corresponding verification.

5.3 The checks carried out by the GL surveyor do not relieve the company of the responsibilities set out in 5.1 and 5.2. GL does not guarantee that the components or welded joints tested generally on a random sampling basis have been fabricated entirely in accordance with the requirements and in all parts meet the specification. Components or welded joints which subsequently turn out to be defective may be rejected, or their dressing required, in spite of preceding tests.

B. Manufacturing Prerequisites, Proof of Qualification

1. Approval of welding works

1.1 Shipyards and manufacturers, including branches and suppliers, intending to carry out welding work within the scope of these Rules must have GL approval for this in accordance with the Rules for Welding. Approval from GL is to be applied for, with the necessary data and documentation (description of works, proof of qualification for welders and welding supervisors), by the yards and manufacturer in good time before welding work is executed.

1.2 The company shall have at their disposal suitable equipment and facilities for the faultless execution of the welding work. Installations outside the works (e.g. testing installations) may be taken into account. The suitability of the company's installations will be checked as part of a manufacturing premises' inspection. GL may state requirements in this connection or restrict the scope of the approval in line with the manufacturer's facilities.

2. Welders, welding supervision

2.1 Work with manually controlled welding equipment, where the quality of the welded joint depends overwhelmingly on the manual skill of the welder, may only be carried out by tested GL-approved welders with valid test certificates. The welding tests are to be carried out in accordance with the GL Rules for Welding or accepted standards (e.g. DIN-EN 287 Part 1 "Steel" or Part 2 "Aluminium"). The operating personnel for fully mechanised or automatic welding procedures is tested on the equipment.

2.2 The work is to be monitored responsibly by a welding supervisor belonging to the company. Regarding the requirements stated for welding supervisors and their duties, see also GL Rules for Welding. The welding supervisor shall be named to GL; GL is to be provided with proof of his/her professional qualification. Changes in welding supervision are to be reported to GL without being asked for.

3. Welding procedures, procedure tests

3.1 The only welding procedures which may be used are those whose suitability for the field of application in question (base materials, plate/component thickness, welding position, etc.) is either established by general experience or has been proved in a procedure test in accordance with the GL Rules for Welding. The procedures shall have been approved by GL for the manufacturer in question.

3.2 As a rule procedure tests are required for:

– materials other than the normal strength Grade A to D ship steel in accordance with GL Rules for Materials or as comparable structural steels in accordance with the standards

– welding procedures other than manual arc welding with rod electrodes and partially mechanised shielded arc welding

– vertical down welding

– single fillet welding on ceramic or other weld pool support

Before starting work for the conventional submerged arc welding of normal strength A to D ship steel, it is sufficient to proof for reliable operation by test welds and non destructive tests (e.g. radiographic inspections) as required by the surveyor.

C. Design and Dimensioning of the Welded Joints

1. Materials and suitability for welding

1.1 Only base materials whose suitability for welding is established may be used for welded structures. The materials shall meet the conditions of Annex C of these Rules and shall be authorised by the test certificates stipulated in Annex C and F. Other materials comparable to ship steels according to recognised standards (e.g. general structural steels Fe 360B or C (St 37-2 or -3U) or Fe 510C (St 52-3U) in accordance with EN 10025, regarding this see also Annex C, Table C.1) require GL approval in each individual case. This applies logically to stainless steels, aluminium alloys and other non-ferrous metals.

Note:

For the ship steels described in the GL Rules for Materials and comparable general structural steels, plus for rolled products for welded structures of the boiler, storage tank, pipeline and machinery construction industry, suitability for welding is assumed proven. The suitability for welding of stainless steels, aluminium alloys and other non-ferrous metals (e.g. Cu-Ni alloys) habitually used in shipbuilding is also generally accepted. The notes and recommendations of the manufacturers of materials, fillers and supplementary materials are to be observed.

1.2 Materials shall be so chosen that materials and welded joints are able to stand up to the demands (stresses from loads, operating temperatures, corrosion, etc.) they are subject to. The materials are to be identified completely and clearly in the design documentation (drawings, etc.). Insofar as materials and/or welded joints require special treatment (e.g. preheating for welding or surface treatment to achieve adequate corrosion resistance) during or after processing, this shall be stated, too.

2. General design principles

2.1 Welded joints shall be planned from the beginning of the design process to be accessible and to be made in as favourable a position and sequence as possible. It shall be assured that the proposed type of seam (e.g. full penetration butt seam) can be faultlessly made and if necessary non destructively tested under the fabrication conditions prevailing.

2.2 Welded joints in load carrying components shall be configured to achieve as undisturbed a flow of forces as possible, without major internal or external notches or sudden changes in rigidity, and without impeding expansion. In zones of high stress concentration necessitated by design - especially if those stresses are dynamic - welded joints shall be avoided if possible or configured to allow for a substantially undisturbed flow of forces without any significant additional notch effect originating from the weld. Thicker components and larger cross sections shall be matched to thinner/smaller ones by gradual transitions (e.g. with a ratio of 1 : 3)

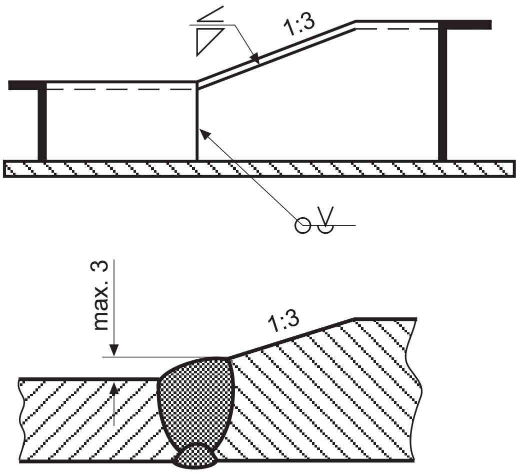


Fig. D.1 Transitions between differing plate thicknesses or section heights

2.3 For locally increased stresses in plating, thicker plates are to be provided if possible (rather than doubling plates). If doubling plates cannot be avoided, they are not to be more than twice as thick as the component to which they are to be welded. Bearing bushes, hubs, reinforcements for holes in eye plates, etc., are on principle to take the form of thicker plates or lengths of round material welded in or on.

2.4 Local accumulation of welds and welded joints spaced too close together shall be avoided. Adjoining butt seams shall be at least 50 mm + 4 t (t = plate thickness) apart; butt seams and fillet welds and fillet welds from one another, at least 30 mm + 3 t.

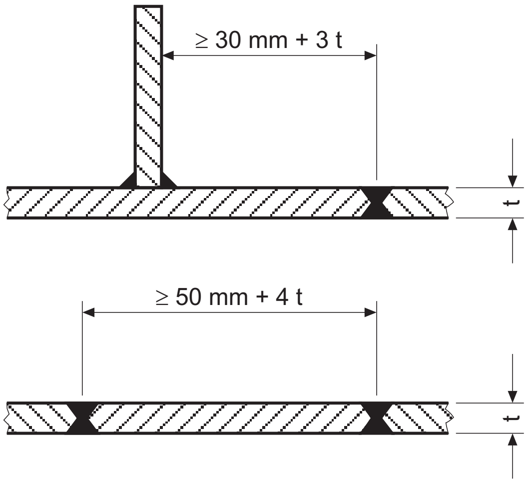


Fig. D.2 Minimum distances between butt seams and fillet seams

The width of strips of plate to be inserted or exchanged shall however be at least 10 t or 150 mm, whichever is the larger.

2.5 Through-welding holes for the (subsequent) welding of butt or fillet seams following the addition of crossing components (e.g. of stiffeners on sheet panels) are to be rounded, the minimum radius being 25 mm. Where welding of seams is completed before crossing components are added, through-welding holes are not needed. Any seam protrusions shall be removed or the component to be added shall be notched.

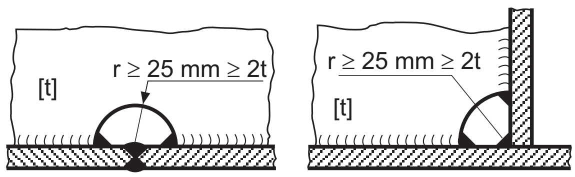


Fig. D.3 Through-welding holes

2.6 For welds in cold formed areas (e.g. at bends), the minimum bend radius for plate thicknesses up to 4 mm is to be 1 · t; for up to 8 mm, 1,5 · t; for up to 12 mm, 2 · t; for up to 24 mm, 3 · t. Edge bending operations may necessitate a larger bend radius.

2.7 Material dependent peculiarities, such as for example the softening of work hardened or precipitation hardened aluminium alloys by welding, are to be taken into account in the design and dimensioning of welded joints. Where joints between different materials, such as for example welds joining mild and stainless steel, are exposed to sea water or other electrolyte, the increased tendency to corrode due to potential differences, particularly near welded seams, is to be taken into consideration. If applicable, the welded joints shall be located in less endangered zones, or special corrosion protection measures taken.

3. Weld geometry and dimensions

3.1 Butt-welded seams (e.g. square, V- or X-seams) and corner or cross welds (e.g. with single-bevel or double-bevel seams (K-seams)) shall be planned for full penetration of the plate- or section cross section in principle. The root shall be grooved out and welded from the reverse side, in principle. In the case of single- or double-bevel (K-)seams, grooving out of the root may be dispensed with and a root defect of up to 0,2 t (t = thickness of the abutting component), max. 3 mm, may be accepted if the missing weld cross section is replaced by additional fillet welds.

3.2 Depending on plate thickness, welding procedure, welding position, etc., seam forms shall be planned to be in accordance with the standards (e.g. DIN 1912, DIN 8551, DIN 8552), with adequate angular opening, sufficient shoulder (air)gap and minimum shoulder height. Other (different) forms of seams shall have the compliance of GL, e.g. as part of the plan approval; if necessary, the seam forms are determined in conjunction with a procedure test.

3.3 Fillet welds in areas of high local stresses (e.g. load transfer zones) shall be planned to be continuous on both sides, if possible. In corrosion endangered zones (e.g. bilges, water tanks, around the bottom of fuel tanks, or in spaces where condensation, spray or leakage water can accumulate), components of non corrosion resistant materials shall be planned only to have fillet or cut-out welds continuous on both sides. The fillet welds shall be continued around the ends of the stiffeners or cut-outs to seal them. The same applies logically to lap welded joints.

3.4 The required fillet weld throat "a" (the height of the inscribed isosceles triangle) depends on component thickness and the relevant stress and is to be determined by calculation if necessary. Regarding this see Rules for Classification and Construction, I – Ship Technology, Part 1 – Seagoing Ships, Chapter 1 – Hull Structures, Section 19 and 20. Generally - for continuous welds on both sides - the fillet weld throats can be inserted in accordance with the following Table:

Plate thickness "t" of the thinner of the components to be joined (mm)	generally required fillet weld throat "a" for continuous welds on both sides (mm)
up to 5	2,5
over 5 up to 10	3,0
over 10 up to 15	3,5
over 20	4,0

3.5 The values according to 3.4 apply to normal and higher strength ship steels and comparable structural steels. For other steels and aluminium alloys it may be necessary to increase the a-dimension; similarly for discontinuous welds in accordance with 3.7, regarding this see also the Rules for Welding. The minimum fillet weld throat is:

$$a_{min} = \sqrt{\frac{(t_1 + t_2)}{3}} \quad [mm]$$

where t_1 and t_2 are the thicknesses of the two components to be joined. The maximum throat thickness is not to exceed 0,7 times the thickness of the thinner plate.

3.6 Reinforced fillet welds shall be planned for areas of locally increased and/or dynamic stress. These are, amongst others, force transfer points such as chain plates, the area around the rudder stock and shaft bracket, the engine seating or the structure supporting the mast. Except where something else is specifically laid down (e.g. under 4. or as part of the plan approval), a throat a = 0,5 t (t = the thickness of the thinner component) is to be planned there. Where stresses are particularly high, single or double V- (K-) welds shall be used.

3.7 Discontinuous, instead of continuous on both sides, fillet welding can be carried out as chain welding (with or without cut-outs) or as zig-zag welding. The subdivision of discontinuous fillet seams is to be so chosen that the shortest length of weld is not less than 10 times, and the longest unwelded length (longest distance between two fillet welds on the same or on opposite sides) is not more than 25 times the lesser thickness of the parts to be joined by welding. The length of cut-outs shall however not exceed 20 times the lesser thickness.

3.8 The thickness "a_u" of discontinuous fillet seams shall be calculated in accordance with the following formula, depending on the subdivision-ratio b/ℓ chosen and the thickness "t" on which the fillet thickness "a" depends,:

$$a_u = 0{,}15\, t\, \frac{b}{\ell}\, 1{,}1 \quad [mm]$$

but not less than the minimum throat size.

Where:

b = subdivision = $e + \ell$ [mm]

e = distance between the welds

ℓ = length of individual fillet welds [mm]

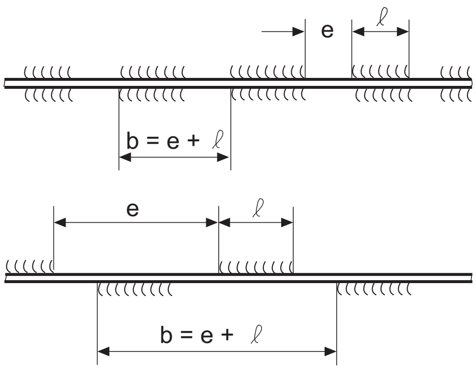


Fig. D.4 Discontinuous welding

3.9 For relatively low stressed components, (e.g. shell longitudinal seams) lap welded joints may be planned instead of butt joints. As far as possible these shall only be arranged parallel to the direction of principal stress (in the example, parallel to the longitudinal bending stress of the hull). In locally high stressed force transfer areas (e.g in way of ballast keel connection, chain plates or rudder stock) lap welded joints shall be avoided, if possible. The width of overlap shall be about 1,5 t + 15 mm, where "t" is the thickness of the thinner plate. The above applies as appropriate to throats.

3.10 When welding with cut-outs, these shall preferably be holes elongated in the direction of the principal stress. Spacing and length of holes shall be logically as in 3.7 for discontinuous welds; the throat shall be determined in accordance with 3.9. If the throat thickness so determined exceeds 0,7 times the plate thickness, the subdivision ratio is to be altered as necessary. Cut-out width is to be at least twice the plate thickness but not less than 15 mm. Cut-out ends shall be made semicircular. Plates or sections placed underneath shall be at least as thick as the plate with cut-outs.

4. Welded joints between separate components

4.1 Floor-to-frame welded joints shall be made as shown in Fig. D.5. The a dimension necessary shall be determined in accordance with the Table under 3.4. In corrosion endangered areas (cf. 3.3) welding shall be continuous, i.e. the weld taken right around the overlap to act as a seal, see also under 3.3

4.2 Frame-to-bracket-to-deck beam welded joints or frame-to-deck beam ones without any bracket may be made as show in Fig. D.6, depending on the loading. As regards the fillet welds, 4.1 applies logically. In areas of localised higher stresses (e.g in way of the mast of sailing yachts), the design shall have reinforcement (e.g. corners of frames flange reinforced) with correspondingly enlarged welded joints.

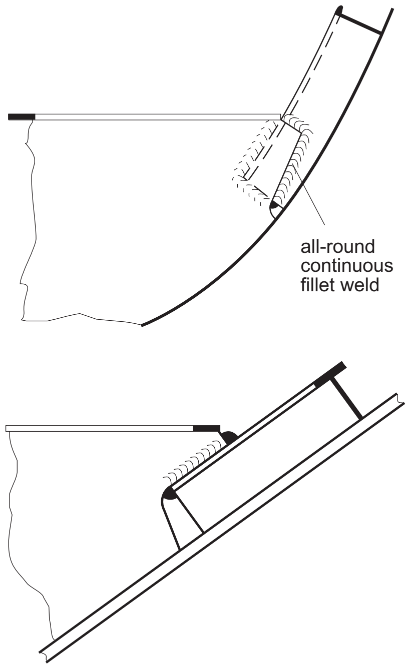


Fig. D.5 Floor-to-frame welded joint

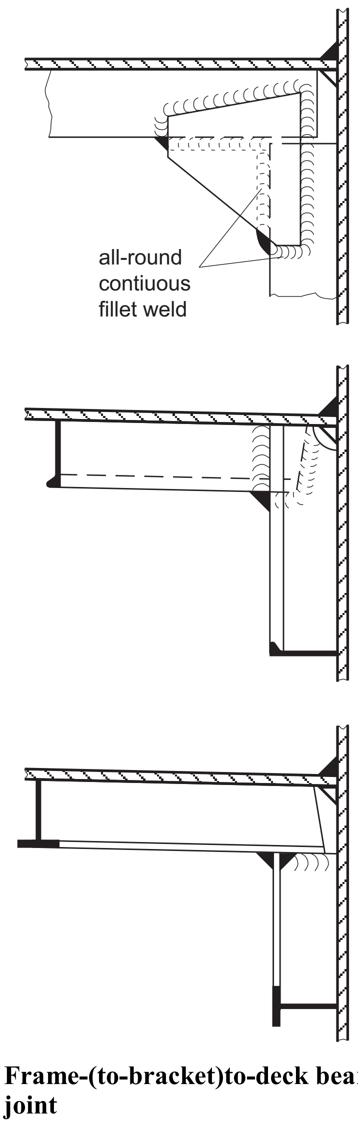


Fig. D.6 Frame-(to-bracket)to-deck beam welded joint

4.3 Examples of welded joints between rudder (coupling plate) and rudder stock are shown in Fig. D.7. Particularly when welding the stock into the coupling plate or the rudder, care shall be taken to achieve a notch free weld with "soft" transitions to the stock; as a rule the surface of the weld and the transitions are given a ground finish. Other solutions, equivalent to the ones shown, may be authorised - subject to the submission of detailed drawings and calculations if necessary (fatigue strength).

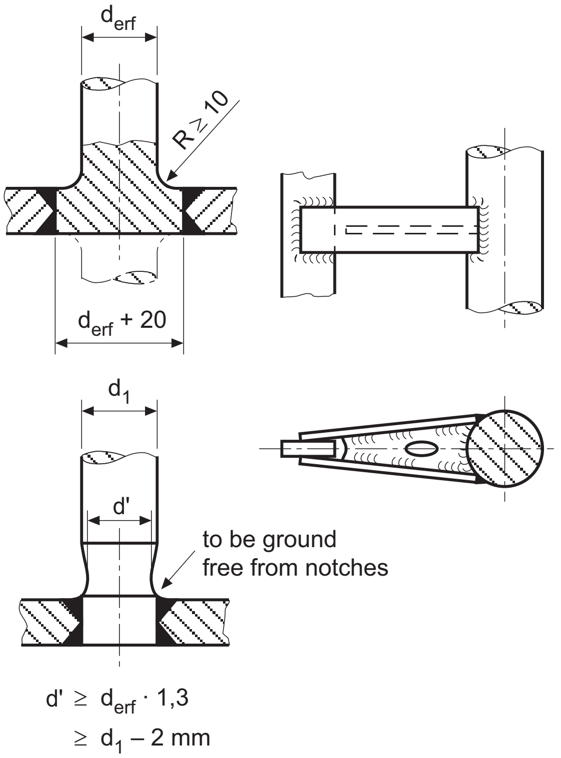


Fig. D.7 Welded joints between rudder (coupling plate) and stock

D. Making and Testing the Welded Joints

1. Seam preparation and part assembly

1.1 When preparing the components and fitting them together, attention is to be paid to the maintenance of the seam forms and shoulder (air)gaps stated in the design documentation and/or the standards. Particularly in the case of single or double V-(K)seams accessible only from one side, care is to be taken to leave an air gap large enough to achieve adequate penetration. Where temporary or permanent pool support is used, the air gap is to be increased appropriately.

1.2 The component butts to be welded shall be aligned as accurately as possible. In the case of sections etc. welded to plating the ends shall left loose to achieve this. If longitudinal girders and frames etc. are interrupted by bulkheads and similar components, or for example web frames (flanges) are interrupted by decks etc., their alignment shall be checked by test drillings through the transverse component, if necessary. These shall later be welded-up again.

Note

Useful guidance concerning acceptable fabrication tolerances is given in the "Fertigungsstandard des Deutschen Schiffbaus" (Manufacturing Standard of the German Shipbuilding Industry) issued by the "Verband für Schiffbau und Meerestechnik" (Shipbuilding and Marine Technology Association) in Hamburg. GL has approved this standard with the proviso that in exceptional cases, for instance important, highly stressed components or where there is an accumulation of deviations from the specified size, it may make a decision deviating from the standard and demand dressing.

2. Tacking, auxiliary materials

2.1 Tack welds shall be made as sparingly as possible and by trained personnel. If the quality of tack welds is not up to that required for the welds to be carried out on the component, they shall be carefully removed before the proper welding. Cracked tacks must never be welded over; they shall all be ground out.

2.2 Clamps, tack ties, fitting pins, etc. shall be of easily weldable steel (e.g. ship steel) or in the case of stainless steel and aluminium alloys of the same material if possible, but at least of one of the same kind, as the components to be joined. They must not to be used more often than necessary; for welding on, the same fillers shall be used as for joining the components.

2.3 Auxiliary materials and welds shall be removed after use in such a way that damage to the component surfaces is avoided as far as possible. Places damaged by inexpert removal of auxiliary material are to be ground out neatly, then welded up and ground notch free. GL may require a surface crack detection test before and/or after the welding up.

3. Weather protection, preheating

3.1 The working environment of the welder is to be protected against wind, wet and cold - especially in the case of outdoor work. Particularly for shielded arc welding, attention shall be paid to effective draught screening. Where work in the open is done under unfavourable weather conditions, heating the seam edges to dry them before welding is recommended.

3.2 In cold weather (below 0 °C) faultless execution of the welds shall be ensured by suitable measures (covering the components, large scale warming, preheating especially when welding thick walled components with relatively little heat input, e.g thin fillet welds). If possible, welding is to be suspended at temperatures below 0 °C.

3.3 Ordinary hull structural steels (e.g. Grade A to D) and comparable structural steels in general do not need preheating, apart from the measures in accordance with 3.1 and 3.2. In the case of components with very thick walls and that sort of forging or steel casting, slight preheating to about 80 to 120 °C before welding is recommended. The preheating temperature necessary for other materials (e.g. higher strength ship steels) shall be determined from the GL Rules for Welding, if applicable.

4. Welding position, welding sequence

4.1 Welding work should be done in the most favourable position (e.g. down hand position). Unfavourable welding positions welding shall be used only where absolutely necessary. Welders compelled to perform unfavourable welding positions must have been tested in this, see also under B.2.1. This applies especially to welding vertically downwards.

4.2 Even following a successful procedure test and approval of the procedure (cf. B.3.2), vertical downward welding may not be used for joining components to high local and/or dynamic stresses, as for example described in C.3.6. In case of doubt, the extent of vertical downward welding shall be agreed with GL before work starts (e.g. in the course of plan approval).

4.3 The welding sequence shall be chosen so as to minimise the interference with shrinkage. As far as possible, welding of plating butts shall be completed before stiffeners are set up, but in any case before they are welded to the plating. At T-shaped seam crossings (e.g where individual plates or patches are inserted later), the longitudinal seams shall be opened (or left open) over the transverse butts, and the latter shall be welded before the former.

5. Workmanship, repair of defects

5.1 The components shall be clean and dry around the weld seams. Scale, rust, slag, paint, grease and dirt shall be carefully removed before welding. Fabrication coating (shop primer) permitted by GL which may be welded over may be so treated if the layer is no thicker than the limiting value (usually 0,03 mm) stated in the permission. In cases of doubt, GL may require fillet weld fracture tests to prove that welds are faultless, without excessive porosity (regarding this see also Rules for Welding).

5.2 Regarding welding over tacked places see 2.1. In multi pass welding the slag from the preceding pass shall be removed carefully before welding the next pass. Visible defects such as pores, slag inclusions or cracks must not be welded over but rather machined out and repaired.

5.3 The welded seams shall have adequate penetration and clean, even surfaces with "soft" transitions to the base material. Excessively proud seams and undercuts, and notches at the edges of components or cut-outs, shall be avoided.

5.4 Butt welded joints must be welded right through the cross section of the plate or section. To this end the root is generally to be grooved out and welded from the reverse side. Single side welds (e.g. on ceramic weld pool support) shall be so prepared and carried out that here also full penetration is achieved. Single side welds on permanent, welded in, weld pool supports require GL approval, e.g. as part of the plan approval.

5.5 In the case of fillet welds attention shall be paid to good root cover. The penetration shall at least extend close to the theoretical root point. The fillet weld cross section to be aimed at is an isosceles flat seam without excessive bulge and with notch free transition to the base material. In storage tanks and other corrosion endangered spaces (cf. C.3.3) the fillet weld is to be continued around at web ends, cut-outs, through welding holes, etc. to provide a seal.

5.6 The repair of major workmanship defects or of flaws in the material requires the approval of the surveyor. Minor surface defects shall be eliminated by shallow grinding, if possible; deeper defects ground out cleanly and welded-up, the surfaces to be smoothed, see also 2.3.

6. Visual checks, non destructive testing

6.1 All welds shall be subjected to a visual check by the manufacturer's welding supervisor for completeness and proper execution of the work. Following the check on the part of the works and dressing if necessary, the components shall be presented to the GL surveyor in sensible phases of construction, easily accessible and as a rule unpainted, for the acceptance survey. The surveyor may reject components not adequately checked beforehand and demand presentation again after successful checking by the manufacturer, and if necessary dressing. Regarding this see also A.5.

6.2 If due to inadequate or lacking data in the fabrication documentation (cf. A.4.) the quality of the welded joints or the strength or operability of the components is in doubt, the GL surveyor may demand more extensive tests and/or appropriate improvements. This applies logically to supplementary or additional components (e.g. reinforcements) even if these were not called for at the plan approval or could not be called for because the representation was insufficiently detailed.

6.3 Depending on the importance and stressing of the components or their welded joints, non destructive tests (e.g. radiographic tests) shall be provided on top of the tests listed above. Nature and scope of such tests shall be agreed with the GL surveyor; the surveyor determines the test positions. The results shall be submitted to him for final evaluation. If these tests reveal defects on a major scale, the scope of the tests is to be increased. Repaired defects are to be re-tested. The tests shall be documented by the building yard; the documentation is to be retained there for an appropriate length of time (at least one class period).

Annex E

Workboats, Conversion Formulae

A. Conversion Formulae

1. The equivalent laminate thickness is determined in accordance with the following formula:

$$t_{GRP} = t_{St} \cdot \sqrt{\frac{\sigma_{aSt}}{\sigma_{aGRP}}}$$

For the section modulus of girders subject to bending, correspondingly

$$W_{GRP} = \frac{\sigma_{aSt} \cdot W_{St}}{\sigma_{aGRP}}$$

t_{GRP} = thickness of GRP plating

t_{st} = thickness of steel plating in accordance with Construction Rules

W_{st} = section modulus of steel girders according to Construction Rules

σ_{aSt} = allowable stress for ordinary hull structural steel; for most components 150 N/mm²

σ_{aGRP} = allowable stress for GRP:

= 0,25 · σ_{bB} for solid laminate plates

= 0,25 · R_m for GRP stiffeners

σ_{bB} = ultimate flexural strength [N/mm²], see Section 1, B.3.2

R_m = ultimate tensile strength [N/mm²], see Section 1, B.3.2

Annex F

Notes and Tables

A. Lightning Protection

1. Notes on the design of lightning protection installations on FRP recreational craft

1.1 General

A lightning strike in principle corresponds to a brief direct current shock whose strength may range from 10000 A to several 100000 A. Most discharges, about 80 %, are of current strengths below 60000 A.

The probability of lightning current strengths exceeding 250000 A is very low. However as the possibility of very high currents of around 200000 A occurring cannot be totally excluded, material used for lightning conductor systems shall be capable of withstanding the thermal and dynamic effects even of high lightning currents to guarantee the desired protection for people and objects. The following notes assume that the craft is afloat.

The notes apply only to so called "external lightning protection".

Overvoltage protection of (e.g.) electronic resources is not the subject of these notes.

2. Definitions

2.1 Lightning protection installation is the sum of arrangements for the external and internal protection of structural works against lightning.

2.2 External lightning protection is the sum of arrangements laid and existing on and below deck to trap the lightning current and deflect it into the water.

2.3 Internal lightning protection is measures against the high lightning overvoltages and the electromagnetic fields of lightning currents.

2.4 Earth: this always means the water or the metal surfaces arranged below waterline to discharge the lightning current into the water.

2.5 Earth connections are metal surfaces in the underwater part of the craft, such as earth plates, a metal ballast keel not laminated in, a metal centreboard, which

2.5.1 are connected to the trapping arrangement and

2.5.2 are suitable for discharging the lightning current into the water.

2.6 Trapping arrangement is the sum of the above deck metal components which can serve as points for the lightning to strike.

2.7 Protected zone is the space considered protected against lightning strike by a trapping arrangement.

2.8 Angle of protection is the angle to the vertical through any point of a trapping arrangement.

2.9 Discharge line is a metal connection between a trapping arrangement and an earth connection.

2.10 Potential equalisation is the unbroken linking of metal installations and electrical appliances to the lightning protection installation via leads, separating spark gaps or overvoltage protection equipment. It shall prevent the uncontrolled flashover of lightning from the discharge line to metal equipment in the craft.

2.11 Potential equalisation lead is an electrically conducting link serving to produce potential equalisation.

2.12 Separating spark gap for lightning protection installations is a spark gap for the galvanic separation of installation elements. When lightning strikes, the elements are temporarily electrically connected by triggering of the spark gap.

3. Protected zone

Trapping arrangements have the task of determining the point for lightning to strike, so as to prevent uncontrolled strikes elsewhere.

As both sailing and motor craft normally have a mast, the earthed masthead is most favourably used as the striking point for both crew and craft.

Below the masthead, a conical protected zone is formed whose tip is the earthed masthead. With a mast height up to 20 m above the waterline, the apex angle is about 45° to the vertical.

The mast height, particularly in the case of motor craft, is therefore to be chosen so that the craft, including the superstructures, is in the protected zone over its entire length. With earthed metal masts, or wooden masts with earthed head fittings, whose head is less than 20 m above the waterline, it is considered unlikely that lightning instead of striking the masthead will strike shrouds, stays or superstructure sideways.

4. Lightning protection installation

The lightning protection installation is to be understood as comprising everything above and below deck which serves the safe trapping and discharge of the lightning current.

A lightning protection installation must be installed complete; incomplete lightning protection installations may increase the danger to the persons on board under certain circumstances.

4.1 External lightning protection

4.1.1 Trapping arrangements

Masts of electrically non conducting material shall have a trapping device on the masthead, in the form of a metal rod at least 8 mm in diameter and projecting at least 300 mm above the mast.

Metal head fittings may be used as trapping arrangements if they enclose the mast all around and the material is at least 2 mm thick.

Metal masts do not need special trapping arrangements. Aerials, anemometers, etc. located on the masthead and whose operational requirements preclude direct earthing shall be linked to the masthead by separating spark gaps.

4.2 Discharge lines

Flexible copper leads of type NYY, NYAF, H07V-K or equivalent shall be provided as discharge lines.

The discharge lines running to the earth connection shall be as straight as possible. Sharp bends and tight bights of the conductor shall be avoided.

The ohmic resistance between trapping arrangement and earth connection is not to exceed 0,02 Ohm.

4.2.1 Metal masts

Discharge lines shall be provided in the form of a main line from the mast foot plus secondary ones from all chain plates to which shrouds or stays are fastened.

Minimum cross sections:

– main line 25 mm^2

– secondary line 20 mm^2

Non-metallic masts:

With non-metallic masts, shrouds and stays have to be used as main discharge lines. The associated chain plates and any metal mast tracks for sail luffs shall be conductively linked to the earth connection.

Minimum cross sections:

– all discharge lines 16 mm^2

4.3 Earthing arrangements

The discharge lines are to be conductively connected, as close together as possible and in a place easily to be checked to:

– the bolts of a not laminated-in metal keel which are accessible from inside the craft or

– a copper, or equivalent metal plate at least 0,2 [m^2] in area. This plate shall be so located on the shell of the craft that it will remain below the surface of the water at all attitudes and movements of the craft that are to be expected.

To avoid damage to bearings, propeller shafting should not be used for discharging lightning current into the water.

The notes regarding the provision of cathodic protection for submerged metal parts are to be taken into account when arranging earth connections.

5. Internal lightning protection

If lightning strikes there is a risk of parts of the charge sparking-over to metal appliances in the vicinity of lightning protection arrangements.

To eliminate this risk all major metal parts on and below deck, such as bow and stern pulpits, stern tubes, steering gear, pipelines, metal wash basins and toilets, metal tanks plus the electric system (e.g. battery negative pole) are to be conductively linked to the earth connection of the lightning protection installation to provide potential equalisation. For this, copper conductors with a minimum cross section of 4 mm^2 shall be used.

If direct connection of certain appliances or equipment to the earthed lightning protection installation is not possible for operational reasons, arresters or closed separating spark gaps shall be inserted.

6. Joints

Standard commercial lightning conductor terminals or equivalent means are preferably to be used as connectors for the discharge lines.

Connecting devices as used for electrical installations are unsuitable because they will not withstand the dynamic and thermal stresses to be expected from a lightning strike.

Equally unsuitable are soft soldered joints, twist joints and ones with grub screws, plus joints connecting different materials which because of elemental interaction might lead to corrosion.

7. Setting-up a lightning protection installation

In view of the variety of possible versions, it is strongly recommended that the advice of an expert firm be sought when setting-up a lightning protection installation.

Table F.1 Anchors, anchor cables and lines of sailing craft and motorsailers

Equipment numeral Z [m³]	Deplacement D [t]	Weight of 1. anchor [3] [kg]	Weight of 2. anchor [kg]	Anchor cable Length [4] [m]	Anchor cable Nominal thickness [1] [mm]	Towing line Length [m]	Towing line Nominal diameter [2] [mm]
—	up to 0,15	2,5	—	—	—	5 L_{WL}	12
—	at 0,20	3,0	—	—	—		12
—	at 0,30	3,5	—	—	—		12
—	at 0,40	4,5	—	—	—		12
—	at 0,50	5,0	—	—	—		12
—	at 0,60	5,5	—	—	—		14
—	at 0,75	6,5	—	—	—		14
—	at 1,00	7,5	—	—	—		14
—	at 1,50	8,7	—	—	—		14
up to 10	at 2,00	10,5	9,0	22,5	6,0		16
at 15	at 3,00	12,0	10,0	24,0	6,0		18
at 20	at 4,00	13,0	10,5	25,0	6,0		18
at 25	at 5,00	13,5	11,0	26,0	7,0		18
at 30	at 6,00	15,0	13,0	27,0	7,0		18
at 40	at 8,00	17,0	15,0	29,0	8,0		20
at 55	at 12,00	21,0	18,0	32,5	8,0		22
at 70	at 17,00	25,0	21,0	36,0	9,0	4,75 L_{WL}	22
at 90	at 23,00	29,0	25,0	40,0	10,0		22
at 110	at 29,00	34,5	29,0	43,0	10,0		24
at 130	at 36,00	40,0	34,0	47,0	11,0	4,5 L_{WL}	24
at 155	at 44,00	46,5	40,0	52,5	13,0		24
at 180	at 52,00	53,0	45,0	57,0	13,0		24
at 210	at 57,00	62,0	53,0	62,0	13,0		26
at 245	at 72,00	73,5	62,0	68,0	14,0	4,25 L_{WL}	26
at 280	at 84,00	84,0	71,0	74,0	16,0		26
at 300	at 100,00	95,0	81,0	78,0	16,0		26

Z Equipment numeral in accordance with Section 1, G.

[1] Nominal thickness of round bar steel chain in accordance with DIN 766, ISO 4565, EN 24565.

[2] 3-strand hawser-lay polyamide line in accordance with DIN 83330.

[3] May be reduced by 25 % if the craft in question operates exclusively on inland waterways (Operating Category V) where strong currents and high seas can be excluded. A stock anchor of 1,33 times the weight may be used.

[4] Applies for one anchor in each case.

Table F.2 Anchors, anchor chains and lines of motor craft

Equipment numeral Z [m³]	Deplacement D [t]	Weight of 1. anchor [3] [kg]	Weight of 2. anchor [kg]	Anchor cable Length [4] [m]	Anchor cable Nominal thickness [1] [mm]	Towing line Length [m]	Towing line Nominal diameter [2] [mm]
—	up to 0,15	2,5	—	—	—	5 L_{WL}	12
—	at 0,20	3,0	—	—	—		12
—	at 0,30	3,5	—	—	—		12
—	at 0,40	4,5	—	—	—		12
—	at 0,50	5,0	—	—	—		12
—	at 0,60	5,5	—	—	—		14
—	at 0,75	6,5	—	—	—		14
—	at 1,00	7,5	—	—	—		14
—	at 1,50	8,7	—	—	—		14
up to 10	at 2,00	9,0	—	20,0	6,0		16
at 15	at 3,00	10,0	—	22,0	6,0		18
at 20	at 4,00	11,0	—	23,0	6,0		18
at 25	at 5,00	12,0	—	24,0	6,0		18
at 30	at 6,00	13,0	—	25,0	7,0		18
at 40	at 8,00	14,0	12,0	26,0	7,0		20
at 55	at 12,00	18,0	15,0	29,0	8,0		22
at 70	at 17,00	21,0	18,0	32,5	8,0	4,75 L_{WL}	22
at 90	at 23,00	25,0	21,0	36,0	9,0		22
at 110	at 29,00	29,0	25,0	38,5	10,0		24
at 130	at 36,00	34,5	29,0	42,0	10,0	4,5 L_{WL}	24
at 155	at 44,00	40,0	34,0	47,0	11,0		24
at 180	at 52,00	46,0	39,0	51,0	13,0		24
at 210	at 57,00	52,5	44,0	55,5	13,0		26
at 245	at 72,00	61,0	52,0	61,0	13,0	4,25 L_{WL}	26
at 280	at 84,00	70,5	60,0	66,5	14,0		26
at 300	at 100,00	79,5	67,5	70,0	16,0		26

Z Equipment numeral in accordance with Section 1, G.

[1] Nominal thickness of round bar steel chain in accordance with ISO 4565, EN 24565, DIN 766.

[2] 3-strand hawser-lay polyamide line in accordance with DIN 83330.

[3] May be reduced by 25 % if the craft in question operates exclusively on inland waterways (Operating Category V) where strong currents and high seas can be excluded. A stock anchor of 1,33 times the weight may be used.

[4] Applies for one anchor in each case.

Table F.3 Notes regarding the selection of synthetic fibre ropes

1. Characteristic values and trade names

Material Letter symbol	**Polyamid PA**	**Polyester PES**	**Polypropylene PP**
Trade name	Perlon Nylon	Trevira	Poly
		Diolen	Polyprop
		Terylene	Hostalen
Density [kg/dm³]	1,14	1,38	0,19
Elongation at break [%]	35 – 50	20 – 40	20 – 40
Melting point [°C]	225 – 250	260	163 – 174
Light toughness	good	very good	good only if UV stabilised

2. Mechanical properties of 3-strand hawser-lay ropes

Polyamide ropes [1]		**Polyester ropes** [2]		**Polypropylene ropes** [3]	
Nominal diameter [mm]	**Minimum breaking [4] strength [kN]**	**Nominal diameter [mm]**	**Minimum breaking [4] strength [kN]**	**Nominal diameter [mm]**	**Minimum breaking [4] strength kN**
6	7,35	6	5,80	6	5,90
8	13,20	8	10,50	8	10,40
10	20,40	10	16,80	10	15,30
12	29,40	12	24,00	12	21,70
14	40,20	14	33,70	14	29,90
16	52,00	16	43,40	16	37,00
18	65,70	18	54,80	18	47,20
20	81,40	20	68,20	20	56,90
22	98,00	22	82,00	22	68,20
24	118,00	24	98,50	24	79,70
26	137,00	26	115,50	26	92,20

1 In accordance with DIN 83330.

2 In accordance with DIN 83331.

3 In accordance with DIN 83332.

4 The minimum breaking strength is reduced by the following operational influences.
- Splicing (approx. 10 %)
- Solar radiation
- Internal heating as a result of work
- External heating due to friction (hawsepipe, capstan drum, etc.)
- If lines are knotted, a 50 % loss of strength shall be taken into consideration.
- Polyamide rope tractive power reduces by 10 – 15 % when wet.

Care for synthetic fibre ropes calls for attention as follows:

Stowage below deck, once at sea (solar radiation).

Do not stow near heating appliances.

From time to time inspect ropes carefully for internal and external defects. In heavily stressed lines, the material can be broken down by internal friction (heat), which may also become evident by pulverisation between the strands. Polyamide ropes may harden.

Replace defective thimbles. Splice-in loose thimbles afresh and seize-in firmly.

1. Comments on Table F.4

Where determination of component dimensions gives figures other than whole or half millimetres, these may be rounded down up to 0,2/0,7 to whole or half millimetres; above 0,2/0,7 they shall be rounded up.

2. Section moduli

The section moduli of frames, girders, stiffeners and other components based on sections, determined in accordance with the dimensioning precepts of the Construction Rules apply to the sections in combination with the plate to which they are welded or rivetted. For selection of the section required, the Tables of section moduli that follow may be used without specially determining the effective width of plate. The section moduli may only be used in conjunction with the GL Construction Rules. The section moduli listed are based on the assumption that the thickness of the load supporting plate is $40 \cdot s$ (s = thickness of section web).

The section dimensions stated only apply to angles in accordance with DIN 1028 and 1029, bulb angle bar in accordance with DIN 1020 and bulb plate in accordance with DIN 1019, delivered from German steel works. If other sections, not standardised in Germany, are used GL is to be provided with precise dimensions and section moduli of these.

Table F.4 Section moduli with plate as flange

Section modulus [cm^3]	Sections with plate in [mm]			Bracket dimensions [mm]
				
5	40 x 20 x 4		50 x 5 60 x 4	
6	40 x 25 x 4		50 x 6 65 x 4	
7	50 x 30 x 3		60 x 5 50 x 7	
8	45 x 30 x 4		60 x 6	
9	50 x 30 x 4 45 x 30 x 5		80 x 4 65 x 6	
10	50 x 40 x 4		60 x 8	
11	50 x 30 x 5 60 x 30 x 4	60 x 4	80 x 5 65 x 7	
12		60 x 5	75 x 6	
13	50 x 40 x 5		65 x 8 90 x 5	
14	60 x 30 x 5	60 x 6	75 x 7	
15			80 x 7	
16	60 x 40 x 5		75 x 8	
17				
18				
19	60 x 30 x 7 60 x 40 x 6		75 x 9	
20		80 x 5	100 x 6	
21	60 x 50 x 5		75 x 10	
22	60 x 40 x 7			
23		80 x 6	90 x 8	
24				

Table F.4 Section moduli with plate as flange

Section modulus [cm^3]	Sections with plate in [mm]			Bracket dimensions [mm]
				
25	75 x 50 x 5	80 x 7		100 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	110 x 6,5
32			110 x 8	
33			90 x 11	
34		100 x 6		
35	75 x 50 x 7		100 x 10	
36	65 x 50 x 9		90 x 12	
37	75 x 55 x 7 80 x 40 x 8		110 x 9	120 x 6,5
38		100 x 7	120 x 8	
39	80 x 65 x 6		100 x 11	
40				
41				
42		100 x 8	100 x 10	130 x 6,5
43	90 x 60 x 6			
44	75 x 50 x 9		120 x 9	

B. Example

1. Form F 146

Plans and Technical Data for Yachts and Small Craft

Germanischer Lloyd

Page: 1

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

Project: ______________________

Distribution 1.: ______________________

2.: ______________________

3.: ______________________

Journal No.: ______________________

Hull

- ☐ Midship section, other sections and bulkheads
- ☐ Longitudinal section, shell
- ☐ Deck, superstructures and cabins
- ☐ Fuel and water tanks where integral with hull
- ☐ Machinery seatings
- ☐ Rudder blade with stock, trunk and bearings
- ☐ Propeller brackets
- ☐ Laminate construction [1]
- ☐ Material specification
- ☐ Welded connections
- ☐ Closures, details at GL-form F 434 [2]
- ☐ Anchoring equipment
- ☐ Sailplan with details on standing rigging

  Drawings showing mast and main boom cross-sections, including details on section moduli and moments of inertia, materials, mast fittings, eye plates (including fittings for total fore and aft stays), terminals, turnbuckles, shackles, as far as serving for connection of standing rigging; details of hydraulic equipment, righting lever curve, displacement).
- ☐ Stability calculation or stability tests for vessels **L** < 10 m, inclining test for vessels **L** ≥ 10 m, tests of the turning-circle angle of heel for motor vessels **L** ≥ 10 m.
- ☐ Cooking appliances with open flame, materials, arrangement sketch
- ☐ General arrangement (for information only) one fold
- ☐ Lines plan (for information only), one fold

Plans and Technical Data for Yachts and Small Craft

Germanischer Lloyd

Page: 2

Machinery and Electrical Installations [3]

- ☐ Arrangement of propulsion plant
- ☐ Propeller shaft and sterntube
- ☐ Type, capacity and installation drawing of transverse thruster
- ☐ Plumbing installation and fuel systems
- ☐ Fuel and water tanks
- ☐ Type and drawing of anchor windlass [4]
- ☐ Type and drawing of steering gear scheme of hydraulic system
- ☐ Engine exhaust system
- ☐ Electrical installation on form F 145
- ☐ Basic-circuit diagram of the electrical installation with indication of fuse rating currents and switch gear

Other particulars to be submitted:

Remarks:

Additional information, however, may be required to define the structure and arrangements to the necessary detail. Where the hull scantlings are being determined by direct calculation rather than extracted from the published Rules, the calculations are to be submitted. The drawings must contain details on the main scantlings of the yacht, full details on its structure, equipment, scantlings of the hull structural elements and their materials.

Footnotes:

1 For FRP hulls the following materials are to be specified: Gelcoat, resin, fibre reinforcement materials, core materials of sandwich components and plywood of structural elements. Laminating process to be indicated.

2 It is advisable to have the closing condition examined at as early a state of construction as possible.

3 For motor yachts in service range I and II the rules for machinery installations of seagoing ships are applicable.

4 Required for anchor weights exceeding 50 kg.

Annex G

Cabins and Accommodation

A. General

Pleasure craft for Operating Categories I, II and III shall be provided with cabins and accommodation for the protection of all on board.

B. Cabins

The required minimum size for a cabin is arrived at on the basis of the following recommendation:

– for each person on board there should be one bunk and one seat in the cabin. Minimum dimension of a bunk: 1900 mm length, 500 mm average width.

– The clear headroom in the after half of the cabin should be at least 1.50 m, but in Operating Category I the headroom should be at least 1,70 m.

– There shall be accommodation facilities in accordance with C. and stowage facilities for personal effects, provisions and other consumables commensurate with the duration of the voyage.

C. Accommodation

Depending on the Operating Category, the required facilities are listed in Table G.1.

D. Ventilation

Cabins and living spaces shall have adequate ventilation. The necessary apertures shall be provided with suitable closures for the effective prevention of water penetrating into the hull.

Regarding machinery space ventilation see Section 3.

Table G.1

	Operating Categories		
	I	**II**	**III**
1. Lavatory, permanently fitted	X	X	
2. Lavatory, permanently fitted or suitable container (bucket), permanently fitted			X
3. A cooking devices ***Note:*** *Cooking devices shall be permanently fitted or semi-gimbal mounted. Specifications for heating- and cooking devices see Section 3, F.*	X	X	X
4. Complete and permanently fitted galley ***Note:*** *"galley" means, apart from a fixed sink, all parts and appliances needed for the preparation of hot meals in a seaway in average weather.* *In Operating Category III, a tub or bucket for washing dishes will be sufficient in lieu of a permanently fitted sink.*	X	X	X

Annex H

Number of Persons and Freeboard

A. Permissible Number of Persons

This Table is to be viewed as a recommendation; deviation from it is therefore permitted where there are reasons for it.

When calculating stability, the determined number of persons shall be taken as a minimum.

Table H.1

Operating Category	Requirements	Comment
V, IV, III	Minimum seat surface area per person width 0,50 m depth 0,75 m [1]	(1)
II and I	Beyond the requirements of Operating Category V – III: bunk and seat in the cabin	(1) and (2)

[1] including footroom

(1) Supply of places and spaciousness are to be commensurate with the Operating Category and voyage duration.
(2) Cabin and accommodation, see Annex G.

B. Freeboard

Tables are to be viewed as a recommendation; deviation from it is therefore permitted where there are reasons for it.

When calculating freeboard, the determined value shall be taken as minimum freeboard.

Table H.2

Minimum freeboard for open and partially decked craft [1]		Comment
Operation Category	Requirement	
V	$F_b = 0{,}15 + 0{,}15\,\mathbf{B}\ [m]$	(1) (2) and (4)
IV	$F_b = 0{,}15 + 0{,}20\,\mathbf{B}\ [m]$	

[1] In the case of open and partially decked craft the freeboard is the minimum distance between the flotation plane and the gunwale top edge or any opening in the shell without a watertight closure.

Table H.3

Minimum freeboard for decked craft		Comment
Operation Category	**Requirement**	
IV – I	$F_b = 0{,}15 + 0{,}25\,\mathbf{B}\ [m]$	(3) and (4)

(1) In the case of outboard powered craft, the freeboard shall also be maintained when one person on board is near the outboard engine (attitude when starting the engine by hand)

(2) The requirements when the craft is swamped in accordance with Section 5, A.11 shall be observed.

(3) If operating exclusively in Operating Category V, decked craft may have freeboards as for open and partially decked craft.

(4) Craft for operation in sheltered waters may on application be given a lower freeboard.