PART 3 Hull Construction and equipment

Contents

CHAPTER 1 Structural Design Principles

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SECTION 1 General

1.1 Definitions

1.1.1 The following definitions are used throughout the present Rules except where specifically defined otherwise.

1.1.2 Length, L, is the distance, in meters, on the summer load line or design waterline from the forward side of the stem to the after side of the rudder post, or the sternpost, or the centre of the rudder stock if there is no rudder post or sternpost. L is to be not less than 96% and need not be greater than 97% of the length on the summer load line or design waterline. In ships without rudder stock (e.g. ships fitted with azimuth thrusters), the Rule length L is to be taken equal to 97% of the extreme length on the waterline at the scantling draught. In ships with unusual stern and bow arrangement the Rule length *L* will be specially considered.

1.1.3 Breadth, B, is the greatest moulded breadth, in meters. For craft of composite construction, breadth B is the greatest moulded breadth excluding rubbing strakes. For multi-hull craft it is to be taken as the sum of the breadths of the individual hulls.

1.1.4 Depth, D, is the moulded depth, measured in meters at the middle of the length L and at the side of the craft, from the top of keel to the top of the freeboard deck beams.

1.1.5 Draught, T, is the draught, in meters, measured at the middle of the length L, from the top of keel to the summer load waterline.

1.1.6 The freeboard deck is the uppermost continuous exposed deck, having permanent means for weathertight closing of all openings, and below which all openings in the craft side are equipped with permanent means for watertight closure.

1.1.7 Bulkhead deck is the uppermost deck, up to which watertight bulkheads extend.

1.1.8 Strength deck is normally the uppermost continuous deck. Other decks may be considered as the strength deck provided that they are structurally effective.

1.1.9 A closing appliance is considered weathertight if it is designed to prevent the passage of water in any sea condition. Generally, all openings at the freeboard deck and all enclosed superstructures are to be provided with weathertight closing appliances.

1.1.10 A closing appliance is considered watertight if it is designed to prevent the passage of water in either direction under a specified head of water. Generally, all openings below the freeboard deck at the craft side and the main bulkheads are to be provided with watertight closing appliances.

1.1.11 A superstructure is defined as an enclosed structure on the freeboard deck, either extending from side to side of the craft, or not fitted inboard of the hull side more than 4% of the Breadth B.

1.1.12 A deckhouse is defined as an enclosed structure above the freeboard deck fitted inboard of the hull side plating more than 4% of the breadth B.

1.1.13 Displacement Δ is the mass displacement of the vessel in the design condition in metric tons.

1.1.14 Block coefficient C_b is given by the formula:

$$C_b = \frac{\Delta}{1{,}025 \cdot L \cdot B_{WL} \cdot T}$$

1.1.15 Gross tonnage is the internal volume of spaces within the craft, as defined by the International Convention on Tonnage Measurements of Ships, 1969.

1.1.16 Significant wave height is the average height of the one-third highest observed wave heights over a given period.

1.1.17 Helideck is a purpose-built helicopter landing area located on a yacht including all structure, fire-fighting appliances and other equipment necessary for the safe operation of helicopters.

1.1.18 Helicopter facility is a helideck including any refuelling and hange facilities.

1.2 Internal Subdivision

1.2.1 The hull is to be subdivided into watertight compartments as required for the service of the craft.

1.2.2 All craft with length greater than 15 m are to have, at least, watertight bulkheads as follows:

(a) A collision bulkhead.

(b) A bulkhead at each end of the machinery space.

1.2.3 For craft with length less than 15 m and craft with the additional class notation YACHT and PATROL, alternative arrangements may be accepted based on special considerations.

1.2.4 In all craft, the stern tube is to be enclosed in a watertight compartment if possible.

1.2.5 Chain lockers located abaft the collision bulkhead and extending into the forepeak tanks, are to be watertight.

1.2.6 Collision bulkhead

.1 The collision bulkhead in all craft other than passenger craft, patrol craft and yachts is to be positioned as detailed in the following table. Consideration will, however, be given to proposals for the collision bulkhead to be positioned slightly further aft on Arrangement (b) craft, but not more than 0,08L from the fore end of L L, provided that the application is accompanied by calculations showing that flooding of the space forward of the collision bulkhead will not result in any part of the freeboard deck becoming submerged, or any unacceptable loss of stability. Special consideration may be given to the extent of the collision bulkhead above the bulkhead deck for multi-hull craft.

Arrangement	Distance of collision bulkhead aft of the fore end of length L [m]	
	Minimum	Maximum
(a) No part of craft's underwater body extends forward of the fore end of L	0.05L	0.08L
(b) Part of craft's underwater body extends forward of the fore end of L (e.g. bulbous bow).	0.05L - f_1	0.08L - f_1
Notes: f_1 = G/2 or 0.015L, whichever is the lesser G = Projection of bulbous bow forward of fore end of L, in metres		

.2 Collision bulkhead - passenger craft, patrol craft and yachts

A craft shall have a forepeak or collision bulkhead, which shall be watertight up to the bulkhead deck. The collision bulkhead is to be positioned as detailed in the following table.

If the craft has a long forward superstructure, the forepeak or collision bulkhead is to be extended weathertight to the next deck above the bulkhead deck. The extension need not be fitted directly over the bulkhead below, provided it is located within the limits specified and the part of the bulkhead deck which forms the step is made effectively weathertight.

Arrangement	Distance of collision bulkhead aft of the fore end of length L [m]	
	Minimum	Maximum
(a) No part of craft's underwater body extends forward of the fore end of L	$0.05L_{bp}$	$3+ 0.05L_{bp}$
(b) Part of craft's underwater body extends forward of the fore end of L (e.g. bulbous bow).	$0.05L_{bp} - f_1$	$3+ 0.05L_{bp} - f_1$
Notes: f_1 = G/2 or 0.015L, whichever is the lesser G = Projection of bulbous bow forward of fore end of L, in metres		

.3 Alternative arrangements may be submitted for consideration in the case of sailing and auxiliary craft.

.4 Special consideration shall be given to the arrangement of collision bulkheads for governmental service craft (Patrol, SAR etc).

1.3 Materials

1.3.1 The choice of hull construction material affects fire protection requirements, for which reference shall be made to Part 7, Chapter 1, 2 and 3.

SECTION 2 Structural Arrangements

2.1 Scantlings and Structural Calculations

2.1.1 The structure is to be capable of withstanding the static and dynamic loads, which can act on the craft under operating conditions, without such loading resulting in inadmissible stresses and deformation, and loss of watertightness or interfering with the safe operation of the craft.

2.1.2 Yachts with the notation "COMMERCIAL YACHT" should have a freeboard deck, be fitted with a weather deck throughout the length of the vessel and be of adequate strength to withstand the sea and weather conditions likely to be encountered in the declared area(s) of operation.

2.1.3 For yachts with the notation "COMMERCIAL YACHT" attention shall be paid to local or global hull strength requirements for the provision of ballast.

2.2 Bottom

2.2.1 Single bottoms as well as double bottoms are normally to be longitudinally stiffened in craft built in single skin construction. In craft with sandwich construction, the bottom stiffening will be considered in each individual case. Longitudinals should preferably be continuous through transverse members. At their ends, longitudinals are to be fitted with brackets or to be tapered out beyond the point of support. Longitudinals are to be supported by bulkheads and /or web frames.

2.2.2 Web frames are to be continuous around the cross section of the craft, i.e. web and flange laminates of floors, side webs and deck beams are to be efficiently connected together. In the engine room, floors are to be fitted at every frame. In way of thrust bearings, additional strengthening is to be provided.

2.2.3 In craft built in sandwich construction, longitudinal girders may be fitted to support bottom panels. A centre girder is to be fitted for docking purposes, if the external keel or bottom shape does not give sufficient strength and stiffness. If openings are located at the ends of girders, special attention is to be given to shear forces.

2.2.4 Main engines are to be supported by longitudinal girders with suitable local reinforcement, preferably of metallic construction, to take the engine and gear mounting bolts. Rigid core materials are to be applied in all through bolt connections.

2.2.5 Manholes are to be made in the inner bottom, floors and longitudinal girders to provide access to all parts of the double bottom, if possible. The vertical extension of openings is not to exceed one half of the girder height. Exposed edges of openings in sandwich constructions are to be sealed with resin impregnated mat. All openings are to have well-rounded corners.

2.3 Side

2.3.1 Normally, the craft sides are to be longitudinally or vertically stiffened. The continuity of the longitudinals is to be as required for bottom and deck longitudinals respectively.

2.4 Deck

2.4.1 Decks of single skin construction are normally to be longitudinally stiffened. The longitudinals should preferably be continuous through transverse members. At their ends longitudinals are to be fitted with brackets or to be tapered out beyond the point of support.

2.4.2 Bulwark sides shall have the same scantlings as required for a superstructure in the same position. A strong flange is to be fitted along the upper edge of the bulwark. Bulwark stays are to be arranged in line with transverse beams or local stiffening. If the deck is of sandwich construction, solid core inserts are to be fitted at the foot of the bulwark stays. Stays of increased strength are to be fitted at ends of bulwark openings. Openings in bulwarks should not be made near the ends of superstructures.

2.4.3 For yachts with the notation "COMMERCIAL YACHT", bulwarks and/or guardrails on all accessible decks shall be 1000 millimetres high except that on vessels built to 1959 Load Line Rules these may be 915 millimetres high. Any opening shall not exceed 380 millimetres. Where no bulwarks are fitted, or bulwark height is less than 230 millimetres, the lowest opening shall not exceed 230 millimetres. They shall be supported at intervals not exceeding 2.2 metres. Intermediate courses of rails or wires shall be evenly spaced.

2.4.4 For yachts with the notation "COMMERCIAL YACHT", satisfactory means (in the form of guard rails, life lines, gangways or underdeck passages, etc.) shall be provided for the protection of the crew in getting to and from their quarters, the machinery space and all other areas used in the necessary work of the craft.

2.4.5 For yachts with the notation "COMMERCIAL YACHT", where Sun Pads are located within 600mm of any Bulwarks and / or Guardrails, the minimum height of the Bulwark and / or Guardrails shall be at least 1m above the surface of the Sun Pad (taken as the height of the Sun Pad + 50% of the thickness of the mattress). This requirement does not apply to bench seating or any other horizontal surfaces, which persons would not reasonably be expected to step or stand on.

2.4.6 For yachts with the notation "COMMERCIAL YACHT", where the function of the vessel would be impeded by the provision of bulwarks and/or guard rails complying with 2.4.3, alternative proposals detailed to provide equivalent safety for persons on deck shall be submitted to the Administration for approval, where recognised national or international standards may be accepted as equivalence.

2.4.7 The structural strength of any bulwarks or guardrails shall comply with the requirements of a Recognised Classification Society, or a recognised international standard as appropriate to the vessel and its areas of operation.

2.5 Bulkheads

2.5.1 The watertight bulkheads are in general to extend to the freeboard deck. However, the afterpeak bulkhead may terminate at the first watertight deck above the load waterline at draught T.

2.5.2 Watertight bulkheads are, in general, to extend to the bulkhead deck.

2.5.3 Bulkheads are to be spaced at reasonably uniform intervals. Where non-uniform spacing is necessary and the length of a specific compartment is unusually large, the transverse strength of the craft is to be maintained by fitting of web frames, increased framing, etc., and details are to be submitted.

2.5.4 In any case, the number and position of bulkheads of the craft are to be so arranged as to comply with the applicable requirements for subdivision, floodability and damage stability, and are to be in accordance with the requirements of the National Authority.

2.5.5 The strength of watertight bulkheads and their watertight integrity of the division should be in accordance with the requirements of L.H.R. as mentioned in Part 3, Chapter 5, Section 9.

2.6 Superstructures

2.6.1 In superstructures and deckhouses, the front bulkhead is to be in line with a transverse bulkhead in the hull below or be supported by a combination of girders and pillars. The after end bulkhead is also to be effectively supported. As far as practicable, exposed sides and internal longitudinal and transverse bulkheads are to be located above girders and frames in the hull structure and are to be in line in the various tiers of accommodation. Where such structural arrangement in line is not possible, there is to be other effective support.

2.6.2 Sufficient transverse strength is to be provided by means of transverse bulkheads or girders.

2.6.3 At the break of superstructures which have not set-in from the craft’s side, the side plating is to extend beyond the ends of the superstructure and is to be gradually reduced in height down to the deck or bulwark.

2.6.4 In long deckhouses, openings in the sides are to have well-rounded corners. In deckhouses of single skin construction, horizontal stiffeners are to be fitted along the upper and lower edge of large openings for windows. Openings for doors in the sides are to be adequately stiffened along the edges.

2.7 Multihulls

2.7.1 The requirements indicated in this sub-Section are particular for multi-hull craft and are to be applied in addition to the general requirements of this Chapter. The craft is to be considered as one complete structure when determining the minimum geometric summer freeboard. The block coefficient is to be calculated using the actual displacement determined from the hydrostatic data and using the total breadth of the structure and not just a single hull. If, by using normal procedures, the minimum geometric summer freeboard determined is unreasonable for the operation of the craft, special consideration may be given, on a case by case basis, based on the proposed design configuration.

2.7.2 The scantlings and arrangements indicated are for twin hulled craft. Craft with a greater number of hulls will be specially considered on the basis of the Rules. Structural members which contribute to the over-all hull girder strength are to be carefully aligned so as to avoid discontinuities resulting in abrupt variations of stresses and are to be kept clear of any form of openings which may affect their structural performances. Particular care is to be given to the continuity and alignment in way of the end connections of transverse bridging structures.

2.7.3 For craft with multi-hulls linked by cross-deck structures, sufficient clearance is to be provided between the cross-deck structure and water surface to limit impact loads. Where part or all of the cross-deck is intended to provide additional buoyancy to limit craft motion, the loading will be specially considered.

2.7.4 Longitudinal watertight bulkheads are to be arranged within the bridging structures of multi- hull craft to prevent cross flooding and the spread of smoke and flames in the event of fire. The number and distribution of bulkheads will be specially considered dependent upon the structural configuration and size of the craft, but in no case is the number to be less than two for catamarans and four for trimarans. These bulkheads are in general to be positioned in way of the inboard sides of the hulls.

2.7.5 The forefoot and bow regions of fast craft that may be subjected to frequent impacts from flotsam are to be easily accessible for inspection. Access to the forepeak compartments may be provided through the forepeak bulkhead where access would otherwise be impracticable. The aft end regions of all craft are to be easily accessible for inspections. Access may be provided through the aft peak bulkhead or by means of deck hatches or manholes.

2.7.6 Where an engine is fitted within a narrow hull, where engine room temperatures may rise quickly, the ventilation requirements may be increased. Within machinery spaces where space is limited, access is to be provided for inspection.

2.7.7 Superstructures and deckhouses which enclose large flat open areas, that are subjected to racking loads and which may be of several tiers, are to be additionally stiffened with large web frames, partial bulkheads and pillars.

SECTION 3 Closing Arrangements

3.1 General

3.1.1 Downflooding angle is the least angle of heel at which openings in the hull, superstructure or deckhouses, which cannot be closed weathertight, immerse and allow flooding to occur.

3.1.2 Doors, hatches, ventilators, windows, portlights etc. provided with closing appliances which can be secured weathertight, and small openings through which progressive flooding cannot take place, are not considered as downflooding points.

3.1.3 Air pipes are to be fitted with automatic closing appliances, if the openings are immersed at an angle of heel of 40° or the angle of downflooding, if this is less than 40°.

3.2 Double bottom openings

3.2.1 Provision is to be made for the free passage of air and water from all tanks of the double bottom to the air pipes and suctions, taking into account the required pumping rates.

3.2.2 Adequate access is also to be provided to all parts of the double bottom for maintenance, surveys and repairs. Attention is to be given to any relevant International on National regulations regarding the minimum size of access openings.

3.2.3 Manholes and their covers are to be of an approved design, in accordance with a recognized

National or International Standard.

3.2.4 The size of openings is not, in general, to exceed 50 per cent of the double bottom depth, unless adequate edge reinforcement is provided.

3.2.5 Manholes, lightening holes and other openings are to be suitably framed and stiffened where necessary.

3.3 Side and stern doors and other shell openings

3.3.1 Side and stern doors are to be so fitted as to ensure the structural integrity of the surrounding structure.

3.3.2 In general, the lower edge of door openings is not to be below the uppermost Load Line. In the opposite case, the arrangement will be specially considered.

3.3.3 Doors are generally to be arranged to open outwards. Inward opening doors will be specially considered. See also related sub paragraph 3.3.8, applying to yachts with the notation "COMMERCIAL YACHT"»

3.3.4 Doors may be of steel, aluminum alloy or FRP construction. They are to be efficiently connected to the adjoining structure and be of equivalent strength. Doors are to be adequately stiffened and to have proper securing and sealing arrangements. Door openings in the side shell are to have well-rounded corners, and adequate compensation is to be arranged with web frames at sides and stringers or equivalent above and below.

3.3.5 Regarding the closing and securing devices of doors, the following are to be taken into account:

(a) Doors are to be fitted with adequate means of closing and securing. Devices are also to be arranged for doors to be secured in the open position.

(b) Closing devices are to be simple to operate and easily accessible. The spacing for cleats or closing devices is not to exceed 2,5 m and cleats or closing devices are to be positioned as close to the corners as practicable.

(c) Doors with a clear opening area of 12 m^2 or greater are to be provided with closing devices operable from a remote control position. The location of the remote control panel is to be such that the opening/closing operation can be easily observed by the operator or by other suitable means. Means are to be provided to prevent unauthorized operation of the doors and indication is to be provided at each remote control panel to show when the door is open and when fully closed and secured. This indication is to be repeated on the bridge, and means are to be provided on the navigating bridge to indicate leakage via doors. Where hydraulic cleating is applied, the system is to be mechanically lockable in the closed position so that in case of hydraulic system failure, the cleating will remain locked.

3.3.6 For passenger craft, gangway and ports fitted below the margin line are to be sufficiently strengthened. They are to be effectively closed and secured watertight before the craft leaves port, and kept closed during the voyage.

3.3.7 For yachts with the notation "COMMERCIAL YACHT", external doors in deckhouses and superstructures shall be weathertight. Doors opening directly onto staircases which are located in the following positions, shall have coaming heights of at least:

Location	Unrestricted Yachts	Short Range Yachts
A	600 mm	300 mm
B	300 mm	150 mm
C	150 mm	75 mm

Where

Location A: The door is in the forward quarter length of the vessel and is used when the vessel is at sea.

Location B: The door is in an exposed forward facing location aft of the forward quarter length.

Location C: The door is in a protected location aft of the forward quarter length, or an unprotected door on the first tier deck above the weather deck.

3.3.8 Additionally, for yachts with the notation "COMMERCIAL YACHT", weathertight doors shall be arranged to open outwards and when located in a superstructure side, be hinged at the forward edge. Alternative closing arrangements shall be considered providing it can be demonstrated that the efficiency of the closing arrangements and their ability to prevent the ingress of water shall not impair the safety of the vessel.

3.3.9 For yachts with the notation "COMMERCIAL YACHT", an access door leading directly to the engine room from the weather deck shall be fitted with a coaming of height of at least:

Location	Unrestricted Yachts	Short Range Yachts
Position 1	600 mm	450 mm
Position 2	380 mm	200 mm

Where

"Position 1" means upon exposed freeboard and raised quarter decks, and upon exposed superstructure decks situated forward of a point located a quarter of the ship's length from the forward perpendicular.

"Position 2" means upon exposed superstructres decks situated abaft a quarter of the ship's length from the forward perpendicular.

3.3.10 Proposals to reduce the coaming heights required by paragraphs 3.3.7 and 3.3.9 shall be subject to special consideration and approval by the L.H.R., having regard for the protected location of the weathertight door, the space to which it serves, increased freeboard and increased water freeing arrangements.

3.4 Hatches on exposed decks

3.4.1 The number and size of hatchways and other access openings are to be kept to a minimum, necessary for the satisfactory operation of the craft.

3.4.2 All openings in decks are to be sufficiently framed, to provide adequate support.

3.4.3 Hatch covers may be of steel, aluminum alloy or FRP construction and they are to be of equivalent strength to the deck on which they are fitted. The thickness of the coamings is to be not less than the Rule thickness for the deck in the positions in which they are fitted. Stiffening of the coamings is to be appropriate to their length and height. The covers are to be adequately stiffened.

3.4.4 Hatch covers are to be weathertight when closed. The means of securing are to be such that weathertightness can be maintained in any sea condition. The covers are to be hose-tested in position under a water pressure of at least 2 bar, at the time of installation.

3.4.5 Additionally, for yachts with the notation "COMMERCIAL YACHT", the following are to be satisfied:

1) Hatches shall be kept closed at sea. However, hatchways which may be kept open for access at sea shall

be as small as practicable (a maximum of 1 square metre in clear area), and fitted with coamings of at least 300 millimetres in height in positions 1 and 2 Hatchways shall be as near to the centreline as practicable, especially on sailing vessels. Covers of hatchways shall be permanently attached to the hatch coamings and, where hinged, the hinges shall be located on the forward side.

2) Hatches which are designated for escape purposes shall be provided with covers which shall be openable from either side and in the direction of escape they shall be openable without a key. All handles on the inside shall be non-removable. An escape hatch shall be readily identified and easy and safe to use, having due regard to its position. The escape hatch shall not be required to have a coaming provided that the hatch cover is weathertight and the hatch shall be closed at sea and marked accordingly and shall be provided with open/close indication at the navigating position.

3) All openings leading to spaces below the weather deck not capable of being closes weathertight, shall be enclosed within either an enclosed superstructure or a weathertight deckhouse of adequate strength. All exposed hatchways which give access from position 1 and position 2 are to be of substantial weathertight construction and provided with efficient means of closure.

3.5 Bulkhead openings

3.5.1 Where applicable, the number and construction of watertight doors in bulkheads shall be considered in accordance with the requirements of Chapter X of SOLAS 1974, as amended (Safety measures for high-speed craft).

3.5.2 Watertight doors in bulkheads are to be of equivalent strength to the bulkhead, and capable of being closed watertight. Watertight doors are to be pressure tested from both sides, at the time of installation, for the maximum head of water indicated by any required damage stability calculations or up to the bulkhead deck, whichever is the greater. Indicators are to be provided on the bridge showing whether the doors are open or closed.

3.5.3 Watertight doors are to be efficiently constructed and fitted, and are to be capable of being operated when the craft is listed up to 15° either way.

3.5.4 Doors are to be capable of being operated from both sides of the bulkhead.

3.5.5 No accesses are to be fitted in collision bulkheads. In particular designs where it would be impracticable to arrange access to the forepeak other than through the collision bulkhead, access may be permitted subject to special consideration. Where accesses are provided, the openings are to be as small as practicable and positioned as far above the design waterline as possible. The closing appliances are to be watertight, open into the fore peak compartment and consideration will be given to operation from one side only.

3.5.6 Where subdivision and damage stability requirements apply and where penetration of watertight divisions by pipes, ducts, trunks or other penetrations is necessary, arrangements are to be made in order to maintain the watertight integrity. Ventilators from deep tanks and tunnels passing through tween-decks are to have scantlings suitable for withstanding pressures to which they may be subjected, and are to be made watertight.

3.5.7 The strength of penetrations of watertight bulkheads should be in accordance with the requirements of L.H.R., as provided for in 2.5.5 for the watertight bulkheads.

3.5.8 For yachts with the notation "COMMERCIAL YACHT" openings in watertight bulkheads shall further satisfy the following:

1) They shall comply with the standards required for passenger vessels, as defined in SOLAS II-1. Hand operation from above the bulkhead deck and a hydraulic accumulator may be omitted if each door has its own individual power-pack electrically driven via the emergency switchboard, and control voltage

from emergency battery, and each door can be operated manually at the door. Edge strips which stop the door closing on contact are not permitted.

2) Watertight doors may be located outboard of the B/5 Line. However, where powered watertight doors are provided, the main control system shall in all cases be located inboard of the B/5 line in order to ensure the continued opeartion of undamaged doors.

3) Approved hinged doors may be provided for infrequently used openings in watertight compartments, where a crew member shall be in immediate attendance when the door is open at sea. Audible and visual alarms shall be provided in the wheelhouse.

4) Unless otherwise required by paragraph 4.3, watertight doors in yachts under 500GT may be approved hinged doors provided that there is an audible and visual alarm on the Bridge indicating when the door is open. The doors shall be kept closed at sea and marked accordingly. A time delay for the alarm is acceptable.

5) Procedures for the operation of watertight doors shall be posted in suitable locations. Watertight doors shall be normally closed, with the exception of sliding watertight doors providing the normal access to frequently used living and working spaces. Additionally when an access is unlikely to be used for lengthy periods, the door shall be closed. Operational tests of watertight doors, shall take place weekly. For Yachts in which the voyage exceeds one week in duration, a complete set of operational tests shall be held before the voyage commences, and others thereafter at least once a week during the voyage.

3.6 Miscellaneous openings

3.6.1 Manholes and flush scuttles within superstructures other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

3.6.2 Openings in freeboard decks other than hatchways, machinery space openings, manholes and flush scuttles are to be protected by an enclosed superstructure, or by a deckhouse or companionway of equivalent strength and weathertightness. Any such opening in an exposed superstructure deck or in the top of a deckhouse on the freeboard deck, which gives access to a space below the freeboard deck or a space within an enclosed superstructure, is to be protected by an efficient deckhouse or companionway.

3.6.3 Additionally, for yachts with the notation “COMMERCIAL YACHT” the following apply:

1) companionway hatch openings which give access to spaces below the weather deck shall be fitted with a coaming, the top of which is at least 300 millimetres above the deck, or 150 millimetres in the case of Short Range Yachts. The maximum breadth of an opening in a companion hatch shall not exceed 1 metre.

2) coaming height, construction and securing standards for weathertight doors which are provided for use only when the vessel is in port or at anchor in calm sheltered waters and are locked closed when the vessel is at sea, may be considered individually.

3) washboards may be used to close the vertical opening. When washboards are used, they shall be so arranged and fitted that they shall not be dislodged readily. Whilst stowed, provisions shall be made to ensure that they are retained in a secure location.

SECTION 4 Additional Requirements for Commercial Yachts

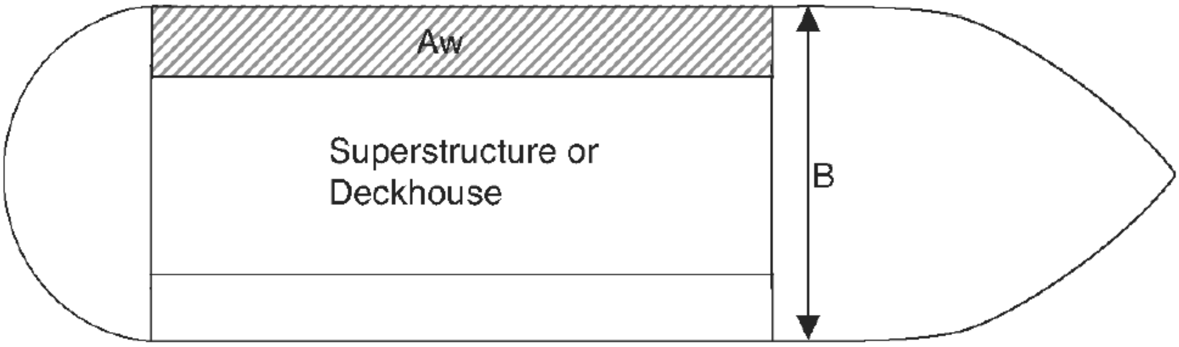
4.1 General

4.1.1 In addition to the requirements of SECTIONS 1, 2 and 3 of this Chapter 1, yachts with the notation of "COMMERCIAL YACHT" must also comply with requirements of SECTION 4.

4.2 Water – freeing arrangements

4.2.1 The standards for water freeing arrangements shall comply with ICLL on any weather decks in the forward quarter, and up to Position 2 elsewhere. In any case the intention shall be to achieve a standard of safety which is at least equivalent to the standard of the ICLL to the satisfaction of the Administration given the design and use of the vessel.

4.2.2 Additionally, where a well is created on each side of the vessel between a superstructure or deckhouse, and the bulwark in way of that superstructure or deck house, the following formula may be used to determine the required freeing port areas on each side of the vessel for the well concerned:



$$FP_{REQ} = 0.28xA_w/B$$

Where; FP_{REQ}= Freeing port area required, A_w = Area of well in way of superstructure or deckhouse and B= Full beam at deck.

4.2.3 On sailing vessels, where the solid bulwark height does not exceed 150 millimetres, specific freeing ports, as defined above, are not required.

4.2.4 For Short Range Yachts, it is considered that the requirement for freeing port area for a forward or aft well may be reduced by a form factor equal to the ratio of (actual area well) divided by (length of well x breadth of well). Dimensions shall be taken at half height of the bulwark. This may be reduced by 50% providing it can be shown that the intact stability of the yacht remains acceptable if the well is flooded to any level up to the bulwark height and that area provided shall allow the well to drain in less than 3 minutes.

4.2.5 Any recess in the weather deck shall be of weathertight construction and shall be self draining under all normal conditions of heel and trim of the vessel.

A swimming pool or spa bath, open to the elements, shall be treated as a recess.

4.2.6 The means of drainage provided shall be capable of efficient operation when the vessel is heeled to an angle of 10° in the case of a motor vessel (see Part 5, Chapter 5, paragraph 6.1.4), and 30° in the case of a sailing vessel. The drainage arrangements shall have the capability of draining the recess (when fully charged with water) within 3 minutes when the vessel is upright and at the load line draught. Means shall be provided to prevent the backflow of sea water into the recess.

4.2.7 When it is not practical to provide drainage which meets the requirements of paragraph 4.2.6, alternative safety measures may be proposed for approval by the L.H.R.. Where the above requirements for quick drainage cannot be met, the effect on intact and damage stability shall be considered taking into account the mass of water and its free surface effect.

4.2.8 All swimming pools shall have their effect on intact and damage stability considered taking into account the mass of water and its free surface effect.

4.2.9 If there are loading conditions where swimming pools shall be emptied in order to comply with stability requirements of Part 3, Chapter 11, these loading conditions shall be placed in a separate section of the approved stability booklet with the following note added:

In this loading condition the vessel may not have its [swimming pool] [spa bath] [jacuzzi] full, due to insufficient stability

4.2.10 All loading conditions included in the approved stability book shall be shown to meet the damage stability requirements of Part 3, Chapter 11.

4.3 Enclosed Compartments Within the Hull and Below the Bulkhead Deck Provided with Access Through Openings in the Hull

4.3.1 Compartment(s) below the bulkhead deck, provided for recreational purposes, oil fuelling/fresh water reception or other purposes to do with the business of the vessel and having access openings in the hull, shall be bounded by watertight divisions without any opening (i.e. doors, manholes, ventilation ducts or any other opening) separating the compartment(s) from any other compartment below the bulkhead deck, unless provided with sliding watertight doors complying with paragraphs 3.5.7-3.5.11, or for vessels under 500GT, hinged doors complying with paragraph 4.3.2.

4.3.2 For vessels under 500GT, openings from any other compartment below the bulkhead deck may be fitted with hinged watertight doors provided:

a) after flooding through the shell opening of the space containing the shell opening, the resultant waterline is below the sills of the internal openings in that space; or

b) bilge alarms are fitted in the compartment containing the shell opening, with a visual and audible warning both on the bridge and locally; and

c) any hinged door opens into the compartment containing the shell opening; and

d) "open" door alarms, both visual and audible fitted on the bridge; and

e) the door shall be fitted with a single closing mechanism; and

f) where the sill height of the internal door is not higher above the deepest loaded waterline than the sill height of the shell opening, then paragraphs 4.3.4(b) and 4.3.4(c) shall also be considered to the satisfaction of the Administration.

4.3.3 Openings in the hull shall comply with SOLAS II-1/15-1 -External openings in cargo ships. Provision shall be made to ensure that doors may be manually closed and locked in the event of power or hydraulic failure. Openings are generally to be fitted with a sill not less than 600 millimetres above the Design Waterline. Means shall be provided to prevent the unauthorised use of the doors locally through provision of secondary or remote control, through an interlock, dual control process or procedure.

4.3.4 Openings in the hull with a sill height less than 600 millimetres above the Design Waterline may be specially considered by the Administration. This consideration shall include but is not limited to:

a) doors from the space providing internal access are to have a sill height at least 600 millimetres above the Design Waterline;

b) the effect of flooding on stability is considered;

c) operational controls and limitations on when and where opening may be used.

4.3.5 Protection of safety critical systems such as those for securing of the hull opening closed and any provided in accordance with Part 7, Chapter 1, shall have a liquid ingress protection of level 5 (e.g. IP 65) in accordance with the International Protection (IP) Marking, IEC Standard 60529 or equivalent.

4.4 Virtual Freeboard Deck

4.4.1 Where actual freeboard to the weather deck exceeds that required by ICLL by at least one standard superstructure height, openings on that deck, abaft of the forward quarter, may be assumed to be in Position 2. This shall be taken, unless otherwise stated, as defined in ICLL.

4.4.2 For vessels up to 75 metres load line length, a standard superstructure height shall be taken as 1.8 metres. For vessels over 125 metres load line length, this shall be taken as 2.3 metres. Superstructure heights for vessels of intermediate lengths shall be obtained by interpolation.

4.5 Glazed Openings & Skylights

4.5.1 Glazed openings & Skylights shall:

a) be made from toughened safety glass. In case of chemically toughened glass, it shall be qualified by testing in accordance with EN 1288-3, based on the requirements given in ISO 11336-1. Regular inspections of the glazed openings, with particular reference to the surface condition, shall form part of the operational procedures and annual surveys;
b) not be fitted in such a position that their sills are below a line drawn parallel to the freeboard deck at side and having its lowest point 2.5% of the breadth (B), or 500 millimetres, whichever is the greatest distance, above the design waterline;
c) be attached to the ship in such a manner, that they are capable of fulfilling their role in the application of ICLL requirements;
d) follow the requirements of Chapter 5 of "L.H.R. Guidance for the Classification and Construction of Commercial Yachts up to 60 meters", where they are for glazed openings in the navigating position;
e) not be fitted in the hull in the way of the machinery space; and
f) be of the non-readily opening type which shall be securely closed when the vessel is in navigation and indication provided on the bridge that they are closed.

4.5.2 When glazed openings are fitted by bonding, the following provisions shall be observed:

a) proposals shall include measures to ensure the integrity of the bond line taking into account environmental and ageing effects; and
b) when required to be fire rated, arrangements shall be such that glazed openings and doors cannot fall from their mounting should the bond line fail, except where the glazed opening or door assembly has successfully passed the standard fire test without the need to provide any additional means of fastening.

4.5.3 Where glazed openings protect buoyant volumes, they shall be designed using the pressure heads derived from a recognised International Standard such as ISO 5780 or ISO 11336-1.

4.5.4 Where glazed openings do not protect buoyant volumes, they shall be designed using the pressure heads rules of a Recognised Classification Society or a recognised International Standard such as ISO 11336-1.

4.5.5 Deadlights:

i. In all cases, it shall be ensured that any limitations (i.e. aspect ratio, maximum window size, etc) included in the Rules of the Recognised Classification Society or International Standard being used are observed and complied with.
ii. Glazed openings within the buoyant part of the hull shall be provided with deadlights so arranged

that they can be easily and effectively closed and secured watertight.

iii. Deadlights may be portable provided these are stored in an easily accessible location and are readily mountable in a seaway. Instructions to the Master as to when deadlights shall be applied to portlights shall be provided.

4.5.6 Storm Covers:

i. For all vessels other than Short Range Yachts, storm covers shall be required in the following locations, where deadlights are not already required by paragraph 4.5.5ii
   a) glazed openings in the front and sides of Level 1;
   b) glazed openings in the front of Level 2; and
   c) where storm covers are interchangeable between port and starboard, a minimum of 50% of each size shall be provided.

ii. Where required by paragraph 4.5.6i, if the glazed openings meet an enhanced structural standard, in accordance with Recognised Classification Society rules, a recognized International Standard, or a factor of 1.5 applied to the design pressure of the glazed opening, then storm covers are not required provided the glazing is of laminated construction. The ratio between the thicknesses of the plies in the laminate shall not exceed 4/3.

iii. A and B Class Cabin Bulkheads and Doors are accepted in place of deadlights or storm covers fitted to glazed openings, except in the following locations where deadlights or storm covers are to be provided:
   a) In Levels 1 and 2 when considered buoyant in the Stability Calculations;
   b) in Levels 1 and 2 when above the buoyant part of the Hull and separating forward facing glazed openings from a direct access leading below;
   c) In Level 1 when above the buoyant part of the Hull and separating side facing glazed openings from a direct access leading below.

4.5.7 Skylights:

i. Fixed or opening skylights shall
   a) have a glazing thickness appropriate to their size and position as required for glazed openings;
   b) be provided with protection from mechanical damage to the skylight load-bearing glazing in any position;
   c) except where the arrangements comply with paragraph 4.5.7ii, when fitted in Level 1 or 2, be provided with deadlights or storm covers that can be easily and safely mounted in a seaway; and
   d) if designated for escape purposes, be provided with a means of opening from either side of the skylight provided that in the direction of escape they are able to be opened without a key.

ii. L.H.R. may permit the storm covers specified in paragraphs 4.5.7i(c) to be omitted provided the glazing meets paragraph 4.5.6ii.

4.5.8 Strength

i. Glazed openings, together with their frames, deadlights and storm covers, if fitted, shall meet an appropriate national or international standard or the rules regarding side scuttles and windows of LHR or an IACS member.

ii. Where the glazing material, glazing thickness, or fixing of the glazed opening do not meet the requirements of a recognised standard they may be tested, to the satisfaction of L.H.R, in accordance with the following provisions:
   a) the glazed opening shall be tested to a minimum test pressure of 4 times the required design pressure derived from an appropriate national or international standard, provided that as a minimum, the calculated thicknesses shall meet the LHR or IACS member requirements; and
   b) the testing shall be witnessed by LHR.

4.6 Ventilators and Exhausts

4.6.1 Adequate ventilation shall be provided throughout the vessel. The accommodation shall be protected from the entry of gas and/or vapour fumes from machinery, exhaust and fuel systems, where machinery exhaust systems pass though accommodation they shall be fitted in a gas tight trunk or each space shall be fitted with a carbon monoxide detector, having an alarm provided locally and at a continuously manned station.

4.6.2 Ventilators shall be of efficient construction. Generally, ventilators serving spaces below the freeboard deck or an enclosed superstructure, shall have a minimum coaming height of:

Location	Unrestricted Yachts	Short Range Yachts
Forward quarter length	900 mm	450 mm
Elsewhere	760 mm	380 mm

4.6.3 Ventilators shall be kept as far inboard as practicable and the height above the deck of the ventilator opening shall be sufficient to prevent the ingress of water when the vessel heels.

4.6.4 The ventilation of spaces such as the machinery space, which shall remain open, requires special attention with regard to the location and height of the ventilation openings above the deck, taking into account the effect of down flooding angle on stability standard and alternative ventilation for use in bad weather. The means of closure of ventilators serving the machinery space shall be selected with regard to the fire protection and extinguishing arrangements provided in the machinery space.

4.6.5 Engine exhaust outlets which penetrate the hull below the freeboard deck shall be provided with means to prevent back flooding into the hull through a damaged exhaust system. For vessels operating on unrestricted service a positive means of closure shall be provided. The system shall be of equivalent construction to the hull on the outboard side of the closure. For Short Range Yachts, where the fitting of a positive closure is not practicable, the exhaust shall be looped up above the waterline on the outboard side of the system, to a minimum height of 1000 millimetres, and be of equivalent construction to the hull.

4.6.6 Ventilators shall be provided with permanently attached means of weathertight closure. Where the full coaming heights of paragraph 4.6.2 are met, permanently attached means of closure may be omitted if it can be shown that the open end of a ventilator is afforded adequate protection by other structure(s) which shall prevent the ingress of water.

4.6.7 Proposals to reduce the coaming heights required by paragraph 4.6.2 may be subject to special consideration and approval by L.H.R., having regard for their protected location, means to prevent the ingress of water, excess freeboard and impact on stability.

4.7 Air Pipes

4.7.1 Air pipes serving fuel and other tanks shall be of efficient construction, led to above the bulkhead deck and provided with automatic closing devices. Where the full coaming heights of paragraph 4.7.2 are met, automatic closing devices may be omitted if it can be shown that the open end of an air pipe is afforded adequate protection by other structure(s) which shall prevent the ingress of water.

4.7.2 Air pipes shall be kept as far inboard as practicable and be fitted with a coaming of sufficient height to prevent inadvertent flooding. Generally, air pipes to tanks shall have a minimum coaming height of:

Location	Unrestricted Yachts	Short Range Yachts
On weather deck	760 mm	380 mm
Elsewhere	450 mm	225 mm

4.7.3 Air pipes to fuel tanks shall terminate at a height of not less than 760 millimetres above either, the top of the filler pipe for a gravity filling tank or, the top of the overflow tank for a pressure filling tank.

4.7.4 Proposals to reduce the coaming heights required by paragraph 4.7.2 may be subject to special consideration and approval by L.H.R, having regard for their protected location, means to prevent the ingress of water, excess freeboard and impact on stability.

4.8 Scuppers, Sea Inlets and Discharges and Other Hull Penetrations

4.8.1 The standards of ICLL shall be applied to every discharge led through the shell of the vessel as far as it is reasonable and practicable to do so, and in any case, all sea inlet and overboard discharges shall be provided with efficient shut-off valves arranged in positions where they are readily accessible at all times.

4.8.2 Underwater lights and associated penetrations fitted in the hull shall be approved by L.H.R.

4.9 Freeboard and Datum Draught Marks

4.9.1 In addition to paragraphs 2.1.2 and 2.1.3, yachts shall comply with International Convention on Load Lines (1966) for the assignment of a freeboard mark which corresponds to the deepest loading condition included in the stability information booklet for the vessel.4.9.2 The freeboard assigned shall be compatible with the strength of hull structure, intact and damage stability requirements for the vessel, and shall ensure that minimum bow height requirements of the International Convention on Load Lines (1966) are met.

4.9.3 The Assigning Authority shall approve the freeboard and its marking, issue the International Load Line Certificate (1966) and provide the owner(s)/managing agent(s) of the vessel with a copy of the particulars of the freeboard assigned and a copy of the record of particulars relating to the conditions of assignment. The declared area(s) of operation and any other conditions which restrict the use of the vessel at sea shall be recorded on the load line certificate issued to the vessel.

4.9.4 The freeboard mark applied shall be positioned port and starboard at amidships on the load line length and may be an all-seasons mark. The mark shall be a permanent disc and be of contrasting colour to the hull of the vessel in way of the mark.

4.9.5 The fresh water freeboard allowance shall be obtained by deducting from the all-seasons freeboard assigned, the quantity

$$\frac{\Delta}{4T}\ millimetres$$

Where Δ=displacement in salt water in tonnes at the all-seasons draught and T=tones per centimetres immersion at the all seasons load waterline

Alternatively the deduction may be taken as 1/48th of the all-seasons draught of the ship at amidships.

4.9.6 A vessel shall not operate in any condition which shall result in its appropriate freeboard marks being submerged when it is at rest and upright in calm water.

4.9.7 Datum draught marks shall be provided at the bow and stern, port and starboard, and be adequate for assessing the condition and trim of the vessel. Such draught marks may be single datum lines.

4.9.8 The marks shall be permanent and easily read but need not be of contrasting colour to the hull. The marks need not indicate more than one draught at each position and shall be above, but within 1000 millimetres, of the deepest load waterline.

4.9.9 The draught to which marks relate shall be indicated either above the mark on the hull and/or in the stability information booklet for the vessel. The position of the marks shall be verified at initial placement by the Administration or the vessel's Assigning Authority.

CHAPTER 2 Design Loads

Contents

SECTION 1 Symbols and Definitions

1.1 Symbols - Units

1.1.1 In addition to the symbols defined in each particular section the following symbols are used in this Chapter:

L = length of the ship, defined in 1.2.2, m,

B = breadth of the ship, defined in 1.2.5, m,

T = draught of the ship, defined in 1.2.6, m,

D = depth of the ship, defined in 1.2.7, m,

Δ = displacement of the ship in tonnes, defined in 1.2.8, tonnes,

C_b = block coefficient, defined in 1.2.9,

V = maximum speed in service in m/sec, at maximum displacement, m/sec,

Fr = Froude number, defined in 1.2.10,

FP = forward perpendicular, defined in 1.2.3,

AP = after perpendicular, defined in 1.2.4,

WL= water line, defined in 1.2.1,

LCG= longitudinal centre of gravity,

L_{WL}= waterline length, m,

B_{WL}= maximum moulded breadth at the waterline, m,

g = acceleration due to gravity (= 9,80665 m/sec^2).

1.2 Definitions

1.2.1 As a general rule, the waterline is the summer freeboard waterline.

1.2.2 Length L of the ship is the length between perpendiculars. Amidships is defined as the middle of L.

1.2.3 Forward perpendicular is the perpendicular at the intersection of the waterline (when the ship is at rest) with the foremost point of the bow stem.

1.2.4 After perpendicular is the perpendicular at the intersection of the waterline (with the ship at rest) with the abaft side of the stern post or the transom.

1.2.5 Breadth B of the ship is the maximum moulded breadth.

1.2.6 Draught T is measured amidships from the top of keel to the waterline.

1.2.7 Depth D is measured amidships from the top of keel to the moulded deck-line at side of the uppermost continuous deck.

1.2.8 Displacement of the ship is the fully loaded displacement in salt water (ρ=1,025t/m^3) on draught T.

1.2.9 Block coefficient C_b is given by the formula:

$$C_b = \frac{\Delta}{1{,}025 \cdot L \cdot B_{WL} \cdot T}$$

1.2.10 Froude number Fr is defined by the formula:

$$F_r = \frac{V}{\sqrt{gL}}$$

1.2.11 Freeboard deck is the lowest deck above the waterline, weather-tightly closed, which is used to measure the freeboard.

1.2.12 Weather decks are open decks or parts of decks, which are exposed to sea and weather loads.

1.2.13 Bulkhead deck (for passenger ships) is a deck above flooded waterline up to which the watertight bulkheads are carried.

1.2.14 A superstructure is defined as a decked structure on the freeboard deck, extending from side to side of the ship, or inboard of the shell plating at a distance not more than 0,04B. A deckhouse is a decked structure other than a superstructure.

SECTION 2 Accelerations

2.1 Design vertical acceleration

2.1.1 The formulas for the vertical acceleration given in this section apply to planing craft as defined in Part 1, Chapter 2, SECTION 1, 1.2.4(b).

2.1.2 The average impact acceleration at the centre of gravity of a planing craft operating in irregular head seas is given by the following formula:

$$a_{v,1/100}^{cg} = 1{,}5 \cdot \tau \cdot \frac{L_{WL} B_c^3}{B_{WL}} (\frac{H_{1/3}}{B_{WL}} + 0{,}084)(5 - 0{,}1\beta) \frac{V^2}{L_{WL}} 10^{-3}$$

Where:

$a_{v,1/100}^{cg}$	=	Average of the 1/100 highest accelerations at the centre of gravity, in g's
$H_{1/3}$	=	Significant weight height, deifned in 2.1.3, m,
τ	=	Equilibrium trimming angle, deg,
β	=	Deadrise angle, deg,
B_C	=	Maximum moulded breadth at the chine in m. In the case of more than one chines, the lower one should be used in the calculations.
B_{WL}	=	Maximum breadth of hull at LCG at the waterline, m,
L_{WL}	=	Waterline length, m,
V	=	Ship's speed, Kn,
Δ	=	Displacement, tonnes

2.1.3 Significant wave height $H_{1/3}$ is the average of the $^1/_3$ highest wave heights. In general, the significant wave height is 20% higher than the "wave height" observed by an experienced person. If no information is available for the significant wave height this is to be taken not less than L/12.

2.1.4 The value of the trim angle depends on the speed of the ship and is provided by the builder. In the case its value is not available it may be taken to be 4 degrees.

2.1.5 Different values of $a_{v,1/100}^{cg}$ may be taken into account if results of model tests or full-scale measuremenets are available.

2.1.6 The vertical acceleration at the bow of ship, which is defined as the average of the 1/100 highest accelerations at bow, is given by the following formula:

$$a_{v,1/100}^{b} = a_{v,1/100}^{cg} \cdot \left[1 + 1{,}13 \cdot \frac{\left(\frac{L_{WL}}{B_{WL}} - 2{,}25\right)}{F_r}\right]$$

2.1.7 The mean vertical acceleration a_v along the length of the ship can be considered to be constant between AP and LCG and lineraly varying between LCG and FP.

2.1.8 The average 1/Nth highest accelerations $a_{v,1/N}$ is related to the average acceleration $a_v$by means of the formula:

$$a_{v,1/N} = a_v(1 + \log_e N)$$

2.1.9 The design vertical acceleration, a_d, at the centre of gravity of planing ships, taken as basis for the scantlings, is to be taken as the average of the 1/100 highest accelerations $a_{v,1/100}^{cg}$:

$$a_d = a_{v,1/100}^{cg} = a_v^{cg} \cdot (1 + \log_e 100) = 5{,}605 \cdot a_v^{cg}$$

2.1.10 In order to keep the acceleration at the centre of gravity smaller than the design acceleration $a_{v,1/100}^{cg}$ the speed of the ship must remain limited according to the significant wave height $H_{1/3}$. Relationship between allowable speed and significant wave height will be stated in the "Appendix to the Classification Certificate".

2.1.11 For passenger ships the design acceleration at the centre of gravity $a_{v,1/100}^{cg}$ must be limited to 1,0. Installation of an accelerometer at LCG may be required.

2.1.12 The application area of the above formula is constrained by the following limits:

$$3200 \leq \frac{\Delta}{(0{,}01 \cdot L)^3} \leq 8000$$

$$3 \leq \frac{L_{WL}}{B_{WL}} \leq 5$$

$$3° \leq \tau \leq 7°$$

$$10° \leq \beta \leq 30°$$

$$0{,}2 \leq \frac{H^{\frac{1}{3}}}{B_{WL}} \leq 0{,}7$$

$$1{,}8 \leq \frac{V}{\sqrt{L}} \leq 5{,}6$$

Special considerations (that is model tests or full scale measurements) should be given for a_v^{cg} when some of the vessels parameters lie outside the above ranges.

SECTION 3 Design loads for planing craft

3.1 General

3.1.1 Design loads given in this section apply to planing craft as defined in Part 1, Chapter 2, SECTION 1, 1.2.4(b).

3.1.2 Different values for design loads may be taken into account if the builder provides results of model tests, or of full-scale measurements, or of accepted theoretical studies.

3.1.3 For some special cases model tests may be required and may result to an increase of the values of the design loads given in this section.

3.1.4 The load point for which the design pressure given below is to be calculated is defined according to the various strength members as follows:

(a) The midpoint for horizontally stiffened plates

(b) Half of the stiffener spacing above the lower support for vertically stiffened plates

(c) The midpoint of span for stiffeners

(d) The midpoint of load area for girders.

3.2 Bottom design pressure

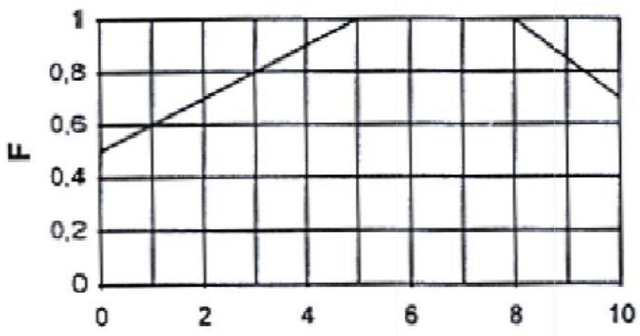
3.2.1 The design pressure on the bottom of the ship is to be taken as:

$$p_b = p_h + 100.54 \cdot F \cdot K_d \cdot a^{cg}_{v,1/100} \cdot T$$

Where:

p_b	=	Bottom design pressure in kN/m²,
p_h	=	Hydrostatic pressure in kN/m²,
	=	ρgT,
K_1	=	Longitudinal pressure distribution factor given in Figure 2.3.1
K_d	=	Pressure reduction coefficient given in Figure 2.3.2
T	=	Draught of the ship in m,
$a^{cg}_{v,1/100}$	=	Design vertical acceleration not to be less than that given in 2.1.2.

Figure 2.3.1: Longitudinal pressure distribution factor



3.2.2 The design area AD for the considered stiffeners and girders is to be taken as the product spacing x span (in m2)

3.2.3 The reference area A_R is defined by the following formula:

$$A_R = \frac{0.7\Delta}{T} \quad [m^2]$$

3.2.4 The bottom pressure defined above is to be applied for the scantling determinations of the structural elements within the area extending from the keel to the chine or the bilge upper edge. For ships with rounded bilge, the bilge upper edge is defined as the tangential point of the bilge with an inclined line at slope 60° with the horizontal line (see figure below)

Figure 2.3.2: Pressure reduction coefficient K_d

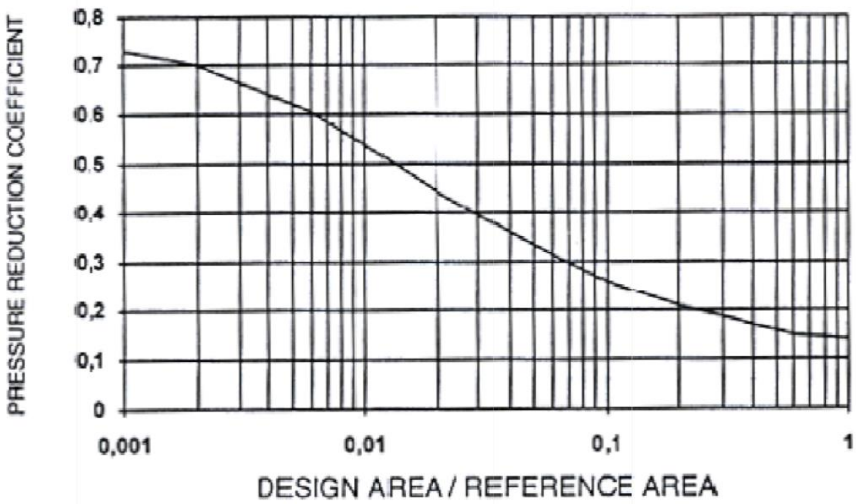
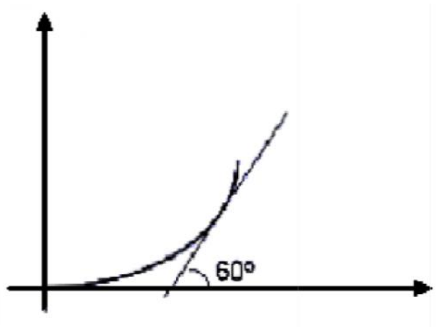


Figure 2.3.3



3.3 Side design pressure

3.3.1 The desgin pressure on the side of the ship is to be taken as:

(a) For load point below the waterline:

$$p_s = 10h_0 + S_w\left(1 - \frac{0{,}2 \cdot h_0}{T}\right) \quad [kN/m^2]$$

(b) For load point above the waterline:

$$p_s = S_w - 5 \cdot h_0 \quad [kN/m^2]$$

With:

$$p_s > p_{s,min}$$

Where:

p_s = Side design pressure in kN/m^2,

h_0 = Vertical distance in m between the waterline at draft T and the plating lower edge or the frame mid-span,

T = Draught of the ship, m,

S_w , $p_{s,min}$ given in the following table

	S_w	$p_{s,min}$ (kN/m^2)
Fore End	1,0 x L x a_d	20
Amidship	0,55 x L x a_d	10
Aft End	0,55 x L x a_d	10

NOTES:

1. The vertical design acceleration a_d shall be not less than 1 and not greater than 2.
2. Between amidships and fore end of the ship the quantities S_w and $p_{s,min}$ are linearly interpolated.

3.4 Deck design pressure

3.4.1 The design pressure on the decks of the ship is to be taken as:

$$p_d = \alpha \cdot (S_w - 5 \cdot h_0) \quad [kN/m^2]$$

with:

$$p_d > 7 \quad [kN/m^2]$$

where:

p_d = Design pressure on decks in kN/m^2,

α = 1,0 for exposed freeboard deck

= 0,8 for freeboard deck inside superstructures and weather decks above freeboard deck,

h_0 = Vertical distance in m between the waterline and the load point on deck,

S_w = as defined in 3.3.1

3.5 Design pressure on superstructures and deckhouses

3.5.1 The design pressure to be considered for the determination of the scantlings of superstructures and deckhouses is not to be less than:

$$p = \alpha \cdot (S_w - 5 \cdot h_0) \quad [kN/m^2]$$

where:

p	=	Design pressure on decks in kN/m^2,
α	=	2,0 for lowest tier of unprotected fronts
	=	1,5 for unprotected superstructure and deckhouse front
	=	1,0 for sides and superstructures
	=	0,8 for superstructure decks, sides of deckhouses, aft end of superstructures and deckhouses
h_0	=	Vertical distance in m between the waterline and the load point on deck,
S_w	=	as defined in 3.3.1

The minimum values of p to be considered are:

~ for the lowest tier of unprotected fronts $p_{min} = 15 kN/m^2$

~ for unprotected superstructures and deckhouse fronts elsewhere $p_{min} = 10 kN/m^2$

~ for other sides and decks $p_{min} = 7 kN/m^2$

3.6 Design pressure on bulkheads

3.6.1 The design pressure on watertight bulkheads is to be taken as:

$$p = \rho \cdot g \cdot h$$

with:

$$p_d > 15 \quad [kN/m^2]$$

where:

p	=	design pressure in kN/m^2,
ρ	=	1,025 t/m^3,
h	=	vertical distnace in m from the load point to the top of the bulkhead or the flooded line,

As load point we consider the plating lowest edge or the midpoint of the stiffener span.

3.6.2 The design pressure on a deck or inner bottom, which forms part of the watertight bulkhead, is to be taken at least equal to that for the bulkhead at the same level.

3.6.3 The design pressure on bulkheads in liquid tanks is to be taken as the greatest of:

$$p = \rho \cdot (g + a_v) \cdot h$$
$$p = \rho \cdot g \cdot (h + 0{,}5 \cdot h_s)$$
$$p = \rho \cdot g \cdot (h + 1{,}5)$$

where:

p	=	design pressure in kN/m^2,
a_v	=	Vertical acceleration at the considered point as given in 2.1.7,
h_s	=	Vertical distance in m between the load point and the top of the air pipe,
h	=	Vertical distance in m between the load point and the top of tank,

3.7 Loads from heavy units

3.7.1 The vertical forces acting on structural elements and coming from heavy units as cargo, equipment etc are to be taken as:

$$P = \rho \cdot (g + a_v) \cdot M$$

where:

P	=	vertical force, kN,
M	=	mass of unit, t,
a_v	=	Vertical acceleration at the considered point as given in 2.1.7,

SECTION 4 Design loads for displacement craft

4.1 General

4.1.1 Design loads given in this section apply to displacement craft as defined in Part 1, Chapter 2, SECTION 1, 1.2.4(a).

4.1.2 Different values for design loads may be taken into account if results of model tests or of full scale measurements or of accepted theoretical studies are provided by the builder.

4.1.3 For some special cases model tests may be required and may result to an increase of the values of the design loads given in this section.

4.1.4 The load point for which the design pressure given below is to be calculated is defined according to the various strength members as follows:

(a) The midpoint for horizontally stiffened plates.

(b) Half of the stiffener spacing above the lower support for vertically stiffened plates.

(c) The midpoint of span for stiffeners.

(d) The midpoint of load area for girders.

(e) The plating lowest edge or the midpoint of the stiffener span for bulkheads.

For ships with service restrictions the S_w factor used in this Section may be reduced according to the Table 2.4.1:

Table 2.4.1: Reduction to S_w due to service restrictions

Service notation	Reduction (%)
Costal service	20
Extended protected waters service	40
Protected waters service	50
NOTE: 1. In the case of 'Specified route service' or 'Specific operating area service' notations the reduction will be specially considered.	

4.1.5 The minimum pressure values in KN/m² are given in Table 2.4.2.

Table 2.4.2: Minimum pressure values

	Protected waters service	Extended protected waters service	Costal service	Unrestricted
Bottom	12	12	12	12
Sides	4	5	6.5	8
Weather deck	3,5	4	5	6
Lowest tier of unprotected fronts	4	5	6,5	8

4.2 Bottom design pressure

4.2.1 The design pressure on the bottom of the ship is to be taken as:

$$p = 10h_0 + S_w \cdot \left(K_s - \frac{0,2 \cdot h_0}{T}\right), but\ not\ less\ than\ 12kN/m^2$$

where:

p	=	bottom design pressure, kN/m,
S_w	=	0,8L,
K_s	=	distribution factor as follows:
	=	0,75 between Aft End and Amidships
	=	1,4 at Fore End
	=	in intermediate positions the factor K_S is linearly interpolated
h_0	=	vertical distance between the waterline at draught T and the load point, m,
T	=	draught of the ship, m,

4.3 Side and deck design pressure

4.3.1 The design pressure on the side and decks of the ship is to be taken as follows:

(a) For load points below the waterline:

$$p = 10h_0 + S_w \cdot \left(K_s - \frac{0,2 \cdot h_0}{T}\right), but\ not\ less\ than\ p_{min}$$

(b) For load points above the waterline:

$$p = \alpha \cdot K_s \cdot (S_w - 5 \cdot h_0), but\ not\ less\ than\ p_{min}$$

where:

p	=	design pressure, kN/m²,
K_s, S_w	=	as defined in 4.2.1
h_0	=	vertical distance between the waterline at draught T and the load point, m,
T	=	draught of the ship, m,
α	=	1,0 for the side plating and the exposed freeboard deck

= 0,8 for the freeboard deck inside superstructures and weather decks above freeboard deck

4.4 Design pressure on superstructures and deckhouses

4.4.1 The design pressure on superstructures and deckhouses is not to be less than:

$$p = \alpha \cdot K_s \cdot (S_w - 5 \cdot h_0)$$

where:

p	=	design pressure for the considered structural element, kN/m^2,
K_s, S_w	=	as defined in 4.2.1
h_0	=	vertical distance between the waterline at draught T and the load point, m,
T	=	draught of the ship, m,
α	=	2,0 for lowest tier of unprotected fronts
	=	1,5 for unprotected superstructure and deckhouse front
	=	1,0 for sides of superstructures
	=	0,8 for superstructure decks, sides of deckhouses, aft end of superstructures and deckhouses,

4.5 Design pressure on bulkheads

4.5.1 The design pressure on watertight bulkheads is to be taken as:

$$p = \rho \cdot g \cdot h$$

where:

p	=	design pressure, kN/m^2,
ρ	=	1,025 t/m^3
h	=	vertical distance from the load point to the top of the bulkhead or the flooded line, m

As load point we consider the plating lowest edge or the midpoint of the stiffener span.

4.5.2 The design pressure on a deck or inner bottom which forms part of the watertight bulkhead is to be taken at least equal to that for the bulkhead at the same level.

CHAPTER 3 Longitudinal Strength

Contents

SECTION 1 General

1.1 Application

1.1.1 For ships of ordinary hull form with length less than 50m, longitudinal strength requirements are normally satisfied for scantlings obtained from local strength calculations.

1.1.2 In some cases, longitudinal strength calculations may be required at LHR discretion, dependent upon the proposed ship loading condition. In these cases, longitudinal strength is to be calculated as described in the sequel.

1.1.3 In addition to the symbols defined in each particular section, the symbols defined in Part 3, Chapter 2, SECTION 1 will be used in this Chapter.

1.1.4 For ships the class of which is valid only for a restricted range of service, the wave bending moments and the wave shear forces as calculated from 2.2, 2.3, 2.4 may be reduced as follows:

(a) Coastal service by 25%

(b) Extended protected waters service by 30%

(c) Protected waters service by 40%

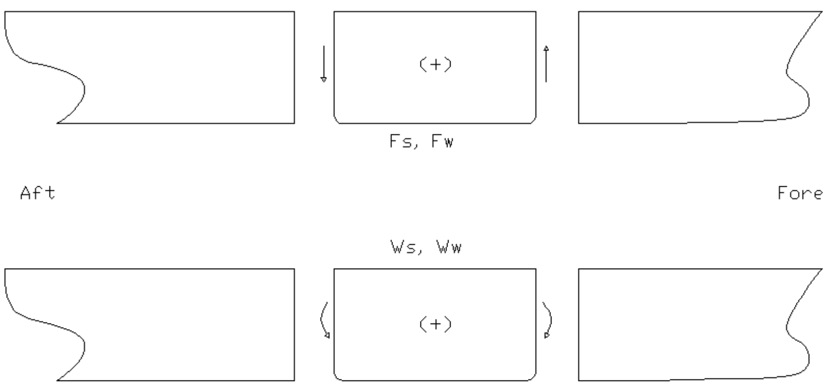
In the case of 'Specified route service' or 'Specific operating area service' notations, the reductions in the wave bending moments and the wave shear forces will be specially considered.

SECTION 2 Hull girder loads

2.1 Sign convention

2.1.1 The sign convention of the bending moments and shear forces is shown in Figure 3.2.1.

Figure 3.2.1: Sign convention



2.2 Still-water bending moment and shear force

2.2.1 The still-water bending moment M_S, and shear force F_S, given by the following formulae may be used within 0,4L amidships:

$$M_s = 0{,}075 \cdot SM_o$$

$$F_s = 0{,}8 \cdot F_W$$

Where:

M_s = still-water bending moment, in kNm,

SM_o = required section modulus of the midship section as defined in 3.1.1,,

F_W = wave-shear force $F_W(+)$ or $F_W(-)$, whichever is greater, as defined in 2.4.1.,

2.3 Wave bending moments

2.3.1 The wave bending moments M_W at each section along the ship length are given by the following formulae:

$$M_W(+) = +\,0{,}3 \cdot M \cdot C_w \cdot L^2 \cdot B \cdot C_b\ , for\ positive\ moment\ (hogging)$$

$$M_W(-) = -0{,}15 \cdot M \cdot C_w \cdot L^2 \cdot B \cdot (C_b + 0{,}7) \cdot (1{,}5 \cdot F_r + 0{,}8)\ , for\ negative\ moment\ (sagging)$$

Where:

C_W = 0,08L,

L = length of the ship in m,

B = breadth of the ship in m,

C_b = block coefficient,

F_r = Froude number,

M = distribution factor as follows:

= 1,0 between 0,4L and 0,8L from AP

= 0 at A.P and F.P

in intermediate positions the factor M is linearly interpolated

2.3.2 For planing craft where Fr>1,0, the wave bending moment will be subject to special consideration due to dynamic effects. In this case, a slamming pressure is acting on an area at the bottom of the ship equal to the reference area A_R defined by:

$$A_R = \frac{0{,}7\Delta}{T} \quad [m^2]$$

Where:

A_R = reference area, m^2,

Δ = displacement of the ship, tonnes,

T = draught of the ship, m

This area is to be considered with its center at LCG of the ship. The hull beam is to be considered out of water with the actual weight distribution along it.

2.3.3 The wave bending moment due to slamming M_{sl} at each section along the ship length may be assumed to be given by the formula:

$$M_{sl}(+) = M \cdot \frac{\Delta}{2} \cdot (1{,}0 + a_d) \cdot g_0 \cdot \left(m - \frac{A_R}{4 \cdot B_c}\right), \qquad for\ positive\ moment\ (hogging)$$

Where:

M_{sl} = wave bending moment due to slamming in kN m,

Δ = displacement of the ship, tonnes,

a_d = design vertical acceleration at LCG in g's, defined in Part 3, Chapter 2, SECTION 2, 2.1.9,

m = mean lever arm in m, defined as follows:

= $m = \frac{M_{AF}+M_{FR}}{\Delta}$, where:

M_{AF} = moment about midship perpendicular of the displacement of the after half of the ship in t m,

M_{FR} = moment about midship perpendicular of the displacement of the fore half of the ship in t m,

m = 0,25L, if not known,

B_c = maximum moulded breadth at the chine in m,

M = distribution factor as defined in 2.3.1.

2.3.4 Different values based on accepted theoretical studies may be accepted subject to the approval of the Society.

2.4 Wave shear forces

2.4.1 The wave shear forces F_W at each section along the ship length are given by the following formulae:

$$F_W(+) = +\,0{,}3 \cdot F_1 \cdot C_W \cdot L \cdot B \cdot (C_b + 0{,}7), \qquad for\ positive\ shear\ force$$

$$F_W(-) = -\,0{,}3 \cdot F_2 \cdot C_W \cdot L \cdot B \cdot (C_b + 0{,}7), \qquad for\ negative\ shear\ force$$

Where:

L, B, C_b, C_W = as defined in 2.3.1,

F_W = wave shear force, kN

F_1 = distribution factor:

= 0 at A.P. and F.P.,

= 0,7 between 0,2L and 0,6L from A.P.,

= 1,2 between 0,7L and 0,85L from A.P.,

= in intermediate positions the factor F_1 is linearly interpolated

F_2	=	distribution factor:
	=	0 at A.P. and F.P.,
	=	0,95 between 0,2L and 0,3L from A.P.,
	=	0,7 between 0,4L and 0,85L from A.P.,
	=	in intermediate positions the factor F_2 is linearly interpolated

2.4.2 For planing craft where Fr>1,0, the wave shear force due to slamming F_{sl} may be related to the wave bending moment given in 2.3.3 as follows:

$$F_{sl} = \frac{4M_{sl}}{L} \quad [kN]$$

Where:

F_{sl}	=	shear force due to slamming, kN,
M_{sl}	=	bending moment as defined in 2.3.3.

SECTION 3 Hull girder strength

3.1 Hull girder bending strength

3.1.1 The section modulus to the strength deck and to the keel of the midship section is not to be less than the greatest of the following values:

$$SM_o = C_W \cdot L^2 \cdot B \cdot (C_b + 0{,}7)$$

$$SM = |M_s + M_{wave}|/\sigma \cdot 10^{-3}$$

Where:

SM_o, SM	=	required section modulus in cm^3,
L, B, C_w, C_b	=	as defined in 2.3.1,
M_S	=	maximum still water bending moment, in kN m, calculated according to 2.2.1,
M_{Wave}	=	wave-induced bending moment M_W or M_{sl}, whichever is greater, as defined in 2.3.1 and 2.4.1, respectively
σ	=	For constructions of FRP or wood minimum ultimate tensile or compressive strength whichever is less in N/mm², verified by approved test results in accordance with the requirements of Part 2.
	=	175 / k N/mm² for steel or aluminium constructions
K	=	material factor
	=	1,0 for ordinary hull structural steel
	=	0,78 for steel with minimum upper yield point 315 N/mm²
	=	0,72 for steel with minimum upper yield point 355 N/mm²
	=	235 / σ_{al} for aluminum constructions
σ_{al}	=	guaranteed minimum 0,2% proof stress of the alloy in the welded condition, in

N/mm^2

3.1.2 In general all members which are continuous or effectively developed within 0,4L amidships and gradually tapered beyond the 0,4L may be included in the section modulus calculation. The section modulus to the strength deck or to the keel is obtained by dividing the moment of inertia of the section by the vertical distance from the neutral axis to the moulded deck line at side amidships, or to the base line, respectively.

3.1.3 For ships having wide and/or long hatch openings or where a relatively large portion of the deck is open, calculations of combined stresses may be required. In this case, the section modulus may be required to be increased.

SECTION 4 Twin hull girder loads

4.1 General

4.1.1 The transverse strength of twin hull connecting structure may be analyzed for moments and forces specified below.

4.1.2 Design forces and moments given in 4.2 and 4.3 are to be used unless other values are verified by model tests or full scale measurements or if similar structures have proved to be satisfactory in service.

4.1.3 Superstructure is normally not to be included in the structure giving transverse strength.

4.2 Vertical bending moment and shear force.

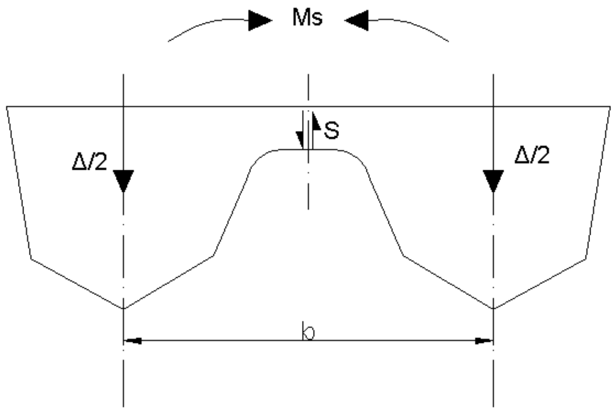
4.2.1 For craft with $(V/\sqrt{L} \geq 3)$ the twin hull transverse bending moment may be assumed to be:

$$M_s = \frac{\Delta \cdot a_d \cdot b}{s} \quad [kNm]$$

Where:

Δ	=	displacement of the ship in tones,
a_d	=	design vertical acceleration as given in Part 3, Chapter 2, SECTION 2, 2.1.9
b	=	transverse distance between the centerlines of the two hulls
s	=	factor given in Table 3.4.1.

Figure 3.4.1:



4.2.2 For craft with $(V/\sqrt{L} < 3)$ the twin hull transverse bending moment may be assumed to be greater of:

$$M_S = M_{S0} \cdot \left(1 + \frac{a_d}{g_0}\right), \qquad [kNm]$$

$$M_S = M_{S0} + F_y \cdot (z - 0{,}75 \cdot T), \qquad [kNm]$$

Where:

M_{so} = still water transverse bending moment in kNm,

a_d = design vertical acceleration as given in Part 3, Chapter 2, SECTION 2, 2.1.9,

T = draught of the ship in meters,

F_y = horizontal split force on immersed hull,

= $0{,}1 \cdot L^2 \cdot C_1 \cdot C_2 \cdot \left(1 + 0{,}1 \cdot \frac{V}{\sqrt{L}}\right) \cdot \left(53 - \frac{L}{0{,}5 \cdot B_{WL}}\right), kN$

Where:

$C_1 = 1{,}6 - \frac{6}{\sqrt{L}}$

$C_2 = \frac{70}{\left(\frac{L}{T}\right)^{1{,}5}}$

L = length of the ship in meters,

T = draught of the ship in meters,

B_{WL} = The net sum of the waterline breadths,

z = height in m from base line to neutral axis of cross structure,

4.2.3 The vertical shear force in centerline between twin hull may be assumed to be:

$$S = \frac{\Delta \cdot a_d}{q}, [kN]$$

Where:

a_d = design vertical acceleration as given in Part 3, Chapter 2, SECTION 2, 2.1.9,

Δ = displacement of the ship in tones,

q = factor given in Table 3.4.1.,

Table 3.4.1: s and q factors

Service restriction	s	q
Extended protected waters service	8	6
Specified costal service	7,5	5,5
Unrestricted	4	3

4.3 Twin hull torsional moment

4.3.1 Hull torsional moment of twin hull may be assumed to be:

$$M_t = \frac{\Delta \cdot a_d \cdot b}{4}, \qquad [kNm]$$

Where:

a_d = design vertical acceleration as given in Part 3, Chapter 2, SECTION 2, 2.1.9,

Δ = displacement of the ship in tones,

b = distance in m between the two hull centerlines.

CHAPTER 4 Hull construction - FRP

Contents

SECTION 1 General

1.1 General Requirements

The Rules are applicable to mono and multi-hull craft of normal form, proportions and speed. Although the Rules are, in general, for fibre reinforced composite craft of laminated construction, other materials for use in hull construction will be specially considered on the basis of the Rules.

1.2 Documentation to be submitted

1.2.1 Plans covering the following items are to be submitted:

- Midship sections showing longitudinal and transverse material
- Profile and decks
- Deck hatches
- Bridging structure
- Shell expansion
- Laminate schedule
- Oiltight and watertight bulkheads
- Propeller brackets
- Integral tanks
- Double bottom construction
- Pillars and girders
- Aft end construction
- Engine room construction
- Engine and thrust seatings
- Fore end construction
- Doors, hatches, windows and portlights
- Deckhouses and superstructures
- Sternframe
- Rudder, stock and tiller
- Anchor and mooring equipment
- Any special arrangements (e.g. anchor deployment systems, submarine anchor pockets).
- Loading manuals, preliminary and final (where applicable).
- Ice strengthening
- Welding (where applicable)
- Hull penetration plans
- Support structure for masts, derrick posts or cranes
- Bilge keels showing connections and detail design
- Chain-plates

1.2.2 The following supporting documents are to be submitted:

- General arrangement
- Capacity plan
- Modes of operation for which the craft is designed (speeds corresponding to displacement and non-displacement mode as applicable)
- Lines plan or equivalent
- Dry-docking plan
- Towing and mooring arrangements
- Sail/rigging plan, indicating loadings (as applicable to sailing craft)

1.2.3 The following supporting calculations are to be submitted:

- Equipment Number
- Hull girder still water and dynamic wave bending moment and shear force as applicable

- Midship section stiffness
- Structural items in the aft end, midship and fore end regions of the craft
- Preliminary freeboard calculation

SECTION 2 Structural Details

2.1 Laminates

2.1.1 Structural continuity is to be maintained and where changes in thickness or structural section occur, they are to be gradual to prevent notches, hard spots and other structural discontinuities. The ends of all internal members are to provide end fixity and load transmission to the supporting member; departures from this may be considered where the alternative structure has equivalent strength.

2.1.2 A gradual taper is to be used for all changes in laminate thickness. Where the construction changes from sandwich laminate to a solid laminate, the thickness of the core material is, in general, to be reduced by a gradual taper of not less than 2:1.

2.1.3 Access and lightening holes with suitable radius corners are to be arranged as necessary and clear of areas of load concentration or high stresses. Their depths and lengths are generally not to exceed, respectively, 0,5 and 0,75 the depths of the members. Air and timber holes are to be arranged to eliminate air pockets and avoid any accumulation of water or other liquids. In general, their radius is not to be less than 40 mm and not more than 1/3 the depth of the member. All exposed edges of FRP single-skin laminates are to be sealed with resin. Edges of sandwich panels and edges of holes in sandwich panels are to be sealed with resin-impregnated mat. Ferrules installed in sandwich panels or stiffeners for drains or wire penetrations are to be set in bedding compound. All hatch openings are to be supported by a system of transverse and longitudinal stiffeners.

2.1.4 Discontinuities and hard points in the structure are to be avoided, and where the strength of a stiffening member is impaired by any attachment of fittings, openings, drainage arrangements, etc., compensation is to be provided.

2.1.5 Where items are prefabricated outside the mould, they are to be connected by boundary angles formed by layers of reinforcement, structural fillets or other approved method. Where structural fillets are proposed, the scantlings and arrangements will be specially considered.

2.1.6 Polyester, vinylester or epoxy resin may be used in bonded joints, provided that the joint is so designed that the resin bond is in shear. The contact area is to be as large as practicable and the surfaces are to be suitably prepared in accordance with the resin manufacturer's instructions.

2.1.7 The submitted plans are to clearly define the laminate sequence at corner joints. In general, corner laminates are to be boxed and all cuts are to be alternately staggered to avoid a fault line. At corner joints, vertical and horizontal laminates are to be laid alternately and butts are to be staggered accordingly.

2.1.8 The submitted plans are to clearly define the details of scarfed joints. In general, scarfs are not to be steeper than a 12:1 taper. Scarf joints may be either ground or stepped. Where single taper scarf joints are proposed, a sealing laminate is to be provided, details of which are to be submitted. Where stepped joints are proposed, care is to be taken to ensure that over-cutting does not occur. All joints are to be arranged so that they can be reinforced internally to maintain structural continuity of the laminate.

2.1.9 Lap joints may be bolted or adhesively bonded, or both. They may be single or double lapped dependent upon the specific application.

2.1.10 Where tray mouldings form part of the integral structure of the craft, full details are to be indicated on the submitted plans. Information regarding tolerances is to be presented together with details of all adhesives and proposed bonding-in techniques. Particular attention is to be given to the design so as to maintain the structural continuity of the webs of any stiffening members.

2.1.11 Chine details are to be clearly indicated on the submitted plans. Spray rails may form part of the structural laminate or may be installed as a laminated or bolted appendage. Where the chine is a laminated appendage, provision is to be made for a sacrificial ply at which failure may occur without undue damage to the remaining structure of the hull. Sandwich structures are to be returned to single skin laminates at chine rails, unless agreed otherwise on the approved construction plans. Chine rails are to be infilled and over laminated on the inner surface of the hull. Additional reinforcement is to be laminated into the chine area.

2.1.12 Reinforcements are to be arranged to maintain continuity of strength throughout the laminate. Joints in each layer of reinforcement are, in general, to be overlapped. The length of the overlap is dependent upon the type of reinforcement, but is not to be less than 50 mm. The positions of the joints in the laminate are to be staggered, in general by 150 mm, to maintain as near uniform laminate thickness as practicable. Tests may be required to demonstrate continuity of strength when bi-directional, multi-axial or cross-plied reinforcements are used.

2.1.13 As an alternative to overlapping, as required by 2.1.12, individual consideration will be given, on the basis of test results, to partial butting of reinforcements manufactured with a salvedge. For such reinforcements the salvedge tails are to be laid on top of each other to provide continuity. Butts in the same vertical plane are to be separated by not less than five passing plies.

2.1.14 Areas of single skin structure in way of the attachment of fittings or equipment are, in general, to be increased in thickness by not less than 50%, with the additional layers staggered beyond the extremities of the surrounding stiffening.

2.1.15 The design of the structure in way of the attachment of fittings or equipment in sandwich structures is to be such that the induced loads can be transmitted into the surrounding structure by bending as opposed to shear. The areas are in general to take the form of suitably reinforced single skin areas, with the additional layers of reinforcement staggered out onto the surrounding inner and outer skins.

2.1.16 Laminate overlapping and staggering arrangements may require to be tested at the discretion of the Surveyor.

2.1.17 Laminates may be fastened mechanically, provided that the fastenings are of a corrosion resistant metal and are spaced and positioned so as not to impair the efficiency of the joint. The fastenings are to be of an acceptable type and, where washer plates are used, they are to be of a compatible material. The edges of the laminates and the fastening holes are to be sealed.

2.1.18 Where plywood and timber members are to be matted on to, or encapsulated within, the laminate, the surface of the wood is to be suitably prepared prior to bonding.

2.2 Stiffeners

2.2.1 Stiffeners, frames, girders, deck beams, bulkhead stiffeners, etc. used to support FRP panels may be entirely of FRP, FRP laid over nonstructural cores or forms, or composites of FRP and other approved structural materials, such as plywood or wood.

2.2.2 Stiffeners without cores or with cores other than Balsa wood and PVC, are to conform to Figure 4.1.1 and the thickness of the crown and web of the stiffeners is to be not less than obtained from the following equations:

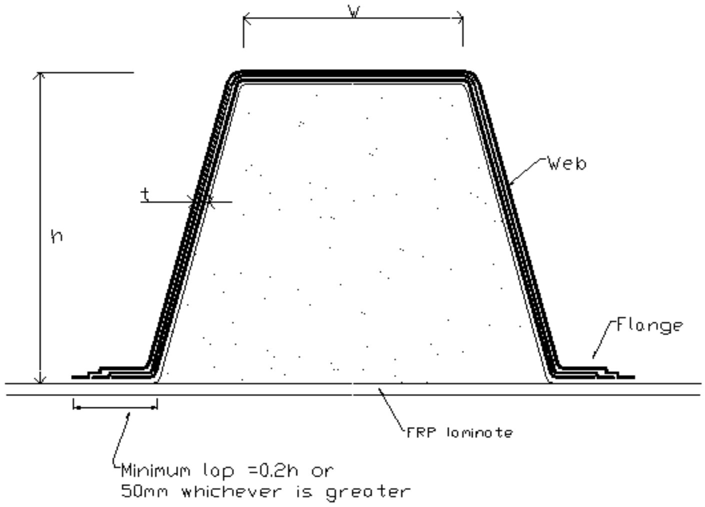
$$t_i = w/20 \ [mm], \qquad t = h/30 \ [mm]$$

Where:

t_i = thickness of the stiffener crown,

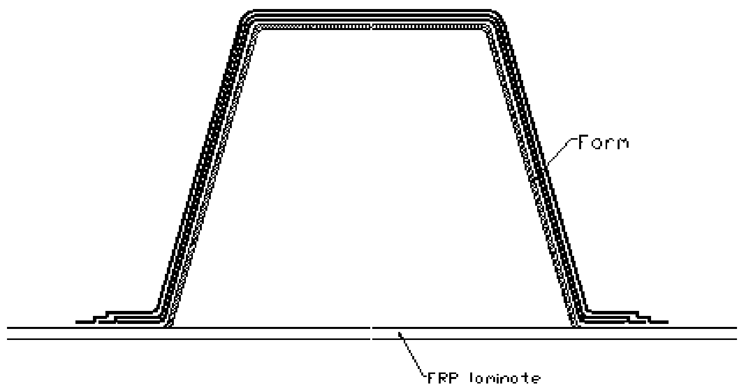
w	=	width of stiffener crown,
t	=	thickness of stiffener web,
h	=	height of stiffener webs

Figure 4.1.1: Proportions of Stiffeners



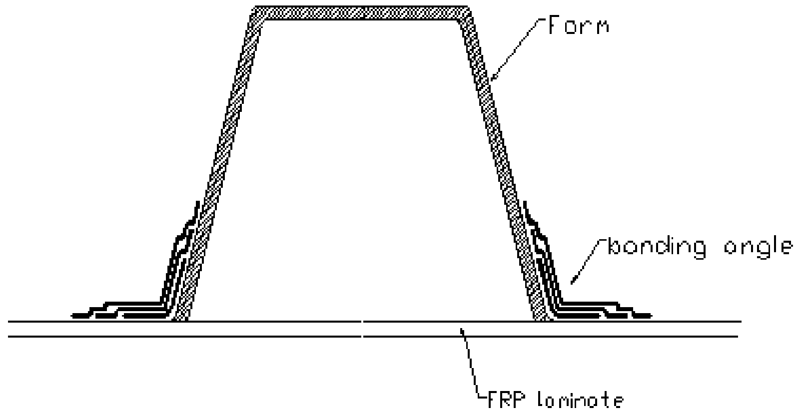
2.2.3 Hat section stiffeners constructed by laying FRP over premolded FRP forms are to conform to Figure 4.1.2 and the above equations. The premolded forms may be considered structurally effective if their physical properties are at least equal to those of the overlay laminates.

Figure 4.1.2: Pre-Molded Stiffeners



2.2.4 Premolded stiffeners bonded to the laminates with FRP angles, flanges or tapes are to conform to Figure 4.1.1 and Figure 4.1.3 and the above equations. The thickness of each bonding angle flange or tape is to be not less than the thickness of the webs of the stiffener, and the length of the legs of the bonding angle, flange or tape are given in 2.1.12. Joints in premolded stiffeners are to be scarphed and spliced or otherwise reinforced to maintain the full strength of the stiffeners.

Figure 4.1.3: Bonding Angles



2.2.5 Girders and longitudinal frames are to be continuous through floors and web frames. Except in way of integral tank end bulkheads, girders and longitudinal frames are also to be continuous through bulkheads. Where such members are intercostal, attention is to be given to minimizing structural discontinuities. The laps of the connections onto the supporting structure are to be not less than the overall widths of the members including flanges, and the thickness of the connections are to be not less than the thickness of the structural member flanges or tapes.

2.2.6 Moulding on the hull of reinforcing elements is to be undertaken before the laminate is fully cured and in the shortest possible lapse of time after moulding of the hull, to avoid internal strains by differential shrinkage and a poor connection of joined surfaces.

2.2.7 Addition of moulded working elements to the hull during the hull construction is acceptable, provided that these elements, when connected to the hull, are at the same state of maturity of resins and before complete curing of the laminate.

2.2.8 Moulding of reinforcing elements on the hull already cured and addition by gluing of rigid elements separately moulded and cured can be carried out, if these processes are used with a preparation of surfaces to allow adherence. The connection is then to be carried out so that the possible deformations do not involve a too large straining of parts. The surface of contact has to be as wide as possible.

2.2.9 Mechanical connections by bolts, rivets or screws crossing through the laminate, used for fastening wooden or metallic elements or for fastening of superstructure or equipment are to be made in order to avoid excessive local stresses in the laminate. They are, in no case, to go against the tightness of this laminate.

2.2.10 As a general rule, it is necessary to recreate the protection of the laminate in the holes and openings made for the passage of connections.

2.2.11 Attachments, by means of studs or other arrangements implying insertion of metallic pieces in the laminate thickness during moulding, are to be avoided. Wood insertions are acceptable, if the wood is entirely sealed, so that any increase of moisture is practically prevented.

2.3 Fittings, Flanges & Bondings

2.3.1 Deck fittings such as cleats and chocks are to be bedded in sealing compound or gasketed, through-bolted, and supported by either oversize washers, or metal, plywood or wood backing plates. Where washers are used, the laminate in way of the fittings is to be increased at least 25% in thickness.

2.3.2 Generally, all through-hull penetrations are to be formed by solid FRP laminates. When sandwich construction is used for the hull, the core material is to be completely sealed off from the through hull penetration. All through hull penetrations are to be taped on both sides of the penetration.

2.3.3 Boundary Angles, Flanges or Tapes

(a) FRP to FRP:

At the end connections of sandwich laminates the core shear strength is to be effectively developed. The thickness of each boundary angle, flange or tape having similar strength to the members being connected is to be not less than obtained from the following:

1. Single-skin to single-skin: One half the thickness of the thinner of the two laminates being joined.
2. Sandwich to sandwich: The greater of the mean thickness of the skins of the sandwich panels being attached.
3. Sandwich to single skin: Either one half the thickness of the single skin laminate or the mean thickness of the sandwich panel being attached, whichever is less.

The thickness of each FRP-FRP boundary angle is also to be not less than obtained from the following equation:

$$t = 0{,}105 \cdot L + 1{,}11 \; [mm]$$

Where:

L = Length, m

The width of each flange, not including end taper is to be not less than 10 times the thickness given above and including the end taper, 13 times the thickness given above, and in general not less than 50 mm. Typical arrangements are shown in Figure 4.1.4 and Figure 4.1.5.

Figure 4.1.4: Sandwich to Sandwich connection

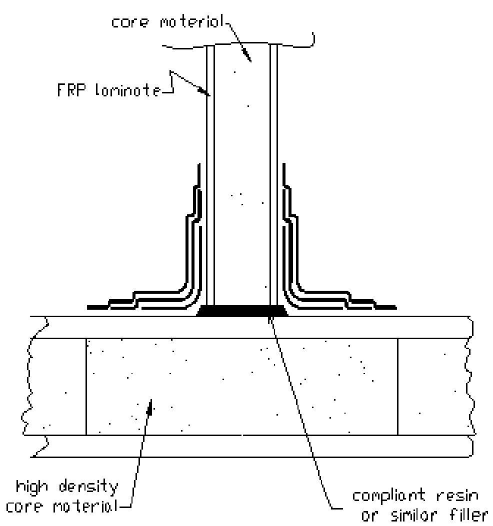
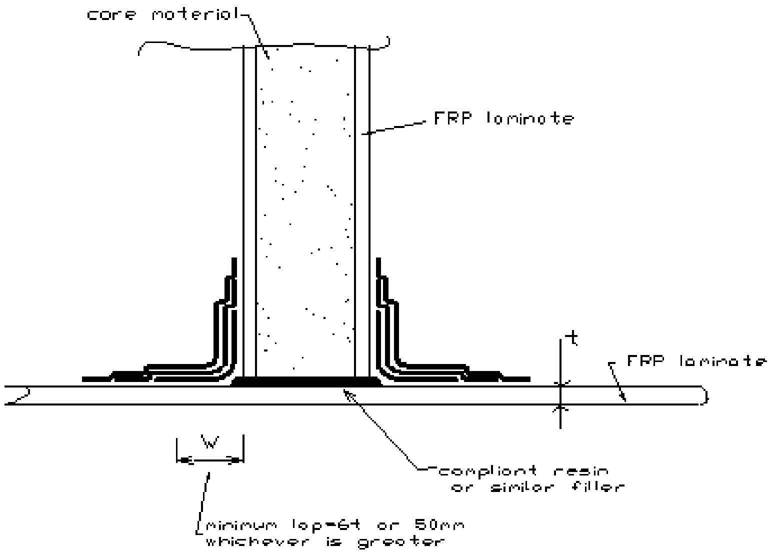


Figure 4.1.5: Sandwich to Single-Skin connection



(b) Plywood or Wood to FRP

Plywood bulkheads are to be bedded in foam, a slow curing polyester putty, a micro-balloon and resin mixture, or other approved material. The boundary angles are to be at least equal in thickness to one- half the thickness of the laminate. The width of each flange is given above, for FRP to FRP connections. Typical arrangements are shown in Figure 4.1.6 and Figure 4.1.7.

Figure 4.1.6: Plywood or wood to FRP connection

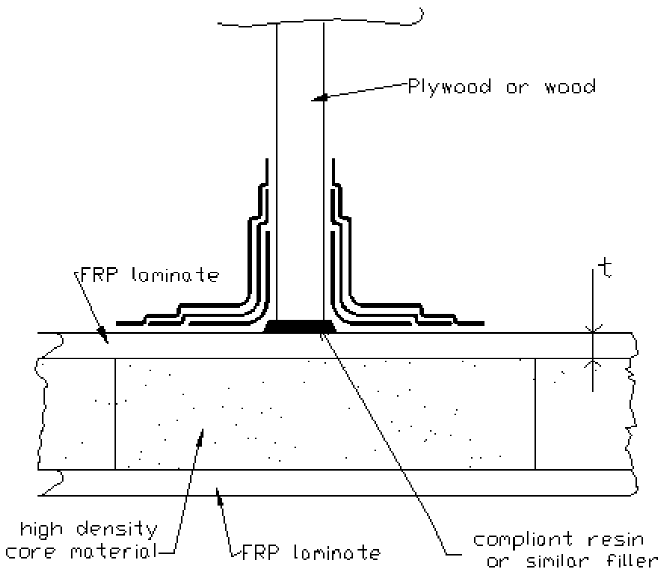
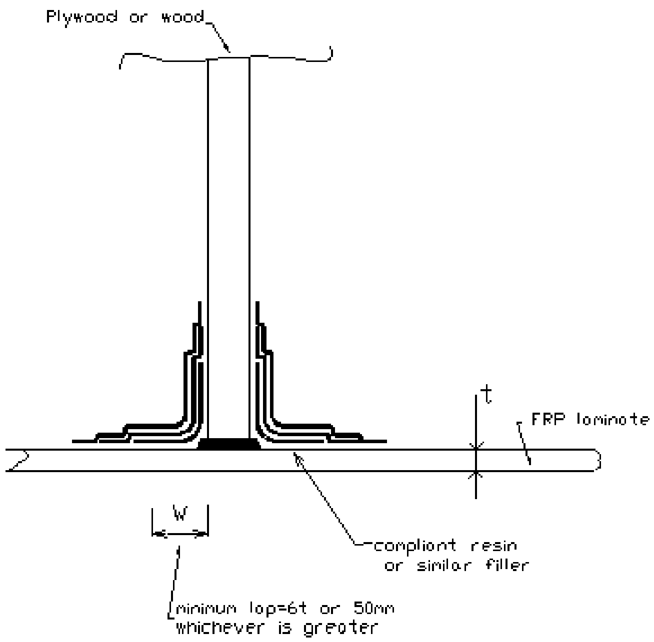


Figure 4.1.7: Plywood or wood to FRP connection



2.4 Shell Details

Plate keels are to meet the requirements in Figure 4.1.8. They are to be adequate for docking loads, which are provided by the designer. Keelsons are to meet the requirements in Figure 4.1.9 and Figure 4.1.10. Chines, spray rails and transoms are to meet the requirements in Figure 4.1.11, Figure 4.1.12, Figure 4.1.13, Figure 4.1.14, Figure 4.1.15 and Figure 4.1.16. Engine foundations are to be of thickness and widths appropriate to the holding down bolts. They are to be set in mat or resin putty to assure uniform bearing against the girders, and are to be bolted through the webs of the girders. Acceptable typical engine foundations are shown in Figure 4.1.17 and Figure 4.1.18.

Figure 4.1.8: Plate keel

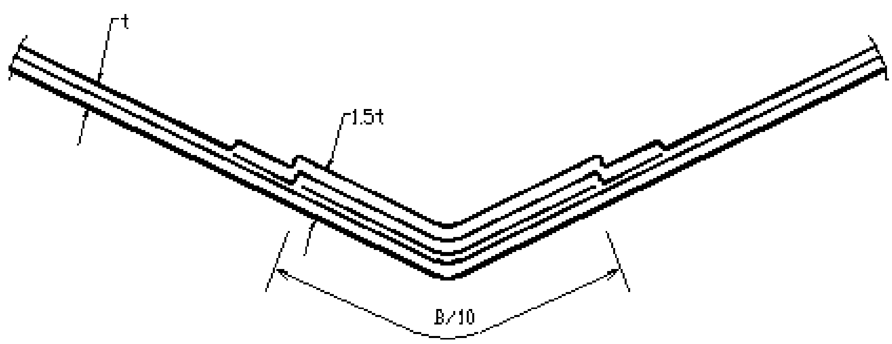


Figure 4.1.9: Keelson

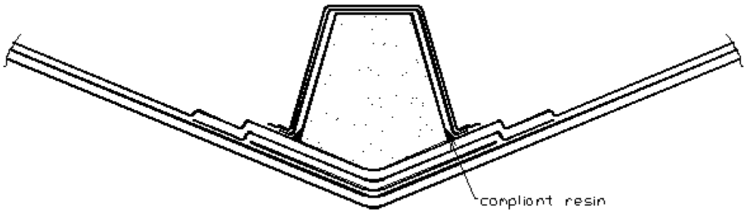


Figure 4.1.10: Keelson

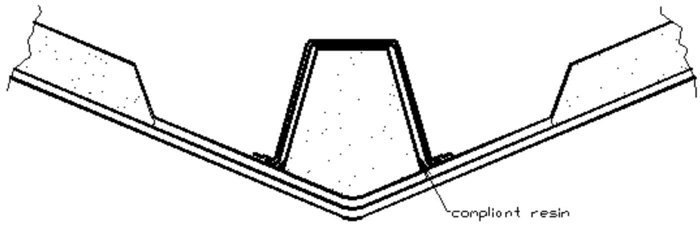


Figure 4.1.11: Chine detail

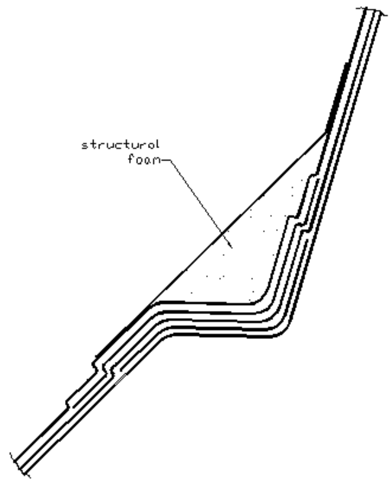


Figure 4.1.12: Chine detail

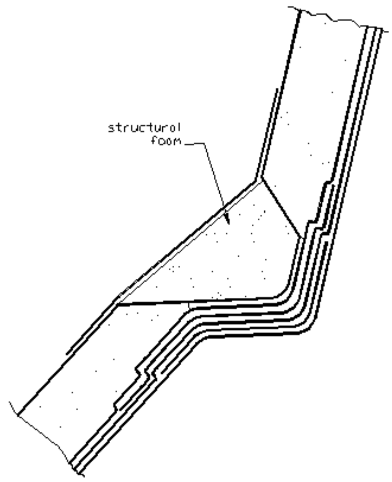


Figure 4.1.13: Spray Rail

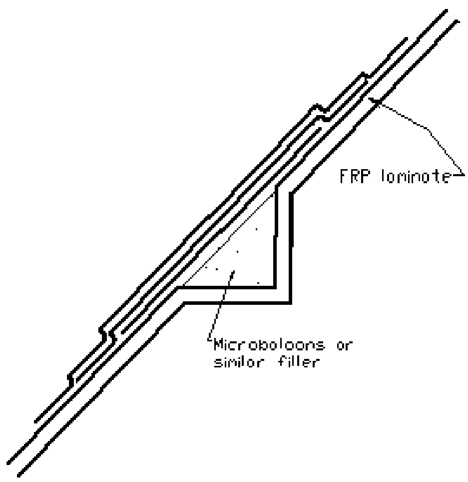


Figure 4.1.14: Spray Rail

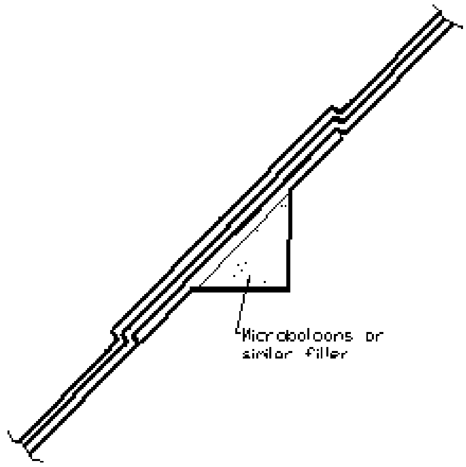


Figure 4.1.15: Transom

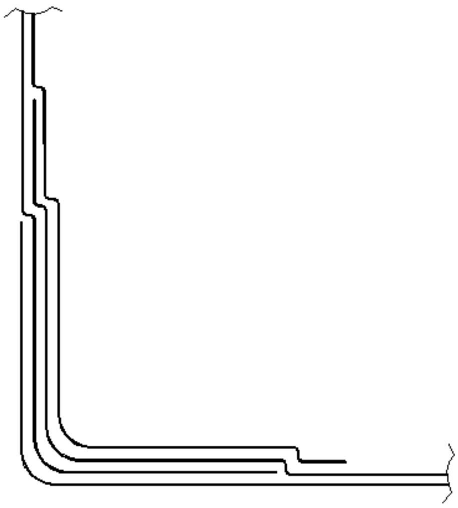


Figure 4.1.16: Transom

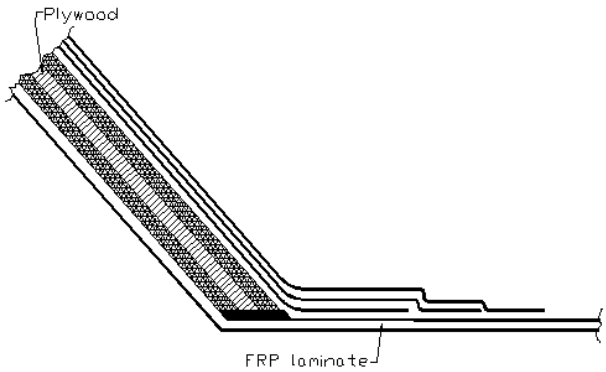


Figure 4.1.17: Engine Foundation

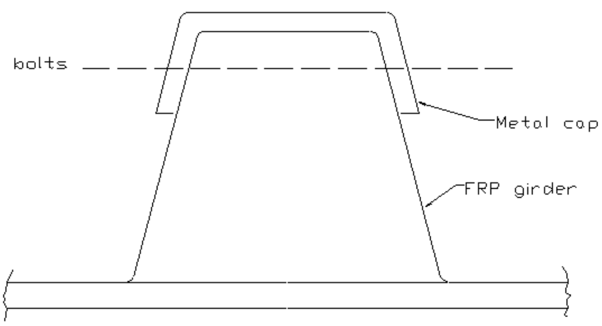
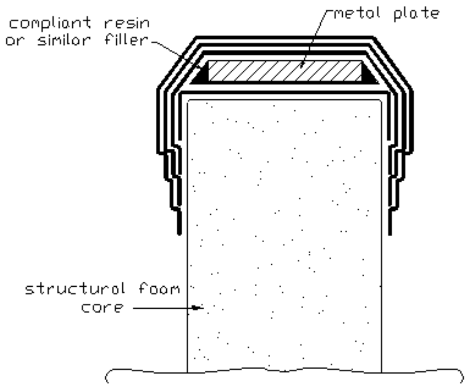


Figure 4.1.18: Engine Foundation



2.5 Mechanical Connections

2.5.1 Generally, components may be fastened with bolts, machine screws, or self-tapping screws. Where machine screws or self-tapping screws are used, they are not to have countersunk heads. Shanks of all threaded fastenings are to be long enough to pass through the joints. Where watertight joints are required, suitable sealants or bedding compounds are to be used in addition to the fastenings. Mechanical fastenings are to be of material suitable for the service intended and are to be either galvanically compatible with the materials being fastened or provided with the necessary insulation. Brass fastenings are not to be used. Non corrosion resistant fastenings are to be galvanized. Fastenings used with aluminum alloys are to be austenitic corrosion-resistant (stainless) steel or suitable aluminum alloy. Sizes and specifications are to be indicated on the submitted plans. The diameter of a fastening is not to be less than the thickness of the thinner component being fastened, with a minimum diameter of 6 mm.

2.5.2 Bolts or machine screws are to be used where accessibility permits. The diameter of each fastener is to be at least equal to the thickness of the thinner component being fastened. Bolts and machine screws less than 6,5 mm in diameter are not to be used. Where d is the fastener diameter, fastener centers are to be spaced at a minimum of 3d apart and are to be set in from edges of laminates a minimum of 3d.

2.5.3 Generally, in fiber reinforced plastic construction, all bolted connections are to be made through solid fiber reinforces plastic inserts. Where this is not possible, all low-density core material is to be replaced with a structurally effective insert. Diameters of fastening holes arc not to exceed fastening diameters by more than 0,4 mm.

2.5.4 Washers or backing plates are to be installed under all fastening heads and nuts that otherwise would bear on laminates. Washers are to measure not less than 2,25d in outside diameter and 0,1d in thickness. Nuts are to be either of the self-locking type, or other effective means are to be provided to prevent backing off. Care is to be taken to ensure that the nut or other component into which the bolt is screwed is of materials having the same mechanical properties. Where materials of different strength arc used, this is to be considered in determining the length of thread engagement between members.

2.5.5 Bolted connections are, in general, to be bonded along all mating surfaces using an accepted structural adhesive, applied in accordance with the manufacturer's requirements. Boltholes are to be drilled, without undue pressure at breakthrough, having a diametric tolerance of two percent of the bolt diameter. Where bolted connections are to be made watertight, the hole is to be sealed with resin and allowed to cure before the bolt is inserted. In areas of high stress or where unusual bolting configurations, on the basis of equivalence with the above requirements, are proposed, testing may be required.

2.5.6 In general, no self-tapping screws are to be used in fiber reinforced plastic construction. Self-tapping screws having straight shanks may be used for non-structural connections, where lack of accessibility prohibits the use of through fastenings. Where used, self-tapping screws are to have coarse threads.

2.5.7 Backing bars and tapping plates. The requirements for backing plates and bars will be individually considered on the basis of the loading imposed, details of which are to be indicated on the submitted plans. Metal plates and bars are to be suitably protected against corrosion. Tapping plates may be encapsulated within the laminate, laminated to or bolted to the structure. Tapping plate edges or corners are to be suitably rounded.

SECTION 3 Deck / Hull and Bulkhead Joints

3.1 Weather joints

3.1.1 The connection is to develop the strength of the deck and shell laminate, whichever is stronger, by either a bolted or bonded connection. Where flanges are used, the hull flanges are to be equal in thickness and strength to the hull laminates and the deck flanges are to be equal in strength and thickness to the deck laminates. Where bolts are used to develop the required strength of the connection, the faying surfaces are to be set in bedding compound, polyester putty, or other approved material. Minimum widths of overlaps and minimum bolt diameters are to be in accordance with Table 4.2.1. Intermediate values may be obtained by interpolation. FRP bonding angles, where used, are to have flanges of the same strength and of at least one half the thickness of single skin hull or deck laminate. On sandwich laminates, they are to have the same strength and thickness as the skin of a sandwich laminate, based on the thicker of the two laminates being connected. The widths of the flanges are to be in accordance with the widths of overlaps in Table 4.2.1. Typical acceptable arrangements for deck to hull and deck to deckhouse connections are shown in Figure 4.2.1, Figure 4.2.2, Figure 4.2.3, Figure 4.2.4, Figure 4.2.5, Figure 4.2.6, Figure 4.2.7 and Figure 4.2.8.

Table 4.2.1:

Length of craft (m)	Minimum width of overlap (mm)	Minimum bolt diameter (mm)
9	63,5	6,50
12	75,0	7,75
15	87,5	9,00
18	100,0	10,25
21	112,5	11,50
24	125,0	12,75
* Intermediate values may be obtained by linear interpolation		

Figure 4.2.1: Hull-Deck joint

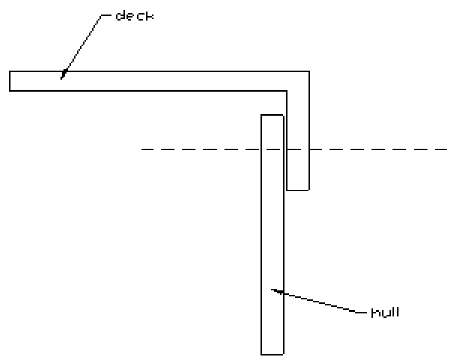


Figure 4.2.2: Hull-Deck joint

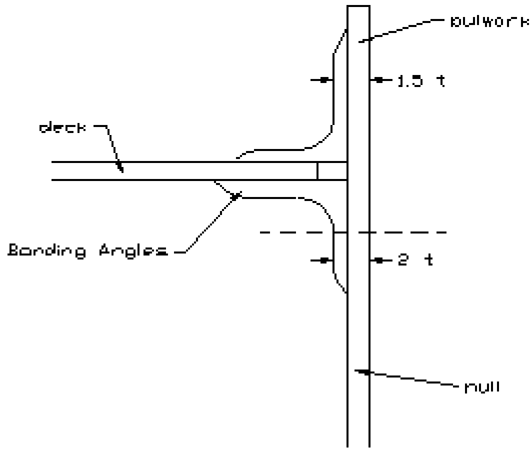


Figure 4.2.3: Hull-Deck joint

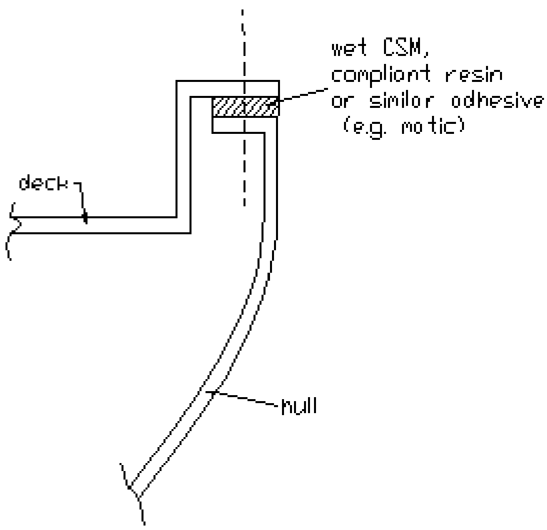


Figure 4.2.4: Hull-Deck joint

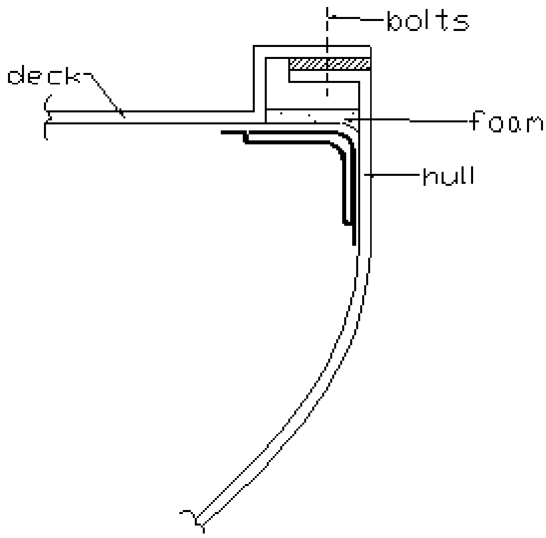


Figure 4.2.5: Hull-Deck joint

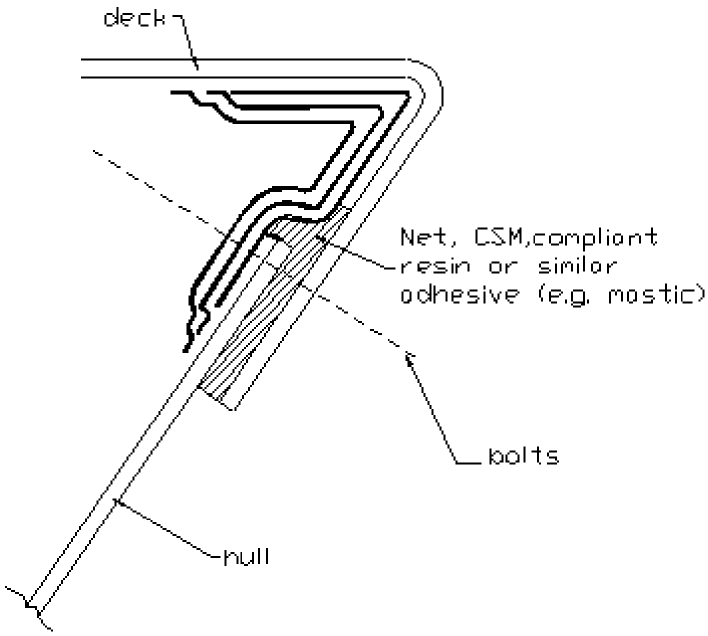


Figure 4.2.6: Hull-Deck joint

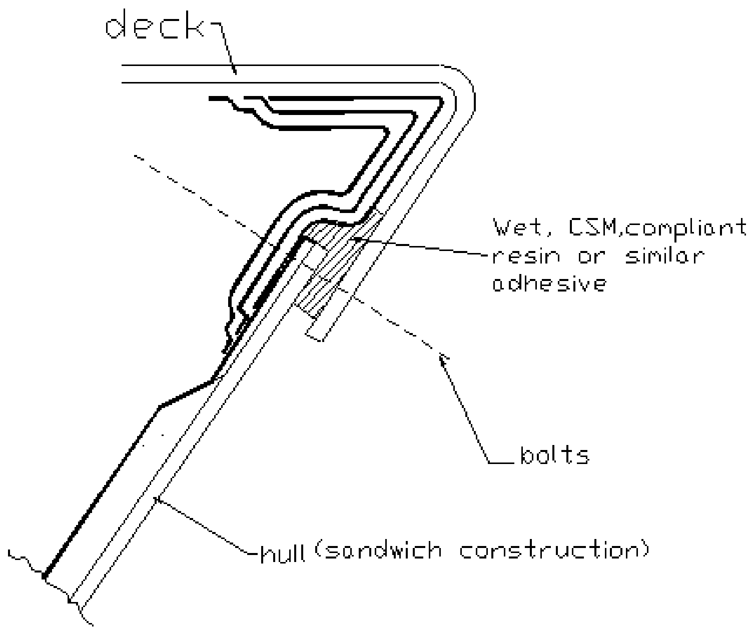


Figure 4.2.7: Deck-Deckhouse joint

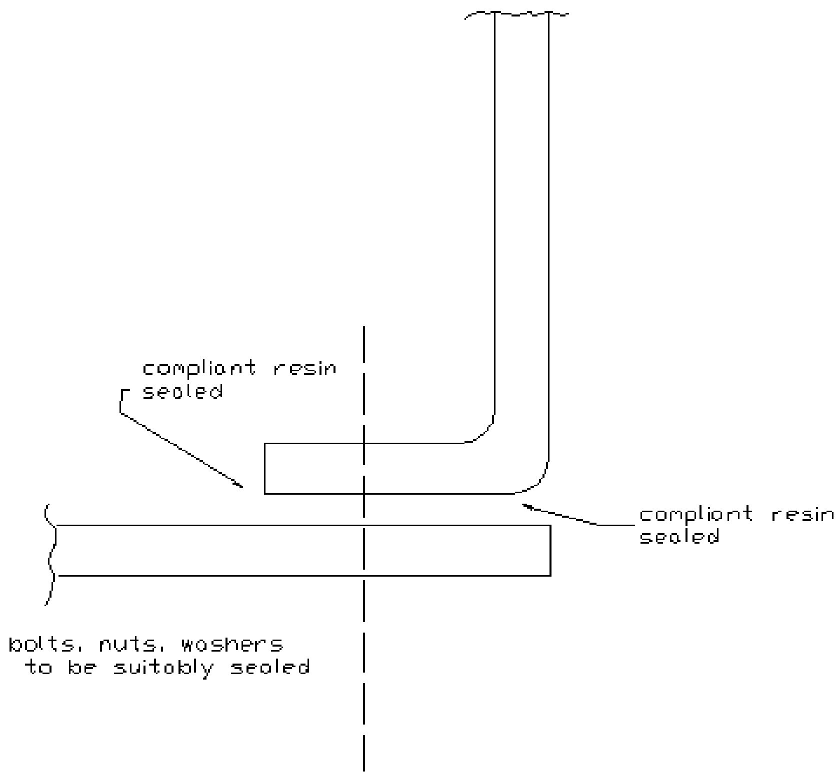
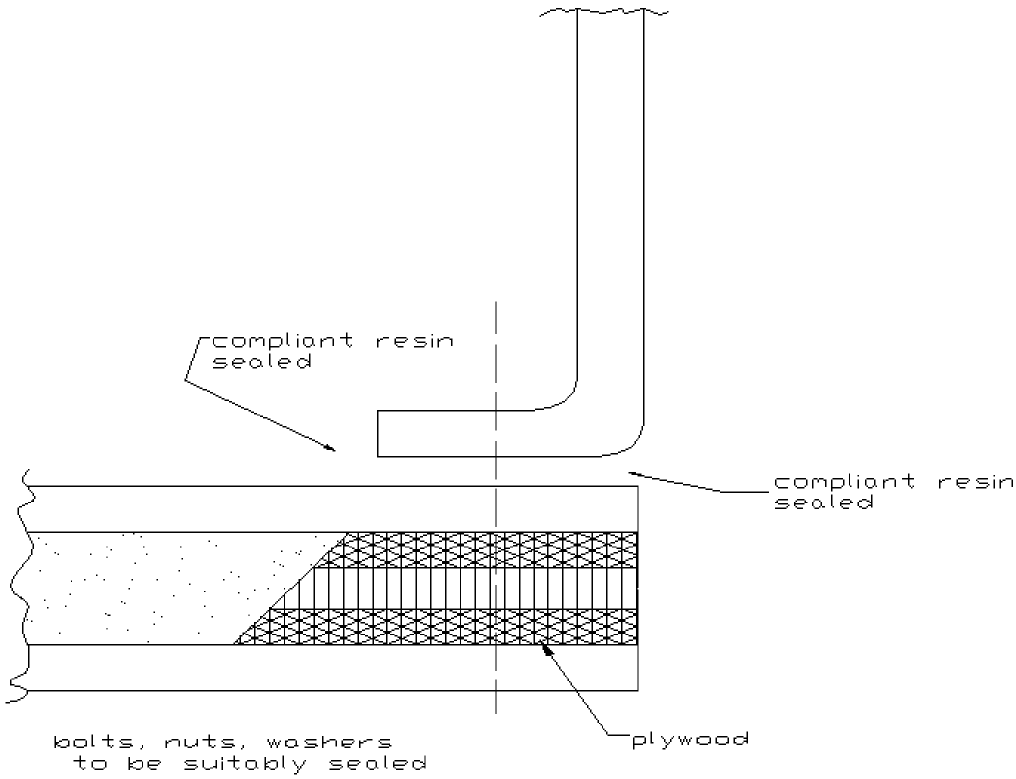


Figure 4.2.8: **Deck-Deckhouse joint**



3.2 Interior Joints

3.2.1 Interior decks are to be connected to the hull by shelves, stringers or other structural members on both sides by FRP tapes. The connection is to effectively develop the strength of the interior deck. Typical acceptable arrangements for bulkhead to hull or deck connections are shown in Figure 4.1.4, Figure 4.1.5, Figure 4.1.6 and Figure 4.1.7.

SECTION 4 Structural scantlings

4.1 Application

4.1.1 The rules of this section generaly apply to monohull planing craft with an overall length not exceeding 36 m and displacement craft up to 60 m in length.

4.1.2 Other types of planing craft like catamarans, hydrofoils, air-cushion vehicles, surface effect ships, wave piercers and small waterplane area twin hulls will be specially considered on a case by case basis.

4.2 Assumptions

4.2.1 The rules of this chapter apply to Fiber Reinforced Plastic hulls built either as a single-skin structure reinforced as necessary by stiffeners, or as a sandwich structure.

4.2.2 The two principal material axes of a laminate or of the skins of a sandwich panel are parallel to the edges of the laminate or the sandwich panel, respectively.

4.2.3 The lateral load acting on the various laminates or sandwich panels is considered to be uniformly distributed.

4.2.4 The laminates or sandwich panels can be either isotropic or orthotropic, without any limit in the difference between the moduli of elasticity in the two principal material axes.

4.3 Notation

4.3.1 The following notation is followed throughout this section:

- a = longest side of laminate, in m.
- A_s = required stiffener shear area, in cm^2.
- b = shortest side of laminate, in m.
- E = modulus of elasticity of isotropic laminates or stiffeners, in N/mm^2 (MPa).
- E_a = modulus of elasticity in the direction parallel to side a, in N/mm^2 (MPa).
- E_b = modulus of elasticity in the direction parallel to side b, in N/mm^2 (MPa).
- G = shear modulus of elasticity in the plane of the laminate, in N/mm^2 (MPa).
- I = required stiffener moment of inertia, in cm^4.
- k_1 = section modulus coefficient, given in Table 4.3.2.
- k_2 = moment of inertia coefficient, given in Table 4.3.2.
- k_3 = shear area coefficient, given in Table 4.3.2.
- k_c = reduction coefficient for plate curvature.
- k_{sa} = laminate stress coefficient, given in Figure 4.3.3 and Figure 4.3.5.
- k_{sb} = laminate stress coefficient, given in Figure 4.3.3 and Figure 4.3.5.
- k_w = laminate deflection coefficient, given in Figure 4.3.2 and Figure 4.3.4.
- l = unsupported span of stiffener, in m.
- p = design pressure in kN/m^2 (kPa), as given in Chapter 2.
- s = stiffener spacing, in m.
- SM = required stiffener section modulus, in cm^3.
- t = laminate thickness, in mm.
- η = non-dimensional generalized rigidity ratio, given in 3.4.4.
- ν = Poisson's ratio for transverse strain in the direction parallel to side b when stressed in the direction parallel to side a, that is, $\nu = -\varepsilon_b / \varepsilon_a$.
- ρ = non-dimensional affine aspect ratio, given in 3.4.5.
- σ = design stress of isotropic laminates or stiffeners, in N/mm^2 (MPa).
- σ_a = design stress in the direction parallel to side a, in N/mm^2 (MPa), given in Table 4.3.1.

σ_{au} = ultimate stress in flexure in the direction parallel to side a, in N/mm² (MPa).

σ_b = design stress in the direction parallel to side b, in N/mm² (MPa), given in Table 4.3.1.

σ_{bu} = ultimate stress in flexure in the direction parallel to side b, in N/mm² (MPa).

σ_u = ultimate tensile stress of the stiffener's laminate, in N/mm² (MPa).

τ = design shear stress for stiffeners, in N/mm² (MPa).

τ_u = ultimate shear stress of the stiffener's web laminate, in N/mm² (MPa).

4.3.2 When the material under consideration has different tensile and compressive moduli of elasticity in the two principal material directions, E_a and E_b are proposed to be taken as the mean value of the respective tensile and compressive moduli.

4.4 Single skin construction plating

4.4.1 The required laminate thickness given by the formulae of this sub-section is based on a maximum permissible deflection and a maximum permissible bending stress criterion and is in accordance with local strength requirements.

4.4.2 Bottom shell is considered to extend up to the chine (the upper chine in case of two chines) or to the upper turn of bilge.

4.4.3 The sides of the laminate can be considered as either simply supported or clamped. It is recommended in general that clamped boundary conditions should be considered for the bottom and bulkhead laminates and simply supported boundary conditions for the side, deck, superstructure and deckhouses laminates, provided that laminates have approximately the same dimensions. However, other boundary conditions may be taken into account, based on an acceptable stiffness analysis of the adjacent structure.

4.4.4 The non-dimensional generalized rigidity ratio η, used in Figure 4.3.1, Figure 4.3.2, Figure 4.3.3 and Figure 4.3.4 is defined as follows:

$$\eta = \frac{\nu \cdot E_b + 2 \cdot G \cdot \left(1 - \nu^2 \cdot \frac{E_b}{E_a}\right)}{\sqrt{E_a \cdot E_b}}$$

For laminates that can be considered isotropic, it is η=1,0.

4.4.5 The non-dimensional affine aspect ratio ρ used in Figure 4.3.1, Figure 4.3.2, Figure 4.3.3 and Figure 4.3.4 is defined as follows:

$$\rho = \frac{a}{b} \cdot \sqrt[4]{\frac{E_b}{E_a}}$$

For laminates that can be considered isotropic, it is ρ =a/b.

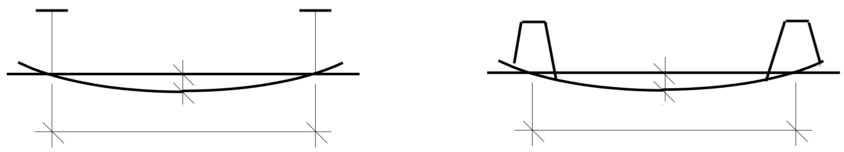
4.4.6 In initial design stages, Poisson's ratio ν can be taken equal to 0,3. In any case, the values considered both for the Poisson's ratio and for the ultimate stresses σ_{au} and σ_{bu} are to be verified from the approved test results.

4.4.7 For laminates exhibiting significant curvature, the following reduction coefficient is to be taken into account:

$$k_c = 1 - \frac{d}{S}$$

without being less than 0,75, where distances d and S are defined in Figure 4.3.1 and S is either side a or side b of the laminate, depending on which direction curvature is more significant.

Figure 4.3.1: Definition of curvature reduction coefficient



4.4.8 For simply supported laminates, the required thickness is to be not less than given by any of the following formulae:

$$t = 100 \cdot k_c \cdot \sqrt[3]{\frac{0{,}6 \cdot k_w \cdot p \cdot b^3 \cdot (E_a - \nu^2 \cdot E_b)}{E_a \cdot E_b}}\ [mm]$$

$$t = 31{,}623 \cdot k_c \cdot \sqrt{\frac{p \cdot (a^2 \cdot k_{sa} + \nu \cdot b^3 \cdot k_{sb})}{\sigma_a}}\ [mm]$$

$$t = 31{,}623 \cdot k_c \cdot \sqrt{\frac{p \cdot \left(\nu \cdot a^2 \cdot k_{sa} \cdot \frac{E_b}{E_a} + b^2 \cdot k_{sb}\right)}{\sigma_b}}\ [mm]$$

where coefficients k_w, k_{sa} and k_{sb} are given in Figure 4.3.2 and Figure 4.3.3 as functions of the non-dimensional ratios η and ρ and design stresses σ_a and σ_b are given in Table 4.3.1. Coefficient k_c is given in 3.4.7.

4.4.9 For simply supported laminates that can be considered isotropic, the required thickness is to be not less than given by any of the following formulae:

$$t = 100 \cdot k_c \cdot \sqrt[3]{\frac{0{,}6 \cdot k_w \cdot p \cdot b^3 \cdot (1 - \nu^2)}{E}}\ [mm]$$

$$t = 31{,}623 \cdot k_c \cdot \sqrt{\frac{p \cdot (\nu \cdot a^2 \cdot k_{sa} + b^2 \cdot k_{sb})}{\sigma}}\ [mm]$$

where coefficients k_w, k_{sa} and k_{sb} are given in Figure 4.3.2 and Figure 4.3.3 for η=1,0 and ρ=a/b and design stress σ is given in Table 4.3.1. Coefficient k_c is given in 3.4.7.

4.4.10 For clamped laminates, the required thickness is to be not less than given by any of the following formulae:

$$t = 100 \cdot k_c \cdot \sqrt[3]{\frac{0{,}6 \cdot k_w \cdot p \cdot b^3 \cdot (E_a - \nu^2 \cdot E_b)}{E_a \cdot E_b}}\ [mm]$$

$$t = 31{,}623 \cdot k_c \cdot \sqrt{\frac{p \cdot a^2 \cdot k_{sa}}{\sigma_a}} \; [mm]$$

$$t = 31{,}623 \cdot k_c \cdot \sqrt{\frac{p \cdot b^2 \cdot k_{sb}}{\sigma_b}} \; [mm]$$

where coefficients k_w, k_{sa} and k_{sb} are given in Figure 4.3.4 and Figure 4.3.5 as functions of the non-dimensional ratios η and ρ design stresses σ_a and σ_b are given in Table 4.3.1. Coefficient k_c is given in 3.4.7.

4.4.11 For clamped laminates that can be considered isotropic, the required thickness is to be not less than given by any of the following formulae:

$$t = 100 \cdot k_c \cdot \sqrt[3]{\frac{0{,}6 \cdot k_w \cdot p \cdot b^3 (1 - \nu^2)}{E}} \; [mm]$$

$$t = 31{,}623 \cdot k_c \cdot \sqrt{\frac{p \cdot b^2 \cdot k_{sb}}{\sigma}} \; [mm]$$

where coefficients k_w, k_{sa} and k_{sb} are given in Figure 4.3.4 and Figure 4.3.5 for η = 1,0 and ρ = a/b and design stress σ is given in Table 4.3.1. Coefficient k_c is given in 3.4.7.

Table 4.3.1: Design stresses $\sigma, \sigma_a, \sigma_b$

Part of the Structure	**$\sigma, \sigma_a, \sigma_b$**
Bottom shell	$0{,}333\sigma_u$
Side shell	$0{,}333\sigma_u$
Decks	$0{,}333\sigma_u$
Bulkheads	$0{,}333\sigma_u$
Superstructures	$0{,}333\sigma_u$
Deckhouses	$0{,}333\sigma_u$

NOTE:

Ultimate stress σ_u is σ_{au} for design stress σ_a and σ_u for design stress σ_b

Figure 4.3.2: **Simply supported laminates: Deflection coefficient k_w for five values of ratio, namely 0,2, 0,4, 0,6, 0,8 and 1,0**

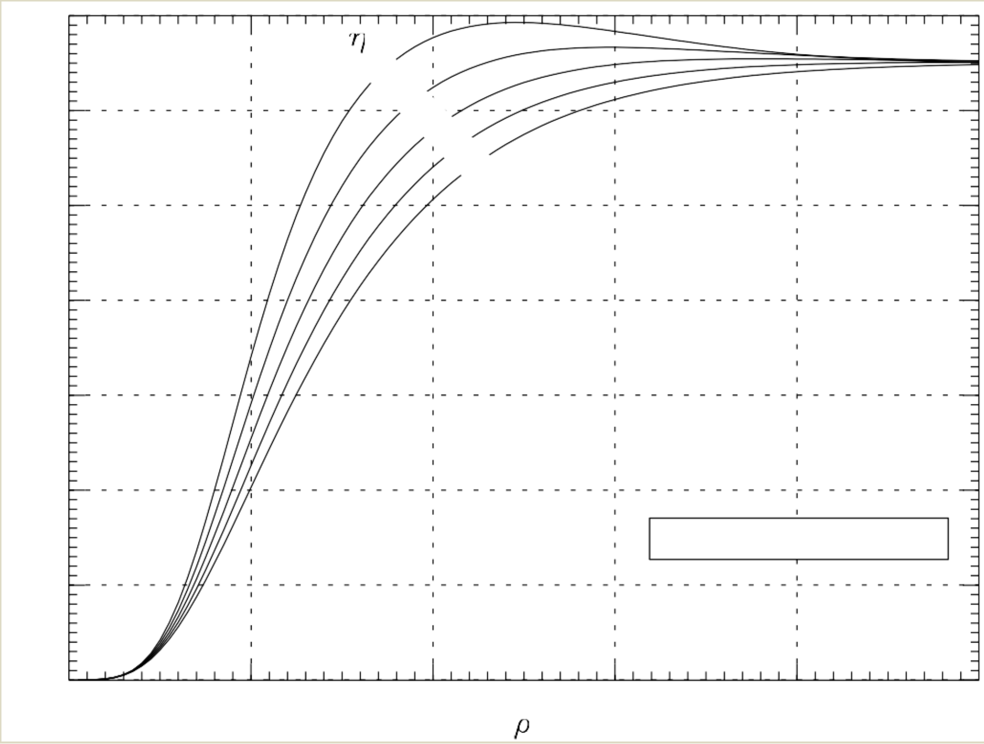


Figure 4.3.3: **Simply supported laminates: Stress coefficient k_{sa} and k_{sb} for five values of ratio , namely 0,2, 0,4, 0,6, 0,8 and 1,0**

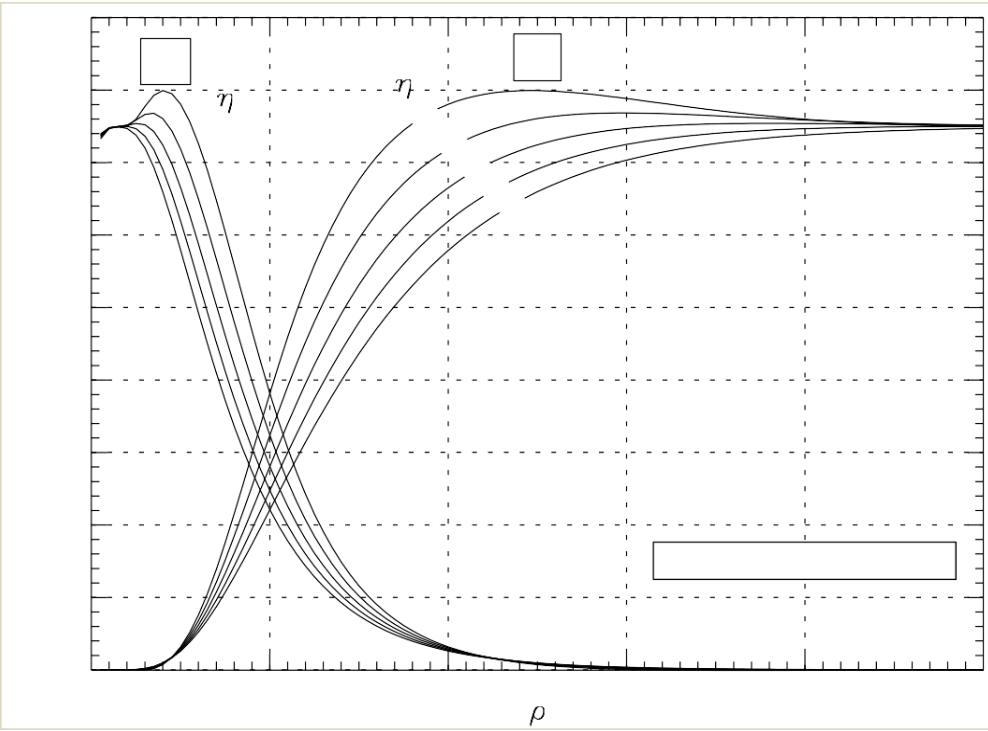
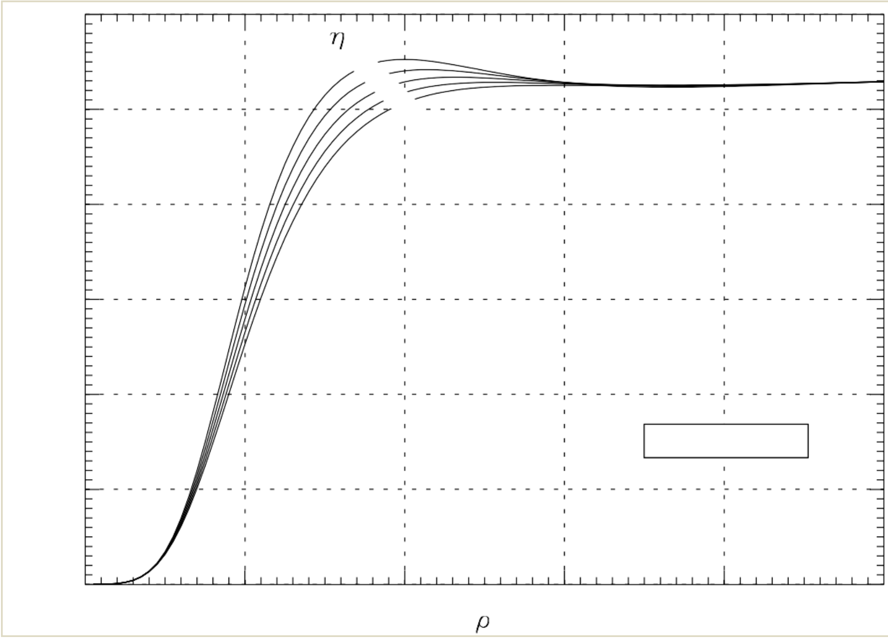
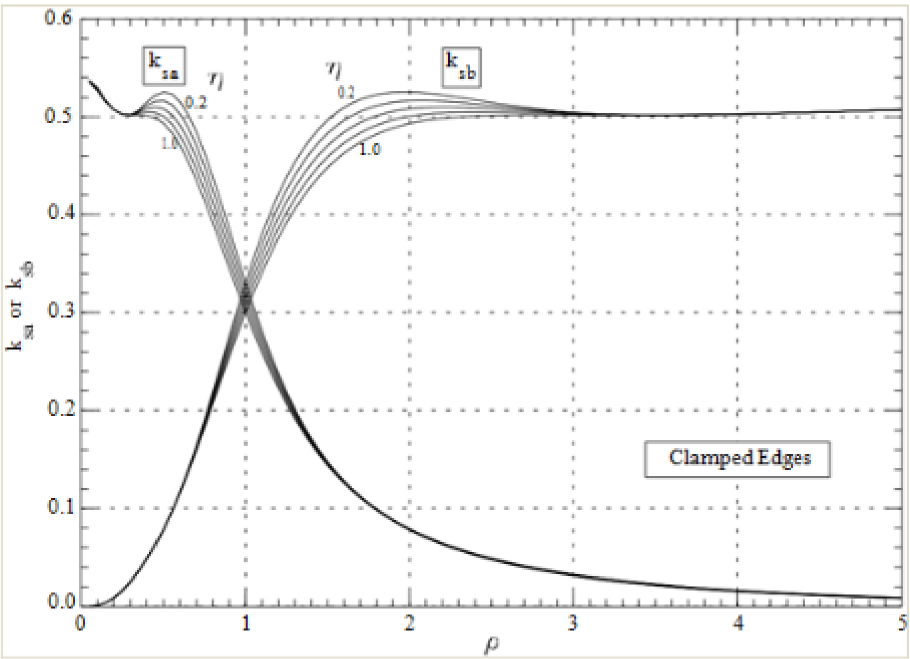


Figure 4.3.4: Clamped laminates: Deflection coefficient k_w for five values of ratio η, namely 0,2, 0,4, 0,6, 0,8 and 1,0



3.0

Figure 4.3.5: Clamped laminates: Stress coefficient k_{sa} and k_{sb} for five values of ratio , namely 0,2, 0,4, 0,6, 0,8 and 1,0



4.5 Stiffeners

4.5.1 The requirements for section modulus, moment of inertia and shear area of this subsection are based on bending of stiffeners by a lateral load, uniformly or linearly distributed over its whole length. Other types of loading is to be specially considered.

4.5.2 In general, plies that form the stiffener profile are layed-up parallel to the direction of the stiffener. They can be either bi-directional with approximately the same stiffness and strength properties in the two principal material in-plane axes, or uni-directional with different stiffness and strength properties in these two material axes.

4.5.3 Laminates that work as bonding means between the plating and the stiffener (bonding angles, flanges, tapes, etc.) are to have comparable stiffness and strength properties with the laminates of the plating and the stiffness they bond.

4.5.4 Great differences between the stiffness and strength properties of the laminates forming the stiffener and those forming the corresponding plating are in general to be avoided.

4.5.5 In case where the stiffener is formed by materials with different moduli of elasticity, this variation should be also taken into account in the section modulus, moment of inertia and shear area calculations.

4.5.6 For stiffeners supporting sandwich panels, only the skin laminate at which the stiffener is attached should be taken into account as effective flange for the section modulus and moment of inertia calculations.

4.5.7 The section modulus of each longitudinal or transverse stiffener, girder and web, including the laminate to which it is attached, is to be not less than given by the following formula:

$$SM = k_1 \cdot \frac{p \cdot s \cdot l^2}{\sigma} \ [cm^3]$$

where coefficient k_1 is given in Table 4.3.2 for beams with various boundary conditions and load distributions. In general, the boundary conditions and load distribution for each specific structural member are to be in accordance with Table 4.3.3. Design bending stress σ is not to be taken greater than 0,333σ_u.

4.5.8 The moment of inertia of each longitudinal or transverse stiffener, girder and web, including the laminate to which it is attached, is to be not less than given by the following formula:

$$I = k_2 \cdot \frac{p \cdot s \cdot l^3}{E} \cdot 10^3 \ [cm^4]$$

where coefficient k_2 is given in Table 4.3.2 for beams with various boundary conditions and load distributions. In general, the boundary conditions and load distribution for each specific structural member are to be in accordance with Table 4.3.3. Modulus of elasticity E is to be taken as the equivalent modulus of elasticity of the stiffener cross section, used in the moment of inertia calculations.

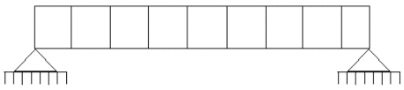
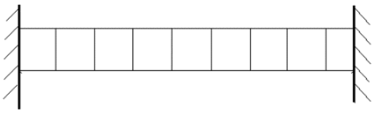
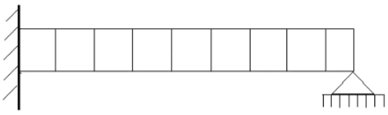
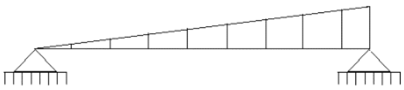
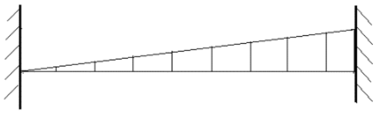
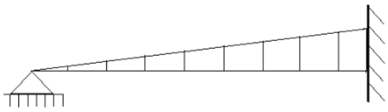
4.5.9 The web area (shear area) of each longitudinal or transverse stiffener, girder and web is to be not less than given by the following formula:

$$A_s = k_3 \frac{p \cdot s \cdot l}{\tau} \ [cm^2]$$

where coefficient k_3 is given in Table 4.3.2 for beams with various boundary conditions and load distributions. In general, the boundary conditions and load distribution for each specific structural member are to be in accordance with Table 4.3.3. Design shear stress τ is not to be taken greater than 0,333τ_u.

4.5.10 According to general beam theory, coefficients k_1, k_2 and k_3 of paragraphs 3.5.2, 3.5.3 and 3.5.4, respectively, are given in Table 4.3.2, for various boundary conditions and load distributions that are normally met in a ship structure:

Table 4.3.2: Stiffener coefficients k_1, k_2 and k_3

case	Boundary conditions and load distribution	k_1	k_2	k_3
1		125,0	65,0	7,5
2		83,33	13,0	7,5
3		125,0	27,5	9,4
4		128,3	66,0	10,0
5		100,0	13,1	10,5
6		133,3	24,0	12,0

4.5.11 In general, boundary conditions and load distribution for each specific structural member are to be in accordance with Table 4.3.3, provided that the respective stiffeners are approximately evenly spaced:

Table 4.3.3: Recommended stiffener boundary conditions and load distribution

Structural member		Boundary conditions	Load distribution	Case No.
Bottom	Web frames	CC - SS	Uniform	3
	Longitudinals between webs	CC - CC	Uniform	2
	Transverse stiffeners	CC - CC	Uniform	2
Side	Web frames	SS - SS	Triangular	4
	Longitudinals between webs	SS - SS	Uniform	1
	Vertical stiffeners	SS - SS	Triangular	4
Deck	All stiffeners	SS - SS	Uniform	1

Superstructure & Deckhouses	All stiffeners	SS - SS	Uniform	1
Bulkheads	Vertical girders	CC - CC	Triangular	5
	Horizontal girders	CC - CC	Uniform	2
	Vertical stiffeners	CC - CC	Triangular	5
	Horizontal stiffeners	CC - CC	Uniform	2

CHAPTER 5 Hull Construction Steel

Contents

SECTION 1 General

1.1 General Requirements

1.1.1 The Rules apply to mono-hull and multi-hull vessels of normal form, speed and proportions.

1.2 Documentation to be submitted

1.2.1 Documentation including the following particulars is to be submitted:

- Profile and decks
- Shell expansion
- Propeller brackets
- Midship sections showing longitudinal and transverse material
- Pillars and girders
- Oiltight and watertight bulkheads
- Engine room construction
- Engine and thrust seatings
- Double bottom construction
- Aft end construction
- Hatch cover construction
- Fore end construction
- Deckhouses and superstructures
- Sternframe
- Equipment
- Rudder, stock and tiller
- Loading Manuals, preliminary and final (where applicable)
- Welding schedule
- Ice strengthening
- Scheme of corrosion control (where applicable)
- Bilge keels showing material grades, welded connections and detail design
- Hull penetration plans
- Support structure for masts, derrick posts or cranes

1.2.2 The following additional documentation are also to be submitted:

- Capacity plan
- Dry-docking plan
- General arrangement
- Lines plan or equivalent
- Sail/rigging plan, indicating loadings (as applicable to sailing craft)
- Towing and mooring arrangements

1.2.3 The following additional calculations are also to be submitted:

- Calculation of hull girder still water and dynamic bending moments and shear forces as applicable
- Calculation of equipment number
- Preliminary freeboard calculation
- Calculation of midship section modulus

1.3 Exceptions

1.3.1 In case of craft which are not covered by the present Rules, such as craft of unusual form, speed or proportions, intended for the carriage of special cargoes, or for special or restricted service, they will be individually considered based on the general requirements of the Rules.

SECTION 2 Design and construction principles

2.1 Continuity and alignment

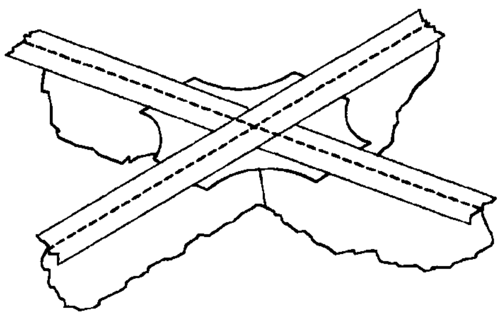
2.1.1 The arrangement of material is to be such as will ensure structural continuity. Abrupt changes of shape or section, sharp corners and points of stress concentration are undesirable and are to be avoided.

2.1.2 Where members abut on both sides of a bulkhead or similar structure, care is to be taken to ensure good alignment.

2.1.3 Pillars and pillar bulkheads are to be fitted in the same vertical line wherever possible, and elsewhere arrangements are to be made to transmit the out of line forces satisfactorily. The load at head and heel of pillars is to be effectively distributed and arrangements are to be made to ensure the adequacy and lateral stability of the supporting members.

2.1.4 Continuity is to be maintained where primary members intersect and where the members are of the same depth, a suitable gusset plate is to be fitted (see Figure 5.2.1).

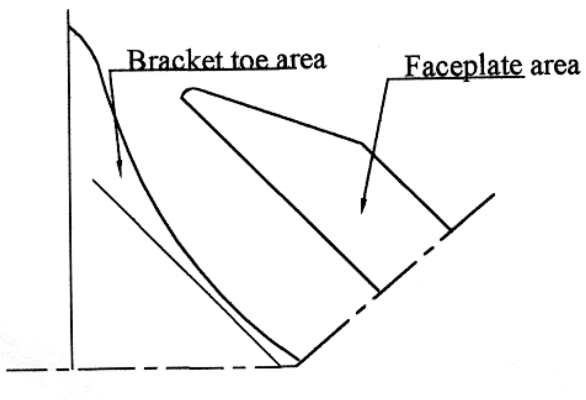
Figure 5.2.1: Primary member intersection



2.1.5 End connections of structural members are to provide adequate end fixity and effective distribution of the load into the supporting structure.

2.1.6 The stress concentrations can be minimised by paying particular attention to the design of the end bracket toes. Sniped face plates which are welded onto the edge of primary member brackets are to be carried well around the radiuses bracket toe and are to incorporate a taper not exceeding one in three. Adequate cross sectional area is to be provided through the bracket toe at the end of the snipe, in case sniped face plates are welded adjacent to the edge of primary member brackets.Generally, this area measured perpendicular to the face plate, is to be not less than 60% of the full cross-sectional area of the face plate (see Figure 5.2.2).

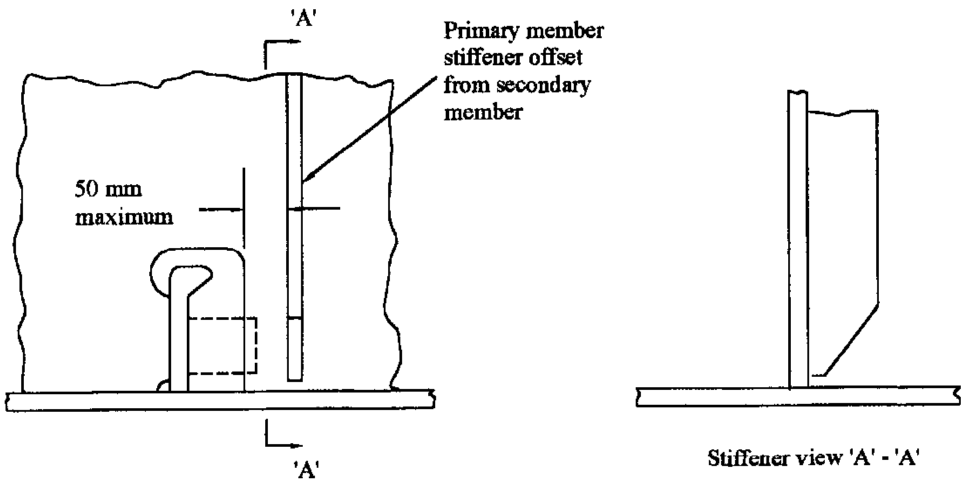
Figure 5.2.2: Bracket toe construction



2.2 Arrangement with offset stiffener

2.2.1 Where the stiffeners of the double bottom floors and transverse bulkheads are unconnected to the secondary members and offset from them (see Figure 5.2.3) the collar arrangement for the secondary members are to satisfy the requirements of 2.3. Moreover, the fillet welds attaching the lugs to the secondary members are to be based on a weld factor of 0,44 for the throat thickness. To facilitate access for welding the offset stiffeners are to be located 50 mm from the slot edge furthest from the web of the secondary member. The ends of the offset stiffeners are to be suitably tapered and softened.

Figure 5.2.3: Arrangement with offset stiffener



2.3 Arrangements at intersection of continuous secondary and primary members

2.3.1 In order to minimise stress concentrations around the perimeter of the opening and in the attached hull envelope or bulkhead plating, cut-outs for the passage of secondary members through the webs of primary members, and the related collaring arrangements, are to be designed. It is necessary to proceed to an investigation of the critical shear buckling stress of the panel, in which the cut-out is made. In high stress areas, the cut-outs for longitudinals are to have double lugs.

2.3.2 The cut-outs are to have a breadth as small as practicable, with the top edge suitably radiuses. Cut-outs are to have smooth edges, and the corner radii are to be as large as practicable, with a minimum of 20% of the breadth of the cut-out or 25 mm, whichever is the greater. It is suggested that the web plate connection to the hull envelope, or bulkhead, end in a smooth tapered 'soft toe'. In Figure 2.2.4 of Part 2, Chapter 2 are shown recommended shapes of cut-out. However, consideration will be given to other shapes, in order to maintain equivalent strength and minimise stress concentration.

2.3.3 Symmetrical secondary members are to be connected by lugs on one or both sides, as necessary.

2.3.4 Asymmetrical secondary members are to be connected on the heel side to the primary member web plate. Additional connection by lugs on the opposite side may be required.

2.3.5 Where the primary member stiffener is connected to the secondary member it is to be aligned with the web of the secondary member, except where the face plate of the latter is offset and abutted to the web. In that case the stiffener connection is to be lapped.

2.3.6 Fabricated longitudinals, which may have the face plate welded to the underside of the web, leaving the edge of the web exposed, are not recommended for side shell and longitudinal bulkhead longitudinals. Where it is proposed to fit such sections, a symmetrical arrangement of connection to transverse members is to be incorporated. This can be achieved by fitting backing structure on the opposite side of the transverse web or bulkhead.

2.3.7 Where a bracket is fitted to the primary member web plate in addition to a connected stiffener it is to be arranged on the opposite side to, and in alignment with the stiffener. The arm length of the bracket is to be not less than the depth of the stiffener, and its cross-sectional area through the throat of the bracket is to be included in the calculation of the area of the primary web stiffener in way of the connection.

2.3.8 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Testing procedures and details of the calculations made are to be submitted.

2.4 Openings

2.4.1 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear.In particular, manholes and similar openings are not to be cut in vertical or horizontal diaphragm plates in narrow cofferdams or in floors and double bottom girders close to their span ends, or below the heels of pillars, unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory.

2.4.2 Manholes, lightening holes and other openings are to be suitably framed and stiffened where necessary.

2.4.3 Drain and air holes, scallops and notches are to be kept at least 200 mm clear of the toes of end brackets and other areas of high stress. Openings are to be well rounded with smooth edges. Closely placed scallops are not permitted. Widely spaced air or drain holes may be accepted, only if they have elliptical shape, or equivalent, to minimise stress concentration and are, in general, cut clear of the weld connection.

2.5 Openings in the web

2.5.1 Where openings are cut in the web, the depth of opening is not to exceed 50% of the web depth, and the opening is to be so located that the edges are not less than 25% of the web depth from the face plate. The length of opening is not to exceed the web depth or 60% of the secondary member spacing, whichever is the greater, and the ends of the openings are to be equidistant from the corners of cut-outs for secondary members. Where larger openings are proposed, the arrangements and compensation required will be specially considered. Openings are to have well rounded corners and smooth edges.

2.6 Tank boundary penetrations

2.6.1 Where structural members pass through the boundary of a tank, and leakage into the adjacent space could be hazardous or undesirable, full penetration welding is to be adopted for the members for at least 150 mm on each side of the boundary. Alternatively a small scallop of suitable shape may be cut in the member close to the boundary outside the compartment, and carefully welded all round.

2.7 Web stability

2.7.1 Primary members of asymmetrical section are to be supported by tripping brackets at alternate secondary members. If the section is symmetrical, the tripping brackets may be four spaces apart.

2.7.2 Tripping brackets are in general required to be fitted at the toes of end brackets and in way of heavy or concentrated loads such as the heels of pillars.

2.8 Welding

2.8.1 All weldings must complie with the requirements specified in the "Rules and Regulations for the Classification and Constuction of Steel Ships", Part 2, Chapter 9, Part 2, Chapter 10, Part 2, Chapter 11.

SECTION 3 Structural Scantlings for Mono-Hull Vessels – General Principles and Requirements

3.1 Application

3.1.1 The requirements of this Chapter are applicable to mono-hull craft of steel construction.

3.2 Direct calculations

3.2.1 In case the design, form or proportions of the craft are unsual, or the speed of the craft exceeds 60 knots, the scantlings are to be determined by direct calculation.

3.2.2 In any case direct calculations based on well established principles of mechanics may be used alternatively or complementary to these Rules, provided that the achieved level of safety remains equivalent.

3.3 Symbols and definitions

3.3.1 The following symbols are used in this chapter:

L = Rule length of craft, in metres, is the distance on the summer load waterline from the forward side of the stem to the after side of the rudder post or to the centre of the rudder stock if there is no rudder post. L is to be not less than 96%, and need not be greater than 97%, of the extreme length on the summer load waterline. In craft without rudders, the Rule length, L, is to be taken as 97% of the extreme length on the summer load waterline

B = moulded breadth of craft, in metres

I = moment of inertia, in cm^4

SM= section modulus of the stiffening member, in cm^3

A = shear area of stiffener web, in cm^2

p = design pressure, in kN/m^2

s = stiffener spacing, in mm

l = stiffener overall length, in metres l_e = effective span length, in metres

K_{AR}= panel aspect ratio correction factor as defined in 3.9

t_p = plating thickness, in mm

K_c = convex curvature correction factor as defined in 3.8

σ_s = guaranteed minimum yield strength of the material, in N/mm^2

$\tau_s = \sigma_s/\sqrt{3}$

k_1 = high tensile steel factor

= $235/\sigma_s$

$k_2 = 635/(\sigma_s+\sigma_u)$

σ_u = specified minimum ultimate tensile strength of the material, N/mm^2

E = modulus of elasticity, in N/mm^2

3.4 Material properties

3.4.1 The basic grade of steel used in the determination of the Rule scantling requirements is taken as mild steel with the following mechanical properties:

Table 5.3.1:

	N/mm^2
Yield strength (minimum)	235
Tensile strength	400-490
Modulus of elasticity	200 x 10^3

3.5 Higher tensile steels

3.5.1 Steels having a yield stress not less than 265 N/mm^2 are regarded as higher tensile steels.

3.5.2 Where higer tensile steels are to be used, due allowance is given in the determination of the Rule requirement for plating thickness and stiffener section modulus, inertia and cross-sectional area by use of the following correction factors:

(a) Plating thickness factor $=\sqrt{k_1}$

(b) Section modulus and cross sectional area factor = k_1 where k_1 is as defined in 3.3.1.

3.5.3 The minimum moment of inertia of higher tensile steel stiffening members is to be not less than that required for mild steel stiffening members.

3.6 Corrosion

3.6.1 All steelwork, except inside integral fuel tanks, is to be suitably protected against corrosion. This may be by coating or, where applicable, by a system of cathodic protection.

3.6.2 Steelwork is to be suitably cleaned and cleared of millscale before the application of any coating. It is recommended that blast cleaning, or other equally effective means, be employed for this purpose.

3.6.3 Where an impressed current cathodic protection system is fitted, plans showing the proposed layout of anodes, reference cells, wiring diagram and the means of bonding-in of the rudder and propeller are to be submitted.

3.6.4 The minimum thickness of plating given in this chapter is based on the assumption that there is negligible loss in strength by corrosion. Where this is not the case the minimum thickness will be specially considered.

3.7 Effective width of attached plating

3.7.1 In case of primary support members the effective width of the attached plating may be taken equal to one-half of the sum of the spacings between parallel adjacent members or equivalent support.

3.7.2 In case of secondary support members the effective width of the attached plating may be taken as:

$$2 \cdot t_p \cdot \sqrt{\frac{E}{\sigma_s}} \ [mm]$$

but not greater than the actual spacing of the stiffeners. In the above formula σ_s is not to be taken greater than 235 N/mm² for mild steel or 340 N/mm² for higher tensile steel.

3.7.3 Where the web of the stiffener intersects the actual plating at an angle less than 70° the properties of the section are to be determined about an axis parallel to the attached plating.

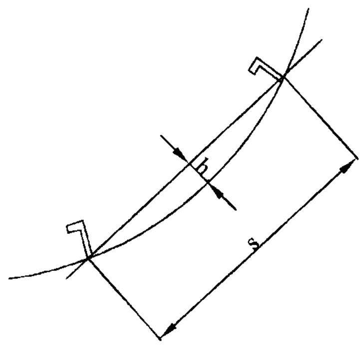
3.8 Consideration of convex curvature

3.8.1 For panels exhibiting significant curvature, the following reduction coefficient is to be taken into account:

$$K_c = 1 - \frac{h}{s}$$

without being less than 0,75, where distances h and s are defined in Figure 5.3.1.

Figure 5.3.1: Convex curvature



3.9 Aspect ratio correction

3.9.1 The thickness of plating as determined by the Rules may be reduced when the panel aspect ratio is taken into consideration. In such cases a panel aspect ratio correction factor may be applied:

K_{AR} = aspect ratio correction factor $= A_R \cdot (1 - 0{,}25 \cdot A_R)\ for\ A_R \leq 2$

$= 1\ for\ A_R > 2$

Where:

A_R = panel aspect ratio

= panel length/panel breadth

3.10 General plating thickness

3.10.1 The thickness of plating, t, is, in general to be in accordance with the following formula:

$$t = 0{,}0225 \cdot s \cdot K_c \cdot K_{AR} \cdot \sqrt{\frac{p}{\sigma}}\ [mm]$$

Where:

σ = limiting bending stress value for the plating element under consideration given in Table 5.3.2

$s, K_c, K_{AR}, p, \sigma_a$ = as defined in 3.3.1.

3.11 Stiffening general

3.11.1 The requirements for section modulus, inertia and web area stiffening members are in general to be in accordance with the following:

(a) Section modulus:

$$SM = C_{SM} \cdot \frac{p \cdot s \cdot l_e^2}{\sigma}\ [cm^3]$$

Where:

C_{SM} = section modulus coefficient dependent on the loading model assumption taken from Table 5.3.5

σ = limiting bending stress value for stiffening member given in Table 5.3.2

p, s, l_e and σ_s = as defined in 3.3.1.

(b) Inertia:

$$I = C_I \cdot f_d \cdot \frac{p \cdot s \cdot l_e^3}{E} \cdot 10^4\ [cm^4]$$

Where:

C_I = inertia coefficient dependent on the loading model assumption taken from Table 5.3.5

f_δ = limiting deflection value for stiffener member given in Table 5.3.3

p, s, l_e and E = as defined in 3.3.1.

(c) Web area:

$$A = C_A \cdot \frac{p \cdot s \cdot l_e}{100 \cdot \tau} \; [cm^4]$$

Where:

C_A = web area coefficient dependent on the loading model assumption taken from Table 5.3.5

τ = limiting shear stress value for stiffener member given in Table 5.3.2

p, s, l_e and τ_s = as defined in 3.3.1.

Table 5.3.2: Limiting stress coefficients for local loading (to be continued)

Item		Limiting stress value		
		Bending stress σ	Shear stress τ	Equivalent stress
Shell envelope				
Bottom shell plating	- slamming zone	$0{,}85 \cdot \sigma_S$	-	-
	- elsewhere	$0{,}75 \cdot \sigma_S$	-	-
Side shell plating	- slamming zone	$0{,}85 \cdot \sigma_S$	-	-
	- elsewhere	$0{,}75 \cdot \sigma_S$	-	-
Keel		$0{,}75 \cdot \sigma_S$	-	-
Bottom structure				
Secondary stiffening	- slamming zone	$0{,}75 \cdot \sigma_S$	$0{,}75 \cdot \tau_S$	-
	- elsewhere	$0{,}65 \cdot \sigma_S$	$0{,}65 \cdot \tau_S$	-
Primary girders and web frames		$0{,}65 \cdot \sigma_S$	$0{,}65 \cdot \tau_S$	$0{,}75 \cdot \sigma_S$
Engine girders		$0{,}55 \cdot \sigma_S$	$0{,}55 \cdot \tau_S$	$0{,}75 \cdot \sigma_S$
Side structure				
Secondary stiffening	- slamming zone	$0{,}75 \cdot \sigma_S$	$0{,}75 \cdot \tau_S$	-
	- elsewhere	$0{,}65 \cdot \sigma_S$	$0{,}65 \cdot \tau_S$	-
Primary girders and web frames		$0{,}65 \cdot \sigma_S$	$0{,}65 \cdot \tau_S$	$0{,}75 \cdot \sigma_S$
Bow doors				
Plating		$0{,}65 \cdot \sigma_S$	-	-
Secondary stiffening		$0{,}51 \cdot \sigma_S$	$0{,}433 \cdot \tau_S$	-
Primary stiffening		$0{,}51 \cdot \sigma_S$	$0{,}34 \cdot \tau_S$	$0{,}64 \cdot \sigma_S$
Main / strength deck plating and stiffeners				
Plating		$0{,}75 \cdot \sigma_S$	-	-
Secondary stiffening		$0{,}65 \cdot \sigma_S$	$0{,}65 \cdot \tau_S$	-
Primary girders and web frame		$0{,}65 \cdot \sigma_S$	$0{,}65 \cdot \tau_S$	$0{,}75 \cdot \sigma_S$
Hatch covers		$0{,}55 \cdot \sigma_S$	$0{,}55 \cdot \tau_S$	$0{,}64 \cdot \sigma_S$
Superstructures / deckhouses				
Deckhouse front 1st tier	- plating	$0{,}65 \cdot \sigma_S$	-	-
	- stiffening	$0{,}60 \cdot \sigma_S$	$0{,}60 \cdot \tau_S$	-
Deckhouse front upper tiers	- plating	$0{,}75 \cdot \sigma_S$	-	-
	- stiffening	$0{,}65 \cdot \sigma_S$	$0{,}65 \cdot \tau_S$	-
Deckhouse aft and sides	- plating	$0{,}75 \cdot \sigma_S$	-	-
	- stiffening	$0{,}75 \cdot \sigma_S$	$0{,}75 \cdot \tau_S$	-

Item		Limiting stress value		
		Bending stress σ	Shear stress τ	Equivalent stress
Coachroof	- plating	$0,65 \cdot \sigma_S$	-	-
	- stiffening	$0,65 \cdot \sigma_S$	$0,65 \cdot \tau_S$	-
House top	- plating	$0,75 \cdot \sigma_S$	-	-
	- stiffening	$0,75 \cdot \sigma_S$	$0,75 \cdot \tau_S$	-
Lower/inner decks and house top subject to personnel loading	- plating	$0,75 \cdot \sigma_S$	-	-
	- stiffening	$0,60 \cdot \sigma_S$	$0,60 \cdot \tau_S$	-
Bulkheads				
(a) Collision bulkhead	- plating	$0,75 \cdot \sigma_S$	-	-
	- secondary stiffening	$0,65 \cdot \sigma_S$	$0,65 \cdot \tau_S$	-
	- primary stiffening	$0,65 \cdot \sigma_S$	$0,65 \cdot \tau_S$	$0,75 \cdot \sigma_S$
(b) Watertight bulkhead	- plating	$1,00 \cdot \sigma_S$ s	-	-
	- secondary stiffening	$0,90 \cdot \sigma_S$	$0,95 \cdot \tau_S$	-
	- primary stiffening	$0,90 \cdot \sigma_S$	$0,90 \cdot \tau_S$	$1,00 \cdot \sigma_S$
Watertight bulkhead doors		$0,825 \cdot \sigma_S$	$0,825 \cdot \tau_S$	-
Structure supporting watertight doors		$0,80 \cdot \sigma_S$	$0,80 \cdot \tau_S$	-
(c) Minor bulkheads	- plating	$0,65 \cdot \sigma_S$	-	-
	- secondary stiffening	$0,65 \cdot \sigma_S$	$0,65 \cdot \tau_S$	-
	- primary stiffening	$0,65 \cdot \sigma_S$	$0,65 \cdot \tau_S$	$0,75 \cdot \sigma_S$
(d) Deep tank bulkheads	- plating	$0,65 \cdot \sigma_S$	-	-
	- secondary stiffening	$0,65 \cdot \sigma_S$	$0,65 \cdot \tau_S$	-
	- primary stiffening	$0,75 \cdot \sigma_S$	$0,75 \cdot \tau_S$	-

Table 5.3.3: Limiting deflection ratio

Item		Deflection ratio, f_δ
Bottom structure		
	- secondary stiffening	8,00
	- primary girders and web frames	10,00
Side structure		
	- secondary stiffening	8,00
	- primary girders and web frames	10,00
Main/strength deck structures		
	- secondary stiffening	10,00
	- primary girders and web frames	12,50
	- hatch covers	12,50
Superstructures/deckhouses stiffeners		
Generally	- secondary	6,00
	- primary	7,50
Coachroof	- secondary	8,00
	- primary	10,00
House top	- secondary	6,00
	- primary	6,00

Lower/inner decks and house top subject to personnel loading		
	- secondary members	8,00
	- primary members	10,00
Deep tank structures		
Stiffeners	- secondary members	10,00
	- primary members	12,50
Watertight bulkhead structures		
Stiffeners	- secondary members	6,00
	- primary members	7,50

3.12 Geometric properties and proportions of stiffener sections

3.12.1 In order to avoid structural instability and appearance of local buckling, the proportions of stiffening members are in general to be in accordance with the requirements of paragraphs 3.12.2 and 3.12.3.

3.12.2 In case of flat bars the minimum web thickness should be greater than 1/15 of the web depth and always greater than 3 mm.

3.12.3 Where rolled or built sections are used the minimum web thickness should be at least equal to 1/50 of the web depth and always greater than 3 mm. In this case the width of the unsupported face plate or flanges should not be greater than 16 times the thickness of the face plate or flange.

3.13 Effective span length

3.13.1 The effective length of span of a stiffening member depends on length of the member and the design of each end connections. In general, the effective length of span is always equal or less than the physical length of the member.

3.13.2 The effective length of span of primary supporting members is the distance between the two span points, which should be taken at a distance b_e from each end of the member, where b_e is defined as follows:

$$b_e = b_b\left(1 - \frac{d_w}{d_b}\right)$$

Where:

b_e, b_b, d_w and d_b = as shown in Figure 5.3.2.

3.13.3 The effective length of span of rolled or built up secondary stiffening members is the distance between the two span points, which in this case should be taken at the point where the depth of the end bracket, measured from the face of the secondary stiffening member, is equal to the depth of the member, see Figure 5.3.2. Where there is no end bracket, the span point is to be measured between primary member webs.

3.13.4 Where the stiffening member is curved then the span is to be taken as the effective chord length between span points.

3.14 End brackets

3.14.1 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the scantlings of the end brackets are to be such that their section modulus and effective cross-sectional area are not less than those of the member.

3.14.2 In other cases the scantlings of the bracket are to be based on the modulus, according to the Table 5.3.4.

Figure 5.3.2: Span points

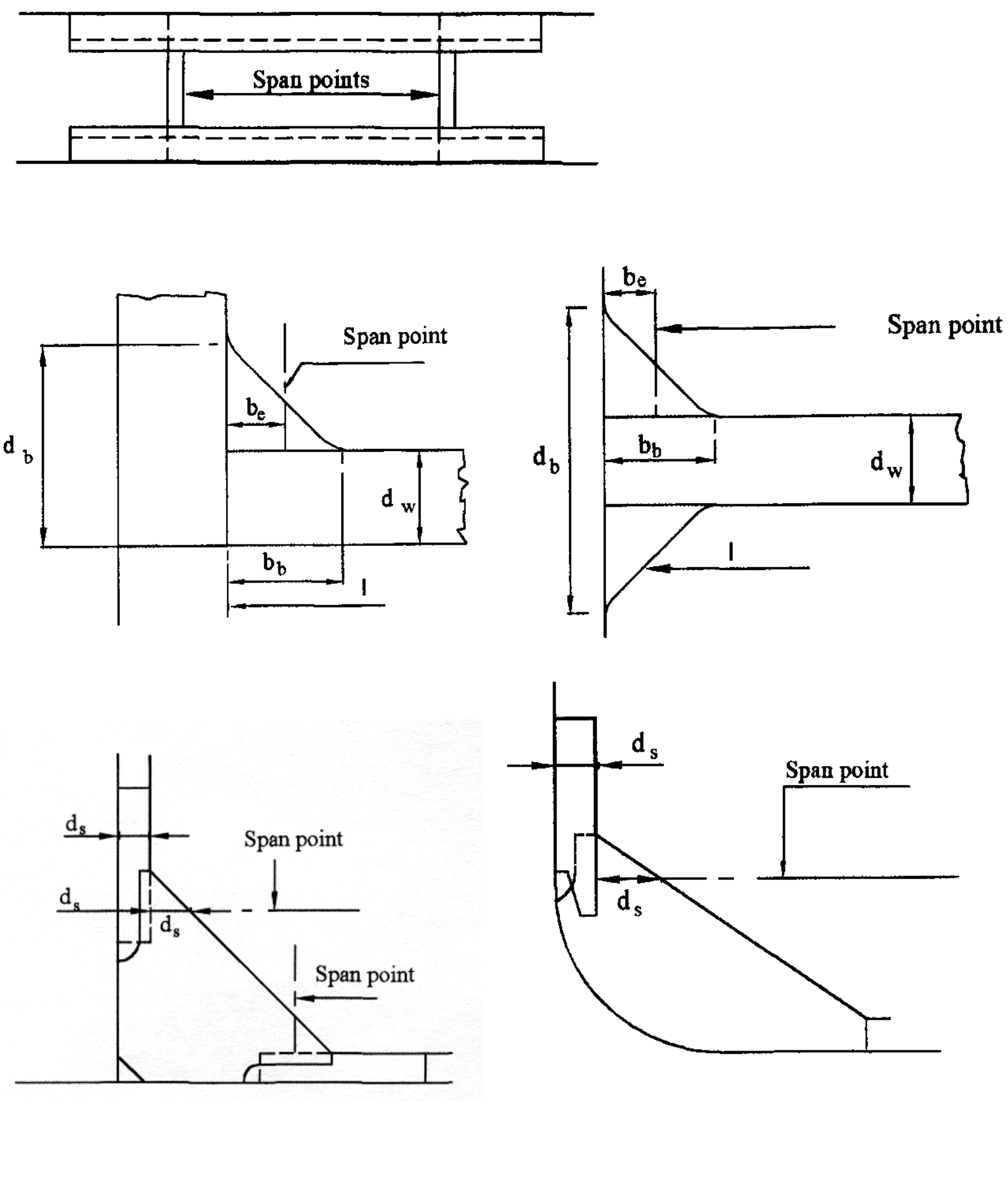
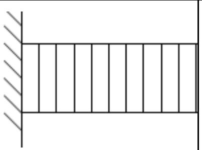
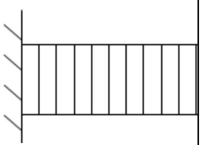
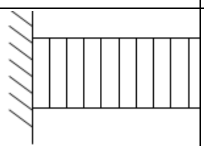
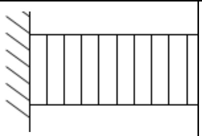
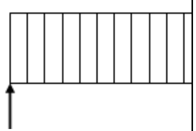


Table 5.3.4:

Location of the bracket	Section Modulus of the bracket
Bracket at the head of a main transverse frame where frame terminates	modulus of the frame
Bracket connecting stiffener to primary member	modulus of the stiffener
Brackets connecting lower deck beams or longitudinals to the main frame in the forward 0,5L	modulus of the frame
Elsewhere	the lesser modulus of the members being connected by the bracket

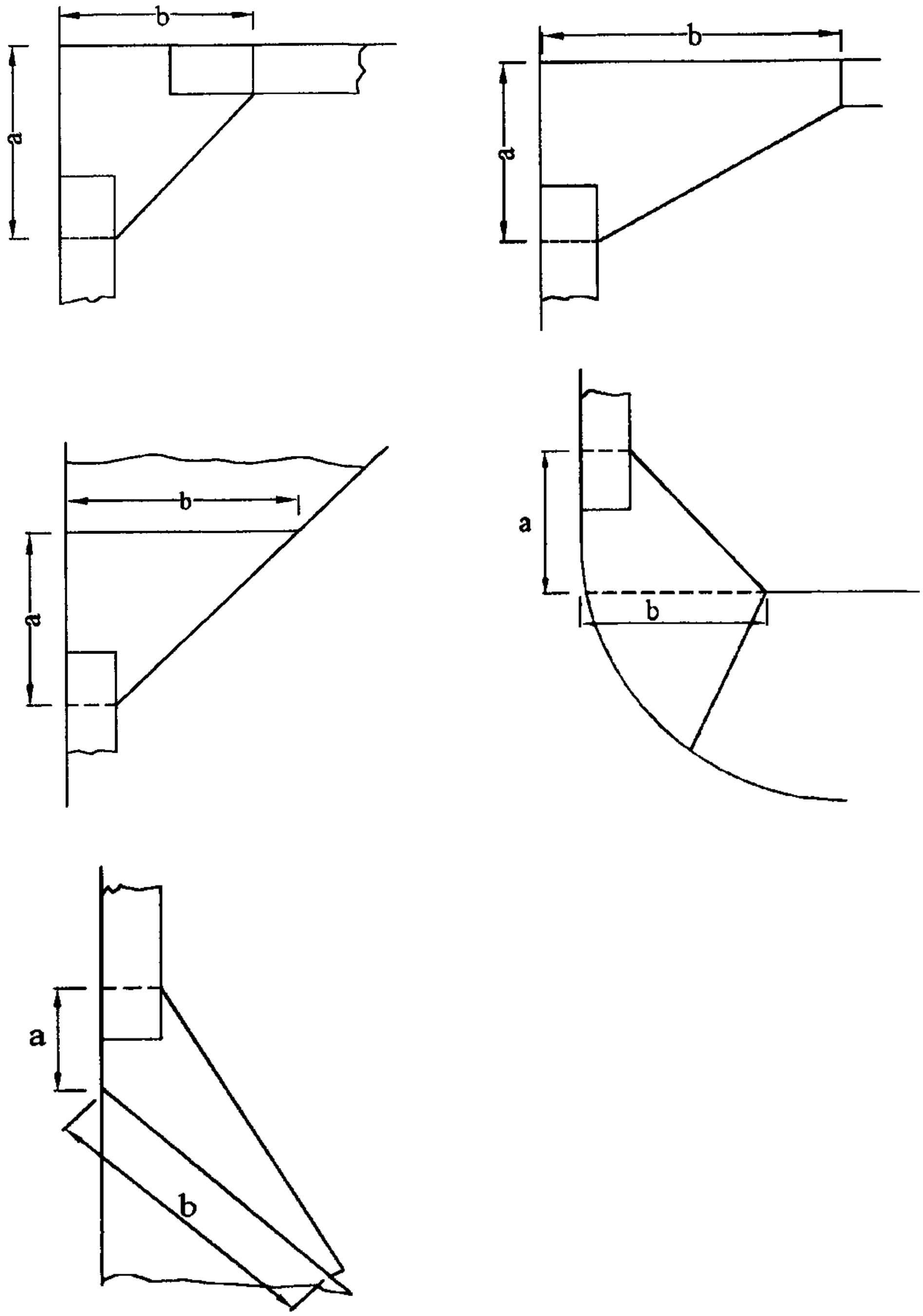
Table 5.3.5: Section modulus, inertia and web area coefficients

Load model	Position 123	Position	Web area coefficient C_A	Section modulus coefficient C_{SM}	Inertia coefficient C_I	Application
(a)		1 2 3	1/2 - 1/2	1/12 1/24 1/12	- 1/384 -	Primary and other members where the end fixity is considered encastre
(b)		1 2 3	1/2 - 1/2	1/10 1/10 1/10	- 1/288 -	Local, secondary and other members where the end fixity is considered to be partial
(c)		1 2 3	5/8 - 3/8	1/8 9/128 -	- 1/185 -	Various
(d)		1 2 3	1 - -	1/2 - -	- - 1/8	Various
(e)		1 2 3	1/2 - 1/2	- 1/8 -	- 5/384 -	Hatch covers, glazing and other members where the ends are simply supported

3.14.3 The web thickness and face flat area of end brackets are not in general to be less than those of the connecting stiffeners. In addition to this, the stiffener proportion requirements of 3.12 are to be satisfied.

3.14.4 In Figure 5.3.3 are shown diagrammatically typical arrangements of stiffener end brackets.

Figure 5.3.3: Stiffener end brackets



3.14.5 The lengths, a and b of the arms are measured from the plating to the toe of the bracket and are to be such that:

(a) $a \geq 0,8\ l_b$

(b) $b \geq 0,8\ l_b$

(c) $a + b \geq 2,0\ l_b$

where a and b are the actual lengths of the two arms of the bracket, in mm, measured from the plating to the toe of the bracket.

$$I_b = 90\left(2 \cdot \sqrt{\frac{SM}{14 + \sqrt{SM}}} - 1\right)\ [mm]$$

Where:

SM = the section modulus of the secondary member, in cm^3

l_b should not be taken as less than twice the web depth of the stiffener on which the bracket scantlings are to be based.

3.14.6 Where any of the following apply, the free edge of the bracket is to be stiffened:

(a) The bracket is fitted at the lower end of main transverse side framing.

(b) The section modulus, SM, exceeds 500 cm^3.

(c) The length of free edge exceeds 40 times the bracket thickness.

3.14.7 Where a face flat is fitted, its breadth, b_f, is to be not less than:

$$b_f = 40 \cdot \left(1 + \frac{SM}{1000}\right)\ [mm]$$

but not less than 50 mm.

3.14.8 Where the stiffening member is lapped onto the bracket, the length of overlap is not to be less Than $10\sqrt{SM}$, or the depth of stiffener, whichever is the greater.

3.14.9 Where the edge is stiffened by a welded face flat, the cross-sectional area of the face flat is to be not less than:

(a) $0{,}009 \cdot k_1 \cdot b_f \cdot T_B$ cm^2 for offset edge stiffening.

(b) $0{,}014 \cdot k_1 \cdot bf \cdot T_B$ cm^2 for symmetrically placed stiffening.

where:

T_B = the thickness of the bracket, in mm

b_f = breadth of face flat, in mm

k_1 = as defined in 3.3.1

3.14.10 Where the free edge of the bracket is hollowed out, it is to be stiffened or increased in size to ensure that the modulus of the bracket through the throat is not less than that of the required straight edged bracket.

3.14.11 The arrangement of the correction between the stiffener and the bracket is to be such that at no point in the connection is the actual modulus reduced to less than that of the stiffener with associated plating.

3.15 Primary member end connections

3.15.1 The scantling requirements for primary member end connections in dry spaces and in tanks of all craft types are generally to comply with the requirements of 3.14, taking SM as the section modulus of the primary member.

3.15.2 Primary members must have adequate lateral stability and web stiffening. Furthermore, the structure is to be arranged in such a way to minimise hard spots and other sources of stress concentration. The openings are to have smooth edges and well rounded corners and are to be located having regard to the stress distribution and buckling strength of the panel.

3.15.3 Primary members are to be arranged in such a way to ensure effective continuity of strength, and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead, or on other members, arrangements are to be made to ensure that they are in alignment. Primary members in tanks are to form a continuous line of support and wherever possible, a complete ring system.

3.15.4 Primary members are to be provided with adequate end fixity by end brackets or equivalent structure. The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.

3.15.5 Where primary members are subject to concentrated loads, particularly if these are out of line with the member web, additional strengthening may be required.

3.15.6 Where the primary member is supported by structure which provides only a low degree of restraint against rotation, the member is generally to be extended beyond the point of support and thereafter tapered and/or scarfed into the adjacent structure over a distance generally not less than two frame spaces.

3.15.7 The thickness of the bracket is to be not less than that of the primary member web. The free edge of the bracket is to be stiffened.

3.15.8 Where a member is continued over a point of support, such as a pillar or pillar bulkhead stiffener, the design of the end connection is to be such as to ensure the effective distribution of the load into the support.

3.15.9 Where a deck girder or transverse is connected to a vertical member on the shell or bulkhead, the scantlings of the latter may be required to be increased to provide adequate stiffness to resist rotation of the joint.

3.15.10 Connections between primary members forming a ring system are to minimise stress concentrations at the junctions.Integral brackets are generally to be radiuses or well rounded at their toes. The arm length of the bracket, measured from the face of the member, is to be not less than the depth of the smaller member forming the connection.

3.16 Secondary member end connections

3.16.1 Secondary members, such as, beams, longitudinals, frames and bulkhead stiffeners forming part of the hull structure, are to be effectively continuous and are to be suitably bracketed at their end connections.

SECTION 4 Single bottom structure

4.1 Single bottom structure and appendages

4.1.1 The following requirements apply to ships with single bottom construction in association with transverse and longitudinal framing systems.

4.2 Keel

4.2.1 The breadth, and thickness of plate keels are to comply with the requirements of 6.2.

4.2.2 The cross-sectional area, A, and thickness, t, of bar keels are not, in general, be taken as less than:

$$A = k_1(L+1)\ [cm^2]$$

$$t = \sqrt{k_1} \cdot (0{,}5 \cdot L + 6)\ [mm^2]$$

Where:

L, k_1 = as defined in 3.3.1

4.3 Centre keelson

4.3.1 A centre keelson is to be fitted throughout the length of the hull in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

4.3.2 Centre keelsons are to be formed of intercostal or continuous plate webs with a face plate welded to the upper edge. The face plate should be continuous. Where girder webs are intercostal, additional bracketing and local reinforcement will be required to maintain the continuity of structural strength.

4.3.3 The web depth of the centre keelson is, in general, to be equal to the depth of the floors at the centreline as specified in 4.5.3.

4.3.4 The web thickness t is to be taken not less than:

$$t = \sqrt{k_1} \cdot \left(\sqrt{L} + 1\right)\ [mm]$$

or

$$t = \sqrt{k_2} \cdot \left(3 \cdot \sqrt{\frac{1}{14} \cdot L} + 1\right)\ [mm]$$

or

$$4{,}0\ [mm]$$

whichever is greater

Where:

L, k_1, k_2 = as defined in 3.3.1

4.3.5 The cross sectional area of the face plate of the centre girder A, is to be not less than:

$$A = 0{,}3 \cdot L \cdot k_1 \ \ [cm^2]$$

4.3.6 The face flat area of the centre girder outside 0,5·L amidships may be 80% of the value given in 4.3.5.

4.3.7 The thickness of the face plate is not to be less than the thickness of the web.

4.3.8 The ratio of the width to thickness of the face plate is to be not less than eight but should n ot exceed sixteen

4.3.9 Additionally, the requirements of 7.3 for bottom longitudinal primary stiffeners are to be complied with.

4.4 Side girders

4.4.1 Where the floor breadth at the upper edge exceeds 6,0 m, side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 metres. Side girders where fitted are to extend as far forward and aft as practicable and are, in general, to terminate in way of bulkheads, deep floors or other primary transverse structure.

4.4.2 The web thickness of side girders is to be taken as not less than:

$$t = \sqrt{k_1 \cdot L}\ [mm]$$

or

$$t = \sqrt{k_2} \cdot \left(2 \cdot \sqrt{\frac{1}{11} \cdot L} + 0{,}8\right)\ [mm]$$

or

$$3{,}5\ [mm]$$

whichever is greater

Where:

L, k_1, k_2 = as defined in 3.3.1

4.4.3 The cross sectional area of the face plate and the thickness of side girders are to comply with the requirements for plate floors as defined in 4.5.6 and 4.5.7.

4.4.4 Watertight side girders, and side girders forming the boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads and deeptanks as detailed in 9.3 and 9.5 respectively.

4.5 Floors general

4.5.1 In transversely framed craft, plate floors are generally to be fitted at each frame and underneath every bulkhead.

4.5.2 In longitudinally framed craft, plate floors are to be fitted at every transverse web frame and bulkhead and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are in general to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast /bilge keels and the bottom of the craft forward.

4.5.3 The overall depth, d_f, of plate floors at the centreline is not to be taken as less than:

$$d = 40 \cdot B + 35 \cdot D\ [mm] \qquad when\ B < 10\ m$$

$$d = 65 \cdot B + 35 \cdot D - 200\ [mm] \qquad when\ B \geq 10\ m$$

Where:

D = the depth

4.5.4 The web thickness, t, of plate floors, is to be in accordance with 3.12 and is to be taken as not less than:

$$t = \sqrt{k_1} \cdot (0{,}0034 \cdot d + 2{,}25) \cdot (0{,}001 \cdot s + 0{,}5)\ [mm]$$

or

$$t = \sqrt{k_2} \cdot \left(2 \cdot \sqrt{\frac{1}{11} \cdot L} + 0{,}8\right)\ [mm]$$

or

$$3{,}5\ [mm]$$

whichever is greater

Where:

d = to be determined from 4.5.3

L, k_1, k_2 = as defined in 3.3.1

4.5.5 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15% and the floor thickness determined using the reduced depth. The brackets are to be flanged and have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

4.5.6 The cross sectional area of the face plate, A, is not to be taken as less than:

$$A = 0{,}15 \cdot k_1 \cdot L\ [cm^2]$$

Where:

L, k_1 = as defined in 3.3.1

4.5.7 The thickness of the face plate is to be not less than the thickness of the web and the ratio of the web to the thickness of the face flat is to be not less than eight but is not to exceed sixteen.

4.5.8 Additionally the requirements of 7.6 for bottom transverse web frames are to be complied with.

4.5.9 Floors are generally to be continuous from side to side.

4.5.10 The floors in the aft peak are to extend over and provide effective support to the stern tube(s) where applicable.

4.5.11 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in 9.3 and 9.5.

4.6 Floors in machinery spaces

4.6.1 The thickness, t, of the floors in machinery spaces is to be 1mm greater than that required by 4.5.4.

4.6.2 The depth and section modulus of floors anywhere between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50% of the depth given in 4.5.3.

4.7 Rudder horns

4.7.1 The scantlings of the rudder horn are to be such that the section modulus against transverse bending at any horizontal section XX (see Figure 5.4.1) is not less than:

$$SM = 1,5 \cdot k_1 \cdot R_A \cdot K_v \cdot (V + 3)^2 \cdot \sqrt{(a^2 + 0,5 \cdot b^2)}\ [cm^3]$$

Where:

R_A = total rudder area, in m^2

V = maximum speed in the fully loaded condition, in knots

K_v = 1,0 for displacement craft with $\frac{V}{\sqrt{L_{WL}}} < 3,0$

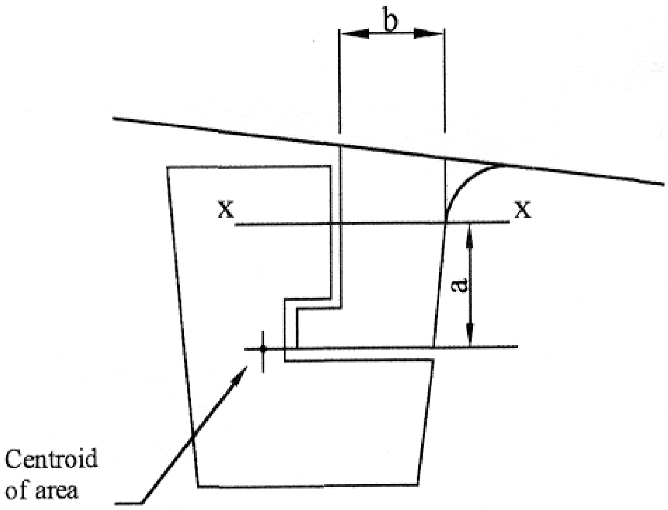
= $(1,12 - 0,005 \cdot V)^3$ for planing and semi-planing creaft with $\frac{V}{\sqrt{L_{WL}}} \geq 3,0$

a,b = dimensions, in metres, as given in Figure 5.4.1.

L_{WL} = waterline length

4.7.2 The shell plating thickness in way of the rudder horn does not need to be taken as greater than the keel thickness required by 6.2.

Figure 5.4.1: Rudder horn



4.8 Skeg construction

4.8.1 Skegs are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

4.9 Forefoot and stem

4.9.1 The thickness of plate stems at the waterline is to comply with the requirements for plate keels as given in 6.2.

4.9.2 The cross-sectional area of bar stems, A, is not to be taken as less than:

$$A = 0{,}8 \cdot k_1 \cdot L \ [cm^2]$$

Where:

L, k_1 = as defined in 3.3.1

SECTION 5 Double bottom structure

5.1 General

5.1.1 The following requirements provide for double bottom construction of steel mono-hull craft in association with either transverse or longitudinal framing.

5.1.2 The double bottom is to be made as wide as possible.

5.1.3 The double bottom is to be fitted extending from the collision bulkhead to the aft peak bulkhead.

5.1.4 If the double bottom is not continuous from the aft peak bulkhead to the collision bulkhead, the margin plate, side girders and centre girder must be connected to the longitudinal structure of the single bottom or shall scarf two frame spaces into the single bottom structure.

5.1.5 If the depth of the double bottom does not remain constant, efficient means of transmission of loads within 0,6L amidships are to be provided.

5.2 Keel

5.2.1 The scantlings of bar and plate keels are to comply with the requirements of 4.3.

5.2.2 Duct keels, where arranged, are to have a side plate thickness not less than:

$$t = \sqrt{k_1} \cdot (0{,}008 \cdot d_{DB} + 1)\ [mm]$$

but need not be taken as greater than 90% of the centre girder thickness given in 5.3,

Where:

d_{DB} = the Rule centre girder depth given in 5.3.3

k_1 = as defined in 3.3.1

5.2.3 Where a duct keel forms the boundary of a tank, the requirements of 9.4 and 9.5 for deep tanks are to be complied with.

5.2.4 The duct keel width is in general to be 15% of the beam or 2 metres, whichever is the lesser, but in no case is it to be taken as less than 630 mm.

5.3 Centre girder

5.3.1 A centre girder is to be fitted throughout the length of the craft. The web thickness, t, is not to be less than that required by:

$$t = \sqrt{k_1} \cdot (0{,}1 \cdot L + 3)\ [mm]$$

or

$$t = \sqrt{k_2} \cdot \left(3 \cdot \sqrt{\frac{1}{14} \cdot L} + 1\right)\ [mm]$$

or

$$4{,}0\ [mm]$$

whichever is greater

- Outside 0,4·L amidships:

$$t = \sqrt{k_1} \cdot (0{,}1 \cdot L + 2)\ [mm]$$

or

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{1}{2} \cdot L} + 1\right)\ [mm]$$

or

$$4{,}0\ [mm]$$

whichever is greater

Where:

L, k_1, k_2 = as defined in 3.3.1

5.3.2 The geometric properties of the girder section are to be in accordance with 3.12.

5.3.3 The overall depth of the centre girder, d_{DB}, is to be taken as not less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

5.3.4 Additionally, the requirements of 7.3 for bottom longitudinal primary stiffeners are to be complied with.

5.4 Side girders

5.4.1 Where the floor breadth does not exceed 6,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

5.4.2 Where the breadth of floor is greater than 6,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 3,0 metres. The web thickness of the side girders is to be taken as not less than:

$$t = \sqrt{k_2} \cdot \left(2 \cdot \sqrt{\frac{1}{11} \cdot L} + 0{,}8 \right) \; [mm]$$

or

$$3{,}5 \; [mm]$$

whichever is greater

Where:

L, k_2 = as defined in 3.3.1

5.4.3 Side girders, where fitted, are to extend as far forward and aft as practicable and are in general to terminate in way of bulkheads, deep floors or other primary transverse structure.

5.4.4 Where additional side girders are fitted in way of main machinery seatings, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

5.4.5 Under the main engine, girders extending from the bottom shell to the top plate of the engine seating are to be fitted. The height of the giders is to be not less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors and/or hanging brackets are to be fitted.

5.4.6 Additionally, the requirements of 7.3 for bottom longitudinal primary stiffeners are to be complied with.

5.5 Plate floors

5.5.1 The web thickness of non-watertight plate floors, t, is to be not less than:

$$t = \sqrt{k_1} \cdot (0{,}05 \cdot L + 3{,}5)\ [mm]$$

or

$$t = \sqrt{k_2} \cdot \left(2 \cdot \sqrt{\frac{1}{11} \cdot L} + 0{,}8\right)\ [mm]$$

or

$$3{,}5\ [mm]$$

whichever is greater

Where:

L, k_1, k_2 = as defined in 3.3.1

5.5.2 Additionally, the requirements of 7.6 for bottom transverse web frames stiffeners are to be complied with.

5.5.3 Plate floors are, in general, to be continuous between the centre girder and the margin plate.

5.5.4 In longitudinally framed craft, plate floors or equivalent structure are in general to be fitted in the following positions:

(a) At every half frame in way of the main engines, thrust bearings, and bottom of the craft forward.

(b) Outboard of the engine seatings, at every frame within the engine room.

(c) Underneath pillars and bulkheads.

(d) Outside of the engine room at a spacing not exceeding 2,0 m.

5.5.5 Vertical flat bar stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than 10·t and a thickness of not less than t, where t is thickness of the plate floor as calculated in 5.5.1.

5.5.6 In transversely framed craft, plate floors are to be fitted at every frame in the engine room, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 2,0 m.

5.6 Bracket floors

5.6.1 Between plate floors, the shell and inner bottom plating is to be supported by bracket floors. The brackets are to have the same thickness as plate floors and are to be stiffened on the unsupported edge.

5.6.2 In longitudinally framed craft, the brackets are to extend from the centre girder and margin plate to the adjacent longitudinal, but in no case is the breadth of the bracket to be taken as not less than 75% of the depth of the centre girder. They are to be fitted at every web frame at the margin plate, and those at the centre girder are to be spaced not more than 1,0 m apart.

5.6.3 In transversely framed craft, the breadth of the brackets, attaching the bottom and inner bottom frames to the centre girder and margin plate, is to be not less than 75% of the depth of the centre girder.

5.7 Additional requirements for watertight floors

5.7.1 The scantlings of watertight floors are to comply with the requirements for plate floors as given in 5.5.

5.8 Tankside brackets

5.8.1 The scantlings of tankside brackets are to comply with the requirements for plate floors given in 5.5.

5.9 Inner bottom plating

5.9.1 The thickness of the inner bottom plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{4}} + 1 \right) \, [mm]$$

or

$$2{,}5 \, [mm]$$

whichever is greater

Where:

L, k_2 = as defined in 3.3.1

5.9.2 Inner bottom plating forming the boundaries of tank spaces is, in addition, to comply with the requirements for watertight bulkheads or deeptanks as detailed in 9.2 or 9.4 respectively. Where the plating forms vehicle, passenger or other decks the requirements of SECTION 8 are to be complied with.

5.9.3 Inner bottom longitudinals are to be supported by inner bottom transverse web frames, floors, bulkheads or other primary structure, generally spaced not more than 2 m. apart.

5.9.4 The requirements of section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I, and C_A as detailed in Table 5.3.5 for the load model (a).

5.10 Margin plates

5.10.1 A margin plate, if fitted, is to have a thickness as required for inner bottom plating.

5.11 Manholes

5.11.1 Sufficient manholes are to be cut in the inner bottom, floors and side girders to provide adequate access to, and ventilation of, all parts of the double bottom. The size of the manhole openings is not, in general, to exceed 50% of the double bottom depth unless edge reinforcement is provided.

SECTION 6 Shell envelope plating

6.1 General

6.1.1 The following requirements are applicable to longitudinally and transversely framed shell envelopes.

6.2 Plate keel

6.2.1 The width b and the thickness t of the keel plate are not to be taken as less than:

$$b = 7 \cdot L + 340 \; [mm]$$

$$t = 1{,}35 \cdot \sqrt{k_1} \cdot L^{0{,}45} \; [mm]$$

Where:

L, k_1 = as defined in 3.3.1

6.2.2 In no case is the thickness of the keel plate to be less than that of the adjacent bottom shell plating.

6.2.3 The thickness and width of the plate keel are to be maintained throughout the length of the craft from the transom to a point not less than 25% of the freeboard (measured at the forward perpendicular) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by 6.3.1 for the stem.

6.2.4 For large or novel craft and for yachts with externally attached ballast keels, the scantlings of the keel will be specially considered.

6.2.5 For bar keels, see 4.2.2.

6.3 Plate stem

6.3.1 The thickness of plate stems, t, is not to be taken as less than:

$$t = \sqrt{k_1} \cdot (0{,}1 \cdot L + 3) \; [mm]$$

Where:

L, k_1 = as defined in 3.3.1

6.3.2 In no case is the thickness of the plate stem to be taken as less than the thickness of the adjacent shell plating.

6.3.3 Plate stems are to be supported by horizontal diaphragms, and where the stem radius is large, a centreline stiffener or web may be required.

6.3.4 For large or novel craft the scantlings of the stem will be specially considered.

6.3.5 The breadth of plate stems is to be not less than the width of keel as required by 6.2.1.

6.4 Bottom shell plating

6.4.1 The thickness of the bottom shell plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{6}} + 2 \right) \; [mm]$$

or

$$3{,}5 \; [mm]$$

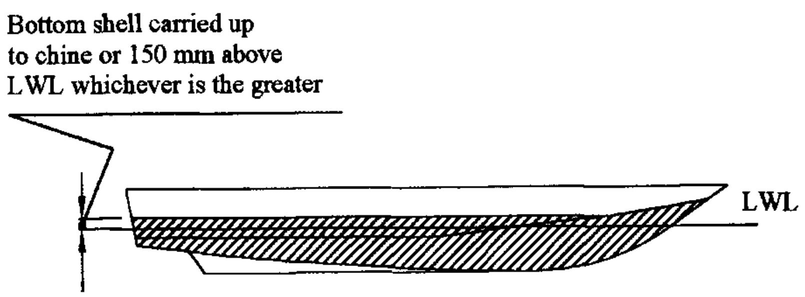
whichever is greater

Where:

L, k_2 = as defined in 3.3.1

6.4.2 For all craft types the minimum thickness requirement for bottom shell plating is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater see Figure 5.6.1.

Figure 5.6.1: Extent of bottom shell



6.5 Side shell plating

6.5.1 The thickness of the side shell plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{7}} + 1{,}2 \right) \; [mm]$$

or

$$3{,}0 \; [mm]$$

whichever is greater

Where:

L, k_2 = as defined in 3.3.1

6.6 Sheerstrake

6.6.1 The sheerstrake is generally to be taken as the side shell, locally reinforced in way of deck/ hull connection and fender attachment. The amount of local reinforcement will be dependent upon the arrangement of structure and the proposed service.

6.6.2 Only the designers/builders are responsible for the fendering arrangements of all craft types. The above mentioned arrangements are outside the scope of classification.

6.6.3 Fishing crafts are in general to have their shell plating scantling as required to satisfy the Rule loadings, increased by 20%. In addition to this, the side shell is not to be taken less than as bottom shell thickness, and where there are gallows, gantries, nets, or lines etc. the plating in way is to be further increased locally and /or suitably protected by sheathing or other means.

6.6.4 Where a rounded sheerstrake is adopted, the radius, in general, is to be not less than 15 times the thickness.

6.6.5 The sheerstrake thickness is to be increased by 20% at the ends of a bridge superstructure extending out to the craft's side. In case of a bridge superstructure exceeding 0,15·L, the side plating at the ends of the superstructure is also to be increased by 25% and tapered gradually into the upper deck sheerstrake.

6.7 Chines

6.7.1 The chine plate thickness is to be equivalent to the bottom shell thickness required to satisfy the Rule pressure loading, increased by 20%, or 6 mm, whichever is the greater.

6.7.2 Where tube is used in chine construction, the minimum wall thickness is to be not less than the thickness of the bottom shell plating increased by 20%.

6.8 Skegs

6.8.1 The thickness of the skeg plating is to be not less than the thickness of the adjacent bottom shell.

6.9 Transom

6.9.1 The thickness of the stern or transom is to be not less than that required for the side or bottom shell as appropriate.

6.10 Shell openings

6.10.1 Sea-inlets, or other openings, are to have well rounded corners and, so far as is practicable, are to be kept clear of the bilge radius, chine or radiused sheerstrake.

6.10.2 Openings on or near the bilge radius may be accepted provided that they are of elliptical shape, or equivalent, to minimise stress concentrations and are, in general, to be cut clear of weld connections.

6.11 Sea inlet boxes

6.11.1 The thickness of the sea inlet box plating is to be 2 mm thicker than the adjacent shell plating, or 6 mm, whichever is the greater.

SECTION 7 Shell envelope framing

7.1 General

7.1.1 The following requirements are applicable to longitudinally and transversely framed shell envelopes.

7.2 Bottom longitudinal stiffeners

7.2.1 Bottom longitudinal stiffeners are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 metres apart.

7.2.2 Bottom longitudinals are to be continuous through the supporting structures.

7.2.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules and the coefficients C_{SM}, C_I, and C_A as detailed in Table 5.3.5 for the load model (b).

7.3 Bottom longitudinal primary stiffeners

7.3.1 Bottom longitudinal primary stiffeners are to be supported by bottom deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 6 metres apart.

7.3.2 Bottom longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

7.3.3 The requirements for section modulus,inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I, and C_A as detailed in Table 5.3.5 for the load model (a).

7.4 Bottom transverse stiffeners

7.4.1 Bottom transverse stiffeners are defined as local stiffening members which support the bottom shell, and which may be continuous or intercostal.

7.4.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I, and C_A as detailed in Table 5.3.5 for the load model (b).

7.5 Bottom transverse frames

7.5.1 Bottom transverse frames are defined as stiffening members which support the bottom shell. They are to be effectively continuous and bracketed at their end connections to side frames and bottom floors as appropriate.

7.5.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I, and C_A as detailed in Table 5.3.5 for the load model (a).

7.6 Bottom transverse web frames

7.6.1 Bottom transverse web frames are defined as primary stiffening members which support bottom shell longitudinals.They are to be continuous and substantially bracketed at their end connections to side web frames and bottom floors.

7.6.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM},C_I,and C_A as detailed in Table 5.3.5 for the load model (a).

7.7 Side longitudinals stiffeners

7.7.1 The side longitudinals stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 metres apart.

7.7.2 Side longitudinals are to be continuous through the supporting structures.

7.7.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM},C_I,and C_A as detailed in Table 5.3.5 for the load model (b).

7.8 Side longitudinal primary stiffeners

7.8.1 Side longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 metres apart.

7.8.2 Side longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

7.8.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM},C_I,and C_A as detailed in Table 5.3.5 for the load model (a).

7.9 Side transverse stiffeners

7.9.1 Side transverse stiffeners are defined as local stiffening members supporting the side shell and may be continuous or intercostal.

7.9.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM},C_I,and C_A as detailed in Table 5.3.5 for the load model (b).

7.10 Side transverse frames

7.10.1 Side transverse frames are defined as stiffening members which support the side shell. They are to be effectively continuous and bracketed at their end connections to bottom floors/frames and deck beams as appropriate.

7.10.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I, and C_A as detailed in Table 5.3.5 for the load model (a).

7.11 Side transverse web frames

7.11.1 Side transverse web frames are defined as primary stiffening members which support side shell longitudinally. They are to be continuous and substantially bracketed at their head and heel connections to deck transverses and bottom web frames respectively.

7.11.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I, and C_A as detailed in Table 5.3.5 for the load model (a).

SECTION 8 Deck structures

8.1 General

8.1.1 The strength deck is:

(a) The uppermost continuous deck which forms the upper flange of the longitudinal hullgirder.

(b) A superstructure deck which extends up to 0,4L amidships and the length of which exceeds 0,15L. Superstructure decks the length of which is less than 12 m, need not be considered as strength decks.

(c) A quarter deck or the deck of a superstructure in part below the main deck, which extends through 0,4L amidships.

8.1.2 Deck sectional areas used in the deck area and section modulus calculations are to be maintained throughout the 0,4L amidships. They may be gradually reduced to 50% the normal requirement at 0,15L from the ends.

8.1.3 The geometric properties of stiffener sections are to be in accordance with 3.12.

8.2 Strength/Weather deck plating

8.2.1 The thickness of strength/weather deck plating is to be determined from the general plating equation given in 3.10 using the design pressure head from Part 3, Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{7}} + 1{,}2 \right) [mm]$$

or

$$3{,}0 \ [mm]$$

whichever is greater

Where:

L, k_2 = as defined in 3.3.1

8.2.2 The scantlings of watertight cockpits are to be of equivalent strength to those of the strength/weather deck.

8.3 Lower deck / Inside deckhouse plating

8.3.1 The thickness of the lower deck/inside deckhouse plating is to be determined from the general plating equation given in 3.10 using the design pressure head from Part 3, Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{29}} + 1{,}7 \right) \, [mm]$$

or

$$2{,}0 \, [mm]$$

whichever is greater

Where:

L, k_2 = as defined in 3.3.1

8.4 Accommodation deck plating

8.4.1 Accommodation decks are in general to be treated as lower deck/inside deckhouse decks, with their plating requirements determined in accordance with 8.3.

8.5 Cargo deck plating

8.5.1 The thickness of cargo deck plating is to be determined from the general plating equation given in 3.10 using the design pressure head from Part 3, Chapter 2 of the present Rules.

8.6 Strength / Weather deck stiffening

8.6.1 The Rule requirements for section modulus, inertia and web area for the strength/weather deck primary stiffening are to be determined from the general equations given in 3.11, using the design pressure heads from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (a). The minimum thickness for the strength/weather deck primary stiffening is to be determined from the following equation:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{7}} + 1{,}2 \right) \, [mm]$$

or

$$3{,}0 \, [mm]$$

whichever is greater

Where:

L, k_2 = as defined in 3.3.1

8.6.2 The Rule requirements for section modulus, inertia and web area for the strength / weather deck secondary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (b).

8.7 Lower deck / Inside deckhouse stiffening

8.7.1 The Rule requirements for section modulus, inertia and web area for lower deck / inside deckhouse stiffening are to be determined from the general equations given in 3.11, using the design pressure head from Part 3,Chapter 2 of the present Rules, and the coefficients C_{SM},C_I and C_A as detailed in Table 5.3.5. Primary members are assumed to be load model (a) and secondary members load model (b).The minimum thickness for lower deck/inside deckhouse stiffening is to be determined from the following equation:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{29}} + 1{,}7 \right) [mm]$$

or

$$2{,}0 \ [mm]$$

whichever is greater

Where:

L, k_2 = as defined in 3.3.1

8.8 Accommodation deck stiffening

8.8.1 Accommodation decks are in general to be treated as lower deck/inside deckhouse decks, with their scantling requirements determined in accordance with 8.7.

8.9 Cargo deck stiffening

8.9.1 The Rule requirements for section modulus, inertia and web area for cargo deck stiffening are to be determined from the general equations given in 3.11, using the design pressure head from Part 3, Chapter 2 of "Rules and Regulations for the Classification and Construction of Small Craft", and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5. Primary members are assumed to be load model (a) and secondary members load model (b).

8.10 Deck openings

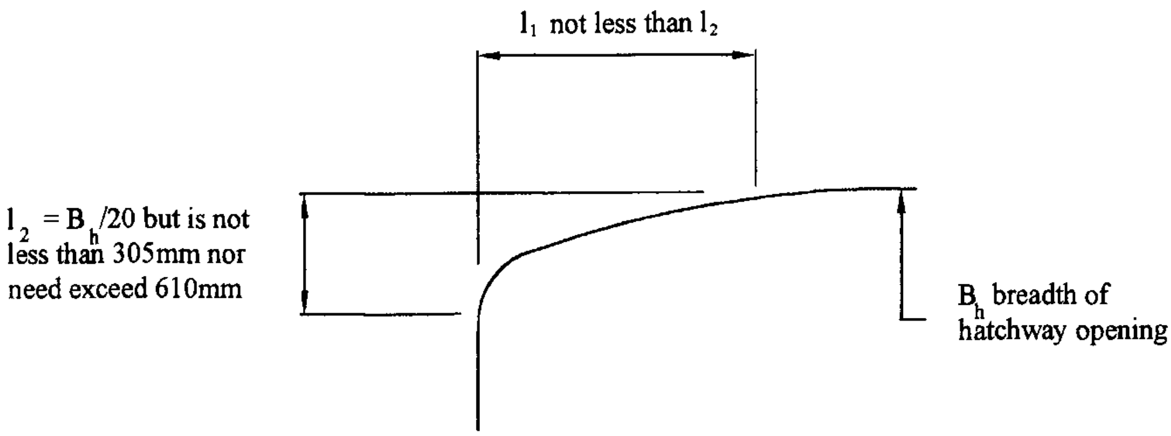
8.10.1 All openings are to be supported by an adequate framing system, pillars or cantilevers. When cantilevers are used scantlings may be derived from direct calculations.

8.10.2 Where stiffening members terminate in way of an opening they are to be attached to carlings, girders, transverses or coaming plates.

8.10.3 The corners of large hatchways in the strength/weather deck within 0,5·L amidships are to be elliptical, parabolic or rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.10.4 Where elliptical corners are arranged, the major axis is to be fore and aft, the ratio of the major to minor axis is to be not less than two to one nor greater than 2,5 to one, and the minimum half- length of the major axis is to be defined by l_1 in Figure 5.8.1. Where parabolic corners are arranged, the dimensions are also to be shown in Figure 5.8.1.

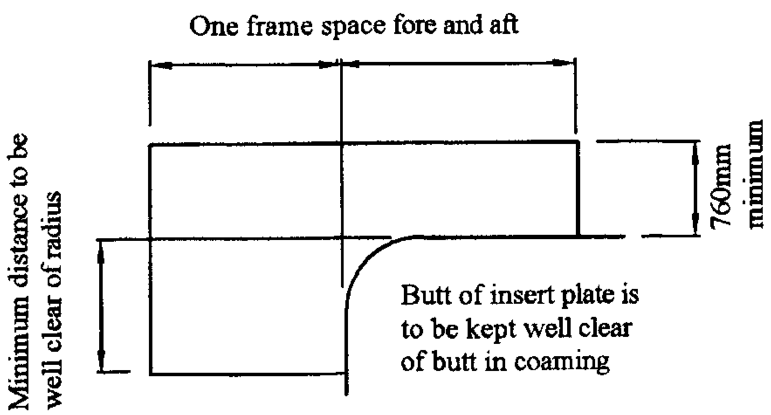
Figure 5.8.1: Hatch opening geometry



8.10.5 Where the corners are parabolic or elliptical, insert plates are not required.

8.10.6 For other shapes of corner, insert plates of the size and extent shown in Figure 5.8.2 will, in general, be required. The required thickness of the insert plate is to be not less than 25% greater than the adjacent deck thickness, outside line of openings.

Figure 5.8.2: Inserts in way of hatch opening



8.10.7 For lower decks the corners of large openings are to be rounded, with a radius generally not less than $^1/_{24}$ of the breadth of the opening.

SECTION 9 Bulkheads

9.1 General

9.1.1 The following requirements apply to bulkheads with both vertical and horizontal framing systems.

9.1.2 Bulkheads, or part bulkheads, forming the boundary of tanks are to comply with the requirements of 9.5 and 9.6.

9.1.3 A centreline bulkhead is, generally, to be fitted in deep tanks which extend from side to side. The bulkhead may be intact or perforated as desired. If intact, the scantlings are to comply with the requirements of 9.5 and 9.6 for tank boundary bulkheads. If perforated, they are to comply with the requirements of 9.10 for washplates.

9.2 Watertight bulkhead plating

9.2.1 The thickness of the watertight bulkhead plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{9}} + 1 \right) \ [mm]$$

or

$$2{,}5 \ [mm]$$

whichever is greater

Where:

L, k_2	=	as defined in 3.3.1

9.3 Watertight bulkhead stiffening

9.3.1 The Rule requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressure from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 using the appropriate load model.

9.4 Deep tank plating

9.4.1 The thickness of deep tank plating is to be determined from the general plating equation given in

3.10 using the design pressure from Part 3, Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{7}} + 1{,}2 \right) \; [mm]$$

or

$$3{,}0 \; [mm]$$

whichever is greater

Where:

L, k_2 = as defined in 3.3.1

9.5 Deep tank stiffening

9.5.1 Deep tank bulkhead stiffeners are to be bracketed at both ends. The thickness of the brackets is to be not less than the web thickness of the stiffener.

9.5.2 The Rule requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressure from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for load model (b).

9.6 Double bottom tanks

9.6.1 The scantlings of double bottom tanks are to comply with the requirements for deep tanks given in 9.4 and 9.5.

9.6.2 Where the crown of a double bottom tank forms a vehicle, passenger or other deck, the requirements of SECTION 8 are to be complied with.

9.7 Collision bulkheads

9.7.1 The scantlings of collision bulkheads are to be not less than as required for deep tank bulkheads contained in 9.4 and 9.5.

9.8 Non-watertight or partial bulkheads

9.8.1 Where a bulkhead is structural but non-watertight the scantlings are in general to be as for watertight bulkheads. Partial bulkheads that are non-structural are outside the scope of classification.

9.9 Corrugated bulkheads

9.9.1 The plating thickness and section modulus for symmetrical corrugated bulkheads are to be in accordance with watertight bulkheads or deep tank bulkheads as appropriate.

9.9.2 In addition, the section geometric properties of 3.12 are to be complied with.

9.10 Wash plates

9.10.1 Tanks are to be subdivided as necessary by internal baffles or wash plates. Baffles or wash plates which support hull framing are to have scantlings equivalent to web frames in the same position.

9.10.2 Wash plates and wash bulkheads are, in general, to have an area of perforation not less than 10% of the total area of the bulkhead. The perforations are to be so arranged that the efficiency of the bulkhead as a support is not impaired.

9.10.3 The plate thickness is to be not less than the structural element from which the wash bulkhead is formed.

9.10.4 The general stiffener requirements are to be in accordance with 9.5. However, the section modulus may be 50% of that required by 9.5.

SECTION 10 Superstructures and deckhouses

10.1 Superstructure and deckhouse side plating

10.1.1 The thickness of house side plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{11}} + 1 \right) \; [mm]$$

or

$$2{,}0 \; [mm]$$

whichever is greater

Where:

L, k_2 = as defined in 3.3.1

10.2 Superstructure and deckhouse front plating

10.2.1 The thickness of the house front plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules, and not to be less than that following from the equations:

(a) Superstructure and deckhouse front 1st tier plating:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{2}{9} \cdot L} + 1{,}5 \right) \; [mm]$$

or

$$3{,}0 \; [mm]$$

whichever is greater

(b) Superstructure and deckhouse front upper tiers plating:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{2}{11} \cdot L} + 1{,}3 \right) [mm]$$

or

$$3{,}0 \; [mm]$$

whichever is greater

Where:

L, k_2 = as defined in 3.3.1

10.3 Superstructure and deckhouse end plating

10.3.1 The thickness of the house end plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{25}} + 0{,}6 \right) [mm]$$

or

$$2{,}0 \; [mm]$$

whichever is greater

Where:

L, k_2 = as defined in 3.3.1

10.4 Superstructure and deckhouse top plating

10.4.1 The thickness of the house top plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules.

10.5 Coachroof plating

10.5.1 The thickness of the coachroof plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules.

10.6 Machinery casing plating

10.6.1 The thickness of the plating of machinery casings is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules.

10.7 Forecastle requirements

10.7.1 The forecastle side plating may be a continuation of the hull side shell plating or fitted as a separate assembly.In both cases the plating thickness is to be the same as the side shell plating at deck edge.Where fitted as a separate assembly, suitable arrangements are to be made to ensure continuity of the effect of the sheerstrake at the break and at the upper edge of the forecastle side. Full penetration welding is to be used.

10.7.2 The side plating is to be stiffened by side frames effectively connected to the deck structure. Deep webs are to be fitted to ensure overall rigidity.

10.7.3 The deck plating thickness is to be increased by 20% in way of the end of the forecastle if this occurs at a position aft of 0,25·L from the F.P. No increase is required if the forecastle end bulkhead lies forward of 0,2·L from the F.P. The increase at intermediate positions of end bulkhead is to be obtained by interpolation.

10.8 Superstructure and deckhouse side stiffeners

10.8.1 The Rule requirements for section modulus, inertia and web area for the house side primary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (b).

10.9 Superstructure and deckhouse front stiffeners

10.9.1 The Rule requirements for section modulus, inertia and web area for house front primary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (a).

10.9.2 The Rule requirements for section modulus, inertia and web area for house front secondary stiffening are to be determined from the general equations given in 6.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (b).

10.10 Superstructure and deckhouse aft end stiffeners

10.10.1 The Rule requirements for section modulus, inertia and web area for house aft end primary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (a).

10.10.2 The Rule requirements for section modulus, inertia and web area for house aft end secondary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (b).

10.11 Superstructure and deckhouse top stiffeners

10.11.1 The superstructure and deckhouse top is to be effectively supported by a system of transverse or longitudinal beams and girders. The span of the beams is in general not to exceed 2,4 metres and the beams are to be effectively connected to the house upper coamings and girders.

10.11.2 The Rule requirements for section modulus, inertia and web area for house top primary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (a).

10.11.3 The Rule requirements for section modulus, inertia and web area for house top secondary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (b).

10.12 10.12 Coachroof stiffeners

10.12.1 The Rule requirements for section modulus, inertia and web area for coachroof primary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (a).

10.12.2 The Rule requirements for section modulus, inertia and web area for coachroof secondary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (b).

10.13 Machinery casing stiffeners

10.13.1 The Rule requirements for section modulus, inertia and web area for machinery casing primary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (a).

10.13.2 The Rule requirements for section modulus, inertia and web area for machinery casing secondary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (b).

10.14 Forecastle stiffeners

10.14.1 The scantlings of forecastle primary and secondary stiffening members are to be equivalent to those for the side shell envelope framing at the deck edge as required by SECTION 7.

10.15 Superstructures formed by extending side structures

10.15.1 Superstructure first tier sides formed by extending the hull side structure are to be in accordance with the requirements for house fronts given in 10.2 and 10.9 for plating and stiffeners respectively, but need not be taken as greater than the side structure requirements at the deck edge at the same longitudinal position.

10.16 Bulwarks

10.16.1 The thickness of the bulwark plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules.

10.16.2 Fishing craft are to have bulwarks fitted. The bulwark may be formed from a continuation of the side shell plating or connected as a separate assembly. Where the bulwark is considered to be stressed and contributing to the global strength of the craft, the plate thickness of the bulwark is not to be less than the sheerstrake plating thickness. In no case is the thickness of the bulwark plating to be taken as less than 80% of the side shell thickness.The bulwark is to be supported by suitable stiffening members which may be formed from a continuation of the side frames, or from flanged plate stays of the same thickness as the bulwark. In general these frames are to be spaced not more than two side frame spacings apart.

SECTION 11 Structural scantlings for multi-hull vessels-General principles and requirements

11.1 Application

11.1.1 The requirements of SECTION 11, SECTION 12, SECTION 13, SECTION 14, SECTION 15 and SECTION 16 are applicable to multi-hull craft of steel construction.

11.2 Direct calculations

11.2.1 In case the design, form or proportions of the craft are unusual, or the speed of the craft exceeds 60 knots, the scantlings are to be determined by direct calculation.

11.2.2 In any case direct calculations based on well established principles of mechanics may be used alternatively or complementary to these Rules, provided that the achieved level of safety remains equivalent.

11.3 Symbols and definitions

11.3.1 The symbols used in this Section are defined below:

L = Rule length of craft, in metres

s = stiffener spacing, in mm

σ_s = guaranteed minimum yield strength of the material, in N/mm²

$\tau_s = \sigma_s/\sqrt{3}$

k_1 = high tensile steel factor

$= 235/\sigma_s$

$k_2 = 635/(\sigma_s + \sigma_u)$

σ_u = specified minimum ultimate tensile strength of the material, N/mm²

t = plating thickness, in mm

11.3.2 **Bottom outboard:** For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom outboard shell is defined as the area of the hull between the outboard edge of the keel and the outer bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom outboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

11.3.3 **Bottom inboard:** For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom inboard shell is defined as the area of the hull between the inboard edge of the keel and the inner bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom inboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

11.3.4 **Haunch:** The haunch is defined as the transition area between the cross-deck and the inboard side shell plating.

11.3.5 **Cross-deck:** The cross-deck is defined as the structure which forms the bridge connection between any two adjacent hulls.

11.3.6 **Side inboard:** The side inboard is defined as the area between the bottom inboard shell and the wet-deck (or lower edge of the haunches, where fitted).

11.3.7 **Side outboard:** The side outboard is defined as the area between bottom outboard shell and the deck at side.

11.3.8 **Wet-deck:** The wet-deck is defined as the area between the upper edges of the side inboard plating (or upper edges of the haunches, where fitted).

SECTION 12 Single bottom structure and appendages

12.1 Keel

12.1.1 The scantlings and arrangements of plate keels are to be in accordance with 14.1.

12.1.2 Where fitted, the cross-sectional area, A, and thickness, t, of bar keels should not, in general, be taken as less than:

$$A = k_1 \cdot 0{,}75 \cdot L \; [cm^2]$$

$$t = \sqrt{k_1} \cdot (0{,}5 \cdot L + 2) \; [mm]$$

Where:

L, k_1 = as defined in 3.3.1

12.2 Centre girder

12.2.1 Centreline girders are to be fitted throughout the length of each hull and are generally to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

12.2.2 The web depth of the centre girder is, in general, to be equal to the depth of the floors at the centreline as specified in 12.4.3.

12.2.3 The web thickness, t, of the centre girder is to be taken as not less than:

$$t = \sqrt{k_1} \cdot \left(3 \cdot \sqrt{\frac{1}{14} \cdot L} + 1\right) \; [mm]$$

or

$$t = \sqrt{k_2} \cdot \left(3 \cdot \sqrt{\frac{1}{14} \cdot L} + 1\right) \; [mm]$$

or

$$4{,}0\ [mm]$$

whichever is greater

Where:

L, k_1, k_2 = as defined in 3.3.1

12.2.4 The face flat area, A, of the centre girder is to be not less than:

$$A = 0{,}22 \cdot k_1 \cdot L\ [cm^2]$$

Where:

L, k_1, k_2 = as defined in 3.3.1

12.2.5 The face flat area of the centre girder outside 0,5·L may be 80% of the value given in 12.2.4.

12.2.6 The face flat thickness, t, is to be not less than the thickness of the web.

12.2.7 The ratio of the width to thickness of the face flat is to be not less than eight but is not to exceed sixteen.

12.2.8 Additionally, the requirements of 15.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

12.3 Side girders

12.3.1 Where the floor breadth at the upper edge exceeds 4,0 m side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 2 metres.

12.3.2 The web thickness, t, of side girder is to be taken as not less than:

$$t = \sqrt{0{,}43 \cdot k_1 \cdot L}\ [mm]$$

or

$$t = \sqrt{k_2} \cdot \left(2 \cdot \sqrt{\frac{1}{11} \cdot L} + 0{,}8\right)\ [mm]$$

or

$$3{,}5\ [mm]$$

whichever is greater

Where:

L, k_1, k_2 = as defined in 3.3.1

12.3.3 The face flat area and thickness of side girders are to comply with the requirements for plate floors as defined in 12.4.5 and 12.4.6.

12.3.4 Additionally, the requirements of 15.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

12.4 Floors general

12.4.1 In transversely framed craft, floors are generally to be fitted at every frame and underneath each bulkhead.

12.4.2 In longitudinally framed craft, floors are, in general, to be fitted at every transverse web frame and bulkhead and generally at a spacing not exceeding 2 metres.

12.4.3 The overall web depth, d, of floors at the centreline, is not to be taken as less than:

$$d = 6{,}2 \cdot L + 50\ [mm]$$

Where:

L = as defined in 3.3.1

12.4.4 The web thickness of plate floors, t, is to be not less than:

$$t = \sqrt{k_1} \cdot (0{,}0034 \cdot d + 2{,}25) \cdot (0{,}001 \cdot s + 0{,}5)\ [mm]$$

or

$$t = \sqrt{k_2} \cdot \left(2 \cdot \sqrt{\frac{1}{11} \cdot L} + 0{,}8\right)\ [mm]$$

or

$$3{,}5\ [mm]$$

whichever is greater

Where:

d = determined from 12.4.3

L, k_1, k_2, s = as defined in 3.3.1

12.4.5 The face flat area, A, of floors is not to be taken as less than:

$$A = 0{,}11 \cdot k_1 \cdot L\ [cm^2]$$

Where:

L, k_1 = as defined in 3.3.1

12.4.6 The face flat thickness, t, is to be not less than the thickness of the web and the ratio of the web to the thickness of the face flat is to be not less than eight but is not to exceed sixteen.

12.4.7 Additionally, the requirements of 15.6 for bottom outboard transverse web frames are to be complied with.

12.5 Floors in machinery spaces

12.5.1 The web thickness, t, of floors in machinery spaces is to be 1 mm greater than that required by 12.4.4.

12.6 Forefoot and stem

12.6.1 The thickness of plate stems at the waterline is to comply with the requirements for plate keels as given in 14.1.

12.6.2 The cross-sectional area of bar stems, A, is not to be taken as less than:

$$A = 0{,}6 \cdot k_1 \cdot L \ [cm^2]$$

Where:

L, k_1 = as defined in 3.3.1

SECTION 13 Double bottom structure

13.1 Keel

13.1.1 The scantlings of plate and bar keels are to comply with the requirements of 12.1.

13.2 Centreline girder

13.2.1 A centre girder is to be fitted throughout the length of the craft. The web thickness, t, is to be not less than that required by:

(a) Within 0,4·L amidships

$$t = \sqrt{k_1} \cdot (0{,}06 \cdot L + 3) \ [mm]$$

or

$$t = \sqrt{k_2} \cdot \left(2 \cdot \sqrt{\frac{1}{14} \cdot L + 1}\right) \ [mm]$$

or

$$4{,}0 \ [mm]$$

whichever is greater

(b) At ends

$$t = \sqrt{k_1} \cdot (0{,}06 \cdot L + 2) \ [mm]$$

or

$$t = \sqrt{k_2} \cdot \left(2 \cdot \sqrt{\frac{1}{2} \cdot L} + 1\right) \; [mm]$$

or

$$4{,}0 \; [mm]$$

whichever is greater

Where:

L, k_1, k_2 = as defined in 3.3.1

13.2.2 The overall web depth, d, of the centre girder is to be taken as not less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

13.2.3 Additionally, the requirements of 15.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

13.3 Side girders

13.3.1 The thickness of the side girder plating is not to be taken as less than:

$$t = \sqrt{k_2} \cdot \left(2 \cdot \sqrt{\frac{1}{11} \cdot L} + 0{,}8\right) \; [mm]$$

or

$$3{,}5 \; [mm]$$

whichever is greater

Where:

L, k_2 = as defined in 3.3.1

13.3.2 Where the floor breadth does not exceed 4,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

13.3.3 Where the breadth of floor is greater than 4,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 2,0 metres.

13.4 Plate floors

13.4.1 The web thickness, t, of non-watertight plate floor is to be not less than:

$$t = \sqrt{k_1} \cdot (0{,}03 \cdot L + 3{,}5)\ [mm]$$

or

$$t = \sqrt{k_2} \cdot \left(2 \cdot \sqrt{\frac{1}{11} \cdot L} + 0{,}8\right)\ [mm]$$

or

$$3{,}5\ [mm]$$

whichever is greater

Where:

L, k_1, k_2 = as defined in 3.3.1

13.4.2 Additionally, the requirements of 15.6 for bottom outboard transverse web frames are to be complied with.

13.4.3 Plate floors are, in general, to be continuous between the centre girder and the margin plate.

13.4.4 In longitudinally framed craft, plate floors are to be fitted in the following positions:

(a) At every half frame in way of the main engines, thrust bearings, and bottom of the craft forward.

(b) Outboard of the engine seatings, at every frame within the engine room.

(c) Underneath pillars and bulkheads.

(d) Outside of the engine room at a spacing not exceeding 2,0 m.

13.4.5 Vertical flat bar stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than 10·t and a thickness of not less than t, where t is the thickness of the plate floor as calculated in 13.4.1.

13.4.6 In transversely framed craft, plate floors are to be fitted at every frame in the engine room, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 2,0m.

SECTION 14 Shell envelope plating

14.1 Keel plates

14.1.1 The breadth, b, and thickness, t, of plate keels are not to be taken as less than:

$$b = 0{,}5 \cdot L + 250\ [mm]$$

$$t = 1{,}35 \cdot \sqrt{k_1} \cdot L^{0{,}45}\ [mm]$$

Where:

L, k_1 = as defined in 3.3.1

14.1.2 In no case is the thickness of the keel to be less than that of the adjacent bottom shell plating.

14.2 Bottom outboard

14.2.1 The thickness of the bottom outboard plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3,Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{6}} + 2,0 \right) \; [mm]$$

or

$$3,5 \; [mm]$$

whichever is greater

Where:

L, k_2 = as defined in 3.3.1

14.2.2 For all craft types, the minimum bottom outboard shell thickness requirement given in 14.2.1 is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

14.3 Bottom inboard

14.3.1 The thickness of the bottom inboard plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3,Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{6}} + 2,0 \right) \; [mm]$$

or

$$3,5 \; [mm]$$

whichever is greater

Where:

L, k_2 = as defined in 3.3.1

14.3.2 For all craft types, the minimum bottom inboard shell thickness requirement given in 7.4 is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

14.4 Side outboard

14.4.1 The thickness of the side outboard plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{7}} + 1,2 \right) \; [mm]$$

or

$$3,0 \; [mm]$$

whichever is greater

Where:

L, k_2 = as defined in 3.3.1

14.5 Side inboard

14.5.1 The thickness of the side inboard plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{7}} + 1{,}2 \right) \; [mm]$$

or

$$3{,}0 \; [mm]$$

whichever is greater

Where:

L, k_2 = as defined in 3.3.1

14.6 Wet-deck

14.6.1 The thickness of the wet-deck plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{7}} + 1{,}2 \right) \; [mm]$$

or

$$3{,}0 \; [mm]$$

whichever is greater

Where:

L, k_2 = as defined in 3.3.1

14.6.2 Additionally, the thickness of the wet-deck plating is in no case to be less than the thickness of the side inboard shell plating determined from 14.5.

14.7 Transom

14.7.1 The scantlings and arrangements of the stern or transom are to be not less than that required for the adjacent bottom inboard or side outboard structure as appropriate.

SECTION 15 Shell envelope framing

15.1 General

15.1.1 The following requirements apply to longitudinally and transversely framed shell envelopes.

15.2 Bottom outboard longitudinal stiffeners

15.2.1 Bottom outboard longitudinal stiffeners are to be supported by transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 metres apart.

15.2.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (b).

15.3 Bottom outboard longitudinal primary stiffeners

15.3.1 Bottom outboard longitudinal primary stiffeners are to be supported by deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 4 metres apart.

15.3.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (a).

15.4 Bottom outboard transverse stiffeners

15.4.1 Bottom outboard transverse stiffeners are defined as local stiffening members which support the bottom shell.

15.4.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (b).

15.5 Bottom outboard transverse frames

15.5.1 Bottom outboard transverse frames are defined as stiffening members which support the bottom shell.

15.5.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM},C_I and C_A as detailed in Table 5.3.5 for the load model (a).

15.6 Bottom outboard transverse web frames

15.6.1 Bottom outboard transverse web frames are defined as primary stiffening members which support bottom shell longitudinals.

15.6.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3,Chapter 2 of the present Rules, and the coefficients C_{SM},C_I and C_A as detailed in Table 5.3.5 for the load model (a).

15.7 Bottom inboard longitudinal stiffeners

15.7.1 The scantlings and arrangements for bottom inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 15.2 using the bottom inboard stiffening member design pressure from Part 3, Chapter 2 of the present Rules.

15.8 Bottom inboard longitudinal primary stiffeners

15.8.1 The scantlings and arrangements for bottom inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 15.3 using the bottom inboard stiffening member design pressure from Part 3, Chapter 2 of the present Rules.

15.9 Bottom inboard transverse stiffeners

15.9.1 The scantlings and arrangements for bottom inboard transverse stiffeners are to be determined in accordance with the procedures described in 15.4 using the bottom inboard stiffening member design pressure from Part 3, Chapter 2 of the present Rules.

15.10 Bottom inboard transverse frames

15.10.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in 15.5 using the bottom inboard stiffening member design pressure from Part 3, Chapter 2 of the present Rules.

15.11 Bottom inboard transverse web frames

15.11.1 The scantlings and arrangements for bottom inboard transverse web frames are to be determined in accordance with the procedures described in 15.6 using the bottom inboard stiffening member design pressure from Part 3, Chapter 2 of the present Rules.

15.12 Side outboard longitudinal stiffeners

15.12.1 The side outboard longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 metres apart.

15.12.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (b).

15.13 Side outboard longitudinal primary stiffeners

15.13.1 Side outboard longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 4 metres apart.

15.13.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (a).

15.14 Side outboard transverse stiffeners

15.14.1 Side outboard transverse stiffeners are defined as local stiffening members supporting the side shell.

15.14.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (b).

15.15 Side outboard transverse frames

15.15.1 Side outboard transverse frames are defined as stiffening members which support the side shell.

15.15.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (a).

15.16 Side outboard transverse web frames

15.16.1 Side outboard transverse web frames are defined as primary stiffening members which support side shell longitudinals.

15.16.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (a).

15.17 Side inboard longitudinal stiffeners

15.17.1 The scantlings and arrangements for side inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 15.12 using the side inboard design pressure from Part 3, Chapter 2 of the present Rules.

15.18 Side inboard longitudinal primary stiffeners

15.18.1 The scantlings and arrangements for side inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 15.13 using the side inboard design pressure from Part 3, Chapter 2 of the present Rules.

15.19 Side inboard transverse stiffeners

15.19.1 The scantlings and arrangements for side inboard transverse stiffeners are to be determined in accordance with the procedures described in 15.14 using the side inboard design pressure from Part 3, Chapter 2 of the present Rules.

15.20 Side inboard transverse frames

15.20.1 The scantlings and arrangements for side inboard transverse stiffeners are to be determined in accordance with the procedures described in 15.16 using the side inboard design pressure from Part 3, Chapter 2 of the present Rules.

15.21 Side inboard transverse web frames

15.21.1 The scantlings and arrangements for side inboard transverse stiffeners are to be determined in accordance with the procedures described in 15.15 using the side inboard design pressure from Part 3, Chapter 2 of the present Rules.

15.22 Wet-deck longitudinal stiffeners

15.22.1 The wet-deck longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 metres apart.

15.22.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (b).

15.22.3 In no case are the scantlings and arrangements for the wet-deck longitudinal stiffeners to be taken as less than those required for the side inboard longitudinal stiffeners detailed in 15.17.

15.23 Wet-deck longitudinal primary stiffeners

15.23.1 Wet-deck longitudinal primary stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced no more than 4 metres apart.

15.23.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (a).

15.23.3 In no case are the scantlings and arrangements for the wet-deck longitudinal primary stiffeners to be taken as less than those required for the side inboard longitudinal primary stiffeners detailed in 15.18.

15.24 Wet-deck transverse stiffeners

15.24.1 Wet-deck transverse stiffeners are defined as local stiffening members supporting the wet- deck.

15.24.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (b).

15.24.3 In no case are the scantlings and arrangements for the wet-deck transverse stiffeners to be taken as less than those required for the side inboard transverse stiffeners detailed in 15.19.

15.25 Wet-deck transverse frames

15.25.1 Wet-deck transverse frames are defined as stiffening members which support the wet-deck.

15.25.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (a).

15.25.3 In no case are the scantlings and arrangements for the wet-deck transverse frames to be taken as less than those required for the side inboard transverse frames detailed in 15.20.

15.26 Wet-deck transverse web frames

15.26.1 Wet-deck transverse web frames are defined as primary stiffening members which support wet-deck longitudinals.

15.26.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (a).

15.26.3 In no case are the scantlings and arrangements for the wet-deck transverse web frames to be taken as less than those required for the side inboard transverse web frames detailed in 15.21.

SECTION 16 Deck structures

16.1 Cross-deck plating

16.1.1 The thickness of the cross-deck plating is to be determined from the general plating equation given in 3.10, using the design pressure from Part 3, Chapter 2 of the present Rules.

16.1.2 The thickness of the cross-deck plating is in no case to be less than the appropriate minimum requirements given below:

(a) Strength/Main deck plating

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{7}} + 1{,}2 \right) \; [mm]$$

or

$$3{,}0 \; [mm]$$

whichever is greater

(b) Lower deck/Inside deckhouse plating

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{29}} + 1{,}7 \right) \; [mm]$$

or

$$2{,}0 \; [mm]$$

whichever is greater

Where:

L, k_2 = as defined in 3.3.1

16.2 Cross-deck stiffening

16.2.1 The Rule requirements for section modulus, inertia and web area for the cross-deck primary stiffeners are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (a).

16.2.2 The Rule requirements for section modulus, inertia and web area of the strength / weather deck secondary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 5.3.5 for the load model (a).

SECTION 17 Bulkheads and deep tanks

17.1 Longitudinal bulkheads within the cross-deck structure

17.1.1 The scantlings and arrangements for cross deck longitudinal bulkheads are to be determined in accordance with the procedures described in 9.2 and 9.3 for bulkheads in mono-hull craft.

17.2 Transverse bulkheads within the cross-deck structure

17.2.1 The scantlings of cross deck transverse bulkheads are to be determined in accordance with the procedures described in 9.2 and 9.3 for bulkheads in mono-hull craft.

SECTION 18 Superstructures, deckhouses and bulwarks

18.1 General

18.1.1 The scantlings and arrangements for superstructures, deckhouses and bulwarks are to be determined in accordance with the procedures described in SECTION 10 for mono-hull craft.

CHAPTER 6 Hull Construction - Aluminium

Contents

SECTION 1 General

1.1 General Requirements

1.1.1 The Rules apply to mono-hull and multi-hull vessels of normal form, speed and proportions. Despite the fact that the Rules refer to aluminium craft of all welded construction, other materials will be specially considered on the basis of the Rules.

1.2 Documentation to be submitted

1.2.1 Documentation including the following particulars is to be submitted:

- Profile and decks
- Shell expansion
- Propeller brackets
- Midship sections showing longitudinal and transverse material
- Pillars and girders
- Oiltight and watertight bulkheads
- Engine room construction
- Engine and thrust seatings
- Double bottom construction
- Aft end construction
- Hatch cover construction
- Fore end construction
- Deckhouses and superstructures
- Sternframe
- Equipment
- Rudder, stock and tiller
- Loading Manuals, preliminary and final (where applicable)
- Welding schedule
- Ice strengthening
- Scheme of corrosion control (where applicable)
- Bilge keels showing material grades, welded connections and detail design
- Hull penetration plans
- Support structure for masts, derrick posts or cranes

1.2.2 The following additional documentation are also to be submitted:

- Capacity plan
- Dry-docking plan
- General arrangement
- Lines plan or equivalent
- Sail/rigging plan, indicating loadings (as applicable to sailing craft)
- Towing and mooring arrangements

1.2.3 The following additional calculations are also to be submitted:

- Calculation of hull girder still water and dynamic bending moments and shear forces as applicable
- Calculation of equipment number
- Preliminary freeboard calculation

– Calculation of midship section modulus

1.3 Exceptions

1.3.1 In case of craft which are not covered by the present Rules, such as craft of unsual form, speed or proportions, intended for the carriage of special cargoes, or for special or restricted service, they will be individually considered based on the general requirements of the Rules.

SECTION 2 Design and construction principles

2.1 Continuity and alignment

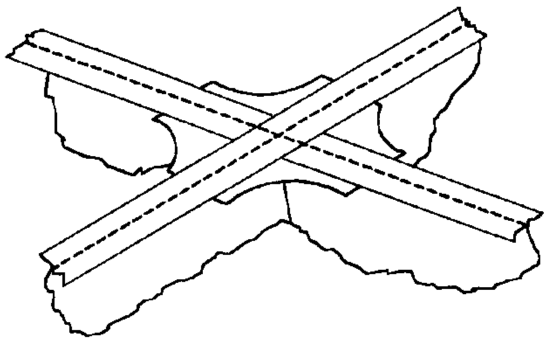
2.1.1 The arrangement of material is to be such as will ensure structural continuity. Abrupt changes of shape or section, sharp corners and points of stress concentration are undesirable and are to be avoided.

2.1.2 Where members abut on both sides of a bulkhead or similar structure, care is to be taken to ensure good alignment.

2.1.3 Pillars and pillar bulkheads are to be fitted in the same vertical line wherever possible, and elsewhere arrangements are to be made to transmit the out of line forces satisfactorily. The load at head and heel of pillars is to be effectively distributed and arrangements are to be made to ensure the adequacy and lateral stability of the supporting members.

2.1.4 Continuity is to be maintained where primary members intersect and where the members are of the same depth, a suitable gusset plate is to be fitted (see Figure 6.2.1).

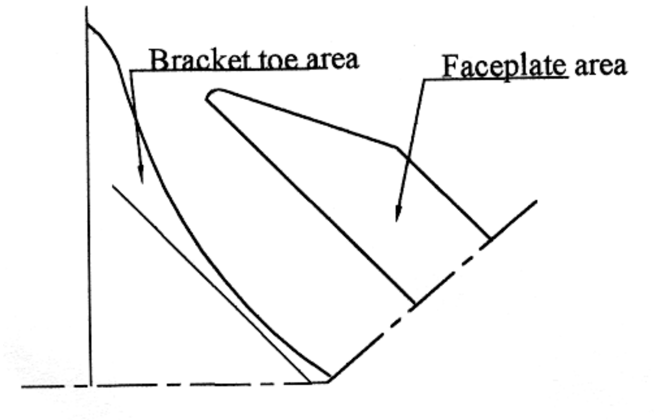
Figure 6.2.1: Primary member intersection



2.1.5 End connections of structural members are to provide adequate end fixity and effective distribution of the load into the supporting structure.

2.1.6 The stress concentrations can be minimised by paying particular attention to the design of the end bracket toes. Sniped face plates which are welded onto the edge of primary member brackets are to be carried well around the radiuses bracket toe and are to incorporate a taper not exceeding one in three. Adequate cross sectional area is to be provided through the bracket toe at the end of the snipe, in case sniped face plates are welded adjacent to the edge of primary member brackets.Generally, this area measured perpendicular to the face plate, is to be not less than 60% of the full cross-sectional area of the face plate (see Figure 6.2.2).

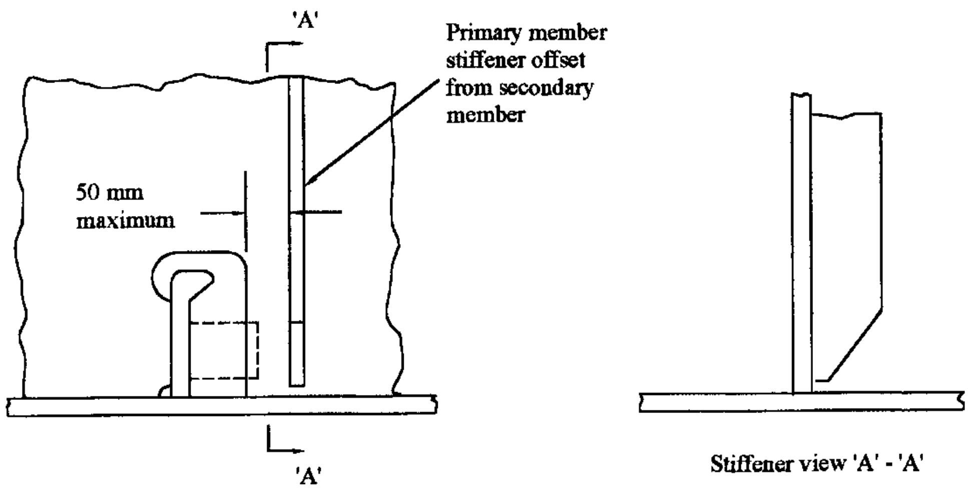
Figure 6.2.2: Bracket toe construction



2.2 Arrangement with offset stiffener

2.2.1 Where the stiffeners of the double bottom floors and transverse bulkheads are unconnected to the secondary members and offset from them (see Figure 6.2.3) the collar arrangement for the secondary members are to satisfy the requirements of 2.3. Moreover, the fillet welds attaching the lugs to the secondary members are to be based on a weld factor of 0,44 for the throat thickness. To facilitate access for welding the offset stiffeners are to be located 50 mm from the slot edge furthest from the web of the secondary member. The ends of the offset stiffeners are to be suitably tapered and softened.

Figure 6.2.3: Arrangement with offset stiffener



2.3 Arrangements at intersection of continuous secondary and primary members

2.3.1 In order to minimise stress concentrations around the perimeter of the opening and in the attached hull envelope or bulkhead plating, cut-outs for the passage of secondary members through the webs of primary members, and the related collaring arrangements, are to be designed. It is necessary to proceed to an investigation of the critical shear buckling stress of the panel, in which the cut-out is made. In high stress areas, the cut-outs for longitudinals are to have double lugs.

2.3.2 The cut-outs are to have a breadth as small as practicable, with the top edge suitably radiuses. Cut-outs are to have smooth edges, and the corner radii are to be as large as practicable, with a minimum of 20% of the breadth of the cut-out or 25 mm, whichever is the greater. It is suggested that the web plate connection to the hull envelope, or bulkhead, end in a smooth tapered 'soft toe'. In Part 2, Chapter 2, Figure 2.2.4 are shown recommended shapes of cut-out. However, consideration will be given to other shapes, in order to maintain equivalent strength and minimise stress concentration.

2.3.3 Symmetrical secondary members are to be connected by lugs on one or both sides, as necessary.

2.3.4 Asymmetrical secondary members are to be connected on the heel side to the primary member web plate. Additional connection by lugs on the opposite side may be required.

2.3.5 Where the primary member stiffener is connected to the secondary member it is to be aligned with the web of the secondary member, except where the face plate of the latter is offset and abutted to the web. In that case the stiffener connection is to be lapped.

2.3.6 Fabricated longitudinals, which may have the face plate welded to the underside of the web, leaving the edge of the web exposed, are not recommended for side shell and longitudinal bulkhead longitudinals. Where it is proposed to fit such sections, a symmetrical arrangement of connection to transverse members is to be incorporated. This can be achieved by fitting backing structure on the opposite side of the transverse web or bulkhead.

2.3.7 Where a bracket is fitted to the primary member web plate in addition to a connected stiffener it is to be arranged on the opposite side to, and in alignment with the stiffener. The arm length of the bracket is to be not less than the depth of the stiffener, and its cross-sectional area through the throat of the bracket is to be included in the calculation of the area of the primary web stiffener in way of the connection.

2.3.8 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Testing procedures and details of the calculations made are to be submitted.

2.4 Openings

2.4.1 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear.In particular, manholes and similar openings are not to be cut in vertical or horizontal diaphragm plates in narrow cofferdams or in floors and double bottom girders close to their span ends, or below the heels of pillars, unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory.

2.4.2 Manholes, lightening holes and other openings are to be suitably framed and stiffened where necessary.

2.4.3 Drain and air holes, scallops and notches are to be kept at least 200 mm clear of the toes of end brackets and other areas of high stress. Openings are to be well rounded with smooth edges. Closely placed scallops are not permitted. Widely spaced air or drain holes may be accepted, only if they have elliptical shape, or equivalent, to minimise stress concentration and are, in general, cut clear of the weld connection.

2.5 Openings in the web

2.5.1 Where openings are cut in the web, the depth of opening is not to exceed 50% of the web depth, and the opening is to be so located that the edges are not less than 25% of the web depth from the face plate. The length of opening is not to exceed the web depth or 60% of the secondary member spacing, whichever is the greater, and the ends of the openings are to be equidistant from the corners of cut-outs for secondary members. Where larger openings are proposed, the arrangements and compensation required will be specially considered. Openings are to have well rounded corners and smooth edges.

2.6 Tank boundary penetrations

2.6.1 Where structural members pass through the boundary of a tank, and leakage into the adjacent space could be hazardous or undesirable, full penetration welding is to be adopted for the members for at least 150 mm on each side of the boundary. Alternatively a small scallop of suitable shape may be cut in the member close to the boundary outside the compartment, and carefully welded all round.

2.7 Web stability

2.7.1 Primary members of asymmetrical section are to be supported by tripping brackets at alternate secondary members. If the section is symmetrical, the tripping brackets may be four spaces apart.

2.7.2 Tripping brackets are in general required to be fitted at the toes of end brackets and in way of heavy or concentrated loads such as the heels of pillars.

SECTION 3 Structural Scantlings for Mono-Hull Vessels – General Principles and Requirements

3.1 Application

3.1.1 The requirements of this Chapter are applicable to mono-hull craft of aluminium construction.

3.2 Direct calculations

3.2.1 In case the design, form or proportions of the craft are unusual, or the speed of the craft exceeds 60 knots, the scantlings are to be determined by direct calculation.

3.2.2 In any case direct calculations based on well established principles of mechanics may be used alternatively or complementary to these Rules, provided that the achieved level of safety remains equivalent.

3.3 Symbols and definitions

3.3.1 The following symbols are used in this chapter:

L = Rule length of craft, in metres, is the distance on the summer load waterline from the forward side of the stem to the after side of the rudder post or to the centre of the rudder stock if there is no rudder post. L is to be not less than 96%, and need not be greater than 97%, of the extreme length on the summer load waterline. In craft without rudders, the Rule length, L, is to be taken as 97% of the extreme length on the summer load waterline

B = moulded breadth of craft, in metres

I = moment of inertia, in cm^4

SM = section modulus of the stiffening member, in cm^3 A = shear area of stiffener web, in cm^2

p = design pressure, in kN/m^2

s = stiffener spacing, in mm

l = stiffener overall length, in metres

le = effective span length, in metres

K_{AR} = panel aspect ratio correction factor as defined in 3.9

t_p = plating thickness, in mm

K_c = convex curvature correction factor as defined in 3.8

σ_a = guaranteed minimum 0,2% proof stress of the alloy in the welded condition, in N/mm^2

τ_a = $\sigma_a/\sqrt{3}$

k_1, k_2 = material factors as defined in Table 6.3.1

E = modulus of elasticity, in N/mm^2

3.4 Material properties

3.4.1 The basic grade of aluminium alloy is taken as marine grade 5083-0 with the following mechanical properties:

	N/mm^2
0,2% proof stress (minimum)	125
Tensile strength	260
Modulus of elasticity	69 x 10^3

3.4.2 Where alloys other than the basic one mentioned in 3.4.1 are used, then the Rule Requirements should be properly modified by taking into account the following material factors:

Table 6.3.1: Material factors

Alloy	k_1	k_2
5083-0 and F	1,00	1,00
5083-H321	0,58	0,75
5086-0 and F	1,32	1,15
5086-H112	1,14	1,1
5086-H321	0,64	0,83
6061-T6	0,52	0,73
6082-T6	0,52	0,73

3.5 High strength sheet and plate

3.5.1 The welding procedures for the welding of high strength sheet and plate are of great importance and should be taken into consideration. The 0,2% yield strength values in the welded condition will, in general, be significantly less than in the unwelded condition. These reduced values are to be used in the determination of the Rule scantlings.

3.6 High strength extrusions

3.6.1 High strength extrusions are generally used in superstructures, deckhouses, decks and bulkheads. Special consideration will be given to their use in other areas.

3.6.2 Butt welds and seams are to be carefully positioned clear of areas of high stress and where practicable are to be orientated parallel to the direction of the main stresses.

3.7 Effective width of attached plating

3.7.1 In case of primary support members the effective width of the attached plating may be taken equal to one-half of the sum of the spacings between parallel adjacent members or equivalent support.

3.7.2 In case of secondary stiffening members the effective width of the attached plating may be taken as:

$$2 \cdot t_p \cdot \sqrt{\frac{E}{\sigma_a}} \ [mm]$$

but not greater than the actual spacing of the stiffeners. In the above formula σ_a is not to be taken greater than 160 N/mm^2.

3.7.3 Where the web of the stiffener intersects the actual plating at an angle less than 70° the properties of the section are to be determined about an axis parallel to the attached plating.

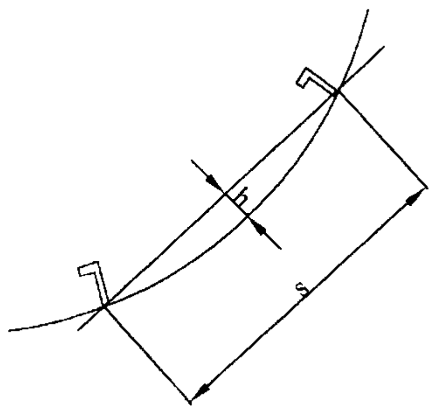
3.8 Consideration of convex curvature

3.8.1 For panels exhibiting significant curvature, the following reduction coefficient is to be taken into account:

$$K_c = 1 - \frac{h}{s}$$

without being less than 0,75, where distances h and s are defined in Figure 6.3.1.

Figure 6.3.1: Convex curvature



3.9 Aspect ratio correction

3.9.1 The thickness of plating as determined by the Rules may be reduced when the panel aspect ratio is taken into consideration. In such cases a panel aspect ratio correction factor may be applied:

3.10 General plating thickness

3.10.1 The thickness of plating, t, is, in general to be in accordance with the following formula:

$$t = 0{,}0225 \cdot s \cdot K_c \cdot K_{AR} \cdot \sqrt{\frac{p}{\sigma}}\ [mm]$$

Where:

σ	=	limiting bending stress value for the plating element under consideration given in Table 6.3.2,
s, K_c, K_{AR}, p, σ_a	=	as defined in 3.3.1.,

3.11 Stiffening general

3.11.1 The requirements for section modulus, inertia and web area stiffening members are in general to be in accordance with the following:

(a) Section

$$SM = C_{SM} \cdot \frac{p \cdot s \cdot l_e^2}{\sigma}\ [cm^3]$$

Where:

C_{SM}	=	section modulus coefficient dependent on the loading model assumption taken from Table 6.3.5,
σ	=	limiting bending stress value for stiffening member given in Table 6.3.2,
p, s, l_e, σ_a	=	as defined in 3.3.1.

(b) Inertia:

$$I = C_I \cdot f_\delta \cdot \frac{p \cdot s \cdot l_e^3}{100 \cdot E} \cdot 10^4\ \ [cm^4]$$

Where:

C_I	=	inertia coefficient dependent on the loading model assumption taken from Table 6.3.5,
f_δ	=	limiting deflection value for stiffener member given in Table6.3.3,
p, s, l_e, E	=	as defined in 3.3.1.

(c) Web area:

$$A = C_A \cdot \frac{p \cdot s \cdot l_e}{100 \cdot \tau}\ \ [cm^2]$$

Where:

C_A	=	web area coefficient dependent on the loading model assumption taken from

Table 6.3.5,

τ = limiting shear stress value for stiffener member given in Table 6.3.2,

p, s, l_e, τ_a = as defined in 3.3.1.

Table 6.3.2: Limiting stress coefficients for local loading

Item		Limiting stress value		
		Bending stress σ	**Shear stress τ**	**Equivalent stress**
Shell envelope				
Bottom shell plating	- slamming zone	$0{,}85 \cdot \sigma_a$	-	-
	- elsewhere	$0{,}75 \cdot \sigma_a$	-	-
Side shell plating	- slamming zone	$0{,}85 \cdot \sigma_a$	-	-
	- elsewhere	$0{,}75 \cdot \sigma_a$	-	-
Keel		$0{,}75 \cdot \sigma_a$	-	-
Bottom structure				
Secondary stiffening	- slamming zone	$0{,}75 \cdot \sigma_a$	$0{,}75 \cdot \tau_a$	-
	- elsewhere	$0{,}65 \cdot \sigma_a$	$0{,}65 \cdot \tau_a$	-
Primary girders and web frames		$0{,}65 \cdot \sigma_a$	$0{,}65 \cdot \tau_a$	$0{,}75 \cdot \sigma_a$
Engine girders		$0{,}55 \cdot \sigma_a$	$0{,}55 \cdot \tau_a$	$0{,}75 \cdot \sigma_a$
Side structure				
Secondary stiffening	- slamming zone	$0{,}75 \cdot \sigma_a$	$0{,}75 \cdot \tau_a$	-
	- elsewhere	$0{,}65 \cdot \sigma_a$	$0{,}65 \cdot \tau_a$	-
Primary girders and web frames		$0{,}65 \cdot \sigma_a$	$0{,}65 \cdot \tau_a$	$0{,}75 \cdot \sigma_a$
Bow doors				
Plating		$0{,}65 \cdot \sigma_a$	-	-
Secondary stiffening		$0{,}51 \cdot \sigma_a$	$0{,}433 \cdot \tau_a$	-
Primary stiffening		$0{,}51 \cdot \sigma_a$	$0{,}34 \cdot \tau_a$	$0{,}64 \cdot \sigma_a$
Main / strength deck plating and stiffeners				
Plating		$0{,}75 \cdot \sigma_a$	-	-
Secondary stiffening		$0{,}65 \cdot \sigma_a$	$0{,}65 \cdot \tau_a$	-
Primary girders and web frame		$0{,}65 \cdot \sigma_a$	$0{,}65 \cdot \tau_a$	$0{,}75 \cdot \sigma_a$
Hatch covers		$0{,}55 \cdot \sigma_a$	$0{,}55 \cdot \tau_a$	$0{,}64 \cdot \sigma_a$
Superstructures / deckhouses				
Deckhouse front 1st tier	- plating	$0{,}65 \cdot \sigma_a$	-	-
	- stiffening	$0{,}60 \cdot \sigma_a$	$0{,}60 \cdot \tau_a$	-
Deckhouse front upper tiers	- plating	$0{,}75 \cdot \sigma_a$	-	-
	- stiffening	$0{,}65 \cdot \sigma_a$	$0{,}65 \cdot \tau_a$	-
Deckhouse aft and sides - plating	- plating	$0{,}75 \cdot \sigma_a$	-	-
	- stiffening	$0{,}75 \cdot \sigma_a$	$0{,}75 \cdot \tau_a$	-
Coachroof	- plating	$0{,}65 \cdot \sigma_a$	-	-

Item		Limiting stress value		
		Bending stress σ	Shear stress τ	Equivalent stress
	- stiffening	$0{,}65 \cdot \sigma_a$	$0{,}65 \cdot \tau_a$	-
House top	- plating	$0{,}75 \cdot \sigma_a$	-	-
	- stiffening	$0{,}75 \cdot \sigma_a$	$0{,}75 \cdot \tau_a$	-
Lower/inner decks and house top subject to personnel loading				
	- plating	$0{,}75 \cdot \sigma_a$	-	-
	- stiffening	$0{,}60 \cdot \sigma_a$	$0{,}60 \cdot \tau_a$	-
Bulkheads				
(a) Collision bulkhead	- plating	$0{,}75 \cdot \sigma_a$	-	-
	- secondary stiffening	$0{,}65 \cdot \sigma_a$	$0{,}65 \cdot \tau_a$	-
	- primary stiffening	$0{,}65 \cdot \sigma_a$	$0{,}65 \cdot \tau_a$	$0{,}75 \cdot \sigma_a$
(b) Watertight bulkhead	- plating	$1{,}00 \cdot \sigma_a$	-	-
	- secondary stiffening	$0{,}95 \cdot \sigma_a$	$0{,}95 \cdot \tau_a$	-
	- primary stiffening	$0{,}90 \cdot \sigma_a$	$0{,}90 \cdot \tau_a$	$1{,}00 \cdot \sigma_a$
Watertight bulkhead doors		$0{,}825 \cdot \sigma_a$	$0{,}825 \cdot \tau_a$	-
Structure supporting watertight doors		$0{,}80 \cdot \sigma_a$	$0{,}80 \cdot \tau_a$	-
(c) Minor bulkheads	- plating	$0{,}65 \cdot \sigma_a$	-	-
	- secondary stiffening	$0{,}65 \cdot \sigma_a$	$0{,}65 \cdot \tau_a$	-
	- primary stiffening	$0{,}65 \cdot \sigma_a$	$0{,}65 \cdot \tau_a$	$0{,}75 \cdot \sigma_a$
(d) Deep tank bulkheads	- plating	$0{,}65 \cdot \sigma_a$	-	-
	- secondary stiffening	$0{,}65 \cdot \sigma_a$	$0{,}65 \cdot \tau_a$	-
	- primary stiffening	$0{,}75 \cdot \sigma_a$	$0{,}75 \cdot \tau_a$	-

Table 6.3.3: Limiting deflection ratio

Item		Deflection ratio, f_δ
Bottom structure		
	- secondary stiffening	4,75
	- primary girders and web frames	6,25
Side structure		
	- secondary stiffening	4,75
	- primary girders and web frames	6,25
Main/strength deck structures		
	- secondary stiffening	6,25
	- primary girders and web frames	7,75
	- hatch covers	7,75
Superstructures/deckhouses stiffeners		
Generally	- secondary	4,00
	- primary	4,75
Coachroof	- secondary	4,75
	- primary	6,25
House top	- secondary	4,00
	- primary	4,00
Lower/inner decks and house top subject to personnel loading		
	- secondary	4,75

	- primary	6,25
Deep tank structures		
Stiffeners	- secondary members	5,50
	- primary members	6,25
Watertight bulkhead structures		
Stiffeners	- secondary members	4,00
	- primary members	4,75

3.12 Geometric properties and proportions of stiffener sections

3.12.1 In order to avoid structural instability and appearance of local buckling, the proportions of stiffening members are in general to be in accordance with the requirements of paragraphs 3.12.2 and 3.12.3.

3.12.2 In case of flat bars the minimum web thickness should be greater than 1/15 of the web depth and always greater than 3 mm.

3.12.3 Where rolled or built sections are used the minimum web thickness should be at least equal to 1/50 of the web depth and always greater than 3 mm. In this case the width of the unsupported face plate or flanges should not be greater than 16 times the thickness of the face plate or flange.

3.13 Effective span length

3.13.1 The effective length of span of a stiffening member depends on length of the member and the design of each end connections.In general, the effective length of span is always equal or less than the phisical length of the member.

3.13.2 The effective length of span of primary supporting members is the distance between the two span points, which should be taken at a distance b_e from each end of the member, where b_e is defined as follows:

$$b_e = b_b \cdot \left(1 - \frac{d_w}{d_b}\right)$$

Where:

b_e, b_b, d_w, d_b = as shown in Figure 6.3.2.

3.13.3 The effective length of span of rolled or built up secondary stiffening members is the distance between the two span points, which in this case should be taken at the point where the depth of the end bracket, measured from the face of the secondary stiffening member, is equal to the depth of the member, see Figure 6.3.2. Where there is no end bracket, the span point is to be measured between primary member webs.

3.13.4 Where the stiffening member is curved then the span is to be taken as the effective chord length between span points.

3.14 End brackets

3.14.1 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the scantlings of the end brackets are to be such that their section modulus and effective cross-sectional area are not less than those of the member.

3.14.2 In other cases the scantlings of the bracket are to be based on the modulus, according to the Table 6.3.4.

Figure 6.3.2: Span points

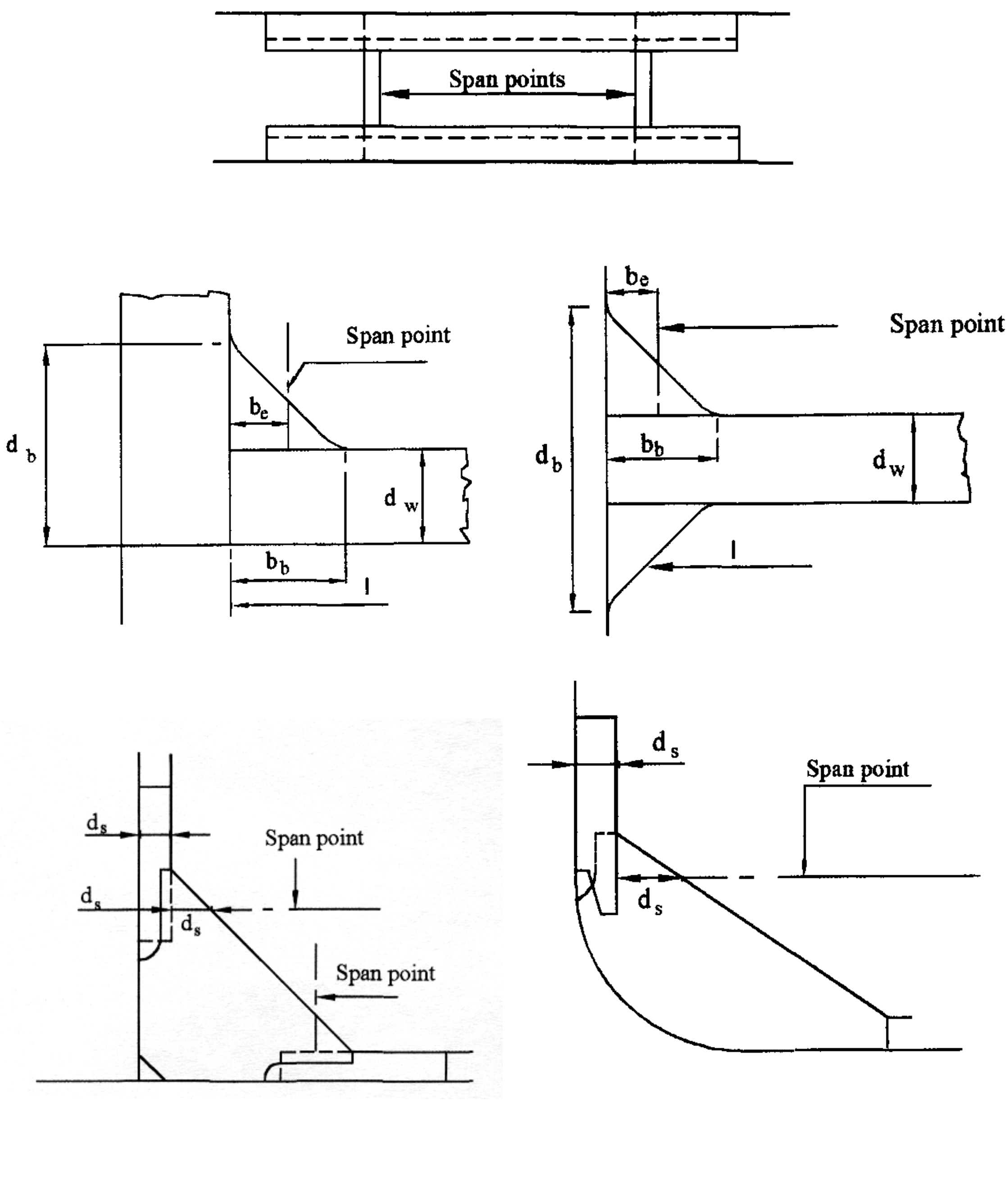
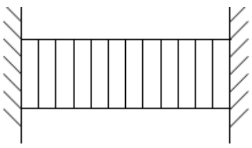
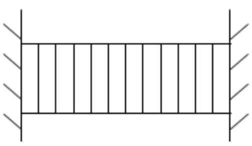
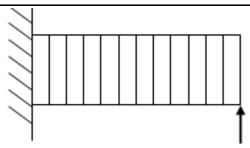
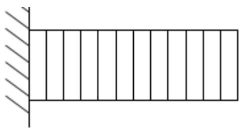
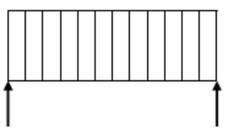


Table 6.3.4: Section modulus of brackets

Location of the bracket	Section Modulus of the bracket
Bracket at the head of a main transverse frame where frame terminates	modulus of the frame
Bracket connecting stiffener to primary member	modulus of the stiffener
Brackets connecting lower deck beams or longitudinals to the main frame in the forward 0,5L	modulus of the frame
Elsewhere	the lesser modulus of the members being connected by the bracket

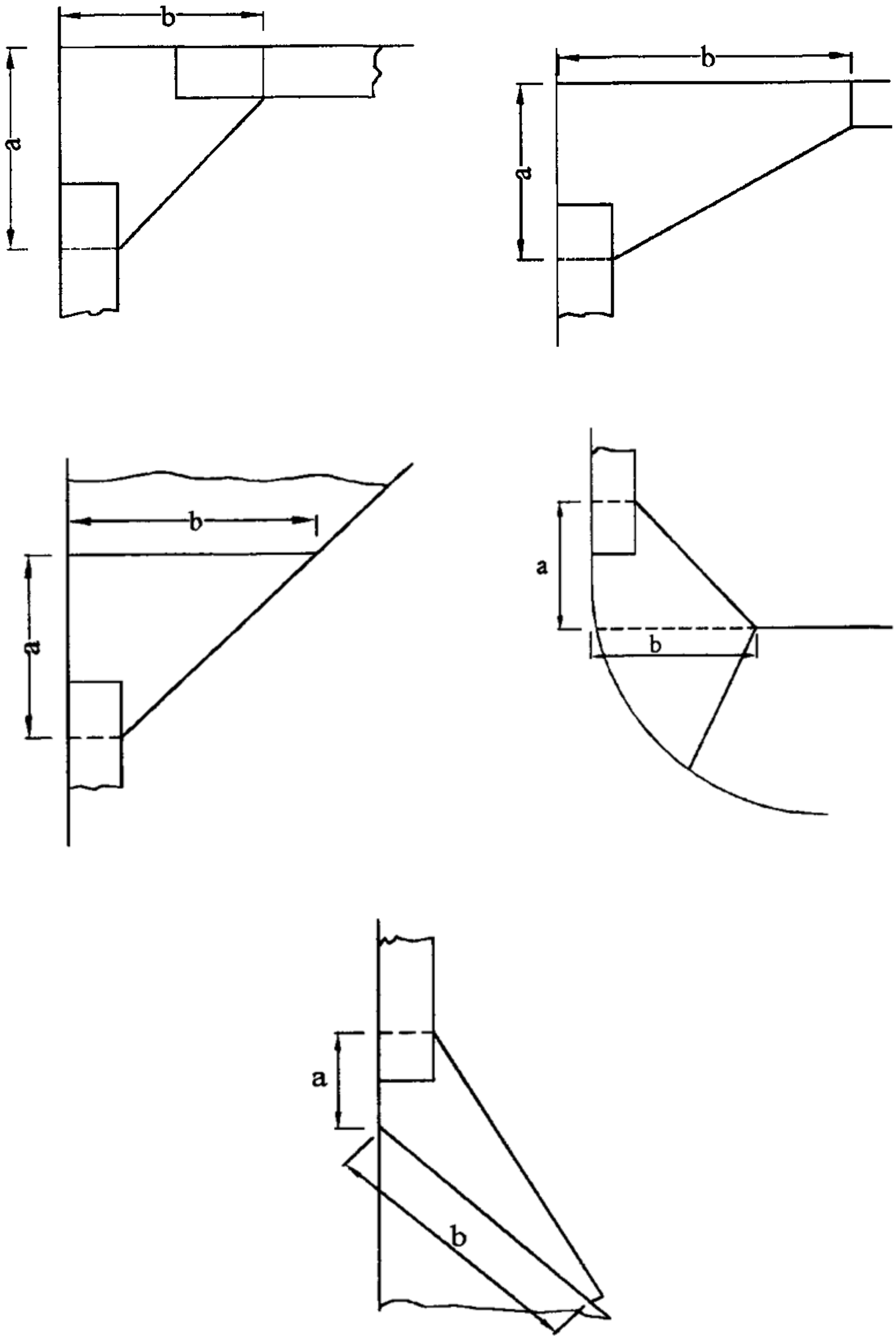
Table 6.3.5: Section modulus, inertia and web area coefficients

Load model	Position 123	Position	Web area coefficient C_A	Section modulus coefficient C_{SM}	Inertia coefficient C_I	Application
(a)		1 2 3	1/2 - 1/2	1/12 1/24 1/12	- 1/384 -	Primary and other members where the end fixity is considered encastre
(b)		1 2 3	1/2 - 1/2	1/10 1/10 1/10	- 1/288 -	Local, secondary and other members where the end fixity is considered to be partial
(c)		1 2 3	5/8 - 3/8	1/8 9/128 -	- 1/185 -	Various
(d)		1 2 3	1 - -	1/2 - -	- - 1/8	Various
(e)		1 2 3	1/2 - 1/2	- 1/8 -	- 5/384 -	Hatch covers, glazing and other members where the ends are simply supported

3.14.3 The web thickness and face flat area of end brackets are not in general to be less than those of the connecting stiffeners. In addfition to this, the stiffener proportion requirements of 3.12 are to be satisfied.

3.14.4 In Figure 6.3.3 are shown diagrammatically typical arrangements of stiffener end brackets.

Figure 6.3.3: Stiffener end brackets



3.14.5 The lengths, a and b of the arms are measured from the plating to the toe of the bracket and are to be such that:

a) $a \geq 0{,}8\ l_b$

b) $b \geq 0{,}8\ l_b$

c) $a + b \geq 2{,}0\ l_b$

where:

a,b= the actual lengths of the two arms of the bracket, in mm, measured from the plating to the toe of the bracket.

$$l_b = 90 \cdot \left(2 \cdot \sqrt{\frac{SM}{14 + \sqrt{SM}}} - 1\right) [mm]$$

Where:

SM = the section modulus of the secondary member, in cm^3

l_b should not be taken as less than twice the web depth of the stiffener on which the bracket scantlings are to be based.

3.14.6 Where any of the following apply, the free edge of the bracket is to be stiffened:

a) The bracket is fitted at the lower end of main transverse side framing.

b) The section modulus, SM, exceeds 500 cm^3.

c) The length of free edge exceeds 40 times the bracket thickness.

3.14.7 Where a face flat is fitted, its breadth, b_f, is to be not less than:

$$b_f = 30 \cdot \left(1 + \frac{SM}{1000}\right) [mm]$$

but not less than 40 mm.

3.14.8 Where the stiffening member is lapped onto the bracket, the length of overlap is not to be less than $10\sqrt{SM}$, or the depth of stiffener, whichever is the greater.

3.14.9 Where the edge is stiffened by a welded face flat, the cross-sectional area of the face flat is to be not less than:

(a) $0{,}017 \cdot k_1 \cdot b_f \cdot T_B$ cm^2 for offset edge stiffening.

(b) $0{,}014 \cdot k_1 \cdot b_f \cdot T_B$ cm^2 for symmetrically placed stiffening.

Where:

T_B = the thickness of the bracket, in mm

b_f = breadth of face flat, in mm

k_1 = as defined in 3.3.1

3.14.10 Where the free edge of the bracket is hollowed out, it is to be stiffened or increased in size to ensure that the modulus of the bracket through the throat is not less than that of the required straight edged bracket.

3.14.11 The arrangement of the correction between the stiffener and the bracket is to be such that at no point in the connection is the actual modulus reduced to less than that of the stiffener with associated plating.

3.15 Primary member end connections

3.15.1 The scantling requirements for primary member end connections in dry spaces and in tanks of all craft types are generally to comply with the requirements of 3.14, taking SM as the section modulus of the primary member.

3.15.2 Primary members must have adequate lateral stability and web stiffening. Furthermore, the structure is to be arranged in such a way to minimise hard spots and other sources of stress concentration. The openings are to have smooth edges and well rounded corners and are to be located having regard to the stress distribution and buckling strength of the panel.

3.15.3 Primary members are to be arranged in such a way to ensure effective continuity of strength, and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead, or on other members, arrangements are to be made to ensure that they are in alignment. Primary members in tanks are to form a continuous line of support and wherever possible, a complete ring system.

3.15.4 Primary members are to be provided with adequate end fixity by end brackets or equivalent structure. The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.

3.15.5 Where primary members are subject to concentrated loads, particularly if these are out of line with the member web, additional strengthening may be required.

3.15.6 Where the primary member is supported by structure which provides only a low degree of restraint against rotation, the member is generally to be extended beyond the point of support and thereafter tapered and/or scarfed into the adjacent structure over a distance generally not less than two frame spaces.

3.15.7 The thickness of the bracket is to be not less than that of the primary member web. The free edge of the bracket is to be stiffened.

3.15.8 Where a member is continued over a point of support, such as a pillar or pillar bulkhead stiffener, the design of the end connection is to be such as to ensure the effective distribution of the load into the support.

3.15.9 Where a deck girder or transverse is connected to a vertical member on the shell or bulkhead, the scantlings of the latter may be required to be increased to provide adequate stiffness to resist rotation of the joint.

3.15.10 Connections between primary members forming a ring system are to minimise stress concentrations at the junctions. Integral brackets are generally to be radiuses or well rounded at their toes. The arm length of the bracket, measured from the face of the member, is to be not less than the depth of the smaller member forming the connection.

3.16 Secondary member end connections

3.16.1 Secondary members, such as, beams, longitudinals, frames and bulkhead stiffeners forming part of the hull structure, are to be effectively continuous and are to be suitably bracketed at their end connections.

SECTION 4 Single bottom structure

4.1 Single bottom structure and appendages

4.1.1 The following requirements apply to ships with single bottom construction in association with transverse and longitudinal framing systems.

4.2 Keel

4.2.1 The breadth, and thickness of plate keels are to comply with the requirements of 6.2.

4.2.2 The cross-sectional area, A, and thickness, t, of bar keels are not, in general, be taken as less than:

$$A = k_{-1} \cdot (1{,}85 \cdot L + 2)\ [cm^2]$$

$$t = \sqrt{k_{-1}} \cdot (0{,}7 \cdot L + 8{,}25)\ [mm]$$

Where:

L, k_1 = as defined in 3.3.1

4.3 Centre keelson

4.3.1 A centre keelson is to be fitted throughout the length of the hull in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

4.3.2 Centre keelsons are to be formed of intercostal or continuous plate webs with a face plate welded to the upper edge. The face plate should be continuous. Where girder webs are intercostal, additional bracketing and local reinforcement will be required to maintain the continuity of structural strength.

4.3.3 The web depth of the centre keelson is, in general, to be equal to the depth of the floors at the centreline as specified in 4.5.3.

4.3.4 The web thickness t is to be taken not less than:

$$t = 1{,}4 \cdot \sqrt{k_{-1}} \cdot \left(\sqrt{L} + 1\right)\ [mm]$$

or

$$t = \sqrt{k_{-2}} \cdot \left(\sqrt{\frac{5}{4} \cdot L} + 1{,}4\right)\ [mm]$$

or

$$5{,}00\ [mm]$$

Whichever is greater

Where:

L, k_1, k_2 = as defined in 3.3.1

4.3.5 The cross sectional area of the face plate of the centre girder A, is to be not less than:

$$A = 0{,}56 \cdot L \cdot k_{-1}\ [cm^2]$$

4.3.6 The face flat area of the centre girder outside 0,5·L amidships may be 80% of the value given in 4.3.5.

4.3.7 The thickness of the face plate is not to be less than the thickness of the web.

4.3.8 The ratio of the width to thickness of the face plate is to be not less than eight but should not exceed sixteen.

4.3.9 Additionally, the requirements of 7.3 for bottom longitudinal primary stiffeners are to be complied with.

4.4 Side girders

4.4.1 Where the floor breadth at the upper edge exceeds 6,0 m, side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 metres. Side girders where fitted are to extend as far forward and aft as practicable and are, in general, to terminate in way of bulkheads, deep floors or other primary transverse structure.

4.4.2 The web thickness of side girders is to be taken as not less than:

$$t = 1{,}4 \cdot \sqrt{k_{1} \cdot L}\ [mm]$$

or

$$t = \sqrt{k_{2}} \cdot \left(3 \cdot \sqrt{\frac{1}{14} \cdot L} + 1{,}1\right)\ [mm]$$

or

$$4{,}00\ [mm]$$

Whichever is greater

Where:

L, k_1, k_2 = as defined in 3.3.1

4.4.3 The cross sectional area of the face plate and the thickness of side girders are to comply with the requirements for plate floors as defined in 4.5.6 and 4.5.7.

4.4.4 Watertight side girders, and side girders forming the boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads and deeptanks as detailed in 9.3 and 9.5 respectively.

4.5 Floors general

4.5.1 In transversely framed craft, plate floors are generally to be fitted at each frame and underneath every bulkhead.

4.5.2 In longitudinally framed craft, plate floors are to be fitted at every transverse web frame and bulkhead and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are in general to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast /bilge keels and the bottom of the craft forward.

4.5.3 The overall depth, d_f, of plate floors at the centreline is not to be taken as less than:

$$d = 40 \cdot B + 35 \cdot D \ [mm] \qquad when\ B < 10\ m,$$

$$d = 65 \cdot B + 35 \cdot D - 200 \ [mm] \qquad when\ B \geq 10\ m,$$

where:

D = depth

4.5.4 The web thickness, t, of plate floors, is to be in accordance with 3.12 and is to be taken as not less than:

4.5.5 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15% and the floor thickness determined using the reduced depth. The brackets are to be flanged and have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

4.5.6 The cross sectional area of the face plate, A, is not to be taken as less than:

4.5.7 The thickness of the face plate is to be not less than the thickness of the web and the ratio of the web to the thickness of the face flat is to be not less than eight but is not to exceed sixteen.

4.5.8 Additionally the requirements of 7.6 for bottom transverse web frames are to be complied with.

4.5.9 Floors are generally to be continuous from side to side.

4.5.10 The floors in the aft peak are to extend over and provide effective support to the stern tube(s) where applicable.

4.5.11 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in 9.3 and 9.5.

4.6 Floors in machinery spaces

4.6.1 The thickness, t, of the floors in machinery spaces is to be 1mm greater than that required by 4.5.4.

4.6.2 The depth and section modulus of floors anywhere between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50% of the depth given in 4.5.3.

4.7 Rudder horns

4.7.1 The scantlings of the rudder horn are to be such that the section modulus against transverse bending at any horizontal section XX (see Figure 6.4.1) is not less than:

$$SM = 2{,}8 \cdot k_1 \cdot R_A \cdot K_V \cdot (V+3)^2 \cdot \sqrt{a^2 + 0{,}5 \cdot b^2} \ [cm^3]$$

Where:

R_A = total rudder area, in m^2

V = maximum speed in the fully loaded condition, in knots

K_v = 1,0 for displacement craft with $\frac{V}{\sqrt{L_{WL}}} \leq 3,0$

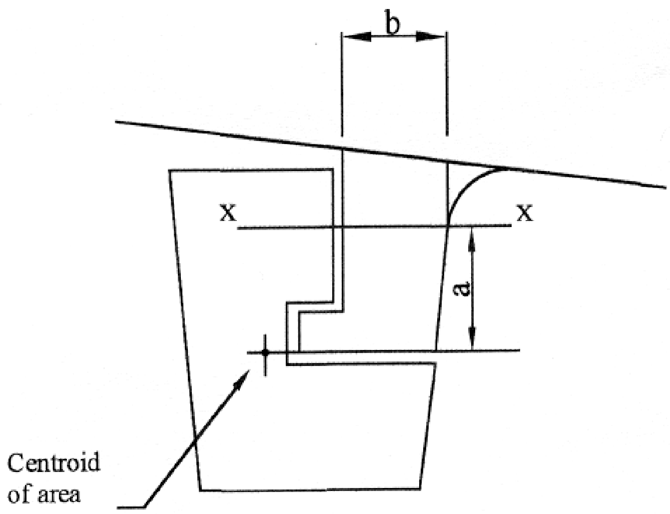
= $(1,12 - 0,005 \cdot V)^3$ for planning and semi-planing craft with $\frac{V}{\sqrt{L_{WL}}} > 3,0$

a,b = dimensions, in metres, as given in Figure 6.4.1.

L_{WL} = waterline length

4.7.2 The shell plating thickness in way of the rudder horn does not need to be taken as greater than the keel thickness required by 6.2.

Figure 6.4.1: Rudder horn



4.8 Skeg construction

4.8.1 Skegs are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

4.9 Forefoot and stem

4.9.1 The thickness of plate stems at the waterline is to comply with the requirements for plate keels as given in 6.2.

4.9.2 The cross-sectional area of bar stems, A, is not to be taken as less than:

$$A = 1,5 \cdot k_1 \cdot L \ [cm^2]$$

Where:

L, k_1 = as defined in 3.3.1..

SECTION 5 Double bottom structure

5.1 General

5.1.1 The following requirements provide for double bottom construction of aluminium mono-hull craft in association with either transverse or longitudinal framing.

5.1.2 The double bottom is to be made as wide as possible.

5.1.3 The double bottom is to be fitted extending from the collision bulkhead to the aft peak bulkhead.

5.1.4 If the double bottom is not continuous from the aft peak bulkhead to the collision bulkhead, the margin plate, side girders and centre girder must be connected to the longitudinal structure of the single bottom or shall scarf two frame spaces into the single bottom structure.

5.1.5 If the depth of the double bottom does not remain constant, efficient means of transmission of loads within 0,6L amidships are to be provided.

5.2 Keel

5.2.1 The scantlings of bar and plate keels are to comply with the requirements of 4.2.

5.2.2 Duct keels, where arranged, are to have a side plate thickness not less than:

$$t = \sqrt{k_1} \cdot (0{,}01 \cdot d_{DB} + 2)\ [mm]$$

but need not be taken as greater than 90% of the centre girder thickness given in 5.3. d_{DB} is the Rule centre girder depth given in 5.3.3 and k_1 as defined in 3.3.1.

5.2.3 Where a duct keel forms the boundary of a tank, the requirements of 9.4 and 9.5 for deep tanks are to be complied with.

5.2.4 The duct keel width is in general to be 15% of the beam or 2 metres, whichever is the lesser, but in no case is it to be taken as less than 630 mm.

5.3 Centre girder

5.3.1 A centre girder is to be fitted throughout the length of the craft. The web thickness, t, is not to be less than that required by:

(a) Within 0,4·L amidships:

$$t = \sqrt{k_1} \cdot (0{,}14 \cdot L + 4)\ [mm]$$

or

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{5}{4} \cdot L} + 1{,}4\right)\ [mm]$$

or

$$5{,}00\ [mm]$$

Whichever is greater

(b) Outside 0,4·L

$$t = \sqrt{k_1} \cdot (0{,}14 \cdot L + 2{,}75)\ [mm]$$

or

$$t = \sqrt{k_2} \cdot \left(0{,}95 \cdot \sqrt{L} + 1{,}4\right)\ [mm]$$

or

$$5{,}00\ [mm]$$

Whichever is greater

Where:

L, k_1, k_2 = as defined in 3.3.1.

5.3.2 The geometric properties of the girder section are to be in accordance with 3.12.

5.3.3 The overall depth of the centre girder, d_{DB}, is to be taken as not less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

5.3.4 Additionally, the requirements of 7.3 for bottom longitudinal primary stiffeners are to be complied with.

5.4 Side girders

5.4.1 Where the floor breadth does not exceed 6,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

5.4.2 Where the breadth of floor is greater than 6,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 3,0 metres. The web thickness of the side girders is to be taken as not less than:

$$t = \sqrt{k_2} \cdot \left(0{,}8 \cdot \sqrt{L} + 1{,}1\right)\ [mm]$$

or

$$4{,}00\ [mm]$$

Whichever is greater

Where:

L, k_2 = as defined in 3.3.1.

5.4.3 Side girders, where fitted, are to extend as far forward and aft as practicable and are in general to terminate in way of bulkheads, deep floors or other primary transverse structure.

5.4.4 Where additional side girders are fitted in way of main machinery seatings, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

5.4.5 Under the main engine, girders extending from the bottom shell to the top plate of the engine seating are to be fitted. The height of the giders is to be not less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors and/or hanging brackets are to be fitted.

5.4.6 Additionally, the requirements of 7.3 for bottom longitudinal primary stiffeners are to be complied with.

5.5 Plate floors

5.5.1 The web thickness of non-watertight plate floors, t, is to be not less than:

$$t = \sqrt{k_1} \cdot (0{,}07 \cdot L + 4{,}75)\ [mm]$$

or

$$t = \sqrt{k_2} \cdot \left(0{,}8 \cdot \sqrt{L} + 1{,}1\right)\ [mm]$$

or

$$4{,}00\ [mm]$$

Whichever is greater

Where:

L, k_1, k_2 = as defined in 3.3.1.

5.5.2 Additionally, the requirements of 7.6 for bottom transverse web frames stiffeners are to be complied with.

5.5.3 Plate floors are, in general, to be continuous between the centre girder and the margin plate.

5.5.4 In longitudinally framed craft, plate floors or equivalent structure are in general to be fitted in the following positions:

(a) At every half frame in way of the main engines, thrust bearings, and bottom of the craft forward.

(b) Outboard of the engine seatings, at every frame within the engine room.

(c) Underneath pillars and bulkheads.

(d) Outside of the engine room at a spacing not exceeding 2,0 m.

5.5.5 Vertical flat bar stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than 10·t and a thickness of not less than t, where t is thickness of the plate floor as calculated in 5.5.1.

5.5.6 In transversely framed craft, plate floors are to be fitted at every frame in the engine room, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 2,0 m.

5.6 Bracket floors

5.6.1 Between plate floors, the shell and inner bottom plating is to be supported by bracket floors. The brackets are to have the same thickness as plate floors and are to be stiffened on the unsupported edge.

5.6.2 In longitudinally framed craft, the brackets are to extend from the centre girder and margin plate to the adjacent longitudinal, but in no case is the breadth of the bracket to be taken as not less than 75% of the depth of the centre girder. They are to be fitted at every web frame at the margin plate, and those at the centre girder are to be spaced not more than 1,0 m apart.

5.6.3 In transversely framed craft, the breadth of the brackets, attaching the bottom and inner bottom frames to the centre girder and margin plate, is to be not less than 75% of the depth of the centre girder.

5.7 Additional requirements for watertight floors

5.7.1 The scantlings of watertight floors are to comply with the requirements for plate floors as given in 5.5.

5.8 Tankside brackets

5.8.1 The scantlings of tankside brackets are to comply with the requirements for plate floors given in 5.5.

5.9 Inner bottom plating

5.9.1 The thickness of the inner bottom plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{2}} + 1{,}3 \right) \; [mm]$$

or

$$3{,}50 \; [mm]$$

Whichever is greater

Where:

L, k_2 = as defined in 3.3.1.

5.9.2 Inner bottom plating forming the boundaries of tank spaces is, in addition, to comply with the requirements for watertight bulkheads or deeptanks as detailed in 9.2 or 9.4 respectively. Where the plating forms vehicle, passenger or other decks the requirements of SECTION 8 are to be complied with.

5.9.3 Inner bottom longitudinals are to be supported by inner bottom transverse web frames, floors, bulkheads or other primary structure, generally spaced not more than 2 metres apart.

5.9.4 The requirements of section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I, and C_A as detailed in Table 6.3.5 for the load model (a).

5.10 Margin plates

5.10.1 A margin plate, if fitted, is to have a thickness as required for inner bottom plating.

5.11 Manholes

5.11.1 Sufficient manholes are to be cut in the inner bottom, floors and side girders to provide adequate access to, and ventilation of, all parts of the double bottom. The size of the manhole openings is not, in general, to exceed 50% of the double bottom depth unless edge reinforcement is provided.

SECTION 6 Shell envelope plating

6.1 General

6.1.1 The following requirements are applicable to longitudinally and transversely framed shell envelopes.

6.2 Plate keel

6.2.1 The width b and the thickness t of the keel plate are not to be taken as less than:

$$b = 7{,}0 \cdot L + 340 \; [mm]$$

$$t = 1{,}85 \cdot \sqrt{k_1} \cdot L^{0{,}45} \; [mm]$$

Where:

L, k_1 = as defined in 3.3.1.

6.2.2 In no case is the thickness of the keel plate to be less than that of the adjacent bottom shell plating.

6.2.3 The thickness and width of the plate keel are to be maintained throughout the length of the craft from the transom to a point not less than 25% of the freeboard (measured at the forward perpendicular) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by 6.3.1 for the stem.

6.2.4 For large or novel craft and for yachts with externally attached ballast keels, the scantlings of the keel will be specially considered.

6.2.5 For bar keels, see 4.2.2.

6.3 Plate stem

6.3.1 The thickness of plate stems, t, is not to be taken as less than:

$$t = \sqrt{k_1} \cdot (0{,}14 \cdot L + 4) \; [mm]$$

Where:

L, k_1, k_2 = as defined in 3.3.1.

6.3.2 In no case is the thickness of the plate stem to be taken as less than the thickness of the adjacent shell plating.

6.3.3 Plate stems are to be supported by horizontal diaphragms, and where the stem radius is large, a centreline stiffener or web may be required.

6.3.4 For large or novel craft the scantlings of the stem will be specially considered.

6.3.5 The breadth of plate stems is to be not less than the width of keel as required by 6.2.1.

6.4 Bottom shell plating

6.4.1 The thickness of the bottom shell plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules, and not to be less than:

$$t_p = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{2}} + 1{,}0 \right) [mm]$$

or

$$4{,}00 \ [mm]$$

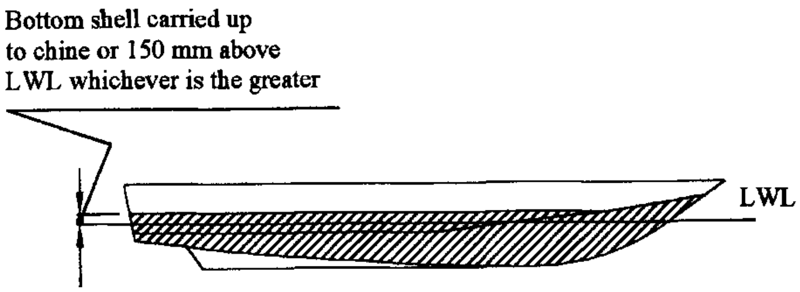
Whichever is greater

Where:

L, k_2 = as defined in 3.3.1.

6.4.2 For all craft types the minimum thickness requirement for bottom shell plating is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater see Figure 6.6.1.

Figure 6.6.1: Extent of bottom shell



6.5 Side shell plating

6.5.1 The thickness of the side shell plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{4}} + 1{,}4 \right) [mm]$$

or

$$3{,}50 \ [mm]$$

Whichever is greater

Where:

L, k_2 = as defined in 3.3.1.

6.6 Sheerstrake

6.6.1 The sheerstrake is generally to be taken as the side shell, locally reinforced in way of deck/ hull connection and fender attachment. The amount of local reinforcement will be dependent upon the arrangement of structure and the proposed service.

6.6.2 Only the designers/builders are responsible for the fendering arrangements of all craft types. The above mentioned arrangements are outside the scope of classification.

6.6.3 Fishing crafts are in general to have their shell plating scantling as required to satisfy the Rule loadings, increased by 20%. In addition to this, the side shell is not to be taken less than as bottom shell thickness, and where there are gallows, gantries, nets, or lines etc. the plating in way is to be further increased locally and /or suitably protected by sheathing or other means.

6.6.4 Where a rounded sheerstrake is adopted, the radius, in general, is to be not less than 15 times the thickness.

6.6.5 The sheerstrake thickness is to be increased by 20% at the ends of a bridge superstructure extending out to the craft's side. In case of a bridge superstructure exceeding 0,15·L, the side plating at the ends of the superstructure is also to be increased by 25% and tapered gradually into the upper deck sheerstrake.

6.7 Chines

6.7.1 The chine plate thickness is to be equivalent to the bottom shell thickness required to satisfy the Rule pressure loading, increased by 20%, or 6 mm, whichever is the greater.

6.7.2 Where tube is used in chine construction, the minimum wall thickness is to be not less than the thickness of the bottom shell plating increased by 20%.

6.8 Skegs

6.8.1 The thickness of the skeg plating is to be not less than the thickness of the adjacent bottom shell.

6.9 Transom

6.9.1 The thickness of the stern or transom is to be not less than that required for the side or bottom shell as appropriate.

6.10 Shell openings

6.10.1 Sea-inlets, or other openings, are to have well rounded corners and, so far as is practicable, are to be kept clear of the bilge radius, chine or radiused sheerstrake.

6.10.2 Openings on or near the bilge radius may be accepted provided that they are of elliptical shape, or equivalent, to minimise stress concentrations and are, in general, to be cut clear of weld connections.

6.11 Sea inlet boxes

6.11.1 The thickness of the sea inlet box plating is to be 1 mm thicker than the adjacent shell plating, or 8 mm, whichever is the greater.

SECTION 7 Shell envelope framing

7.1 General

7.1.1 The following requirements are applicable to longitudinally and transversely framed shell envelopes.

7.2 Bottom longitudinal stiffeners

7.2.1 Bottom longitudinal stiffeners are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 metres apart.

7.2.2 Bottom longitudinals are to be continuous through the supporting structures.

7.2.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules and the coefficients C_{SM}, C_I, and C_A as detailed in Table 6.3.5 for the load model (b).

7.3 Bottom longitudinal primary stiffeners

7.3.1 Bottom longitudinal primary stiffeners are to be supported by bottom deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 6 metres apart.

7.3.2 Bottom longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

7.3.3 The requirements for section modulus,inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I, and C_A as detailed in Table 6.3.5 for the load model (a).

7.4 Bottom transverse stiffeners

7.4.1 Bottom transverse stiffeners are defined as local stiffening members which support the bottom shell, and which may be continuous or intercostal.

7.4.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I, and C_A as detailed in Table 6.3.5 for the load model (b).

7.5 Bottom transverse frames

7.5.1 Bottom transverse frames are defined as stiffening members which support the bottom shell. They are to be effectively continuous and bracketed at their end connections to side frames and bottom floors as appropriate.

7.5.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I, and C_A as detailed in Table 6.3.5 for the load model (a).

7.6 Bottom transverse web frames

7.6.1 Bottom transverse web frames are defined as primary stiffening members which support bottom shell longitudinals.They are to be continuous and substantially bracketed at their end connections to side web frames and bottom floors.

7.6.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I, and C_A as detailed in Table 6.3.5 for the load model (a).

7.7 Side longitudinals stiffeners

7.7.1 The side longitudinals stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 metres apart.

7.7.2 Side longitudinals are to be continuous through the supporting structures.

7.7.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I, and C_A as detailed in Table 6.3.5 for the load model (b).

7.8 Side longitudinal primary stiffeners

7.8.1 Side longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 metres apart.

7.8.2 Side longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

7.8.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I, and C_A as detailed in Table 6.3.5 for the load model (a).

7.9 Side transverse stiffeners

7.9.1 Side transverse stiffeners are defined as local stiffening members supporting the side shell and may be continuous or intercostal.

7.9.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I, and C_A as detailed in Table 6.3.5 for the load model (b).

7.10 Side transverse frames

7.10.1 Side transverse frames are defined as stiffening members which support the side shell. They are to be effectively continuous and bracketed at their end connections to bottom floors/frames and deck beams as appropriate.

7.10.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I, and C_A as detailed in Table 6.3.5 for the load model (a).

7.11 Side transverse web frames

7.11.1 Side transverse web frames are defined as primary stiffening members which support side shell longitudinally. They are to be continuous and substantially bracketed at their head and heel connections to deck transverses and bottom web frames respectively.

7.11.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I, and C_A as detailed in Table 6.3.5 for the load model (a).

SECTION 8 Deck structures

8.1 General

8.1.1 The strength deck is:

(a) The uppermost continuous deck which forms the upper flange of the longitudinal hullgirder.

(b) A superstructure deck which extends up to 0,4L amidships and the length of which exceeds 0,15L. Superstructure decks the length of which is less than 12 m, need not be considered as strength decks.

(c) A quarter deck or the deck of a superstructure in part below the main deck, which extends through 0,4L amidships.

8.1.2 Deck sectional areas used in the deck area and section modulus calculations are to be maintained throughout the 0,4L amidships. They may be gradually reduced to 50% the normal requirement at 0,15L from the ends.

8.1.3 The geometric properties of stiffener sections are to be in accordance with 3.12.

8.2 Strength/Weather deck plating

8.2.1 The thickness of strength/weather deck plating is to be determined from the general plating equation given in 3.10 using the design pressure head from Part 3, Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{4}} + 1{,}4 \right) \; [mm]$$

or

$$3{,}50 \; [mm]$$

Whichever is greater

Where:

L, k_2 = as defined in 3.3.1.

8.2.2 The scantlings of watertight cockpits are to be of equivalent strength to those of the strength/weather deck.

8.3 Lower deck / Inside deckhouse plating

8.3.1 The thickness of the lower deck/inside deckhouse plating is to be determined from the general plating equation given in 3.10 using the design pressure head from Part 3, Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{9}} + 1{,}3 \right) [mm]$$

or

$$3{,}00\ [mm]$$

Whichever is greater

Where:

L, k_2 = as defined in 3.3.1.

8.4 Accommodation deck plating

8.4.1 Accommodation decks are in general to be treated as lower deck/inside deckhouse decks, with their plating requirements determined in accordance with 8.3.

8.5 Cargo deck plating

8.5.1 The thickness of cargo deck plating is to be determined from the general plating equation given in 3.10 using the design pressure head from Part 3, Chapter 2 of the present Rules.

8.6 Strength / Weather deck stiffening

8.6.1 The Rule requirements for section modulus, inertia and web area for the strength/weather deck primary stiffening are to be determined from the general equations given in 3.11, using the design pressure heads from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (a). The minimum thickness for the strength/weather deck primary stiffening is to be determined from the following equation:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{4}} + 1{,}4 \right) [mm]$$

or

$$3{,}50\ [mm]$$

Whichever is greater

Where:

L, k_2 = as defined in 3.3.1.

8.6.2 The Rule requirements for section modulus, inertia and web area for the strength / weather deck secondary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (b).

8.7 Lower deck / Inside deckhouse stiffening

8.7.1 The Rule requirements for section modulus, inertia and web area for lower deck / inside deckhouse stiffening are to be determined from the general equations given in 3.11, using the design pressure head from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM},C_I and C_A as detailed in Table 6.3.5. Primary members are assumed to be load model (a) and secondary members load model (b).The minimum thickness for lower deck/inside deckhouse stiffening is to be determined from the following equation:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{10}} + 1{,}3 \right) [mm]$$

or

$$3{,}00\ [mm]$$

Whichever is greater

Where:

L, k_2 = as defined in 3.3.1.

8.8 Accommodation deck stiffening

8.8.1 Accommodation decks are in general to be treated as lower deck/inside deckhouse decks, with their scantling requirements determined in accordance with 8.7.

8.9 Cargo deck stiffening

8.9.1 The Rule requirements for section modulus, inertia and web area for cargo deck stiffening are to be determined from the general equations given in 3.11, using the design pressure head from Part 3, Chapter 2 of Tentative Rules and Regulations for the Classification and Construction of Small Craft, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5. Primary members are assumed to be load model (a) and secondary members load model (b).

8.10 Deck openings

8.10.1 All openings are to be supported by an adequate framing system, pillars or cantilevers. When cantilevers are used scantlings may be derived from direct calculations.

8.10.2 Where stiffening members terminate in way of an opening they are to be attached to carlings, girders, transverses or coaming plates.

8.10.3 The corners of large hatchways in the strength/weather deck within 0,5·L amidships are to be elliptical, parabolic or rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.10.4 Where elliptical corners are arranged, the major axis is to be fore and aft, the ratio of the major to minor axis is to be not less than two to one nor greater than 2,5 to one, and the minimum half- length of the major axis is to be defined by l_1 in Figure 6.8.1. Where parabolic corners are arranged, the dimensions are also to be shown in Figure 6.8.1.

8.10.5 Where the corners are parabolic or elliptical, insert plates are not required.

8.10.6 For other shapes of corner, insert plates of the size and extent shown in Figure 6.8.2 will, in general, be required. The required thickness of the insert plate is to be not less than 25% greater than the adjacent deck thickness, outside line of openings.

Figure 6.8.1: Hatch opening geometry

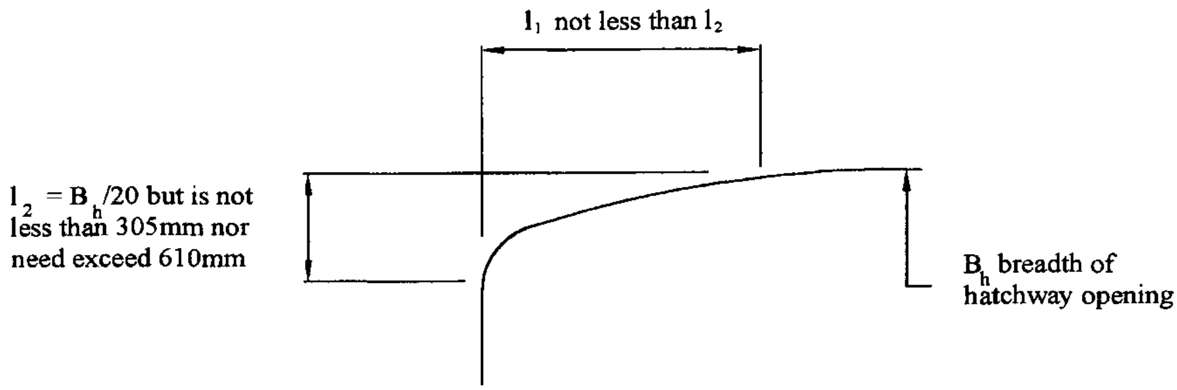
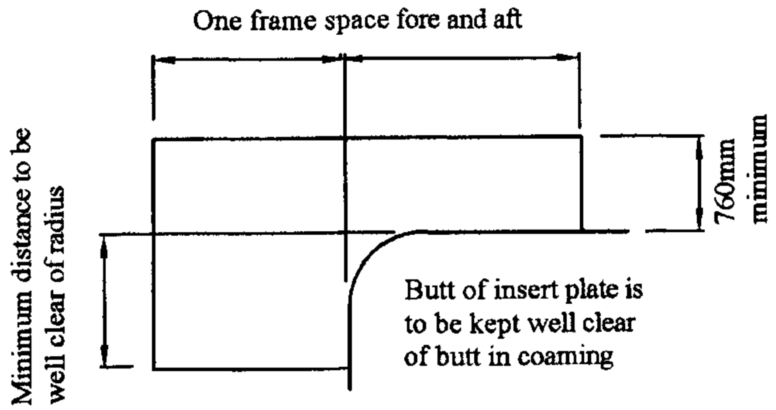


Figure 6.8.2: Inserts in way of hatch opening



8.10.7 For lower decks the corners of large openings are to be rounded, with a radius generally not less than 1/24 of the breadth of the opening.

SECTION 9 Bulkheads

9.1 General

9.1.1 The following requirements apply to bulkheads with both vertical and horizontal framing systems.

9.1.2 Bulkheads, or part bulkheads, forming the boundary of tanks are to comply with the requirements of 9.5 and 9.6.

9.1.3 A centreline bulkhead is, generally, to be fitted in deep tanks which extend from side to side. The bulkhead may be intact or perforated as desired. If intact, the scantlings are to comply with the requirements of 9.5 and 9.6 for tank boundary bulkheads. If perforated, they are to comply with the requirements of 9.10

for washplates.

9.2 Watertight bulkhead plating

9.2.1 The thickness of the watertight bulkhead plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{3}{16} \cdot L} + 1{,}2 \right) \; [mm]$$

or

$$3{,}00 \; [mm]$$

Whichever is greater

Where:

L, k_2 = as defined in 3.3.1.

9.3 Watertight bulkhead stiffening

9.3.1 The Rule requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressure from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 using the appropriate load model.

9.4 Deep tank plating

9.4.1 The thickness of deep tank plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{4}} + 1{,}4 \right) \; [mm]$$

or

$$3{,}50 \; [mm]$$

Whichever is greater

Where:

L, k_2 = as defined in 3.3.1.

9.5 Deep tank stiffening

9.5.1 Deep tank bulkhead stiffeners are to be bracketed at both ends. The thickness of the brackets is to be not less than the web thickness of the stiffener.

9.5.2 The Rule requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressure from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and $C_A$as detailed in Table 6.3.5 for load model (b).

9.6 Double bottom tanks

9.6.1 The scantlings of double bottom tanks are to comply with the requirements for deep tanks given in 9.4 and 9.5.

9.6.2 Where the crown of a double bottom tank forms a vehicle, passenger or other deck, the requirements of SECTION 8 are to be complied with.

9.7 Collision bulkheads

9.7.1 The scantlings of collision bulkheads are to be not less than as required for deep tank bulkheads contained in 9.4 and 9.5.

9.8 Non-watertight or partial bulkheads

9.8.1 Where a bulkhead is structural but non-watertight the scantlings are in general to be as for watertight bulkheads. Partial bulkheads that are non-structural are outside the scope of classification.

9.9 Corrugated bulkheads

9.9.1 The plating thickness and section modulus for symmetrical corrugated bulkheads are to be in accordance with watertight bulkheads or deep tank bulkheads as appropriate.

9.9.2 In addition, the section geometric properties of 3.12 are to be complied with.

9.10 Wash plates

9.10.1 Tanks are to be subdivided as necessary by internal baffles or wash plates. Baffles or wash plates which support hull framing are to have scantlings equivalent to web frames in the same position.

9.10.2 Wash plates and wash bulkheads are, in general, to have an area of perforation not less than 10% of the total area of the bulkhead. The perforations are to be so arranged that the efficiency of the bulkhead as a support is not impaired.

9.10.3 The plate thickness is to be not less than the structural element from which the wash bulkhead is formed.

9.10.4 The general stiffener requirements are to be in accordance with Part 3, Chapter 6, Section 3, 3.11. However, the section modulus may be 50% of that required by 9.5.

SECTION 10 Superstructures and deckhouses

10.1 Superstructure and deckhouse side plating

10.1.1 The thickness of house side plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{6}} + 1{,}1 \right) \; [mm]$$

or

$$3{,}00\ [mm]$$

Whichever is greater

Where:

L, k_2 = as defined in 3.3.1.

10.2 Superstructure and deckhouse front plating

10.2.1 The thickness of the house front plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules, and not to be less than that following from the equations:

(a) Superstructure and deckhouse front 1st tier plating:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{5}{13} \cdot L} + 1{,}8 \right) [mm]$$

or

$$3{,}50\ [mm]$$

Whichever is greater

(b) Superstructure and deckhouse front upper tiers plating:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{3}{10} \cdot L} + 1{,}5 \right) [mm]$$

or

$$3{,}00\ [mm]$$

Whichever is greater

Where:

L, k_2 = as defined in 3.3.1.

10.3 Superstructure and deckhouse end plating

10.3.1 The thickness of the house end plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{16}} + 1{,}7 \right) [mm]$$

or

$$2{,}50\ [mm]$$

Whichever is greater

Where:

L, k_2 = as defined in 3.3.1.

10.4 Superstructure and deckhouse top plating

10.4.1 The thickness of the house top plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules.

10.5 Coachroof plating

10.5.1 The thickness of the coachroof plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules.

10.6 Machinery casing plating

10.6.1 The thickness of the plating of machinery casings is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules.

10.7 Forecastle requirements

10.7.1 The forecastle side plating may be a continuation of the hull side shell plating or fitted as a separate assembly.In both cases the plating thickness is to be the same as the side shell plating at deck edge.Where fitted as a separate assembly, suitable arrangements are to be made to ensure continuity of the effect of the sheerstrake at the break and at the upper edge of the forecastle side. Full penetration welding is to be used.

10.7.2 The side plating is to be stiffened by side frames effectively connected to the deck structure. Deep webs are to be fitted to ensure overall rigidity.

10.7.3 The deck plating thickness is to be increased by 20% in way of the end of the forecastle if this occurs at a position aft of 0,25·L from the F.P. No increase is required if the forecastle end bulkhead lies forward of 0,2·L from the F.P. The increase at intermediate positions of end bulkhead is to be obtained by interpolation.

10.8 Superstructure and deckhouse side stiffeners

10.8.1 The Rule requirements for section modulus, inertia and web area for the house side primary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (b).

10.9 Superstructure and deckhouse front stiffeners

10.9.1 The Rule requirements for section modulus, inertia and web area for house front primary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (a).

10.9.2 The Rule requirements for section modulus, inertia and web area for house front secondary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (b).

10.10 Superstructure and deckhouse aft end stiffeners

10.10.1 The Rule requirements for section modulus, inertia and web area for house aft end primary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (a).

10.10.2 The Rule requirements for section modulus, inertia and web area for house aft end secondary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (b).

10.11 Superstructure and deckhouse top stiffeners

10.11.1 The superstructure and deckhouse top is to be effectively supported by a system of transverse or longitudinal beams and girders. The span of the beams is in general not to exceed 2,4 metres and the beams are to be effectively connected to the house upper coamings and girders.

10.11.2 The Rule requirements for section modulus, inertia and web area for house top primary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (a).

10.11.3 The Rule requirements for section modulus, inertia and web area for house top secondary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (b).

10.12 Coachroof stiffeners

10.12.1 The Rule requirements for section modulus, inertia and web area for coachroof primary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (a).

10.12.2 The Rule requirements for section modulus, inertia and web area for coachroof secondary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (b).

10.13 Machinery casing stiffeners

10.13.1 The Rule requirements for section modulus, inertia and web area for machinery casing primary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (a).

10.13.2 The Rule requirements for section modulus, inertia and web area for machinery casing secondary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (b).

10.14 Forecastle stiffeners

10.14.1 The scantlings of forecastle primary and secondary stiffening members are to be equivalent to those for the side shell envelope framing at the deck edge as required by SECTION 7.

10.15 Superstructures formed by extending side structures

10.15.1 Superstructure first tier sides formed by extending the hull side structure are to be in accordance with the requirements for house fronts given in 10.2 and 10.9 for plating and stiffeners respectively, but need not be taken as greater than the side structure requirements at the deck edge at the same longitudinal position.

10.16 Bulwarks

10.16.1 The thickness of the bulwark plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules.

10.16.2 The requirements for section modulus, inertia and web area for machinery casing primary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (d).

10.16.3 Fishing craft are to have bulwarks fitted. The bulwark may be formed from a continuation of the side shell plating or connected as a separate assembly. Where the bulwark is considered to be stressed and contributing to the global strength of the craft, the plate thickness of the bulwark is not to be less than the sheerstrake plating thickness. In no case is the thickness of the bulwark plating to be taken as less than 80% of the side shell thickness.The bulwark is to be supported by suitable stiffening members which may be formed from a continuation of the side frames, or from flanged plate stays of the same thickness as the bulwark. In general these frames are to be spaced not more than two side frame spacings apart.

SECTION 11 Structural scantlings for multi-hull vessels-General principles and requirements

11.1 Application

11.1.1 The requirements of this Section are applicable to multi-hull craft of aluminium construction.

11.2 Direct calculations

11.2.1 In case the design, form or proportions of the craft are unusual, or the speed of the craft exceeds 60 knots, the scantlings are to be determined by direct calculation.

11.2.2 In any case direct calculations based on well established principles of mechanics may be used alternatively or complementary to these Rules, provided that the achieved level of safety remains equivalent.

11.3 Symbols and definitions

11.3.1 The symbols used in this Section are defined below:

L = Rule length of craft, in metres

s = stiffener spacing, in mm

σ_a = 0,2% proof stress of the alloy in the welded condition, in N/mm² k_1, k_2=material factors as defined in Table 6.3.1

t = plating thickness, in mm

11.3.2 **Bottom outboard.** For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom outboard shell is defined as the area of the hull between the outboard edge of the keel and the outer bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom outboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

11.3.3 **Bottom inboard.** For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom inboard shell is defined as the area of the hull between the inboard edge of the keel and the inner bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom inboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

11.3.4 **Haunch.** The haunch is defined as the transition area between the cross-deck and the inboard side shell plating.

11.3.5 **Cross-deck.** The cross-deck is defined as the structure which forms the bridge connection between any two adjacent hulls.

11.3.6 **Side inboard.** The side inboard is defined as the area between the bottom inboard shell and the wet-deck (or lower edge of the haunches, where fitted).

11.3.7 **Side outboard.** The side outboard is defined as the area between bottom outboard shell and the deck at side.

11.3.8 **Wet-deck.** The wet-deck is defined as the area between the upper edges of the side inboard plating (or upper edges of the haunches, where fitted).

SECTION 12 Single bottom structure and appendages

12.1 Keel

12.1.1 The scantlings and arrangements of plate keels are to be in accordance with 14.1.

12.1.2 Where fitted, the cross-sectional area, A, and thickness, t, of bar keels should not, in general, be taken as less than:

$$A = k_1 \cdot (1{,}85 \cdot L + 2)\ [mm]$$

$$t = \sqrt{k_1} \cdot (0{,}7 \cdot L + 8{,}25)\ [mm]$$

Where:

L, k_1 = as defined in 3.3.1.

12.2 Centre girder

12.2.1 Centreline girders are to be fitted throughout the length of each hull and are generally to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

12.2.2 The web depth of the centre girder is, in general, to be equal to the depth of the floors at the centreline as specified in 12.4.3.

12.2.3 The web thickness, t, of the centre girder is to be taken as not less than:

$$t = \sqrt{k_1} \cdot \left(\sqrt{1{,}9 \cdot L} + 1{,}3\right)\ [mm]$$

or

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{5}{4} \cdot L} + 1{,}4\right)\ [mm]$$

or

$$5{,}00\ [mm]$$

Whichever is greater

Where:

L, k_1, k_2 = as defined in 3.3.1.

12.2.4 The face flat area, A, of the centre girder is to be not less than:

$$A = 0{,}42 \cdot k_1 \cdot L\ \ [cm^2]$$

Where:

L, k_1 = as defined in 3.3.1.

12.2.5 The face flat area of the centre girder outside 0,5·L may be 80% of the value given in 12.2.4.

12.2.6 The face flat thickness, t, is to be not less than the thickness of the web.

12.2.7 The ratio of the width to thickness of the face flat is to be not less than eight but is not to exceed sixteen.

12.2.8 Additionally, the requirements of 15.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

12.3 Side girders

12.3.1 Where the floor breadth at the upper edge exceeds 4,0 m side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 2 metres.

12.3.2 The web thickness, t, of side girder is to be taken as not less than:

$$t = (0{,}85 \cdot k_1 \cdot L)\ [mm]$$

or

$$t = \sqrt{k_2} \cdot \left(3 \cdot \sqrt{\frac{1}{4} \cdot L} + 1{,}1 \right)\ [mm]$$

or

$$4{,}00\ [mm]$$

Whichever is greater

Where:

L, k_1, k_2 = as defined in 3.3.1.

12.3.3 The face flat area and thickness of side girders are to comply with the requirements for plate floors as defined in 12.4.5 and 12.4.6.

12.3.4 Additionally, the requirements of 15.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

12.4 Floors general

12.4.1 In transversely framed craft, floors are generally to be fitted at every frame and underneath each bulkhead.

12.4.2 In longitudinally framed craft, floors are, in general, to be fitted at every transverse web frame and bulkhead and generally at a spacing not exceeding 2 metres.

12.4.3 The overall web depth, d, of floors at the centreline, is not to be taken as less than:

$$d = (6{,}2 \cdot L + 50)\ [mm]$$

Where:

L = as defined in 3.3.1.

12.4.4 The web thickness of plate floors, t, is to be not less than:

$$t = \sqrt{k_1} \cdot (0{,}0047 \cdot d + 3{,}1) \cdot (0{,}001 \cdot s + 0{,}5)\ [mm]$$

or

$$t = \sqrt{k_2} \cdot \left(3 \cdot \sqrt{\frac{1}{14} \cdot L + 1{,}1}\right)\ [mm]$$

or

$$4{,}00\ [mm]$$

Whichever is greater

Where:

d_w = determined from 12.4.3 and L, k_1, k_2, s are as defined in 3.3.1.

L, k_1, k_2, s = as defined in 3.3.1.

12.4.5 The face flat area, A, of floors is not to be taken as less than:

$$A = k_1 \cdot 0{,}21 \cdot L\ \ [cm^2]$$

Where:

L, k_1 = as defined in 3.3.1.

12.4.6 The face flat thickness, t, is to be not less than the thickness of the web and the ratio of the web to the thickness of the face flat is to be not less than eight but is not to exceed sixteen.

12.4.7 Additionally, the requirements of 15.6 for bottom outboard transverse web frames are to be complied with.

12.5 Floors in machinery spaces

12.5.1 The web thickness, t, of floors in machinery spaces is to be 1 mm greater than that required by 12.4.4.

12.6 Forefoot and stem

12.6.1 The thickness of plate stems at the waterline is to comply with the requirements for plate keels as given in 14.1.

12.6.2 The cross-sectional area of bar stems, A, is not to be taken as less than:

$$A = 0{,}11 \cdot k_1 \cdot L\ \ [cm^2]$$

Where:

L, k_1 = as defined in 3.3.1.

SECTION 13 Double bottom structure

13.1 Keel

13.1.1 The scantlings of plate and bar keels are to comply with the requirements of 12.1.

13.2 Centreline girder

13.2.1 A centre girder is to be fitted throughout the length of the craft. The web thickness, t, is to be not less than that required by:

(a) Within 0,4·L amidships

$$t = \sqrt{k_1} \cdot (0{,}082 \cdot L + 4{,}1)\ [mm]$$

or

$$t = \sqrt{k_2} \cdot \left(3 \cdot \sqrt{\frac{6}{5} \cdot L} + 1{,}4\right)\ [mm]$$

or

$$5{,}00\ [mm]$$

Whichever is greater

(b) At ends

$$t = \sqrt{k_1} \cdot (0{,}0082 \cdot L + 2{,}7)\ [mm]$$

or

$$t = \sqrt{k_2} \cdot \left(3 \cdot \sqrt{\frac{1}{10} \cdot L} + 1{,}4\right)\ [mm]$$

or

$$5{,}00\ [mm]$$

Whichever is greater

Where:

L, k_1, k_2 = as defined in 3.3.1.

13.2.2 The overall web depth, d, of the centre girder is to be taken as not less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

13.2.3 Additionally, the requirements of 15.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

13.3 Side girders

13.3.1 The thickness of the side girder plating is not to be taken as less than:

$$t = \sqrt{k_2} \cdot \left(3 \cdot \sqrt{\frac{1}{14} \cdot L} + 1{,}1\right) \; [mm]$$

or

$$4{,}00 \; [mm]$$

Whichever is greater

Where:

L, k_1, k_2 = as defined in 3.3.1.

13.3.2 Where the floor breadth does not exceed 4,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

13.3.3 Where the breadth of floor is greater than 4,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 2,0 metres.

13.4 Plate floors

13.4.1 The web thickness, t, of non-watertight plate floor is to be not less than:

$$t = \sqrt{k_1} \cdot (0{,}41 \cdot L + 4{,}8) \; [mm]$$

or

$$t = \sqrt{k_2} \cdot \left(3 \cdot \sqrt{\frac{1}{14} \cdot L} + 1{,}1\right) \; [mm]$$

or

$$4{,}00 \; [mm]$$

Whichever is greater

Where:

L, k_1, k_2 = as defined in 3.3.1.

13.4.2 Additionally, the requirements of 15.6 for bottom outboard transverse web frames are to be complied with.

13.4.3 Plate floors are, in general, to be continuous between the centre girder and the margin plate.

13.4.4 In longitudinally framed craft, plate floors are to be fitted in the following positions:

(a) At every half frame in way of the main engines, thrust bearings, and bottom of the craft forward.

(b) Outboard of the engine seatings, at every frame within the engine room.

(c) Underneath pillars and bulkheads.

(d) Outside of the engine room at a spacing not exceeding 2,0 m.

13.4.5 Vertical flat bar stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than 10·t and a thickness of not less than t, where t is the thickness of the plate floor as calculated in 13.4.1.

13.4.6 In transversely framed craft, plate floors are to be fitted at every frame in the engine room, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 2,0m.

SECTION 14 Shell envelope plating

14.1 Keel plates

14.1.1 The breadth, b, and thickness, t, of plate keels are not to be taken as less than:

$$b = 5{,}0 \cdot L + 250 \; [mm]$$

or

$$t = \sqrt{k_1} \cdot 1{,}85 \cdot L^{0{,}45} \; [mm]$$

or

$$4{,}00 \; [mm]$$

Whichever is greater

Where:

L, k_1, = as defined in 3.3.1.

14.1.2 In no case is the thickness of the keel to be less than that of the adjacent bottom shell plating.

14.2 Bottom outboard

14.2.1 The thickness of the bottom outboard plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3,Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{2}} + 1{,}0\right) [mm]$$

or

$$4{,}00 \; [mm]$$

Whichever is greater

Where:

L, k_2 = as defined in 3.3.1.

14.2.2 For all craft types, the minimum bottom outboard shell thickness requirement given in 14.2.1 is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

14.3 Bottom inboard

14.3.1 The thickness of the bottom inboard plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3,Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{2}} + 1{,}0\right) [mm]$$

or

$$4{,}00 \; [mm]$$

Whichever is greater

Where:

L, k_2 = as defined in 3.3.1.

14.3.2 For all craft types, the minimum bottom inboard shell thickness requirement given in 7.4 is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

14.4 Side outboard

14.4.1 The thickness of the side outboard plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{4}} + 1{,}4 \right) [mm]$$

or

$$3{,}50\ [mm]$$

Whichever is greater

Where:

L, k_2 = as defined in 3.3.1.

14.5 Side inboard

14.5.1 The thickness of the side inboard plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{4}} + 1{,}4 \right) [mm]$$

or

$$3{,}50\ [mm]$$

Whichever is greater

Where:

L, k_2 = as defined in 3.3.1.

14.6 Wet-deck

14.6.1 The thickness of the wet-deck plating is to be determined from the general plating equation given in 3.10 using the design pressure from Part 3, Chapter 2 of the present Rules, and not to be less than:

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{4}} + 1{,}4 \right) [mm]$$

or

$$3{,}50\ [mm]$$

Whichever is greater

Where:

L, k_2 = as defined in 3.3.1.

14.6.2 Additionally, the thickness of the wet-deck plating is in no case to be less than the thickness of the side inboard shell plating determined from 14.5.

14.7 Transom

14.7.1 The scantlings and arrangements of the stern or transom are to be not less than that required for the adjacent bottom inboard or side outboard structure as appropriate.

SECTION 15 Shell envelope framing

15.1 General

15.1.1 The following requirements apply to longitudinally and transversely framed shell envelopes.

15.2 Bottom outboard longitudinal stiffeners

15.2.1 Bottom outboard longitudinal stiffeners are to be supported by transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 metres apart.

15.2.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (b).

15.3 Botto outboard longitudinal primary stiffeners

15.3.1 Bottom outboard longitudinal primary stiffeners are to be supported by deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 4 metres apart.

15.3.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (a).

15.4 Bottom outboard transverse stiffeners

15.4.1 Bottom outboard transverse stiffeners are defined as local stiffening members which support the bottom shell.

15.4.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (b).

15.5 Bottom outboard transverse frames

15.5.1 Bottom outboard transverse frames are defined as stiffening members which support the bottom shell.

15.5.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM},C_I and C_A as detailed in Table 6.3.5 for the load model (a).

15.6 Bottom outboard transverse web frames

15.6.1 Bottom outboard transverse web frames are defined as primary stiffening members which support bottom shell longitudinals.

15.6.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3,Chapter 2 of the present Rules, and the coefficients C_{SM},C_I and C_A as detailed in Table 6.3.5 for the load model (a).

15.7 Bottom inboard longitudinal stiffeners

15.7.1 The scantlings and arrangements for bottom inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 15.2 using the bottom inboard stiffening member design pressure from Part 3, Chapter 2 of the present Rules.

15.8 Bottom inboard longitudinal primary stiffeners

15.8.1 The scantlings and arrangements for bottom inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 15.3 using the bottom inboard stiffening member design pressure from Part 3, Chapter 2 of the present Rules.

15.9 Bottom inboard transverse stiffeners

15.9.1 The scantlings and arrangements for bottom inboard transverse stiffeners are to be determined in accordance with the procedures described in 15.4 using the bottom inboard stiffening member design pressure from Part 3, Chapter 2 of the present Rules.

15.10 Bottom inboard transverse frames

15.10.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in 15.5 using the bottom inboard stiffening member design pressure from Part 3, Chapter 2 of the present Rules.

15.11 Bottom inboard transverse web frames

15.11.1 The scantlings and arrangements for bottom inboard transverse web frames are to be determined in accordance with the procedures described in 15.6 using the bottom inboard stiffening member design pressure from Part 3, Chapter 2 of the present Rules.

15.12 Side outboard longitudinal stiffeners

15.12.1 The side outboard longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 metres apart.

15.12.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (b).

15.13 Side outboard longitudinal primary stiffeners

15.13.1 Side outboard longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 4 metres apart.

15.13.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (a).

15.14 Side outboard transverse stiffeners

15.14.1 Side outboard transverse stiffeners are defined as local stiffening members supporting the side shell.

15.14.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (b).

15.15 Side outboard transverse frames

15.15.1 Side outboard transverse frames are defined as stiffening members which support the side shell.

15.15.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (a).

15.16 Side outboard transverse web frames

15.16.1 Side outboard transverse web frames are defined as primary stiffening members which support side shell longitudinals.

15.16.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (a).

15.17 Side inboard longitudinal stiffeners

15.17.1 The scantlings and arrangements for side inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 15.12 using the side inboard design pressure from Part 3, Chapter 2 of the present Rules.

15.18 Side inboard longitudinal primary stiffeners

15.18.1 The scantlings and arrangements for side inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 15.13 using the side inboard design pressure from Part 3, Chapter 2 of the present Rules.

15.19 Side inboard transverse stiffeners

15.19.1 The scantlings and arrangements for side inboard transverse stiffeners are to be determined in accordance with the procedures described in 15.14 using the side inboard design pressure from Part 3, Chapter 2 of the present Rules.

15.20 Side inboard transverse frames

15.20.1 The scantlings and arrangements for side inboard transverse stiffeners are to be determined in accordance with the procedures described in 15.16 using the side inboard design pressure from Part 3, Chapter 2 of the present Rules.

15.21 Side inboard transverse web frames

15.21.1 The scantlings and arrangements for side inboard transverse stiffeners are to be determined in accordance with the procedures described in 15.15 using the side inboard design pressure from Part 3, Chapter 2 of the present Rules.

15.22 Wet-deck longitudinal stiffeners

15.22.1 The wet-deck longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 metres apart.

15.22.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (b).

15.22.3 In no case are the scantlings and arrangements for the wet-deck longitudinal stiffeners to be taken as less than those required for the side inboard longitudinal stiffeners detailed in 15.17.

15.23 Wet-deck longitudinal primary stiffeners

15.23.1 Wet-deck longitudinal primary stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced no more than 4 metres apart.

15.23.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (a).

15.23.3 In no case are the scantlings and arrangements for the wet-deck longitudinal primary stiffeners to be taken as less than those required for the side inboard longitudinal primary stiffeners detailed in 15.18.

15.24 Wet-deck transverse stiffeners

15.24.1 Wet-deck transverse stiffeners are defined as local stiffening members supporting the wet- deck.

15.24.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (b).

15.24.3 In no case are the scantlings and arrangements for the wet-deck transverse stiffeners to be taken as less than those required for the side inboard transverse stiffeners detailed in 15.19.

15.25 Wet-deck transverse frames

15.25.1 Wet-deck transverse frames are defined as stiffening members which support the wet-deck.

15.25.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (a).

15.25.3 In no case are the scantlings and arrangements for the wet-deck transverse frames to be taken as less than those required for the side inboard transverse frames detailed in 15.20.

15.26 Wet-deck transverse web frames

15.26.1 Wet-deck transverse web frames are defined as primary stiffening members which support wet-deck longitudinals.

15.26.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (a).

15.26.3 In no case are the scantlings and arrangements for the wet-deck transverse web frames to be taken as less than those required for the side inboard transverse web frames detailed in 15.21.

SECTION 16 Deck structures

16.1 Cross-deck plating

16.1.1 The thickness of the cross-deck plating is to be determined from the general plating equation given in 3.10, using the design pressure from Part 3, Chapter 2 of the present Rules.

16.1.2 The thickness of the cross-deck plating is in no case to be less than the appropriate minimum requirements given below:

(a) Strength/Main deck plating

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{4}} + 1{,}4 \right) [mm]$$

or

$$3{,}50 \ [mm]$$

Whichever is greater

Where:

L, k_2 = as defined in 3.3.1.

(b) Lower deck/Inside deckhouse plating

$$t = \sqrt{k_2} \cdot \left(\sqrt{\frac{L}{11}} + 1{,}3 \right) [mm]$$

or

$$3{,}00 \ [mm]$$

Whichever is greater

Where:

L, k_2 = as defined in 3.3.1.

16.2 Cross-deck stiffening

16.2.1 The Rule requirements for section modulus, inertia and web area for the cross-deck primary stiffeners are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table

6.3.5 for the load model (a).

16.2.2 The Rule requirements for section modulus, inertia and web area of the strength / weather deck secondary stiffening are to be determined from the general equations given in 3.11, using the design pressures from Part 3, Chapter 2 of the present Rules, and the coefficients C_{SM}, C_I and C_A as detailed in Table 6.3.5 for the load model (a).

SECTION 17 Bulkheads and deep tanks

17.1 Longitudinal bulkheads within the cross-deck structure

17.1.1 The scantlings and arrangements for cross deck longitudinal bulkheads are to be determined in accordance with the procedures described in 9.2 and 9.3 for bulkheads in mono-hull craft.

17.2 Transverse bulkheads within the cross-deck structure

17.2.1 The scantlings of cross deck transverse bulkheads are to be determined in accordance with the procedures described in 9.2 and 9.3 for bulkheads in mono-hull craft.

SECTION 18 Superstructures, deckhouses and bulwarks

18.1 General

18.1.1 The scantlings and arrangements for superstructures, deckhouses and bulwarks are to be determined in accordance with the procedures described in SECTION 10 for mono-hull craft.

CHAPTER 7 Hull Construction – Wood

Contents

SECTION 1 Structural scantlings of sailing vessels with or without auxiliary engine

1.1 General

1.1.1 The scantling in this section apply generally to hulls of length not exceeding 36 meters with round bottom of shape and fitted with fixed ballast or drop keel. Vessels of length exceeding 36 meters or hull shaped other than the above will be considered in case on the basis of equivalence criteria.

1.2 Keel

1.2.1 The scantlings of wooden keels are given in Table 7.1.1. The keel thickness is to be maintained throughout the length, while the width may be gradually tapered at the ends so as to be faired to the stem and the sternpost. The breadth of the rabbet on the keel for the first plating strake is to be at least twice the thickness and not less than 25 mm.

1.2.2 When the length, L, does not exceed 12 m the wood keel is to be in one length. In larger craft the keel should, where is possible, be in one length but when a scarph is necessary in the centerline structure is to have a length, l, not less than 6 times the moulding, m, of the item. The scarph is to be of the hookes or tabled type if bolted or plain type without lips id glued. The depth of the lips is to be about 1/4 to 1/7 of the moulding.

1.2.3 Where the keel is cut for the passage of a drop keel width is to be increased.

1.2.4 Where the mast is stepped on the keel it is be arranged aft of the forward end of the ballast keel. Where this is not practicable effective longitudinal stiffeners are to be arranged extending well forward and of the mast step and effectively connected to the keel.

1.2.5 Bolted scarfs are to be made watertight by means of softwood stopwaters.

1.2.6 The scantlings of wooden keels are given in Table 7.1.1.

1.3 Stempost and sternpost

1.3.1 The stempost shall be adequately scarfed to the keel and increased in width at the heel as necessary so as to fit the keel fairing.

1.3.2 Stempost and sternpost scantlings are given in Table 7.1.1.

1.3.3 The lower portion of the sternpost shall be tenoned or otherwise attached to the keel. The connection is completed by a stern deadwood and a large bracket fastening together false keel, keel and post by means of through bolts.

1.3.4 The counter stern shall be effectively connected to the sternpost. Where practicable such connection shall be effected by scatfs with through bolts. The section area of the counter stern at the connection with the sternpost shall be not less than that of the latter. Such area may be reduced at the upper end by 25%.

Table 7.1.1: Keel, Stempost, Sternpost

Length L [m]	Keel		Stempost				Sternpost	
	width mm	depth mm	at heel		at head		width mm	depth mm
			width mm	depth mm	width mm	depth mm		
10	220	110	120	120	100	100	100	100
12	255	125	140	140	115	115	115	115
14	285	140	155	155	125	125	125	125
16	320	160	170	170	140	140	140	140
18	355	175	190	190	150	150	150	150
20	385	195	205	205	165	165	165	165
22	410	210	220	220	175	175	175	175
24	435	230	240	240	190	190	190	190
26	455	245	255	255	200	200	200	200
28	470	260	270	270	215	215	215	215
30	480	280	290	290	230	230	230	230
32	490	300	310	310	245	245	245	245
34	495	315	325	325	255	255	255	255
36	500	330	340	340	270	270	270	270

1.4 Frames

1.4.1 Bent frames

Bent frames consist of steam warped listels. Their width and thickness are to be uniform over the whole length. The frames are to be in one piece from keel to gunwale and where practicable from gunwale to gunwale running continuous above the keel.

1.4.2 Grown frames

Grown frames consist of naturally curved timbers connected by means of scarfs or butted and strapped. Their width is to be uniform while their depth is to gradually tapered from heel to head. The length of scarfs is to be not less than 6 times the width and they are to be glued.

1.4.3 Laminated frames

Laminated frames consist of glued wooden layers. The glued may take place before forming where the latter is slight. Otherwise it should be carried out in loco or be prefabricated by means of suitable strong moulds.

1.4.4 Metal frames

Steel frames consist of angles properly curved and bevelled such that the flange to planking is closely fayed to the same planking.

1.4.5 Framing systems and scantlings

(a) The admissible framing systems and the frame scantlings are indicated in Table 7.1.1.

The following framing systems are taken into consideration:

Type I : all equal frames of the bent type,

Type II : all equal frames of grown laminated or steel angle type,

Type III: frames of scantlings as required for Type II but with one two or three bent frames.

These types are hereafter referred to respectively as Type III_1, Type III_2, Type III_3.

When a frame spacing other than that specified in the table is adopted, the section modulus of the frame is to be modified proportionally. For wooden rectangular sections, a being the width and b the height of the Rules section for the spacing s, a_1 and b_1 the actual values for the assumed spacing s_1, it follows that:

$$a_1 \cdot b_1 = a \cdot b^2 \cdot \frac{s_1}{s}$$

(b) The width of frames is to be nor less than that necessary for the fastening. Their depth is in any case to be assumed as not less than 2/3 of the width, except where increased width is required for local strengthening in way of masts. The table scantlings duly modified where necessary for the specific gravity of the timber and for the frame spacing are to be maintained for 0,6 of the hull length amidships. Outside the said zone the following reductions may be applied:

1. for bent or laminated frames:10% in width,
2. for grown frames: 20% in width throughout the length of the frame and 20% in depth of the head,metal frames: 10% in thickness.

(c) Frames are to be properly shaped so as to fit the planking perfectly. Where no floors are arranged the frames are to be wedged into and fastened at the heels of the centerline structural member If the hull. When internal ballast supported by the frames is arranged the latter are to be increased in scantlings.

(d) Frames adjacent to masts are to be strengthened on each side as follows or equivalent arrangements are to be provided:

1. Type I framing

- Three grown frames are to be fitted with scantlings as required for Type II framing but with constant depth equal to that indicated in Table 7.1.2 for the heel. Such frames are to be arranged instead of alternate bent frames. Otherwise six consecutive bent frames with a cross section increased by 60% in respect of that shown in the above mentioned table may be fitted.

2. Type II framing

- Three grown frames are to be fitted with a cross section increased by 50% in respect of that required for the heel in the above mentioned table and constant depth. Such frames are to be alternated with ordinary grown frames. If alternate frames are adopted they are to be stiffened by reverse frames of scantlings as prescribed for the reverse frames of plate floors.

3. Type III framing

- Three grown frames with a cross section increased by 50% in respect of that required for the heel in the above mentioned table and constant depth are to be arranged at Rules spacing with one or two intermediate bent frames. If steel frames are adopted three are to be stiffened by reverse frames with scantlings as required for the frames of plate floors and arranged with one or two intermediate bent frames.

When on way of the mast a sufficiently strong bulkhead is provided such increased frames may be reduced in number to two.

Table 7.1.2: Frames

Depth D mm	TYPE I Bent frames only			TYPE II Grown or laminated or steel frames only						
					Grown frames			Laminated frames		Steel frames
	spacing mm	width mm	depth mm	spacing mm	width mm	depth mm at heel	depth mm at head	width mm	depth mm	Section modulus cm^3
1,6	145	19	1	185	18	23	18	20	20	0,7
1,8	155	24	19	200	24	30	24	24	24	0,7
2	165	30	23	220	30	37	28	28	28	0,8
2,2	175	35	27	237	36	44	33	31	31	1
2,4	185	41	30	255	43	50	37	35	37	1,2
2,6	195	46	34	270	48	57	42	38	40	1,7
2,8	205	51	37	288	55	65	47	42	46	2,3
3	215	57	40	305	61	74	53	47	52	3,1
3,2	225	62	43	322	68	83	58	50	59	4,4
3,4	235	67	46	340	75	91	68	54	66	6
3,6	245	72	59	355	81	100	80	59	74	7,9
3,8	255	77	52	375	87	112	92	63	84	10,2
4	265	82	55	390	94	124	100	67	94	12,5
4,2	-	-	-	408	100	140	117	72	102	14,5

Depth D mm	TYPE III Grown or laminated or steel frames alternated with bent frames				
	Spacing between frames and intermediate ones			Bent frames	
	1 bent frames mm	2 bent frames mm	3 bent frames mm	length mm	depth mm
1,6	330	440	520	20	18

1,8	365	470	545	25	20
2	390	500	570	29	22
2,2	410	520	590	33	24
2,4	440	540	620	37	28
2,6	460	570	640	39	29
2,8	490	590	670	41	31
3	515	620	695	43	33
3,2	560	650	730	45	35
3,4	590	690	770	48	39
3,6	620	725	800	50	43
3,8	650	765	840	53	47
4	380	800	870	546	51
4,2	-	-	-	-	-

1.5 Floors

1.5.1 Floors may be made of wood or metal (steel or aluminium). The type of floors to be fitted is dependent on the frame type adopted as follows:

(a) Wooden floors as a rule may only be employed in association with grown frames and are to be flanked by them.

(b) Metal floors are employed in association with either bent grown or laminated frames and are arranged on the internal profile of the frames.

(c) Angle floors may be employed with either bent grown or laminated frames and may be arranged as show in Table 7.1.3.

(d) When they are arranged with a flange inside an angle lug is to be fitted in way of the throat for the connection to the wooden keel.

(e) Plate floors may be employed in association with either grown or angle frames. The internal edge is to be provided with a reverse angle or a flange, in the latter case the thickness is to be increased by 10%.

1.5.2 Where type I framing with bent frames is adopted floors are to be fitted inside amidships as 0,6L follows:

(a) on every second frame of the hull depth does nor exceed 2,75 meters and on every frame in hulls of greater depth.

(b) on every second frame inside 0,6L amidships and outside such area over an extent corresponding to the length on the waterline.

(c) on every third frame elsewhere.

1.5.3 Where type III framing is adopted a floor is to be fitted in way of every grown laminated or angle frame. Where one or two intermediate bent frames are to be arranged and the depth D exceeds 2,4 m floors are to be fitted on bent frames located inside 0,6 L amidships. Where three intermediate bent frames are arranged floor is to be fitted on the central one.

1.5.4 The scantlings of floors are given in Table 7.1.3.

1.5.5 The length of arms of wooden forged or angle floors is measured from the corner following the external profile. The depth of plate floors is to be measured vertically.

1.5.6 At the hull ends the length of arms need not exceed one third of the frame span.

1.5.7 Wooden floors are to be made of suitably grained or laminated and their height at the ends is to be not less than the height of the throat.

1.5.8 Where the ballast keel bolts cross wooden floors the width of the latter at the throat is to be locally increased of necessary so as to be not less than three and a half times the diameter of the bolt.

1.5.9 Lugs for the connection of angle or plate floors to the wooden keel of penetrated by the ballast keel bolts are to have a flange width at least three times the diameter of the bolt and thickness equal to that of the plate floor plus 2,5mm.

1.5.10 At the end of the hull when frames are continuous through the center structure by means of three through-bolts.

1.5.11 Floors are to be connected to frames by at least three bolts for arms with length l<250 mm and at least 6 bolts for greater l for diameters of bolts, see Table 7.1.4.

Table 7.1.3: Floors

Depth D mm	Floors on bent frames				Plate floors on grown or steel floors	
	Length of arms mm	forged floors		steel angles floors		
		at throat mm	at the ends mm	Section modulus cm^3	for 2/3 L amidships mm	outside 2/3 L amidships mm
1,6	220	25x6	15x6	0,3	120x3	100x3
1,8	250	25x6	15x6	0,3	150x3	110x3
2	280	25x8	16x6	0,3	170x3	130x3
2,2	310	25x10	18x6	0,6	200x3	145x3
2,4	350	25x10	19x6	1	230x3	170x4
2,6	375	26x13	20x6	1	270x3	180x4
2,8	405	27x14	22x6	1,2	280x4	190x4
3	430	29x15	24x6	1,4	300x5	200x4
3,2	465	31x16	25x6	1,4	320x5	220x4
3,4	495	33x17	27x6	1,5	330x5	230x4
3,6	530	35x17	28x6	1,5	340x6	240x4
3,8	-	-	-	-	345x6	245x4
4	-	-	-	-	350x6	250x4

4,2	-		-	-	-	360x6	260x5
Depth D mm	Floors on grown or laminated frames						
	Length of arms mm		forget floors		steel angle	wooden floors	
	for 2/3 L amidships mm	outside 2/3 L amidships mm	at throat mm	at the ends mm	Section modulus cm^3	width mm	depth mm
1,6	350	230	19x9	19x9	0,34	20	40
1,8	380	250	25x10	20x10	0,36	23	55
2	410	280	31x12	27x10	0,71	26	68
2,2	150	320	38x14	33x10	1	31	80
2,4	180	350	44x16	40x10	1,2	36	95
2,6	510	380	48x18	43x10	1,2	42	108
2,8	550	400	52x20	47x10	1,9	47	120
3	580	430	56x22	50x12	2,4	51	135
3,2	610	460	60x24	52x13	3,6	56	148
3,4	650	500	64x26	54x14	5,7	60	160
3,6	680	530	69x28	56x16	6,9	64	170
3,8	710	560	73x30	58x17	6,9	70	180
4	750	590	77x31	61x18	9	75	190
4,2	780	620	80x31	63x20	10,6	80	200

Table 7.1.4: Floor Fastenings

Depth D mm	Diameter of bolts			
	at throat		in the arms	
	Grown or laminated or steel frames mm	Bent frames mm	Grown or laminated or steel frames mm	Bent frames mm
1,8	8	7	7	7
2	9	8	8	7
2,2	10	8	8	7
2,4	12	8	8	8
2,6	12	9	9	8
2,8	14	10	10	8
3	14	12	12	8
3,2	16	12	12	9
3,4	18	14	14	9
3,6	20	14	14	9
3,8	20	-	14	-
4	20	-	16	-
4,2	22	-	16	-

Fastenings of longitudinal structures			
Length of boat L mm	Diameter of bolts		
	Centraline structures of ships mm	Scarphs and breasthook arms mm	Beamshelves and beam knees mm
14	14	11	8
16	16	11	8
18	18	12	10
20	18	14	11
22	20	14	11
24	20	14	11
26	20	14	11
28	22	16	12
30	22	18	14
32	23	19	15
34	24	20	16

36	25	21	17

1.1 Beams, Bilge stringer

1.6.1 Beam shelves

(a) The cross sectional area of beam shelves through 0,6 L amidships is to be nor less than that indicated in Table 7.1.5. Outside such zone the cross section may be gradually decreased to reach at the end a value equal to 75% of that show.

(b) Where beam shelves are made of two or more pieces the connection is to be effected by means of glued scarfs adequality arranged so as to be staggered in respect of the sheerstrake, waterway and bracket joints. Scarfs are generally arranged vertically.

(c) When the weather deck is not continuous owing to the presence of raised decks the shelf is to extend to the hull end or alternatively stiffeners are to be fitted to prevent excessive discontinuity due to the interruption of suitable chocks.

(d) The shelves are to be connected to each frame by a through bolt for heights ≤ 180 mm and by two through bolts for greater heights. If metal frames are adopted bolting of the shelf is to be effected on a reverse lug.

1.6.2 Beam clamps in way of masts

In way of masts a beam clamp is to be arranged of length approximately equal to the hull breadth in the same position. Such clamp with cross section equal to approximately 75% of that requited for shelves may be arranged so that its wider side is faying to the shelf or alternatively; it may be arranged below the shelf.

1.6.3 Bilge stringers

(a) In hulls with type I or type III_3 framing a bilge stringer is to be arranged having cross section may be decreased to reach at the ends a vale equal to 75% of that required. The greater dimension of the stringer is to be arranged against the frames.

(b) When the stringer is built of two or more pieces these are to be connected by means of glued scarfs parallel to the planking. Such scarfs are to be properly staggered in the port and starboard stringers and arranged clear of the joints of other longitudinal elements.

(c) Where angle frames are adopted these are to be fitted for the connection between stringer and intermediate bent frames. In lieu of bilge stringer two side stringer having cross section equal to 60% of that required for the bilge stringer may be fitted.

(d) The beam shelves and the stringers are to be connected to each other at the hull ends and with the centerline structure by means of suitable breasthooks or brackets.

(e) The beam shelves and the stringers are to be connected to each other at the hull ends and with the centerline structure by means of suitable breasthooks or brackets. In hulls with exceptionally raked ends such breasthooks are to be given adequate attention.

Table 7.1.5: Beam shelves and bilge stringers

Length m	Cross sectional area of beam shelves, cm^2	Cross sectional area of bilge stringers, cm^2
14	90	55
16	110	68

18	130	77
20	150	105
22	170	120
24	190	140
26	220	160
28	250	175
30	280	190
32	310	205
34	340	220
36	370	235

1.7 Beams

1.7.1 The scantlings of beams are given in Table 7.1.6. Where the spacing adopted is other than that shown in the table the scantlings following correction as necessary for the weight of the timber employed are to be modified in accordance with the following relationship:

$$a_1 \cdot b_1 = a \cdot b^2 \cdot \frac{s_1}{s}$$

Where:

a,b = the width and height of the rule cross section,

a_1,b_1 = the width and height of the modified section,

s = the rule spacing,

s_1 = the assumed spacing

Laminated beams may be reduced in width by 15%.

Table 7.1.6: Beams

Length of beam m	spacing mm	Ordinary beams for amidships 3/5 L			Ordinary beams outside 3/5 L amidships, half beams			Strong beams		
		Width mm	Depth		Width mm	Depth		Width mm	Depth	
			at midbeam	at beam ends mm		at midbeam mm	at beam ends mm		at midbeam mm	at beam ends mm
1,5	220	23	37	25	20	27	22	34	42	34
2	270	31	50	34	26	36	29	43	55	43
2,5	310	36	61	42	33	41	37	53	68	53
3	350	45	72	50	39	54	43	61	81	61
3,5	390	51	80	57	47	61	48	72	91	72

4	430	57	90	63	48	67	53	78	101	78
4,5	480	62	99	69	52	74	57	85	111	85
5	520	68	106	75	57	80	62	93	120	93
5,5	560	72	114	80	59	87	65	98	128	98
6	600	78	121	86	62	95	69	107	136	107
6,5	640	83	129	92	64	103	71	116	144	116
7	680	86	132	96	67	113	74	128	156	128
7,5	720	95	146	105	69	125	76	140	168	140

1.7.2 Beams are to be dovetailed on the shelf. When plywood deck planking is employed in place of the dovetail a simple dapping may be adopted having depth nor less than 1/4 of the beam depth. In the case the beam is to be fastened to the shelf by means of a screw or pin.

1.7.3 Vertical knees are to be fitted to the extent required in Table 7.1.7 to strong beams and to suitable distributed ordinary beams. At the ends of the hull the length of knee arms may be not more than one third of the span of the beam or frame. Horizontal knees re to be fitted on way of hatch end beams and beams adjacent to mast wedging. These knees need not be arranged when plywood deck planking is adopted.

Table 7.1.7: Vertical knees of beams

Length of beams m	Number of knees on each side	Length of arms		Forget knees		Steel angle knees	Plate thickness
		for 3/5 L amidships mm	outside 3/5 L amidships	at throat mm	at the ends mm	Section modulus cm^3	mm
1,5	3	280	220	20x7	17x4	0,25	3
2	4	320	250	23x10	20x5	0,4	3
2,5	4	360	290	27x13	24x6	0,8	3
3	5	400	320	34x17	30x7	1,7	4
3,5	6	440	350	41x20	37x7	3	4
4	7	490	390	48x23	42x8	4,3	4
4,5	8	530	420	53x26	46x9	5,9	5
5	9	570	450	57x28	49x10	7,5	5
5,5	10	610	490	62x30	52x11	9,3	5
6	10	650	520	67x32	54x12	11,5	6
6,5	11	700	560	72x34	55x14	14	6
7	12	740	590	78x35	57x16	16	6
7,5	12	780	620	81x37	58x17	19	7

1.7.4 The beams and decks shall be locally strengthened at the attachments of halliards, bollards, cleats, at skylight ends and on way of foundations of winches. All openings on deck shall be properly frames so as to constitute an effective support for half beams.

1.8 Planking

1.8.1 Shell planking

(a) The basic thickness of shell planking is given in Table 7.1.8. If the frame spacing is other than that indicated in Table 7.1.2 the thickness is to be increased where there is greater spacing or may be reduced where there is smaller spacing by 6mm for every 100mm of difference if type I framing is adopted, 4mm for every 100mm of difference if type II or III framing is adopted.

Table 7.1.8: Planking thickness

Length, m	Shell and deck plating mm	Deck planking in deckhouses and coatchroofs mm	Coamings of coatchroofs mm
14	29	20	26
16	32	22	28
18	35	23	30
20	39	24	32
22	43,5	25	34
24	45,5	26	36
26	47,5	27	36
28	50	28	36
30	52	29	36
32	54	30	36
34	56	31	36
36	58	32	36

(b) After correction for spacing as indicated above and for the weight of the timber where necessary the planking thickness may be reduced by 10% if arranged in diagonal or longitudinal double skin, by 10% if laminated and cold moulded in loco when the frames are reduced in scantlings by 25% in respect of the value given in Table 7.1.2. The thickness may be reduced by 25% where the frames have not been reduced in respect of the requirement of the table.

(c) When plywood is employed the thickness may be reduced in relation to the type of framing adopted, the maximum reduction permitted is 25%.

1.8.2 Deck planking

(a) The structure of the deck planking may be alternatively as following:

1. by planks parallel to the gunwale limited by a stringer board at side and by a kingplank at the centerline

2. plywood
3. plywood with associated planks

(b) The thickness of the deck is given in Table 7.1.8 and is subject to the following modifications:

1. if the beam spacing is other than that indicated in Table 7.1.6 the thickness is to be modified by 3mm for every 100mm of variation in spacing.
2. if plywood if employed the thickness may be reduced by 30%
3. if plywood is adopted in association with planking the specific mass of the plywood planking assembly is to be not less than 430 kg/m^3 and the combined thickness may be reduced by 30%.

1.8.3 Superstructures-Skylights

(a) When coachroofs are adopted the opening on deck is to be well framed and the coaming on the weather deck is to be nor less in thickness than that required in Table 7.1.8. The coachroofs deck is to have sheathing as prescribed in Table 7.1.8 which may be reduced in thickness in accordance with the specifications on 1.8.2 for the weather deck. If the beam spacing is other than that indicated in Table 7.1.6 the thickness is to be modified by 3mm for every 100mm of difference in spacing.

(b) When deckhouses are adopted they are to have a coaming fastened to the beams and carlings by means of through bolts. The structure of deckhouses is to be similar to that required for coachtoofs.

1.8.4 Mast and rigging

(a) The scantlings of masts and rigging are left to the experience of builders and shipowners.

(b) The mast step shall be of strong construction and shall be extended so as not to be connected to the hull. The wedging on deck shall be provided with watertight means.

(c) When the mast rests on deck the underlying structure shall be strengthened in way such as to avoid giving way. If the mast rest on a coachroof the hull is to be strengthened in way by means of a bulkhead or a stiffened frame.

(d) For shrouds and stays in wire and nor in rod the breaking loads of wires in galvanized steel 160 UNI 4434, in spiral shape, 1x19 wire and in stainless steel AISI 316 18/10 (ASTM-A 368-55) 1x19 wires in spiral shape are included below for information purposes.

Diameter, mm	Metallic cross section mm^2	Breaking load kN	
		Col. 1	Col. 2
3	5,37	7,75	7,36
4	9,55	13,73	13,73
5	14,2	21,1	20,6
6	21,5	30,9	29,43
7	29,2	41,69	40,22
8	38,2	54,94	52,97
10	59,7	65,73	83,39
12	86	122,63	117,72

1.9 Bulkheads

1.9.1 Wooden bulkheads

(a) Wooden watertight bulkheads normally consist of plywood boards of adequate thickness in relation to the hull size and the spacing and strength of stiffeners.

(b) The plywood normally arranged in vertical panels, shall be scarfed or strapped in way of vertical stiffeners. Connection to the hull shall be effected by means a grown or laminated frame and made watertight by packing where necessary.

1.9.2 Steel bulkheads

(a) Steel watertight bulkheads are to be of thickness as shown in Table 7.1.9 as a function of the spacing of stiffeners and the height of the bulkhead. The scantlings are given on the assumption that the lowest strakes is horizontal and subsequent strakes vertical. When all strake are horizontal the thickness of the third and higher strakes may be decreased by a maximum of 0,5mm per strake so as to reach a reduction of 25% in respect of the table thickness for the highest strake.

(b) If the spacing is other than that shown in the table the thickness is to be modified by 0,5 mm for every 100 mm of difference in spacing. The spacing of vertical stiffeners is nor to exceed 600mm for the collision bulkhead.

Table 7.1.9: Watertight steel bulkheads

Height of bulkhead, mm	Spacing of vertical stiffeners, mm	Thickness of lower strake, mm	Thickness of plate, mm
1,6	310	3	2,5
1,8	325	3	3
2	340	3,5	3
2,2	360	4	3,5
2,4	375	4	3,5
2,6	390	5	4,5
2,8	410	5	4,5
3	425	5,5	5
3,2	440	5,5	5
3,4	460	5,5	5
3,6	475	6	5,5
3,8	490	6	5,5
4	510	6	5,5
4,2	525	6	5,5
4,4	540	6,5	6
4,6	560	6,5	6
4,8	575	6,5	6
5	590	6,5	6

(c) The scantlings of vertical stiffeners in cm^3 without end connections are to be not less than:

$$Z = (4{,}2 + 4 \cdot h) \cdot s \cdot S^2$$

Where:

Z = section modulus of vertical stiffener with associated strip of plating one spacing wide, cm^3,

h = distance from midpoint of stiffener to top of bulkhead, m,

s = spacing of vertical stiffeners, m,

S = aggregate span of vertical stiffeners, m

(d) The connection of the bulkhead to planking is to be effected on grown or laminated frames and provided with watertight packing where necessary.

1.10 Machinery space structure

1.10.1 The scantlings of floors web frames and foundation girders shall be adequate for the weight power and type of machinery. Their suitability and that of associated connections shall be satisfactory with particular regard to engine running and navigation tests when required by these rules.

SECTION 2 Structural scantlings of motor vessels

2.1 General

2.1.1 The scantlings in this chapter apply to motor vessels and/or motor-sailing vessels having length not exceeding 36 m with a chine hull and speed not greater than 40 knots. The craft which differ substantially from the above, as regards dimensions and/or vessels with round keels, the scantlings are determined by equivalence criteria.

2.2 Keel, Stempost

2.2.1 The minimum breadth of the keel and the aggregate cross sectional area of keel and hog frame are given in Table 7.1.1. Such scantlings are to be maintained up to the stem and while they may be reduced by 30% at the stern end.

2.2.2 Where they do not form one piece the keel and hog frame are to be scarfed. The scarfs are to be 6 times the thickness and of hooked or tabled type if bolted or of plain type if glued, the length may be reduced to not less than 4 times the thickness where the scarf is bolted glued. The keel scarfs are to be spaced not less than 1,5 meters apart from those of the hog frame.

Table 7.2.1: Keel and Stempost

Length m	Keel		Stempost		
	minimum breadth mm	cross section of keel or keel and hog cm^2	width at heel and at head mm	cross section at heel cm^2	cross section at head cm^2
14	140	189	140	189	132
16	160	228	160	228	160
17	175	270	175	270	189
20	195	312	195	312	218
22	210	360	210	360	252
24	230	413	230	413	289
26	245	462	245	462	324
28	260	516	260	516	361
30	280	570	280	570	399
32	295	615	295	615	615
34	310	670	310	670	670
36	325	735	325	735	735

2.3 Transom

2.3.1 In chine hulls the sternpost is replaced by a transom. The transom structure consists of a frame having profile parts with a cross section not less than 120% of bottom frames, side frames or beams. Moreover the structures vertical stiffeners arranged in way of keel and bottom girders are to have a cross section with a height equal to that of the side frames and width increased by 50% .

2.3.2 The stiffeners above are generally to be spaced not more than 600 mm apart. The thickness of transom planking is to be equal to that given in Table 7.1.2 with any modifications required in accordance with those specified for shell planking.

2.4 Floors and frames

2.4.1 The ordinary framing of the hull is divided into three parts:

(a) bottom frames comprising those between the keel and the chine stringers

(b) side frames comprising those between the chine sringers and the waterways

(c) beams

2.4.2 The bottom frames generally made of two pieces one port and one starboard of the keel are butted in way of the centerline and connected by means of a double plywood floor. The side frames are in one piece connected to the bottom frames by means of double plywood brackets. The beams are connected to the side frames by means of double plywood brackets.

2.4.3 Bottom and side frames

(a) Frame scantlings are given in Table 7.2.3 where three different types of frames are considered:

1. Type I: solid or laminate frames of constant scantlings throughout the length of the hull
2. Type II: solid or laminated frames alternated with one or two bent frames. Only the former are connected by means of floors and brackets.
3. Type III: solid or laminated frames associated with bent longitudinal. This type of framing is to be associated with double skin cross planking or alternatively with plywood planking.

Table 7.2.2: Shell and deck planking

Length m	Shell planking		weather deck planking mm	Deck of superstructures mm
	transverse framing mm	longitudinal mm		
14	21,5	17,5	21,5	17,5
16	25	21	25	19
18	27	24	27	21
20	29	25	29	21
22	31	27	31	21
24	32	28,5	32	21
26	34	30	34	21
28	36	32	36	21
30	37,5	33,5	37,5	21
32	39,5	35	39,5	21
34	42	37	42	21
36	44	38,5	44	21

Table 7.2.3: Frames

Depth m	Type I framing (grown, or laminated frames)										
	spacing of web mm	Between keel and chine					Between chine and deck				
		Grown frames			Laminated frames		Grown frames			Laminated frames	
		width mm	depth		width mm	depth mm	width mm	depth		width mm	depth mm
			at heel mm	at head mm				at heel mm	at head mm		
1,9	237	24	60	54	24	47	24	50	44	24	43
2,1	255	26	72	65	26	56	26	60	55	26	51
2,3	270	28	82	75	28	61	28	70	63	28	56
2,5	288	30	96	88	30	71	30	81	74	30	65
2,7	305	32	112	102	32	82	32	93	84	32	75

2,9	322	35	127	116	35	93	35	103	90	35	85
3,1	340	39	140	127	39	104	39	117	108	39	94
3,3	355	44	148	135	44	113	44	122	110	44	103
3,5	375	50	162	148	50	125	50	131	115	50	114
3,7	390	55	178	162	55	135	55	143	123	55	125
3,9	408	60	200	182	60	157	60	156	130	60	143

Depth m	Type II framing (grown or laminated frames with bent frames in between)				
	Spacing between main frames with alternated			Bent frames	
	one bent frame mm	two bent frames mm	three bent frames, mm	width mm	depth mm
1,9	410	520	590	26	17
2,1	446	540	620	30	19
2,3	460	570	640	31	20
2,5	490	590	670	33	22
2,7	515	620	695	34	23
2,9	560	650	730	36	25
3,1	590	690	770	38	27
3,3	620	725	800	40	30
3,5	-	-	-	-	-
3,7	-	-	-	-	-
3,9	-	-	-	-	-

Depth m	Type III framing (grown, or laminated frames or bentwood longitudinal)										
	spacing of web mm	Between keel and chine					Between chine and deck				
		Grown frames			Laminated frames		Grown frames			Laminated frames	
		width mm	depth at heel mm	depth at head mm	width mm	depth mm	width mm	depth at heel mm	depth at head mm	width mm	depth mm
1,9	470	25	69	58	25	46	25	48	44	25	43
2,1	510	27	83	70	27	55	27	58	54	27	50
2,3	540	29	97	82	29	62	29	68	65	29	56
2,5	570	31	113	96	31	70	31	79	74	31	64
2,7	610	34	130	110	34	82	34	91	82	34	74
2,9	640	37	148	126	37	92	37	104	94	37	84
3,1	680	41	160	136	41	103	41	112	106	41	93
3,3	710	46	176	150	46	112	46	122	110	46	103
3,5	750	52	192	164	52	124	52	135	115	52	113
3,7	780	58	208	176	58	135	58	146	122	58	123
3,9	820	62	232	197	62	156	62	160	129	62	142

Dept h m	Type III framing (grown or laminated frames or bentwood longitudinal)				
	Bentwood longitudinal				
	spacing mm	Between keel and chine		Between chine and deck	
		width, mm	depth, mm	width, mm	depth, mm
1,9	210	33	20	33	17
2,1	225	37	23	37	19
2,3	240	39	25	39	20
2,5	255	41	27	41	22
2,7	270	43	28	43	23
2,9	285	45	30	45	25
3,1	300	48	33	48	27
3,3	315	50	36	50	30
3,5	330	53	39	53	33
3,7	345	55	42	55	36
3,9	360	58	45	58	39

2.4.4 Floors

The floors connecting bottom frames shall have thickness equal to half that required for the latter extend at the vessels centerlines to a height not less than twice that prescribed for the heel of such frames and overlap the frames by a distance not less than 2,5 times their depth so as to constitute an effective connection by means of glue and clenched volts. The space between the two levelers above the frames shall be fitted with a chock. Alternatively the frames nay be shafted so as to have at the centerline a depth above the keel equal to that required for the heel of the frames.

2.4.5 Frame and beam brackets

(a) The connection of bottom frames to side frames and of the latter to beams is to be achieved be means of double brackets similar to those described for floors but overlapping both frames and beams by a distance nor less than twice their respective depths.

(b) In lieu of the brackets above the frame beam connection may be effected by simply overlapping preferably dovetailing the beam on the shelf\geq and provided that transverse bulkheads are arranged with spacing not exceeding approximately 2 meters so as to constitute main transverse strengthening element of the hull and that no superstructure is arranged on the weather deck.

2.5 Side girders and longitudinal

2.5.1 On bottom frames at least two continuous girders are to be fitted each side with a cross section not less than 30 cm^2 for $L \leq 14$ meters, not less than 90 cm^2 for $L \geq 20$ meters and intermediate values for L between 15L between 14 and 20 meters.

2.5.2 For hulls with $L > 15$ meters such girders continuous over bottom frames are to be connected to the bottom planking by means of chocks between frames set on a bent longitudinal continuous through the floors and connected to the planking. The chocks and the bent longitudinal may be omitted but in such case the bottom planking thickness given in Table 7.2.4 is to be augmented such as to achieve a cross section throughout the bottom increased by at least half that of the longitudinal.

2.5.3 A similar longitudinal but with a cross section reduced to 0,65 of those described above and nor fastened to the planking is to be fitted on side frames of hulls with L>14 meters. Such longitudinal nay be omitted where type III framing is adopted.

Table 7.2.4:

Length of the hull, m	Cross section area of beams shelves, cm^2	Cross section area of chine stringers, cm^2
14	45	52
16	55	64
18	65	72
20	75	84
22	85	96
24	95	112
26	110	128
28	125	140
30	140	152
32	155	165
34	165	180
36	175	195

2.6 Beams

2.6.1 The arrangement of beams shall generally be carried out as follows:

(a) for hulls with type I framing ,beams on every frame

(b) for hulls with type II or III framing, beams on way of solid or laminated frames with bracket connection and intermediate beams without brackets let into the shelf.

2.6.2 Beams are to have width equal to that of the frames to which they are connected and section modulus in, cm^3 , not less than:

$$Z_1 = K_1 \cdot a \cdot s$$

At the ends of large openings beams are to be fitted having a section modulus, in cm^3, not less than:

$$Z_2 = K_2 \cdot a \cdot s$$

Where:

Z_1, Z_2 = section modulus of beams without planking contribution in cm^3,

a = width of beams, in cm,

s = beam spacing, in cm,

K_1, K_2 = coefficient given by the following Table 7.2.5 as a function of the beam span.

Table 7.2.5:

Beam span m	Coefficients for calculation of beam section modulus			
	K_1		K_2	
	at the centerline	at the ends	at the centerline	at the ends
1,2	9,4	4,26	17,1	8,7
2	14,3	6,43	23	11,4
2,5	18	8,5	3	15,1
3	22,2	10,7	38,6	17,7
3,5	24,7	12,5	43,6	22,2
4	28,3	13,9	48,7	23,6
4,5	30,6	14,9	52,5	25,2
5	32,4	16,3	56,8	27,7
5,5	35,1	17,1	60	28,7
6	36,9	18,1	63,5	31,8
6,5	38,7	19,5	70	35
7	39,6	20,5	73,5	40,2
7,5	40,5	23	81	45,4

2.6.3 Where laminated beams are arranged the section modulus Z_1, Z_2 may be reduced of those indicated above.

2.7 Beam shelves and chine stringers

2.7.1 The cross sectional area of beam shelves and chine stringer is to be not less than that given by the following Table 7.2.4 as a function of L and to have the ratio h/t<3 where h is the depth and t the thickness of the bar. The cross section of shelves and stringers is to be considered as inclusive of the dappings for beam and frame ends.

2.8 Shell planking

2.8.1 The basic thickness of shell planking is given in Table 7.2.2. If the frame spacing is other than that shown in Table 7.2.3 the planking thickness is to be increased or may be reduced accordinary by 10% for every 10 mm of difference. After correction for spacing the planking thickness may be reduced:

(a) by 10% of a diagonal or longitudinal double skin planking is adopted.

(b) by 15% of composite planking constituted by inner plywood skin and one or two outer longitudinal diagonal strakes is adopted

(c) by 25% if laminated planking or plywood is adopted

2.8.2 Vessels with speed>25 knots are to have bottom frames stiffened in respect of the scantlings in this article and planking thickness increased as follows

(a) speed from 26 to 30 knots: 5%

(b) speed from 31 to 35 knots: 10%

(c) speed from 36 to 40 knots: 15%

2.8.3 When the deadrise is between 25° and 30° and outer longitudinal strakes are fitted on the bottom planking the above increase in thickness may be reduced but generally not less than half of the percentage values above.

2.9 Deck planking

2.9.1 Weather deck

(a) Deck planking may be constituted by planks limited by a stringer board at side and by a kingplank at the centerline. Such planking may be solely plywood or plywood with associated planking arranged as described above.

(b) The thickness of deck planking is given in Table 7.2.2 of the beam spacing is other than that prescribed in Table 7.2.3 the planking thickness is to be increased or may be reduced accordingly by 10% for every 100 mm of difference.

(c) After correction for spacing the planking thickness may be reduced:

1. by 30% of plywood or plywood associated with planking is employed.

Moreover the plywood thickness is to be not less than 30% of the total thickness or less than 6mm.

2.9.2 Superstructure decks

The thickness of planking of superstructure decks is given in Table 7.2.2.

2.9.3 Lower deck

(a) In hulls with depth measured between the upper keel side and the weather deck beam greater than or equal to 3.1 meters a lower or cabin deck is to be arranged with beams having a section modulus not less than 60% of that prescribed in article 2.6 for weather deck beams and effectively fastened to the sides by means of a shelf with a cress sectional area nor less than 2/3 of that required in Table 7.2.4.

(b) When the depth as measured above exceeds 4,3 meters the fastening of beams to side is to be completed by means of plywood brackets arranged at least at every second beam and having scantlings as prescribed in 2.4.5. The scantlings of the deck planking are to be not less than those required in 2.9.2.

CHAPTER 8 Equipment

Contents

SECTION 1 General

1.1 Application

1.1.1 The requirements in this Chapter apply to equipment and installation for anchoring and mooring. Requirements for towlines are not a subject of Classification. However, lengths and breaking strengths are given as guidance in SECTION 6.

1.1.2 For ships intended to operate only in special areas or conditions which have been approved by the Society, equipment differing from the requirements of this Chapter may be accepted, if considered in accordance to the particular service on which they are to be engaged.

1.2 Plans to be submitted

1.2.1 The following plans and particulars are to be submitted for approval:

(a) Calculation of the equipment number.

(b) Type of anchor, grade of anchor chain, type and breaking load of steel and fibre ropes.

(c) Design of anchor if different from a standard type. Material specification.

(d) Design of windlass and material specification.

(e) Design of chain stopper and material specification.

1.2.2 Test certificates will be required for the following:

(a) Anchor

(b) Anchor chain cable

(c) Windlass

(d) Wire rope

(e) Wire rope for mooring

SECTION 2 Equipment number - Equipment tables

2.1 Definition

2.1.1

(a) The basic equipment number for determining the required equipment is to be calculated from the following equation:

$$EN = \Delta^{2/3} + 2 \cdot B \cdot H + 0{,}1 \cdot A$$

Where:

Δ	=	Moulded displacement to the summer load waterline, in tones,
B	=	Breadth of ship, in m,
H	=	$\alpha + \sum h$ in m (see Figure 8.2.1),

α = Freeboard from the summer load waterline amidships, in m.

∑h = Sum of the heights on the centerline of each tier of deckhouses having a breadth greater than 0,25B, in m.

A = Sum of the profile area of the hull above summer load waterline, and of superstructures and deckhouses having a breadth greater than 0,25B, which are within the length of ship L, in m².

(b) For vessels having EN of 200 or above the required equipment is to be obtained from Table 8.3.1, Table 8.3.3, Table 8.3.4 and Table 8.6.1.

(c) For vessels having EN according to (a) less than 200 the EN used for obtaining the required equipment from Table 8.3.1, Table 8.3.3, Table 8.3.4 and Table 8.6.1 is to be calculated from the following equation:

$$EN = \Delta^{2/3} + 2 \cdot (C + B \cdot a) + 0{,}1 \cdot A$$

Where:

Δ = loaded displacement in tones,

C = the sum of b_i h_i for all deckhouses and superstructures tiers.

b_i = mean breadth of deckhouse or superstructure tier, in meters,

h_i = mean height of deckhouse or superstructure tier in meters,

a = The distance in meters, from the waterline to the underside of the first tier of deckhouse or superstructure.

B = Breadth of ship, in m,

A = Sum of the profile area of the hull above summer load waterline, and of superstructures and deckhouses having a breadth greater than 0,25B, which are within the length of ship L, in m².

(d) The equipment of light displacement craft and yachts described in Table 8.3.2 and Table 8.6.2 is based on the “Equipment Number” which is calculated as follows:

$$EN = \Delta^{2/3} + 2 \cdot (C + B \cdot a) + 0{,}1 \cdot A$$

Where:

Δ = loaded displacement in tones,

C = the sum of b_i h_i and $\cos\theta_i$ for all deckhouses and superstructures tiers.

b_i = mean breadth of deckhouse or superstructure tier, in meters,

h_i = mean height of deckhouse or superstructure tier in meters,

θ_i = angle of inclination aft, of tier of deckhouse front, with a line perpendicular to the static load waterline,

a = The distance in meters, from the waterline to the underside of the first tier of deckhouse or superstructure.

B = Breadth of ship, in m,

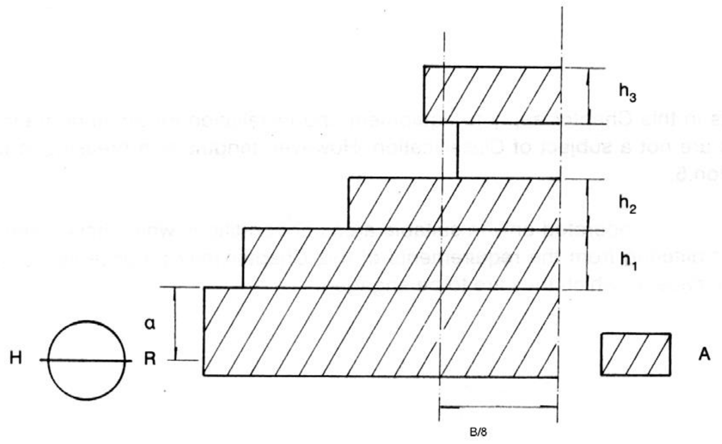
A = Sum of the profile area of the hull above summer load waterline, and of superstructures and deckhouses having a breadth greater than 0,25B, which are within the length of ship L, in m².

2.1.2 When calculating H and A, sheer, camber and trim may be ignored. Windscreens and bulwarks more than 1,5 m in height are to be regarded as parts of superstructures or deckhouses when calculating H and A. Where the height of a windscreen or bulwark is not constant, the portion exceeding 1,5 m in height is to be included. Hatch coamings more than 1,5 m in height are to be included when calculating A.

2.1.3 The formula in 2.1.1 for the required anchoring equipment is based on the assumption that the current speed is 2,5 m/sec, the wind speed is 25 m/sec, and the scope of chain cable lies between 6 and 10. The scope is defined as the ratio between the length of chain paid out and the water depth. If the anchoring equipment is to be used in worse conditions special calculations should be given.

2.1.4 The required equipment of anchors and chain cables is suitable for temporary mooring of the vessel within a harbor, in sheltered waters or for use in emergencies. In the case the equipment is intended to be used in open sea operations (e.g. research ships) special considerations should be given.

Figure 8.2.1:



2.2 Additional Requirements for Commercial Yachts

2.2.1 All yachts with the notation "COMMERCIAL YACHT" are to have at least 2 anchors, one of which must be ready for use at all times. Any powered deployment system shall be connected to an emergency power supply or be capable of being manually operated.

SECTION 3 Anchors

3.1 Anchor types

3.1.1 Anchors are usually of stockless type of an approved design. Anchors of stocked type may be also used. In the latter case, the mass of the stocked anchor, without the stock, is not to be less than

80% of the value given in Table 8.3.1 and Table 8.3.3 for ordinary stockless anchors. The mass of the stock is to be 20% of the total mass of the anchor including the shackle, etc., and the stock.

3.1.2 It is assumed that under normal circumstances the ship will use only one anchor and chain cable at a time.

3.1.3 The design of all anchor heads is to be such as to minimize stress concentrations. In particular, the radii on all parts of cast anchor heads are to be as large as possible, especially when there is considerable change of section.

3.1.4 The mass of each anchor given in Table 8.3.1 and Table 8.3.3 is for anchors of equal mass. The masses of individual anchors may vary ±7% of the masses given in Table 8.3.1 and Table 8.3.3, provided that the total mass of all anchors is not less than that required for anchors of equal mass. The mass of the head, including pins and fittings, of an ordinary stockless anchor is not to be less than 60% of the total mass of the anchor.

3.1.5 The anchors are normally housed in hawse pipes of suitable size and form in order to prevent movement of anchor and chain due to the motions of the ship. The deck arrangements must provide an easy way of the chain cable from the windlass to the anchor. Upon release of the brake, the anchor has to immediately start falling by its own weight. The radius of curvature of the upper end of the hawse pipe should be such that at least 3 link of chain bear simultaneously. Where hawse pipes are not fitted special arrangements should be given.

3.1.6 The shell plating in the area of the hawse pipes is to be increased in thickness and framing in such a way so that to ensure a rigid fastening of the hawse pipes to the hull of the ship.

3.2 Additional requirements for High Holding Power (HHP) and Super High Holding Power (SHHP) anchors

3.2.1 H.H.P. and S.H.H.P. anchors are designed for effective hold of the sea bed irrespective of the angle or position at which they first settle. If the anchor is not of a standard type, a demonstration of this property may be required.

3.2.2 Anchor of design for which approval as H.H.P. anchor is sought, is to be tested at sea to prove that it has a holding power per unit of mass at least twice the holding power of an ordinary stockless anchor of the same mass. In this case its weight may be reduced up to a maximum of 10% from weights specified in Table 8.3.1 and Table 8.3.3.

3.2.3 Anchor of design for which approval as S.H.H.P. anchor is sought, is to be tested at sea to prove that it has a holding power per unit of mass at least 4 times the holding power of an ordinary stockless anchor of the same mass. In this case its weight may be reduced up to a maximum of 20% from weights specified in Table 8.3.1 and Table 8.3.3.

3.2.4 The tests are to be conducted on at least 3 different types of bottom, which normally are to be soft mud or silt, sand or gravel, and hard clay or similarly compacted material.

3.2.5 If approval is sought for a range of anchor sizes, at least two sizes are to be tested. The smaller of them is to have a mass not less than 1/10 of the mass of the larger one. The larger one is to have a mass not less than 1/10 of that of the largest anchor for which approval is sought.

3.2.6 The tests should normally be carried out from a tug, and the pull measured by a dynamometer or derived from recently verified curves of tug bollard pull as a function of propeller rpm. A scope of 10 is recommended for the anchor cable, which may be a wire rope for these tests, but in no case a scope less than 6 is to be used. The same scope is to be used for the anchor for which approval is sought and the anchor that is being used for comparison purposes.

3.3 Materials - Manufacture

3.3.1 Forged or cast anchors and anchor components must be made of weldable carbon or carbon manganese steel with a carbon content not exceeding 0,22%, or 0,23% for cast steel.

3.3.2 Rolled steels for the manufacture of anchors of welded construction must meet the requirements specified in Chapter 3 of Part 2 of "Rules and Regulations for the Classification and Construction of Steel Ships".

Table 8.3.1: Equipment - Anchors and chain cables for small craft

Equipment number		Stockless anchors		Stud-link chain cables			
					Diameter (mm)		
Exceeding	Not exceeding	Number	Mass of anchor (Kg)	Total length (m)	Mild steel	Special quality steel	Extra special quality steel
30	40	2	80	192,5	12,5	-	-
40	50	2	100	192,5	12,5	-	-
50	60	2	120	192,5	14	12,5	-
60	70	2	140	192,5	14	12,5	-
70	80	2	160	220	16	14	-
80	90	2	180	220	16	14	-
90	100	2	190	220	17,5	16	-
100	110	2	240	220	17,5	16	-
110	120	2	270	247,5	19	17,5	-
120	130	2	300	247,5	19	17,5	-
130	140	2	340	275	20,5	17,5	-
140	150	2	390	275	20,5	17,5	-
150	160	2	450	275	22	19	-
160	170	2	475	275	22	19	-
170	180	2	500	302,5	24	20,5	-
180	190	2	530	302,5	24	20,5	-
190	200	2	560	302,5	24	20,5	-
200	220	2	615	302,5	26	22	20,5
220	240	2	670	302,5	26	22	20,5
240	260	2	725	330	28	24	22
260	280	2	780	330	28	24	22
280	300	2	840	357,5	30	26	24
300	320	2	900	357,5	30	26	24
320	340	2	955	357,5	32	28	24
340	360	2	1020	357,5	32	28	24
360	380	2	1080	385	34	30	26
380	400	2	1135	385	34	30	26
400	425	2	1290	385	36	32	28
425	450	2	1340	385	36	32	28
450	475	2	1390	412,5	38	34	30
475	500	2	1440	412,5	38	34	30

500	550	2	1590	412,5	40	34	30
550	600	2	1740	440	42	36	32
600	650	2	1920	440	44	38	34
650	700	2	2100	440	46	40	36
700	750	2	2220	467,5	48	42	36
750	800	2	2370	467,5	50	44	38
800	850	2	2460	467,5	50	44	38
850	900	2	2640	467,5	52	46	40
900	950	2	2850	495	54	48	42
950	1050	2	3060	495	56	50	44
1050	1150	2	3300	495	58	50	46

Table 8.3.2: Equipment - Anchors and chain cables for light displacement craft and yachts

Equipment number		High holding power bower anchors			Stud link chain cable diameter, in mm		
Exceeding	Not exceeding	Number of anchors	Mass of anchor, in kg	Length of chain cable in meters	Mild steel	Special quality Steel	Extra special quality Steel
-	5	1	1 1	55	8	-	-
5	10	1	13	55	8	-	-
10	15	1	17	55	8	-	-
15	20	1	22	55	9	-	-
20	25	1	27	55	9	-	-
25	30	1	32	83	11,2	-	-
30	35	1	37	83	11,2	-	-
35	40	1	44	83	11,2	-	-
40	45	1	52	110	11,2	-	-
45	50	1	59	110	12,5	-	-
50	70	1	80	110	12,5	-	-
70	90	1	117	110	14	12,5	-
90	110	1	154	110	16	14	-
110	130	1	197	138	17,5	16	-
130	150	1	240	138	19	17,5	-
150	175	1	292	138	20,5	17,5	-
175	205	1	360	138	22	19	-
205	240	1	428	165	24	20,5	-
240	280	1	495	165	26	22	20,5
280	320	1	585	165	28	24	22
320	360	1	675	193	30	26	24
360	400	1	765	193	32	28	24
400	450	1	855	193	34	30	26
450	500	1	968	193	36	32	28
500	550	1	1080	220	38	34	30
550	600	1	1193	220	40	34	30
600	660	1	1305	220	42	36	32
660	720	1	1440	220	44	38	34

720	780	1	1575	220	46	40	36
780	840	1	1710	248	48	42	36
840	910	1	1845	248	50	44	38
910	980	1	1980	248	52	46	40
980	1060	1	2138	248	54	48	42
1060	1140	1	2295	248	56	50	44

Table 8.3.3: Equipment of fishing vessels-Bower anchors and chain cables

Equipment number		Stockless anchors				
					Diameter (mm)	
Exceeding	Not exceeding	Number	Mass of anchor (Kg)	Total length (m)	Mild steel	Special quality steel
30	40	2	80	165	11	-
40	50	2	100	192,5	11	-
50	60	2	120	192,5	12,5	-
60	70	2	140	192,5	12,5	-
70	80	2	160	220	14	12,5
80	90	2	180	220	14	12,5
90	100	2	210	220	16	14
100	110	2	240	220	16	14
110	120	2	270	247,5	17,5	16
120	130	2	300	247,5	17,5	16
130	140	2	340	275	19	17,5
140	150	2	390	275	19	17,5
150	175	2	480	275	22	19
175	205	2	570	302,5	24	20,5
205	240	2	660	302,5	26	22
240	280	2	780	330	28	24
280	320	2	900	357,5	30	26
320	360	2	1020	357,5	32	28
360	400	2	1140	385	34	30
400	450	2	1290	385	36	32
450	500	2	1440	412,5	38	34
500	550	2	1590	412,5	40	34
550	600	2	1740	440	42	36
600	660	2	1920	440	44	38
660	720	2	2100	440	46	40

Table 8.3.4: Equipment reduction for ships operating in restricted areas

Class Notation	Stockless Bower anchors		Stud-link chain cables	
	Number	Mass change per anchor	Length reduction	Diameter
Coastal service	2	-10%	0%	0%
	1	40%	-40%	0%
Extended protected waters service	2	-20%	0%	-10%
	1	10%	-45%	0%
Protected waters service	2	-30%	-20%	-10%
	1	0%	-50%	0%
NOTE: In the case of 'Specified route service' or 'Specific operating area service' notations the reduction will be specially considered.				

3.3.3 Forged or cast anchors and anchor components must be normalized.

3.3.4 Anchor shackles must be made of forged or cast steel and must be properly heat treated.

3.3.5 Forged steel must meet the requirements set out in Chapter 5 and cast steel those contained in Part 2, Chapter 4 of "Rules and Regulations for the Classification and Construction of Steel Ships".

3.4 Quality of anchors

3.4.1 All anchors must be free from defects liable to impair their function, e.g. cracks, major casting and forging defects and improperly executed welds.

3.5 Testing of anchors

3.5.1 Anchors are to be submitted for testing in the fully assembled condition and may not be coated with paint or preservatives.

3.5.2 Anchors with a total weight (including the stock) of 75 kg or more (56 kg in the case of high holding power anchors) are to be tested at an establishment approved by the Society in the presence of a Surveyor. Each anchor is to be subjected to a load test in an approved testing machine and is to withstand the load given in Table 8.3.5 for the appropriate weight of the anchor. On completion of the test each anchor is to be examined and is to be free from significant defects. In addition, in the case of anchors of composite construction, the freedom of movement of the arms over the whole angle of deflection must be preserved following the test, and no excessive changes may be caused by deformation of the bearings.

3.5.3 The weight to be used in Table 8.3.5 is:

(a) For stockless anchors, the total weight of the anchor.

(b) For stocked anchors, the weight of the anchor excluding the stock.

(c) For high holding power anchors, a nominal weight equal to 1,33 times the actual weight of the anchor (i.e. for stocked anchors the weight includes the stock).

(d) For super high holding power anchors, a nominal weight equal to 2,0 times the actual weight of the anchor

3.6 Identification

3.6.1 All identification marks are to be stamped on one side of the anchor reserved for this purpose.

3.6.2 The following details are to be shown on all anchors:

(a) Manufacturer's symbol.

(b) LHR and abbreviated name of the Society's local office issuing the certificate.

(c) Number of the certificate.

(d) Month and year of test.

(e) Weight (also the letters 'HHP' or 'SHHP when approved as high holding power or super high holding power anchors, respectively).

(f) Weight of stock (in the case of stocked anchors).

3.6.3 In addition to 3.6.2, each important part of an anchor is to be plainly marked by the maker with the words "forged steel" or "cast steel" as appropriate. Fabricated steel anchor heads do not require special marking.

Table 8.3.5: Test loads for anchors

Weight (kg)	Test load (kN)	Weight (kg)	Test load (kN)
50	23	650	140
55	25	700	149
60	27	750	158
65	29	800	166
70	31	850	175
75	32	900	182
80	34	950	191
90	36	1000	199
100	39	1050	208
120	44	1100	216
140	49	1150	224
160	53	1200	231
180	57	1250	239
200	61	1300	247
225	66	1350	255
250	70	1400	262

275	75	1450	270
300	80	1500	278
325	84	1600	292
350	89	1700	307
375	93	1800	321
400	98	1900	335
425	103	2000	349
450	107	2100	362
475	112	2200	376
500	116	2300	388
550	125	2400	401
600	132	2500	414

NOTE:

1. Intermediate values can be determined by linear interpolation.

3.7 Repair and testing of damaged anchors

3.7.1 Damaged anchors may be repaired by straightening and/or welding, provided that the Surveyor approves the method used. Straightening must be performed hot.

3.7.2 Welds are to be executed, preferably in the horizontal position, by certified welders using approved electrodes. After welding, the anchor component concerned is to be stress relieved. Welds must be free from defects liable to impair the function of the anchor, e.g. cracks, slag inclusions, serious undercutting and lack of fusion.

3.7.3 Repaired anchors are to be retested in accordance with 3.5.

SECTION 4 Anchor chain cables

4.1 Cable types

4.1.1 Anchor cables are to be stud link chains of Grades LHR-1, LHR-2 or LHR-3 (see 4.2) corresponding to the nominal diameter of chain and equipment number given in Table 8.3.1 and Table 8.3.3.

4.1.2 Chain cables are to be made by makers approved by the Society for the pertinent type of the chain cable, size and method of manufacture.

4.1.3 The form and proportion of chain cable links and shackles are to be in accordance with International Standard ISO/1704-1973 (see Figure 8.4.1).

4.1.4 If steel wire rope or ordinary short link chain cable is used instead of stud link chain cable, that is to have length equal to 1,5 times the corresponding tabular length of stud link chain cable and to be of strength equal to that of tabular stud link chain cable of grade A.

4.1.5 When chain cable is substituted by wire or synthetic fibre rope, a short length of chain cable is to be fitted between the anchor and wire rope. Its length is at least to be the distance between anchor in stowed position and windlass. Shorter length may be considered in special cases. The ropes are to be stored on drums protected from the weather and sea and are to be led over rollers in order to reduce wear and tear.

4.1.6 The chain locker is to have adequate capacity and suitable form to provide a proper stowage of the chain cable, and an easy direct lead for the cable into the chain pipes, when the cable is fully stowed. Port and starboard cables are to have separate spaces. The chain locker boundaries and access openings are to be watertight. Adequate drainage facilities are to be adopted for the chain locker. Provisions are also to be made for securing the inboard ends of chain to the structure.

4.2 Materials

4.2.1 Depending on the nominal tensile strength of the chain cable steel used for manufacture, stud link chain cables are to be subdivided into Grades LHR-1, LHR-2 or LHR-3. For studless short link chain cables Grades LHR-1 and LHR-2 only are applicable.

4.2.2 These Rules apply to rolled steels, forging and castings used for the manufacture of anchor chain cables and accessories.

4.2.3 The mechanical properties of rolled steels, forging and castings used for the manufacture of chain cables and accessories must be in accordance with the values indicated in Table 8.4.1.

4.3 Rolled steel bars

4.3.1 The steels are to be manufactured by the basic oxygen, electric furnace or open hearth process. Grade LHR-1 steel is to be cast in killed condition, all other steels fully killed and fine grain treated.

4.3.2 Unless otherwise stipulated, the steels will be supplied in the as rolled condition.

4.3.3 The chemical composition of the steel bars is to be generally within the limits given in Table 8.4.2.

4.3.4 Generally the steel bars are to be supplied with a works' acceptance test certificate indicating the chemical composition of each heat and the mechanical tests are to be carried out by the chain cable manufacturer. However, the Society may require mechanical testing of the bar materials at the steel mill in a heat treatment condition equivalent to that of the finished chain cable, in which case the properties are to be those indicated in Table 8.4.1.

Table 8.4.1: Mechanical properties of chain cable materials

Grade	Yield stress (N/mm^2) min.	Tensile strength (N/mm^2)	A_5 (%) min.	Z (%) min.	Notched bar impact test	
					Test temp. (°C)	KV (Note 1) (J) min.
LHR-1	-	max. 490	25	-	-	-
LHR-2	295	490-690	22	-	0	27 (Note 2)
LHR-3	410	min. 690	17	40	0 (-20)	60 (35) (Note 3)

NOTES:

1. Average value from 3 test specimens. One individual value may be lower than the average value, but not below 70% of the average value stipulated.
2. The impact test of Grade LHR-2 materials may be waived, if the chain cable is to be supplied in a heat treated condition.
3. At the option of the Society the impact test of Grade LHR-3 materials may alternatively be carried out at -20°C

Table 8.4.2: Chemical composition of rolled steel bars

Grade	Chemical composition (%)					
	C max	Si	Mn	P max.	S max.	Al tot (Note 1) min.
LHR-1	0,2	0,15-0,35	min. 0,040	0,04	0,04	-
LHR-2 (Note 2)	0,24	0,15-0,55	max. 1,60	0,035	0,035	0,02
LHR-3	In accordance with an approved specification					

NOTES:

1. Aluminium may be replaced partly by other grain refining elements.
2. At the option of the Society, additional alloying elements may be added.

4.3.5 Diameter tolerances are subject to recognized standards to be mentioned in the order.

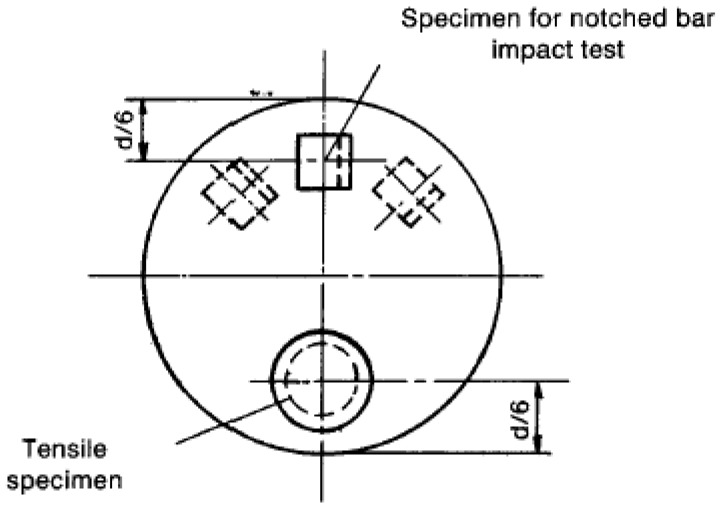
4.3.6 The materials have to be free from internal and surface defects that might impair proper workability and use. Surface defects may be repaired by grinding, provided the admissible tolerance is not exceeded.

4.3.7 Manufacturers will have to establish an identification system ensuring traceability of the material to the original cast.

4.3.8 For performance of the mechanical tests the steel bars shall be sorted according to heats and diameters into batches not exceeding 50 t each. From each batch a test sample will be taken for the tests mentioned in 4.3.10 and 4.3.11. Prior to sampling, the test samples must be subjected to the heat treatment provided for the finished chain cable; see 4.8. Details of the heat treatment must be indicated by the chain cable manufacturers.

4.3.9 The tensile and notched bar impact test specimens shall be taken from the test sample in the longitudinal direction at a distance of 1/6 diameter from the surface or as close as possible to this position (see Figure 8.4.1).

Figure 8.4.1: Sampling of chain cable steel



4.3.10 10 For the tensile test, one specimen shall be taken from each test unit and tested in accordance with Chapter 2 of Part 2 of "Rules and Regulations for the Classification and Construction of Steel Ships".

4.3.11 For round steel bars of Grade LHR-3, and when required also for Grade LHR-2, notched bar impact tests shall be carried out in accordance with Part 2, Chapter 2 of "Rules and Regulations for the Classification and Construction of Steel Ships". To this effect, from each test unit one set of longitudinal V-notch test specimens shall be taken and tested at the temperature prescribed in Table 8.4.1. The notch is to be radial to the bar.

4.3.12 All products must be checked by manufacturers as to their surface condition and their dimensions.

4.3.13 Where during tensile or notched bar impact tests the requirements are not met, for each unsatisfactory test two re-test specimens or sets of specimens shall be tested. The re-test specimens must be taken from pieces of the test unit, different from those from which the original test specimens were taken. The test unit will be considered satisfactory, if both re-test specimens or sets of specimens meet the requirements. If failure to pass the test is definitely attributable to improper heat treatment of the test sample, a new test sample may be taken from the same piece and re-heat treated. The complete test (both tensile and impact test) is to be repeated; the original results obtained may be disregarded.

4.3.14 The minimum markings required for the steels are the manufacturers' mark, the steel grade and an abbreviated symbol of the heat. Steels having diameters of up to and including 40 mm combined into bundles, may be marked on permanently affixed labels.

4.3.15 For each consignment manufacturers shall hand to the Surveyor a certificate containing at least the following data:

(a) Manufacturer's and/or purchaser's order No.

(b) Number and dimensions of bars and weight of consignment.

(c) Steel grade.

(d) Heat number.

(e) Manufacturing procedure.

(f) Chemical composition.

(g) Details of heat treatment of the test sample.

(h) Results of mechanical tests (where applicable).

(i) Number of test specimens (where applicable).

4.4 Forged steels

4.4.1 Forged steels used for the manufacture of chain cables and accessories must be in compliance with Part 2, Chapter 5, SECTION 2 of "Rules and Regulations for the Classification and Construction of Steel Ships", unless otherwise specified in the following paragraphs.

4.4.2 The chemical composition is to comply with the specification approved by the Society. The steel manufacturer must determine and certify the chemical composition of every heat of material.

4.4.3 The stock material may be supplied in the as-rolled condition. Finished forging are to be properly heat treated, i.e. normalized or quenched and tempered, whichever is specified for the relevant steel grade.

4.4.4 Unless otherwise specified, the forging must at least comply with the mechanical properties given in Table 8.4.1, when properly heat treated.

4.4.5 For test sampling, forging of similar dimensions originating from the same heat treatment charge and the same cast of steel are to be combined into one test unit. From each test unit one tensile and three impact test specimens are to be taken and tested. For the location of the test specimens see 4.3.9 and Figure 8.4.1.

4.5 Cast steels

4.5.1 Cast steels used for the manufacture of chain cables and accessories must be in compliance with Part 2, Chapter 4, SECTION 2 of "Rules and Regulations for the Classification and Construction of Steel Ships", unless otherwise specified in the following paragraphs.

4.5.2 The chemical composition is to comply with the specification approved by the Society. The foundry is to determine and certify the chemical composition of every heat.

4.5.3 All castings must be properly heat treated, i.e. normalized or quenched and tempered, whichever is specified for the relevant cast steel grade.

4.5.4 Unless otherwise specified, the castings must at least comply with the mechanical properties given in Table 8.4.1.

4.5.5 For test sampling, castings of similar dimensions originating from the same treatment charge and the same cast of steel are to be combined into one test unit. From each test unit one tensile and three impact test specimens are to be taken and tested. For the location of the test specimens see 4.3.9 and Figure 8.4.1.

4.6 Materials for studs

4.6.1 The studs are to be made of steel corresponding to that of the chain cable or from rolled, cast or forged mild steels. The use of other materials, e.g. gray or nodular cast iron is not permitted.

4.6.2 Stud link chain cables should preferably be manufactured by flash butt welding using Grade LHR-1, LHR-2 or LHR-3 bar material. Manufacture of the links by drop forging or steel casting is permitted. On request, pressure butt welding may also be approved for studless, Grade LHR-1 and LHR-2 chain cables, provided that the nominal diameter of the chain cable does not exceed 26 mm.

4.6.3 Accessories such as shackles, swivels and swivel shackles are to be forged or cast in steel of at least Grade LHR-2. The welded construction of these parts may also be approved.

4.7 Design and manufacturing process

4.7.1 Stud link chain cables should preferably be manufactured by flash butt welding using Grade LHR-1, LHR-2 or LHR-3 bar material. Manufacture of the links by drop forging or steel casting is permitted. On request, pressure butt welding may also be approved for studless, Grade LHR-1 and LHR-2 chain cables, provided that the nominal diameter of the chain cable does not exceed 26 mm.

4.7.2 Accessories such as shackles, swivels and swivel shackles are to be forged or cast in steel of at least Grade LHR-2. The welded construction of these parts may also be approved.

4.7.3 Chain cables must be manufactured according to an approved standard. Typical designs are given in Figure 8.4.4, Figure 8.4.5 and Figure 8.4.6. A length of chain cable must comprise an odd number of links. Where designs do not comply with this and where accessories are of welded construction, drawings giving full details of the manufacturing process and the heat treatment are to be submitted to the Society for approval.

4.8 Heat treatment

4.8.1 According to the grade of steel, chain cables are to be supplied in one of the conditions specified in Table 8.4.3. The heat treatment shall in every case be performed before the load or rupture test.

Table 8.4.3: Heat treatment of chain cables

Grade	Condition of supply
LHR-1 (Note 1)	As-welded or normalized condition
LHR-2	Normalized, normalized and tempered or quenched and tempered condition
LHR-3	

NOTE:

1. Grade 2 chain cables are generally to be normalized. The Society may, however, refrain from this requirement on the basis of an approval test, in which case it may specify additional requirements.

4.9 Mechanical properties

4.9.1 The mechanical properties of finished chain cables and accessories, i.e. tensile strength, elongation, reduction of area and impact energy, are to be in accordance with Table 8.4.1.

4.10 Proof and breaking load properties

4.10.1 Chain cables and accessories are to be manufactured in a manner such as to withstand the proof and breaking loads indicated in Table 8.4.4 depending on the relevant chain cable grade.

4.11 Freedom from defects

4.11.1 All individual parts must have a clean surface consistent with the method of manufacture and be free from cracks, notches, inclusions and other defects impairing the performance of the product. The flashes produced by upsetting or drop forging must be properly removed.

4.11.2 Minor surface defects may be ground off so as to leave a gentle transition to the surrounding surface. Remote from the crown local grinding up to 5% of the nominal link diameter may be permitted.

4.12 Dimensions and dimensional tolerances

4.12.1 The dimensions of links and swivels must conform to an approved standard. Typical designs are given in Figure 8.4.7, Figure 8.4.8, Figure 8.4.9 and Figure 8.4.10.

4.12.2 The following tolerances are applicable to links:

(a) Nominal diameter:

1. up to 40 mm diameter : -1 mm
2. over 40 mm up to 84 mm diameter: -2 mm
3. over 84 up to 122 mm diameter : -3 mm
4. over 122 mm diameter : -4 mm

The plus tolerance may be up to 5% of the nominal diameter. The cross sectional area of the crown must have no negative tolerance. For the tolerances of the diameter of the weld the approved manufacturer's specification is applicable.

(b) The maximum allowable tolerance on assembly measured over a length of 5 links may equal

+2,5%, but may not be negative (measured with the chain under tension after proof load test).

(c) All other dimensions are subject to a manufacturing tolerance of + 2,5%, provided always that all parts of the chain cable fit together properly.

(d) Studs must be located in the links centrally and at right angles to the sides of the link, although the studs of the final link at each end of any length may also be located off-centre to facilitate the insertion of the joining shackle. The following tolerances are regarded as being inherent in the method of manufacture and will not be objected to provided that the stud fits snugly and its ends lie practically flush against the inside of the link.

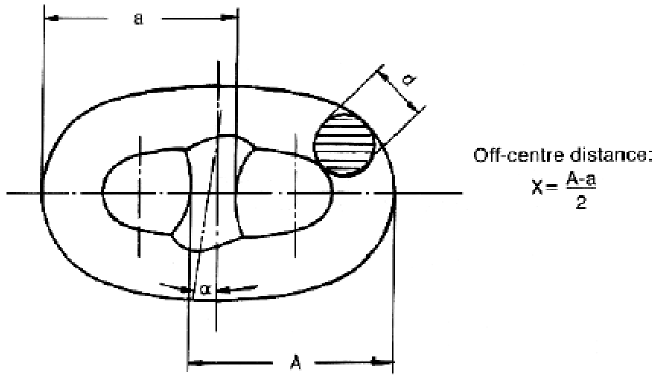
1. Maximum off-centre distance "X": 10% of the nominal diameter d
2. Maximum deviation "a" from the 90°-position: 4°
3. The tolerances are to be measured in accordance with Figure 8.4.2.

4.12.3 The following tolerances are applicable to accessories:

(a) nominal diameter : +5%, -0%

(b) other diameter : +2,5%

Figure 8.4.2: Manufacturing tolerances



4.13 Welding of studs

4.13.1 The welding of studs is to be in accordance with an approved procedure subject to the following conditions:

(a) The studs must be of weldable steel; cf. 4.6.

(b) The studs are to be welded at one end only, i.e. opposite to the weldment of the link. The stud ends must fit the inside of the link without appreciable gap.

(c) The welds, preferably in the horizontal position, shall be executed by qualified welders using suitable welding consumables.

(d) All welds must be carried out before the final heat treatment of the chain cable.

(e) The welds must be free from defects liable to impair the proper use of the chain. Undercuts, end craters and similar defects shall, where necessary be ground off.

The Society reserves the right to call for a procedure test for the welding of chain studs.

4.14 Proof and breaking load tests of finished chain cables

4.14.1 All finished chain cables are to be subjected to the following tests in the presence of the Surveyor. For this purpose, the chain cables must be free from paint and anti-corrosion media.

4.14.2 Each chain cable length (27,5 m) is to be subjected to a loading test at the proof load appropriate to the particular chain cable as shown in Table 8.4.6 and using an approved testing machine.

4.14.3 Sample lengths comprising at least of three links in the quantity specified in Table 8.4.4 are to be taken from the chain cables and tested at the breaking loads shown in Table 8.4.6. The links concerned shall be made in a single manufacturing cycle together with the chain cable and must be welded and heat treated together with it. Only after this may they be separated from the chain cable in the presence of the Surveyor.

4.14.4 If the tensile loading capacity of the testing machine is insufficient to apply the breaking load for chain cables of large diameter, another equivalent testing method shall be agreed with the Society.

4.15 Re-tests

4.15.1 Should a breaking load test fail, a further test specimen may be taken from the same length of chain cable and tested. The test shall be considered successful if the requirements are then satisfied. If the re-test fails, the length of chain cable concerned shall be rejected. If the manufacturer so wishes, the remaining three lengths belonging to the unit test quantity may then be individually subjected to test at the breaking load. If one such test fails to meet the requirements, the entire unit test quantity is rejected.

4.15.2 Should a proof load test fail, the defective link(s) is (are) to be replaced, a local heat treatment to be carried out on the new link(s) and the proof load test is to be repeated. In addition, an investigation is to be made to identify the cause of the failure.

4.16 Mechanical tests on Grade LHR-2 and LHR-3 finished chain cable

4.16.1 For Grade LHR-3, and where required for Grade LHR-2, chain cables one tensile and one set of three ISO V-notch impact test specimens is to be taken from every four lengths from the base material of the link opposite to the weldment, cf. Table 8.4.4. The Society may also require on Grade LHR-3, and non-heat treated Grade LHR-2, chain cables one tensile test across the weld and one set of impact tests carried out on specimens having their notch located in the weld.

4.16.2 To provide the specimens an additional link (or where the links are small, several links) is/are to be provided in a length of chain cable which is not to supply a specimen for the breaking test. The specimen link must be manufactured and heat treated together with the length of chain cable.

4.16.3 The mechanical properties and the impact energy must be in accordance with the values indicated in Table 8.4.5.

4.17 Marking

4.17.1 Chain cables which meet the requirements are to be stamped at both ends of each length at least with the following marks, cf. Figure 8.4.3:

(a) Chain cable grade.

(b) Certificate number.

(c) LHR's mark.

Figure 8.4.3: Marking of chain cables

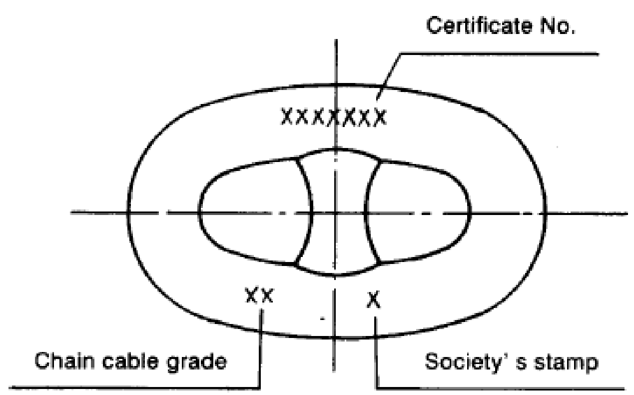


Table 8.4.4: Scope of the mechanical tests on finished chain cables

Grade	Manufacturing method	Heat treatment (Note 1)	Number of test specimens on every four lengths			
			Breaking load test (Note 2)	Tensile test base material	Notched bar impact test	
					base material	weldment
LHR-1	Welding	without	1	-	-	-
LHR-2	Welding	N	1	-	-	-
LHR-2	Welding	without	1	1 (Note 3)	3	3 (Note 4)
LHR-3	Welding	N, Q+T	1	1 (Note 3)	3	3 (Note 4)
LHR-2	Cast or drop forged	N	1	1	3	-
LHR-3	Cast or drop forged	N, Q+T	1	1	3	-

NOTES:

1) N = Normalizing, Q+T = Quenching and tempering.
2) For test sampling see 2.18.3.
3) The Society also requires one tensile test across the weld, see 2.20.1.
4) The Society also requires one set of impact tests on specimens having their notch located in the weld.

Table 8.4.5: Mechanical properties of finished chain cables

Grade	Base material	Welded area		
		Tensile test elongation A_5 (%) min. (Note 1)	Notched bar impact test	
			Test temperature (°C)	Impact energy (J) (Note 2) min.
LHR-1	The requirements of Table 8.4.1 are applicable	25	-	-
LHR-2		18	0	27
LHR-3		14	0 (-20)	50 (27) (Note 3)

NOTES:

1. For the tensile and yield strength the requirements of Table 8.4.1 are applicable. For Grade LHR-3 a reduction of area is not specified.
2. Average value from 3 test specimens. One individual value may be lower than the average value, but not below 70% of the average value stipulated.
3. At the option of the Society the impact test of Grade LHR-3 materials may alternatively be carried out at -20°C.

Table 8.4.6: Proof and breaking loads for stud link chain cables

Chain diameter (mm)	Grade LHR-1		Grade LHR-2		Grade LHR-3	
	Proof Load (kN)	Breaking load (kN)	Proof load (kN)	Breaking load (kN)	Proof load (kN)	Breaking load (kN)
1	2	3	4	5	6	7
11	36	51	51	72	72	102
12,5	46	66	66	92	92	132
14	58	82	82	116	116	165
16	76	107	107	150	150	216
17,5	89	127	127	179	179	256
19	105	150	150	211	211	301
20,5	123	175	175	244	244	349
22	140	200	200	280	280	401
24	167	237	237	332	332	476
26	194	278	278	389	389	556
28	225	321	321	449	449	642
30	257	368	368	514	514	735
32	291	417	417	583	583	833
34	328	468	468	655	655	937
36	366	523	523	732	732	1050
38	406	581	581	812	812	1160
40	448	640	640	896	896	1280
42	492	703	703	981	981	1400
44	538	769	769	1080	1080	1540
46	585	837	837	1170	1170	1680
48	635	908	908	1270	1270	1810
50	696	981	981	1370	1370	1960
52	739	1060	1060	1480	1480	2110
54	794	1140	1140	1590	1590	2270
56	851	1220	1220	1710	1710	2430
58	909	1290	1290	1810	1810	2600
60	969	1380	1380	1940	1940	2770
62	1030	1470	1470	2060	2060	2940
64	1100	1560	1560	2190	2190	3130
66	1160	1660	1660	2310	2310	3300
68	1230	1750	1750	2450	2450	3500
70	1290	1840	1840	2580	2580	3690
73	1390	1990	1990	2790	2790	3990
76	1500	2150	2150	3010	3010	4300
78	1580	2260	2260	3160	3160	4500
81	1690	2410	2410	3380	3380	4820
84	1800	2580	2580	3610	3610	5160
87	1920	2750	2750	3850	3850	5500

Chain diameter (mm)	Grade	LHR-1	Grade	LHR-2	Grade	LHR-3
	Proof Load (kN)	Breaking load (kN)	Proof load (kN)	Breaking load (kN)	Proof load (kN)	Breaking load (kN)
90	2050	2920	2920	4090	4090	5840
92	2130	3040	3040	4260	4260	6080
95	2260	3230	3230	4510	4510	6440
97	2340	3340	3340	4680	4680	6690
100	2470	3530	3530	4940	4940	7060
102	2560	3660	3660	5120	5120	7320
105	2700	3850	3850	5390	5390	7700
107	2790	3980	3980	5570	5570	7960
111	2970	4250	4250	5940	5940	8480
114	3110	4440	4440	6230	6230	8890
117	3260	4650	4650	6510	6510	9300
120	3400	4850	4850	6810	6810	9720
122	3500	5000	5000	7000	7000	9990
124	3600	5140	5140	7200	7200	10280
127	3750	5350	5350	7490	7490	10710
130	3900	5570	5570	7800	7800	11140
132	4000	5720	5720	8000	8000	11420
137	4260	6080	6080	8510	8510	12160
142	4520	6450	6450	9030	9030	12910
147	4790	6840	6840	9560	9560	13660
152	5050	7220	7220	10100	10100	14430
157	5320	7600	7600	10640	10640	15200
162	5590	7990	7990	11170	11170	15970

Figure 8.4.4: Common link

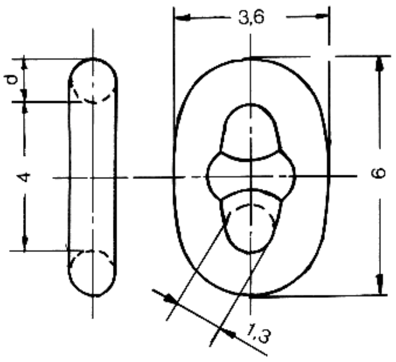


Figure 8.4.5: Enlarged link

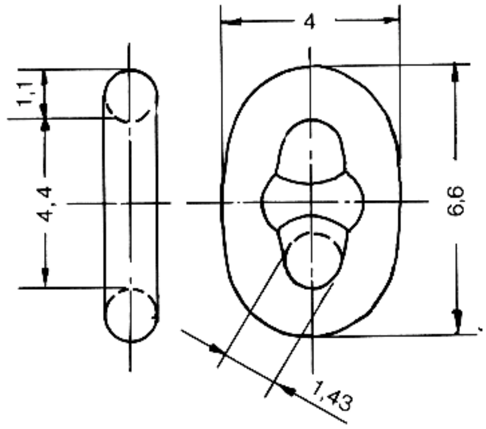


Figure 8.4.6: Studless link

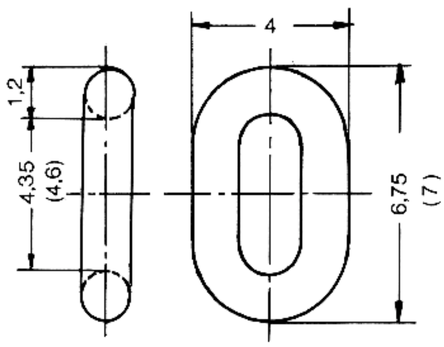


Figure 8.4.7: Kenter shackle

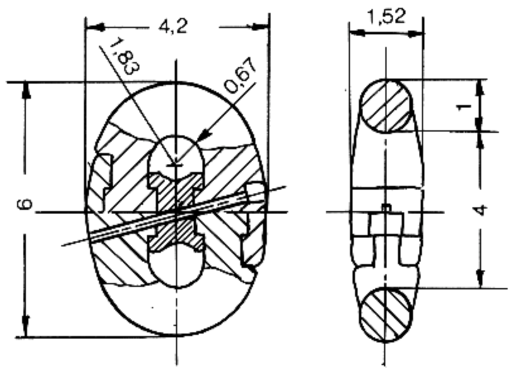


Figure 8.4.8: Joining shackle

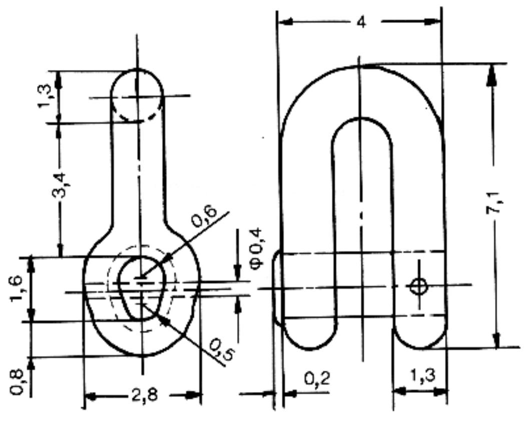


Figure 8.4.9: End shackle

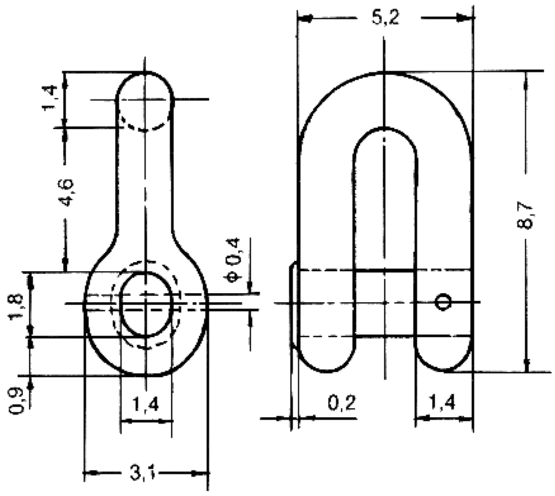
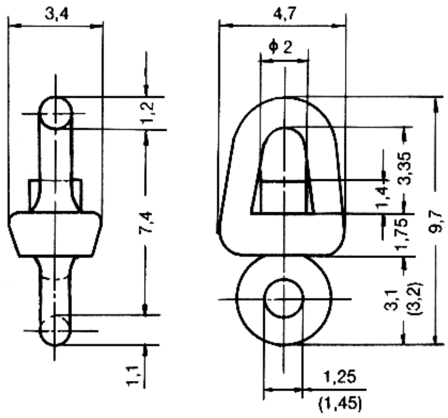


Figure 8.4.10: Swive



SECTION 5 Windlass and chain stoppers

5.1 Design

5.1.1 A windlass of sufficient power and suitable for the size of chain is to be fitted to the ship. The windlass is to have one cable lifter or wire drum for each anchor stowed in hawse pipe.

5.1.2 For each chain cable there is normally to be a chain stopper, arranged between windlass and hawse pipe.

5.1.3 The windlass unit prime mover is to be able to supply for at least 30 minutes a continuous duty pull, P, corresponding to the grade of the steel of which the cables are made of, and given by the following formula:

$P = 25 \cdot d^2$ N, for grade A

$= 27.5 \cdot d^2$ N, for grade B

$= 30 \cdot d^2$ N, for grade C

where:

d = Nominal diameter of common link, in mm (see Table 8.3.1 and Table 8.3.3).

For double windlasses the requirements apply to one side at a time.

5.1.4 The values of P include the influences of buoyancy and hawse pipe efficiency, which is assumed to be 70%.

5.1.5 The windlass unit prime mover is to provide the necessary temporary overload capacity for breaking out the anchor. The temporary overload capacity should not be less than 1,5 times the continuous duty pull and should be provided for at least two minutes. The speed in this period can be lower than the nominal speed.

5.1.6 The nominal speed of the chain cable when hoisting the anchor and cable can be a mean speed only and this speed should not be less than 0,15 m/sec. The speed is to be measured over two shots of chain cable during the total trip. The trial should be commenced with 3 shots (82,5 m) of chain fully submerged.

5.1.7 The capacity of the windlass brake is to be sufficient for safe stopping of the anchor and chain cable when paying out the chain cable. If a chain stopper is not fitted, the windlass is to be able to withstand a pull of 80% of the breaking load of the chain without any permanent deformation of the stressed part and without brake slip. If a chain stopper is fitted it should withstand a pull of 80% of the breaking load of the chain without any permanent deformation of the stressed part and without brake slip.

5.1.8 The windlass with brakes engaged and cable lifters disengaged is to be able to withstand a pull of 45% of the breaking load of the chain without any permanent deformation of the stressed parts and without brake slip.

5.1.9 The windlass and chain stoppers are to be efficiently bedded to the deck. The deck plating in the area of windlass and chain stopper is to be increased in thickness and supported by pillars carried down to rigid structures.

5.2 Materials

5.2.1 Cable lifter shafts are to be made from forged or rolled steel or from ordinary cast steel. Cable lifters are to be made from nodular cast iron or from ordinary cast steel. Chain stoppers may be cast or fabricated from plate materials. In the first case the material is cast steel or nodular cast iron with elongation not less than 18%.

5.3 Testing

5.3.1 Before assembly the following parts are to be tested:

(a) housing with covers for hydraulic motors and pumps

(b) hydraulic pipes

(c) valves and fittings

(d) pressure vessels

5.3.2 After completion, at least one prime mover of the windlass is to be tested with respect to required lifting and breaking forces.

5.3.3 After installation of the windlass on board, an anchoring test is to be carried out to demonstrate that the windlass functions satisfactorily. The mean speed on the chain cable when hoisting the anchor and chain cable is not to be less than 0,15m/sec, and is to be measured with a load at least corresponding to the total weight of 30% of the length of the chain cable or wire rope plus the weight of the anchor. The brakes are to be tested during lowering.

SECTION 6 Towlines and mooring lines

6.1 Line types

6.1.1 The number, length and breaking strength of towlines and mooring lines which are given in Table 8.6.1, are based on the Equipment Number calculated according to 2.1.

6.1.2 Towlines and mooring lines may be of wire, natural fibre or synthetic fibre, or a mixture of wire and fibre.

6.1.3 The lengths of individual mooring lines given in Table 8.6.1, may be reduced by 7%, provided that the total length of the mooring lines is not less than would have resulted if all lines had been of equal length.

6.1.4 In addition to the strength requirements given in Table 8.6.1 above, no fibre rope is to be less than 15 mm in diameter.

6.2 Steel wire ropes

6.2.1 Steel wire ropes are to be manufactured in works approved by the Society. The surveyors are to be allowed access to all relevant parts of the works.

6.2.2 Where steel wire ropes are used, they are to be made in equal lay construction, and are normally to be divided in groups as follows:

(a) 6 x 19 Group consists of 6 strands with min. 16 and max. 27 wires in each strand

(b) 6 x 36 Group consists of 6 strands with min. 27 and max. 49 wires in each strand

Other rope construction may be accepted by the Society upon special consideration.

6.2.3 Wire ropes for use in association with mooring winches where the ropes are to be stored on the drum may be constructed with an independent wire rope core instead of fibre core.

Table 8.6.1: Equipment - Tow lines and mooring lines for small craft

Equipment number		Tow line		Mooring lines		
Exceeding	Not Exceeding	Minimum length (m)	Minimum breaking strength (kN)	Number	Minimum length of each line (m)	Minimum breaking strength (kN)
30	40	170	80	2	80	30
40	50	170	80	2	80	30
50	60	180	80	2	80	32
60	70	180	80	2	80	32
		70				
70	80	180	100	2	100	35
80	90	180	100	2	100	35
90	100	180	100	2	100	38
100	110	180	100	3	100	38
110	120	180	100	3	110	42
120	130	180	100	3	110	42
130	140	180	100	3	120	46
140	150	180	100	3	120	46
150	160	180	110	3	120	50
160	170	180	110	3	120	50
170	180	180	110	3	120	55
180	190	180	110	3	120	55
190	200	180	110	3	120	60
200	220	180	125	3	120	60
220	240	180	125	3	120	66
240	260	180	125	3	120	66
260	280	180	150	3	120	72
280	300	180	150	3	140	72
300	320	180	175	4	140	78
320	340	180	175	4	140	78
340	360	180	200	4	140	84
360	380	180	200	4	140	84
380	400	180	225	4	140	90
400	425	180	225	4	140	90

Equipment number		Tow line		Mooring lines		
Exceeding	Not Exceeding	Minimum length (m)	Minimum breaking strength (kN)	Number	Minimum length of each line (m)	Minimum breaking strength (kN)
425	450	180	250	4	140	96
450	475	180	250	4	140	96
475	500	180	275	4	140	102
500	550	190	300	4	160	120
550	600	190	325	4	160	130
600	650	190	350	4	160	145
650	700	190	400	4	160	155
700	750	190	425	4	170	165
750	800	190	450	4	170	175
800	850	190	500	4	170	185
850	900	190	525	4	170	200
900	950	190	550	4	170	215
950	1050	200	600	4	180	230
1050	1150	200	650	4	180	250

Table 8.6.2: Equipment - Tow lines and mooring lines for light displacement craft and yachts

Equipment Number		Towline (See Notes)		Mooring lines		
Exceeding	Not exceeding	Minimum length, in metres	Minimum breaking strength, in kN	Number of lines	Minimum length of each line, in metres	Minimum breaking strength, in kN
5	5	90	19,9	2	55	13,9
10	10	90	22,5	2	55	17,6
15	15	90	27,7	2	55	21,5
20	20	90	32,9	2	55	24,5
25	25	110	38,1	2	55	26,6
30	30	110	43,3	2	55	28,2
35	35	110	48,5	2	55	29,6
40	40	135	53,7	2	55	30,8
45	45	135	58,9	2	70	31,8
50	50	135	64,1	2	85	32,7
70	70	180	71,0	2	100	35,5
90	90	180	82,1	2	100	39,3
110	110	180	93,2	2	110	43,1
130	130	180	104,3	2	110	46,6
150	150	180	115,3	2	120	50,2
175	175	180	127,8	2	120	54,4
205	205	180	143,0	2	120	58,8
240	240	180	161,1	2	120	64,2
280	280	180	181,8	3	120	71,1
320	320	180	204,0	3	140	78,5
360	360	180	226,1	3	140	85,8
400	400	180	248,3	3	140	93,2
450	450	180	273,2	3	140	100,5
500	500	180	300,9	3	140	107,9
550	550	180	328,6	4	160	112,8
600	600	180	356,3	4	160	117,7
660	660	180	386,8	4	160	122,6
720	720	180	420,1	4	160	127,5
780	780	180	453,3	4	170	132,4
840	840	180	486,5	4	170	137,3
910	910	180	522,5	4	170	142,2

Equipment Number		Towline (See Notes)		Mooring lines		
Exceeding	Not exceeding	Minimum length, in metres	Minimum breaking strength, in kN	Number of lines	Minimum length of each line, in metres	Minimum breaking strength, in kN
980	980	180	561,3	4	170	147,1
1060	1060	180	602,9	4	180	156,9
	1140	180	647,2	4	180	166,7

NOTES

1) Towline specified for guidance only.

2) Wire ropes used for towlines and mooring lines are generally to be of a flexible construction with not less than:

- 144 wires in six -strands with seven fibre cores for strengths up to 490 kN
- 222 wires in six strands with one fibre core for strengths exceeding 490 kN

The wires to be laid around the fibre centre of each strand are to be up in not less than two layers.

3) Wire ropes for towlines and mooring lines used in association with mooring winches (on which the rope is stored on the winch drum) are to be of suitable construction.

4) Irrespective of strength of requirements, no fibre rope is to be less than 12 mm diameter.

6.3 Manufacture and testing

6.3.1 The wires are to be drawn from steel manufactured by the open hearth, electric or basic oxygen furnace. Other processes may be specially approved by the Society. The wires are to be of homogeneous quality, consistent strength and free from visual defects likely to impair the performance of the rope.

6.3.2 The tensile strength is generally to be within the ranges 1420 to 1570 N/mm², 1570 to 1770 N/mm² or 1770 to 1960 N/mm².

6.3.3 The wire is to be galvanized by a hot dip or electrolytic process to give a continuous uniform coating which may be any of the following grades:

(a) Grade 1-heavy coating, drawn after galvanizing

(b) Grade 2-heavy coating, finally galvanized

(c) Grade 3-light coating, drawn after galvanizing

6.3.4 Torsion and zinc coating tests are to be carried out on wire samples taken from a suitable length of the completed rope. After unstranding and straightening, six wires are to be subjected to both a torsion test and a wrap test for adhesion of coating. Moreover, tests to determine the mass and uniformity of the zinc coating are to be carried out. As an alternative to test specimens specified above, tests may be carried out on the wire before the rope is stranded. These tests are to be made in accordance with ISO standard 2232.

6.4 Tests of completed ropes

6.4.1 The breaking load is to be determined by testing to destruction a sample cut from the completed rope. This sample is to be of sufficient length to provide a clear test length of at least 30 times the rope diameter between the grips.

6.4.2 Not more than four-fifths of the nominal breaking load may be applied quickly, and thereafter the load is to be applied slowly and steadily until the maximum load is obtained. Tests in which a breakage occurs adjacent to the grips may , at the option of the manufacturer, be neglected. The actual breaking load is to be not less than that given in an appropriate national standard.

6.4.3 If facilities are not available for making a breaking test on completed ropes, consideration will be given to the acceptance of the determination of the breaking load by the summation of the tests of individual wires. A percentage deduction is to be applied to the calculated breaking load to compensate for laying up. This percentage is to be not less than that given in Table 8.6.3.

Table 8.6.3: Laying up deduction on the calculated breaking load

Construction of rope	Percentage deduction (see Note)
6x19	13
6x36	17,5

NOTE:

Percentage deductions for other constructions should either be in accordance with a recognized national standard or are to be established by breaking tests carried out on completed ropes.

6.4.4 Manufacturers desiring to adopt the method of testing described in 6.4.3 may be required to arrange for check breaking tests to be carried out on completed ropes.

6.5 Marking

6.5.1 All completed ropes are to be identified with attached labels detailing the rope type, diameter and length.

6.5.2 Where ropes have been tested in the presence of the Surveyor, each rope length is to be additionally identified with a lead seal stamped with the Surveyor's personal marking.

6.6 Certification

6.6.1 When tests have not been witnessed by the Surveyor, manufacturers are authorized to complete and issue the Society's printed certificate forms. These forms are available on request.

6.6.2 In cases where purchasers require tests to be witnessed by the Surveyor, certificates will be issued by the Society.

6.7 Manufacture of fibre ropes

6.7.1 Fibre ropes intended as mooring lines may be made of coir, hemp, manila or sisal, or may be composed of synthetic fibres. They may be three-strand (hawser laid), four-strand(shroud laid) or nine-strand (cable laid), but other constructions will be specially considered.

6.7.2 Each length of rope is to be manufactured from suitable material of good and consistent quality. Rope materials should, in general, comply with a recognized national standard.

6.7.3 Synthetic fibre ropes are to be suitable for the purpose intended and should comply with a recognized standard.

6.7.4 Weighting and loading matter is not to be added, and any lubricant is to be kept to a minimum. Any rot-proofing or water repellence treatment is not to be deleterious to the fibre nor is it to add to the weight or reduce the strength of the rope.

6.8 Tests of completed ropes

6.8.1 The breaking load is to be determined by testing to destruction a sample cut from the completed rope.

6.8.2 The minimum test length and the initial test load are to be as given in Table 8.6.4. After application of the initial load, the diameter and evenness of lay up of the sample are to be checked. The sample is then to be uniformly strained at the rate given in Table 8.6.4 until it breaks.

Table 8.6.4: Breaking load test

	Test length (mm) minimum	Initial load (%) (see Note)	Rate of straining (mm/min.)
Natural fibre Synthetic fibre	**1800** **900**	**2** **1**	**150 ± 50** **100 max.**

NOTE:

Percentage of specified minimum breaking load.

6.8.3 The actual breaking load is to be not less than that given in an appropriate national standard.

6.8.4 If the sample is held by grips and the break occurs within 150 mm of the grips, the test may be repeated, but not more than two tests may be made on any one coil.

6.8.5 Where difficulty is experienced in testing a sample of a completed synthetic fibre rope, the Society will consider alternative methods of testing.

6.9 Marking

6.9.1 Each coil of rope is to be identified with an attached label detailing the material, construction, diameter and length.

6.10 Certification

6.10.1 Printed certificates issued by the manufacturer or a competent governmental, municipal or similar responsible body will be accepted. These certificates are to give the breaking load, test length and rate of straining.

6.11 Winches

6.11.1 Each winch should be fitted with drum brakes the strength of which is sufficient to prevent unreeling of the mooring line when the rope tension is equal to 80% of the breaking strength of the rope as fitted on the first layer. Where this is achieved by the winch being fitted with a pawl and ratchet or other positive locking device, the breaking mechanism should be such that the winch drum can be released in a controlled manner while the mooring line is under tension.

6.11.2 For powered winches the maximum hauling tension which can be applied to the mooring line (the reeled first layer) should not be less than 0,22 times the rope's breaking strength and not more than 0,33 times that strength. For automatic winches these figures should apply when the winch is set on the maximum power with automatic control.

6.11.3 The rendering tension which the winch can exert on the mooring line (reeled first layer) should not exceed 1,5 times, nor be less than 1,05 times the hauling tension for that particular power setting of the winch on automatic control.

6.11.4 The winch is to be marked with the range of rope strength for which it is designed.

CHAPTER 9 Rudders

Contents

SECTION 1 General

1.1 Application and basic assumptions

1.1.1 The following requirements are based on IACS UR S10 (Rev. 6, 2019) and apply to to ordinary profile rudders, and to some enhanced profile rudders with special arrangements for increasing the rudder force, such as fins, flaps, steering propellers, etc. The following requirements apply to rudders made of steel. Rudders not conforming with the ordinary types will be subject to special consideration.

1.2 Design considerations

1.2.1 Effective means are to be provided for supporting the weight of the rudder without excessive bearing pressure, e.g. by a rudder carrier attached to the upper part of the rudder stock. The hull structure in way of the rudder carrier is to be suitably strengthened.

1.2.2 Suitable arrangements are to be provided to prevent the rudder from lifting.

1.2.3 In rudder trunks which are open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline, two separate stuffing boxes are to be provided.

1.3 Materials

1.3.1 Welded parts of rudders are to be made of approved rolled hull materials.

1.3.2 Material factor k for normal and high tensile steel plating may be taken into account when specified in each individual rule requirement. The material factor k is to be taken as defined in UR S4, unless otherwise specified.

1.3.3 Steel grade of plating materials for rudders and rudder horns are to be in accordance with UR S6.

1.3.4 Rudder stocks, pintles, coupling bolts, keys and cast parts of rudders are to be made of rolled, forged or cast carbon manganese steel in accordance with UR W7, W8 and W11.

1.3.5 For rudder stocks, pintles, keys and bolts the specified minimum yield stress is not to be less than 200 N/mm^2. These requirements are based on a material's specified minimum yield stress of 235 N/mm^2. If material is used having a specified minimum yield stress differing from 235 N/mm^2 the material factor k is to be determined as follows:

$$k = \left(\frac{235}{R_{eH}}\right)^e$$

with:

e	=	0,75 for $R_{eH} > 235\ N/mm^2$,
	=	1,00 for $R_{eH} \le 235\ N/mm^2$,
R_{eH}	=	specified minimum yield stress, in N/mm^2, of material used, and is not to be taken greater than $0{,}7\sigma_\tau$ or 450 N/mm^2, whichever is the smaller value,
σ_τ	=	tensile strength, in N/mm^2, of material used,

1.4 Welding and design details

1.4.1 Slot-welding is to be limited as far as possible. Slot welding is not to be used in areas with large in-plane stresses transversely to the slots or in way of cut-out areas of semi-spade rudders.

When slot welding is applied, the length of slots is to be minimum 75 mm with breadth of 2 t, where t is the rudder plate thickness, in mm. The distance between ends of slots is not to be more than 125 mm. The slots are to be fillet welded around the edges and filled with a suitable compound, e.g. epoxy putty. Slots are not to be filled with weld.

Continuous slot welds are to be used in lieu of slot welds. When continuous slot welding is applied, the root gap is to be between 6-10 mm. The bevel angle is to be at least 15°.

1.4.2 In way of the rudder horn recess of semi-spade rudders, the radii in the rudder plating except in way of solid part in cast steel are not to be less than 5 times the plate thickness, but in no case less than 100 mm. Welding in side plate is to be avoided in or at the end of the radii. Edges of side plate and weld adjacent to radii are to be ground smooth.

1.4.3 Welds between plates and heavy pieces (solid parts in forged or cast steel or very thick plating) are to be made as full penetration welds. In way of highly stressed areas e.g. cut-out of semi-spade rudder and upper part of spade rudder, cast or welding on ribs is to be arranged. Two sided full penetration welding is normally to be arranged. Where back welding is impossible welding is to be performed against ceramic backing bars or equivalent. Steel backing bars may be used and are to be continuously welded on one side to the heavy piece.

1.4.4 Requirements for welding and design details of rudder trunks are described in 9.3.

1.4.5 Requirements for welding and design details when the rudder stock is connected to the rudder by horizontal flange coupling are described in 6.1.

1.4.6 Requirements for welding and design details of rudder horns are described in 9.2.

1.5 Equivalence

1.5.1 LHR may accept alternatives to requirements given in this UR, provided they are deemed to be equivalent.

1.5.2 Direct analyses adopted to justify an alternative design are to take into consideration all relevant modes of failure, on a case by case basis. These failure modes may include, amongst others: yielding, fatigue, buckling and fracture. Possible damages caused by cavitation are also to be considered.

1.5.3 If deemed necessary by the LHR, lab tests, or full scale tests may be requested to validate the alternative design approach..

SECTION 2 Rudder force and rudder torque

2.1 Rudder blades without cut-outs (Figure 9.2.1)

2.1.1 The rudder force upon which the rudder scantlings are to be based is to be determined from the following formula:

$$C_R = K_1 \cdot K_2 \cdot K_3 \cdot 132 \cdot A \cdot V^2 \ [N]$$

Where:

C_R = rudder force [N],

A	=	area of rudder blade [m²]
V	=	maximum service speed (knots) with the ship on summer load waterline.
		When the speed is less than 10 knots, V is to be replaced by the expression:
		V_{min} = (V + 20) / 3
		For the astern condition the maximum astern speed is to be used, however, in no case less than:
		V_{astem} = 0,5V
K_1	=	factor depending on the aspect ratio λ of the rudder area
K_1	=	(λ + 2) / 3, with λ not to be taken greater than 2
λ	=	b^2/A_t
b	=	mean height of the rudder area in [m]. Mean breadth and mean height of rudder are calculated according to the coordinate system in Figure 9.2.1.
A_t	=	sum of rudder blade area A and area of rudder post or rudder horn, if any, within the height b, in [m²]
K_2	=	coefficient depending on the type of the rudder and the rudder profile according to Table 9.2.1.
K_3	=	0,8 for rudders outside the propeller jet
	=	1,15 for rudders behind a fixed propeller nozzle
	=	1,0 otherwise

Figure 9.2.1:

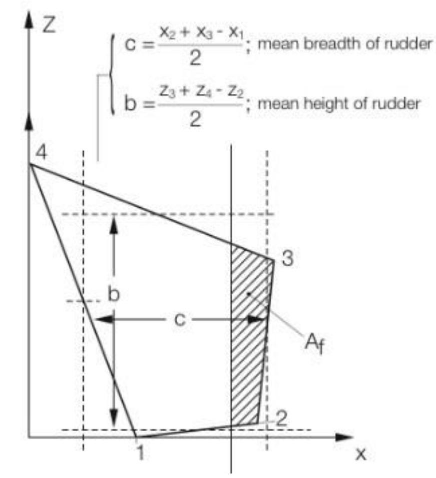
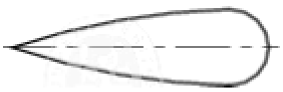
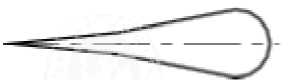
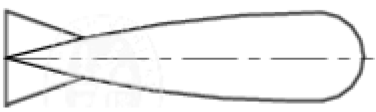
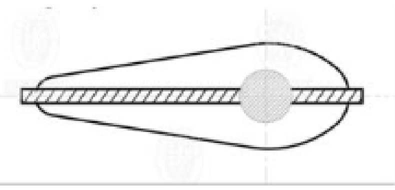


Table 9.2.1:

	K_2 Ahead condition	K_2 Astern condition
NACA-00 Gottingen-profiles 	1,10	0,80
Flat side 	1,10	0,90
Hollow 	1,35	0,90
High lift rudders 	1,70	1,30
Fish tail 	1,40	0,80
Single plate 	1,00	1,00
Mixed profiles (e.g. HSVA)	1,21	0,90

2.1.2 The rudder torque is to be calculated for both the ahead and astern condition according to the formula:

$$Q_R = C_R \cdot r \; [N \cdot m]$$

r	=	$c \cdot (a - k_1)$, m,
c	=	mean breadth of rudder area, m, see Figure 9.2.1.
α	=	0,33 for ahead condition
	=	0,66 for astern condition

k_1 = A_f/A

A_f = portion of the rudder blade area situated ahead of the centre line of the rudder stock

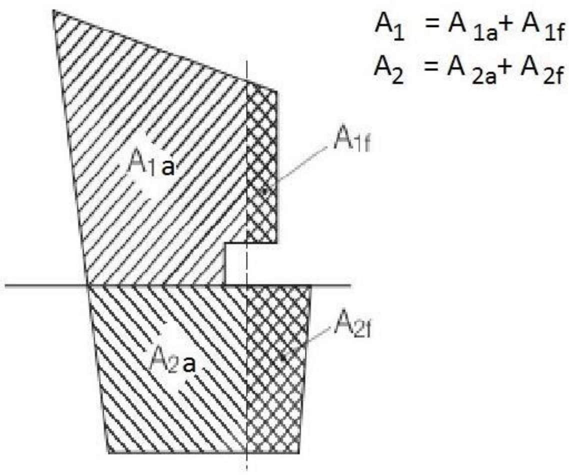
r_{min} = 0,1·c, m, for ahead condition

2.2 Rudder blades with cut-outs (semi-spade rudders)

The total rudder force C_R is to be calculated according to 2.1.1. The pressure distribution over the rudder area, upon which the determination of rudder torque and rudder blade strength is to be based, is to be derived as follows:

The rudder area may be divided into two rectangular or trapezoidal parts with areas A_1 and A_2, so that $A = A_1 + A_2$ (see Figure 9.2.2).

Figure 9.2.2:



The levers r_1 and r_2 are to be determined as follows:

$$r_2 = c_2 \cdot (a - k_2)\ [m]$$

$$r_1 = c_1 \cdot (a - k_1)\ [m]$$

Where:

c_1, c_2 = mean breadth of partial areas A_1 A_2, determined, where applicable, in accordance with Figure 9.2.1.,

k_1 = A_{1f} / A_1

k_2 = A_{2f} / A_2

A_{1a} = portion of A_1 situated aft of the centre line of the rudder stock.

A_{1f} = portion of A_1 situated ahead of the centre line of the rudder stock.A_{2a} = portion of A_2 situated aft of the centre line of the rudder stock.

A_{2f} = portion of A_2 situated ahead of the centre line of the rudder stock.

α = 0,33 for ahead condition

= 0,66 for astern condition

For parts of a rudder behind a fixed structure such as rudder horn

α = 0,25 for ahead condition

= 0,55 for astern condition

The resulting force of each part may be taken as:

$$C_{R1} = C_R \cdot A_1/A \ [N]$$

$$C_{R2} = C_R \cdot A_2/A \ [N]$$

The resulting torque of each part may be taken as:

$$Q_{R1} = C_{R1} \cdot r_1 \ [N \cdot m]$$

$$Q_{R2} = C_{R2} \cdot r_2 \ [N \cdot m]$$

The total rudder torque is to be calculated for both the ahead and astern condition according to the formula:

$$Q_R = Q_{R1} + Q_{R2} \ [N \cdot m]$$

For ahead condition Q_R is not to be taken less than:

$$Q_{Rmin} = 0{,}1 \cdot C_R(A_1 \cdot c_1 + A_2 \cdot c_2)/A$$

SECTION 3 Rudder strength calculation

3.1 The rudder force and resulting rudder torque as given in SECTION 2 causes bending moments and shear forces in the rudder body, bending moments and torques in the rudder stock, supporting forces in pintle bearings and rudder stock bearings and bending moments, shear forces and torques in rudder horns and heel pieces. The rudder body is to be stiffened by horizontal and vertical webs enabling it to act as bending girder.

3.2 The bending moments, shear forces and torques as well as the reaction forces are to be determined by a direct calculation or by an approximate simplified method considered appropriate by the Society. For rudders supported by sole pieces or rudder horns these structures are to be included in the calculation model in order to account for the elastic support of the rudder body. Guidelines for calculation of bending moment and shear force distribution are given in the Annex to this Chapter.

SECTION 4 Rudder stock scantlings

4.1 The rudder stock diameter required for the transmission of the rudder torque is to be dimensioned such that the torsional stress is not exceeding the following value:

$$\tau_t = 68 \cdot k \; [N/mm^2]$$

The rudder stock diameter for the transmission of the rudder torque is therefore not to be less than:

$$d_t = 4{,}2 \cdot \sqrt[3]{Q_R/k} \;\; [mm]$$

Q_R = total rudder torque, Nm, as calculated in 2.1.2 and/or 2.2.

k = material factor for the rudder stock as given in 1.3.5.

4.2 Rudder stock scantlings due to combined loads

If the rudder stock is subjected to combined torque and bending the equivalent stress in the rudder stock is not to exceed 118/ $\boldsymbol{k}$.

k = material factor for the rudder stock as given in 1.3.5.

The equivalent stress is to be determined by the formula:

$$\sigma_c = \sqrt{\sigma_b^2 + 3\tau_t^2} \; [N/mm^2]$$

Where:

σ_b = $10{,}2 \cdot 10^3$ M / d_c^3, N/mm², is the Bending stress,

τ_t = $5{,}1 \cdot 10^3$ Q_R / d_c^3, N/mm², is the Torsional stress

The rudder stock diameter is therefore not to be less than:

$$d_c = d_t \cdot \sqrt[6]{1 + 4/3 \cdot (M/Q_R)^2} \; [mm]$$

Where:

M = bending moment [Nm] at the station of the rudder stock considered

4.3 Before significant reduction in rudder stock diameter are granted due to the application of steel with specified minimum yield stress exceeding 235 N/mm^2, the Society may require the evaluation of the rudder stock deformations. Large deformations of the rudder stock are to be avoided in order to avoid excessive edge pressures in way of bearings.

SECTION 5 Rudder blade

5.1 Permissible stresses

The section modulus and the web area of a horizontal section of the rudder blade made of ordinary hull structural steel are to be such that the following stresses will not be exceeded:

(a) In general, except in way of rudder recess sections where b) applies

.1 bending stress σ_b 110/ k N/mm^2

.2 shear stress τ 50/ k N/mm^2

.3 equivalent stress σ_e 120/ k N/mm^2

Where

$$\sigma_e = \sqrt{\sigma_b^2 + 3\tau_t^2}\ [N/mm^2]$$

k = material factor for the rudder plating as given in 1.3.2.

(b) In way of the recess for the rudder horn pintle on semi-spade rudders

.1 bending stress σ_b 75 N/mm^2

.2 shear stress τ 50 N/mm^2

.3 equivalent stress σ_e 100 N/mm^2

Where

$$\sigma_e = \sqrt{\sigma_b^2 + 3\tau_t^2}\ [N/mm^2]$$

Note: The stresses in **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.** apply equally to high tensile and ordinary steels.

5.2 Rudder plating

The thickness of the rudder side, top and bottom plating is not to be less than: $t = 5{,}5 \cdot s \cdot \beta \cdot \sqrt{k} \cdot \sqrt{d + C_R \cdot \frac{10^{-4}}{A}} + 2{,}5\ [mm]$

Where:

d	=	summer loadline draught, m, of the ship
C_R	=	rudder force, N, according to 2.1.1
b	=	rudder area, m^2,

β = $\sqrt{1{,}1 - 0{,}5 \cdot (s/b)^2}$, max. 1,00 if b/s > 2,5

s = smallest unsupported width of plating, m

b = greatest unsupported width of plating, m

k = material factor for the rudder plating as given in 1.3.2.

The thickness of the nose plates may be increased to the discretion of the society. The thickness of web plates is not to be less than 70% of the rudder side plating, however, not less than 8 mm. For higher tensile steels the material factor according to Part 3, Chapter 5, SECTION 3, 3.5 is to be used correspondingly.

The rudder plating in way of the solid part is to be of increased thickness per 5.3.4.

5.3 Connections of rudder blade structure with solid parts

5.3.1 Solid parts in forged or cast steel, which house the rudder stock or the pintle, are to be provided with protrusions, except where not required as indicated below.

These protrusions are not required when the web plate thickness is less than:

- mm for web plates welded to the solid part on which the lower pintle of a semi-spade rudder is
- housed and for vertical web plates welded to the solid part of the rudder stock coupling of spade rudders.
- 20 mm for other web plates.

5.3.2 The solid parts are in general to be connected to the rudder structure by means of two horizontal web plates and two vertical web plates.

5.3.3 Minimum section modulus of the connection with the rudder stock housing.

The section modulus of the cross-section of the structure of the rudder blade, in cm^3, formed by vertical web plates and rudder plating, which is connected with the solid part where the rudder stock is housed is to be not less than:

$$W_s = c_s \cdot d_c^3 \cdot (\frac{H_E - H_X}{H_E})^2 \cdot \frac{k}{k_s} \cdot 10^{-4}\ [cm^3]$$

Where:

c_s = coefficient, to be taken equal to:

= 1,0 if there is no opening in the rudder plating or if such openings are closed by a full penetration welded plate.

= 1,5 if there is an opening in the considered cross-section of the rudder.

d_c = rudder stock diameter, in mm.

H_E = vertical distance between the lower edge of the rudder blade and the upper edge of the solid part, in m.

H_X = vertical distance between the considered cross-section and the upper edge of the solid part, in m.

k = material factor for the rudder blade plating as given in 1.3.2.

k_s = material factor for the rudder stock as given in 1.3.5.

The actual section modulus of the cross-section of the structure of the rudder blade is to be calculated with respect to the symmetrical axis of the rudder.

The breadth of the rudder plating, in m, to be considered for the calculation of section modulus is to be not greater than:

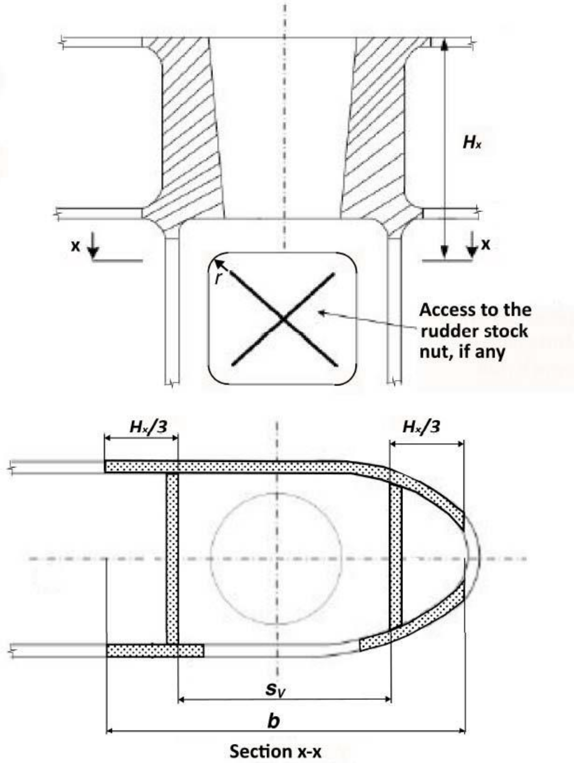
$$b = s_v + 2 \cdot H_X/3 \ [m]$$

Where:

s_v = spacing between the two vertical webs, in m, (see Figure 9.5.1).

Where openings for access to the rudder stock nut are not closed by a full penetration welded plate, they are to be deducted.

Figure 9.5.1: Cross-section of the connection between rudder blade structure and rudder stock housing, example with opening in only one side shown



5.3.4 The thickness of the horizontal web plates connected to the solid parts, in mm, as well as that of the rudder blade plating between these webs, is to be not less than the greater of the following values:

$$t_H = 1{,}2 \cdot t \ [mm]$$
$$t_H = 0{,}045 \cdot d_s^2/s_H \ [mm]$$

Where:

t = defined in 5.2.

d_s = diameter, in mm, to be taken equal to:

= d_c, as pe 4.2, for the solid part housing the rudder stock.

= d_p, as per 7.1, for the solid part housing the pintle.

s_H = spacing between the two horizontal web plates, in mm.

The increased thickness of the horizontal webs is to extend fore and aft of the solid part at least to the next vertical web.

5.3.5 The thickness of the vertical web plates welded to the solid part where the rudder stock is housed as well as the thickness of the rudder side plating under this solid part is to be not less than the values obtained, in mm, from Table 9.5.1.

Table 9.5.1: Thickness of side plating and vertical web plates

Type of rudder	Thickness of vertical wed plates, in mm		Thickness of rudder plating, in mm	
	Rudder blade without opening	Rudder blade with opening	Rudder blade without opening	Area with opening
Rudder supported by sole piece	1,2· t	1,6· t	1,2· t	1,4· t
Semi-spade and spade rudders	1,4· t	2,0· t	1,3· t	1,6· t
t = thickness of the rudder plating, in mm, as defined in 5.2				

The increased thickness is to extend below the solid piece at least to the next horizontal web.

5.4 Single plate rudders

5.4.1 Mainpiece diameter

The mainpiece diameter is calculated according to 4.1 and 4.2 respectively. For spade rudders the lower third may taper down to 0,75 times stock diameter.

5.4.2 Blade thickness

The blade thickness is not to be less than:

$$t_b = 1{,}5 \cdot s \cdot V \cdot \sqrt{k} + 2{,}5\ [mm]$$

Where:

s = spacing of stiffening arms, in m, not to exceed 1 m.

V = speed, in knots, see 2.1.1.

k = material factor for the rudder plating as given in 1.3.2.

5.4.3 Arms

The thickness of the arms is not to be less than the blade thickness

$$t_a = t_b\ [mm]$$

The section modulus is not to be less than:

$$Z_a = 0{,}5 \cdot s \cdot C_1^2 \cdot V^2 \cdot k\ [cm^3]$$

Where:

C_1 = horizontal distance from the aft edge of the rudder to the centreline of the rudder stock, in meters

k = material factor as given in 1.3.2 or 1.3.5 respectively.

SECTION 6 Rudder stock couplings

6.1 Horizontal flange couplings

6.1.1 The diameter of the coupling bolts is not to be less than:

$$d_b = 0,62 \cdot \sqrt{d^3 \cdot \frac{k_b}{n} \cdot e_m \cdot k_s} \ [mm]$$

Where:

d	=	stock diameter, the greater of the diameters d_t or d_c according to SECTION 4 and 4.2 mm
k_s	=	total number of bolts, which is not to be less than 6
e_m	=	mean distance [mm] of the bolt axes from the centre of the bolt system
k_s	=	material factor for the stock as given in 1.3.5.
k_b	=	material factor for the bolts as given in 1.3.5.

6.1.2 The thickness of the coupling flanges is not to be less than the greater of by the following formulae:

$$t_f = d_b \cdot \sqrt{\frac{k_f}{k_b}}$$

$$t_f = 0,9 \cdot d_b$$

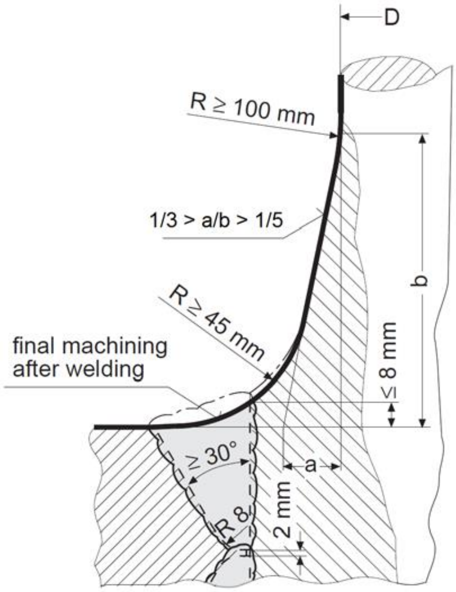
Where:

k_f	=	material factor for flange as given in 1.3.5
k_b	=	material factor for flange as given in 1.3.5
d_b	=	bolt diameter calculated for a number of bolts not exceeding 8

6.1.3 The width of material between the perimeter of the bolt holes and the perimeter of the lange is not to be less than 0,67· d_b

6.1.4 The welded joint between the rudder stock and the flange is to be made in accordance with **Figure 9.6.1** or equivalent.

Figure 9.6.1: Welded joint between rudder stock and coupling flange



6.1.5 Coupling bolts are to be fitted bolts and their nuts are to be locked effectively.

6.2 Vertical flange couplings

6.2.1 The diameter of the coupling bolts is not to be less than:

$$d_b = 0{,}81 \cdot d/\sqrt{n} \cdot \sqrt{\frac{k_b}{k_s}}\ [mm]$$

Where:

d	=	stock diameter, in mm, in way of coupling flange.
n	=	total number of bolts, which is not to be less than 8
k_b	=	material factor for bolts as given in 1.3.5.
k_s	=	material factor for stock as given in 1.3.5.

6.2.2 The first moment of area of the bolts about the centre of the coupling, m, must be at least:

$$m = 0{,}00043 \cdot d^3 [cm^3]$$

6.2.3 The thickness of the coupling flanges must be at least equal to the bolt diameter, and the width of the flange material outside the bolt holes must be greater than or equal to 0,67· d_b.

6.2.4 Coupling bolts are to be fitted bolts and their nuts are to be locked effectively.

6.3 Cone couplings with key

6.3.1 Tapering and coupling length

Cone couplings without hydraulic arrangements for mounting and dismounting the coupling should have a taper c on diameter of 1:8-1:12 and be secured by a slugging nut. The nut is to be secured, e.g. by a secure plate. Where:

$c = (d_0 - d_u)/l_c$ (**Figure 9.6.2** *and*

Figure 9.6.4.)

The diameters d_0 and d_u are shown in Figure 9.6.2 and the cone length, l_c, is defined in

Figure 9.6.4. The cone shapes are to fit exactly. The coupling length l_c is to be, in general, not less than 1,5· d_0.

Figure 9.6.2: Cone coupling with key

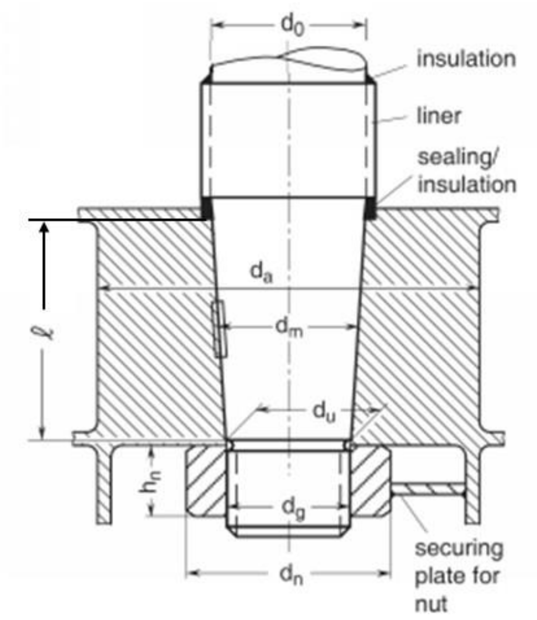


Figure 9.6.3: Gudgeon outer diameter(*da*) measurement

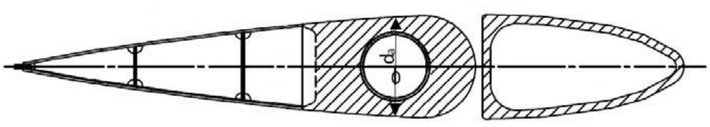
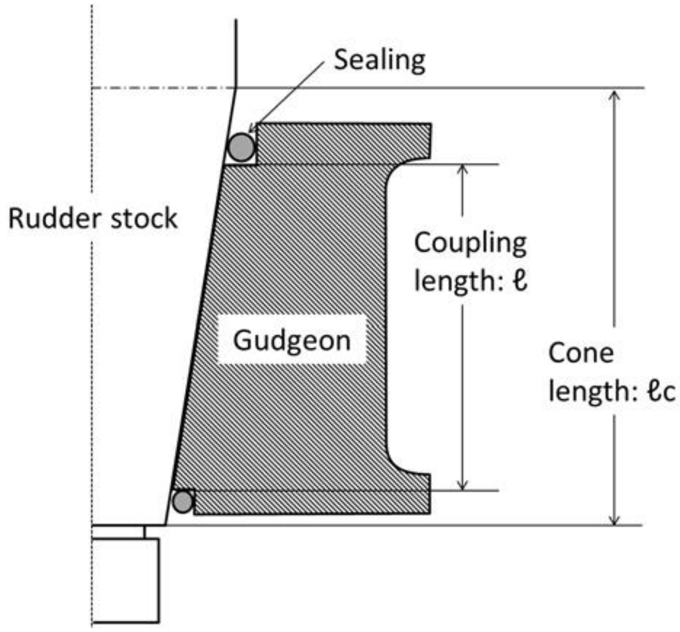


Figure 9.6.4: Cone length and coupling length



6.3.2 For couplings between stock and rudder a key is to be provided, the shear area of which, in cm^2, is not to be less than:

$$a_s = (17{,}55 \cdot Q_F)/(d_k \cdot R_{eH1})$$

Where:

Q_F	=	designed yield moment of rudder stock, in Nm
Q_F	=	$0{,}02664 \cdot d_t^3/k$

Where the actual diameter d_{ta} is greater than the calculated diameter d_t, the diameter d_{ta} is to be used. However, d_{ta} applied to the above formula need not be taken greater than 1,145· d_t,.

d_t	=	stock diameter, in mm, according to 4.1
k	=	material factor for stock as given in 1.3.5
d_k	=	mean diameter of the conical part of the rudder stock, in mm, at the key
R_{eH1}	=	specified minimum yield stress of the key material, in N/mm^2

The effective surface area, in cm^2, of the key (without rounded edges) between key and rudder stock or cone coupling is not to be less than:

$$a_k = (5 \cdot Q_F)/(d_k \cdot R_{eH2})$$

Where:

R_{eH2}	=	specified minimum yield stress of the key, stock or coupling material, in N/mm^2, whichever is less.

6.3.3 The dimensions of the slugging nut are to be as follows (see Figure 9.6.2):

external thread diameter: $d_g > 0{,}65 \cdot d_0$

length of nut: $h_n > 0{,}6 \cdot d_g$

outer diameter of nut: $d_n > 1{,}2 \cdot d_u$ or $1{,}5 \cdot d_g$ whichever is the greater.

6.3.4 Push up

It is to be proved that 50% of the design yield moment is solely transmitted by friction in the cone couplings. This can be done by calculating the required push-up pressure and push-up length according to 6.4.2 and 6.4.3 for a torsional moment $Q'_F = 0.5 \cdot Q_F$.

6.3.5 Notwithstanding the requirements in 6.3.2 and 6.3.4, where a key is fitted to the coupling between stock and rudder and it is considered that the entire rudder torque is transmitted by the key at the couplings, the scantlings of the key as well as the push-up force and push-up length are to be at the discretion of the society.

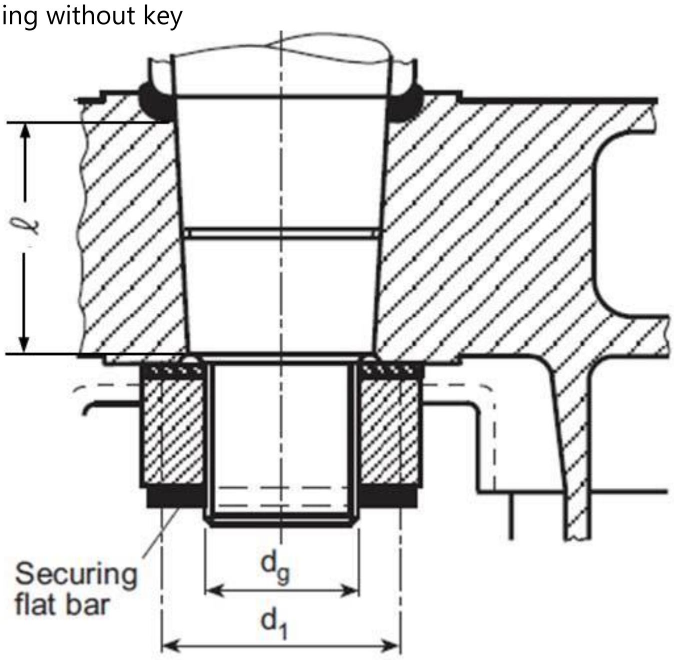
6.4 Cone couplings with special arrangements for mounting and dismounting the couplings

6.4.1 Where the stock diameter exceeds 200 mm, the press fit is recommended to be effected by a hydraulic pressure connection. In such cases the cone is to be more slender, $c \approx 1{:}12$ to $\approx 1{:}20$.

In case of hydraulic pressure connections, the nut is to be effectively secured against the rudder stock or the pintle.

For the safe transmission of the torsional moment by the coupling between rudder stock and rudder body the push-up pressure and the push-up length are to be determined according to 6.4.2 and 6.4.3 respectively.

Figure 9.6.5: Cone coupling without key



6.4.2 Push-up pressure

The push-up pressure is not to be less than the greater of the two following values:

$$p_{req1} = \frac{2 \cdot Q_F}{d_m^2 \cdot l \cdot \pi \cdot \mu_0} \cdot 10^3 [N/mm^2]$$

$$p_{req2} = \frac{6 \cdot M_b}{l^2 \cdot d_m} \cdot 10^3 [N/mm^2]$$

Where:

Q_F	=	design yield moment of rudder stock, as defined in 6.3.2 in Nm.
d_m	=	mean cone diameter, in mm, see Figure 9.6.2.
l	=	coupling length, in mm.
μ_0	=	frictional coefficient, equal to 0,15.
M_b	=	bending moment in the cone coupling (e.g. in case of spade rudders), in Nm.

It has to be proved by the designer that the push-up pressure does not exceed the permissible surface pressure in the cone. The permissible surface pressure, in N/mm², is to be determined by the following formula:

$$p_{perm} = \frac{0{,}95 \cdot R_{eH} \cdot (1 - a^2)}{\sqrt{3 + a^4}} - p_b \ [N/mm^2]$$

Where:

$$p_b = \frac{3{,}5 \cdot M_b}{l^2 \cdot d_m} \cdot 10^3$$

R_{eH}	=	specified minimum yield stress of the material of the gudgeon, in N/mm².
a	=	d_m/d_a
d_m	=	diameter, in mm, see Figure 9.6.2.
d_a	=	outer diameter of the gudgeon, in mm, see Figure 9.6.2 and Figure 9.6.3: . (The least diameter is to be considered).

The outer diameter of the gudgeon in mm shall not be less than 1,25· d_0, with d_0 defined in Figure 9.6.2.

6.4.3 Push-up length

The push-up length Δl, in mm, Δl is to comply with the following formula:

$$\Delta l_1 \leq \Delta l \leq \Delta l_2$$

Where:

$$\Delta l_1 = \frac{p_{req} \cdot d_m}{E \cdot (\frac{1 - a^2}{2}) \cdot c} + \frac{0{,}8 \cdot R_{tm}}{c} \ [mm]$$

$$\Delta l_2 = \frac{p_{perm} \cdot d_m}{E \cdot (\frac{1 - a^2}{2}) \cdot c} + \frac{0{,}8 \cdot R_{tm}}{c} \ [mm]$$

R_{tm}	=	mean roughness, in mm, taken equal to 0,01.
c	=	taper on diameter defined in 6.3.1.

Note: In case of hydraulic pressure connections the required push-up force P_e, in N, for the cone may be determined by the following formula:

$$P_e = p_{req} \cdot d_m \cdot \pi \cdot l \cdot (\frac{c}{2} + 0{,}02)$$

The value 0,02 is a reference for the friction coefficient using oil pressure. It varies and depends on the mechanical treatment and roughness of the details to be fixed. Where due to the fitting procedure a partial push-up effect caused by the rudder weight is given, this may be taken into account when fixing the required push-up length, subject to approval by the Society.

SECTION 7 Pintles

7.1 Scantlings

7.1.1 Pintles are to have a conical attachment to the gudgeons with a taper on diameter not greater than:

1:8 - 1:12 for keyed and other manually assembled pintles applying locking by slugging nut, 1:12 - 1:20 on diameter for pintles mounted with oil injection and hydraulic nut.

The length of the pintle housing in the gudgeon is not to be less than the maximum pintle diameter

$$d_p = 0{,}35 \cdot \sqrt{B \cdot k_p}$$

where B is the relevant bearing force and k_p is the material factor as given in 1.3.5

7.2 Couplings

7.2.1 Tapering

Pintles are to have a conical attachment to the gudgeons with a taper on diameter not greater than:

1:8 - 1:12 for keyed and other manually assembled pintles applying locking by slugging nut,

1:12 - 1:20 on diameter for pintles mounted with oil injection and hydraulic nut.

7.2.2 Push-up pressure for pintle

The required push-up pressure for pintle, in N/mm², is to be determined by the following formula:

$$p_{req} = 0{,}4 \cdot \frac{B_1 \cdot d_0}{d_m^2 \cdot l} \ [\frac{N}{mm^2}]$$

Where:

B_1 = Supporting force in the pintle, in N.

d_0 = Pintle diameter, in mm, see Figure 9.6.2.

The push-up length is to be calculated similarly as in 6.4.3, using required push-up pressure and properties for the pintle.

7.3 The minimum dimensions of threads and nuts are to be determined according to 6.3.3.

7.4 Pintle housing

The length of the pintle housing in the gudgeon is not to be less than the pintle diameter d_p. d_p is to be measured on the outside of liners.

The thickness of the pintle housing is not to be less than 0,25 d_p.

SECTION 8 Rudder stock bearing, rudder bearing and pintle bearing

8.1 Liners and bushes

8.1.1 Rudder stock bearing

Liners and bushes are to be fitted in way of bearings. The minimum thickness of liners and bushes is to be equal to:

- t_{min} = 8 mm for metallic materials and synthetic material.
- t_{min} = 22 mm for lignum material.

8.1.2 Pintle bearing

The thickness of any liner or bush, in mm, is neither to be less than:

$$t = 0{,}01 \cdot \sqrt{B}$$

Where:

B = relevant bearing force, in N.

nor than the minimum thickness defined in 8.1.1.

8.2 Minimum bearing surface

An adequate lubrication is to be ensured. The bearing surface A_b (defined as the projected area: length x outer diameter of liner) is not to be less than:

$$A_b = \frac{P}{q_a}[mm^2]$$

Where:

P = reaction force [N] in bearing as determined in 3.2

q_a = allowable surface pressure according to Table 9.8.1: below

The maximum surface pressure q_a for the various combinations is to be taken as:

Table 9.8.1: Allowable surface pressure q_a

Bearing material	q_a [N/mm^2]
Lignum vitae	2,5

White metal, oil lubricated	4,5
Synthetic material with hardness greater than 60 Shore D (1)	5,5 (2)
Steel (3) and bronze and hot-pressed bronze-graphite materials	7,0

NOTES:

1. Indentation hardness test at 23°C and with 50% moisture, according to a recognized standard. Synthetic bearing materials to be of approved type.
2. Surface pressures exceeding 5,5 N/mm^2 may be accepted in accordance with bearing manufacturer's specification and tests, but in no case more than 10 N/mm^2.
3. Stainless and wear-resistant steel in an approved combination with stock liner.

Higher values than given in the table may be taken if they are verified by tests.

8.3 Bearing Dimensions

The length/diameter ratio of the bearing surface is not to be greater than 1,2.

The bearing length L_p of the pintle, in mm, is to be such that:
$D_p \leq L_p \leq 1{,}2 \cdot D_p$ Where:

D_p = Actual pintle diameter, in mm, measured on the outside of liners.

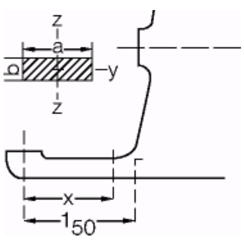
8.4 Bearing clearances

With metal bearings clearances should not be less than d_b/1000 + 1,0, mm, on the diameter. If non- metallic bearing material is applied, the bearing clearance is to be specially determined considering the material's swelling and thermal expansion properties. This clearance in no way is to be taken less than 1,5 mm on bearing diameter unless a smaller clearance is supported by the manufacturer's recommendation and there is documented evidence of satisfactory service history with a reduced clearance.

SECTION 9 Strength of sole pieces and rudder horns

9.1 Sole Piece

Figure 9.9.1: Sole piece



The section modulus around the vertical (z)-axis is not to be less than:

$$Z_z = M_b \cdot \frac{k}{80} [cm^3]$$

The section modulus around the transverse (y)- axis is not to be less than:

$$Z_y = 0,5 \cdot Z_z$$

The sectional area is not to be less than:

$$A_s = B_1 \cdot \frac{k}{48} [mm^2]$$

Where:

k	=	material factor as given in 1.3.2 or 1.3.5 respectively.

9.1.1 Equivalent stresses

At no section within the length l_{50} the equivalent stress is to exceed $115/k$. The equivalent stress is to be determined by the following formula:

$$\sigma_e = \sqrt{\sigma_b^2 + 3 \cdot \tau^2} \; [N/mm^2]$$

Where:

σ_b	=	$M_b/Z_z(x)$, N/mm^2
τ	=	B_1/A_s , N/mm^2
M_b	=	bending moment at the section considered, Nm
	=	$B_1 \cdot x$, Nm
M_{bmax}	=	$B_1 l_{50}$, Nm
B_1	=	supporting force in the pintle bearing [N] (normally $B_1 = C_R/2$).
k	=	material factor as given in 1.3.2 or 1.3.5 respectively.

9.2 Rudder horn

When the connection between the rudder horn and the hull structure is designed as a curved transition into the hull plating, special consideration should be given to the effectiveness of the rudder horn plate in bending and to the stresses in the transverse web plates.

The bending moments and shear forces are to be determined by a direct calculation or in line with the guidelines given in ANNEX 1 for semi spade rudder with one elastic support and semi spade rudder with 2-conjugate elastic support respectively.

The loads on the rudder horn are as follows:

$$Z_x = M_b \cdot k/67 \ \ [cm^3]$$

M_b = bending moment at the section considered, in Nm.

The shear stress is not to be larger than:

$$\tau = 48/k \ \ [N/mm^2]$$

k = material factor as given in 1.3.2 or 1.3.5 respectively.

9.2.1 Equivalent stresses

At no section within the length d the equivalent stress is to exceed 120/ k. The equivalent stress is to be calculated by the following formula:

$$\sigma_c = \sqrt{\sigma_b^2 + 3 \cdot (\tau^2 + \tau_\tau^2} \ \ [N/mm^2]$$

$$\sigma_b = M_b/Z_x \ \ [N/mm^2]$$

$$\tau = B_1/A_b \ \ [N/mm^2]$$

$$\tau_\tau = M_T \cdot 10^3/2 \cdot A_T \cdot t_h \ \ [N/mm^2]$$

B_1= supporting force in the pintle bearing, in N.

M_T= torsional moment in Nm

A_h = effective shear area of rudder horn in y-direction

A_T = area in the horizontal section enclosed by the rudder horn, mm^2

t_h = plate thickness of rudder horn, mm

k= material factor as given in 1.3.2 or 1.3.5 respectively.

9.2.2 Rudder horn plating

The thickness of the rudder horn side plating is not to be less than:

$$t = 2{,}4 \cdot \sqrt{L \cdot k} \ \ [mm]$$

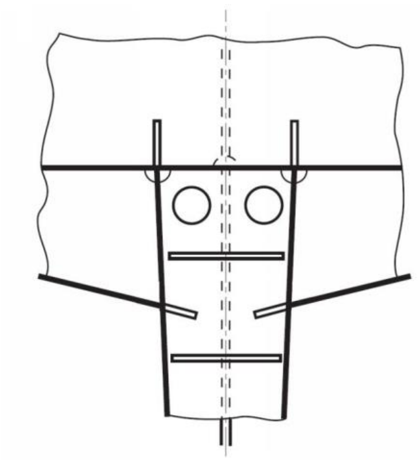
Where:

L	=	Rule length as defined in IACS UR S2, in m.
k	=	material factor as given in 1.3.2 or 1.3.5 respectively.

9.2.3 Welding and connection to hull structure

The rudder horn plating is to be effectively connected to the aft ship structure, e.g. by connecting the plating to side shell and transverse/ longitudinal girders, in order to achieve a proper transmission of forces, see Figure 9.9.2.
Brackets or stringer are to be fitted internally in horn, in line with outside shell plate, as shown in Figure 9.9.2.

Figure 9.9.2: Connection of rudder horn to aft ship structure



Transverse webs of the rudder horn are to be led into the hull up to the next deck in a sufficient number.
Strengthened plate floors are to be fitted in line with the transverse webs in order to achieve a sufficient connection with the hull.
The centre line bulkhead (wash-bulkhead) in the after peak is to be connected to the rudder horn.

Scallops are to be avoided in way of the connection between transverse webs and shell plating.

The weld at the connection between the rudder horn plating and the side shell is to be full penetration. The welding radius is to be as large as practicable and may be obtained by grinding.

9.3 Rudder trunk

The requirements in this section apply to trunk configurations which are extended below stern frame and arranged in such a way that the trunk is stressed by forces due to rudder action.

9.3.1 Materials, welding and connection to hull

The steel used for the rudder trunk is to be of weldable quality, with a carbon content not exceeding 0,23% on ladle analysis or a carbon equivalent C_{EQ} not exceeding 0,41%.
Plating materials for rudder trunks are in general not to be of lower grades than corresponding to class II as defined in IACS UR S6.
The weld at the connection between the rudder trunk and the shell or the bottom of the skeg is to be full penetration.
The fillet shoulder radius r, in mm, (see

Figure 9.9.3) is to be as large as practicable and to comply with the following formulae:

$$r = 0,1 \cdot d_c$$

without being less than:

r = 60 [mm] when $\sigma \geq 40 / k$ [N/mm^2]

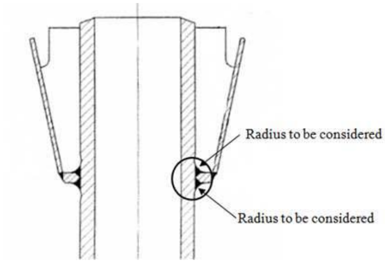
r = 30 [mm] when $\sigma < 40 / k$ [N/mm^2]

Where:

d_c	=	rudder stock diameter axis defined in 4.2.
σ	=	bending stress in the rudder trunk, in N/mm^2.
k	=	material factor as given in 1.3.2 or 1.3.5 respectively.

The radius may be obtained by grinding. If disk grinding is carried out, score marks are to be avoided in the direction of the weld. The radius is to be checked with a template for accuracy. Four profiles at least are to be checked. A report is to be submitted to the Surveyor.
Rudder trunks comprising of materials other than steel are to be specially considered by the society.

Figure 9.9.3: Fillet shoulder radius



9.3.2 Scantlings

The scantlings of the trunk are to be such that:
- the equivalent stress due to bending and shear does not exceed 0,35 R_{eH}.
- the bending stress on welded rudder trunk is to be in compliance with the following formula:

$$\sigma \leq \frac{80}{k}$$

with:

σ	=	bending stress in the rudder trunk, as defined in 9.3.1.
k	=	material factor as given in 1.3.2 or 1.3.5 respectively, not to be taken less than 0.7
R_{eH}	=	specified minimum yield stress, in N/mm^2, of the material used.

For calculation of bending stress, the span to be considered is the distance between the mid-height of the lower rudder stock bearing and the point where the trunk is clamped into the shell or the bottom of the skeg.

ANNEX 1 Guidelines for calculation of bending moment and shear force distribution

General

The evaluation of bending moments, shear forces and support forces for the system rudder - rudder stock may be carried out for some basic rudder types as shown below.

A. Spade rudder

Data for analysis

$l_{10} - l_{30}$ = lengths of the individual girders of the system, m

$I_{10} - I_{30}$ = moments of inertia of these girders, cm^4

Load of rudder body:

$$P_R = \frac{C_R}{10^3} \cdot l_{10} \ [kN/m]$$

Moments and forces

The bending moment M_R and the shear force Q_t in the rudder body, the bending moment M_b in the neck bearing and the support forces B_1 B_2, B_3 are to be evaluated. The so evaluated moments and forces are to be used for the stress analysis.

Estimates for spade rudders

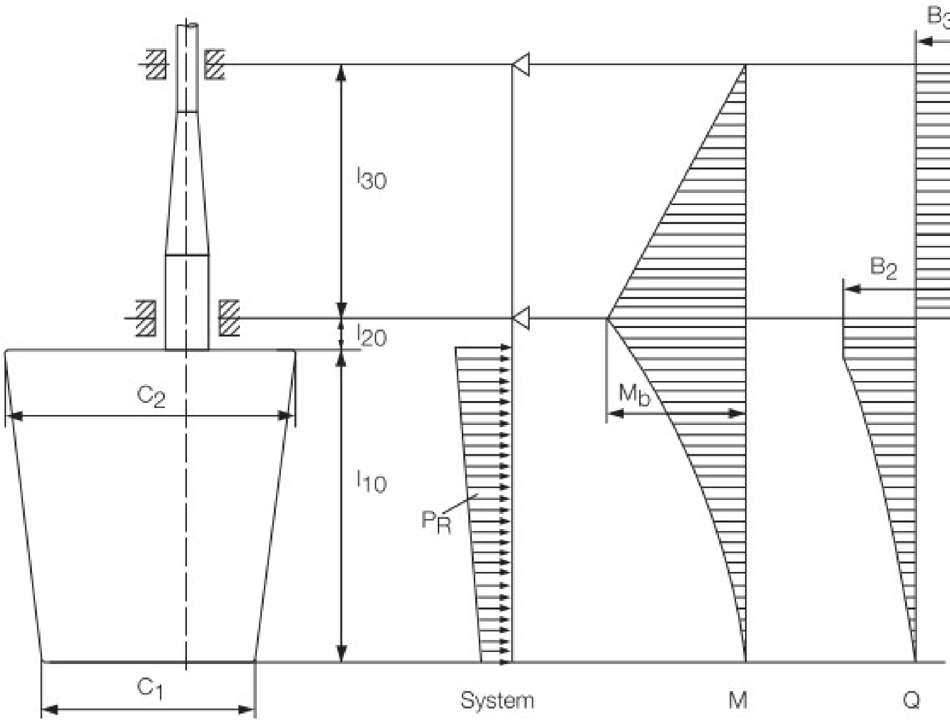
For spade rudders the moments and forces may be determined by the following formulae:

$$M_b = C_R \cdot \left(l_{20} + \left(\frac{l_{10}(2c_1 + c_2)}{3(c_1 + c_2)} \right) \right) \ [Nm]$$

$$B_3 = M_b / l_{30} \ [N]$$

$$B_2 = C_R + B_3 \ [N]$$

Figure A.1



B. Spade rudder with trunk

Data for analysis

$l_{10} - l_{30}$ = lengths of the individual girders of the system, m

$I_{10} - I_{30}$ = moments of inertia of these girders, cm^4

Load of rudder body:

$$P_R = \frac{C_R}{10^3} \cdot (l_{10} + l_{20}) \ [kN/m]$$

Moments and forces

For spade rudders with rudders trunks the moments, in Nm, and forces, in N, may be determined by the following formulae:

M_R is the greatest of the following values:

$M_{CR1} = C_{R1} \cdot (CG_{1Z} - l_{10})$

$M_{CR2} = C_{R2} \cdot (l_{10} - CG_{2Z})$

Where:

C_{R1} : Rudder force over the rudder blade area A_1.

C_{R2}: Rudder force over the rudder blade area A_2.

CG_{1Z} : Vertical position of the centre of gravity of the rudder blade area A_1. from base.

CG_{2Z} : Vertical position of the centre of gravity of the rudder blade area A_2 from base.

$C_R = C_{R1} + C_{R2}$

$B_3 = (M_{CR2} - M_{CR1}) / (l_{20} + l_{30})$

$B_2 = C_R + B_3$

C. Spade rudder with trunk

Data for analysis

$l_{10} - l_{50}$ = lengths of the individual girders of the system, m

$I_{10} - I_{50}$ = moments of inertia of these girders, cm^4

For rudders supported by a sole piece the length l_{20} is the distance between lower edge of rudder body and centre of sole piece and I_{20} the moment of inertia of the pintle in the sole piece.

I_{50} = moment of inertia of sole piece around the z-axis, in cm^4.
l_{50}= effective length of sole piece, in m.

Load of rudder body:

$$P_R = \frac{C_R}{10^3} \cdot l_{10} \ [kN/m]$$

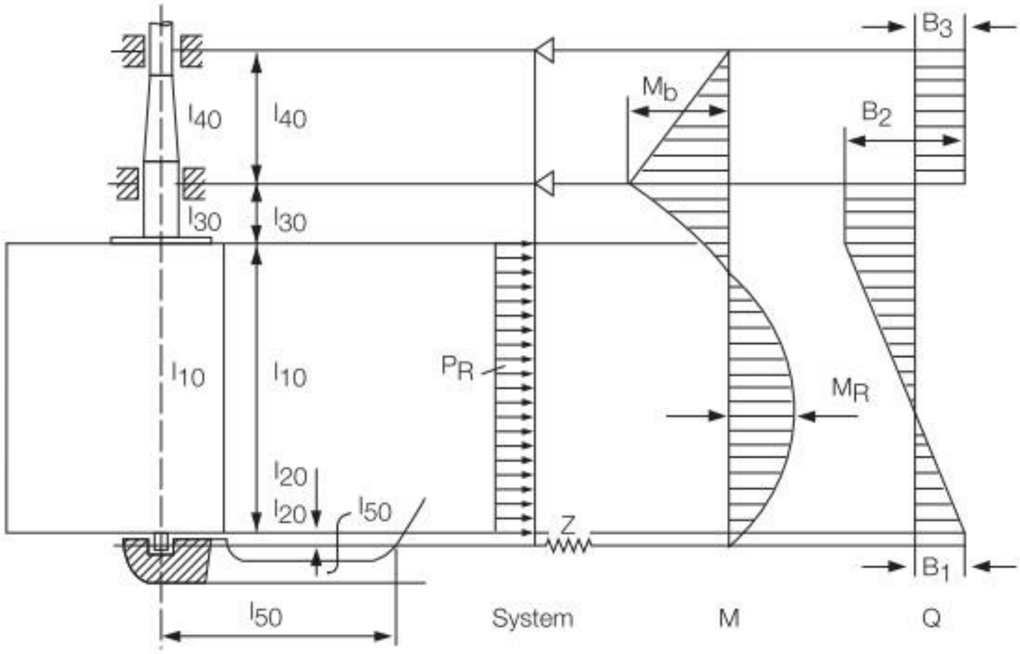
Z = spring constant of support in the sole piece.

Z = 6,18· I_{50} / l_{50}^3 [kN/m]

Moments and forces

Moments and shear forces are indicated in Figure A.1

Figure C.1:



D. Semi spade rudder with one elastic support

Data for analysis

$l_{10} - l_{50}$ = lengths of the individual girders of the system, m

$I_{10} - I_{50}$ = moments of inertia of these girders, cm^4

Z = spring constant of support in the rudder horn.

$Z = \frac{1}{f_b + f_t}$ $[\frac{kN}{m}]$ for the support in the rudder horn (

Figure D.**1**).

f_b = unit displacement of rudder horn, in m, due to a unit force of 1 kN acting in the centre of support.

f_b=1,3 $\cdot d^3/(6{,}18 \cdot I_n)$ [m/kN] (guidance value)

I_n=moment of inertia of rudder horn around x-axis, in cm^4, (see also

Figure D.**1**).

f_t=unit displacement due to torsion.

f_t=$d \cdot e^2 \cdot \frac{\sum u_i}{t_i} / (3{,}14 \cdot 10^8 \cdot F_T^2)$ [m/kN]

F_T=mean sectional area of rudder horn, in m^2.

u_i=breadth, in mm, of individual plates forming the mean horn sectional area.

t_i=thickness withing the individual breadth u_i, in mm.

d=Height of the rudder horn, in m, defined in

Figure D.**1**. This value is measured downwards from the upper horn end, at the point of curvature transition, to the mind-line of the lower rudder horn pintle.

$e(z)$=distance as defined in

Figure D.2, in m.

Load of rudder body:

P_{R10}=$C_{R2}/(l_{10} \cdot 10^3)$ [kN/m]

P_{R20}=$C_{R1}/(l_{20} \cdot 10^3)$ [kN/m]

for C_R, C_{R1}, C_{R2},, see SECTION 2

Moments and forces

Moments and shear forces are indicated in Figure D.**1**.

Rudder horn

The loads on the rudder horn are as follows:

M_b=bending moment = $B_1 \cdot z$ [Nm], M_{bmax}=$B_1 \cdot d$ [Nm]

q=shear force = B_1 {N]

$M_T(z)$=torsinal moment = $B_1 \cdot e(z)$ [Nm]

As estimate for B_1 is:

B_1=$C_R \cdot b/(l_{20} + l_{30})$ [N]

Figure D.1:

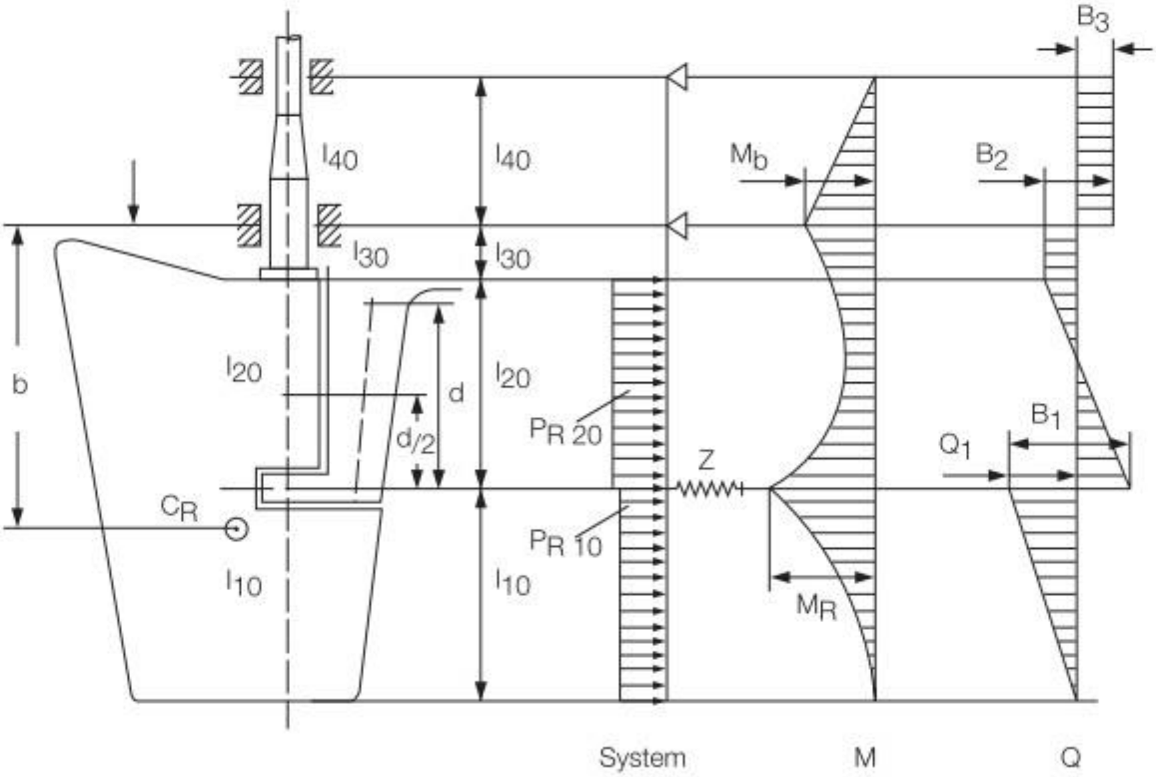
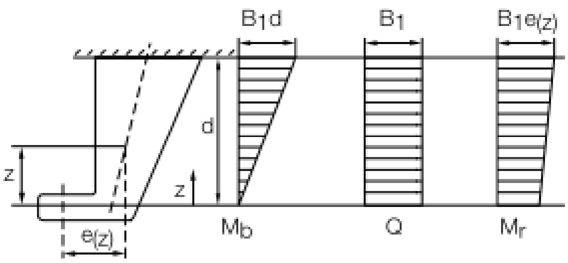


Figure D.2:



E. Semi spade rudder with 2-conjugate elastic support

Data for analysis

K_{11}, K_{22}, K_{12} : Rudder horn compliance constants calculated for rudder horn with 2-conjugate elastic supports (Figure E.1**:**
). The 2-conjugate elastic supports are defined in terms of horizontal displacements, $\boldsymbol{y_i}$, by the following

equations:

at the lower rudder horn bearing:

$y_1 = -K_{12} \cdot B_2 - K_{22} \cdot B_1$

at the upper rudder horn bearing:

$y_2 = -K_{11} \cdot B_2 - K_{12} \cdot B_1$

Where:

y_1, y_2: Horizontal displacements, in m, at the lower and upper rudder horn bearings, respectively.
B_1, B_2: Horizontal support forces, in kN, at the lower and upper rudder horn bearings, respectively.
K_{11}, K_{22}, K_{12}: Obtained, in m/kN, from the following formulae:

$$K_{11} = 1{,}3 \cdot \frac{\lambda^3}{3 \cdot E \cdot J_{1h}} + \frac{e^2 \cdot \lambda}{G \cdot J_{th}}$$

$$K_{22} = 1{,}3 \cdot [\frac{\lambda^3}{3 \cdot E \cdot J_{1h}} + \frac{\lambda^2 \cdot (d \cdot \lambda)}{2 \cdot E \cdot J_{1h}}] + \frac{e^2 \cdot \lambda}{G \cdot J_{th}}$$

$$K_{12} = 1{,}3 \cdot [\frac{\lambda^3}{3 \cdot E \cdot J_{1h}} + \frac{\lambda^2 \cdot (d \cdot \lambda)}{E \cdot J_{1h}} + \frac{\lambda \cdot (d \cdot \lambda)^2}{E \cdot J_{1h}} + \frac{(d \cdot \lambda)^3}{3 \cdot E \cdot J_{2h}}] + \frac{e^2 \cdot d}{G \cdot J_{th}}$$

d: Height of the rudder horn, in m, defined in Figure E.1**:**
. This value is measured downwards from the upper rudder horn end, at the point of curvature transition, to the mid-line of the lower rudder horn pintle.

λ: Length, in m, as defined in Figure E.1**:**
. This length is measured downwards from the upper rudder horn end, at the point of curvature transition, to the mid-line of the upper rudder horn bearing. For $\lambda = 0$, the above formulae converge to those of spring constant Z for a rudder horn with 1-elastic support, and assuming a hollow cross section for this part.

e: Rudder-horn torsion lever, in m, as defined in Figure E.1**:**
(value taken at $z = d/2$).

J_{1h}: Moment of inertia of rudder horn about the x axis, in m^4, for the region above the upper rudder horn bearing. Note that J_{1h} is an average value over the length λ (see Figure E.1**:**
).

J_{th}: Moment of inertia of rudder horn about the x axis, in m^4, for the region between the upper and lower rudder horn bearings. Note that J_{2h} is an average value over the length $d - \lambda$ (see Figure E.1**:**
).

J_{th}: Torsional stiffness factor of the rudder horn, in m^4.

For any thin wall closed section:

$$J_{th} = \frac{4 \cdot F_T^2}{\sum_i \frac{u_i}{t_i}}$$

F_T: Mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn, in m[2].

u_i: Length, in mm, of the individual plates forming the mean horn sectional area.

t_i: Thickness, in mm, of the individual plates mentioned above.

Note that theJ_{th} value is taken as an average value, valid over the rudder horn height.

Load of rudder body:

P_{R10}=$C_{R2}/(l_{10} \cdot 10^3)$ [kN/m]

P_{R20}=$C_{R1}/(l_{20} \cdot 10^3)$ [kN/m]

for C_R, C_{R1}, C_{R2},, see SECTION 2

Moments and forces

Moments and shear forces are indicated in Figure E.1**:**
.

Rudder horn bending moment

The bending moment acting on the generic section of the rudder horn is to be obtained, in Nm, from the following formulae:

- between the lower and upper supports provided by the rudder horn:

  M_H= $F_{A1} \cdot z$

- above the rudder horn upper-support:
  M_H= $F_{A1} \cdot z + F_{A2} \cdot (z - d_{iu})$

Where:

F_{A1}: Support force at the rudder horn lower-support, in N, to be obtained according to Figure E.1**:**
, and taken equal to B_1.

F_{A2}: Support force at the rudder horn upper-support, in N, to be obtained according to Figure E.1**:**
, and taken equal to B_2.

z: Distance, in m, defined in Figure E.2, to be taken less than the distance d, in m, defined in the same figure.

d_{iu}: Distance, in m, between the rudder-horn lower and upper bearings (according to Figure E.1**:**
, d_{iu} = $d - \lambda$).

Rudder horn shear force

The shear force QH acting on the generic section of the rudder horn is to be obtained, in N, from the following formulae:

- between the lower and upper rudder horn bearings:
  $Q_H = F_{A1}$

- above the rudder horn upper-bearing:
  $Q_H = F_{A1} + F_{A2}$

Where:

F_{A1}, F_{A2}: Support forces, in N.

The torque acting on the generic section of the rudder horn is to be obtained, in Nm, from the following formulae:

- between the lower and upper rudder horn bearings:
  $M_T = F_{A1} \cdot e_{(z)}$

- above the rudder horn upper-bearing:
  $M_T = F_{A1} \cdot e_{(z)} + F_{A2} \cdot e_{(z)}$

Where:

F_{A1}, F_{A2}: Support forces, in N.
$e_{(z)}$: Torsion lever, in m, defined in Figure E.2:

Rudder horn shear stress calculation

For a generic section of the rudder horn, located between its lower and upper bearings, the following stresses are to be calculated:

τ_S : Shear stress, in N/mm^2, to be obtained from the following formula:

$$\tau_S = \frac{F_{A1}}{A_H}$$

τ_T : Torsional stress, in N/mm^2, to be obtained for hollow rudder horn from the following formula:

$$\tau_T = \frac{M_T \cdot 10^{-3}}{2 \cdot F_T \cdot t_H}$$

For solid rudder horn, τ_T is to be considered by the Society on a case by case basis.

For a generic section of the rudder horn, located in the region above its upper bearing, the following stresses are to be calculated:

τ_S : Shear stress, in N/mm^2, to be obtained from the following formula:

$$\tau_S = \frac{F_{A1} + F_{A2}}{A_H}$$

τ_T : Torsional stress, in N/mm^2, to be obtained for hollow rudder horn from the following formula:

$\tau_T = \frac{M_T \cdot 10^{-3}}{2 \cdot F_T \cdot t_H}$

For solid rudder horn, τ_T is to be considered by the Society on a case by case basis where:

F_{A1}, F_{A2}: Support forces, in N.

A_H: Effective shear sectional area of the rudder horn, in mm^2, in y-direction.

M_T: Torque, in Nm.

F_T: Mean of areas enclosed by outer and inner boundaries of the thin walled section of rudder horn, in m^2.

t_H: Plate thickness of rudder horn, in mm. For a given cross section of the rudder horn, the maximum value of τ_T is obtained at the minimum value of t_H.

Rudder horn bending stress calculation

For the generic section of the rudder horn within the length d, the following stresses are to be calculated:

σ_B : Bending stress, in N/mm^2, to be obtained from the following formula:

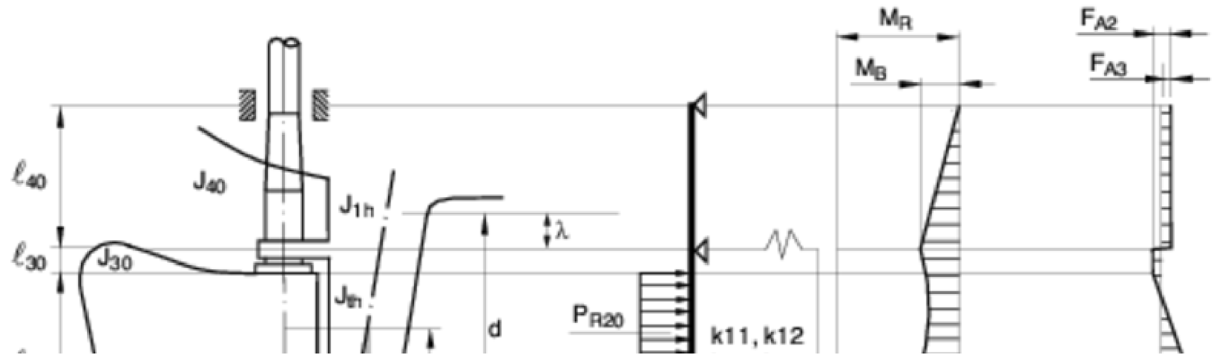
$\sigma_B = \frac{M_H}{W_X}$

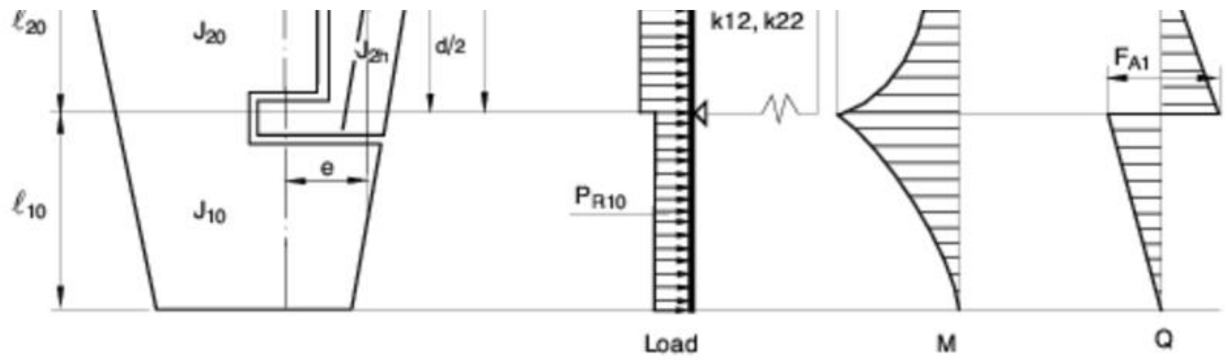
Where:

M_H : Bending moment at the section considered, in Nm.

W_X : Section modulus, in cm^3, around the x-axis (Figure E.2:

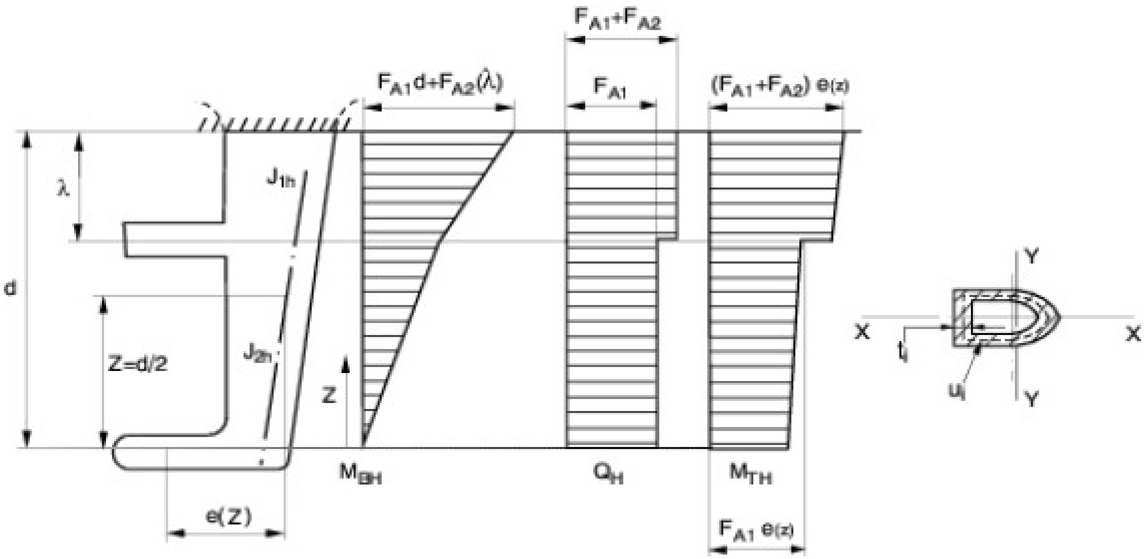
Figure E.1:





ℓ20
J20
J2h
d/2
k12, k22
FA1
e
ℓ10
J10
PR10
Load
M
Q

Figure E.2:



FA1+FA2
FA1d+FA2(λ)
FA1
(FA1+FA2) e(z)
λ
J1h
d
Y
X
X
ti
Z=d/2
J2h
ui
Y
Z
MBH
QH
MTH
e(Z)
FA1 e(z)

CHAPTER 10 Appendages

Contents

SECTION 1 Shaft struts

1.1 Application

1.1.1 The requirements of this Section apply to struts of either V or I type.

1.1.2 Propeller shaft struts may be of V or I type. The thickness of the shaft barrel or boss is to be at least one-forth the diameter of the tail shaft. The length of the strut barrel or boss is to be adequate to accommodate the propeller end bearings. The following equations are for struts having streamline cross-sectional shapes.

1.2 V Srut

1.2.1 The requirements for section modulus and inertia of each strut arm are in general to be in accordance with the following:

Section Moduls

$$SM = 0{,}024 \cdot d^3 \; [mm^3]$$

Inertia

$$I = 0{,}044 \cdot d^4 \; [mm^4]$$

where:

d = required diameter of tail shaft in mm.

Where the included angle is less than 45 degrees the scantlings are to be specially considered.

1.3 I Strut

1.3.1 The requirements for section modulus and inertia of the strut arm are in general to be in accordance with the following:

Section Moduls

$$SM = 0{,}068 \cdot d^3 \; [mm^3]$$

Inertia

$$I = 0{,}018 \cdot d^4 \; [mm^4]$$

where:

d = required diameter of tail shaft in mm.

1.4 Strut length

1.4.1 The length of the longer leg of a V strut or the leg of an I strut, measured from the outside perimeter of the strut barrel or boss to the outside of the shell plating, is not to exceed 10,5 times the diameter of the tail shaft. Where this length is exceeded, the width and thickness of the strut are to be increased and the strut design will be given special consideration.

SECTION 2 Rigging on sailing yachts

2.1 General

2,1,1 The following additional requirements apply for sailing vessels with the notation "COMMERCIAL YACHT".

2.2 Masts and Spars and Standing Rigging

7.1.2 Dimensions and construction materials of masts and spars and dimensions of standing rigging including connection to chain plates shall be in accordance with the requirements or recommendations of a Recognised Organisation or a recognised national or international standard.

7.1.3 The associated structure for masts and spars (including chainplates, fittings, decks and floors) shall be constructed to effectively carry and transmit the forces involved.

7.1.4 Compliance with 2.2.1 and 2.2.2 shall be confirmed by a design review and approval by L.H.R..

2.3 Rigging Fittings

2.3.1 The strength of all blocks, shackles, rigging screws, cleats and associated fittings and attachment points shall exceed the breaking strain of the associated running or standing rigging.

2.4 Sails

2.4.1 Adequate means of reefing or shortening sail shall be provided.

2.4.2 Sailing vessels operating as Short Range Yachts need not carry storm canvas.

2.4.3 All other vessels shall either be provided with separate storm sails or have specific sails designated and constructed to act as storm canvas.

CHAPTER 11 Stability of Commercial Yachts

Contents

SECTION 1 General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to yachts with the notation "COMMERCIAL YACHT" and cover both intact and damage stability.

1.1.2 An intact stability standard proposed for assessment of a vessel type not covered by the standards defined in the Code shall be submitted to the L.H.R. for approval at the earliest opportunity.

1.1.3 If used, permanent ballast shall be located in accordance with a plan approved by the L.H.R. and in a manner that prevents shifting of position. Permanent ballast shall not be removed from the ship or relocated within the ship without the approval of the L.H.R. Permanent ballast particulars shall be noted in the ship's stability booklet. Attention shall be paid to local or global hull strength requirements from the point of view of the fitting of additional ballast.

1.1.4 For the purpose of assessing whether the stability criteria are met, GZ curves shall be produced for the loading conditions applicable to the operation of the vessel.

SECTION 2 Intact Stability Standards

2.1 Standard criteria

2.1.1 The curves of statical stability for seagoing conditions shall meet the following criteria:

i. Proposals to reduce the area under the righting lever curve (GZ curve) shall not be less than 0.055 metre-radians up to 30° angle of heel and not less than 0.09 metreradians up to 40° angle of heel, or the angle of downflooding, if this angle is less;
ii. the area under the GZ curve between the angles of heel of 30° and 40° or between 30° and the angle of downflooding if this is less than 40°, shall not be less than 0.03 metre-radians;
iii. the righting lever (GZ) shall be at least 0.20 metres at an angle of heel equal to or greater than 30°;
iv. the maximum GZ shall occur at an angle of heel of preferably exceeding 30° but not less than 25°;
v. after correction for free surface effects, the initial metacentric height (GM) shall not be less than 0.15 metres; and
vi. in the event that the vessels intact stability standard fails to comply with the criteria defined in (i) to (v) L.H.R. may be consulted for the purpose of specifying alternative but equivalent criteria.

2.2 Vessels operating as Short Range Yachts

2.2.1 Where Short Range Yachts are unable to meet the criteria above, the following criteria may be used:

i. the area under the righting lever curve (GZ curve) shall not be less than 0.07 metre-radians up to 15° angle of heel, when maximum GZ occurs at 15°, and 0.055 metre-radians up to 30° angle of heel, when maximum GZ occurs at 30° or above. Where the maximum GZ occurs at angles of between 15° and 30°, the corresponding area under the GZ curve, A_{req} shall be taken as follows:
$$A_{req} = 0.055 + 0.001(30° - \theta_{max})$$
where θ_{max} is the angle of heel, in degrees, where the GZ curve reaches its maximum;
ii. the area under the GZ curve between the angles of heel of 30° and 40° or between 30° and the angle of downflooding if this is less than 40°, shall not be less than 0.03 metre-radians;
iii. the righting lever (GZ) shall be at least 0.20 metres at an angle of heel equal to or greater than 30°;
iv. the maximum GZ shall occur at an angle of heel not less than 15°;
v. after correction for free surface effects, the initial metacentric height (GM) shall not be less than 0.15 metres.

2.3 Alternative criteria

2.3.1 The curves of statical stability for seagoing conditions shall meet the following criteria:

i. the area under the righting lever curve (GZ curve) shall not be less than 0.075 metre-radians up to an angle of 20° when the maximum righting lever (GZ) occurs at 20° and, not less than 0.055 metre-radians up to an angle of 30° when the maximum righting lever (GZ) occurs at 30° or above. When the maximum GZ occurs at angles between 20° and 30° the corresponding area under the GZ curve, Area shall be taken as follows:

$$A_{req} = 0.055 + 0.002(30° - \theta_{max})$$

where θ_{max} is the angle of heel, in degrees, where the GZ curve reaches its maximum;

ii. the area under the GZ curve between the angles of heel of 30° and 40°, or between 30° and the angle of downflooding if this is less than 40°, shall not be less than 0.03 metre-radians;

iii. the righting lever (GZ) shall be at least 0.20 metres at an angle of heel where it reaches its maximum;

iv. the maximum GZ shall occur at an angle of heel not less than 20°;

v. after correction for free surface effects, the initial metacentric height (GM) shall not be less than 0.15 metres; and

vi. if the maximum righting lever (GZ) occurs at an angle of less than 20° approval of the stability shall be considered by the Administration as a special case.

2.3.2 For the purpose of assessing whether the stability criteria are met, GZ curves should be produced for the loading conditions applicable to the operation of the vessel.

2.4 Superstructures

2.4.1 The buoyancy of enclosed superstructures complying with regulation 3(10)(b) of the ICLL may be taken into account when producing GZ curves.

2.4.2 Superstructures, the doors of which do not comply with the requirements of regulation 12 of ICLL, shall not be taken into account.

2.5 High speed vessels

2.5.1 In addition to the criteria above designers and builders shall address the following hazards which are known to affect vessels operating in planing modes or those achieving relatively high speeds:

i. directional instability, often coupled to roll and pitch instabilities;

ii. bow diving of planing vessels due to dynamic loss of longitudinal stability in calm seas;

iii. reduction in transverse stability with increasing speed in monohulls;

iv. porpoising of planing monohulls being coupled with pitch and heave oscillations;

v. generation of capsizing moments due to immersion of chines in planing monohulls (chine tripping).

2.6 Sailing vessels monohulls

2.6.1 Curves of statical stability (GZ curves) for at least the Loaded Departure with 100% consumables and the Loaded Arrival with 10% consumables shall be produced.

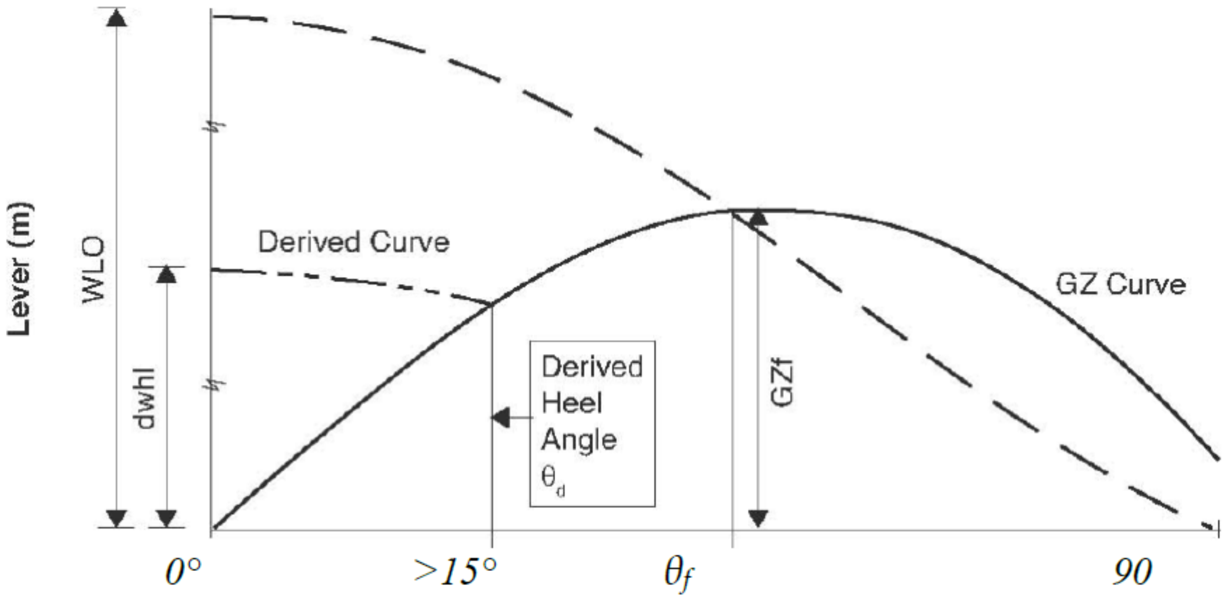
2.6.2 The GZ curves required by paragraph 2.6.1 should have a positive range of not less than 90 degrees. For vessels of more than 45m, a range of less than 90 degrees may be considered but may be subject to agreed operational criteria.

2.6.3 In addition to the requirements of paragraph 2.6.2, the angle of steady heel should be greater than 15 degrees (see figure). The angle of steady heel is obtained from the intersection of a "derived wind heeling lever" curve with the GZ curve required by paragraph 2.6.1.

In the figure: 'dwhl' = the 'derived wind heeling lever' at any angle $\theta°$ = 0.5 x WLO x $Cos^{1.3}\theta$,

where $WLO = \frac{GZ_f}{Cos^{1.3}\theta}$

Figure 3.11.1



Noting that:

WLO = *is the magnitude of the actual wind heeling lever at 0° which would cause the vessel to heel to the 'down flooding angle' θf or 60° whichever is least*

GZ_f = is the lever of the vessel's GZ at the down flooding angle (θf) or 60° whichever is least.

θ_d = is the angle at which the 'derived wind heeling' curve intersects the GZ curve. (If θd is less than 15° the vessel shall be considered as having insufficient stability for the purpose of the Code).

θ_f = the 'down-flooding angle' is the angle of heel causing immersion of the lower edge of openings having an aggregate area, in square meters, greater than:

$$\frac{\Delta}{1500}$$

Where Δ is the vessels displacement in tonnes.

All regularly used openings for access and for ventilation shall be considered when determining the downflooding angle. No opening regardless of size which may lead to progressive flooding shall be immersed at an angle of heel of less than 40°. Air pipes to tanks can, however, be disregarded.

As a result of immersion of openings in a superstructure, a vessel cannot meet the required standard, those superstructure openings may be ignored and the openings in the weather deck used instead to determine θf. In such cases the GZ curve shall be derived without the benefit of the buoyancy of the superstructure.

It might be noted that provided the vessel complies with the requirements of paragraphs 2.6.1 to 2.6.3 and is sailed with an angle of heel which is no greater than the 'derived angle of heel', it shall be capable of withstanding a wind gust equal to 1.4 times the actual wind velocity (i.e. twice the actual wind pressure) without immersing the' down-flooding openings', or heeling to an angle greater than 60°.

2.7 Sailing vessels multi-hulls

2.7.1 Curves of statical stability in both roll and pitch shall be prepared for at least the Loaded Arrival with 10% consumables. The VCG shall be obtained by one of the three methods listed below:

i. inclining of complete craft in air on load cells, the VCG being calculated from the moments generated by the measured forces; or
ii. separate determination of weights of hull and rig (comprising masts and all running and standing

rigging), and subsequent calculation assuming that the hull VCG is 75% of the hull depth above the bottom of the canoe body, and that the VCG of the rig is at half the length of the mast (or a weighted mean of the lengths of more than one mast); or

iii. a detailed calculation of the weight and CG position of all components of the vessel, plus a 15% margin of the resulting VCG height above the underside of canoe body.

2.7.2 If naval architecture software is used to obtain a curve of pitch restoring moments, then the trim angle shall be found for a series of longitudinal centre of gravity (LCG) positions forward of that necessary for the Design Waterline. The curve can then be derived as follows:

GZ in pitch =	CG′ x cos(trim angle)
trim angle =	$tan^{-1}\left(\frac{T_{FP}-T_{AP}}{L_{BP}}\right)$
where	
CG′ =	shift of LCG forward of that required for design trim, measured parallel to baseline
T_{FP} =	draught at forward perpendicular
T_{AP} =	draught at aft perpendicular
L_{BP} =	length between perpendiculars

(Approximations to maximum roll or pitch moments are not acceptable)

2.7.3 Data shall be provided to the user showing the maximum advised mean apparent wind speed appropriate to each combination of sails, such wind speeds being calculated as the lesser of the following:

$$v_w = 1.5\sqrt{\frac{LM_R}{A_s'hcos\varphi_R + A_Db}}$$

$$v_w = 1.5\sqrt{\frac{LM_P}{A_s'hcos\varphi_P + A_Db}}$$

Where

$v_w =$	maximum advised apparent wind speed (knots)
$LM_R =$	maximum restoring moment in roll (N.m)
$LM_P =$	limiting restoring moment in pitch (N.m), defined as the pitch restoring moment at the least angle of the following: a) angle of maximum pitch restoring moment; b) angle at which foredeck is immersed; or c) 0˚ from design trim
$A_s' =$	area of sails set including mast and boom (square metres)
$h =$	height of combined centre of effort of sails and spars above the waterline
$\varphi_R =$	heel angle at maximum roll righting moment (in conjunction with LM_R)
$\varphi_P =$	limiting pitch angle used when calculating LM_P (in conjunction with LM_P)
$A_D =$	plan area of the hulls and deck (square metres)
$b =$	distance from centroid of A_D to the centreline of the leeward hull

This data shall be accompanied by the note:

In following winds, the tabulated safe wind speed for each sail combination shall be reduced by the boat speed

2.7.4 If the maximum safe wind speed under full fore-and-aft sail is less than 27 knots, it shall be demonstrated by calculation using annex D of ISO 12217-2 (2002) that, when inverted and/or fully flooded, the volume of buoyancy, expressed in cubic metres (m^3), in the hull, fittings and equipment is greater than:

$$1.2\ x\ (fully\ loaded\ mass\ in\ tonnes)$$

thus ensuring that it is sufficient to support the mass of the fully loaded vessel by a margin. Allowance for trapped bubbles of air (apart from dedicated air tanks and watertight compartments) shall not be included.

2.7.5 The maximum safe wind speed with no sails set calculated in accordance with (3)above shall exceed 36 knots. For Part A Short Range Yachts this wind speed shall exceed 32 knots.

2.7.6 Trimarans used for unrestricted operations shall have sidehulls each having a total buoyant volume of at least 150% of the displacement volume in the fully loaded condition.

2.7.7 The stability information booklet shall include information and guidance on:

i. the stability hazards to which these craft are vulnerable, including the risk of capsize in roll and/or pitch;
ii. the importance of complying with the maximum advised apparent wind speed information supplied;
iii. the need to reduce the tabulated safe wind speeds by the vessel speed in following winds;
iv. the choice of sails shall be set with respect to the prevailing wind strength, relative wind direction, and sea state;
v. the precautions shall be taken when altering course from a following to a beam wind.

2.7.8 In vessels required to demonstrate the ability to float after inversion (according to 2.3.1 above), an emergency escape hatch shall be fitted to each main inhabited watertight compartment such that it is above both upright and inverted waterlines.

SECTION 3 Damage Stability

3.1 General

3.1.1 The following requirements are applicable to all vessels, other than those operating as Short Range Yachts. Whilst Short Range Yachts are not required to meet the damage stability criteria defined above, ultimate survivability after minor damage ro flooding is recommended.

3.2 Requirements

3.2.1 The watertight bulkheads of the vessel shall be so arranged that minor hull damage that results in the free flooding of any one compartment, shall cause the vessel to float at a waterline which, at any point, is not less than 75 millimetres below the weather deck, freeboard deck, or bulkhead deck if not concurrent.

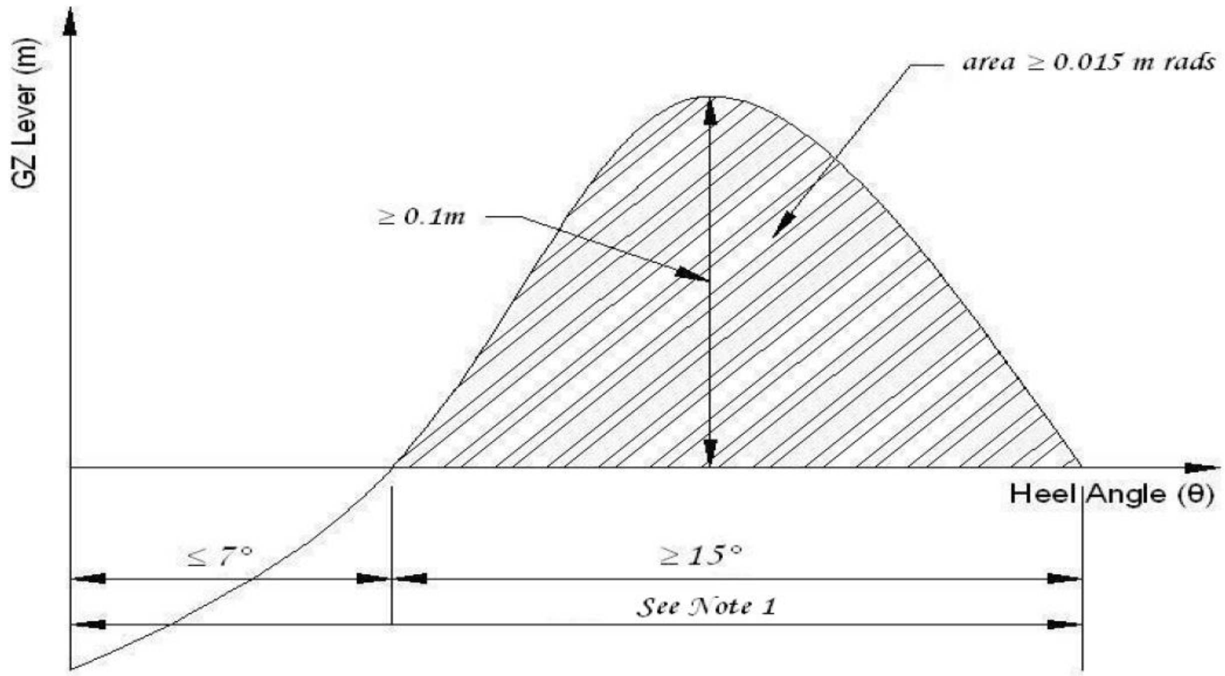
3.2.2 Minor damage shall be assumed to occur anywhere in the length of the vessel, but not on a watertight bulkhead.

3.2.3 Standard permeabilities shall be used in this assessment, as follows:

Space	Percentage Permeability
Stores	60
Stores but not a substantial quantity thereof	95
Accommodation	95
Machinery	85

3.2.4 In the damaged condition, considered in 4.2.1, the residual stability shall be such that any angle of equilibrium does not exceed 7° from the upright, the resulting righting lever curve has a range to the downflooding angle of at least 15° beyond any angle of equilibrium, the maximum righting lever within that range is not less than 100 millimetres and the area under the curve is not less than 0.015 metre radians.

Figure 3.11.2



Notes:

1. Range of stability in “damaged” condition shall have regard, where appropriate, to truncation due to downflooding
2. The required properties of the “damaged” GZ curve, namely max. GZ≥0.1m and the area under the curve of ≥0.015 metre radians is be achieved within the positive range of the curve taking into account any restrictions imposed by Note 1.

3.2.5 A vessel of 85 metres length and above shall meet a SOLAS 90 passenger ship one-compartment standard of subdivision, calculated using the deterministic damage stability methodology. Such vessels shall be provided with a Damage Control Plan and Booklet, in accordance with the requirements of SOLAS Chapter II-I, Regulation 19.

SECTION 4 Elements of Stability

4.1 General

4.1.1 Unless otherwise specified, the lightship weight, vertical centre of gravity (KG) and longitudinal centre of gravity (LCG) of a vessel shall be determined from the results of an inclining experiment.

4.1.2 An inclining experiment shall be conducted in accordance with a detailed standard which is approved by L.H.R. and, in the presence of an authorized surveyor.

4.1.3 The report of the inclining experiment and the lightship particulars derived shall be approved by L.H.R. prior to its use in stability calculations.

4.1.4 When sister vessels are built at the same shipyard, L.H.R. may accept a lightweight check on subsequent vessels to corroborate the results of the inclining experiment conducted on the lead vessel of the class.

SECTION 5 Stability Documents

5.1 General

5.1.1 A vessel shall be provided with a Stability Information Booklet for the master, that shall be approved by L.H.R.

5.1.2 The content, form and presentation of information contained in the stability information booklet shall be based on the model booklet for the vessel type (motor or sailing) published by/for L.H.R.

5.1.3 A vessel with previously approved stability information which undergoes a major conversion or alterations shall be subjected to a complete reassessment of stability and provided with newly approved stability information. A major refit or major alteration is one which results in either a change in the lightship weight of 2% and above and/or the longitudinal centre of gravity of 1% and above (measured from the aft perpendicular) and/or the calculated vertical centre of gravity rises by 0.25% and above (measured from the keel).

5.1.4 Additionally, unless it can be clearly demonstrated that no major change has occurred, a lightweight check shall be carried out at the renewal survey.

5.1.5 Sailing vessels shall have, readily available, a copy of the 'Curves of Maximum Steady Heel Angle to Prevent Downflooding in Squalls', or in the case of a multihull, the values of maximum advised mean apparent wind speed, for the reference of the watchkeeper. This shall be a direct copy taken from that contained in the approved stability booklet.

5.1.6 The overall sail area and spar weights and dimensions shall be as documented in the vessel's stability information booklet. Any rigging modifications that increase the overall sail area, or the weight/dimensions of the rig aloft, shall be accompanied by an approved updating of the stability information booklet.

5.1.7 For Short Range Yachts, where the damage stability has not been assessed, the following note shall be added to the approved stability booklet:

"This vessel has not been assessed for damage stability, and therefore might not remain afloat in the event of damage or flooding".