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 $\mathbf{L_H}$ 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:

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

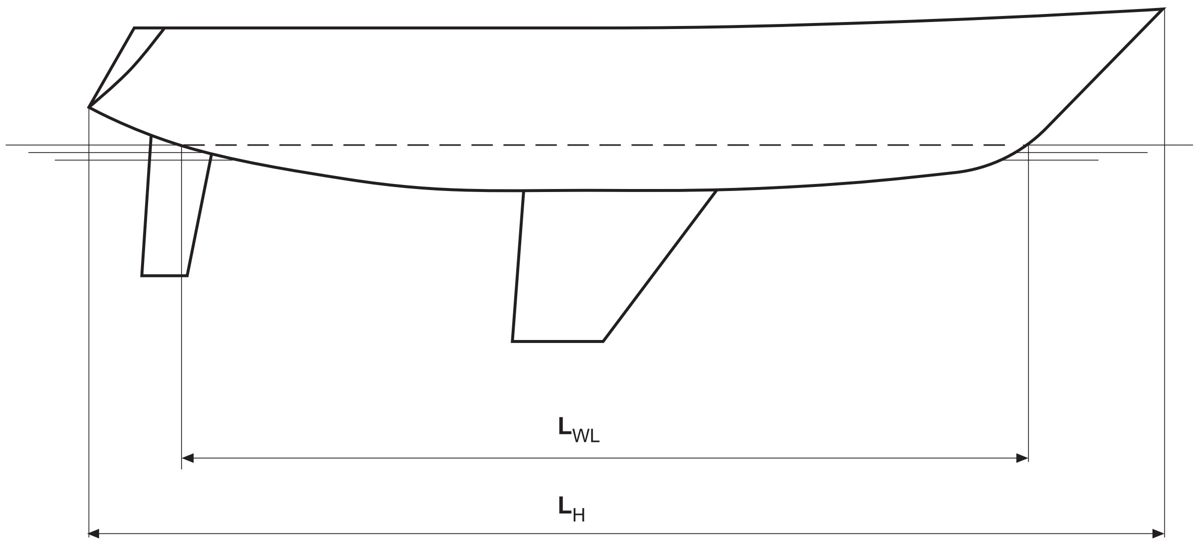


Fig. 1.1

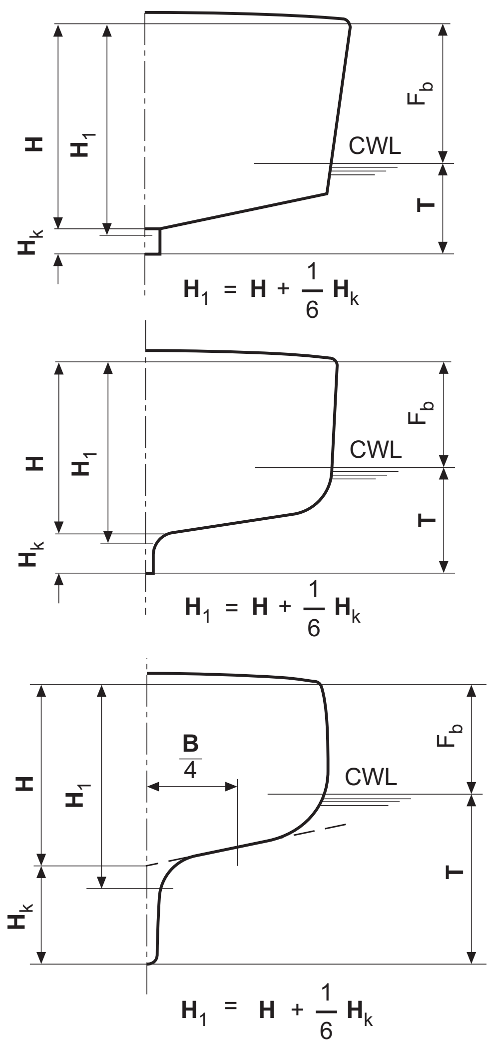


Fig. 1.2

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 $\mathbf{H_1}$

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 $\mathbf{H_k}$ 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.

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.

$$\mathbf{D} = \mathbf{V} \cdot \rho$$

ρ = density of the displaced water [t/m^3]

V = immersed volume up to line of flotation [m^3]

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}
$\geq$ 0,4 **L** ÷ fore	2,7 **L** + 3,29	3,29 **L** – 1,41
< 0,4 **L** ÷ aft	2,16 **L** + 2,63	2,63 **L** – 1,13
Shell side	P_{dSM}	P_{dSS}
$\geq$ 0,4 **L** ÷ fore	1,88 **L** + 1,76	2,06 **L** – 2,94
< 0,4 **L** ÷ aft	1,5 **L** + 1,41	1,65 **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.

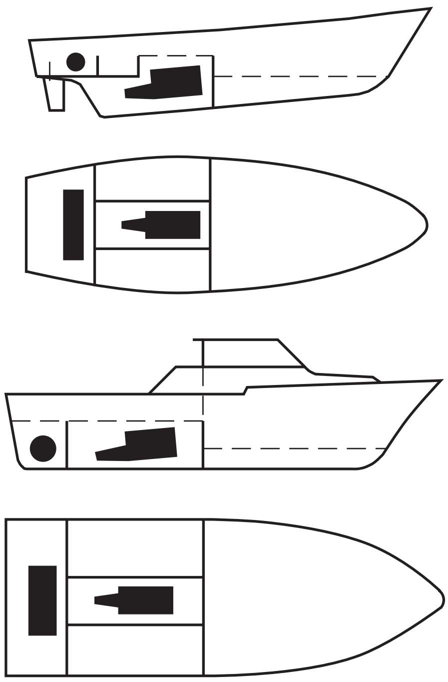
2.1.2 Other bulkheads and subdivisions

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:

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

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 [m²]

= 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:

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

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.

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

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

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

$A_0 = A_1$

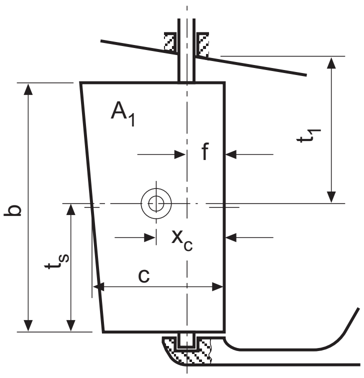


Fig. 1.3

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

für $\frac{A_1}{A_3} \geq 2{,}0$

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

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

$A_0 = A_1 + A_3$

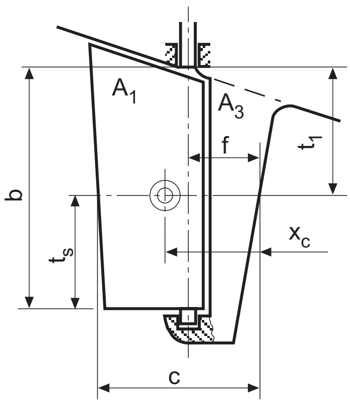


Fig. 1.4

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

für $\frac{A_1}{A_3} < 2{,}0$

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

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

$A_0 = A_1$

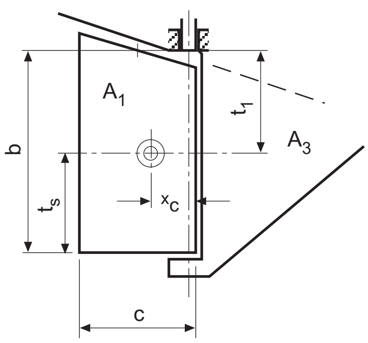


Fig. 1.5

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

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

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

$$A_0 = A_2$$

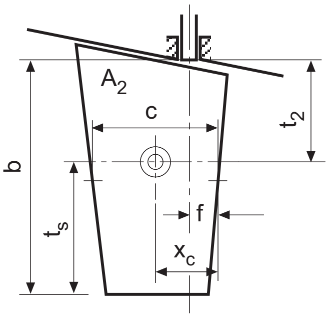


Fig. 1.6

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

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

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

$$A_0 = A_1 + A_2 + A_3$$

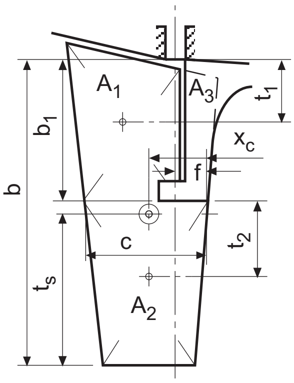


Fig. 1.7

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

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

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.

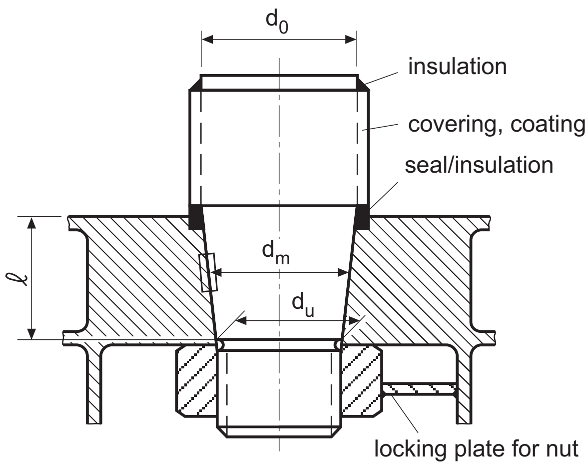


Fig. 1.8

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:

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

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:

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

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

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

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

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

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:

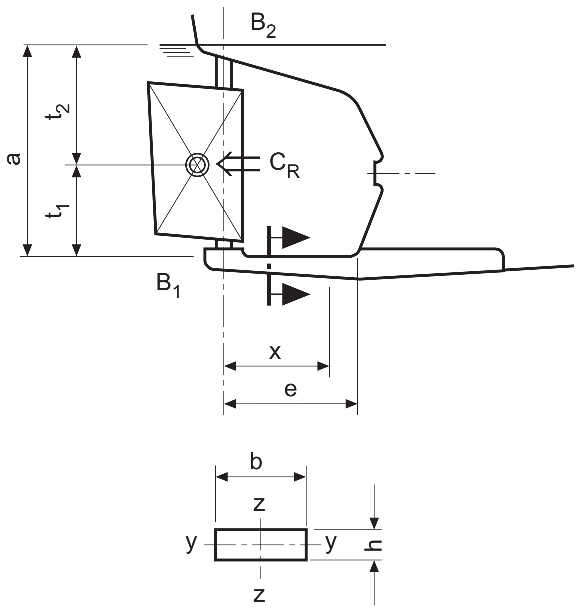


Fig. 1.9

Rudders with bearing in sole piece/skeg:

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

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

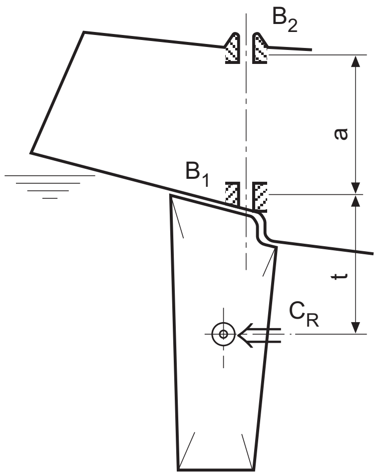


Fig. 1.10 Spade rudder

Bearings of spade rudders:

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

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

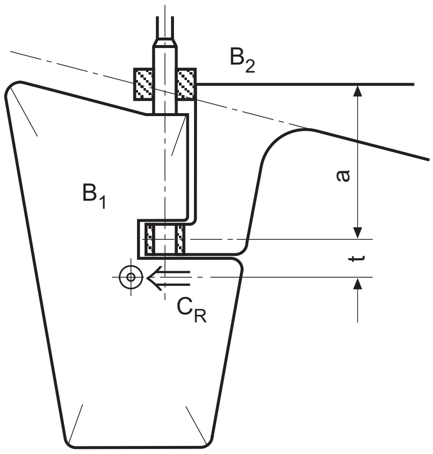


Fig. 1.11 Semi spade rudder

Bearings of semi spade rudders:

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

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

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:

$$S = 0{,}9\,\sqrt{L_{WL}} \cdot \sqrt{k}$$

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:

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

k = material factor according to F.3.3

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

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

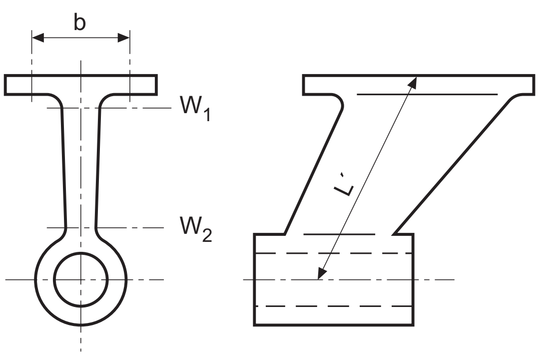


Fig. 1.12

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 $0{,}75 \times$ nominal rpm is to be determined. In these circumstances the following bending stress is not to be exceeded:

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

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

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

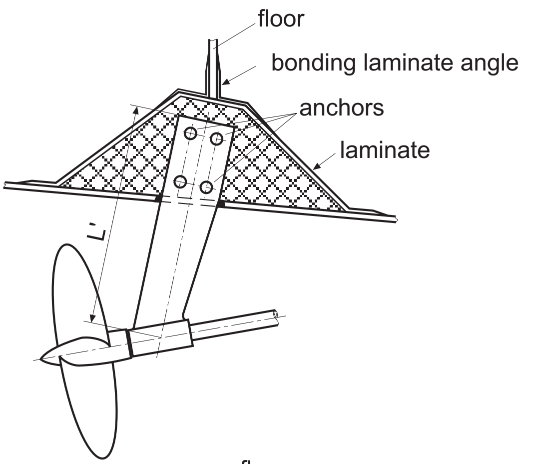
[1] ordinary hull structural steel

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.



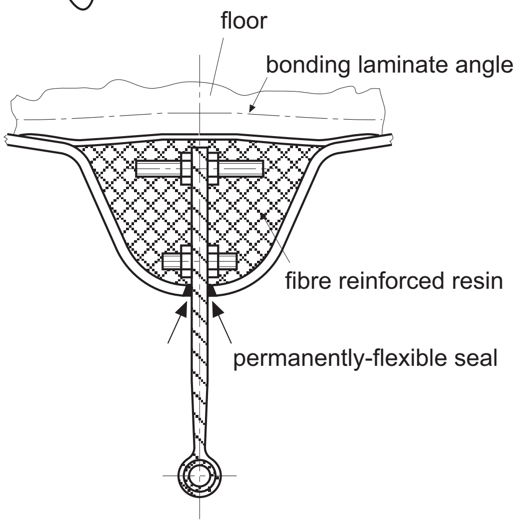


Fig. 1.13

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]

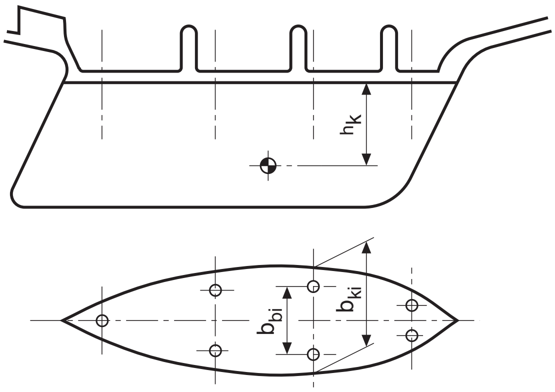


Fig. 1.14

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 bi-directional 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	EN ISO 527-4
	wet	EN ISO 527-4 [1, 2]
Young's modulus (tension)	dry	EN ISO 527-4
Flexural strength	dry	EN ISO 14125, Procedure A
	wet	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)

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

Young's modulus (tension)

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

Flexural strength (fracture)

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

Compressive strength (fracture)

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

Shear strength (fracture)

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

Shear modulus

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

Interlaminar shear strength

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

Ψ = glass content of laminate by weight

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

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

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

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

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

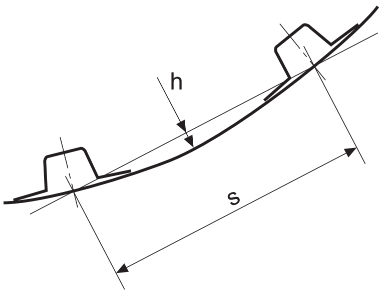


Fig. 1.15

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:

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

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:

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

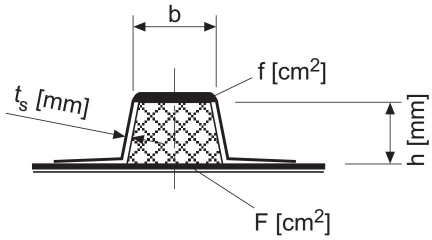


Fig. 1.16

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:

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

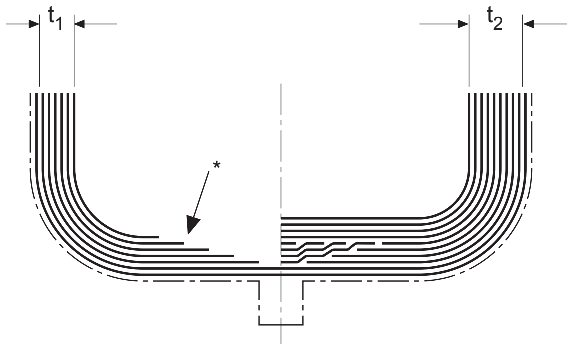
6. Shell laminate

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.



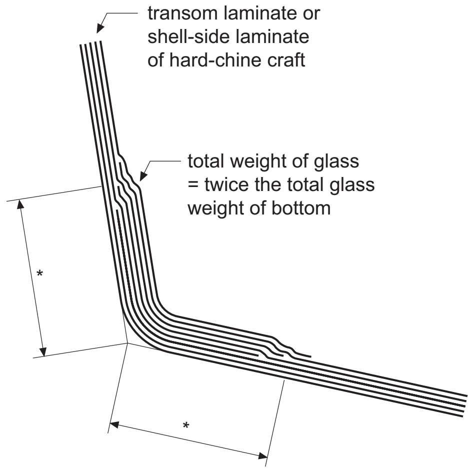
t_1 = laminate before joining the two prefabricated hull halves

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:

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

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:

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

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.

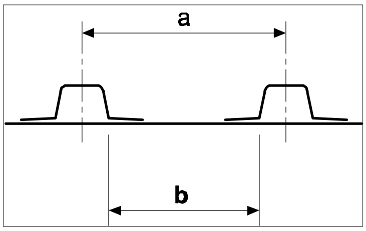
6.3.9 The total reinforcement weight for the stern or the transom must not be less than that for the shell side. Transoms are to be stiffened adequately. Additional reinforcement is required in accordance with 6.1.3.

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

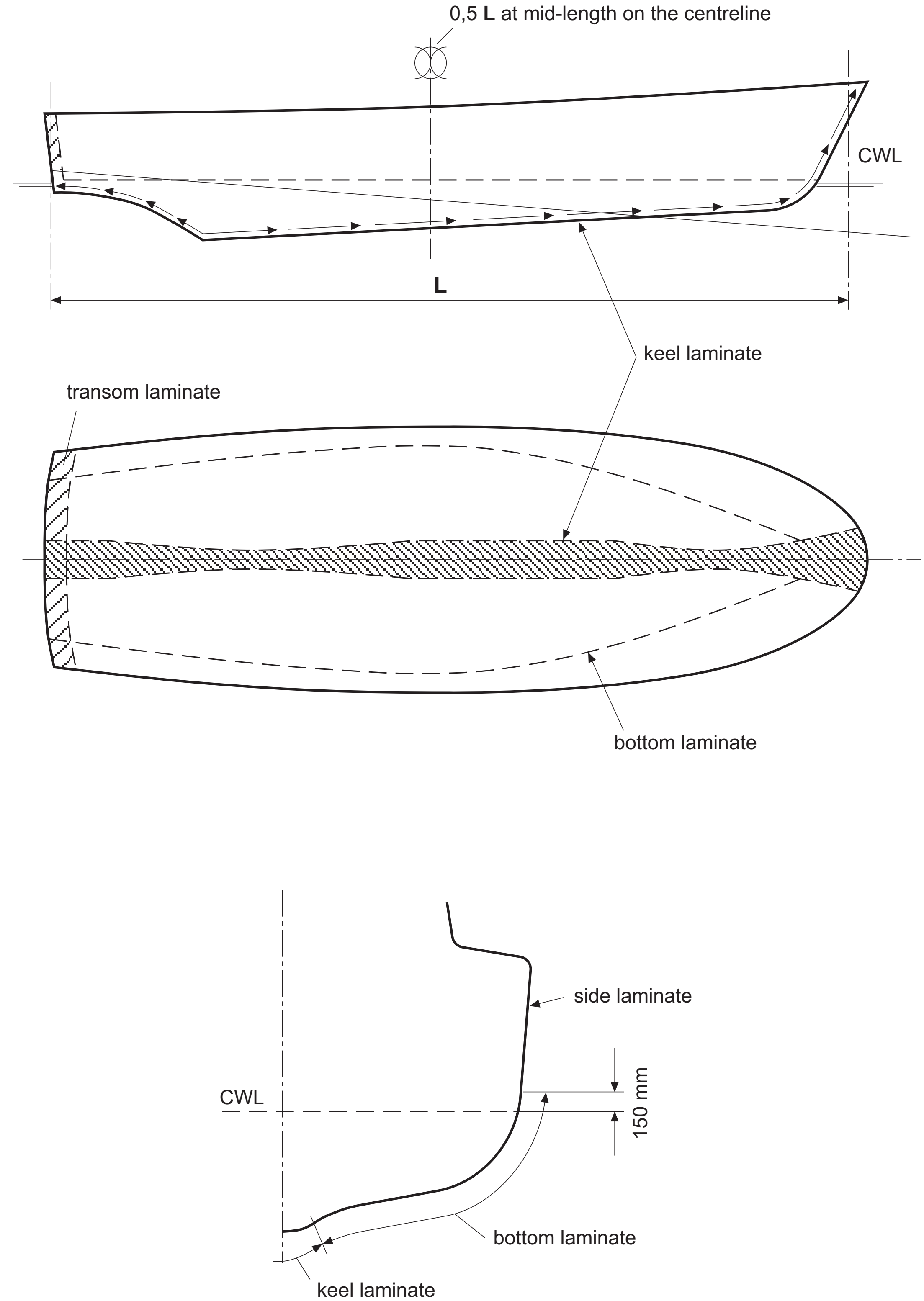
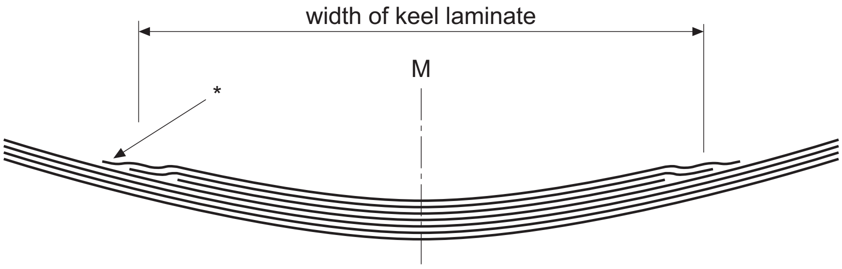
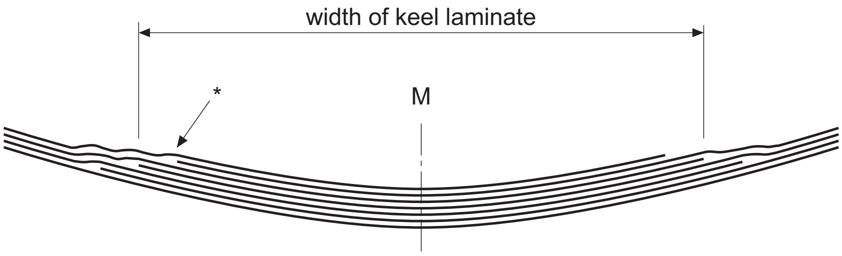

0,5 **L** at mid-length on the centreline
CWL
L
keel laminate
transom laminate
bottom laminate
side laminate
CWL
150 mm
bottom laminate
keel laminate

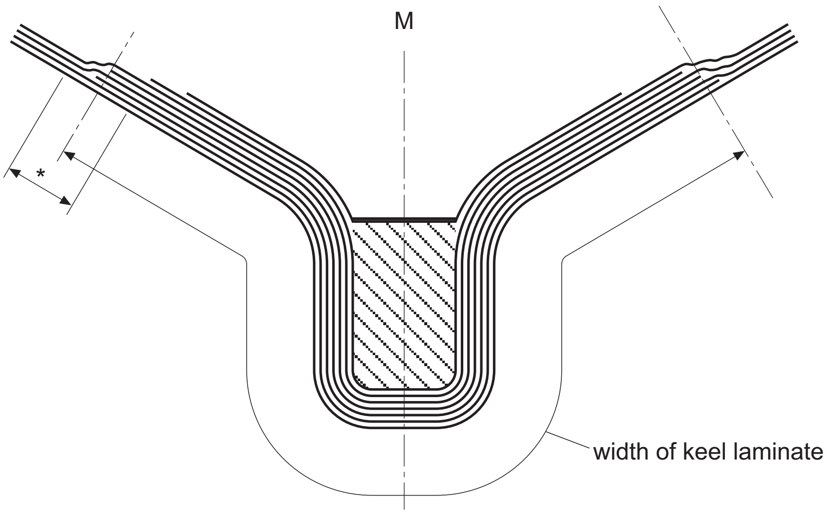
Fig. 1.19



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

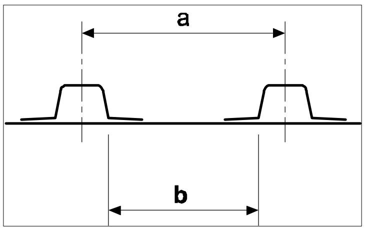
Fin keel may be filled and covered with laminate whose total glass weight must be at least 50 % of that of the shell bottom

* 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

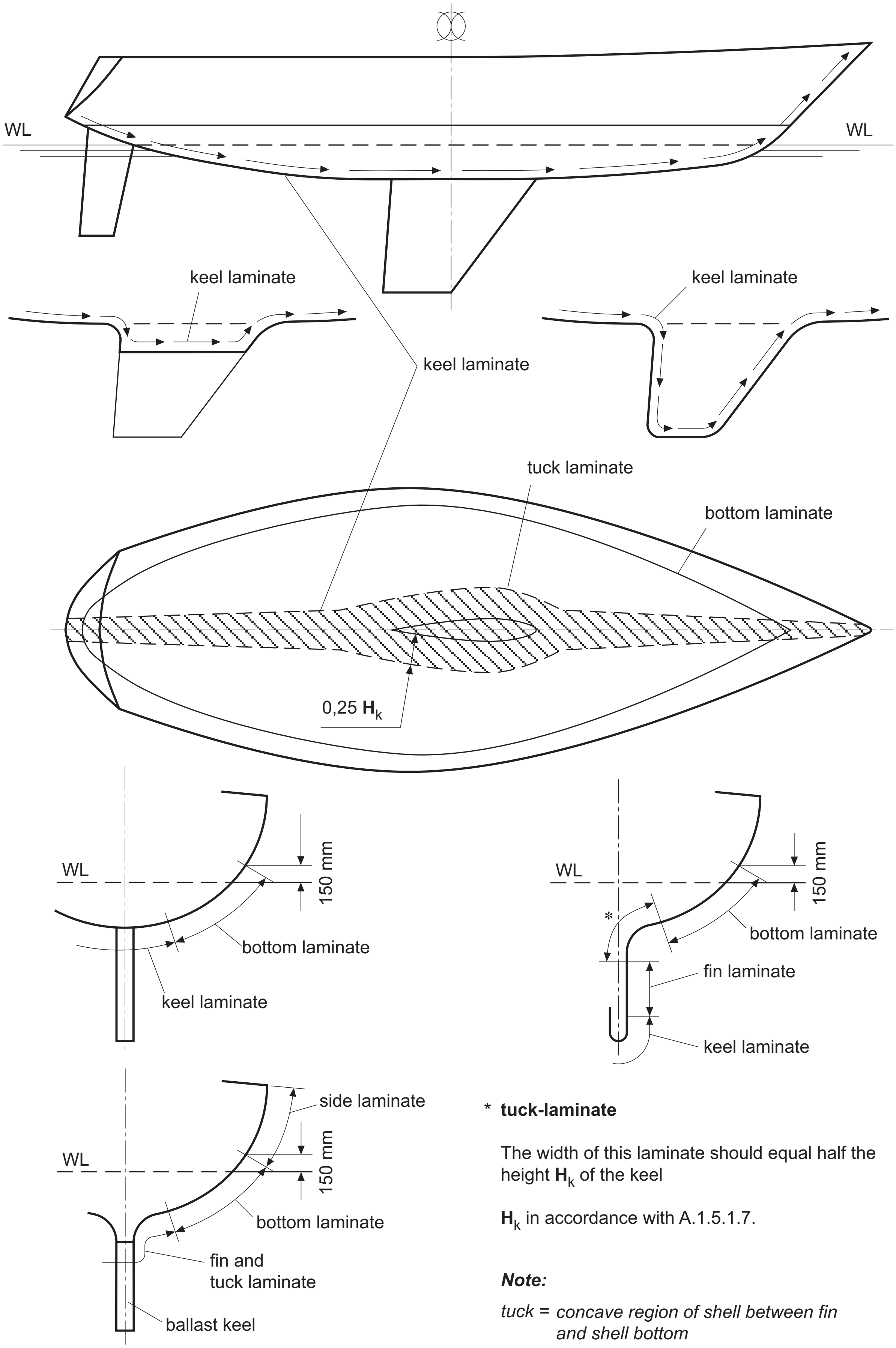
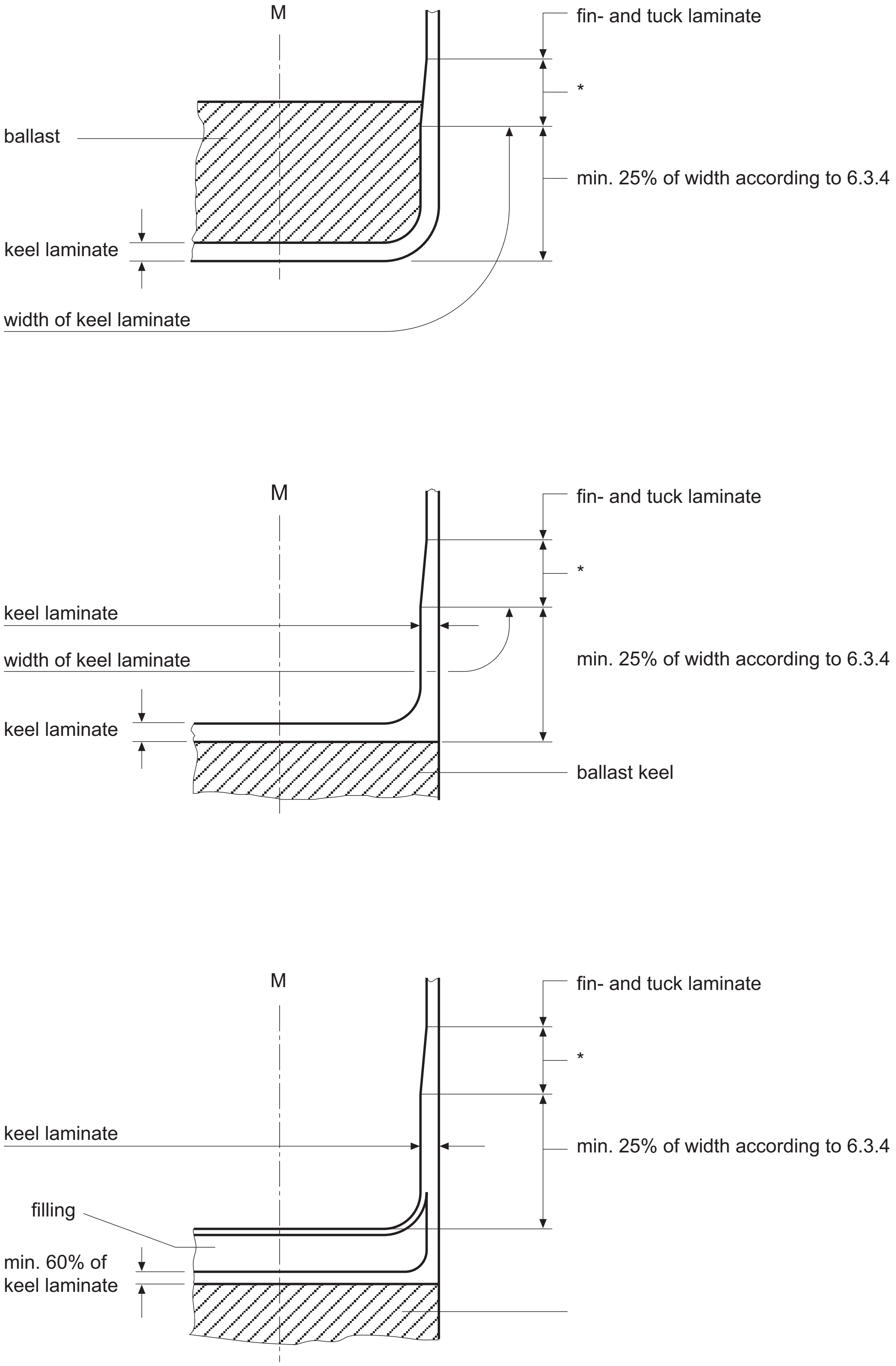

WL
WL
keel laminate
keel laminate
keel laminate
tuck laminate
bottom laminate
0,25 Hk
WL
150 mm
bottom laminate
keel laminate
WL
150 mm
*
bottom laminate
fin laminate
keel laminate
side laminate
WL
150 mm
bottom laminate
fin and
tuck laminate
ballast keel
* tuck-laminate
The width of this laminate should 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 $[\mathrm{kn}]$, 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:

$$W = W_B + W_K$$

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

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]

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

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

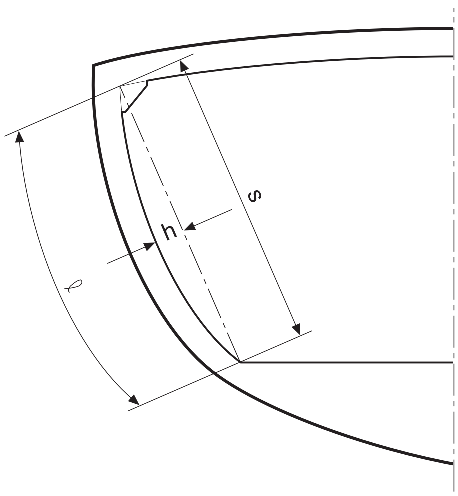


Fig. 1.23

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 dimensions of curved web frames, see 1.14.

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

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

7.6.8.2 for motor crafts

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

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	$W_{RS} = 2{,}26\ e\ \ell^2 \cdot P_{dSS}$ $W_{RS(min)} = 2{,}26\ e\ k_6^2 \cdot P_{dSS} \geq \mathbf{L}$

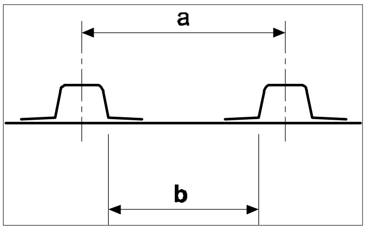
L = see A.1.5
e = web frame spacing [m]
ℓ = unsupported length (span) [m]
F_{VBW} = see A.1.9.3
F_{VSW} = see A.1.9.3
k_6 = $0{,}045 \cdot \mathbf{L} + 0{,}10$ for motor craft [m] or 0,60 [m], the larger value to be used
$0{,}065 \cdot \mathbf{L} + 0{,}30$ for sailing craft and motorsailers [m] to 0,60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

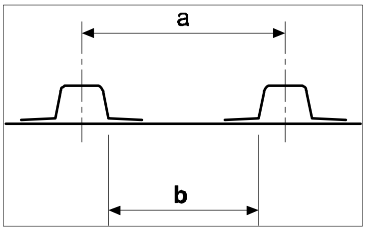
h_2 = vertical distance from the centre of the stiffener's unsupported length to the filler tube [m]

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

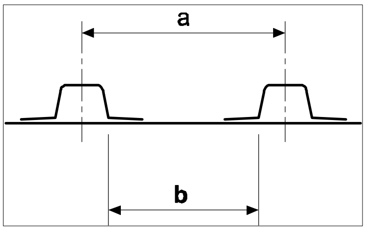
F_{fH} = 1,0 for stiffeners with free ends

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

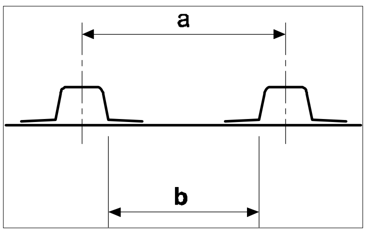
Total glass weight of deckhouse and cabin laminates of motor, sailing craft and motorsailers	
Total glass weight [g/m²]	$G_{WD} = 1{,}57 \cdot \mathbf{b} \cdot F_p \cdot \sqrt{P_{dD}}$ $G_{WD\,(min)} = 1{,}1\left(350 + 5\,\mathbf{L}\right) \cdot \sqrt{P_{dD}}$ $G_{WD\,(min)} = 1200$
 F_p = see 4.4.2.3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

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

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

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

6.1.4 Design area reduction factor k_{ar}

Sailing craft:

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

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

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

Motor craft:

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

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]

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

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

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]

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

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

with

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

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]

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

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]

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

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 super-structure

– 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.

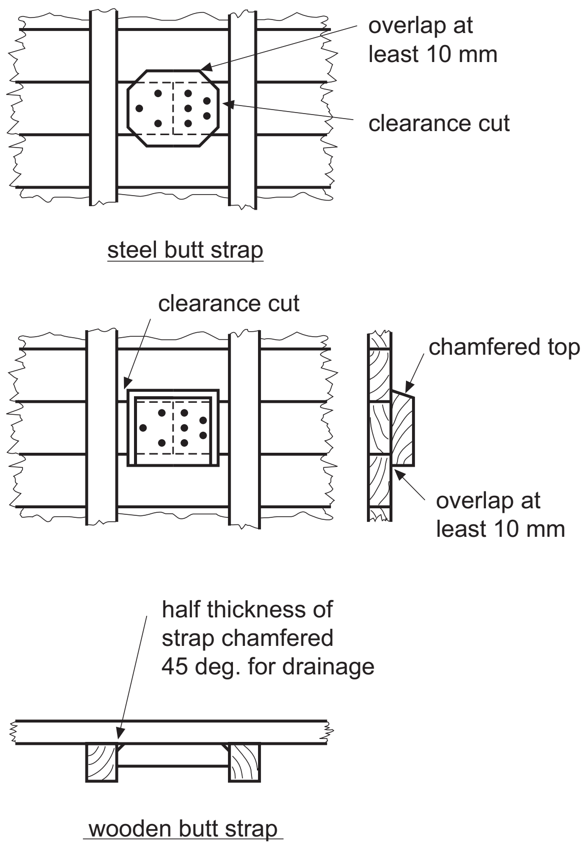


Fig. 1.24

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:

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

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:

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

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

ℓ = length of stiffener in [m]

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.

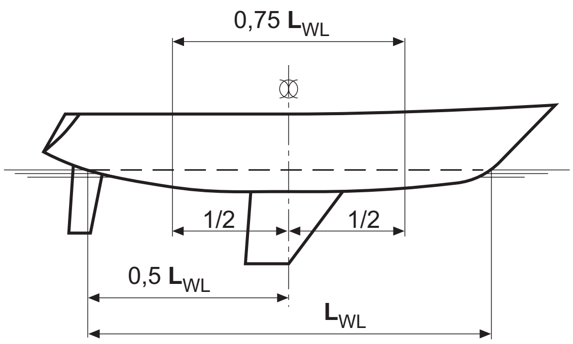


Fig. 1.25

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.

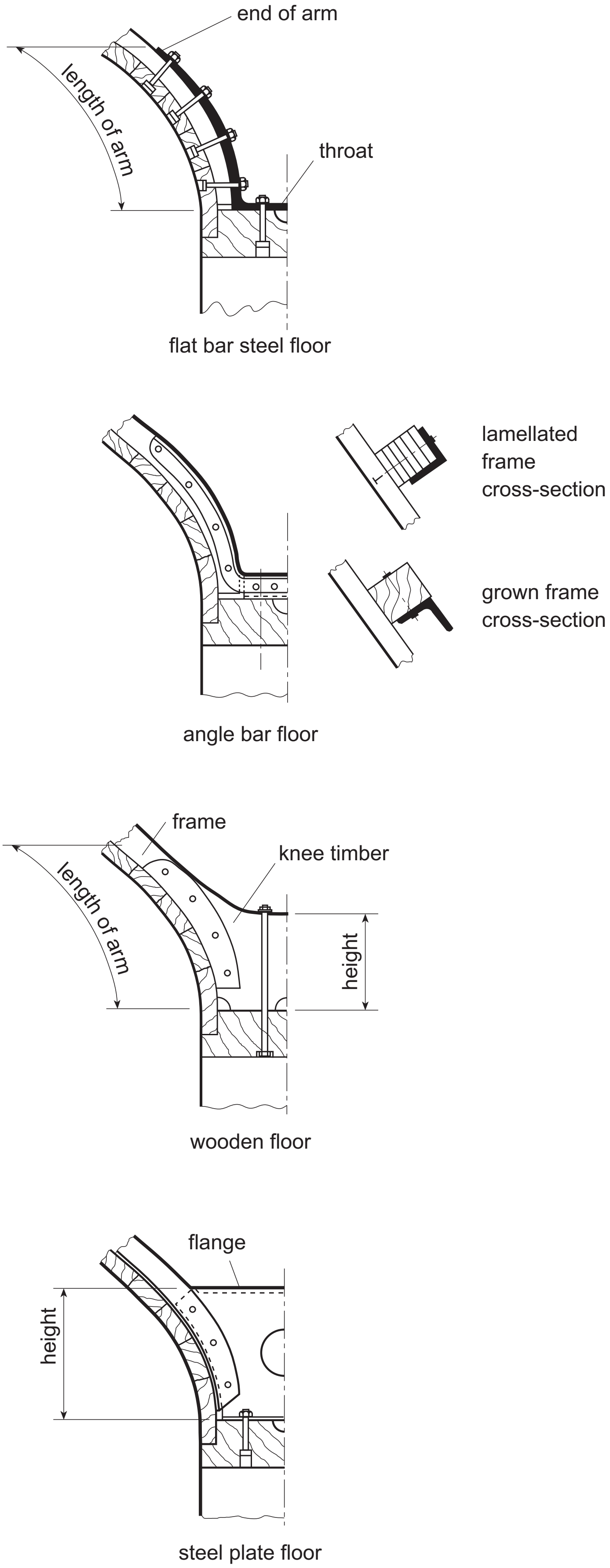

end of arm
length of arm
throat
flat bar steel floor
lamellated
frame
cross-section
grown frame
cross-section
angle bar floor
frame
knee timber
length of arm
height
wooden floor
flange
height
steel plate floor

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 + **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.

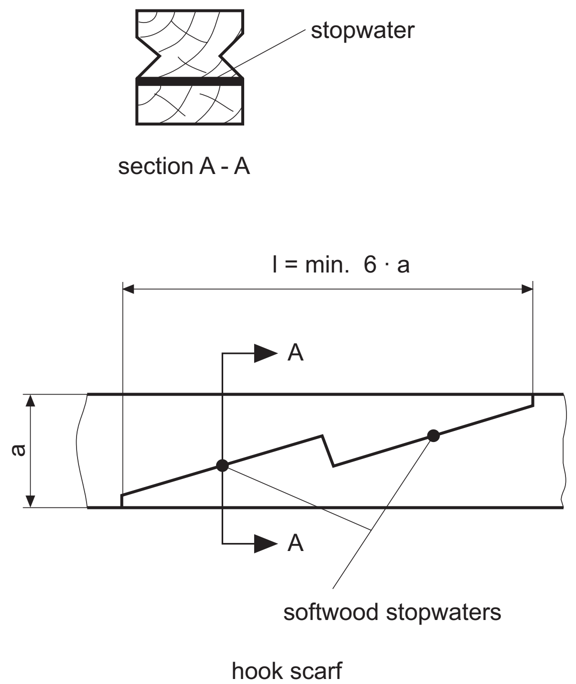


Fig. 1.27

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 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.

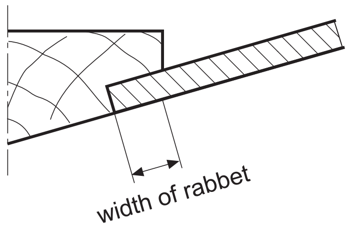


Fig. 1.28

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
m^2	mm	cm^2	cm^2	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	cm^3	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
cm^3	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:

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	Keel			
	Sailing yachts amidships		Motor yachts amidships	
L	height	width	height	cross-section [1]
[m]	[mm]	[mm]	[mm]	[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	Stem foot heights and widths [1]		Stem head and sternpost heights and widths [1]	
L	Sailing yachts	Motor yachts	Sailing yachts	Motor yachts
[m]	[mm]	[mm]	[mm]	[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:

$$\sigma_k \leq \sigma_{zul}$$

$\sigma_{zul} = 0{,}25 \cdot \sigma_{Rm}$

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

σ_k = stress in the individual layer

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

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

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

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

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

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.

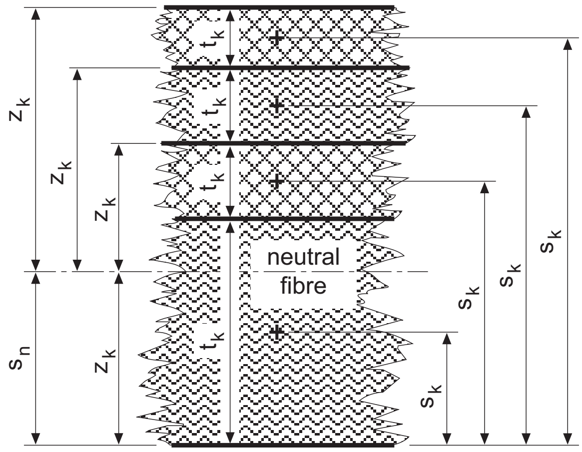


Fig. 1.29

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:

$$t_2 = t_1 \cdot \sqrt{k} \quad [\text{mm}]$$

Section moduli:

$$W_2 = W_1 \cdot k \quad [\text{cm}^3]$$

Diameter:

$$d_2 = d_1 \cdot \sqrt{k} \quad [\text{mm}]$$

for round bar under tensile stress.

$$d_3 = d_1 \cdot \sqrt[3]{k} \quad [\text{mm}]$$

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

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

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

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

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

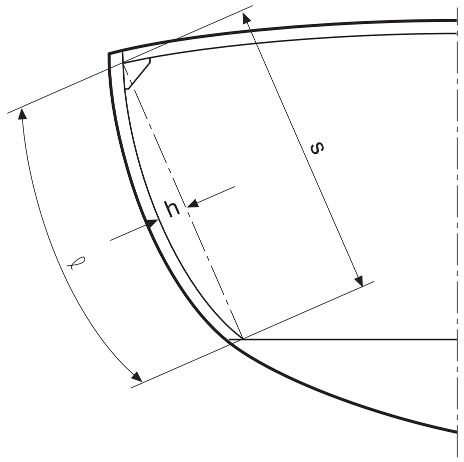


Fig. 1.30

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

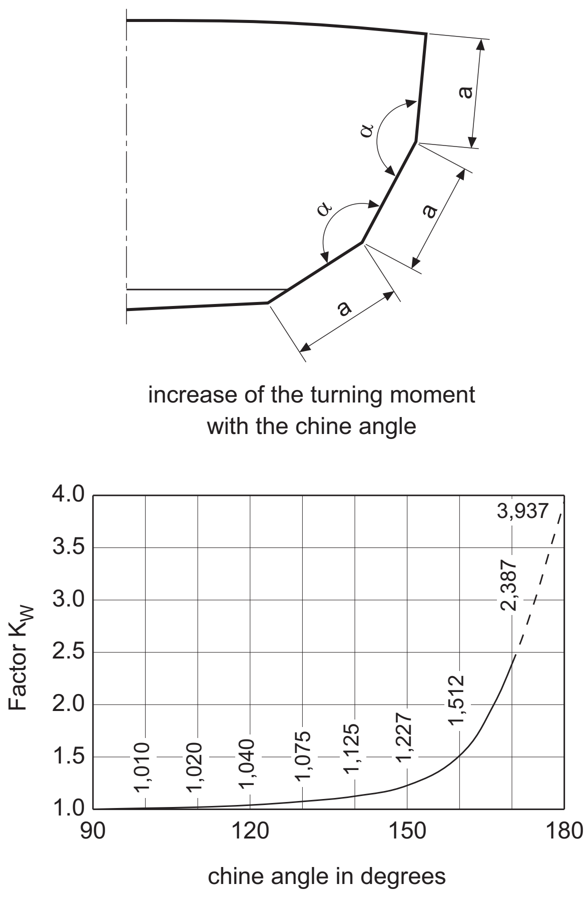


Fig. 1.31

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 $[kN/m^2]$	
	$\geq$ **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.

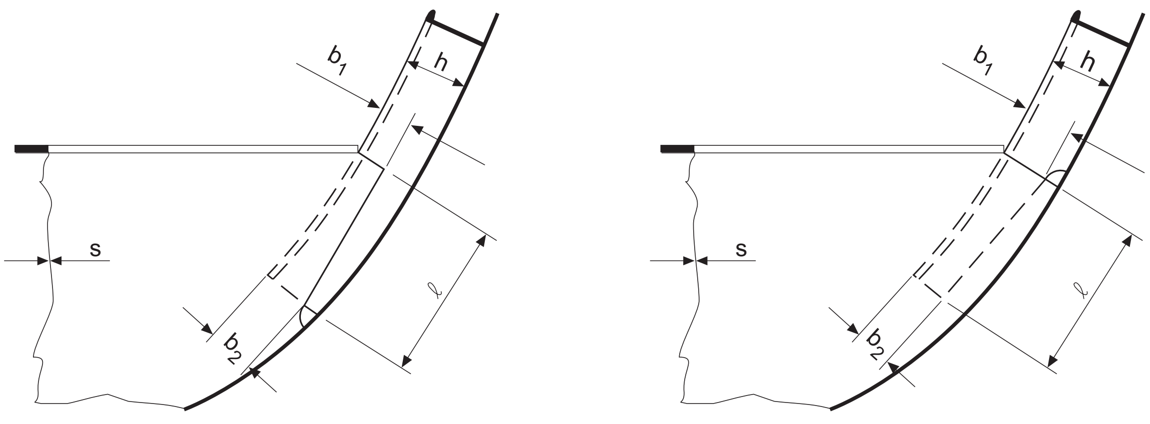
Centreline girders may be omitted in way of motor craft box keels and fins of sailing craft and motorsailers.

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

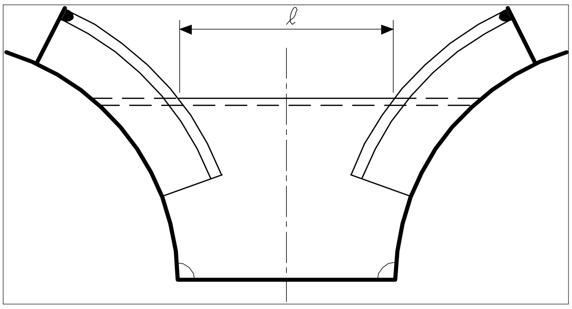


Table 1.41

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 $n > 1000$ 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

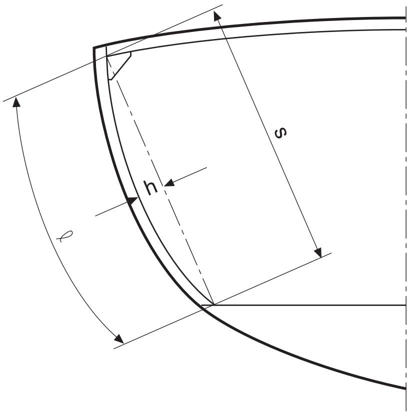


Fig. 1.33

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 [cm³]

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

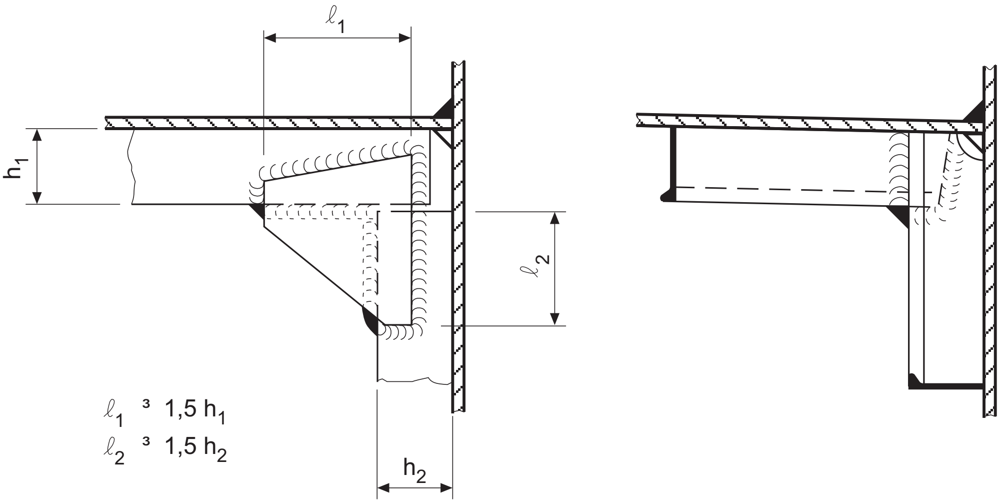


Fig. 1.34

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:

$$A = \frac{10 \cdot P}{\sigma_p} \quad \left[cm^2\right]$$

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
$\leq$ 100	$140 - 0{,}0067 \cdot \lambda^2$	$117 - 0{,}0056 \cdot \lambda^2$
> 100	$\dfrac{7{,}3 \cdot 10^5}{\lambda^2}$	$\dfrac{6{,}1 \cdot 10^5}{\lambda^2}$

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.

λ = $\dfrac{\ell}{i}$ degree of slenderness of pillars

ℓ = length of pillar in [cm]

i = radius of gyration of pillar

i = $\sqrt{\dfrac{J}{f}}$, 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:

$$h = (65 + 1{,}6\,\mathbf{L}) \cdot \sqrt{k} \quad [\text{mm}]$$

$$t = (6{,}5 + 0{,}5\,\mathbf{L}) \cdot \sqrt{k} \quad [\text{mm}]$$

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:

$$b = (530 + 5\,\mathbf{L}) \cdot \sqrt{k} \quad [\text{mm}]$$

$$t = (3{,}3 + 0{,}5\,\mathbf{L}) \cdot \sqrt{k} \quad [\text{mm}]$$

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:

$$t = \left(\sqrt{\mathbf{L}} + 0{,}8 + f\right) \cdot \sqrt{k} \quad [\text{mm}]$$

$$f = (4{,}25\,\mathbf{L} + a - 355) \cdot 10^{-2}$$

k = material factor in accordance with 3.3

a = spacing of floors [mm]

The thickness of the keel sole shall not be less than:

$$t = (3 + 0{,}5 \cdot \mathbf{L}) \cdot \sqrt{k} \quad [\text{mm}]$$

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:

$$h = (50 + 2\,\mathbf{L}) \cdot \sqrt{k} \quad [\text{mm}]$$

$$t = (3{,}5 + 0{,}55\,\mathbf{L}) \cdot \sqrt{k} \quad [\text{mm}]$$

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	$W_{SDH} = 1{,}346 \; a \cdot \ell^2 \cdot P_{dD} \cdot 10^{-4} \cdot k$ $W_{SDH\,(min)} = \left(0{,}1\,\mathbf{L}^2 + 10{,}1\,\mathbf{L} + 220\right) \cdot 10^{-3} \cdot k$
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:

$$Z = 0{,}6 \cdot \mathbf{L} \cdot \mathbf{B} \cdot \mathbf{H}_1 + A$$

L, **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.