Expert Services

Guidelines for Commercial Craft

Version 2021

The objective of the guidelines is to provide a basis for designing and construction of small commercial craft so that a reasonable level of safety and environmental sustainability is achieved.

The guidelines are developed by Eurofins Expert Services Ltd., Finland, and is primarily used for the assessment of small commercial craft for statutory compliance

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1 INTRODUCTION AND PRINCIPLES OF APPLICATION

1.1 Objective

The objective of these *Guidelines* (later also *Rules*) is to assess the safety and environmental sustainability for *Commercial Craft.*

In this chapter the Rule principles are described, and some Rule concepts defined.

1.2 Background

These Rules have been developed using the Nordic Boat Standard for Commercial Craft 1990 (NBS-Y 1990) as a framework, as well as the International Standards developed within the ISO TC 188 workgroup. In the beginning of 21st century these guidelines were also known as FMAW (Finnish Maritime Administration Workboat rule).

For boats in the upper range between hull length 15 m to 24 m Load Line length, the requirements are adapted to "ship rules" where practicable.

1.3 Principles when using ISO-standards

The ISO-standards referred to are mainly developed for CE-certification of boats according to the directive 2013/53/EU (the Recreational Craft Directive). The scope of these standards is for "small craft" up to 24 m hull length and as such not restricted to recreational craft only. The principles used in these standards are often relevant to commercial craft as well, even though the required level for them in the standards in some instances is too low.

The ISO standards are implemented as follows:

- The Guidelines text is to a large extent based on ISO-standards. Often the requirement level is, however, higher than in the corresponding ISO-standards. At the beginning of each chapter, in the section References, the applicable ISO-standards for the chapter are listed. A more detailed list of the standard versions with publication years is shown in Appendix 1.
- These Rules deal with the most common cases, for special cases reference is made to ISO-standards.
- Primarily, the Rules text apply. In the Rule chapters where reference is made to ISO-standards, additionally the applicable parts of the standards apply. In view of this the Rule user should also have access to the standards referred to.

1.4 The Rules vs. International Conventions

To avoid large differences in safety level at the 24 m length limit (Load Line length), the International Conventions that apply to ships are taken into account when considered practical for achieving the intended purpose here.

Of the four design categories that are referred to in these Rules, the most severe, Category A, is intended for extended voyages, but shall not be regarded as unrestricted service in the same sense as in the International Conventions. Therefore, the requirements for Category A craft are in many cases lower than those given in the conventions.

1.5 Unusual arrangements

These Rules are, by their very nature, purely technical. The Rule requirements are primarily aimed at achieving sufficient structural integrity as well as environmental sustainability.

At the beginning of each chapter, there is a paragraph named ”Objective”, where the risks that the Rule requirements attempt to cover are described.

In such cases where the unusual arrangement is not in conformity with the intention of these Commercial Craft Guidelines as applied, or these Guidelines do not cover the particular arrangement, the case shall be described with sufficient accuracy in the inspection report, enabling the responsible authority or end-user to make a decision.

1.6 Scope of the Guidelines

1.6.1 Scope

The Guidelines are intended to enable the structural integrity and environmental sustainability of the craft to be evaluated. in Finland, the requirements in these Guidelines fulfil or exceed the requirements for commercial craft, that were published 2020 by The Finnish Transport and Communications Agency Traficom. Portable safety- and other equipment is not covered by the Rules. Also communication and navigation electronics are outside the scope.

1.6.2 Length of the craft

The Rules apply to commercial craft with a hull length, according to the International Standard ISO 8666, greater than 5.5 m, and a length according to the International Load Line Convention (ILLC), of less than 24 m. The Load Line length is taken as the greater of:

- 96% of the length of the hull measured at a height equal to 85% of the depth (depth of hull from the top of the keel to the weather deck amidships), or
- the horizontal distance from the forward perpendicular (intersection of stem and 85% height waterline) to the rudderpost at the same height.

1.6.3 Types of craft

These Rules shall apply primarily to self-propelled surface craft. The Rules can be applied also to surface vessels without propulsion (barges etc.). Further the Rules can be applied according to Chapter 41 to air propelled craft. The Rules do not apply to sailing craft, nor hydrofoil craft.

1.6.4 Hull construction materials

Fiber-reinforced plastics, aluminium and steel construction are covered in these Rules. Use of other materials may be possible through separate, sufficient testing and studies. This shall be agreed with the responsible authority.

1.6.5 The definitions “Under Way” and “At Sea”

The craft is *under way* when proceeding using its own propulsion.

A craft *at sea* does not necessarily move, but can also be stationary held by an anchor or some other means.

1.7 Conditions of use

1.7.1 Design Categories

A boat given Design Category A is considered to be designed to operate in winds up to Beaufort Force 10 and associated wave heights, and to survive in even worse conditions. Such conditions may be encountered on extended voyages, for example across oceans, or inshore when unsheltered from the wind and waves for several hundred nautical miles. Winds are assumed to gust to 28 m/s.

A boat given design category B is considered to be designed for up to 4 m significant wave height and winds up to Beaufort Force 8. Such conditions may be encountered on offshore voyages of sufficient length or near coasts where shelter may not always be immediately available. Winds are assumed to gust to 21 m/s.

A boat given design category C is considered to be designed for up to 2 m significant wave height and winds up to Beaufort Force 6. Such conditions may be encountered on exposed inland waters, in estuaries and coastal waters in moderate weather conditions. Winds are assumed to gust to 17 m/s.

A boat given design category D is considered to be designed for 0.3 m significant wave height where some waves may reach max. 0.5 m, and typical steady winds up to Beaufort Force 4. Such conditions may be encountered on sheltered inland waters and in coastal waters in good weather. Winds are assumed to gust to 13 m/s.

Table 1.1 — Summary of Design Category definitions

Design Category	A	B	C	D
Wave height up to	approx. 7 m significant	4 m significant	2 m significant	0.3 m significant 0.5 m max
Typical Beaufort wind force	up to 10	up to 8	up to 6	up to 4

The significant wave height is the mean height of the highest one-third of the waves, which approximately corresponds to the wave height estimated by an experienced observer. Some individual waves will be close to double this height.

1.7.2 Temperatures and water salinity

All the materials used in the craft shall stand storing in the temperature range -40...+60 °C. It shall be possible to use the craft and its systems in the temperature range -10...+50 °C.

All the materials getting into contact with sea water shall stand 5 % salinity.

1.8 Additional Notations

All craft shall meet the requirements in Chapters 1-32, provided they are relevant. The assessment can be extended to cover particular additional features related to the craft's special missions. Provided the special mission remains within the Rules and the craft meets the requirements, an Additional Notation can be given in the Certificate of Approval. The following Additional Notations are included in the Rules:

1.8.1 Cargo Transport

The Additional Notation is given to craft with a payload exceeding $(2.5 \cdot LWL \cdot BWL)^{1.5}$ kg. Special attention to be paid to the handling, distribution and lashing of cargo. The stability is to be sufficient for the amount and type of cargo.

1.8.2 Towing

The Additional Notation is given to craft engaged in the towing of floating objects or other vessels. Special attention to be paid to stability and prevention of water intrusion, as well as safety on deck particularly around the towing hook.

1.8.3 Oil Spill Combat

The Additional Notation is given to craft intended for collecting oil spill from the sea or shores and/or transport of the oil spill to the shore or to other vessels. The craft shall be able to operate in an environment containing explosive gases. Special attention is also paid to hazards involved when operating outside fairways, safety on deck and fire suppression.

1.8.4 Passenger Transport

The Additional Notation is given to craft transporting more than 12 passengers, which are not part of the crew. Special attention to be paid to the passenger spaces arrangement and its fast evacuation, location of life saving appliances, and fire suppression.

Craft with the Additional Notation *Passenger Transport* can be examined for transfer to Passenger Vessel.

1.8.5 Self-Righting

The Additional Notation is given to craft having positive stability in the heeling angle range 0...180 degrees in all relevant loading conditions. The engines and other systems shall be arranged so the craft is in working order after returning to the upright condition.

1.8.6 One Compartment Damage Stability

The Additional Notation is given to craft having an equilibrium flotation position and stability meeting the requirements in Chapter 38 with one compartment damaged.

1.8.7 Winter navigation

The Additional Notation is given to craft able to operate in ice and sub-zero conditions. Special attention to be paid in addition to the scantlings and also to the hull shape, the rudder, and the propulsion arrangements. Additionally, the stability assessment needs to consider icing on decks and superstructures.

1.8.8 Deck Crane

The Additional Notation is given to craft having a deck crane. Special attention to be given to the crane attachment as well as the stability while it is in use.

1.8.9 Air-propelled vessels

The Additional Notation is given to hovercraft or hydrocopters. For hovercraft, the notation is valid while the craft operates in the air-born mode. In displacement mode the craft shall meet the requirements in Chapters 1-32 with the exceptions mentioned in the Guidelines.

1.9 Procedures for assessment

1.9.1 Craft identification

For identification purposes each craft shall have a CIN-code, yard number, or other permanent hull marking, which can be referred to in the documentation of the craft

1.9.2 Individual approval

Normally, compliance with these Guidelines is individually assessed for each craft. This means that each craft has to be surveyed, also in the case of series production.

1.9.3 Sisterships

If the craft to be surveyed is the sistership of a previously approved craft, the report can refer to the earlier made survey for those parts of the craft which are identical with the previous one

1.9.4 Type approval plus production control

If the craft is not to be used in Finland, a type approval can be granted for series-built craft. If this option is chosen, the documentation and production control are to be sufficiently comprehensive to facilitate the manufacturing of identical products.

The documentation shall comprise the survey reports listed under section 1.10 Documentation for each Chapter, if applicable.

1.10 Documentation

The manufacturer or his representative shall provide the required information to the assessing authority.

The extent of the documentation depends on the type of craft. The following documents are always required:

- Craft identification marking, the intended Design Category, and possible Additional Notation;
- The craft main particulars and other general information;
- General Arrangement drawing.

In addition to this it is necessary to submit the required additional information listed at the beginning of each Chapter.

1.11 Reporting

The result of the assessment is presented in the Survey Report, and confirmed by the Surveyor with his signature. The Survey Report shall contain at least the following information:

1. The name of the Survey Report, containing the name of the craft;
2. The client contact information;
3. The craft identification marking;
4. Specification for the craft containing the following:
    - Design Category;
    - Additional Notation;
    - Hull information;
    - Engine and propulsion gear information;
    - Lightweight and deadweight;

- Essential equipment;

5. A list of drawings, test protocols, calculations and other documents according to the Document list at the beginning of each applicable Chapter, as referred to in the Survey Report. The mentioned documents shall be identifiable with a numerical code and/or headline and date, and they must be filed together with the Report;
6. The input data for the inspections, tests, and calculations, the methods used as well as the results and possible deviations;
7. A statement containing at least the following information:
   - The client and manufacturer information
   - The craft information including:
     - The craft identification marking;
     - Main dimensions and hull material
     - Hull data
     - Superstrucure
     - Design Category (A, B, C or D);
     - Possible Additional Notation with possible restrictions;
     - Maximum number of persons;
     - Maximum load;
     - Maximum propulsion engine power recommended by the manufacturer;
     - Lightweight and maximum weight;
     - Freeboard height;
     - Propulsion type;
     - Number and power of propulsion engines
   - Description of the method used in the assessment of conformity
   - List of standards, Rules and Guidelines that has been applied fully or partly
   - Description of possible alternative solutions and possible solutions not covered by the standards or these Guidelines, including a description of how an equivalent level of safety has been achieved;
     - If applicable, a statement that the craft meets the requirements of the Guidelines and Traficom requirements for commercial craft, and, if needed, with which limitations the craft fulfils the requirements
     - Possible restrictions to the use of the craft
   - Signature

1.12 Symbols and units commonly used in these Rules

1.12.1 The weight and dimensions of crew

In the loading conditions defined for freeboard- and stability calculations, as well as for other Rule purposes, the following weights and dimensions are to be used, unless the crew uses special equipment (for example diving gear) requiring increased weight and dimensions:

- mass 85 kg

- width of seat 0.5 m
- height above seat 0.9 m
- horizontal dimension from backrest to foot support 0.75 m; and
- vertical position of center of gravity above seat or deck 0.1 m.

For craft with the Additional Marking ”Passenger Transport” the passenger weight and dimensions differ from the above, and are given in Chapter 34.

1.12.2 Symbols

Symbols and parameters used in the whole Guidelines are shown in Table 1.2. Additional symbols have been defined in conjunction with each chapter when necessary.

Table 1.2.: List of symbols

Symbol	Unit	Meaning	Standard reference
L_H	m	Length of hull	ISO 8666
L_{WL}	m	Length of waterline in loading condition LC2	ISO 8666
T_{MAX}	m	Draught in loading condition LC2	
B_H	m	Beam of hull in loading condition LC2	ISO 8666
B_{WL}	m	Beam waterline in loading condition LC2. For multihulls, the sum of the waterline beam for each hull.	ISO 8666
B_C	m	Chine beam	ISO 8666
F_M	m	Freeboard amidships in the actual loading condition	ISO 8666
T_C	m	Draught of canoe body in the actual loading condition	ISO 8666
Δ	t	Displacement tonnes in the actual loading condition	
V_D	m^3	Displacement volume in the actual loading condition	ISO 12217
ø	degree (°)	Angle of heel	ISO 12217
CL		Crew limit = maximum number of persons on board	ISO 12217
GM	m	Transverse metacentric height	ISO 12217
GZ	m	Righting lever	ISO 12217
LCG	m	Longitudinal position of the centre of gravity	ISO 12217
VCG	m	Vertical position of the centre of gravity	ISO 12217

LC1	-	Loading condition "Light service condition"	
LC2	-	Loading condition "Fully loaded departure"	
LC3	-	Loading condition "Fully loaded arrival"	
OFFSET	-	Load offset from centreline	
m_{LC}	kg	Light ship mass	ISO 12217
m_{MO}	kg	Displacement mass in Light service condition (LC1)	ISO 12217
m_{LDC}	kg	Displacement mass in Fully loaded departure condition(LC2)	ISO 12217
m_{LA}	kg	Displacement mass in Fully loaded arrival condition (LC3)	
m_L	kg	Mass of the maximum load	ISO 12217
RM	Nm	Righting moment	ISO 12217
V	kn m/s	Speed at displacement m_{LDC}	ISO 12215
V_{MAX}	kn m/s	Maximum speed	
A_{LV}	m^2	Wind load area in the actual loading condition	ISO 12217

2 CRAFT CONCEPTS

2.1 Objective

The objective in this chapter is to define different types of craft concepts with regard to decking and weathertight protection as well as prevention of downflooding. Craft concepts are used within the Rules to assist in applying the requirements in a fair way.

2.2 References

In this Chapter reference is made to the following documents:

- ISO 12217-1:2015 Small craft - Stability and buoyancy assessment and categorization
- ISO 6185-3:2014 Boats with a hull length less than 8 m with a motor rating of 15 kW and greater
- ISO 6185-4:2011+Corr.2014 Boats with a hull length less than 8 m with a motor rating of 15 kW and greater
- ISO 11812 Small craft - Watertight cockpits and quick-draining cockpits
- ISO 12216 Small craft - Windows, portlights and hatches, deadlights and doors - Strength and water tightness

2.3 Selection of craft concepts

The Rule requirements are in many cases defined considering the general arrangement of the craft. The decking arrangement, its weather tightness and water drainage is frequently referred to. The Rules assume that the craft will fit into one of the concepts 2.3.1-2.3.4 below. The selection uses the principles presented in the international standards ISO 12217 and ISO 6185.

2.3.1 Fully enclosed craft

For *fully enclosed craft* the horizontal projection comprises the following components in any combination:

- watertight deck and superstructure;
- quick-draining recesses complying with Chapter 5, their influence on the stability meeting the requirements in Chapter 4;
- watertight recesses complying with Chapter 5 with a combined volume V not greater than:
- $V \leq \frac{L_H \cdot B_H \cdot F_M}{40}$ [m^3] (2.1)
- closing appliances complying with Chapter 3.

The surface comprising the sum of the parts listed above is defined as the Weather Deck. The strength of the parts comprising the weather deck shall meet the requirements in Chapter 10 (FRP), 14 (aluminium) or 18 (steel),

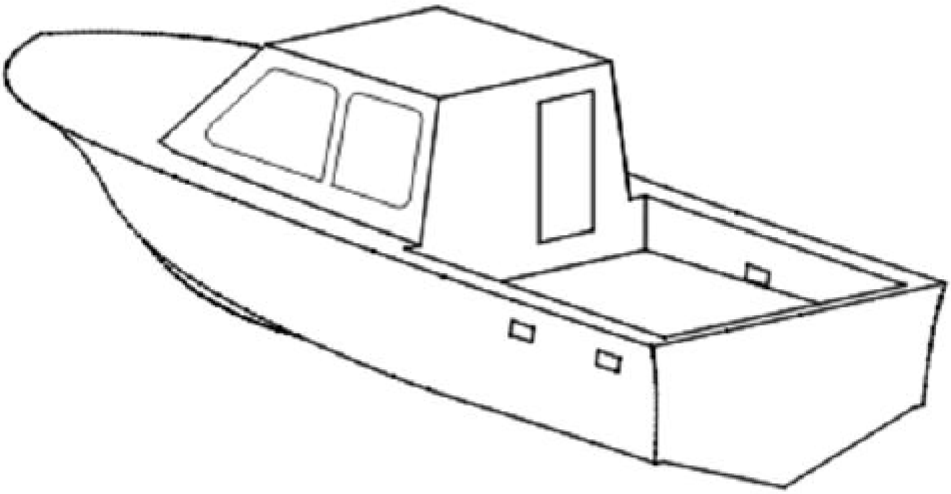

Figure 2.1.: Fully Enclosed craft.

Features of a Fully Enclosed craft:

- Deck arrangement ensures that green water coming on board can drain quickly overboard;
- The water draining from the recesses does not endanger the stability;
- Quickly draining recesses;
- Strong and tight decks and superstructures:
- Strong and tight windows and hatches;
- Sufficient buoyancy reserve;
- Adequate bow height;
- Weather tight doors with sills

2.3.2 Partially protected craft

A craft in which at least one-third of the horizontal projection consists of weather tight decking, superstructure, or other rigid covers that are designed to shed water overboard immediately. Included into this area to be all surfaces within $L_H/3$ from the bow, and also the area 100 mm inboard from the periphery of the boat. The remaining part may be open.

Doors, windows, and hatches need to comply with the requirements in Chapter 3 only if they are located within the mentioned LH /3 decking.

The strength of the decking or covering shall meet the requirements in Chapter 10, 14 or 18, depending on the structural material used. Quick draining recesses shall meet the requirements in Chapter 5, their closing appliances the requirements in Chapter 3. Other than quick draining recesses are accepted only with limitations according to clause 4.8.1.

In addition, the loaded displacement mass of partially protected craft shall not exceed

$$m_{LDC} \leq (11 \cdot L_H \cdot B_H)^{1.5} \text{ [kg]} \quad (2.2)$$

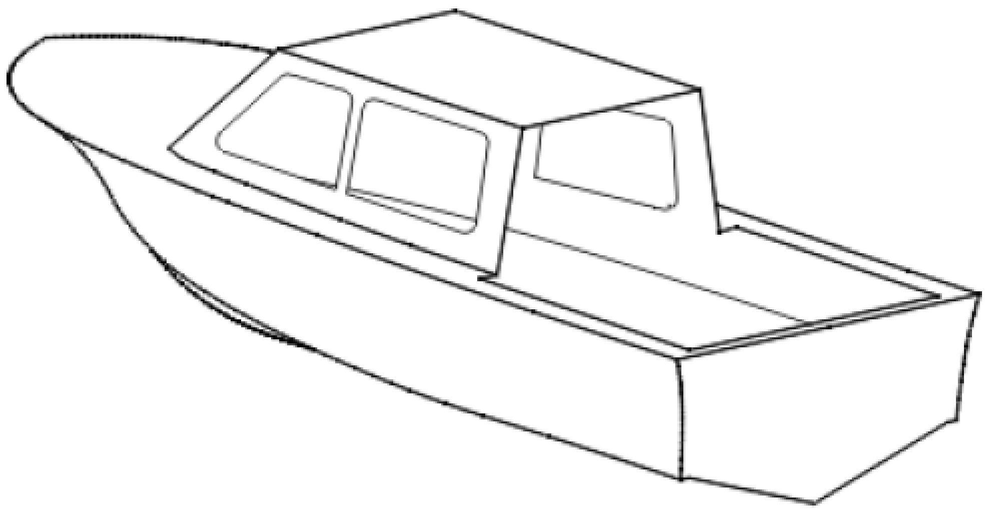

Figure 2.2.: Partially protected craft

The hull sides up to the lowest downflooding point are considered as reserve buoyancy. For a partially protected craft the highest Design Category is C (coastal), assuming that dangerous amounts of big waves are not coming on board. It is assumed, that spray water is emptied from the open space by drain pumps.

2.3.3 Craft with buoyancy chambers for remaining afloat

Within this concept a large part of the total volume consists of closed, fully watertight buoyancy chambers. These chambers must meet the requirements for floats, and the craft shall with the aid of the chambers remain afloat when filled with water according to Chapter 4.

In the craft concept it is assumed that in fully loaded condition all spaces except the closed buoyancy chambers are filled with green water coming onboard, and still sufficient reserve buoyancy must remain.

Generally commercially used craft with buoyancy chambers are hard-bottomed RIB:s (Rigid Inflatable Boats). For them at least half of the necessary volume consists of fiber reinforced polymer skin tubes or pontoons, keeping their shape due to internal pressure. The rigid bottom is of FRP, aluminium, or a similar structural material. The pontoon material shall meet the requirements in the standard ISO 15372, the buoyancy arrangements to meet ISO 6185, and the bottom construction the requirements for the chosen material in Chapters 10, 14, or 18.

Craft with buoyancy chambers may also have rigid air filled, or foam filled floats.

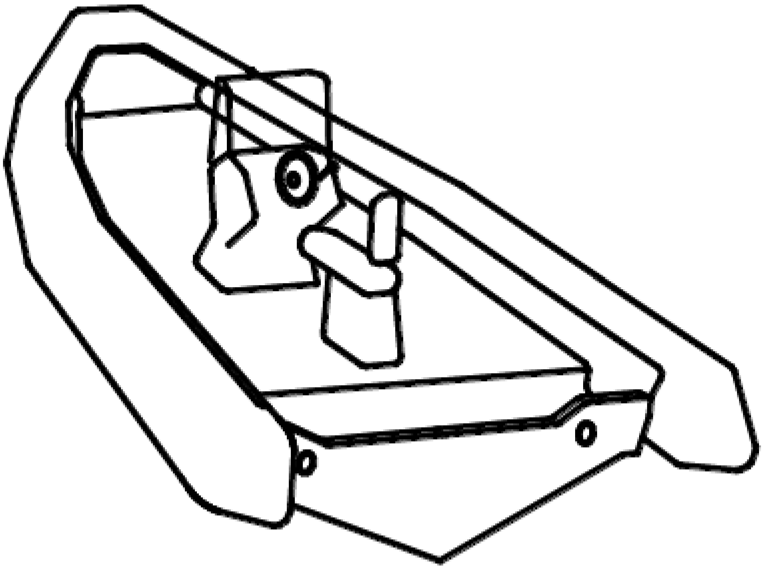

Figure 2.3.: Craft with buoyancy chambers

2.3.4 Open craft without buoyancy chambers

Craft which do not meet the requirements for fully or partially enclosed craft, and do not have buoyancy chambers, are considered *open craft*. The assumption is that the reserve buoyancy for open craft comprises of the watertight topsides, which must be continuous up to the required freeboard height. Recesses that do not fulfil the requirements of standard ISO 11812 for a quick draining recess, are accepted only if they fulfil the limitations according to clause 4.8.1.

For open craft there is a limit for the loaded displacement:

$$m_{LDC} \leq (11 \cdot L_H \cdot B_H)^{1.5} \text{ [kg]} \tag{2.3}$$

3 PREVENTION OF DOWNFLOODING

3.1 Objective

The objective in this chapter is to ensure a sufficient safety level against downflooding caused by improperly located and/or conceived openings or through-hull fittings

3.2 References

In this chapter reference is made to the following documents:

- ISO 12216 Small craft - Windows, portlights, hatches, deadlights and doors – Strength and water tightness
- ISO 12217 Small craft – Stability and buoyancy assessment and categorisation
- ISO 11812 Small craft – Watertight cockpits and quick-draining cockpits
- ISO 9093 Small craft – Seacocks and through-hull fittings
- International Load Line Convention 1966 with amendments

3.3 Documentation

For verifying that the requirements presented in this chapter are met, the following documentation is required:

- Location of openings (for instance on general arrangement drawing);
- Drawings of purpose-built closing appliances;
- Manufacturer and type designation of prefabricated closing appliances;
- Layout of seacocks and through-hull fittings; and
- Testing protocol of watertight integrity for closing appliances

3.4 Application

When applying the rules in this chapter it should be noted that the various types of deck arrangement (see Chapter 2) have different requirements for the water- and weather tight integrity. Only openings penetrating a surface requiring water- and weather tight integrity are subject to the requirements. including weathertight bulwark if it is part of the raised deck at bow, see Chapter 4.10.

Note! The location of an opening may also be limited by freeboard and downflooding angle (see Chapter 4). Further there may be special requirements for openings related to the Additional Notations of the craft, (see Chapters 33-41).

3.5 Exemptions

The requirements in this chapter may be disregarded for single openings on the following conditions:

- Stability- and freeboard requirements are met also when the space behind the opening is filled with water, and flooding into other compartments cannot occur.
- The craft important functions (see Chapter 24) are not affected although the space in question is filled with water.

3.6 Definitions

3.6.1 Opening and closing appliance

An *Opening* may be fitted with a *Closing appliance*, which is a common term for devices protecting an opening, such as windows, doors, hatches, hull ports and thru-hull fittings.

3.6.2 Doorways

Doorways are approximately vertical openings equipped with closing appliances, enabling a nearly upright person to pass through.

3.6.3 Hatchways

Hatchways are openings with closing appliances, allowing access to the space behind them. A vertical hatchway allowing a nearly upright person to pass through, is a doorway.

3.6.4 Windows and portlights

Windows are glassed closing appliances, whose purpose is to pass light into the space where they are installed. Portlight is a small window with an area of maximum 0.16 m^2. Windows and portlights may be openable under particular conditions. An opening window may, depending on its purpose, also be a hatchway.

3.6.5 Hull ports

Hull ports are openings leading into the hull, with closing appliances at surfaces on location areas 0 or 1 according to Figure 3.1, except portlights. Also openable ports at weathertight bulwark, if it is part of the raised deck at bow, see paragraph 4.10, are hull ports.

3.6.6 Air pipes

Air pipes are small ventilation openings with maximum 50 cm^2 cross section. Further they are equipped with a non-return valve, because of this they are considered weather tight when evaluating the stability. Examples of these are fuel tank and battery space vent pipes.

3.6.7 Through-hull fittings

Through-hull fittings are openings in the hull, connected to the craft's on-board systems. They may include a closing appliance (seacock).

3.6.8 Openings without closing appliances

Openings without closing appliances are openings that cannot be closed weather- or watertight without affecting the normal use of the craft. For example, the engine air intakes are such openings.

3.6.9 Coaming or sill height

Coaming or sill height of an opening is the minimum vertical distance from the top of the sill to the closest part of the surface below it. For more detailed definition, see ISO 11812.

3.6.10 Local deck height H_D

The vertical height in meters to the waterline in the fully loaded condition from the deck or similar surface, from which the edge height or sill is measured at the opening.

3.6.11 Application areas for openings

The following application areas are defined, see Figure 3.1:

- *Application area 0* covers the underwater surfaces of the weathertight hull to the deepest waterline.
- *Application area 1* covers the topsides below the weather deck for fully enclosed craft, and to a height corresponding to the freeboard requirements for open and partially protected craft. For multihulls also the underside of the bridge ("wet deck") is included.
- *Application area 2* covers the weather deck including superstructures up to the height h_2, see paragraph 3.9, excluding nearly forward facing surfaces, which belong to Application area 3.
- *Application area 3* covers the nearly forward facing vertical superstructure surfaces.
- *Application area 4* covers the superstructure surfaces above height h_2, see paragraph 3.9, excluding the nearly forward facing surfaces, which belong to Application area 3.

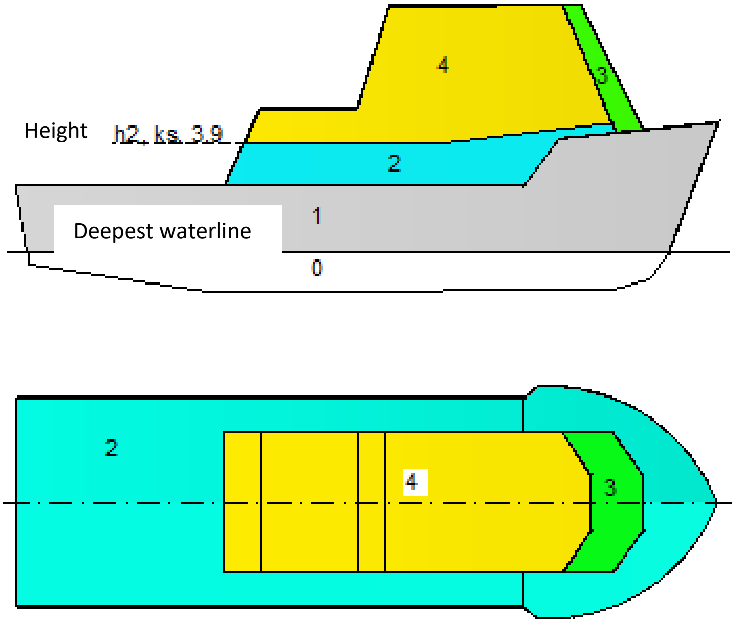

Figure 3.1: Location areas of openings

3.6.12 Opening's closing status in operation

The openings are divided into subsections based on their status when the craft is in operation:

- *Always open* at sea means that the opening in question must necessarily be open whenever the craft is under way. Such openings are for example the engine air intakes, and openings without closing devices.
- *Temporarily open* means that the opening in question may be open for short spells when under way, but they can quickly be closed weather- and watertight. Such openings are for example wheelhouse doors.
- *Always closed* at sea means that the opening in question is kept permanently closed weather- and watertight whenever the craft is under way. Behind such openings are weather deck spaces not requiring access when the craft is in operation.

3.6.13 Degree of Water tightness

The Rules specify two degrees of water tightness:

- Watertight closing appliances (Tightness Level 1) stand continuous hydrostatic pressure without leaking; and
- Weather tight closing appliances (Tightness Level 2) stand temporary immersion without leaking.

The degree of water tightness is defined according to the standard ISO 12216, with the following clarification:

- the water jet pressure shall be 35 kPa corresponding to Area 1 pressure;

Water tightness shall be achieved by an elastic seal or similar arrangement which ensures that there is no leaking gaps if hydrostatic pressure is directed into the seal.

3.7 Requirements

3.7.1 General

The number of openings in the weathertight hull should be as small as possible. Openings which are always open and which are essential for the operation of the craft shall not be located in the foremost third of the ship in ships of design class A.

All openings must be designed in such a way as to minimize the possibility of water ingress and to be strong enough to withstand the loads at the installation location.

Craft to which the additional endorsement “Self-righting” is granted shall also comply with the strength requirements of Chapter 37.

3.7.2 Coaming- and sill heights

Defining the requirements for coaming- or sill heights includes the following:

The values of dimensions h_1 and h_2 are calclulated using formulas 3.1-3.4;

Coaming/sill height requirements h_{s1} (at height h_1) and h_{s2} (at height h_2) are determined using Table 3.1;

If the local deck height h_D at the opening is less than the basic deck height h_1, the coaming or sill height h_s should be increased so that the lower edge of the opening is at least h_1 + h_{s1} above the deepest waterline;

• If the local deck height h_D is greater than h_1 but less than h_2, the coaming or sill height requirement h_s is interpolated between hs1 and hs2 using formula (3.5)

• If the height of the deck at the opening, h_D, is greater than or equal to h_2, the required coaming or sill height h_s = h_{s2}

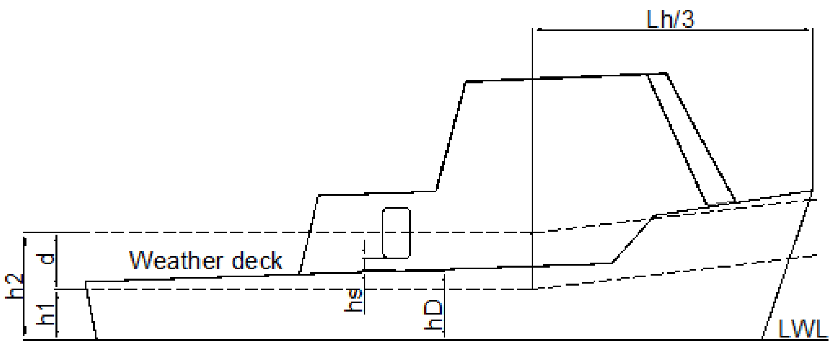

Figure 3.2: The measurements for defining coaming- and sill heights

$$h_1 = 0{,}7 \cdot k_{DC} \cdot k_L \cdot \frac{m_{LDC}}{1000 \cdot L_{WL} \cdot B_{WL}} \text{ [m]} \qquad (3.1)$$

Where k_{DC} is:

- 1.0 for Design Category A
- 0.8 for Design Category B
- 0.75 for Design Category C
- 0.5 for Design Category D

k_L is determined with formula (3.2) as a function of the longitudinal position (from aft end) X/L_H

$k_L = 0.6 \cdot X/L_H + 0.6$	min. 1.0	(3.2)
$d = k_{DC}\,(0.1 \cdot LH – 0.6)$	min. $0.9 \cdot k_{DC}$ [m]	(3.3)
$h_2 = h_1 + d$		(3.4)

$$h_S = h_{S1} - \frac{(h_D - h_1)(h_{S1} - h_{S2})}{d} \text{ [m]} \qquad (3.5)$$

Where

h_1	see formula (3.1)
h_D	local deck height fully loaded [m] see Figure 3.2
h_{S1}	sill height requirement at the level h1 [m], see Table 3.1
h_{S2}	sill height requirement at the level h2 [m], see Table 3.1
d	see Formula (3.3)

Coaming height is not required provided that:

- The opening height above the waterline is in all load cases at least $d+h_1$
- The size of the hatchway is max. 0.4 m^2

This exemption is, however, not valid for doorways to the interior, they must always have a coaming height. In Design Category A temporarily open openings must always have coamings.

3.7.3 Latches and hinges for locking

Latches and hinges for closing appliances shall be arranged so that the required degree of water tightness is achieved irrespectively of from which side the appliance is closed. Latches and hinges shall stand the forces from the pressure in the respective Application area without exceeding the material yield limit.

3.7.4 Hinged closing appliances

Closing appliances which are temporarily openable at sea shall be designed so they stay attached to the surrounding structure when open. In Application area 1 the openable appliances shall be hinged and open inwards. The hinges shall be sufficiently strong. In doubtful cases the hinges shall be evaluated according to the standard ISO 12216.

3.7.5 Sliding hatches

In other areas than Application area 1, closing appliances may be sliding hatches or -doors, provided all relevant requirements in Table 3.1 are met. The depth of the groove shall be sufficient for preventing the closing appliance from tearing out, considering the appropriate loads as well as the stiffness of the appliance and its surrounding structure. The groove shall generally be at least 12 mm deep. The closing appliance needs to have stops at each end position, preventing it from sliding off.

3.7.6 CE-marked closing appliances

All closing appliances, including those made by the manufacturer of the craft or subcontracted by him, shall meet standard ISO 12216 and additionally these Rules where they exceed the requirements in the standard. Prefabricated commercially available closing appliances may be used without restrictions in the locations given in Tables 3.1-3.6 provided they are CE-marked, and according to ISO 12216 suitable for the Design Category and Application area in question.

3.7.7 Particular requirements for closing appliances in Application area 1

The following particular requirements apply for closing appliances in Application area 1:

- the bottom edge of the closing appliance must be at least at the minimum height above the waterline given in Table 3.2 in the fully loaded departure condition;
- openings that are always when under way, are not allowed in application area 1 in design categories A or B;

- the shorter side of the opening must not exceed 300 mm;
- an opening appliance must open inwards;
- no part of the closing appliance must protrude outside a vertical line taken through the widest point of the craft, such as the hull, deck, or fixed rubbing strake;

3.7.8 Protection of gaskets

In applications where Table 3.1 prescribes "protection of gaskets", the gaskets made of rubber or other soft materials must be protected against wear for example according to Figure 3.3.

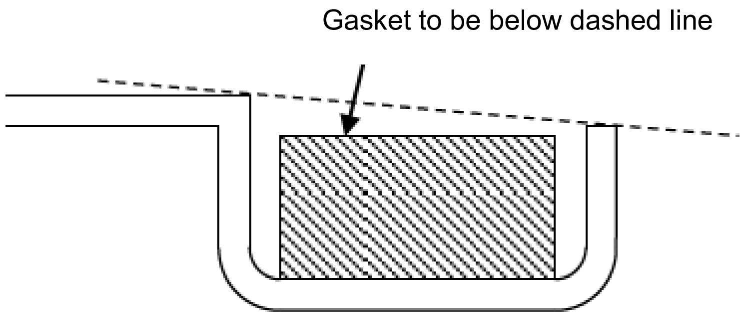

Figure 3.3: Protection of gaskets

3.7.9 Closing appliances on cargo decks

Closing appliances located on cargo decks must not have glazing. Protruding parts like latches must be very strong, or protected to stand the loads occurring in cargo handling.

3.8 Requirements for openings always open when under way.

A summary of requirements for openings always open when under way is given in Table 3.1.

3.8.1 Preventing water from entering

The openings always open when under way must be conceived so that the ingress of water is prevented as far as possible. This requirement is considered met if the intake is equipped with a baffle according to Figure 3.4, or a corresponding arrangement.

The ventilation openings shall primarily be facing aft, or to the sides.

Openings that are always when under way, are not allowed in application area 1 in design categories A or B.

In Design Category C and D craft openings mentioned above may be in Application area 1 provided that the requirements for stability and freeboard given in Chapter 4 are met.

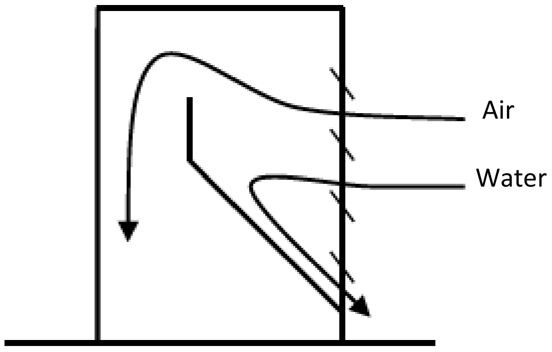

Figure 3.4 Air intake with baffle

3.9 Requirements for doors

3.9.1 Door sills

Half of the required sill height specified in Table 3.1 may be in a semi-fixed sill. The semi-fixed part shall be attached to the fixed sill part, or be continuously ready for use close to the door.

3.9.2 Direction of opening for doors

Doors in the superstructure sides shall have the hinges forward. Hinged doors shall open outwards.

3.9.3 Latches and hinges

Irrespective of the maximum distance between latches specified in Table 3.1, Design Category A and B craft doors shall have at least two latches in addition to the hinges. Doors shall be openable from both sides.

3.10 Requirements for hatches

3.10.1 Special requirements for hatches

Hatches that can be open at sea shall have the possibility to be secured in the open position.

Glazed hatches are not allowed in engine spaces, instead lighting to be arranged according to the guidelines in Chapter 21.

Hatches below the waterline are allowed only provided all relevant freeboard-, stability, and damage stability requirements are met, assuming that the space behind the hatch is water filled without any possibility of leakage into other compartments. Such hatches shall have the same strength as the surrounding hull structure. The strength of the space in question shall be sufficient to stand the local sea pressures.

3.11 Requirements for windows

A summary of the requirements is given in Tables 3.3-3.6

3.11.1 Special requirements for windows

The following special requirements are given:

- the windows around the control position must not be tinted (see Chapter 29)
- windows are not allowed in engine spaces, instead lighting to be arranged according to the guidelines in Chapter 21.
- the thickness of the windows shall be at least according to Tables 3.3-3.6 for tempered glass, and for other materials the window thickness shall be determined according to the standard ISO 12216, using, however, the following dimensioning pressures:
  - Application area 1, all design categories, 70 kPa;
  - Application area 2, design categories A and B, 12 kPa;
  - Application area 2, design categories C and D, 9 kPa;
  - Application area 3, design categories A and B, 28 kPa;
  - Application area 3, design categories C and D, 12 kPa;
  - Application area 4, design categories A and B, 12 kPa;
  - Application area 4, design categories C and D, 9 kPa.
- for laminated glass with the number of layers n and the thickness of individual layers t_n the compliance is determined using Formula (3.6) and (3.7). treq is the thickness requirement for a solid window according to Table 3.3-3.6.

$$\sum t_n = 1{,}2 \cdot t_{vaat} \text{ [mm]; n = 2} \qquad (3.6)$$

$$\sum t_n = 1{,}5 \cdot t_{vaat} \text{ [mm]; n > 2} \qquad (3.7)$$

3.12 Requirements for hull ports

3.12.1 Freeboard to the lower edge of hull ports

The freeboard to the lower edge of hull ports is deemed to be sufficient, if the craft fulfils the freeboard and downflooding angle requirements of the offset load test, when the hull port is open, assuming that the hull port is a downflooding opening.

3.12.2 Strength

The strength of hull ports to be at least the same as the surrounding structure. If the sea pressure can load the hinges or latches, they shall be designed to stand these loads.

3.12.3 Water tightness

Hull ports shall be watertight to Tightness Level 2. The gaskets shall be protected according to Figure 3.3.

3.12.4 Hinges and latching mechanisms

The hinges to be able to carry the sea pressure loads on the hull port.

The latching mechanism shall force the hull port against its gasket so that the required tightness is achieved.

There must be two alternative latching mechanisms, one of them to be independent of hydraulic pressure and/or electrical power.

3.13 Requirements for air pipes

The height above the surrounding deck for air pipes leading into the weather tight hull shall be at least 80% of the height required for openings always open at sea in the same position (see Table 3.1), and at least 250 mm. The cross section must not exceed 50 cm^2, and arrangements for preventing the ingress of water are required.

3.14 Through-hulls connected to on-board systems

3.14.1 General

Through-hull fittings located lower than 100 mm above the fully loaded waterline shall always have seacocks where they penetrate the hull.

For through-hull locations between 100…350 mm above the fully loaded waterline, seacocks are required if the entire system connected to the through-hull fitting is below the 350 mm level, and the system has an open end inside the craft. If this system inside end is closed, a seacock is not required. A non-return valve is considered equivalent to a closed end. Also, a seacock is not required if the system is partly above the 350 mm level (gooseneck), equipped with a siphon break, and can stand 10 degrees of heel without leaking.

In crafts having an additional notation Deck crane, shall through hull fittings close automatically if they submerge at 10 degrees heel.

For through-hulls located more than 350 mm above the fully loaded waterline, neither seacocks nor non-return valves are required, provided the through-hulls do not leak at 10 degrees heel in the fully loaded condition.

The requirements for through-hulls connected to on-board systems are visualized in Figure 3.5.

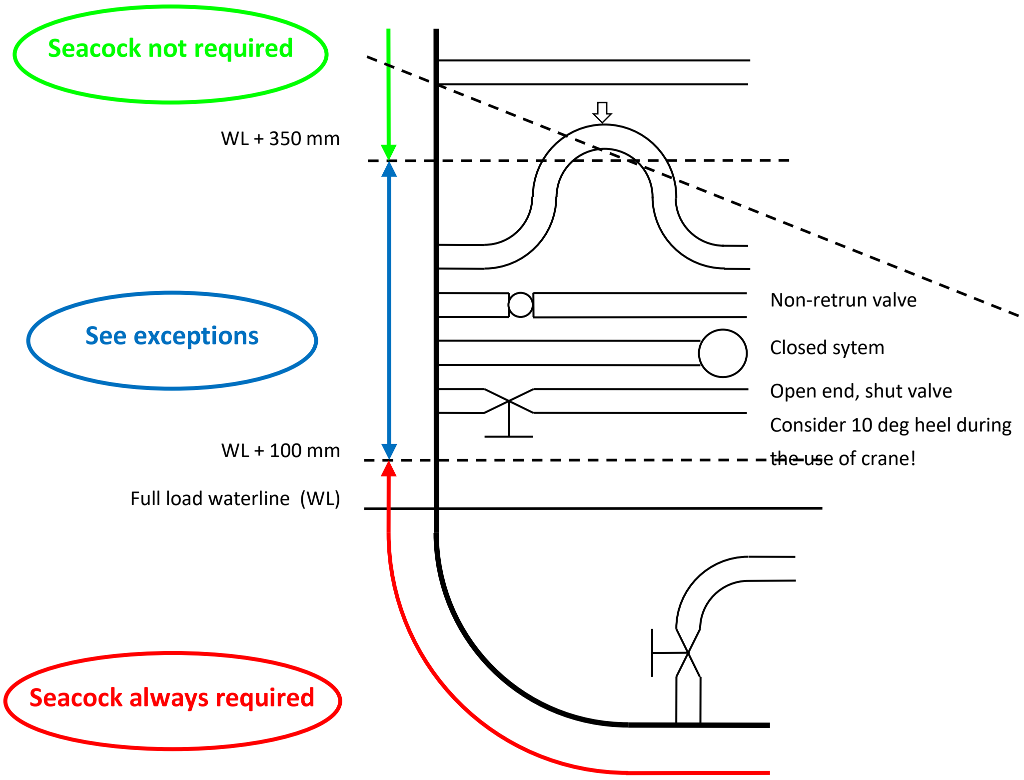

Figure 3.5 Requirements for through-hull fittings connected to on-board systems

3.14.2 Through-hull fittings and seacocks

The through-hull fittings and seacocks shall meet the requirements for such components in the standards ISO 9093 or equal.

For FRP hulls the through-hull fittings of bronze, brass (minimum 80% copper) or stainless steel (AISI 316). These are allowed in all applications. Through-hull fittings of non-metallic materials meeting the standard ISO 9093-2, are allowed outside the engine spaces in craft of less than 15 m length.

For aluminium or steel hulls through-hulls or seacocks of copper alloys are not permitted.

3.14.3 Accessibility

All seacocks shall be easily accessible. The accessibility requirements are given in Chapter 31.

3.14.4 Requirements for on-board systems connected to through-hulls

The hoses connected to through-hull fittings shall be fabric-reinforced and able to stand the pressures occurring in the connected systems. For discharging system hoses there are additional requirements in Chapter 6.

3.14.5 Galvanic corrosion

The combination of materials to be chosen so that galvanic corrosion is avoided.

3.14.6 Hose connections

For the hoses connections in through-hull systems double hose clamps of stainless steel (AISI 316) to be used if the stud diameter exceeds 25 mm. As an alternative to double clamps a single stainless steel super-clamp with two bolts, and over 15 mm width may be used.

3.15 Penetrations in outboard engine wells

3.15.1 Cable and hose penetrations

Closing appliances in outboard engine splash wells shall meet the requirements for watertightness degree 1, if they are located lower than:

- 0.2 m from the deepest waterline

lower than the lowest edge of the engine wellAbove this level the openings and closing appliances shall as minimum have degree 2 of watertightness.

3.15.2 Ventilation openings

Ventilation openings located in the outboard engine well and leading into the hull shall have their lower edge at a height specified in Chapter 4 for freeboard to a downflooding opening.

Table 3.1: Summary of requirements for openings and closing appliances located on the weatherdeck (hatches, doors, and always open ventilation or other openings).

Opening's Closing Status	Always open				Occasionally open at sea				Closed at sea			
Design Category	A	B	C	D	A	B	C	D	A	B	C	D
Freeboard and downflooding angle requirements in Chapter 4	YES								NO			
Location L_H/3 from bow	NO	NO										
Application area 1 (topside)	NO	NO										
Coaming height at level h_{S1},[m], L_H=24 m 1) 2)	0.90	0.68	0.38	0.10	0.60	0.45	0.25	0.10				

Opening's Closing Status	Always open				Occasionally open at sea				Closed at sea			
Coaming height at level h_{S1}, [m], $L_H \leq 15$ m [1] [2]	0.68	0.45	0.38	0.10	0.45	0.38	0.25	0.10				
Coaming height at level h_{S2}, [m],[3]	0.57	0.45	0.38	0.10	0.25	0.15	0.075	0.05				
Min. downflooding angle when appliance is open, degrees.	See Chapter 4 Table 4.1				25	20	15	10				
Max.allowed appliance size [m^2] without coamings					0.4	0.4						
Tightness degree	2	2	2	2	2	2	2	2	2	2	2	2
Prevention of water ingress	x	x	x	x								
Locking device distance C-C, max					800 mm for doors, 600 mm for hatches							
Gaskets protected (see Figure 3.3)					x	x	x	x	x	x	x	x
CE-marked appliances allowed without further requirements					Yes, except for cargo decks. Not for craft with Add.Notation "Winter navigation"							

1) The specified coaming height refers for deck height h1, if the local deck height is greater this reduces the requirement, see clause 3.9.1

2) The height values between 15 and 24 m are found by linear interpolation

3) Hatches without coamings may be allowed on the weather deck provided the following conditions are met:

- The hatch is at least at the height d + h_1 (see paragraph 3.9 in the text)
- The hatch area is maximum 0.4 m^2 in Design Category B
- In Design Category A temporarily open hatches without coamings are not allowed
- Neither does this exception apply to doors leading into the craft interior, they must always have coaming heights according to Table 3.1.

Table 3.2: Summary of requirements for closing appliances in Application area 1 (hull topside)

Appliance status when craft is underway	Closed			
Design Category	A	B	C	D
Material limitations	If glass is used, must be ”high impact resistance” quality according to ISO 12216			
Closing appliance recessed or protected in some other way	x	x	x	x
Largest minimum dimension, [mm]	300	300	300	300
Lower edge above waterline, min. [mm]	500	400	300	200
Lowest downflooding angle when appliance is open, [degrees]	25	20	15	10
Tightness degree	2	2	2	2
Gaskets protected (see Figure 3.3)	x	x	x	x
Storm shutters required	x	x	x	
CE-marked closing appliances allowed without further requirements	See ”Material limitations” higher up in this table!			

Table 3.3 Required thicknesses for tempered glass windows, P=70 kPa, in Application area 1 (hull topside), all Design categories

		Shorter side, mm				
		100	150	200	250	300
Longer side, mm	300	4	4	5	6	6
	400	4	5	6	7	7
	500	5	6	6	7	8
	600	6	6	7	7	8
	700	6	7	8	8	9
	800	7	7	8	9	9
	900	7	8	9	9	10
	1000	8	9	9	10	11

Minimum thickness	
L_H	t_{MIN}
6	6
9	7
12	7
15	7
18	7
21	8
24	8

Table 3.4: Required thicknesses for tempered glass windows, P=28 kPa, in Application area 3 (front bulkhead and other forward facing areas), Design Categories A and B

		Shorter side, mm														
		300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
Longer side, mm	300	6														
	350	6	6													
	400	6	6	6												
	450	6	6	6	6											
	500	6	6	6	6	6										
	550	6	6	6	6	7	7									
	600	6	6	6	7	7	7	7								
	650	6	6	6	7	7	7	8	8							
	700	6	6	7	7	8	8	8	8	8						
	750	6	7	7	7	8	8	8	9	9	9					
	800	6	7	7	7	8	8	9	9	9	9	9				
	850	7	7	7	8	8	8	9	9	9	9	10	10			
	900	7	7	8	8	8	9	9	9	10	10	10	10	10		
	950	7	8	8	8	8	9	9	10	10	10	10	10	10	10	
	1000	7	8	8	8	9	9	9	10	10	10	11	11	11	11	11
	1050	8	8	8	9	9	9	10	10	10	11	11	11	11	11	11
	1100	8	8	8	9	9	9	10	10	10	11	11	11	11	12	12
	1150	8	8	9	9	9	10	10	10	11	11	11	12	12	12	12
	1200	8	8	9	9	9	10	10	10	11	11	11	12	12	12	12
	1250	8	9	9	9	10	10	10	10	11	11	12	12	12	12	13
	1300	8	9	9	10	10	10	10	11	11	11	12	12	12	13	13
	1350	9	9	9	10	10	10	11	11	11	12	12	12	13	13	13
	1400	9	9	10	10	10	10	11	11	11	12	12	12	13	13	13
	1450	9	9	10	10	10	11	11	11	11	12	12	13	13	13	13
	1500	9	9	10	10	11	11	11	11	12	12	12	13	13	13	14

Table 3.5: Required thickness for tempered glass windows P=12 kPa

Application area 2 (weather deck) Design Categories A and B

Application area 4 (above second deck level) Design Categories A and B

Application area 3 (front bulkhead and other forward facing areas) Design Categories C and D

Longer side, mm	Shorter side, mm														
	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
300	5														
350	5	5													
400	5	5	5												
450	5	5	5	5											
500	5	5	5	5	5										
550	5	5	5	5	5	5									
600	5	5	5	5	5	5	5								
650	5	5	5	5	5	5	5	5							
700	5	5	5	5	5	5	5	5	5						
750	5	5	5	5	5	5	5	6	6	6					
800	5	5	5	5	5	5	6	6	6	6	6				
850	5	5	5	5	6	6	6	6	6	6	6	6			
900	5	5	5	6	6	6	6	6	6	6	7	7	7		
950	5	5	6	6	6	6	6	6	6	7	7	7	7	7	
1000	5	6	6	6	6	6	6	7	7	7	7	7	7	7	7
1050	5	6	6	6	6	6	7	7	7	7	7	7	7	7	7
1100	6	6	6	6	6	7	7	7	7	7	7	7	7	8	8
1150	6	6	6	6	7	7	7	7	7	7	7	8	8	8	8
1200	6	6	6	7	7	7	7	7	7	8	8	8	8	8	8
1250	6	6	7	7	7	7	7	7	8	8	8	8	8	8	8
1300	6	6	7	7	7	7	7	8	8	8	8	8	8	8	8
1350	6	6	7	7	7	7	8	8	8	8	8	8	8	8	9
1400	6	7	7	7	7	8	8	8	8	8	8	8	8	9	9
1450	6	7	7	7	7	8	8	8	8	8	8	9	9	9	9
1500	7	7	7	7	8	8	8	8	8	8	9	9	9	9	9

Table 3.6: Required thickness for tempered glass windows P=9 kPa
Application area 2 and 4, Design Categories C and D

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		Shorter side, mm														
		300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
Longer side, mm	300	5														
	350	5	5													
	400	5	5	5												
	450	5	5	5	5											
	500	5	5	5	5	5										
	550	5	5	5	5	5	5									
	600	5	5	5	5	5	5	5								
	650	5	5	5	5	5	5	5	5							
	700	5	5	5	5	5	5	5	5	5						
	750	5	5	5	5	5	5	5	5	5	5					
	800	5	5	5	5	5	5	5	5	5	5	5				
	850	5	5	5	5	5	5	5	5	5	5	5	5			
	900	5	5	5	5	5	5	5	5	5	6	6	6	6		
	950	5	5	5	5	5	5	6	6	6	6	6	6	6	6	
	1000	5	5	5	5	5	6	6	6	6	6	6	6	6	6	6
	1050	5	5	5	5	6	6	6	6	6	6	6	6	6	6	6
	1100	5	5	5	6	6	6	6	6	6	6	6	6	6	7	7
	1150	5	5	6	6	6	6	6	6	6	7	7	7	7	7	7
	1200	5	5	6	6	6	6	6	6	7	7	7	7	7	7	7
	1250	5	6	6	6	6	6	6	7	7	7	7	7	7	7	7
	1300	6	6	6	6	6	6	7	7	7	7	7	7	7	7	7
	1350	6	6	6	6	6	7	7	7	7	7	7	7	7	7	8
	1400	6	6	6	6	7	7	7	7	7	7	7	7	8	8	8
	1450	6	6	6	6	7	7	7	7	7	7	8	8	8	8	8
	1500	6	6	6	7	7	7	7	7	7	8	8	8	8	8	8

4 FREEBOARD AND INTACT STABILITY

4.1 Objective

The objective in this chapter is to ensure that:

- The craft has sufficient reserve buoyancy in reference to the craft concept, the Design Category, and to the fully loaded displacement in order to stand a limited leak or overload without sinking or capsizing;
- The deck arrangement for craft encountering breaking seas is planned so water swiftly drains back to the sea, and for all craft the openings leading into the craft interior are located and protected so water ingress is prevented; and
- The craft stability is such that the heeling angles caused by the expected heeling moments do not prevent the safe use of the craft, and the reserve against capsize or filling with water is sufficiently large in the Design Category worst conditions, also considering the possible special missions for the craft.

Note! In Chapters 33-41 additional requirements are given for craft special missions.

4.2 References

In this chapter reference is made to the following documents:

- ISO 12217-1 Small craft – Stabillity and buoyancy assessment and categorization
- ISO 11812 Small craft – Watertight cockpits and quick-draining cockpits
- ISO 12216 Small craft - Windows, portlights, hatches, deadlights and doors – Strength and watertightness
- ISO 6185-3 Inflatable boats Part 3
- ISO 6185-41 Inflatable boats Part 4
- ISO 15372 Ships and marine technology – Inflatable rescue boats – Coated fabrics for inflatable chambers
- IMO MSC 81(70)

4.3 Documentation

For verifying that the requirements presented in this chapter are met, the following documentation is required:

- Geometry of hull (normally a Lines drawing);
- Geometry of weather tight decks and superstructures (fully and partially decked craft);
- Geometry and location of tanks;
- Load components included in the fully loaded condition, and their location;
- Material certificates and test reports for buoyancy foam and pontoon materials;
- Test protocols for pontoons and other air buoyancy chambers;

- Verification of lightweight and center of gravity (usually inclining test report);
- Stability calculations, or stability test report where the attained numbers are presented in reference to the relevant criteria;
- Stability instruction for the master, where information is given about the maximum allowed load, and possible limitations in this connection;

4.4 Assessment alternatives and requirements

4.4.1 General

The craft is to be assessed using one of the options given in Tables 4.1, 4.2, and 4.3, depending on the craft Design Category, and Craft Concept (see Ch. 2). The principles in the options correspond to those presented in standard ISO 12217. Note that all options in ISO 12217 are not implemented. The requirements in Tables 4.1, 4.2, and 4.3 shall be met in all relevant loading conditions. More detailed explanations can be found in the text sections referred to in the tables.

Table 4.1 The requirements for the alternative Fully enclosed craft

Assessment option Nr.		1A	1B	2C	2D
Craft concept		Fully enclosed			
Design Category		A 1)	B	C	D
Recesses (see. 4.8) *LC3* 1)	Type of recess	Quick draining			
	Consider Free surface effects on stability	x	x	x	
Bow buoyancy (see 4.10) *LC1, LC2, LC3* 2) 4)	Freeboard at bow, F_{BOW} [m]	$0.5+0.02 \cdot L_H$	$0.3+0.02 \cdot L_H$	$0.2+0.02 \cdot L_H$	$0.05+0.02 \cdot L_H$
Height of down-flooding opening (see 4.11) *LC2* 2)	h_D [m]	$L_H/17$	$L_H/17$	$L_H/17$	$L_H/20$
	Minimum [m]	0.50	0.40	0.35	0.30
	Maximum [m]	1.41	1.41	0.75	0.40
Downflooding angle [°] (see 4.12) *LC1, LC2, LC3* 2)	Openings always open at sea $\emptyset_O$ = heeling angle with offset load	$\emptyset_O$+25 min. 30°	$\emptyset_O$+15 min. 25°		
	Openings temporarily open at sea. See also Table 3.1!	25	20	15	10
Stability with offset load (see 4.12) *OFFSET* 2)	Maximum heeling angle[°]	$\emptyset_{O(R)} = 11{,}5 + \frac{(24 - L_H)^3}{520}$			
	Residuary freeboard [m]			$0.014 \cdot L_H$, Min. 0.1	0.01
Maximum righting moment (see 4.13) *LC1, LC2, LC3* 2)	RM_{max} [kNm] $\emptyset_{GZmax} \geq 30°$	25	7		
	RM_{max} [kNm] $\emptyset_{GZmax} < 30°$	$750/\emptyset_{GZmax}$	$210/\emptyset_{GZmax}$		
GZ-curve properties (see 4.14)	GZ_{30} [m], $\emptyset_{GZmax} \geq 30°$	≥0.20		≥0.20	
	GZ_{MAX} [m], $\emptyset_{GZmax} < 30°$	$\geq 6/\emptyset_{GZmax}$		$\geq 6/\emptyset_{GZmax}$	

LC1, LC2, LC3 [2)]	Stability range $\emptyset_v$ [4)]	≥ 90°	≥ 60°		
Rolling in wind and waves from the side *LC1, LC2, LC3* [2)] (see 4.15)	Nominal wind speed v_w [m/s]	28	21		
	Area $A_2 \geq A_1$, when $\emptyset_R$ =	25+20/∇	20+20/∇		
Wind induced heel (see 4.16) *LC1, LC2, LC3* [2)]	If $A_{LV} > 0.5 \cdot L_H \cdot B_H$ and *vw [m/s]*			17	13
	Wind induced heel $\emptyset_w$ $\emptyset_D$=downflooding angle [°]			$<0.7 \cdot \emptyset_{O(R)}$ $<0.7 \cdot \emptyset_D$	
Habitable multihulls (see 4.18) *LC1* [2)]	If "susceptible to capsizing": - To stay afloat inverted - Emergency exit inverted			YES	

[1)] Only for hull length 6 m or over

[2)] Loading conditions in which the criteria shall be evaluated

[3)] Not applied to craft meeting the requirements in Chapter 38 (one compartment subdivision)

[4)] Need not be fulfilled in stability calculations with ice accretion (Additional notation "Winter navigation".

Table 4.2: Requirements and test procedures according to the assessment alternative for rigid bottom inflatables (RIB) and other craft with buoyancy chambers.

Assessment alternative Nr.		3B	3C	3D
Craft concept		Rigid bottom inflatable (RIB) or other craft with buoyancy chambers		
Design Category		B 1)	C	D
Recesses (see 4.8) *LC3* 2)	Recess type	Watertight or quick draining		
Downflooding opening height (see 4.11) *LC1, LC2* 2)	*h_D [m]*	$L_H/17$	$L_H/17$	$L_H/20$
	Minimum [m]	0.40	0.35	0.30
	Maximum [m]	1.41	0.75	0.40
Downflooding angle[°] (see 4.12) *LC1, LC2 LC3* 2)	ϕ_O=heeling angle with offset load	ϕ_O+15 at least 25°		
Stability with offset load (see 4.12) OFFSET 2)	Maximum heel [°]	$\phi_{O(R)} = 11,5 + \frac{(24 - L_H)^3}{520}$		
	Residuary freeboard [m]		$0.014 \cdot L_H$, Min. 0.1	0.01
Maximum righting moment (see 4.13) *LC1, LC2, LC3* 2)	*RM_{max}* [kNm] $\phi_{GZmax} \geq 30°$	7		
	RM_{max} [kNm] $\phi_{GZmax} < 30°$	$210/\phi_{GZmax}$		
GZ-curve properties (see 4.14) *LC1, LC2, LC3* 2)	*GZ_{30} [m]* $\phi_{GZmax} \geq 30°$	≥0.20	≥0.20	≥0.20
	GZ_{MAX} [m] $\phi_{GZmax} < 30°$	$\geq 6/\phi_{GZmax}$	$\geq 6/\phi_{GZmax}$	$\geq 6/\phi_{GZmax}$
	Stability range ϕ_v	≥ 60°		

Weather criterion (see 4.15) *LC1, LC2, LC3* [2)]	Nominal wind speed v_w [m/s]	21		
	Area $A_2 \geq A_1$, kun $\varnothing_R = 20+20/\nabla$			
Wind induced heel (see 4.16) *LC1, LC2, LC3* [2)]	If $A_{LV} > 0.5 \cdot L_H \cdot B_H$ and v_w *[m/s]*		17	13
	Wind induced heel $\varnothing_w$ $\varnothing_D$=downflooding angle [°]		$<0.7 \cdot \varnothing_{O(R)}$ $<0.7 \cdot \varnothing_D$	
Flotation (see 4.17) *LC2* [2)]	Flotation and stability when waterfilled	Shall float fully loaded so that the trim is max. 10°, and min. 2/3 of the upper surface of the pontoon or the edge of the boat is above water. To stand a load of 6·CL on the side rail.		
Flotation elements (see 4.17)	Arrangement	The floatation elements' combined volume (=pontoons+air chambers+foam floatation+solid structure) minimum 1,33 * m_{LDC} [l]		
		[5)] For RIB:s the pontoon volume shall be at least 0.665*m_{LDC} [l]. The pontoon volume to be divided into at least 5 parts. Each part to be ±20 % of the average		
		If no RIB, no requirements for pontoon volume.		
		The number of air chambers depend on their share of the necessary total float volume and the Design Category according to clause 4.17.3		
	Material	The pontoon material shall meet ISO 15372 Foam floatation according to ISO 6185		
	Testing	Air chamber test pressure 5 kPa		
		Pressure and leak testing of pontoons according to ISO 6185		

2) Loading conditions in which the criteria shall be evaluated

5) The craft shall follow RIB-standard ISO 6185 if the pontoon volume exceeds the half of the required volume of the buoyancy chambers

Table 4.3: Requirements for partially protected and open craft

Assessment alternative Nr.		5C	5D	6C	6D
Craft concept		Partially protected		Open	
Design Category		C	D	C	D
Recesses (see 4.8) *LC3* 2)	Recess type	Non-quick draining recesses allowed only if - $V<L_H \cdot B_H \cdot F_M/40$ - the recess is entirely aft of $L_H/3$ - the recess drains to bilge, see 4.8			
Bow buoyancy (see. 4.10) *LC1, LC2, LC3* 2)	Freeboard at bow			$1.15 \cdot L_H/10$ min 0.69 m	min 0.46 m
Height of down-flooding opening (see 4.11) *LC1, LC2* 2)	h_D *[m]*	$L_H/12$	-	$L_H/10$	-
	Minimum [m]	0.50	0.40	0.60	0.40
	Maximum [m]	0.75	-	0.75	-
Stability with offset load (see 4.12) *OFFSET* 2)	Maximum heel [°]	$\emptyset_{O(R)} = 11{,}5 + \frac{(24 - L_H)^3}{520}$			
	Residuary freeboard [m]	$0.11 \cdot \sqrt{L_H}$	$0{,}07 \cdot \sqrt{L_H}$	$0.11 \cdot \sqrt{L_H}$	$0{,}07 \cdot \sqrt{L_H}$
GZ-curve properties (see 4.14) *LC1, LC2, LC3* 2)	GZ_{30} [m] $\emptyset_{GZmax} \geq 30°$	≥0.20			
	GZ_{MAX} [m] $\emptyset_{GZmax} < 30°$	$\geq 6/\emptyset_{GZmax}$			
Wind induced heel (see 4.16)	If $A_{LV} > 0.5 \cdot L_H \cdot B_H$ and v_w [m/s] =	17	13	17	13

LC1, LC2, LC3 [2)]	Wind induced heel $Ø_w$ $Ø_D$=downflooding angle[°]	<0.7·$Ø_{O(R)}$ <0.7·$Ø_D$

[2)] Loading conditions in which the criteria shall be evaluated

4.5 Definitions and assumptions

4.5.1 Lightweight

The lightweight m_{LC} is the weight of the craft including propulsion engine, permanent systems and equipment without crew, stores and cargo as defined in standard ISO 12217-1.

4.5.2 Determination of lightweight and center of gravity

4.5.2.1 Lightweight

The craft lightweight to be determined by one of the following methods:

1) Measurement of flotation position in a known loading condition, determination of the displacement corresponding to the flotation using the craft geometry information, and correcting the result to correspond to the lightweight according to ISO 12217;
2) Weighing the craft in a known loading condition, and correcting the result by calculation to correspond to the lightweight according to ISO 12217-1;
3) By calculation based on a sister ship lightweight and known changes. With this method the allowed lightweight change is maximum 10% compared to the sister ship.

4.5.2.2 Vertical position of center of gravity

The vertical center of gravity, VCG, to be determined by one of the following methods depending on the circumstances:

1) Inclining test performed according to ASTM F-1321-90 or corresponding standard;
2) Determining VCG by calculation based on the mass and VCG for individual components, and raising the resulting position above the keel by 5% of the craft side height;
3) Determining VCG by calculation based on a sister ship mass and known changes. With this method the allowed VCG change is maximum 10% compared to the sister ship.

An inclining test must not be used for craft having a transverse metacentric height GM exceeding 5 m in light condition. Methods relying entirely on weight calculation or sister ship information must not be used for craft having a GM less than 1.5 m in light condition.

4.5.2.3 Longitudinal position of center of gravity

The longitudinal position of center of gravity, LCG, to be determined by one of the following methods:

1) Measurement of flotation position in a known loading condition, determination of the displacement corresponding to the flotation using the craft geometry information, and correcting the result to correspond to the lightweight according to ISO 12217-1;
2) Determining LCG by calculation based on the mass and LCG for individual components;
3) Determining LCG by calculation based on a sister ship mass and known changes.

4.5.3 Change of lightweight that requires renewal of stability evaluation

If the lightweight of a sister ship changes more than ±5% compared to the mothership, the need to update the stability calculations shall be assessed.

4.5.4 Maximum load

The maximum load, ML, is the amount of load the craft is designed to carry. ML includes the following weights:

- The maximum number of persons (CL) times 85 kg;
- Their personal equipment (CL interiors) times 25 kg
- Stores and supply;
- Cargo;
- Consumable liquids like fuel and water;
- Grey and black water
- Water ballast if carried
- Rafts or dinghies if carried
- Other weights not included in lightweight

NOTE! In the Additional Notation “Winter navigation”, icing on hull and superstructures is not included in the maximum load, but rule requirements must be met with icing considered, if not stated otherwise.

In the loading conditions the space required by people, and their center of gravity shall be taken according to Chapter 1 paragraph 12.

4.6 Loading conditions

4.6.1 Loading conditions to be assessed

The craft stability to be assessed in the following loading conditions:

- Minimum operating condition, short notation “LC1”
- Fully loaded, departure, “LC2”
- Fully loaded, arrival, “LC3”
- Offset load condition, “OFFSET”

Some requirements are independent of the loading condition, some are again tied to a certain loading condition. In the Tables 4.1-4.3 information is given under each requirement pointing out the load conditions that refer.

If it can be expected that the stability may be critical for the craft in other relevant loading conditions the stability needs to be assessed also for them. If applicable, icing weights need to be considered according to 4.7.4.

4.6.2 Minimum operating condition, loading condition LC1

In the minimum operating condition the following is included on top of the lightweight:

- the mass of the crew located at the highest steering position;
    - 85 kg, if $L_H \leq 8$ m;
    - 170 kg, if $L_H = 8...16$ m; and
    - 255 kg, if $L_H = 16...24$ m.
- stores and equipment normally kept on board; and
- fuel 10% of the maximum capacity.

4.6.3 Fully loaded, departure, loading condition LC2

In the ”Fully loaded, departure”-condition the maximum load ML is on board, according to clause 4.5.4. The load components are assumed to be in their intended places, see 4.7.2. If there is cargo, it has to be located according to Chapter 33.

4.6.4 Fully loaded, arrival, loading condition LC3

The condition ”Fully loaded, arrival” is similar to the departure condition 4.6.3, except for the amount of consumable stores which is carried 10 % of the capacity. Possible waste water tanks may be full.

4.6.5 Offset load, loading condition OFFSET

The condition ”OFFSET” is similar to the arrival condition 4.6.4, except for that

- All tanks holding liquid supplies shall be 50% full
- Persons and deck cargo, if any, are located towards the side (see paragraph 4.12).

4.7 Assumptions when assessing stability

4.7.1 Hull model for stability calculation

In the hull model used for the stability calculations the recesses, superstructures, and underwater appendages influencing the hydrostatics shall be included. Only items sufficiently watertight (see Chapter 3) and strong (see Chapters 10, 14, and 18, depending on the material used) may be considered.

The floating position and righting levers shall normally be calculated so the water surface in recesses is at the same level as the surrounding water at all heeling angles. In Design Category C and D the righting levers may be calculated assuming the drain openings mentioned below to be closed tight:

- Drain openings with non-return flaps or similar devices
- Drain openings whose combined area do not exceed three times the smallest drain area required by ISO 11812.

The assumption above may be used only for heeling angles smaller than the recess edge immersion angle.

4.7.2 Location of loading components

Liquids are assumed to be contained in their tanks.

The location of persons shall correspond to the normal use of the craft. The mass and centre of gravity for persons are assumed to be taken from Chapter 1 paragraph 12, unless the special mission of the craft gives reason to use different numbers.

For the location of cargo the guidelines in Chapter 33 shall be used.

4.7.3 Free surfaces in the tanks

The free surface effects in the tanks shall be considered if their combined reduction of GM exceeds 2 % with the tanks 10 % full, and always if the maximum breadth of the tank exceeds $0.35 \cdot B_H$.

4.7.4 Icing

When the ice that can form on hull and superstructure is considered, and always for craft having the Additional Notation ”Winter navigation” according to Chapter 39, the weight and distribution of the ice shall be as follows:

- 30 kg/m^2 on open decks, and on structures located on these decks;
- 7.5 kg/ m^2 on both sides of the craft projected side profile area above the water line;
- Icing of other, not already mentioned surfaces is considered by increasing the projected side profile area 5 % on both sides.

4.8 The effect of recesses on stability

4.8.1 Open crafts

Recesses that do not fulfil the requirements for quick-draining recesses in standard ISO 11812, are only accepted in assessment alternatives 5 and 6 with following conditions:

- The volume of the recess does not exceed $L_H \cdot B_H \cdot F_M/40$ m^3, where F_M is the average freeboard height at the recess (m).
- The recess is located entirely aft of $L_H/3$, calculated from the bow

- The recess drains to bilge in a time that does not exceed the time for similar quick draining recess, when applying the standard ISO 11812.

4.8.2 Fully enclosed crafts

The effects of recesses on stability are assessed for fully enclosed craft as following. The loading condition to assess is LC3, fully loaded at arrival, see clause 4.6.4.

For Design Category A and B craft the effect of recesses on stability shall always be assessed. Design Category C craft are assessed only if the craft does not fit any of the following alternatives:

- The combined volume of all recesses not exceed $L_H \cdot B_H \cdot F_M/40$ m^3, where F_M is the average freeboard height at the recess (m)
- The lowest freeboard to the recess coaming is less than $L_H/10$ or 0.75 m, whichever is smaller. In the aft part of the craft, max. $L_H/4$ from stern, a reduced freeboard height calculated according to ISO 12217-1 annex A, is aalowed;
- The stability range of the craft in loading condition LC3 is at least 90°;
- The recess coaming height is maximum 3 % of its maximum width on at least 35 % of its circumference;
- The recess coaming height is maximum 12.5 % of its maximum width, and the drain openings located in the coaming bottom quarter have an area of at least 5 % of the coaming area.
- The drain opening areas per side are at least k·V, where V is recess volume in m^3, and k is:
  - 0.09, if the drain openings are in the bottom quarter of the coaming
  - 0.16, if the drain openings are below the half height
  - 0.30, if the drain openings are located over the entire height of the coaming.

If none of the alternatives fits, the effect on the stability shall be assessed according to ISO 12217-1 item 6.5.3 using the alternative of direct calculation.

The edge over which water drains from or enters into the recess is assumed to be on a height where the effective cross section is $0,005 \cdot L_H \cdot B_H$ [m^2].

4.9 Reserve buoyancy

4.9.1 General

The craft shall have a sufficient weather tight volume above the waterline (reserve buoyancy) in order to carry a certain amount of overload in addition to the full load displacement.

For fully enclosed and open crafts this is regarded as sufficient, if the craft fulfils the requirements of the Assessment alternative in question (see Tables 4.1 and 4.3), regarding stability and downflooding opening heights and angles.

For rigid-bottom inflatables (RIB) the reserve buoyancy is determined according to standard ISO 6185.

4.10 The buoyancy of the bow

The bow needs to have sufficient buoyancy. This is normally achieved with a raised deck or forecastle, the height of which is to be at least F_{BOW} at a point forward of the fore perpendicular. From this point the forecastle can drop to the height F_{min} on a distance $L_H/4$ aft of the bow. For Design Category A and B craft the forecastle needs to be weather tight up to the top. For Design Category C and D the freeboard at the bow can alternatively be taken to the upper edge of a weathertight bulwark.

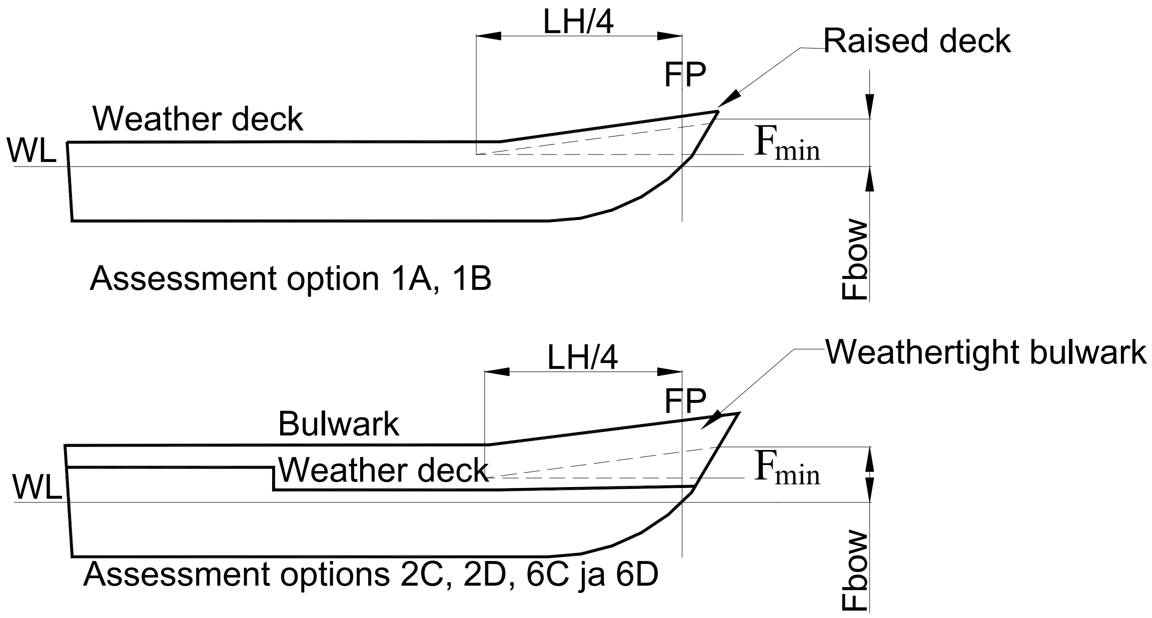

Figure 4.1: Bow height requirement F_{BOW}

4.11 Downflooding height (all craft)

The downflooding height of an opening, h_D, is the lowest height from the waterline in fully loaded condition to any downflooding opening which cannot be closed weather tight, including the edge of recesses.

The required freeboard to a downflooding opening, h_D, is given in Tables 4.1-4.4. Additional requirements for opening features are given in Chapter 3.

Optionally, the required downflooding height may be determined using the more detailed method in ISO 12217-1 appendix A, taking into account other restrictions in chapter 3 and this chapter. In determining the required recess coaming height for paragraph 4.8 recess restrictions, the reduced freeboard height requirement in Appendix A of the standard in question, can only be used in the aft part of the craft, not more than $L_H/4$ from stern.

4.12 Heeling angle and residuary freeboard with offset load

The heeling angle, and residuary freeboard or downflooding angle shall be determined for all craft, and the results must meet the requirements in Tables 4.1-4.3. These can be determined by testing or calculations.

4.12.1 Definitions

The heeling angle with offset load, $Ø_O$, is the heeling angle resulting from the transfer of people and/or cargo on board to one side.

The residuary freeboard with offset load is the freeboard to the lowest downflooding opening at the heeling angle in question.

The downflooding angle is the heeling angle when water begins to flood into the weather tight parts of the craft. A more accurate definition can be found in the standard ISO 12217-1.

4.12.2 The loading condition when measuring heeling angle, and residuary freeboard or downflooding angle

The starting point for offset load condition is LC2, full load condition, however the tanks are filled to 50%, see 4.6.5.

4.12.3 Location of the test weights in offset load test or offset load calculation

Persons or corresponding weights (85 kg each) and possible deck cargo are located on the working deck (for definition see clause 26.4.1) as follows:

- the centre of gravity of the persons closest to the working deck limit is 0.20 m from the limit;
- the centre of gravity of the persons are spaced 0.50 m from each other;
- if the craft has decks narrower than 0.4 m, the weight is put in the center of that part of the deck;
- the center of gravity of a person is assumed to be 0.10 m above the deck or seat; and
- the persons are placed 85 kg at a time so that the largest heel angle after each adding of weight is achieved, considering general arrangement features like upper decks. Weights are added until the largest person number á 85 kg is achieved
- The procedure above is repeated so that for each adding of a weight the smallest residuary freeboard is achieved, instead of the largest heel angle;
- In locating the person weights, it shall be noted that the smallest freeboard may occur when the person weights are located at stern or bow;

if deck cargo is included in the craft full load, the additional heel caused by its shift to one side shall also be considered according to Chapter 33 clause 4.5.

A more detailed description of testing offset loads can be found in the standard ISO 12217-1.

For the evaluation of the result, the number of persons reached is considered to be the total mass of the test weights / 85 kg if the test is limited by the immersion of a visible downflooding opening.

If the test is limited by the maximum allowed heeling angle or by the immersion of a hidden opening, or the loss of stability, the number of persons achieved is the total mass of the test weights / 98 kg rounded down to the next even number.

4.13 Maximum righting moment

In order to prevent too small craft from obtaining Design Category A and B, a requirement is given for the maximum righting moment. The required value, given in Table 4.1, depends on the Design Category, and the heeling angle at which the maximum GZ occurs.

4.14 The GZ-curve properties

If the heeling angle at which the maximum GZ value, $\varnothing_{GZmax}$ occurs, is 30° or larger, the required GZ-value at 3° heel shall be at least 0.2 m.

If the heeling angle at the maximum GZ occurs, $\varnothing_{GZmax}$, is less than 30°, the requirement refers to the largest GZ value, GZ_{MAX}.

Irrespective of the heeling angle at which the maximum GZ occurs, the craft shall meet the requirement for stability range (design categories A nad B only).

4.15 Rolling with wind and waves on the beam (weather criterion)

The purpose of the assessment is to ensure that the craft righting energy is at least equal to the heeling energy caused by the waves on the beam, when simultaneously a steady side wind is blowing.

The waves are assumed to cause rolling with the amplitude:

$\varnothing_R = 25+20/V_D$ Design Category A (4.1)

$\varnothing_R = 20+20/V_D$ Design Category B (4.2)

Where V_D is the displacement volume in cubic meters.

The righting moment curve is limited by the smallest of the angles:

- Downflooding angle
- Capsizing angle
- 50°

The wind heeling moment, M_W [Nm], is assumed to be constant at all heeling angles, and has to be determined with either of these formulas (the smaller value may be used):

$M_{W1} = 0.53 \cdot A_{LV} \cdot h \cdot v_w^2$ [Nm] (4.3)

$M_{W2} = 0.30 \cdot A_{LV} (A_{LV}/L_{WL}+T_M) \cdot v_w^2$ (4.4)

Where

T_M [m] is the mean draught

v_w = wind speed = 28 m/s for Design Category A and 21 m/s for Design Category B

A_{LV} [m2] is the lateral wind area, minimum $0.5 \cdot L_H \cdot B_H$

h = vertical distance between centers of windage area and underwater lateral area, [m]

The righting and heeling moments (or the corresponding moment arms) are plotted as a function of the heeling angle in the same graph as shown in Figure 4.2. The craft meets the stability criterion provided area A2 is equal or larger than area A1.

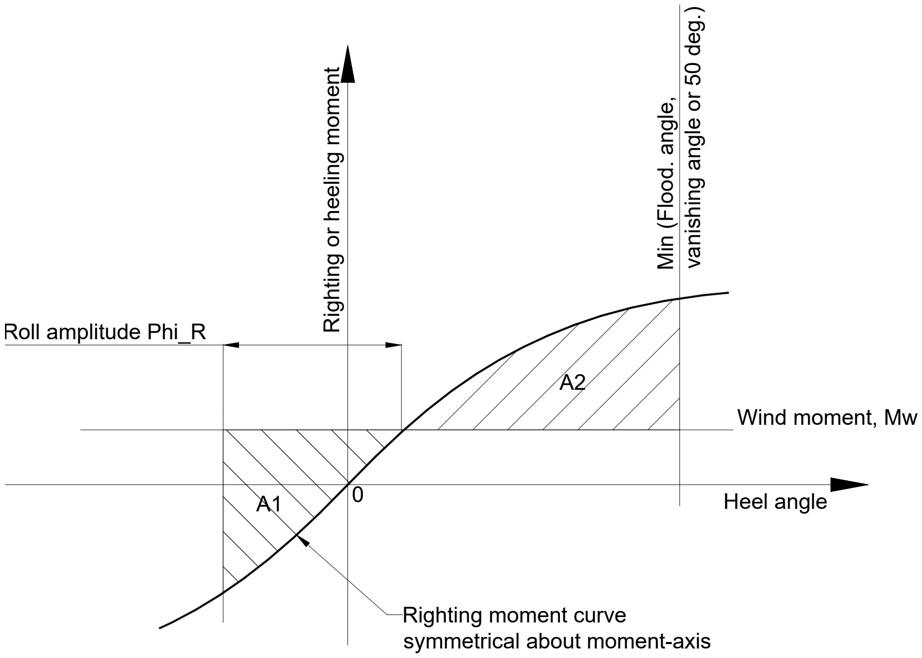

Figure 4.2: Rolling with wind and waves on the beam

4.16 Wind induced heel

This criterion ensures that righting moment of the craft is sufficient in strong beam wind. If the projected lateral windage area $A_{LV} < 0.5 \cdot L_H \cdot B_H$ in the loading condition LC3, it is not necessary to perform this check. Otherwise the procedure is:

Determine the wind induced heeling moment M_W according to 4.15, but use the wind speed v_w = 17 m/s for Design Category C and 13 m/s for design Category D.

The wind induced heeling angle $\varnothing_W$ is determined by comparing the heeling moment curve with the righting moment curve worked out for loading condition LC3.

The heeling angle $\varnothing_W$ must be less than 70% of the allowed heeling angle with offset load, and less than 70% of the downflooding angle as well.

4.17 Buoyancy when swamped

4.17.1 General

Remaining afloat when swamped means that a loaded and waterfilled craft remains afloat due to the buoyancy provided for this purpose, and stays approximately horizontal with a certain minimum stability. The requirements depend both on the used assessment option and on the type of flotation elements.

4.17.2 Types of flotation elements and their requirements

The required buoyancy volume may be comprised of air tanks, pontoons or foam filled floats, and also the craft structure.

Air tanks are water- and airtight compartments, contained within walls of FRP, metal, or other stiff material. It must be possible to remove condensed- and other water from the tanks through an inspection hatch or –opening, which can be closed tight. Air tanks shall be tested to 5 kPa pressure, and during 30 seconds the maximum allowed pressure drop is 1 kPa.

Pontoons are air filled floats with walls of thin, typically fabric reinforced polymer film, keeping the shape due to internal air pressure. Pontoon materials shall meet the requirements in the standard ISO 15372, and they have to be tested according to the same standard. Prefabricated pontoons shall be tested as follows according to standard ISO 6185:

- over pressure test, (ISO 6185-4 item 7.9)
- tightness test, (ISO 6185-4 item 7.9)
- test of pontoon attachment, (ISO 6185-4 item 7.14)

Foam filled floats contain cellular plastic foam. It has to be mechanically protected by hull structure, or have a protecting surface layer. The foam is to meet the requirements in the standard ISO 6185-3, item 5.7

4.17.3 Arrangements for buoyancy

Pontoons must be divided into at least five about equally large compartments, each volume within ± 20% of the average for all pontoon compartments.

Air tanks need to be divided into compartments based on their volume fraction of the required total buoyancy volume according to Table 4.4.

Table 4.4: The number of permanent air tanks in the hull versus Design Category

Volume fraction	Number of permanent air tank compartments		
	B	C	D
≤ 50 %	2	2	1

> 50 %	3	2	2

4.17.4 Assessment of buoyancy

A buoyancy test has to be performed according to standard ISO 12217-1. The floating position as well as stability in swamped condition with full load are assessed.

The buoyancy can also be verified by calculation. The permeability of the waterfilled compartments shall normally be 1, except for the engine space, where 0.85 may be used.

4.18 Multihulls susceptible to inversion

4.18.1 Susceptible to inversion

The requirements apply only to crafts in Design Category C and D.

The craft is regarded susceptible to immersion if:

$h_C/B_H > 0.572$ while $V_D^{1/3} > 2.6$

$h_C/B_H > 0.22 \cdot V_D^{1/3}$ while $V_D^{1/3} \leq 2.6$

Where

h_C is the lateral wind area centre above the waterline, [m]

V_D is the displacement volume in light service condition [m³]

4.18.2 Requirements

Craft vulnerable to capsizing according to clause 4.18.1 shall meet the following requirements:

- The craft shall, fully loaded, remain afloat swamped upside down according to ISO 12217-2 item 7.12;
- There shall be an emergency exit which can be used while the craft is upside down according to item 7.13 in the same standard.

5 DECK ARRANGEMENT AND RECESSES

5.1 Purpose

The purpose of this chapter is to ensure that:

- The deck arrangement is laid out so green water coming on board drains back to the sea as quickly as possible;
- The recesses have acceptable size and location considering the craft reserve buoyancy and stability in relation to the Design Category; and
- The drain arrangements enable quick draining of the recesses; and
- Flooding of the craft weathertight spaces through openings in the recesses is avoided.
- NOTE! The effects of green water to stability is treated in Chapter 4!

5.2 References

In this chapter reference is made to the following documents:

- ISO 12217-1 Small craft – Stability and buoyancy assessment and categorisation
- ISO 11812 Small craft – Water tight cockpits and quick-draining cockpits
- International Load Line Convention 1966 with amendments

5.3 Documentation

For assessment of the requirements given in this chapter the following documentation is required:

- Deck arrangement;
- Volume of recesses;
- Drain opening location and size; and
- Sill heights for doors in recesses leading into the weather tight hull;
- Calculation of draining time, or test protocol

Most of the mentioned information can be given in the general arrangement drawing.

5.4 Handling of the green water coming on board, general

When applying the rules of this chapter it should be noted, that with different deck arrangements (see Chapter 2) the required level of water- and weather tightness varies. For open or partially protected craft it is assumed that water coming on board is led to the bilge, and drained overboard with bilge pumps. For fully enclosed craft and those provided with buoyancy for remaining afloat, the deck, superstructures, and recesses shall be designed so green water coming on board is efficiently drained back to the sea. The assessment is done according to standard ISO 12217-1, as explained in Chapter 4.

5.5 Definitions

5.5.1 Recesses

A recess is any part of the craft where water can collect, as a consequence of green water coming on board, heeling, heavy rain etc. For example, cockpits and deck areas surrounded by bulwarks are recesses.

5.5.2 Basic requirements for recesses

A quick-draining recess shall meet the requirements in standard ISO 11812 for the Design Category in question. A quick-draining recess shall have:

- bottom height above the waterline according to 5.7.1;
- draining arrangements according to 5.7.2;
- coaming height according to 5.7.6; and
- water tightness according to 5.7.7.

5.5.3 Watertight recess

A watertight recess shall have sill height according to 5.7.6 and water tightness according to 5.7.7. For fully enclosed craft the total volume of all watertight recesses must not exceed LH·BH·FM/40.

5.6 Requirements for deck arrangements

5.6.1 Weatherdeck arrangement

The weatherdeck (see definition in Chapter 2) arrangement shall ensure that green water coming on board does not remain on deck for a long period. Arrangements or structures that prevent the water from draining back to the sea are not allowed.

5.6.2 Non-weather tight superstructures in fully enclosed craft

Superstructures not meeting the requirements regarding strength, water tightness, or closing arrangements for the location in question, are not allowed in fully enclosed crafts in design category A and B although the craft's stability would be sufficient without this superstructure. Alternatively, such superstructures could be fitted with drain openings having a capacity meeting the requirements for a recess in the same location, assuming that the recess coaming height is the same as the sill height for the door.

5.7 Detailed requirement for recesses

The following requirements are based on the international standard ISO 11812. Only typical cases are presented, and in other cases the mentioned standard has to be applied.

5.7.1 Height of recess bottom above waterline

For quick-draining recesses the height of the recess bottom above the waterline has to be at least according to Table 5.1. The requirements in the table refer to recesses with straight bottoms. For recesses with other bottom configurations the standard ISO 11812 shall be applied.

NOTE! Achievement of the draining time in 5.7.2 may require a higher located bottom than given in Table 5.1.

Table 5.1 Recess bottom height H_{Bmin}

Design Category	A	B	C	D
h_{Bmin} [mm]	150	100	75	50

5.7.2 Maximum draining time

The recess maximum draining time is shown in Figure 5.1 as a function of the parameter kC, describing recess volume versus craft weather tight volume. The parameter k_C is determined with Formula (5.1)

$$k_C = \frac{V_C}{L_H \cdot B_{MAX} \cdot F_M} \qquad (5.1)$$

Where V_C [m^3] is the recess volume and B_{MAX} the craft maximum beam.

The draining time never must exceed:

- 1 minute for Design Category A;
- 2 minutes for Design Category B;
- 3 minutes for Design Category C; and
- 5minutes for Design Category D.

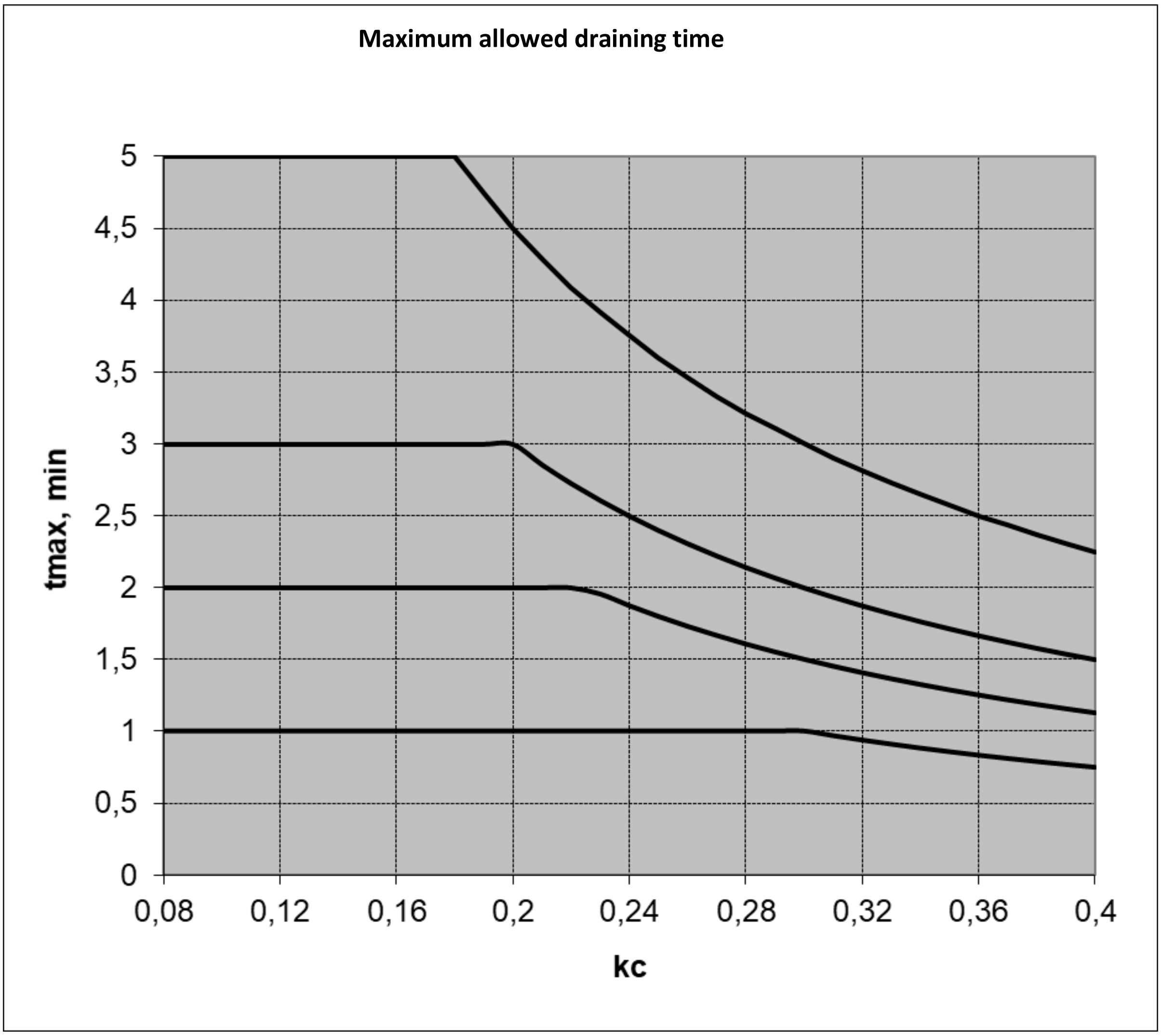

Figure 5.1: Maximum allowed draining time t_{max} [min] for quick draining recesses as a function of k_C.

5.7.3 Area requirement for drain openings

The area for drain openings is to be such that the maximum draining time according to clause 5.7.2 is not exceeded. Compliance can be shown by performing a draining test, or calculations using the method given in standard ISO 11812.

5.7.4 Draining test

Draining time compliance can be demonstrated by a physical draining test. The recess is filled with water, and the draining time is measured. If the time does not exceed the requirement in clause 5.7.2 the recess is compliant in this respect.

5.7.5 Number and location of drains

Recesses shall have at least one drain opening per side. Particularly for working decks and other big recesses the drain location must ensure efficient draining considering the recess volume distribution, and a possible trim change for the craft due to a water filled recess.

5.7.6 Sill heights

The closing appliances leading into the weather tight hull shall have sill heights meeting the requirements for doors or hatches given in Chapter 3.

5.7.7 Water tightness

Closing appliances in the bottom or side of recesses shall at least meet the requirements in Chapter 3.

6 PREVENTION AND CONTROL OF LEAKS, BILGE SYSTEMS

6.1 Purpose

The purpose of this chapter is to ensure that:

- The watertight spaces are arranged so that the consequences of probable damage are minimized;
- There is a draining system sufficient for the craft size and use.

6.2 References

In this chapter the following documents are referred to:

- ISO 12217-1Small craft – Stability and buoyancy assessment and categorisation
- ISO 15083 Small craft – Bilge pumping systems
- ISO 8849 Small craft -- Electrically operated direct-current bilge pumps

6.3 Documentation

For assessment of the requirements given in this chapter the following documentation is required:

- the watertight subdivision, arrangement;
- the structure of watertight bulkheads including WT doors and penetrations;
- the location of openings leading to watertight compartments, their closing arrangements;
- other possible flooding control arrangements
- the location of drainage pumps, manufacturer/type notation and capacity;
- location of high bilge water level alarms;
- drainage lines and their through-hulls as well as used materials
- test protocol for bilge pumping capacity

6.4 Requirements

A summary of the requirements is shown in Table 6.1. The details are treated separately.

The requirements for ”One compartment subdivision” are given in Chapter 38.

6.5 Leak control

Sufficient safety level in case of a leak can be provided in one of three ways. They are:

- *limited unsinkability*, which is the compulsory minimum level for all craft types, except those assessed according to the alternatives 3B, 3C and 3D (craft with buoyancy chambers for remaining afloat, see Table 4.2);
- *one compartment subdivision* as an alternative to limited unsinkability, in case the Additional Notation ”One Compartment Damage Stability” is chosen, see chapter 38.
- *flotation in swamped condition* for craft assessed according to the alternatives 3B, 3C, and 3D.

The details for these are explained in paragraphs 6, 7, and 8.

6.6 Limited unsinkability

6.6.1 Principle

The risk of flooding the hull as a consequence of damage shall be minimized as far as practically possible. ”Limited unsinkability” means that the spaces particularly vulnerable to damage are protected with local watertight subdivision or other damage tolerant arrangements. The aim is to limit the leak so much that the craft does not sink or capsize because of the damage.

6.6.2 The means for achieving limited unsinkability

Depending on the assessment option for the undamaged craft, the watertight subdivision, the underwater appendages, and possible buoyancy for remaining afloat, the following arrangements for improved unsinkability are required according to Table 6.1:

- Collision bulkhead to be installed between 0.05 · LWL and 0.15 · LWL aft of the forward perpendicular. In the vertical direction the collision bulkhead shall extend from the bottom up to weather deck (see definition in Chapter 1)
- An alternative to the previous item could be a collision zone of hard polymer foam or equal, extending at least 0.05 · LWL aft from the forward perpendicular. The vertical extent to be the same as for a corresponding collision bulkhead.
- In craft with unprotected rudders and/or propellers, the bottom above them should be subdivided, or have other precautions taken for limiting a possible leak, in case rudders or propellers should damage the hull in connection with grounding.
- Engine space bulkheads watertight at least to the deck above the full load waterline in fully enclosed craft, and up to 100 mm above the full load waterline in open or partially protected craft.
- For cargo hold bulkheads the same water tightness requirements as for the engine space refer.

Here the forward perpendicular shall be taken as the intersection of the full load waterline with the stem.

Table 6.1 Summary of requirements for leak control

Assessment option (see Chapter 4)		1		2		3		4		5	
Design Category		A	B	C	D	C	D	C	D	C	D
Limited unsinkability	Collision bulkhead	$L_H > 15$ m						$L_H > 15$ m			
	Bottom above propeller and rudder	x	x	x	x			x	x	x	x
	Engine space bulkheads	x	x	x	x	x	x	x	x	x	x
	Cargo hold bulkheads	x	x	x	x			x	x	x	x
One compartment subdivision [1)]		x	x	x	x						
Buoyancy for flotation in swamped condition						x	x	x	x		

[1)] Additional Notation, see Chapter 38. Alternative to ”Limited unsinkability”

6.7 Draining arrangements for the bilge

6.7.1 General

The bilge draining arrangements shall enable removal of water entering during normal use, and controlling limited leaks thereby retaining the craft seaworthiness. The mastering of major leaks, for example after grounding or collision, is not covered within these rules. For craft with Additional Notations, requirements for passenger transport can be found in Chapter 34.

6.7.2 Compartments to be drained

In the following, the term *compartment* means a *watertight compartment* separated by watertight bulkheads, but also *non-watertight compartments* where water can collect in. Non-watertight compartments are such that water can spread to other compartments as the water level rises, e.g. to the level of an opening in the bulkhead.

A compartment with a higher risk of leakage due to hull penetrations below the deepest waterline, opening frame windows, hatches leading from the weather deck without edge height, etc. are *leak-prone compartments*. The engine room is always a leak-prone compartment and, if filled up to the waterline in the minimum operating condition (loading case LC1), water will not lea into other compartments.

The bilge draining system shall be able to pump out all compartments of the weathertigh hull (see chapter 2 for definition) except tanks for the storage of liquids, or compartments used as flotation elements.

Except for engine spaces, small compartments having a total underwater volume of less than 10 % of the (single) hull displacement in full load condition (loading case LC2), can be drained to an adjacent compartment through a drain opening with shut-off valve or plug. Alternatively, these small compartments may be drained with a portable bilge pump.

Water collecting in compartments shall drain to the bilge pump or emptying point, or to an accessible emptying point, taking into account efficient draining in different loading cases and under way.

All bilge pumps and bilge level indicators shall be functional at ±10° heel.

In compartments where the above requirement cannot be met, additional bilge pumps are required, located so that the compartment can be emptied also at 10° heel.

6.7.3 Requirements for the bilge draining system

The requirements for the bilge draining system depend on the craft length, Design Category, subdivision, risk of flooding, and craft concept.

Except for the small compartments mentioned in 6.7.2, it shall be possible to pump out all compartments with the main bilge draining system.

In craft with buoyancy for remaining afloat the main bilge draining system may, with the exception of the engine space, be manual and operated from the working deck, having a capacity corresponding to the secondary draining system, see 6.7.2.

In compartments with inherent risk of flooding, indication for high bilge level is required.

The bilge system discharge line must not be connected to other systems.

Table 6.2 Summary of the requirements for bilge draining systems

Craft concept	Fully enclosed				Floatation buoyancy			Open or partially protected	
Design category	A	B	C	D	B	C	D	C	D
Main system in all compartments	x	x	x	x	x^{M}	x^{M}	x^{M}	x	x
Secondary system in all compartments	x^{R}		x^{RM}		x^{RM}	-		x	x
Secondary system in machinery space, capacity like main system	L_{H}>15m		-						
High bilge water alarm in machinery space and other leak-prone compartments	x								

x^{M}) Manual bilge pump with the reserve pump capacity allowed, with the exception of engine space bilge pump

x^{R}) Requirement applies to lea-prone compartments, see 6.7.2

6.7.4 Main bilge draining system

The main bilge draining system shall consist of a stationary electrical or mechanical pump, enabling pumping out all compartments through pipelines;

Craft with flotation buoyancy are exceptions, for them a manual bilge pump with reserve pumping capacity is allowed, except for the machinery space bilge pumps.

The pipelines shall be arranged so any flooded compartment can be pumped out with the required capacity in all loading conditions, and so that filling does not cause a trim or heel which prevents emptying or an indication of high bilge water.

Alternatively, each compartment can have its own pump, connected to common or separate pipelines.

The main bilge pump of a compartment shall be operable from the steering position, except for the manual pumps used in craft with flotation buoyancy, that shall be operable outside its compartment.

Bilge pumps may be automatic provided there is no risk of transferring polluting substances into the environment.

The capacity of the main bilge pump system shall be at least as shown in Figure 6.1 so that engine rooms and non-watertight compartments (as defined in 6.7.2) have a higher capacity requirement (upper curve) than watertight compartments outside the engine room.

In assessment options 5c, 5d, 6c and 6d, the capacity of the main pump shall be according to the upper curve in Figure 6.1 (engine space and non-watertight compartments).

The capacity requirement for the main bilge draining system is met if the pump nominal output according to standard ISO 8849 is at least in conformity with Figure 6.1 against a back pressure of 1 m hydraulic water head, while considering the requirements in 6.7.6.

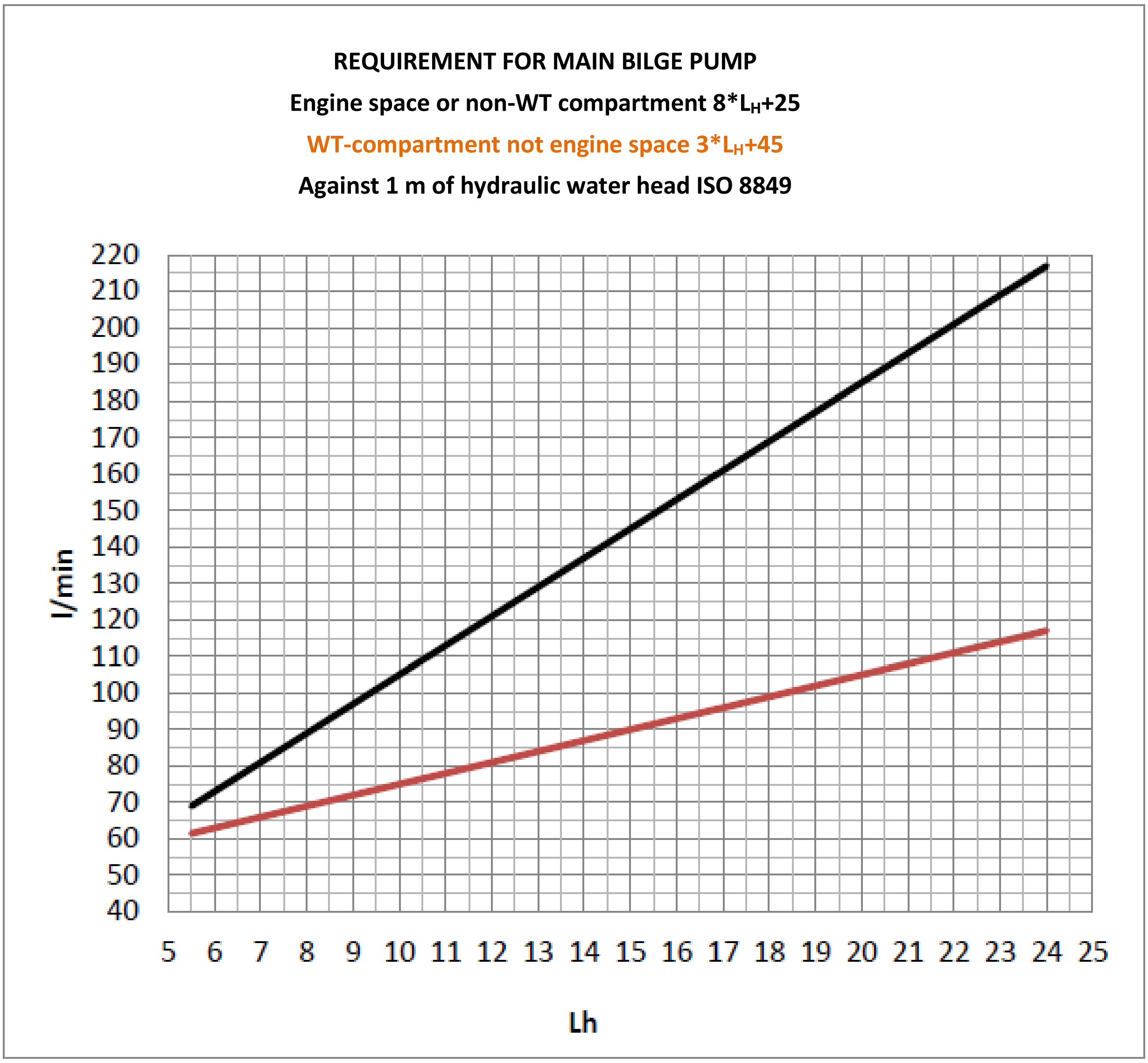

Figure 6.1: Minimum pumping capacity requirement [l/min] for main bilge pump as a function of hull length L_H

6.7.5 Secondary bilge pumping system

For the engine space and other *leak-prone compartments*, except *small compartments*, there shall be a secondary bilge pumping system, completely separate from the main bilge pumping system, according to Table 6.2.

In design category A and B, the secondary bilge pumping system in the machinery space shall have the same capacity than the main bilge pumping system in fully enclosed crafts of hull length over 15 m.

The secondary pump shall be operable outside the compartment.

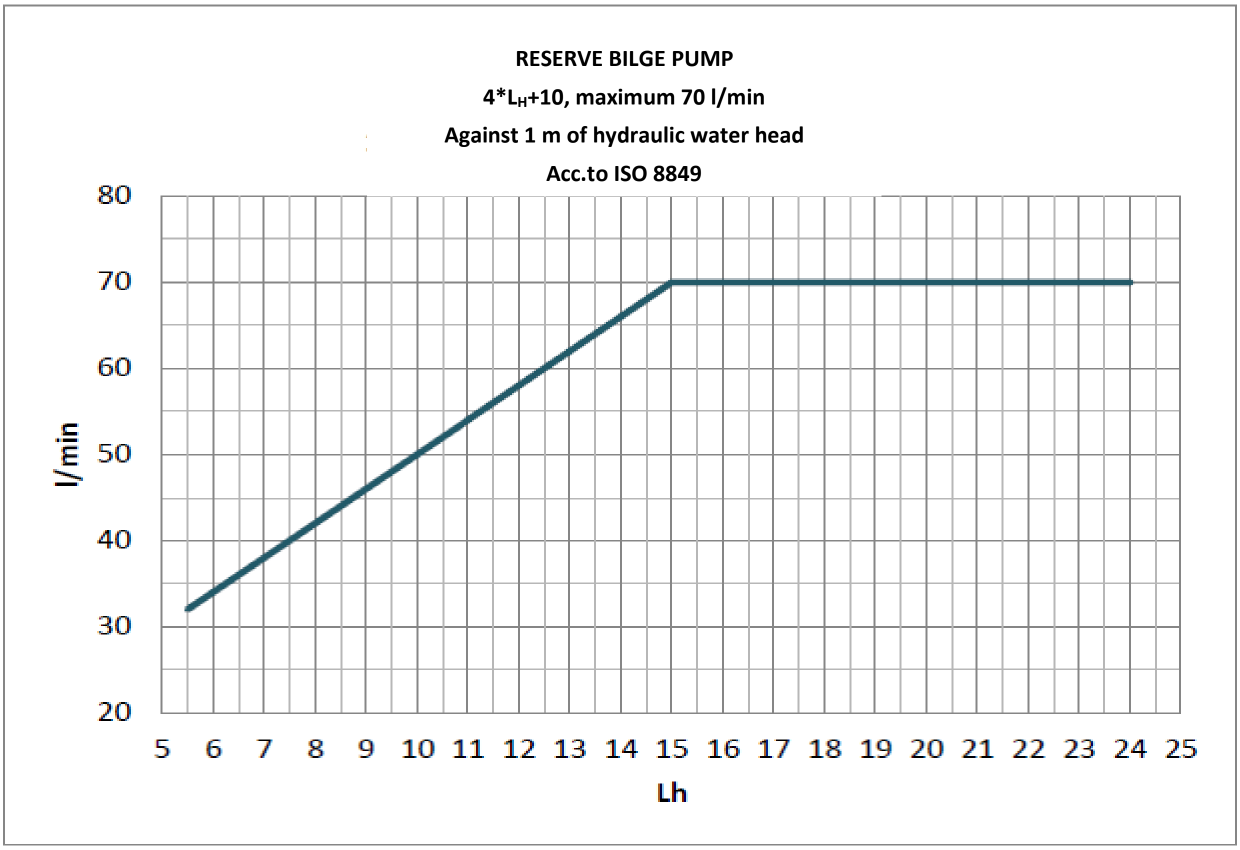

Figure 6.2: Minimum reserve pump capacity requirement [l/min] for bilge pumping as a function of hull length LH

6.7.6 Testing of the bilge pumping system

The functioning of the pumping system shall be tested by a practical test..

6.7.7 Multihull bilge draining arrangements

For multihulls each hull should have bilge draining arrangements corresponding to those required for monohulls.

6.7.8 Alarm for high bilge water level

All Machinery spaces and other *leak-prone compartments* (see 6.7.2), except *small compartments* (see 6.7.2), shall have alarm for high water level in the engine space.

A visual high bilge level indication shall be visible at the steering position.

6.7.9 Material specifications for bilge draining systems

The tubing and hoses used in bilge draining systems shall have a safe working temperature of at least 80 °C.

Hoses used for bilge draining shall stand at least 50 kPa (0.5 bar) vacuum without collapsing, hold their shape when bent, and be oil resistant.

Hoses on deck shall be UV-resistant.

For craft over 15 m hull length in Design Category A and B bilge system hoses and non-metallic discharge tubing in the engine space shall meet the requirements in ISO 7840 or ISO 15540 for short term fire resistance.

Parts of different materials must not be connected so this creates galvanic corrosion.

6.7.10 Strainers for suction hoses or bilge pumps

The suction hose for manual bilge pumps is to be fitted with a strainer if the compartment is vulnerable to the collection of trash or oil.

For powered pumps there shall always be a strainer preventing trash from entering the pump.

The suction hose intake strainer shall be easily accessible for cleaning in compartments vulnerable to collecting trash or oil, such as:

- engine spaces;
- public spaces, and passages between such spaces;
- open spaces, and other spaces connecting to them; and
- cargo spaces

7 DESIGN PRESSURES AND LOADS

7.1 Objective

This chapter gives the design pressures and loads for the dimensioning of the structural strength of scantlings. The level of the loads is determined on the basis of craft size, design category, speed and vertical acceleration at the upper limit. Only design loads related to normal use of the craft are included. Design loads for craft running through ice-covered waters are provided separately in Chapter 39.

7.2 References

The load determination model presented herein is based on the international standard ISO 12215-5 Small craft – Hull construction and scantlings – Part 5: Design pressures for monohulls, design stresses, scantlings determination. The load level is at least the same, but partly higher than in the standard.

The multihull bridge structures design pressure and global loads are based on ISO/WD 12215-7 Small Craft – Scantlings – Part 7: Multihulls. Otherwise the scantling pressures in standard ISO 12215-5 are applied to multihulls.

The fastening of RIB-pontoons to the rigid hull is assessed using ISO 6185-3 and ISO 6185-4, or a , or with a method assessed to be equivalent.

7.3 Principles

The loads as determined in this section are to be used with the calculation formulae in Chapters 10, 14 and 18.

7.3.1 Global loads

Global loads may be significant in multihulls, but also in monohulls in the case of small hull depth, unfavourable weight distribution, etc. The effect of global loads shall be taken into account as required in chapters 8, 12 and 14.

7.3.2 Local loads

The safety against loads from minor groundings, launching, etc., is in general considered satisfactory if the requirements for keel, stem, chine, bulwark and panels are complied with.

7.3.3 Extension of loads

The bottom design pressure to be used in the scantlings formulae in chapters 10, 14 and 18 extends in the vertical direction up to limit of the bottom and the side. The limit between bottom and side is for displacement speed up to the waterline in fully loaded condition. In planing speed

the limit between bottom and side is at the chine provided the deadrise is at most 30 degrees. If the deadrise exceeds 30°, as it usually does in the bow, or in boats having no pronounced chine, the limit between bottom and side is at the waterline in fully loaded condition. Above this limit, the side shell design pressure shall be used in the dimensioning. The top limit of the side is the weather deck for fully enclosed craft. and the rail for open craft. Any higher structural parts (gunwale) shall be dimensioned for minimum pressure as per the formula 7.10. The superstructures shall be dimensioned using for a pressure according to paragraph 7.1

If the panel is completely within one area, the design pressure is determined at the geometric centroid of the panel, or at the mid-span of the stiffener. If the panel extends on several areas, the design pressure is determined according to ISO 12215-5 clause A.7

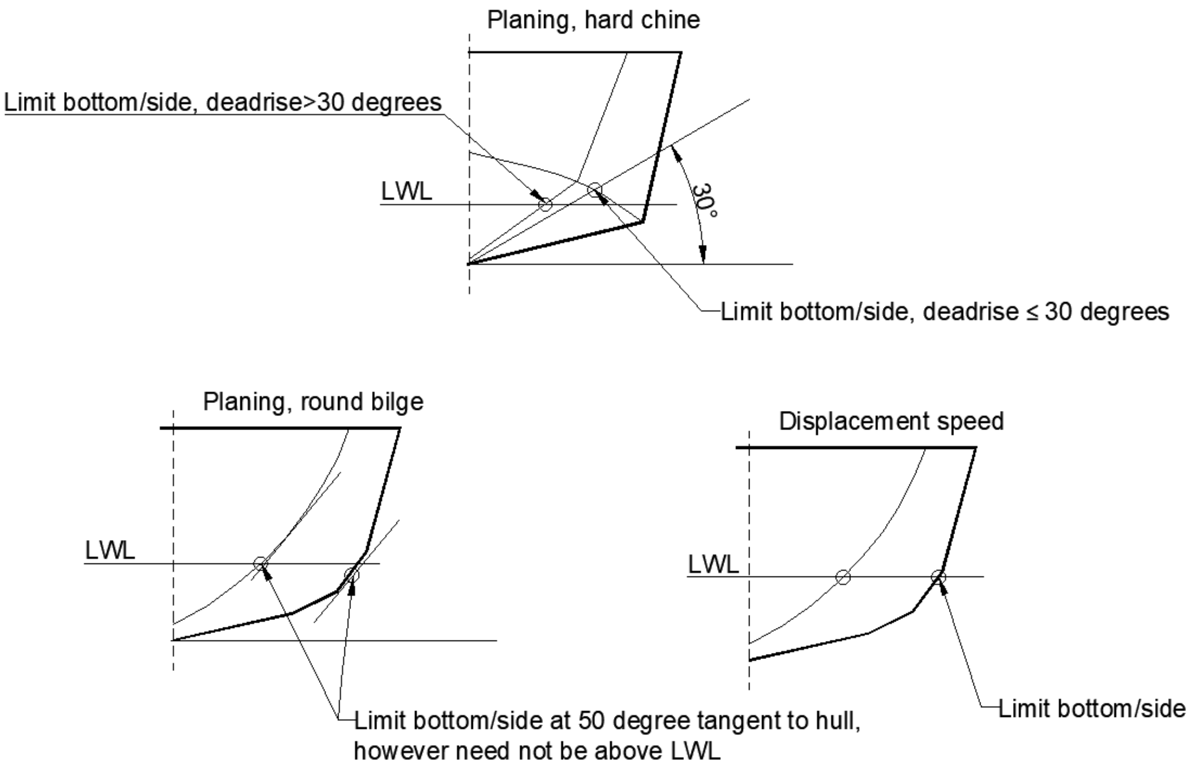

Figure 7.1. Limit between bottom and side pressure.

7.4 Bottom design pressure

The bottom design pressure is to be determined for non-planning mode, and, if the speed of the craft fully loaded exceeds $5 \cdot \sqrt{LWL}$ [kn], also at maximum speed. The design pressure to be used for determining bottom scantlings shall be the greater of these pressures. The bottom design pressure shall however always be $\geq 10\ T_c$ ja ≥ 7 kPa.

The bottom design pressure P_{BM}, is the greatest of the pressures given by formulae 7.1-7.3:

$$P_{BMD} = P_{BMDBASE} \cdot k_{AR} \cdot k_{DC} \cdot k_{L} \text{ [kPa]} \quad (7.1)$$

$$P_{BMP} = P_{BMPBASE} \cdot k_{AR} \cdot k_{L} \text{ [kPa]} \quad (7.2)$$

$$P_{BMMIN} = 0{,}45 \cdot m_{LDC}{}^{0{,}33} + 0{,}9 \cdot L_{WL} \cdot k_{DC} \text{ [kPa]} \quad (7.3)$$

Where

$$P_{BMDBASE} = 2{,}4 \cdot m_{LDC}^{0{,}33} + 20 \text{ [kPa]} \quad (7.4)$$

$$P_{BMPBASE} = 0{,}1 \cdot \frac{m_{LDC}}{L_{WL} \cdot B_{C}} \cdot \left(1 + k_{DC}^{0{,}5} \cdot n_{CG}\right) \text{ [kPa]} \quad (7.5)$$

$$n_{CG} = 0{,}32 \cdot \left(\frac{L_{WL}}{10 \cdot B_{C}} + 0{,}084\right) \cdot (50 - \beta) \cdot \frac{V^{2} \cdot B_{C}^{2}}{m_{LDC}} \text{ [g] ; max 8.0} \quad (7.6)$$

And

k_{DC}	Design category factor, see Table 7.2
k_{L}	Longitudinal pressure distribution factor, see 7.11.3
k_{AR}	Area reduction factor, see 7.11.2
β	Deadrise at 40% of L_{WL} from stern, degrees, however $10° \geq \beta \leq 30°$
V	Maximum speed at full load, kn, minimum $5 \cdot \sqrt{L_{WL}}$

For monohulls the bottom breadth B_{C} is the distance between chines at 40% of L_{WL} from stern, for multihulls the sum of the waterline beams.

If the design category of the craft is D, and the dynamic load factor, n_{CG}, according to formula (7.6) exceeds 3.0, the value obtained by formula (7.7) may be used as n_{CG} in formula (7.5).

For multihulls, the dynamic load factor n_{CG} shall never be taken as less than 1.5. If formula (7.6) gives a value $n_{cg} \geq 3$, formula (7.7) shall be used.

$$n_{CG} = 0{,}5 \cdot \frac{V}{m_{LDC}^{0{,}17}} \text{ [g]; min 3,0; max 7,0;} \quad (7.7)$$

In order not to exceed the upper limit of n_{cg}, the user should be instructed to limit the speed V to value

$$V_{R} = \left\{ \frac{m_{LDC}}{B_{C}^{2}} \times \frac{3{,}125\, k_{DYN1} \times \sqrt{k_{DC}}}{\left[(50 - \beta_{0{,}4}) \times \left(\frac{H_{1/3}}{B_{C}} + 0{,}084 \right) \right]} \right\}^{0{,}5}$$

where $H_{1/3}$ (m) is significant wave height.

7.5 Side design pressure

The side design pressure is to be determined for non-planing mode, and when speed exceeds 5·√LWL, also for the highest speed that the craft reaches in the fully loaded condition. The design pressure to be used in the scantling calculations shall be the greater of the pressures. Bulwarks above weather deck shall be dimensioned using the pressure obtained from formula 7.10.

$$P_{SMD} = [P_{DMBASE} + k_Z \cdot (P_{BMDBASE} - P_{DMBASE})] \cdot k_{AR} \cdot k_{DC} \cdot k_L \text{ [kPa]} \quad (7.8)$$

$$P_{SMP} = [P_{DMBASE} + k_Z \cdot (0{,}25 \cdot P_{BMPBASE} - P_{DMBASE})] \cdot k_{AR} \cdot k_{DC} \cdot k_L \text{ [kPa]} \quad (7.9)$$

$$P_{SMMIN} = 0{,}9 \cdot L_{WL} \cdot k_{DC} \text{ [kPa] ; min 5 kPa} \quad (7.10)$$

Where

k_Z = Vertical pressure distribution factor, see (7.14.4)

$P_{DM\ BASE}$ = Deck base pressure according to paragraph 7.6, and other pressures and factors as per paragraph 7.4.

7.6 Design pressure for decks

Design pressure for weather decks not used for transport of cargo shall be determined by formula 7.11. For sheltered decks, not intended for cargo, the design pressure shall be 5 kPa. For decks intended for cargo, the design pressure shall be the greater value from formulae 7.11 or 7.13.

$$P_{DM} = P_{DMBASE} \cdot k_{AR} \cdot k_{DC} \cdot k_L \quad \text{[kPa]} \quad (7.11)$$

$$P_{DMBASE} = 0{,}35 \cdot L_{WL} + 14{,}6 \quad \text{[kPa] ; not to be taken less than } 0{,}31 \cdot m_{LDC}^{0{,}33} + 12$$

(7.12)

$$P_{DMCARGO} = 10 \cdot Q \cdot n_{CG} \quad \text{[kPa]} \quad (7.13)$$

Where:

Q Amount of cargo per square meter, t/m2

n_{cg} Dynamic load factor according to formula (7.6)

Other factors as defined in paragraph 7.4.

7.7 Design pressure for superstructures

Design pressures for superstructures are based on the design pressure for decks and shall be taken according to formula 7.14. If the craft has an additional notation Self-righting, the superstructures shall be dimensioned using the pressure mentioned in chapter 37 as minimum.

$$P_{SUPM} = P_{DMBASE} \cdot k_{DC} \cdot k_{AR} \cdot k_{SUP} \text{ [kPa]; min 5 kPa} \qquad (7.14)$$

Where:

P_{DMBASE} is calculated using formula 7.12;
k_{SUP} = 1,00 for surfaces facing forward;
0,67 for surfaces faces to the side
0,50 for surfaces aft
0,50 for horizontal surfaces ≤0,8 m above deck without cargo
0,35 for horizontal surfaces >0,8 m above deck without cargo

Other factors as defined in 7.4.

The design pressure for superstructures intended to carry cargo shall be determined as for cargo decks.

7.8 Watertight bulkheads

The design pressure for watertight bulkheads is the hydrostatic pressure which occurs on either side of the bulkhead when the compartment is flooded. This pressure shall be calculated by formula (7.15).

$$P_{WB} = 7 \cdot h_b \text{ [kPa]} \qquad (7.15)$$

Where

h_B is the water head determined as follows:

- For panels 2/3 of the height of the bulkhead [m]
- For vertical stiffeners 2/3 of the stiffeners length, m
- For horizontal stiffeners its distance from the upper edge of the bulkhead, m

7.9 Design pressure for integral tanks

The design pressure for integral tanks is determined by formula 7.16.

$$P_{TB} = 10 \cdot h_b \text{ [kPa] ; min. 20 kPa} \qquad (7.16)$$

Where h_B is the pressure head measured as in 7.8, taken also into account the height of the filling or vent opening.

7.10 Design pressure for multihull wet-decks

The design pressure of multihull wet-decks PWD applies to all structure above the waterline at full load between the demihulls, including the inside topsides of the demihulls.

$$P_{WD} = 3 \cdot n_{CG} \cdot m_{LDC}^{0,33} \cdot k_{DC}^{0,5} \cdot k_l \cdot k_{ZWD} \cdot k_{AR} \qquad (7.17)$$

Where

$$k_{ZWD} = \left(\frac{0,06 \cdot L_{WL}}{z_{WD}}\right)^{1,2}$$ [min 0,5 < k_{ZWD} < 2,0 max]

And

z_{WD} = vertical distance from the loaded waterline to the center of the panel or stiffener in question, [m]

7.11 Global load cases for multihull craft

Global loads shall be taken into account for monohulls if the beam/length ratio exceeds the following value:

$$B_H/L_H > -0,013 * L_H + 0,55 \qquad (7.18)$$

Load case 1. Diagonal load in quartering seas

The load case simulates a situation, where the vessel sails on an oblique course relative the waves, and thereby momentarily is supported by two wave crests, one at the bow at one hull and one at the stern of the other hull.

$$M_{TD} = k_{DC}^{0,5} \frac{m_{LDC}}{1000} \cdot (9,81 \cdot n_{CG}) \cdot 0,076 \cdot \sqrt{L_{WL}^{2} + B_{CB}^{2}} \text{ [kNm]} \qquad (7.19)$$

Where

B_{CB} = distance between centrelines of demihulls

Load case 2. Load corresponding to the righting moment.

A vertical load, acting at the outer hull, which is the smaller of the following:

- The buoyancy force when the outer hull is immersed, acting at its center of buoyancy;
- A vertical force corresponding to the largest righting moment (calculated according to ISO 12217-1) acting at its center of buoyancy

If the bridge structure is shorter than 0,4·LH, also other global loadcases as defined in ISO 12215-7 need to be checked.

7.12 Forces on transoms for high-power outboard motors

In Table 7.1 design forces, based on seatrials, for transoms of planing boats in rough seas, are presented.

Strength assessment of the transom shall be made in load cases I, II and III of table 7.1 for boats if:

- The total outboard engine power exceeds 100 kW; and
- The power factor C_{OB} exceeds 1,0

Load Case I: Simulates the situation where the air-borne craft lands at the next wave crest, when the gravity of the outboard motor induces a backward force on the transom.

Load Case II: Simulates the situation where the air-borne craft lands at the next wave through, when the craft retards and the propulsion simultaneously is acting forward.

Load case III: Simulates the situation after the wave impact, when the propulsion acts with full force.

For craft with schock-mitigating seats, the forces F_X, F_Z and the moment M_Y shall be multiplied by a factor 1,2

Table 7.1. Design forces and moments for outboard transoms

Formula		**Description**
F_X	C_{OB} * 0,42 $P^{0,7}$	Forward force parallel to keel, one engine [kN]
F_Z	C_{OB} * 0,10 m_m	Vertical force, one engine [kN]
M_Y	C_{OB} * 0,36 $P^{0,7}$	Moment at axis of rotation due to mass and propulsion forces, one engine [kNm]
	joissa	
C_{OB}	$15{,}6 \cdot (50 - \beta) \cdot \frac{\sqrt{P_{TOT}} \cdot B_C^2}{m_{ST}^{1{,}333}}$	Power factor based on power/weight
m_m	Mass of outboard or sterndrive [kg]	
m_{ST}	Mass of craft in sea trial condition [kg] = m_{LC} + 150 kg	
P	Power of one engine [kW]	
P_{TOT}	Total engine power [kW]	
β	Deadrise at transom according to ISO 8666 [degrees]	

Loads and moments, coordinate system described in Figure 7.2

Load case	**F_X**	**F_Z**	**M_Y**
I	ei	1,0 F_Z	0,7 M_Y
II	0,5 F_X	1,0 F_Z	1,0 M_Y
III	1,0 F_X	ei	0,5 M_Y

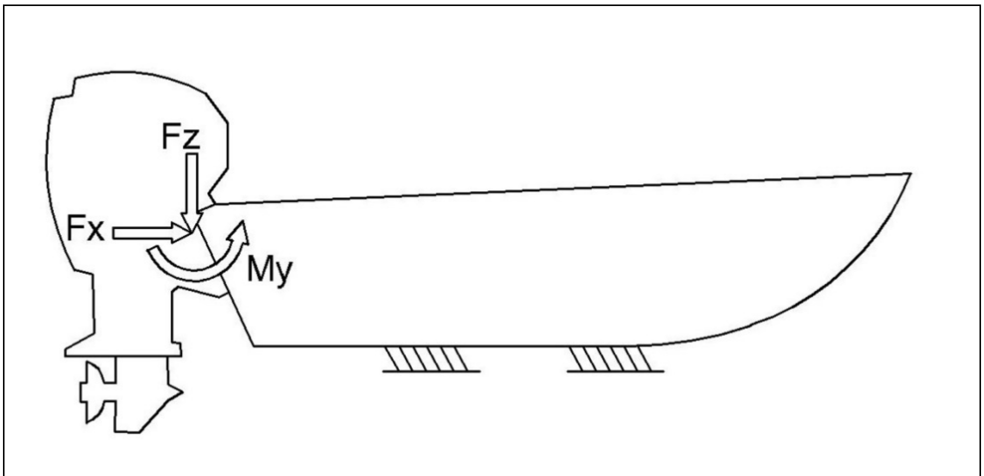

Figure 7.2. The coordinate system for determining the transom forces and moments

7.13 Attachment of RIB pontoons

The attachment of RIB the pontoons to the rigid hull shall be tested as per ISO 6185-3 for craft with a hull length up to 8 m and ISO 6185-4 for crafts with hull length ≥8,0 m, or by some other verified method which gives a level of strength equivalent to the standards mentioned above.

7.14 Design pressure correction factors

7.14.1 Design category factor

The design category coefficient factor k_{DC} to take into account the design pressure differences in various design categories shall be used as per the Table 7.2:

Table 7.2. Design category coefficient

Design category	A	B	C	D
k_{DC}	1,0	0,8	0,6	0,4

7.14.2 Area reduction factor

The area pressure reduction factor k_{AR} takes account of the effect of the size of the strength member on the design pressure. It shall be determined in accordance with the following formula (7.20)

$$k_{AR} = \frac{0{,}1 \cdot k_R \cdot m_{LDC}{}^{0{,}15}}{A_D{}^{0{,}3}} \qquad (7.20)$$

Where

k_R = 1,0

A_D = Design area (m$^{2)}$, to be determined by the formula 7.21 and 7.22:

$A_D = (l \cdot b) \cdot 10^{-6}$; max $2{,}5 \cdot b^2 \cdot 10^{-6}$ [m^2] paneeleille (7.21)

$A_D = (l_U \cdot s) \cdot 10^{-6}$; max $0{,}33 \cdot l_U{}^2 \cdot 10^{-6}$ [m^2] jäykisteille (7.22)

Where

a = Shorter side of panel [mm]

b = Longer side of panel [mm]

l_U = Stiffener unsupported span [mm]

s = Breadth of the loading area of the stiffener [mm]

k_{AR} must not be taken smaller than 0,25 when calculating requirements for panels and stiffeners, based on bending strength or stiffness. When calculating requirements based on allowable shear stress of sandwich cores, k_{AR} must not be taken less than Figure 7.3. For other than bottom and side panels k_{AR} ≥ 0,40. The factor k_{AR} cannot exceed 1,0.

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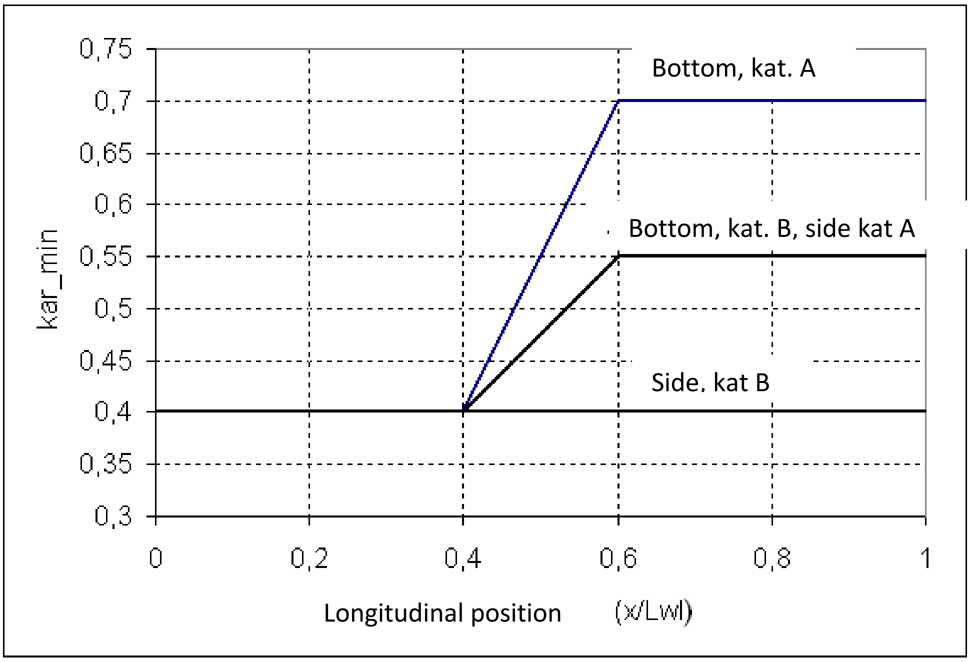

Figure 7.3. Area reduction factor minimum value for sandwich panels.

7.14.3 Design pressure correction based on longitudinal position

The longitudinal pressure distribution factor k_L takes into account variations in the distribution of pressure in the craft's longitudinal direction. It is a function of the dynamic load factor n_{CG}, and shall be determined using the values in Figure 7.4 or the formulae 7.23 and 7.24.:

$$k_L(x) = \frac{1-0{,}167 \cdot n_{CG}}{0{,}6} \cdot \frac{x}{L_{WL}} + 0{,}167 \cdot n_{CG};\ 0 \le x \le 0{,}6 \cdot L_{WL} \text{ from stern to bow} \quad (7.23)$$

$$k_L(x) = 1;\ x > 0{,}6 \cdot L_{WL} \text{ from stern to bow} \quad (7.24)$$

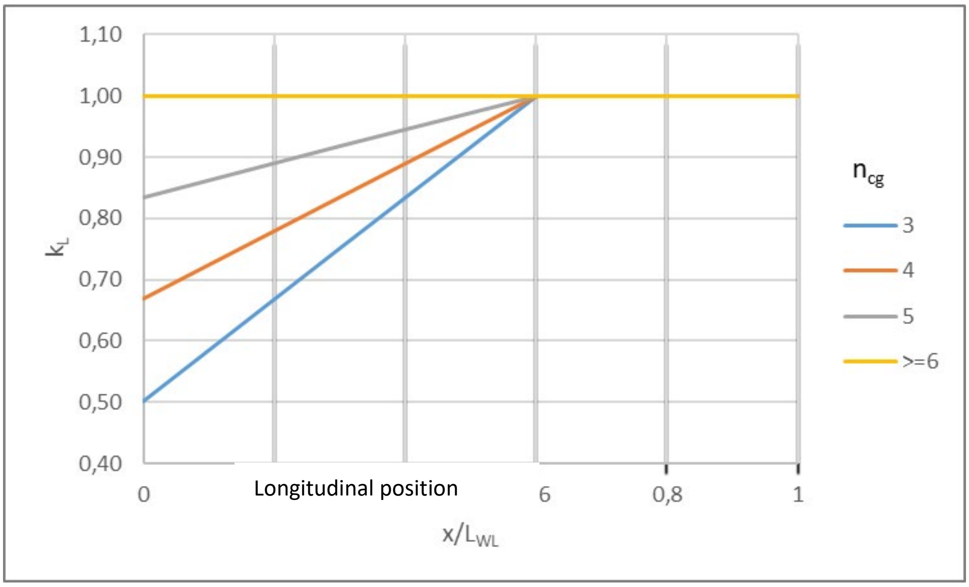

Figure 7.4: Correction factor k_L

7.14.4 Design pressure correction based on vertical position

The vertical pressure distribution factor k_Z takes account of variations in the distribution of pressure in the vertical direction. It is a function of a strength member's location in relation to the limit between the bottom and the side, as depicted in Figure 7.5. The factor k_Z shall be determined with formula 7.25

$$k_Z = \frac{Z-h}{Z} \qquad (7.25)$$

Where

Z = height of freeboard locally to the weather deck (fully enclosed craft) or to the edge of the gunwale (open craft) [m]

h = Vertical distance between the center of gravity of the structural part's design area and the limit between bottom and side [m], see figure 7.5.

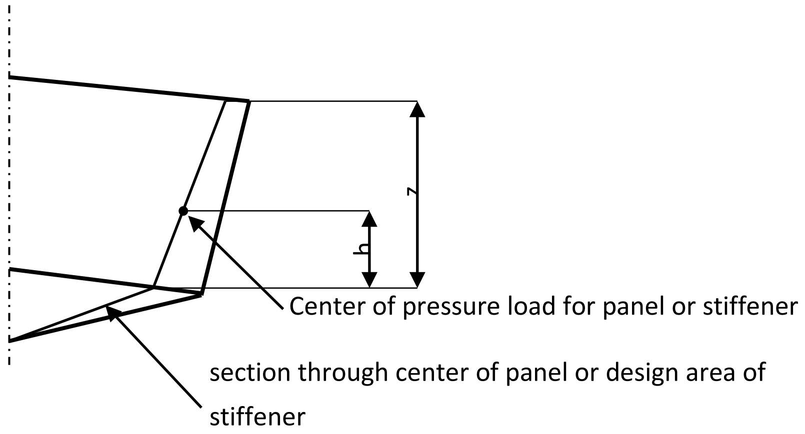

Figure 7.5. Correction of design pressure based on vertical position.

8 DESIGN PRINCIPLES, FIBRE-REINFORCED PLASTIC (FRP)

8.1 Objective

This chapter contains requirements regarding the structural arrangement of the craft and also regarding the design of some critical details. Further, the underlying principles for the assessment are dealt with.

The objective is that the structural arrangement and -details has been carried out correctly from a strength of materials point of view and in accordance with the special properties of fiber-reinforced plastic.

This chapter is applied together with chapters 7 (design loads), 9 (fiber-reinforced plastic materials), and 11 (production)

8.2 References

The requirements in this chapter are based on the international standard *ISO 12215-6 Small craft – Hull construction and scantlings – Part 6: Structural arrangements and details.*

8.3 Principles of analysis

8.3.1 Simple assessment method

The simple assessment method means that the panels, stiffeners and other structural members covered by the Rules are dimensioned according to the formulae in Chapter 10 using the loads of Chapter 7 and the mechanical properties of Chapter 9.

The simple assessment method may be used provided the following conditions are met:

- The structural arrangement meets the requirements in clause 8.6.;
- The assumptions in clause 8.4 are valid;
- The structure has no features that make it critical regarding global loads, see clause 8.5

8.3.2 Assessment using First Principles

In cases, where the assumptions listed in 8.3.1 are not valid, the structure, or parts thereof, is to be assessed using first principles of strength of material. For FRP structures such methods include Laminate Stack Analysis (see ISO 12215-5 Annex H) and Classical Laminate Theory (CLT).

8.3.3 Finite Element Method (FE)

If finite element method is used in the structural analysis, standard ISO 12215-5 (method 5) shall be followed. The allowable stresses can be found in paragraph 10.13.

8.4 Assumptions

8.4.1 Local and global strength/stiffness

The scantling determination method presented in Chapter 10 is based on dimensioning against local loads. Normally, this will result in scantlings, which are adequate also for global loads. Where this is not assessed to be the case, the dimensioning against global loads shall be checked, see Clause 8.5.

8.4.2 Hierarchy of the load carrying elements

When calculating rule requirements for panels and stiffeners according to Chapter 10, the hierarchy of structure is assumed to adhere to the following principles:

- The panel is supported by secondary stiffeners supported by primary stiffeners as indicated in Figure 8.1;
- The primary stiffeners are at least twice as stiff as the secondary stiffeners, or

$$\frac{E_p \cdot I_p}{l_p^3} \Big/ \frac{E_s \cdot I_s}{l_s^3} \geq 2 \qquad (8.1)$$

- The modulus of elasticity of the laminate in the principal directions is within the limits given in 8.9.2;
- The load is uniformly distributed.;
- The edges of the panel are clamped;
- The ends of the stiffeners are fixed.

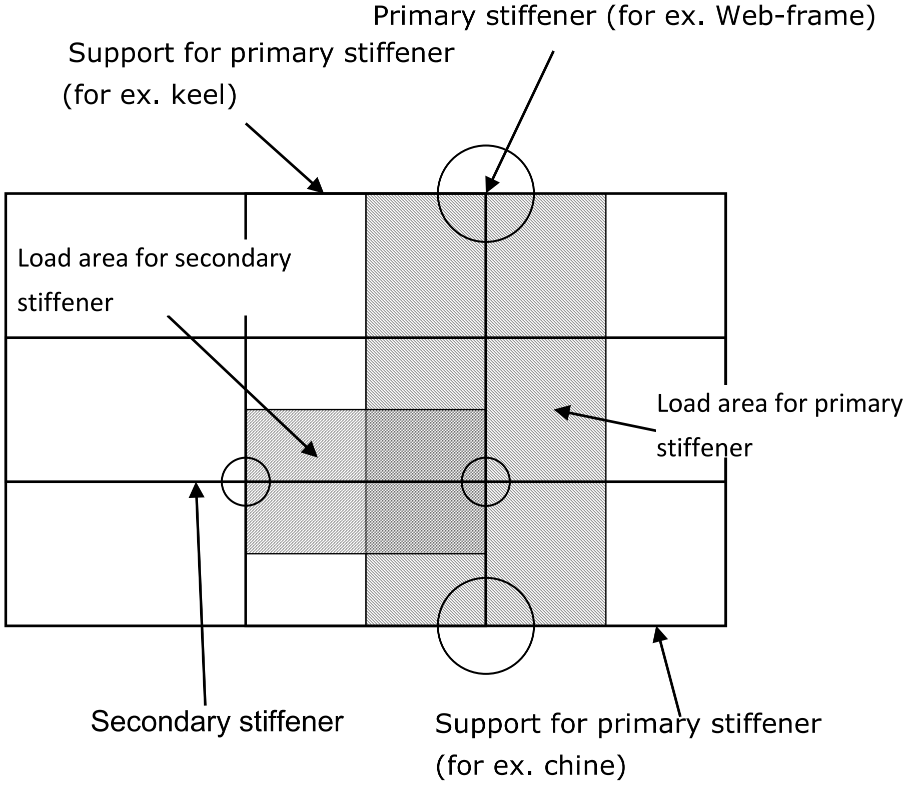

Figure 8.1. Hierachy of load carrying elements

8.4.3 Sandwich panels

When calculating scantling requirements using the formulae in Chapter 10, the following assumptions are made:

- The faces of the sandwich panel are thin (total panel thickness/face thickness > 5.77);
- The stiffness (EI) ratio of a thinner face to a thicker face is in the range 0.75...1,0;
- The ratio of the stiffnesses of the face laminates measured in the main directions of the panel is within the limits given in 8.9.2;
- The modulus of elasticity is much higher in the face than in the core material.

Sandwich panels with faces thicker than mentioned above, shall be analysed according to ISO 12215-5.

8.5 Global strength and stiffness

In the following cases also the global strength and stiffness must be investigated:

- If the bottom is only transversely stiffened and the relative speed of the craft $V/\sqrt{L_{WL}} > 6$
- If there are large openings in the deck;
- If the ratio of the hull length to the hull depth $L_H/D_{MAX} > 12$

The global strength and stiffness shall be determined according to ISO 12215-6 Annex D. At least the deck shall be checked against buckling (compressive stress in the deck). For craft with only transverse stiffening in the bottom, also the strength of the bottom shall be checked.

For multihulls, the global strength shall be checked in the load cases given in Chapter 7.

8.6 Requirements for structural arrangement

8.6.1 Displacement craft, design category D

Boats in design category D with $V/\sqrt{L_{WL}} \leq 6$, may be stiffened by the keel, gunwale and transverse stiffeners only. Boats in higher design categories may only be stiffened by transverse framing alone if an assessment of the global strength and stiffness is carried out, see paragraph 8.5.

8.6.2 Planing craft

Boats with $V/\sqrt{L_{WL}} > 6$, should in general have longitudinal stiffening in the bottom. The details of longitudinal stiffeners shall meet the requirements of paragraph 8.7.

8.6.3 Support for longitudinal stiffeners

The bottom longitudinal stiffeners shall in general be supported by transverse stiffeners such as bulkheads, web frames or deep floors, which are to be designed to carry the load acting on the hull area in question, see Figure 8.1. The details of transverse stiffeners shall meet the requirements in paragraph 8.7.

8.6.4 Keels, stem and chines

The craft shall have a reinforced keel, stem and chines according to Chapter 10 paragraph 10.11.

8.6.5 Torsion stiffness and -strength

The torsion strength and stiffness is considered adequate if the craft has one of the following items:

- A full deck;
- Transverse bulkheads;
- A strengthened bulwark.

8.6.6 Superstructure support points

The loads induced by superstructures shall be led into bulkheads, webframes or other primary structure.

8.7 Hull stiffeners

8.7.1 Continuity of stiffeners

In craft where V/√LWL>6, the bottom longitudinal stiffeners shall be continuous. Terminating of stiffeners on a panel between stiffeners shall be avoided. With the exceptions of clause 8.10.2 the ends of stiffeners shall be fastened to other stiffeners.

8.7.2 Straightness and local discontinuities of stiffeners

Hull stiffeners shall be as straight as possible. At most 30 degrees changes of direction are accepted, provided buckling support is arranged at the points where the direction change. Abrupt changes is the cross section of the stiffeners shall be avoided. If the stiffeners have local discontinuities, the transition shall be smooth and corners shall be rounded, radius at least 30 mm.

8.7.3 Safety against buckling

The cross section of stiffeners shall be such that they are not prone to buckling. Stiffeners with one web without flange are not allowed in the bottom. Stiffeners with one web must not be fastened at an angle exceeding 30 degrees relative to the normal against the panel.

8.7.4 Transverse stiffeners

The hull transverse stiffeners such as bulkheads, webframes and deep floors, shall extend from side to side of the hull. When calculating the section modulus requirement of a web frame as per chapter 10.10,, the span shall be taken as the distance between chines. However, if the section modulus of the keel meets the requirements in Chapter 10 clause 10.11.12, the stiffeners span may be taken as the distance between the chine and keel.

8.7.5 Floating framing

Floating transverse frames, ie. frames not extending to the bottom or side shell, are permitted only if the safety against buckling is checked

8.7.6 Using interior elements as stiffeners

Interior components alone or together with innerliners may be utilised as structurally effective provided that they meet the requirements in clauses 8.7.1...8.7.4 regarding arrangement and Chapter 10 regarding scantling requirements.

8.8 Other stiffeners

The stiffener arrangement of decks, superstructures and structural bulkheads must in general consist of secondary stiffeners supported by primary stiffeners following the principles laid down in clause 8.4.2.

8.9 Laminate design

8.9.1 Fibers carry the load

The structure is to be designed such that the fibers primarily carry the loads. The fibers shall be oriented in the anticipated directions of the load.

8.9.2 Laminate balance

When the stiffness in the main directions of the laminate are different, a sufficient balance of properties has to be maintained. The stiffness ratio in the longer and shorter directions of the panel shall be within the limits given in Table 8.1.

Structural member	Stiffness ratio
Panels, aspect ratio = 1,0	0,80…1,0
Panels, aspect ratio ≥ 2,0 [1)]	0,68…1,0
Crowns of stiffeners	0,25…1,0

[1]Intermediate values to be obtained by linear interpolation

Normally, laminates should contain fibers in the two main directions parallel to the edges, but also in plus/minus 45 degree directions.

8.9.3 Laminates containing several types of fibers

When a laminate contains several types of fibers, the compatibility shall be checked by laminate stack analysis (see ISO 12215-5 Annex H) or classical laminate theory (CLT). No layer shall be loaded more than half of the ultimate stress of that layer when subject to the load determined according to Chapter 7.

8.10 Layer drop-off

8.10.1 Single skin laminates

The drop-off shall in any case be at least 20 times the thickness difference, and for especially stressed areas at least 40 times the difference in thickness. The following are regarded as especially stressed areas:

- Stiffeners ending within a panel (see 8.11.1);
- Engine foundations;
- Crane foundations;
- Fastening points for lifting lugs;
- Fastening points for mooring cleats.

8.10.2 Sandwich

8.10.2.1 Transition from sandwich to single skin

The width of the transition from sandwich to single skin shall be at least two times the core thickness.

In addition, it has to be checked, that the panel is able to carry the bending moment and shear force in the transition zone.

8.11 Laminate bonding

8.11.1 Bonding of stiffeners

The bond shall be capable of carrying the bending moment and shear force according to Chapter 10 clause 10.

The thickness of the bonding laminate shall in general be at least the same as the thickness of the web laminate. For a stiffener with a single web, the sum of the laminates shall meet the requirement. The width of the bonding laminate shall be at least 25+15·t mm, where t is the thickness of the bonding laminate. In especially stressed areas (see 8.9.1) the width shall be increased to 25+20·t mm

The ends of stiffeners shall be bonded to other stiffeners except for the cases listed below. The ending of stiffeners within a panel is allowed in the following case:

1) Bottom, all design categories; Side and bottom, design categories A and B

- The end of the stiffener runs out against the bottom so it forms an angle of at least 15 degrees, see Figure 8.2.
- The stiffener ends at a reinforced area such as near a keel or chine.
- In both cases the bending- and shear stresses must not exceed half the allowable stresses according to Chapter 10.
- The stiffener end shall be sniped in ratio 3:1 as minimum.
- The distance between the end of the stiffener and surrounding stiff structure shall be in the range 30-75 mm.

2) Other applications, all design categories

- The stiffener end shall be sniped in ratio 3:1 as minimum.
- The bonding laminate breadth (also around the stiffener end) shall be according to 8.10.1.

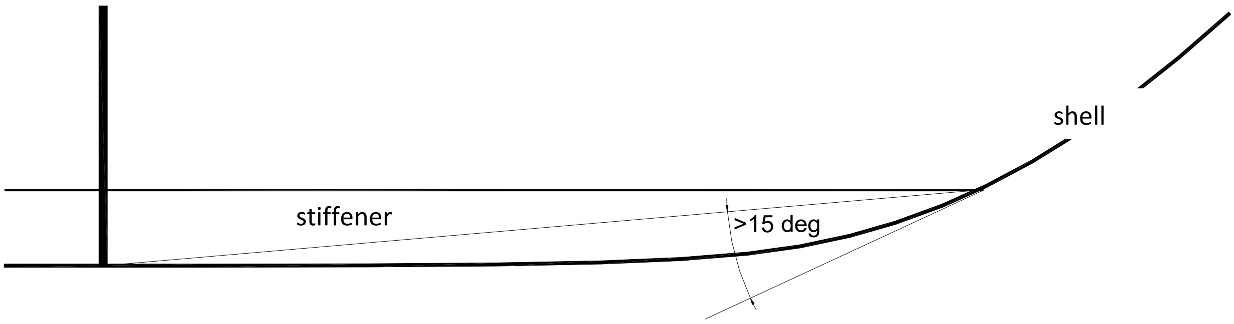

Figure 8.2. The stiffener runs out against the hull shell.

To avoid bonding defects, the stiffener shall be fastened to the panel before lamination with bonding paste or similar, which is formed as a fillet between the panel and the stiffener web.

8.11.2 Bonding of bulkheads

Plywood bulkheads shall be bonded to the hull from both sides with a laminate having a minimum weight/area of 0,1·bulkhead thickness [kg/m2].

For bulkheads made of single skin, the bonding laminate thickness shall in total be at least as the thickness of the bulkhead.

For sandwich bulkheads, the bonding laminate thicknesses shall be at least equal to the thickness of the faces.

The width of the the bonding laminate shall be at least 25+15 · t [mm] where t is the thickness of the bonding laminate.

Prior to bonding, the joint shall be filleted according to clause 8.11.1.

8.11.3 Adhesive bonding

Adhesive joints shall be designed so the load is transferred between the joined parts primarily by shear. Loads perpendicular to the joint surface and peeling forces shall be avoided. The following requirements apply to the bonding flanges of stiffeners bonded to a laminate panel, typically so called top-hat stiffeners. The width of the bonding flange joint shall be at least:

$$b_{wmin} = 1{,}5 \cdot k_j \cdot \frac{t_W}{2} \text{ [mm]; min 50 mm} \qquad (8.1)$$

Where

t_W Thickness of web laminate, for top-hat stiffeners the sum of the two webs

k_i Factor taking into account the shear strength of the adhesive/laminate type, see Table 8.2.

Table 8.2. Factor k_j for the width of the bonding flange.

Fibre reinforcement type	Fibre content by weight Ψ [%]	Polyester or vinyl ester adhesive	Epoxy adhesive, curing in room temperature
CSM/WR /multiaxiali	35	12	7
	50	14	8
Double bias	35	20	11
	50	23	13

For other laminate types, the width of the bonding flange shall be determined according to ISO 12215-6.

8.12 Other structural details

8.12.1 Openings in load-bearing structures

The effect of openings in load-carrying structures shall be taken into account.

If needed, openings shall be fitted with flanges or similar around their perimeter to avoid buckling .

With the exceptions listed below, no openings are allowed in stiffeners unless a detailed calculation shows that the stress level is below the allowable stresses according to paragraph 10.13:

Openings in stiffener webs are not allowed in the ends within 20% of the length between support points. In other locations openings in the webs are allowed provided the height does not exceed 50% and the length 75% of the web height.

8.12.2 Sharp corners

Unless strengthened with unidirectional laminate, sharp corners shall be avoided.

8.12.3 Special issues for sandwich construction

In way of highly loaded fittings, the face laminates shall be reinforced and the sandwich core shall be replaced by a material with a compressive strength of at least 2 MPa or alternatively replaced by single skin laminate.

In way of through-hull fittings the sandwich core shall be replaced with inserts of non-organic material with a compressive strength of at least 2 MPa or alternatively replaced by single skin laminate.

The potential danger of outer skin peeling on sandwich hulls shall be taken into account on fast craft.

8.12.4 Other structural details

Spray strips in craft in design categories A, B or C shall be reinforced with additional laminate or filled and laminated over.

Structures, where water can be entrapped, shall be avoided as much as possible. Where such cannot be avoided, they shall be readily accessible (definition see Chapter 34).

Laminate inside surfaces that are exposed to water, such as bilge water, shall be painted with topcoat or other suitable coating.

9 FIBRE REINFORCED PLASTICS MATERIAL

9.1 Objective

The objective with this chapter is to give requirements for the raw materials used in structural parts of the craft and to define the mechanical properties to be used in the scantlings determination.

This chapter is applied together with Chapters 7 (dimensioning loads), 8 (design principles), 10 (dimensioning of reinforced plastic craft) and 11 (production of reinforced plastic craft).

9.2 References

This chapter is based on the following international standards:

- ISO 12215.1 - Hull construction and scantlings - Part 1: Materials: Thermosetting resins, glass-fibre reinforcement, reference laminate.
- ISO 12215 - Hull construction and scantlings - Part 2: Materials: Core materials for sandwich construction, embedded materials
- ISO 12215-5 - Hull construction and scantlings -- Part 5: Design pressures for monohulls, design stresses, scantlings determination
- ISO 178 Plastics — Determination of flexural properties
- ISO 527-4 Plastics -- Determination of tensile properties -- Part 4: Test conditions for isotropic and orthotropic fibre-reinforced plastic composites
- ISO 527-5 Plastics -- Determination of tensile properties -- Part 5: Test conditions for unidirectional fibre-reinforced plastic composites
- ISO 14126 Fibre-reinforced plastic composites — Determination of compressive properties in the in-plane direction
- ISO 14129 Fibre-reinforced plastic composites — Determination of the in-plane shear stress/shear strain response
- ISO 14130 Fibre-reinforced plastic composites — Determination of apparent interlaminar shear strength by short-beam method

9.3 Documentation

To verify the compliance with the requirements in this chapter, the following documentation is needed:

- Datasheets or similar of the used raw-materials
- Test reports of mechanical properties

9.4 Resins

Resins used in structural components shall meet the requirements of ISO 12215-1 as "Type A" resin.

Resin additives such as agents for adjusting tixotrophy or filling, shall be compatible with the resin.

9.5 Fiber reinforcement

Fiber reinforcements used in structural components shall meet the requirements of ISO 12215-1.

9.6 Compability of fibers with resin

There shall be documentation to show, that materials are suitable for the application in question and for the anticipated environmental conditions. The fiber reinforcement shall have a seizing which is compatible with the laminating resin.

Orthophtalic resin must not be used with powder bounded chopped strand mat.

9.7 Mechanical properties of laminates

The following requirements concern glass/polyester laminates if not stated otherwise. Requirements for other materials shall be determined according to ISO 12215-5. Glassfibre reinforced laminates shall fulfill the following minimum properties:

- Ultimate tension stress σ_T = 80 MPa
- Tensile modulus E_T = 6350 MPa
- Ultimate bending stress σ_B = 135 MPa
- Flexural modulus E_B = 5200 MPa
- Ultimate shear stress in the plane of the laminate τ_{XY} = 50 MPa
- Ultimate interlaminar shear stress τ_{XZ} ja τ_{YZ} = 15 MPa

Mechanical properties shall be determined by testing according to paragraph 8 or by calculation using the method in paragraph 9.9.

9.8 Determination of mechanical properties by testing

When the mechanical properties of laminates are determined by testing, the specimen shall be produced using the same production processes and -parameters as when manufacturing the craft itself.

The relevant values shall be determined in the both main directions of the laminate. Unidirectional laminates shall be tested in one direction only. The laminates shall be tested without gel- or topcoat.

The following standards shall be used for determination of mechanical properties:

- Tensile stress and –modulus, ISO 527-1 and ISO 527-4.
- Compressive stress, ISO 14126
- Bending stress and modulus, ISO 178.
- Shear stress in the plane of the laminate, ISO14126.

When measuring bending strength, the outer surface (=the outside of the hull) shall be in tension.

The average results for each tested property shall meet the requirements in 9.7. No single value shall be less than 80% of the average value.

9.9 Determination of mechanical properties by a nominal fiber content

The mechanical properties of laminates may also be determined on the basis of a nominal fiber content which is a function of the used reinforcement products and the manufacturing process.

9.9.1 Nominal fiber content

The nominal fiber content, Ψ, which is expressed in percent by weight, shall be taken as follows. The formulae are valid for laminates reinforced by glassfibre. For other fiber types the nominal fiber content shall be determined according to ISO 12215-5.

- Chopped strand mat (CSM) laminates Ψ = 30%
- CSM / woven rowing laminates Ψ = 46-18·R, where R = proportion of CSM
- Multidirectional laminate Ψ = 50%
- Unidirectional laminates Ψ = 55%

9.9.2 Mechanical properties

The mechanical properties of laminates is determined from Figure 9.1...9.6 based on the nominal fiber content according to clause 9.9.1. The figures apply to laminates reinforced by chopped strand mat and/or balanced woven rowing and for unidirectional laminates. The mechanical properties for "Double Bias" (±45° fabrics) and multiaxial fabrics shall be determined according to ISO 12215-5.

It shall be noted that the values from figures 9.1...9.6 shall be corrected for scantlings determination according to paragraph 9.11.

9.9.3 Converting the thickness requirements to reinforcement area mass

When assessing the compliance according to Chapter 10, the laminate thickness requirements shall be converted to reinforcement area mass using Figure 9.9 which corresponds with the method in standard ISO 12215-5 Annex C.

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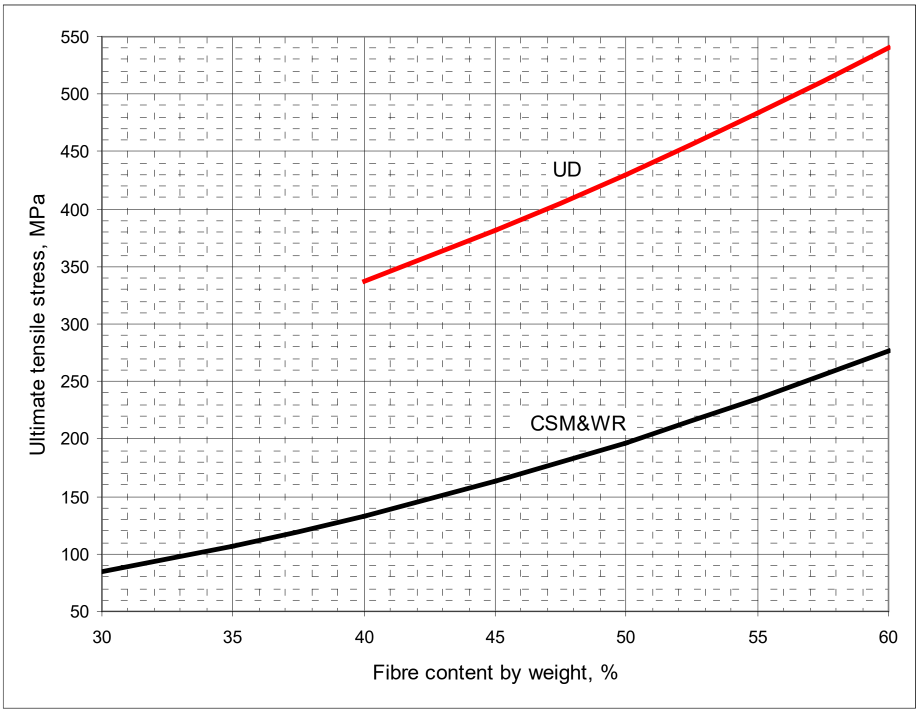

Figure 9.1. Ultimate tensile stress for chopped strand mat/woven rowing laminates and unidirectional laminates as a function of nominal fiber content.

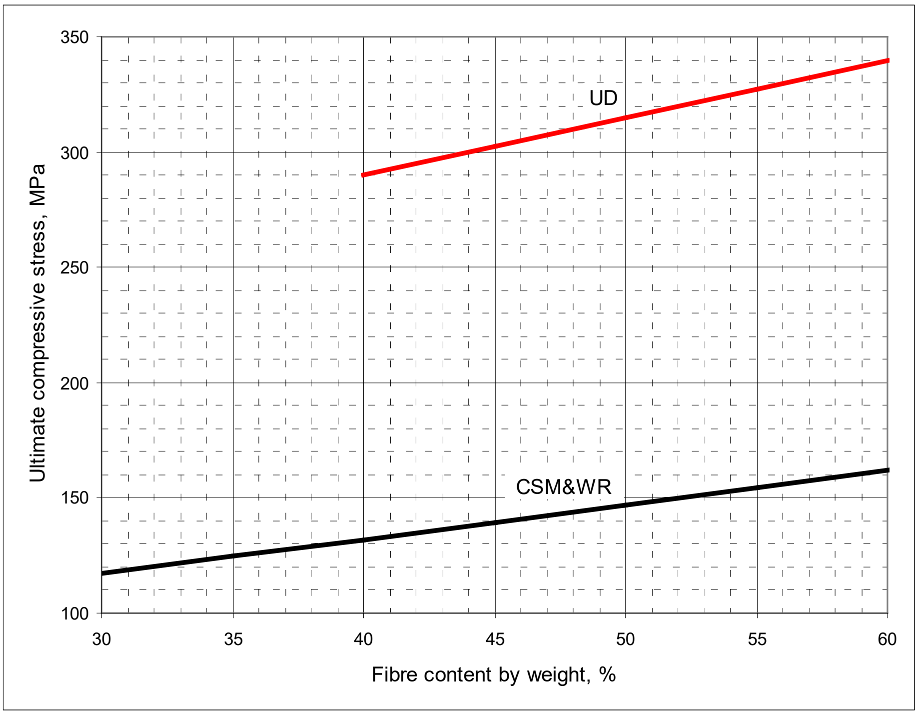

Figure 9.2. Ultimate compressive stress for chopped strand mat/woven rowing laminates and unidirectional laminates as a function of nominal fiber content.

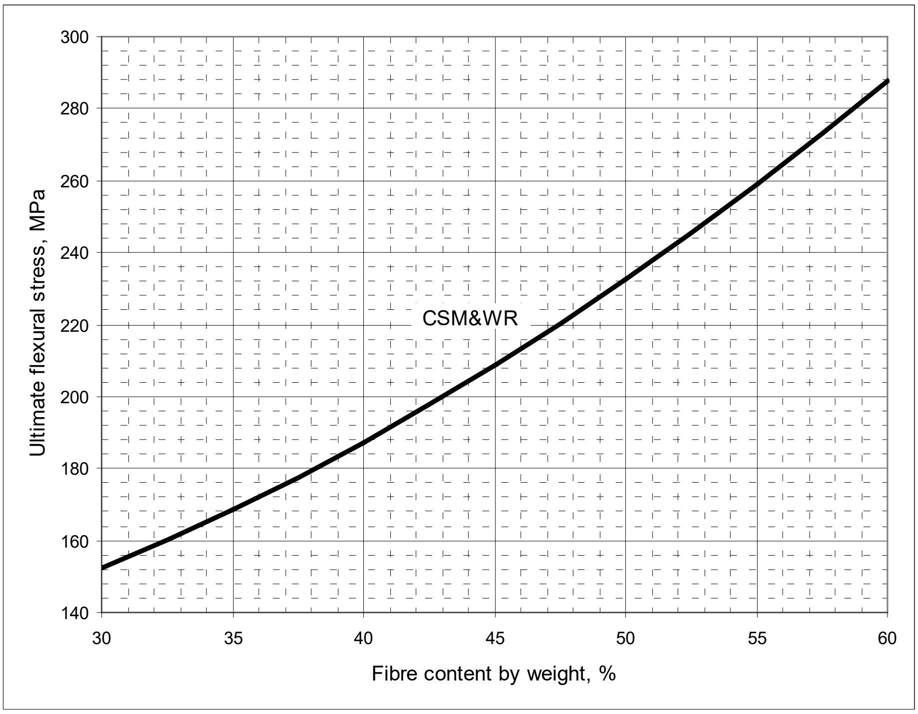

Figure 9.3. Ultimate flexural stress for chopped strand mat/woven rowing laminates and unidirectional laminates as a function of nominal fiber content.

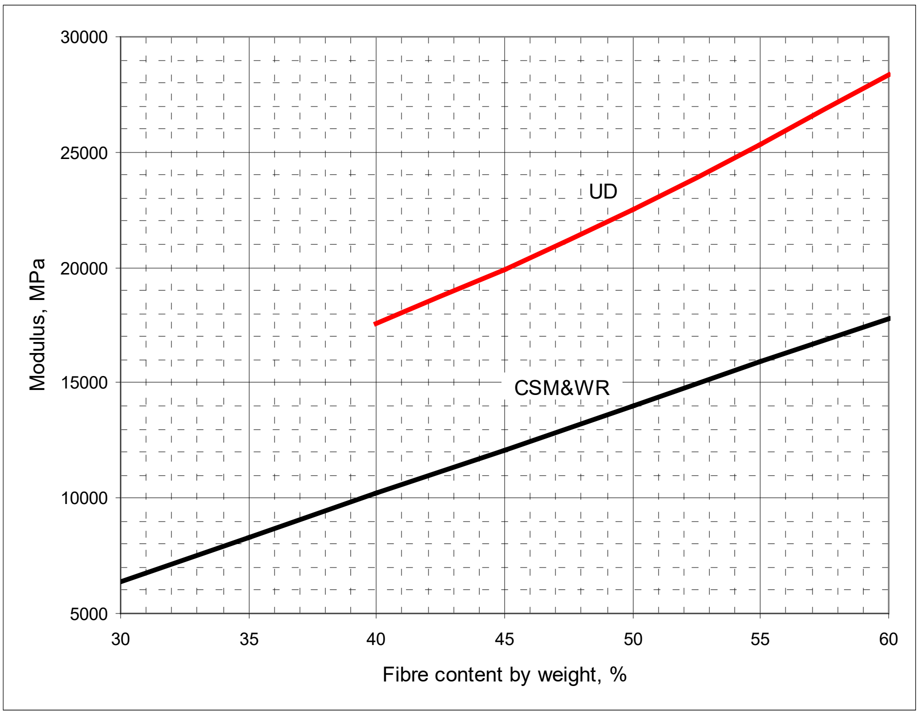

Figure 9.4. Modulus of elasticity for chopped strand mat/woven rowing laminates and unidirectional laminates as a function of nominal fiber content.

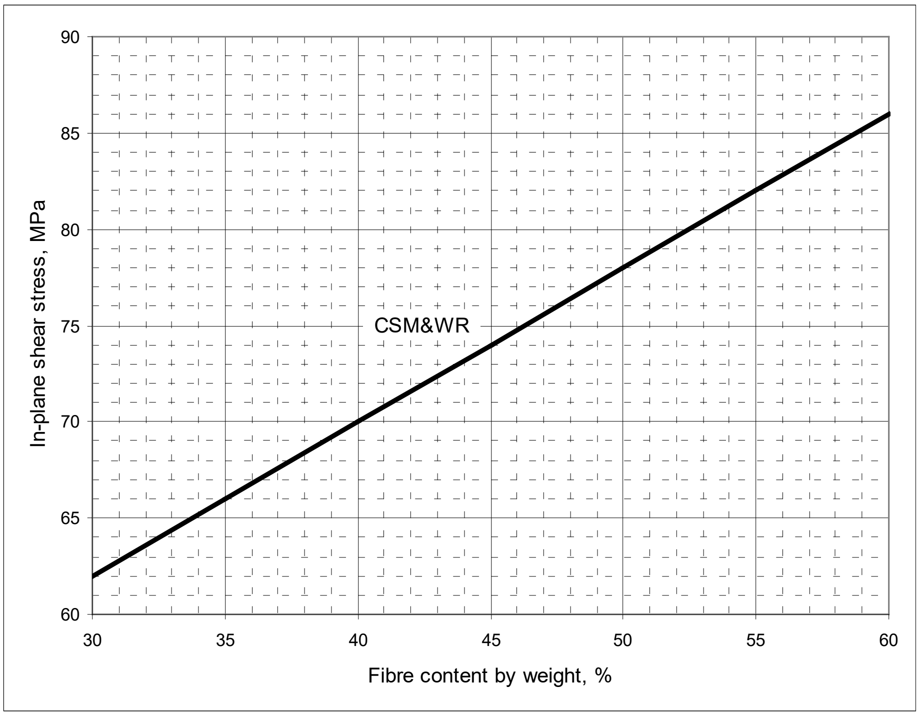

Figure 9.5. Ultimate shear stress in the plane of the laminate for chopped strand mat/woven rowing laminates as a function of nominal fiber content.

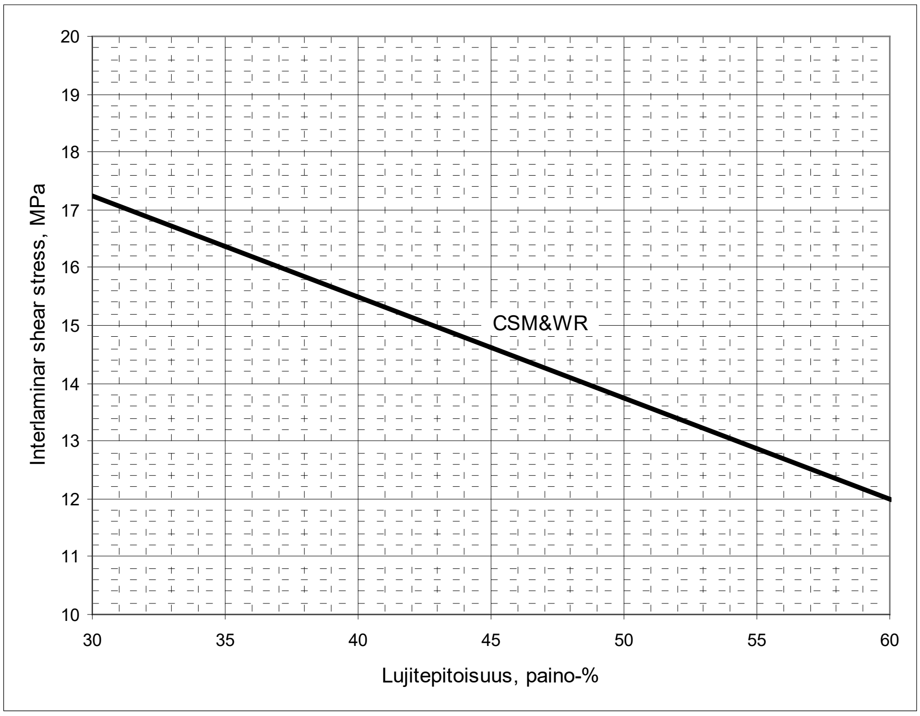

Figure 9.6. Ultimate interlaminar shear stress for chopped strand mat/woven rowing as a function of nominal fiber content.

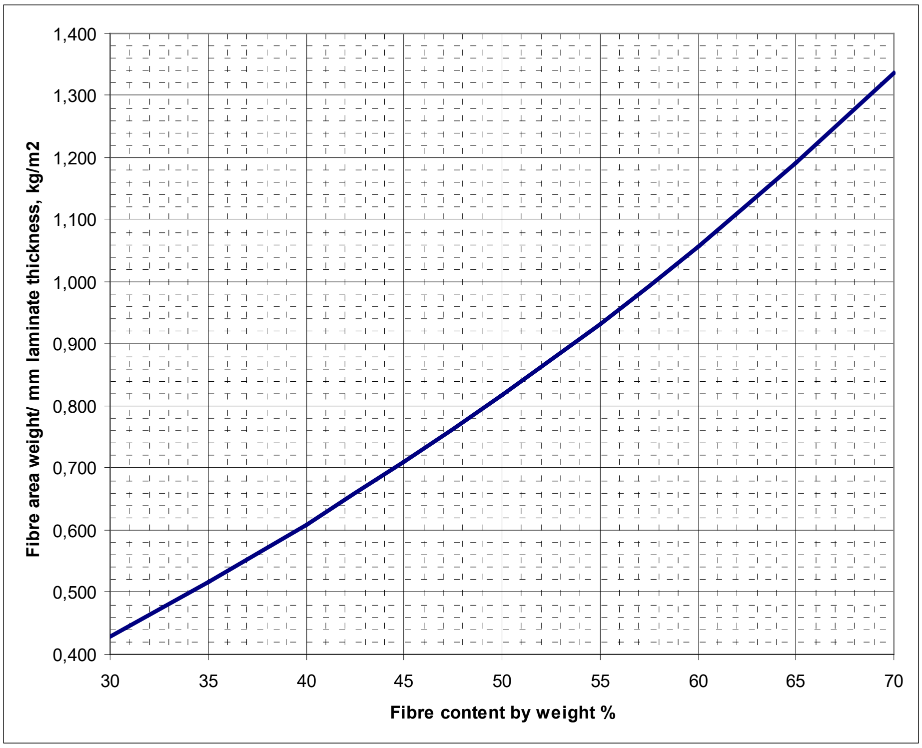

Figure 9.7. Reinforcement area mass as a function of fiber content.

9.10 Sandwich core materials

Sandwich core materials in structural components of the craft shall meet the requirements of ISO 12215-2 "Grade 1."

9.10.1 Mechanical properties of sandwich core materials

Unless samples have been tested from the actual batch used for the craft in question, the mechanical properties of sandwich core materials shall be determined on the basis of the material, the elongation to break and the density of the material using Figures 9.8...9.11.

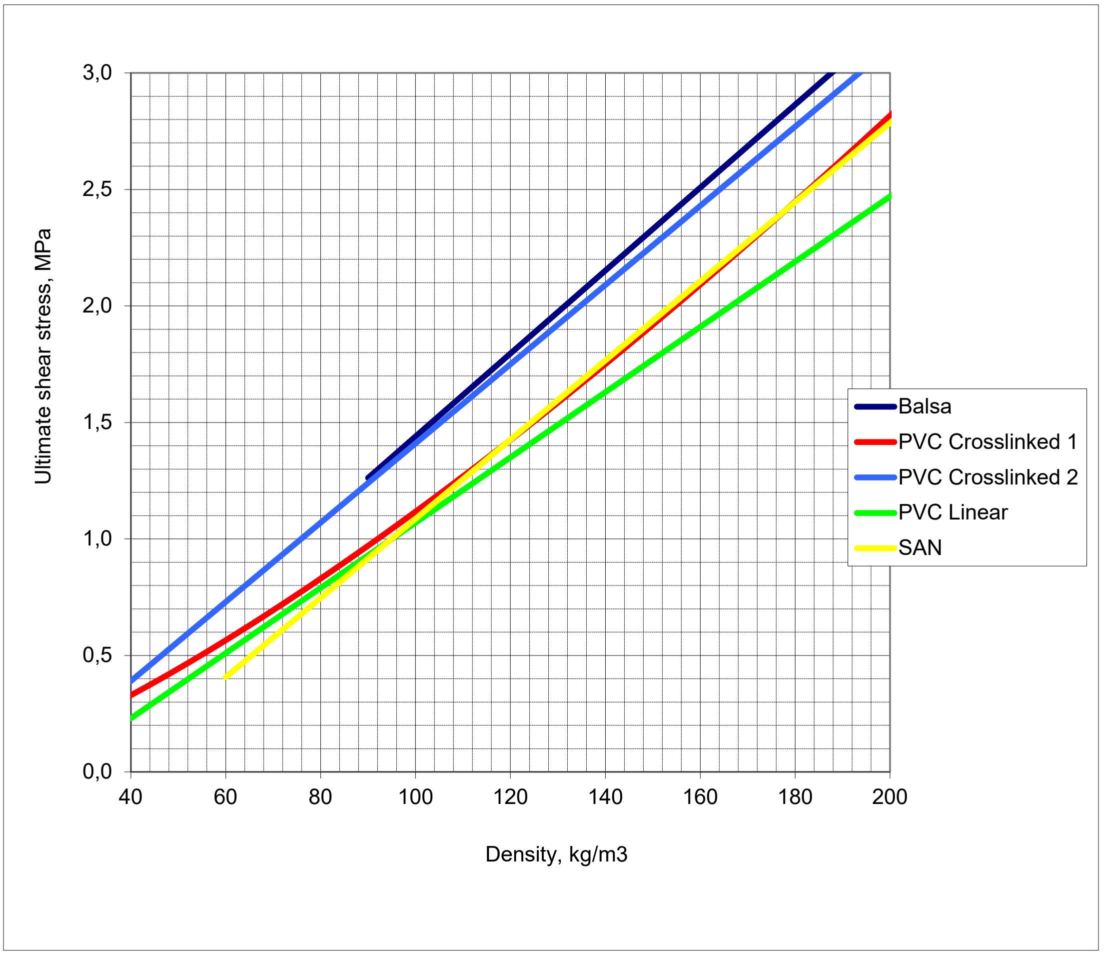

Figure 9.8. Ultimate shear stress for structural polymer foams as a function of density.

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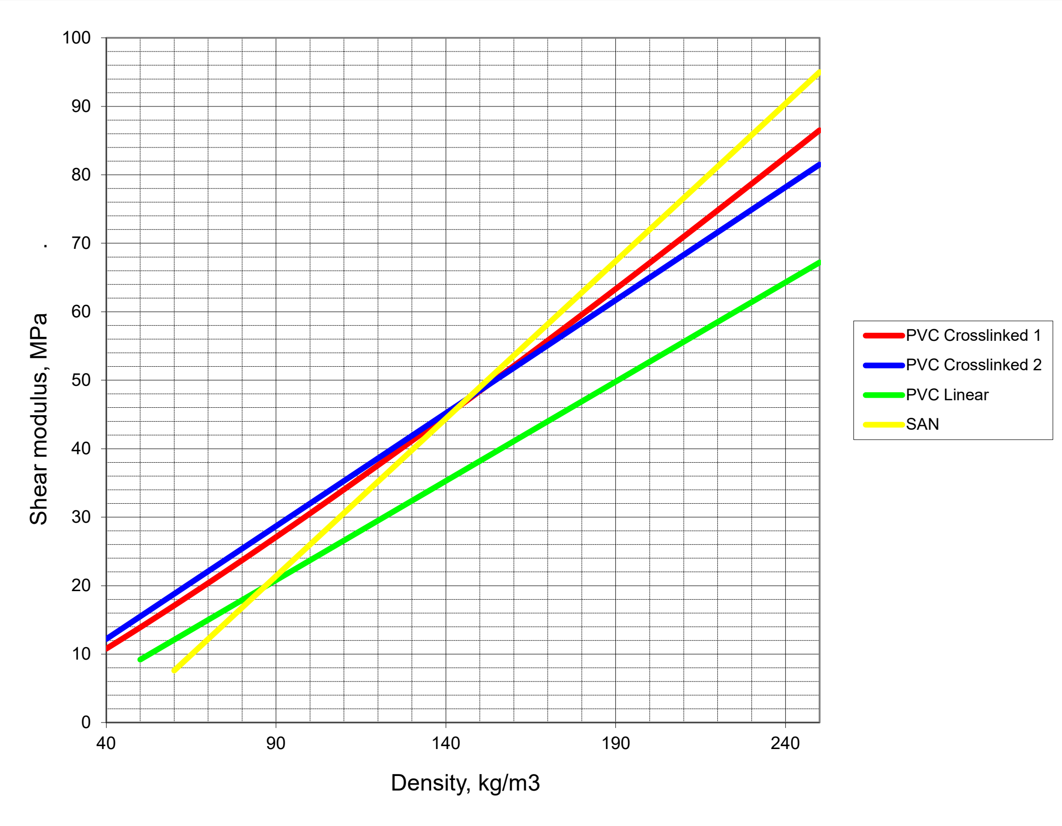

Figure 9.9. Shear modulus for structural foam materials as a function of density.

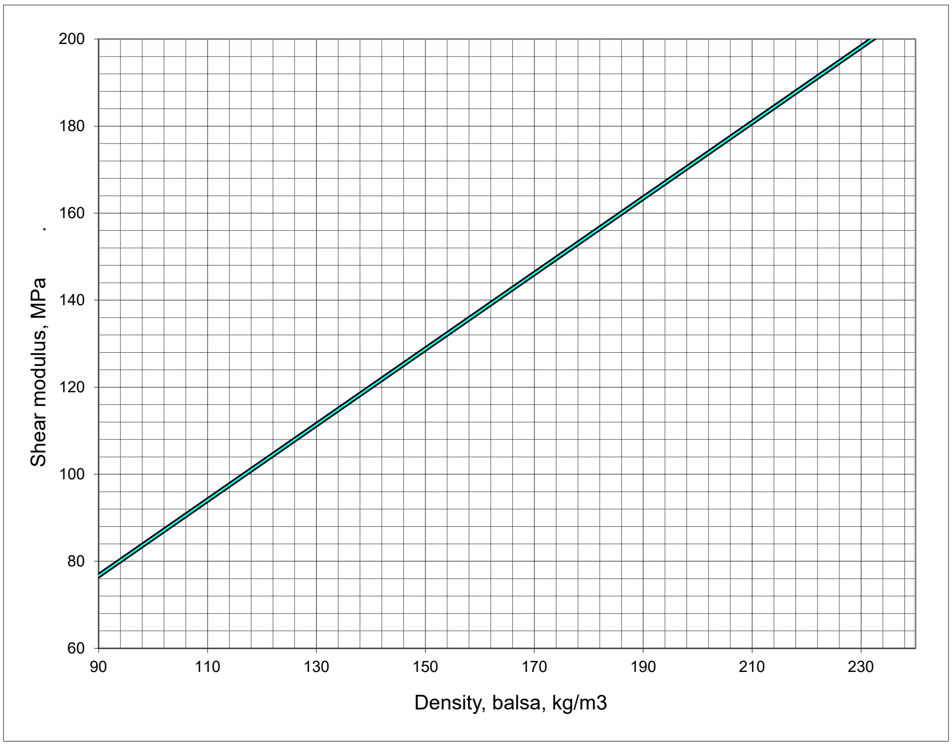

Figure 9.10. Shear modulus of end grain balsa as a function of density

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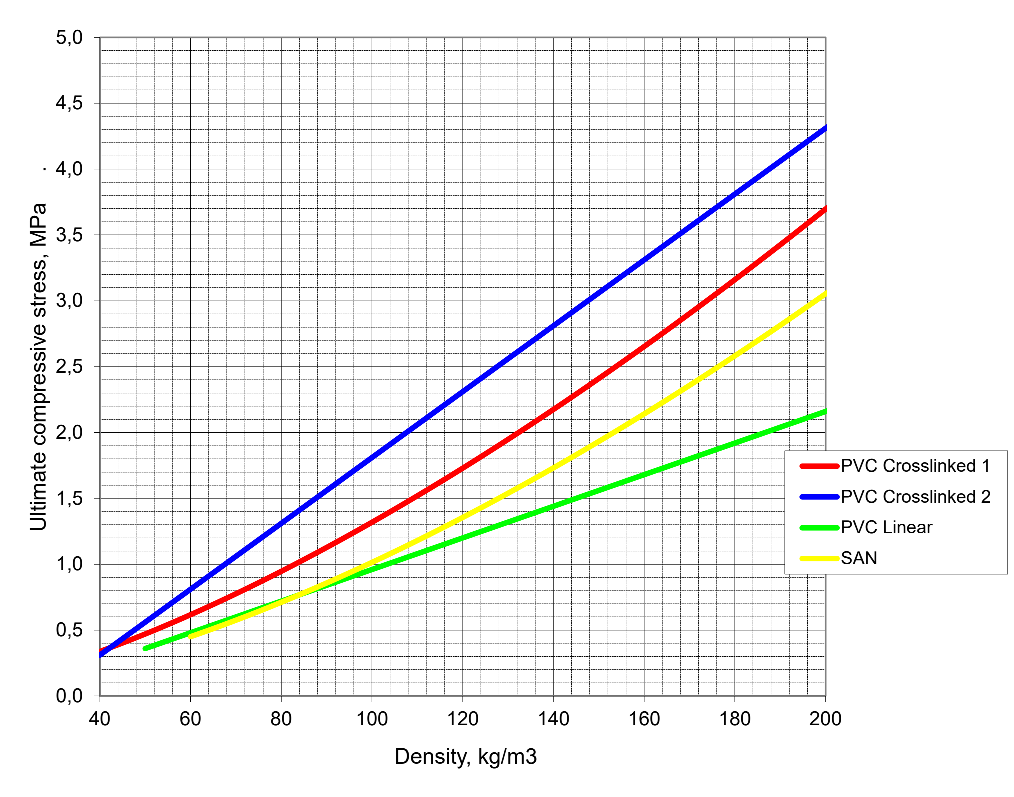


Figure 9.11. Ultimate compressive stress for structural polymer foams as a function of density.

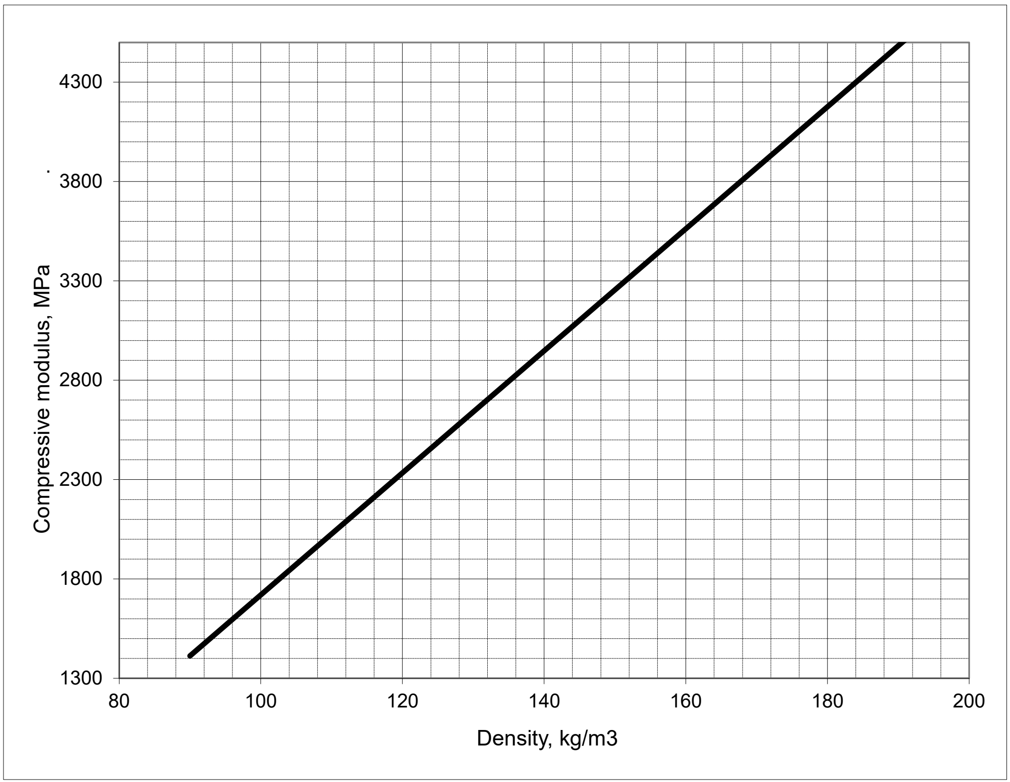


Figure 9.12 Compressive modulus of end grain balsa as a function of density

9.11 Mechanical values to be used for scantling determination

The values used for scantling determination depend on the level of production control, i.e how it is verified that the design values are achieved in production.

If the mechanical properties have been determined by testing, and the tested laminates correspond to the laminate for the structural part in question, the values to be used for scantling determination are:

- For tensile-, compressive-, bending- and shear strength, the smallest of the following
- 90% of the average, μ, value obtained in the tests;
- $\mu - 2 \cdot \sigma$ i.e. the average value μ minus two standard deviations;
- For the modulus, the average value obtained from the test shall be used.

If no testing has been carried out, but the fiber content is regularly monitored in the production, the values determined according to paragraph 9.9.1 are to be used without further correction for scantling determination.

If no testing has been carried out and no monitoring of fiber content during production is done, the values determined according to paragraph 9.9.1 are to be multiplied by 0,8 for scantling determination.

For sandwich core materials, the values obtained from paragraph 9.10.1 shall be used without further correction.

9.12 Adhesives

Adhesives to be used in structural components are to be intended for the combination of materials in question.

For bonding sandwich faces to the core, adhesives developed for that purpose shall be used. Alternatively, shop-made adhesives of the same resin type that is used for lamination may be used.

9.13 Other materials

Plywood shall be water resistant type and its adhesives shall be of class 3: exterior conditions, determined according to standard EN 314-4

Embedded materials such as reinforcements for fittings etc. shall meet the requirements in ISO 12215-3.

10 SCANTLINGS DETERMINATION, FIBRE REINFORCED PLASTICS

10.1 Objective

In this chapter is given equations and allowable stresses for the determination of scantlings for strength members made of fiber-reinforced plastics.

Formulae in this chapter are intended to be used only used with loads defined in Chapter 7, material values from Chapter 9 following the assumptions and structural principles presented in Chapter 8.

10.2 References

The scantlings equations given in this chapter are mainly based on the international standard ISO 12215-5 Small craft – Hull construction and scantlings – Part 5: Design pressures for monohulls, design stresses, scantlings determination.

Compared to the standard, due to the demanding operating conditions of commercial craft , higher minimum reinforcement requirements based on craft length, displacement and speed for minimum strength against local loads are given. Additionally, the allowable stresses are in some cases smaller than in the standard.

In addition, the following standards are referred to for RIB's:

- EN ISO 6185-3 Inflatable boats - Part 3: Boats with a hull length less than 8 m with a motor rating of 15 kW and greater
- EN ISO 6185-4 Inflatable boats. Boats with a hull length of between 8 m and 24 m with a motor power rating of 15 kW and greater

10.3 Documentation

To verify requirements in this chapter, following documentation is required:

- Structural drawings, including the following where relevant:
    - Longitudinal section;
    - Transverse sections;
    - Laminate schedule;
    - The materials used and their mechanical properties (see Chapter 9);
- Scantling calculations indicating the rule requirements for different structural elements and the attained values.

10.4 List of symbols

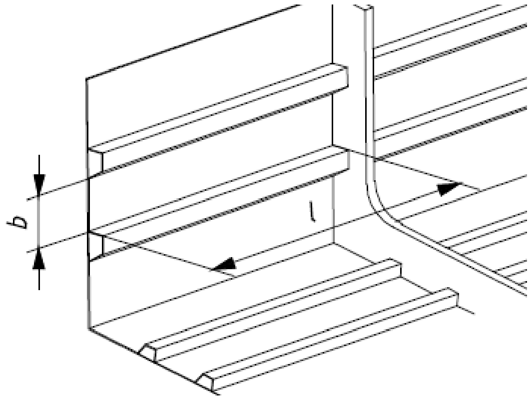
Symbols used in several Chapters are given in Chapter 1. In Table 10.1 some symbols used in this Chapter are listed. In addition, there are symbols defined in their context.

Table 10.1: Symbols used in this Chapter

Symbo	Unit	Description	Reference
p	kPa	Design pressure	Chapter 7
l	mm	Shorter side of panel	
b	mm	Longer side of panel	
s	mm	Stiffener space, load width	
l_U	mm	Unsupported span of stiffener	
t	mm	Laminate thickness	
W	cm^3	Section modulus	
I	cm^4	Second moment of area	
E	MPa	Elasticy modulus	
k_C	-	Correction for curvature	Clause 8.1
σ_d	MPa	Allowable tensile/compressive stress	Clause 12
τ_d	MPa	Allowable shear stress	Clause 12

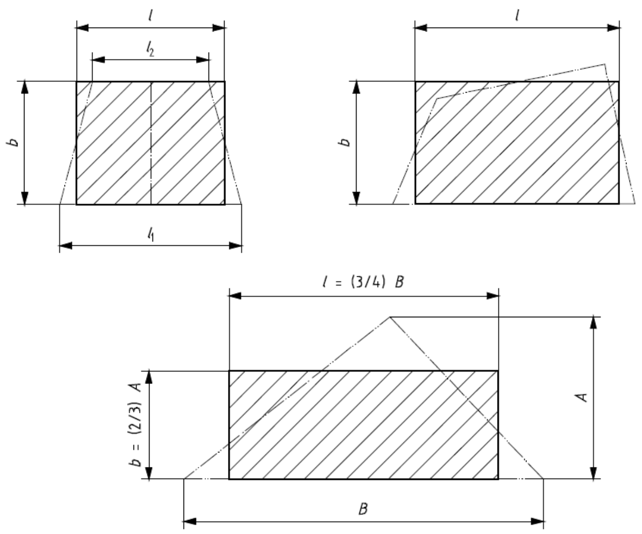
10.5 Dimension of panels

The dimensions of panels are given for some typical cases in Figure 10.1.



a) Rectangle shaped panel. Note that l and b are measured to the web of the stiffener, not to the center of the stiffener, but in the case of stiffeners, l_s is measured to the center of top-hat stiffener that is supporting them.

b)



Some other than rectangular shapes

Figure 10.1 Measures for typical panels

10.6 Scantlings requirements, single skin panels

For single-skin panels, the laminate thickness, excluding gel and topcoats, shall not be less than obtained from formula (10.1):

$$t = b \cdot k_C \cdot \sqrt{\frac{P \cdot k_2}{1000 \cdot \sigma_d}} \text{ [mm]}; \qquad (10.1)$$

Where

k_C = curvature correction factor, see 10.9.

P = design pressure, see Chapter 7.

k_2 = panel aspect correction factor, see. 10.9.

σ_D = allowable stress, see 10.13.

The laminate thickness shall never be less than t_{min} according to Table 10.2.

The thickness requirements obtained from formula 10.1 shall be converted to required area mass of reinforcement as described in Chapter 9 paragraph 9.3.

Note! If the clamping of an edge of a panel is less than that of a panel continuing past its edge stiffeners, the thickness requirement must be adjusted to conform to the actual edge clamping.

if the laminate is strongly directional, and if the stability and global strength of the structure has been confirmed separately, the thickness requirement for laminates can alternatively be calculated using ISO 12215-5 methods 2 (enhanced) or 3 (developed).

10.7 Scantlings requirement, sandwich panels

10.7.1 Bending strength criterion

The section modulus of a 1 cm strip of the sandwich panel, W_O, calculated to the outer (loaded) surface and W_I calculated to the inner side shall be not less than:

$$W_0 \geq \frac{b^2 \cdot k_C^2 \cdot p \cdot k_2}{6 \cdot 10^5 \cdot \sigma_{dto}} \text{ [cm}^3\text{]} \qquad (10.2)$$

$$W_i \geq \frac{b^2 \cdot k_C^2 \cdot p \cdot k_2}{6 \cdot 10^5 \cdot \sigma_{dci}} \text{ [cm}^3\text{]} \qquad (10.3)$$

Where

k_2 correction factor for flexural stress based on panel aspect ratio (see 10.9.2)

σ_{dto} allowable tensile stress in outer face [MPa], see Clause 10.13.

σ_{dto} allowable compressive stress in inner face [MPa]:

$$\sigma_{dci} = 0{,}3 \cdot \sqrt[3]{E_C \cdot E_{CO} \cdot G_C} \text{ or } 0{,}5 \cdot \sigma_{CU} \text{ whichever is less, [MPa]} \qquad (10.4)$$

And

E_C Elasticity modulus of inner face, [MPa]

E_{CO} Elasticity modulus in compression for sandwich core, [MPa]

G_C Shear modulus of the sandwich core in the load direction, [MPa]

σ_{CU} Ultimate compressive strength of laminate, [MPa]

Note! If the clamping of an edge of a panel is less than that of a panel continuing past its edge stiffeners, the thickness requirement must be adjusted to conform to the actual edge clamping.

When determining the section modulus, the laminate thicknesses shall be calculated with the nominal fibre content as described in clause 9.9.1.

10.7.2 Stiffness criterion

The second moment of area of a 1 cm strip of the sandwich panel shall be not less than given in formulae 10.5:

$$I_{1cm} \geq \frac{b^3 \cdot k_C^3 \cdot p \cdot k_3}{12 \cdot 10^6 \cdot k_1 \cdot E_{io}} \text{ [cm}^4\text{]} \qquad (10.5.)$$

Where

k_1 stiffness factor = 0,017

k_3 stiffness correction based on panel aspect ratio, see Clause 10.9.2.

Note! In addition, the requirement in Chapter 8 Clause 8.10.2 shall be met.

When determining the moment of inertia, the thicknesses shall be calculated with the nominal fibre content as described in clause 9.9.1.

10.7.3 Shear criterion

The thickness of a sandwich panel measured as the distance between the mid-points of the skins must be at least as given by formula 10.6:

$$t_s \geq \sqrt{k_C} \cdot \frac{k_{SHC} \cdot P \cdot b}{1000 \cdot \tau_d} \text{ [mm]} \qquad (10.6)$$

Where

$$t_s = t_C + 0{,}5 \cdot (t_i + t_0) \text{ [mm]} \qquad (10.7)$$

And

k_{SHC} shear stress factor based on panel aspect ratio, see Clause 10.9.2.

t_C core thickness, mm

t_i thickness of inner sandwich skin, mm

t_o thickness of outer sandwich skin, mm

10.7.4 Sandwich core minimum compressive strength in hull bottom

The compressive strength of sandwich core material used in hull bottom shall be at least as given by formula 10.8.

$$\sigma_C = 0{,}01 \cdot P_{BMPBASE}\text{, MPa, minimum 1,0 MPa} \qquad (10.8)$$

Where

$P_{PMPBASE}$ bottom slamming pressure, see Chapter 7.

At side the compressive strength of sandwich core material shall be at least 70% of the value given by (10.8).

10.8 Minimum amount of fiber reinforcement for local strength

In addition to the requirements on bending strength, -stiffness and shear load capacity, the mass of the total laminate reinforcement per square meter, w_{min}, must be at least as indicated by the formula below.

$$w_{MIN} \geq 0{,}5 \cdot k_5 \cdot \left(A + k_7 \cdot V + k_8 \cdot m_{LDC}^{\ 0{,}33}\right) \text{ [kg/m}^2\text{]} \qquad (10.9)$$

The speed $V \geq 5 \cdot \sqrt{L_{WL}}$, and the constant A and the factors k_5, k_7 and k_8 are found in Table 10.2.

Table 10.2: Constants and factors to be used in formula 10.9

Area	***A***	***k_5***	***k_7***	***k_8***	**Sandwich outer skin**
Hull bottom	1,5	1)	0,03	0,15	k^5 0,6 w_{MIN}
Hull topside and transom	1,5	1)	0	0,15	k^5 0,6 w_{MIN}
Decks for persons, superstructures	1,5 + 0,2 · L_H	1)	0	0	k^5 0,6 w_{MIN}
Cargo decks, load Q [t/m^2]	3 + 0,5 · Q + 0,15 · L_H	1)	0	0	k^5 0,6 w_{MIN}

1) Correction factor k_5:

- 1,00 for E glass laminate with more than 50% chopped strand mat and the rest woven rowing and/or biaxial.
- 0,90 for E glass laminate with not more than 50% chopped strand mat and the rest woven rowing and/or biaxial.
- 0,70 for Aramid and/or HS carbon fiber laminates consisting of woven and/or bi or multiaxial reinforcements

10.9 Correction factors for panels

10.9.1 Correction for panel curvature

The correction factor kc takes into account the effect the panel curvature has on the flexural strength and flexural rigidity, and on the shear stress of the sandwich panels. It is calculated according to Table 10.3. Intermediate values can be interpolated. Note that the correction factor for curvature is only calculated in the direction of the shorter side of the panel.

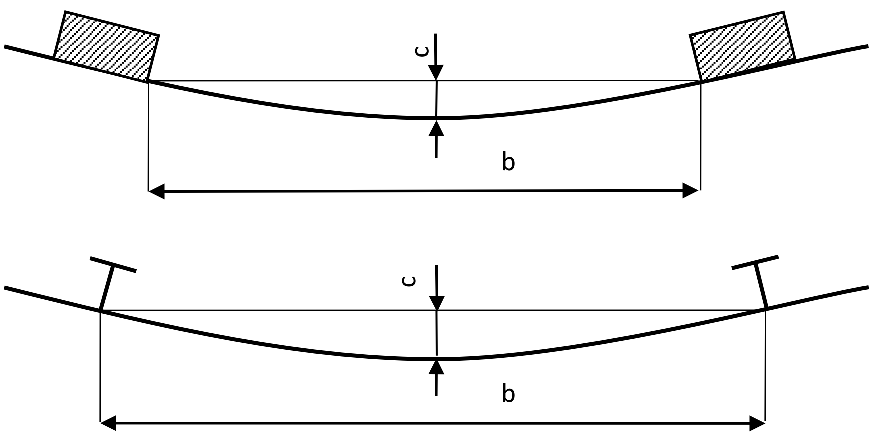


Figure 10.2. Measurements needed for correction for curvature.

Table 10.3. Panel curvature factor kc.

c/*b*	k_C
0…0,03	1,0
0,05	*0,90*
0,10	0,71
0,15	0,60
0,20	0,54
≥0,25	0,5

10.9.2 Correction based on panel aspect ratio

Correction factors based on panel aspect ratio to the flexural stress and stiffness, and core shear stress are found Table 10.4.

Table 10.4. Correction factors on the basis of panel aspect ratio

Aspect ratio	**Correction factor for bending stress**	**Correction factor for bending stiffness**	**Correction factor for shear stress** [1)]
l/*b*	k_2	k_3	k_{SHC}
>2,0	0,500	0,028	0,465
2,0	0,497	0,028	0,463
1,9	0,493	0,027	0,459
1,8	0,487	0,027	0,453
1,7	0,479	0,026	0,445
1,6	0,468	0,025	0,435
1,5	0,454	0,024	0,424
1,4	0,436	0,023	0,410
1,3	0,412	0,021	0,395
1,2	0,383	0,019	0,378
1,1	0,349	0,016	0,360
1,0	0,308	0,014	0,339

10.10 Stiffeners

10.10.1 General

The following requirements apply to stiffeners which have similar laminate stiffnesses. If the rigidity of the flange, web or base laminate of a stiffener differ by more than 25% from each other, the flexural strength and rigidity of the stiffener shall be determined using the method for orthotropic stiffeners in ISO 12215-5.

10.10.2 Section modulus

The section modulus calculated to the outer face (loaded side), W_o, and the flange, W_i, shall be at least as given by equations 10.10 and 10.11.

$$W_0 \geq \frac{83{,}3 \cdot k_{CS} \cdot p \cdot s \cdot l_U^2}{\sigma_{do}} \cdot 10^{-9} \text{ [cm}^3\text{]} \qquad (10.10)$$

$$W_i \geq \frac{83{,}3 \cdot k_{CS} \cdot p \cdot s \cdot l_U^2}{\sigma_{di}} \cdot 10^{-9} \text{ [cm}^3\text{]} \qquad (10.11)$$

Where

l_U stiffener span, measured in the case of top-hat type supporting stiffeners from center to center of them, not needed to be taken greater than $330 \cdot L_H$ [mm]

k_{CS} correction factor for stiffener curvature, see Table 10.5.

σ_{di} allowed design stress for inner skin laminate, [MPa], see clause 10.13

σ_{do} allowed design stress for outer skin laminate, [MPa], see clause 10.13

Table 10.5: Correction factor for stiffener curvature, k_{CS}

c_U/l_U	k_{CS}
0…0,03	1,0
0,03…0,18	1,1 – 3,33 · c_U/l_U
0,18…	0,5

When calculating the section modulus of the actual stiffener, the laminate thicknesses shall be determined for the appropriate fiber content for the laminate in question according to Chapter 9 clause 9.9.1.

If the end fixity of one or both ends of the stiffener differs from the situation, where a stiffener is continuous over its support points, the required section modulus shall be corrected to correspond to the real end fixity.

10.10.3 Second moment of area

The second moment of area, I, including effective flange according to Clause 9.4, shall be at least as given by formula 10.12.

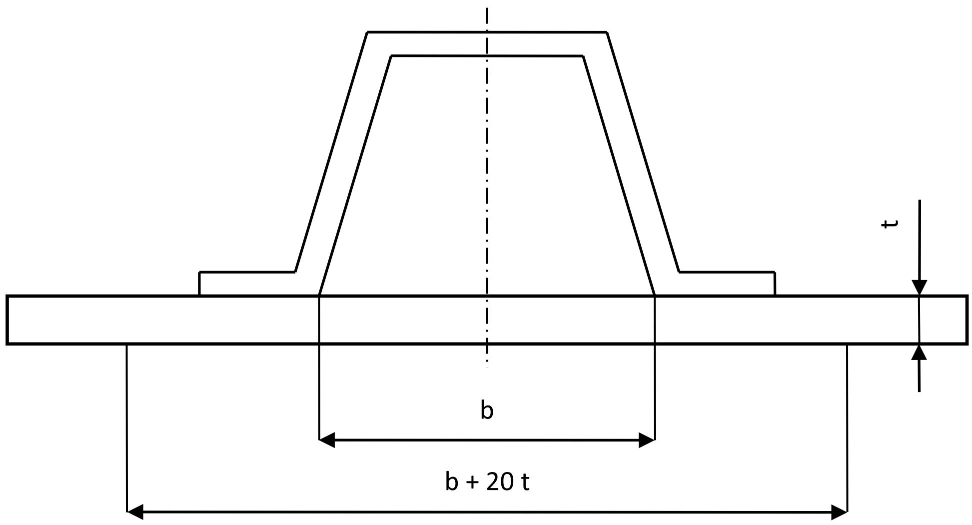
$$I \geq \frac{26 \cdot k_{CS}^{1,5} \cdot p \cdot s \cdot l_U^3 \cdot 10^{-9}}{k_{1S} \cdot E_{TC}} \text{ [cm}^4\text{]} \qquad (10.12)$$

Where

l_U stiffener span, not needed to be taken greater than $330 \cdot L_H$ [mm]
k_{CS} correction factor for stiffener curvature, see Table 10.5.
E_{TC} average value of tensile and compressive moduli, [MPa]
k_{1S} stiffness factor=0,05

10.10.4 Effective flange

When calculating the section modulus SM and moment of inertia I, the effective flange associated with the stiffener shall be taken into account. When calculating the geometric properties, a width equal to the stiffener width plus 20 times the thickness of the laminate may be considered the effective flange of the stiffener, see Figure 10.3. However, if the table A.11 in ISO 12215-5 gives a smaller value, that value shall be used. When determining the moment of inertia, the laminate thicknesses shall be determined for the appropriate fiber content for the laminate in question according to Chapter 9 clause 9.9.1.



Kuva 10.3: Effective flange of stiffener

10.10.5 Cross-section of stiffener web

The cross-section of the web of the stiffener must be at least as given by formula 10.13

$$AW = \frac{k_{SA} \cdot p \cdot s \cdot l_U \cdot 10^{-6}}{\tau_d} \ [cm^2] \quad (10.13)$$

Where

k_{SA} = factor for cross-sectional area.

- k_{SA} = 5 if the stiffener is attached to plating
- k_{SA} = 7.5 for floating stiffeners

t_d = allowable shear stress for webs, MPa

When determining the shear area, the laminate thicknesses shall be determined for the appropriate fiber content for the laminate in question according to Chapter 9 clause 9.9.1

10.10.6 Orthotropic stiffeners

Stiffeners built with laminates with moduli that differ by more than 25% from each other are to be assessed using the procedure presented in the standard ISO 12215-5 item A.12.3.

10.10.7 Buckling of stiffeners

Where the normal stress in the crown or flanges or the shear stress in the web exceeds 80% of allowable stress, the potential risk of stiffener buckling must be estimated using the procedure presented in the standard ISO 12215-5 item A.12.6.

10.11 Reinforced shell areas

10.11.1 General

Where applicable, the strengthened areas of the hull must conform to Figure 10.4

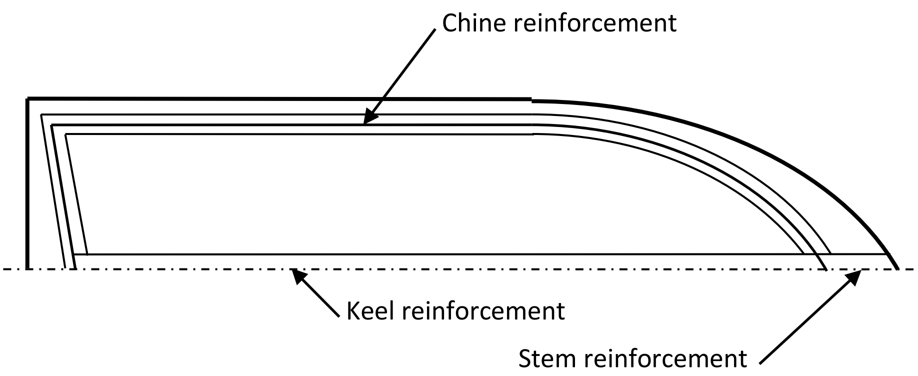


Figure 10.4. Reinforced laminate areas

10.11.2 Reinforced keel

Keel structures shall be strengthened to sustain loads from docking and/or transporting the craft on a trailer. This requirement is considered to be fulfilled, when the requirements for the keel laminates and section modulus presented in Table 10.6 are met. The section modulus of the keel is also to be assessed as a bottom stiffener.

10.11.3 Reinforced stem

The stem post shall be reinforced as given in Table 10.6

10.11.4 Reinforced chine

The corners of chines including the sharp corner of transoms, must be strengthened for their entire length according to Table 10.6

10.11.5 Edge of deck and hull/deck joint

If the edge of the deck or the hull/deck joint is the widest part of the craft, they are to be strengthened to withstand loads from collision with piers, docking and handling of the craft ashore. The deck edge or hull/deck joint usually functions as a stiffener for hull topsides. The hull/deck joint shall be watertight for craft in design category A, B and C.

Table 10.6: Reinforced laminate areas, minimum fibre mass.

Structural member	**Width on both sides of centreline**	**Single skin** [kg/m^2]	**Sandwich outer skin** Inner skin = 0,7 ·outer skin [kg/m^2] w_{MIN} = Eq. 10.9
Keel	80 · B_H	1,0 + 2,2w_{MIN} (bottom) 1)	1,7 w_{MIN} (bottom) 1)
Stem post	40 · B_H	1,0 + 2,0w_{MIN} (bottom) 1)	1,5 w_{MIN} (bottom) 1)
Chine	40 · B_H	1,0 + 1,7w_{MIN} (bottom) 1)	1,2 w_{MIN} (bottom) 1)

1)see 10.8

10.12 Highly loaded structures

10.12.1 Engine foundations

Engine foundations shall be strong and stiff enough to carry the weight and loads of the engine. Such loads are:

- Weight of the engine and additional dynamic forces from craft’s motion;
- Propulsion force (in cases where no thrust bearing is fitted);
- Torsion from the propeller;
- Vibration.

Engine foundations must be securely fixed to primary athwartship stiffeners like bulkheads or web frames. Foundations shall be supported against buckling and collapsing, especially near engine holding down bolts.

Areas where the engine is fixed to the foundation must be strengthened with metal or a corresponding material.

10.12.2 Transoms for outboard and sterndrive engines

The transom design should ensure that the moment, mass forces and thrust from the outboard engine or sterndrive will be transferred into the primary structure without creating excessive stresses.

For engines with big power, the transom shall be engineered using the design loads given in paragraph 7.12

The following requirements apply, assuming sandwich construction of the transom.

The core is to consist of plywood, high density foam or corresponding material with a ultimate compressive stress of at least 4 MPa. If plywood is used, it has to be of durability class 1 or 2 according to ISO 12215-3.

The thickness of the transom, measured between centers of skin laminates, shall be at least as given by formula (10.14)

$$t_{transomcore} = 35 + P^{0,5} \text{ [mm]} \qquad (10.14)$$

Where

P = total engine power installed on the transom, [kW]

The skin laminates shall be at least as given by formula (10.15)

$$w_{transomskin} = 0{,}14\, P^{0,55} \qquad \text{min. 1,40 kg/m2} \qquad (10.15)$$

The engine mounting bolts should be equipped with metal washers that distribute the forces evenly on the inner face of the transom.

10.12.3 Attachment of mooring and other highly loaded fittings

The foundations of mooring and towing fittings, rails, pulpits, lifeline stanchions, winches and similar items must be dimensioned to withstand loads as per ISO 15084.

10.12.4 Attachment of railings, handholds and lifeline hooking points

Attachment of railings, handholds and lifeline hooking points shall meet the requirements of ISO 15085.

10.12.5 Design of attachment points

The reinforcement of single-skin laminate at highly loaded fittings shall in general be carried out by adding additional laminate, installing plywood or metal reinforcements, or a combination of these.

Where highly loaded fittings are fixed to sandwich laminates, the core shall either have sufficient compressive strength or be replaced with spacers or single-skin laminate. The sandwich faces shall be locally reinforced with additional laminate.

10.12.6 Attachment of RIB-pontoon

The attachment of the RIB-pontoon to the rigid hull shall be designed to transmit the loads without stress peaks. Special attention shall be paid to the attachment in the bow and stern. The attachment shall be tested according to ISO 6185-3 for craft with a hull length of less than 8 m and ISO 6185-4 for bigger craft, or a verified method giving the same strength level as the standards mentioned above

10.13 Design stresses

The design stresses to be used in the equations in this chapter are presented in Table 10.7, where σ_{UF} [MPa] is ultimate flexural strength, σ_{UC} [MPa] is ultimate compressive strength, σ_{UT} [MPa] is ultimate tensile strength, and τ_{XY} [MPa] is ultimate shear strength measured in the laminate plane.

Table 10.7 Design stresses

Structural member	**Detail**	**Design stress**
Single skin panels		$\sigma_{UF}/3,00$
Sandwich panels	Outer skin, $\square_{do}$	$\sigma_{UC}/2,00$
	Inner skin, $\square_{di}$	$\sigma_{UT}/2,00$
Sandwich core shear stress	Balsa	$\tau_U/3,00$
	Foam, elongation at break < 20 %	$\tau_U/2,73$
	Foam, elongation at break > 20 %	$\tau_U/2,31$
Stiffeners	Flange	$\sigma_{UC}/2,00$
	Base laminate (effective flange)	$\sigma_{UT}/2,00$
	Webs	$\tau_{XY}/2,00$
Transom structure	Parts under compressive stress	$\sigma_{UC}/2,00$
	Parts under tensile stress	$\sigma_{UT}/2,00$
	Parts aunder shear stress in laminate plane	$\tau_{XY}/2,00$

11 PRODUCTION OF FIBRE-REINFORCED PLASTIC CRAFT

11.1 Objective

The requirements in this chapter apply to the manufacturing of craft of fiber reinforced plastics. A prerequisite for applying the rules in this chapter is that the raw-materials, the structure and scantlings meet the requirements in Chapters 8, 9 and 10 respectively.

The rules apply to individually built craft and, as applicable, to series built boats.

11.2 References

The requirements are partly based on the international standard ISO 12215-4 - Small craft — Hull construction and scantlings —Part 4: Workshop and manufacturing

11.3 Documentation

To verify the compliance with the requirements in this chapter, a production report for each individual craft is to be prepared. The report shall be readily identifiable by means of the Craft Identification Code, the yards' newbuilding number or similar and shall include the following information as relevant:

- Reference to the laminate schedule;
- The manufaturer, typecodes and batch numbers of the used laminating resins, fiber reinforcements, sandwich core materials;
- Lamination log (i.e. the sequence of reinforcement layers, curing, possible surface treatment after curing);
- Temperature and humidity log for the lamination area during the lamination and curing
- Reports of possible problems encountered during lamination and the remedy
- Thickness gauging report of the hull laminate
- Reports of mechanical tests and / or determination of fiber content

11.4 Workshop conditions

The laminating shop shall be substantially free from draughts so that the temperature can be kept constant during the laminating process. Ventilation systems shall ensure a suitable production environment throughout the entire lamination area.

The ambient temperature (i.e. temperature in the laminating shop) shall fulfill requirements by resin manufacturer or be at least 18° and the variation during the moulding process shall not be more than ±3 °C from the required nominal temperature. This temperature shall be reached at least 24 hours before the moulding starts.

A higher temperature is permitted during the curing process or in a separate curing space.

The lamination shop shall be insulated and built in such a way that the indoor temperature is not significantly affected by the outdoor temperature or sunlight. Windows shall be painted over or screened off if they are subject to direct sunlight.

The relative air humidity shall be as constant as possible and shall not exceed 80%. When using a spray lay-up technique, the relative air humidity shall be at least 40%.

Temperature and humidity shall be regularly recorded during the lamination and at least 48 hours after the lamination.

The moulding shop shall be clean and substantially free of dust. Grinding and woodworking shall be avoided during lamination and, when necessary, the laminate shall be cleaned thoroughly before continuing lamination.

11.5 Material storage

The purchase-, receiving- and storage processes shall assure that:

- The correct type of material is used for every craft;
- It can be traced which batch of raw-material is used for a particular craft.

Storage premises shall be dry and clean. In particular, packages of glassfibre reinforcement and sandwich core material shall be kept free from dust and moisture.

Raw materials shall be stored according to the raw-material manufacturer's recommendation. Materials, which have passed their expiry date must not be used for load-carrying structures.

Storage tanks for resin shall be equipped with an effective means of stirring which is to be carried out regularly.

Fibre reinforcements shall be kept for at least 48 hours at a temperature at least 2 ºC higher and at a lower humidity than that of the moulding shop before they are transferred there. If the glassfibre has been sealed in plastic, the package shall be opened and kept for at least 48 hours in the moulding shop prior to use.

11.6 Lamination

11.6.1 Requirements for all types of laminates

All materials shall be according to the laminate schedule.

The amount and mixing of catalyst or hardener shall be according to the resin manufacturer's recommendation.

The reinforcement layers shall be applied in the sequence shown on the lamination drawings. The coverage, fiber directions, overlapping, layer drop-off and other details shall be according to the lamination drawings.

The lamination sequence shall be recorded such that it can be compared with the lamination drawings.

The fiber content of the cured laminate shall correspond to the nominal fiber content (see Chapter 9).

The amount of laminate to be laminated at one time, shall be planned such that the pot-life of the resin is not exceeded.

When laminating thick layers, care shall be taken not to damage the laminate by exothermic heat (the heat distortion temperature or glass transition temperature is not to be exceeded).

When using resin transfer molding or vacuum assisted resin transfer molding, fiber wetting shall be confirmed by documentation of the amount of used resin and knocking inspection of the cured laminate, and also visual monitoring during the lamination, if possible.

11.6.2 Polyester- and vinylester laminates

On all external surfaces there shall be an even gelcoat layer or an equivalent surface treatment applied after the lamination. The gelcoat shall have a thickness of 0.4 - 6 mm and shall be applied without significant thickness variation

As a minimum, the outermost layer of the hull laminate shall be made with isophtalic resin or vinylester resin. If the hull is made entirely using orthophtalic resin, the area beneath the loaded waterline plus 100 mm shall be treated with a minimum of two layers of epoxy paint

Powder-bound mat max 450g/m2 shall in general be used as the first reinforcement layer after the gelcoat in the hull.

In areas where no topcoat is applied, the final layer of the laminate shall contain paraffin or similar to prevent styrene evaporation and ensure that the curing will be satisfactory.

11.6.3 Epoxy laminates

If gelcoat is used together with epoxy laminate, the compatibility shall be documented

A layer of peel-ply shall be applied as the final layer before every curing. The peel-ply shall not be removed until the secondary lamination commences.

11.7 Sandwich construction

The type, thickness and density of the sandwich core shall be according to the laminating drawings.

Sandwich core materials with open cells on the surface shall be impregnated with resin or filling putty before bonding the core to the laminate.

When using core materials which are grid-scored, it shall be ensured that all cavities are filled with resin or putty.

When bonding sandwich cores to wet laminate without vacuum-bagging, the uncured laminate shall be at least 450 g/m^2 on straight surfaces and 900 g/m^2 on curved surfaces.

Sandwich cores or plywood without grid-scoring shall be bonded to the wet laminate with vacuum-bagging, evenly distributed weight or similar to ensure a good bond.

All joints and cavities in the core shall be filled with resin or putty before lamination is commenced. All unevennesses shall be removed.

Other techniques such as vacuum bagging may be used with less adhesive than required above if it can be demonstrated, that it results in an effective bond between the core and laminate.

11.8 Secondary lamination

11.8.1 Polyester- and vinylester laminates

The surface treatment prior to secondary lamination shall be carried out in accordance with the resin manufacturer's recommendations. The following requirements are to be met as a minimum where no such recommendations are given:

- The cured laminate shall always be at least lightly sanded to remove irregularities from the surface before secondary lamination.
- When secondary lamination is started more than 48 hours after lamination of the previous layer, the laminate shall be grinded to expose fibers on the surface. All dust is to be removed.
- If there is paraffin on the surface, it shall be removed by washing or similar unless the previous lamination is so fresh that the paraffin will dilute into the next laminate layer.
- Gel- and topcoat shall always be removed from the bonding area before secondary bonding.
- Where peel-ply has been used, no sanding is required.

11.8.2 Epoxy laminates

After removal of the peel-ply possible (small) areas where the peel-ply has not been in contact with the laminate surface shall be sanded so to achieve a matt surface, and all dust shall be removed. After that the surface is to be washed with acetone unless it can be demonstrated by testing that an acceptable interlaminar shear strength (ILSS) can be achieved without acetone washing.

If the laminate has cured without peel-ply, the surface is to be washed with warm water or acetone, and let to dry. After that the surface is to be sanded thoroughly and cleaned with acetone prior to secondary lamination.

11.9 Adhesive bonding

Adhesive bonding shall be carried out according to the adhesive manufacturer's recommendation. Particularly, attention shall be given to the surface treatment of the bonding surfaces, the control of the bondline thickness and the usable working time to assemble the components to be bonded.

11.10 Curing

Gelcoat must not cure more than 24 hours before the first laminate layer is applied

With the exception of trimming the edges, the laminate must not be machined or be subject to loads during the curing.

The ambient temperature during curing must not be so high that the heat distortion temperature (HDT) for polyester and vinylester or the glass transition temperature for epoxies is reached in the laminate.

The curing shall be carried out within the temperature range recommended by the resin manufacturer.

When demoulding the cured components, they are to be properly supported to avoid distortion until all stiffeners are fitted.

11.11 Thickness gauging

The objective of the thickness gauging is to check, that the laminate is manufactured according to the laminating drawings. The measured thicknesses shall be compared to the laminate thickness requirements calculated using the nominal fiber content (see clause 9.9.1). Alternatively, the total fiber reinforcement area mass in the laminate can be approximatively determined on basis of the nominal fiber content and compared to the laminate drawings. The thickness gauging may be carried out using any of the following methods:

- With an recognized NDT-method after demoulding;
- By measuring directly from cut-outs in the laminate.

The thickness may be measured including gel- and topcoat, but in such case 0,6 mm shall be deducted from the measured thickness for the gelcoat and 0,4 mm for the topcoat.

The thickness requirement is deemed to pass the requirement if, for the laminate area in question, the mean value of measurements exceeds the requirement from Chapter 10. In addition, no single measurement must not be less than 85% of the thickness requirement

11.12 Material testing

It shall be ensured, that the used raw materials in conjunction with the manufacturing process results in mechanical properties of the laminate, which are at least as the assumed values for determination of the scantlings. The production control is connected to the assumptions in the scantling calculations through the mechanical properties of the laminates. There are three levels of production controls to choose from. These depend on the extent of the mechanical testing and monitoring of fiber content (see paragraph 9.11).

Mechanical testing shall be carried out according to the standards listed in Chapter 9.

12 STRUCTURAL DESIGN PRINCIPLES, ALUMINIUM

12.1 Objective

In this chapter is given requirements for the structural arrangement and the details of the structure. In addition, the principles for the assessment of the structure are defined. The purpose of the requirements presented in this chapter is to ensure that the structural arrangement and details of the craft has been carried out correctly taking into account the special properties of aluminium and that the procedures for assessing the structure are unambiguous.

This Chapter is to be used in conjunction with Chapter 7 (Design pressures and loads), Chapter 13 (Aluminium materials), Chapter 14 (Scantlings, aluminium craft) and Chapter 15 (Production of aluminium craft)

12.2 References

Requirements in chis chapter are partly based on international standard ISO 12215-6. Small craft - Hull construction and scantlings -- Part 6: Structural arrangements and details.

12.3 Principles of structural analysis

12.3.1 Simplified calculation method

If the following conditions are met the scantlings may be analysed using the simplified calculation method:

- The structural arrangement is according to paragraph 12.6;
- The assumptions in paragraph 12.4 are valid;
- The craft does not have features, which makes it critical to global loads, see paragraph 12.5.

The "Simplified calculation method" means that the scantlings are determined using the formulae for panels, stiffeners etc. given in Chapter 14 using the loads in Chapter 7 and the allowable stresses given in Chapter 14.

12.3.2 Direct calculation of stresses and strains

For other cases than those mentioned in 12.3.1, general methods of strength of materials shall be followed, for example finite element method For such analysis, the loads given in Chapter 7 and the design stresses given in Chapter 14 shall be used.

12.4 Assumptions

12.4.1 Assumptions regarding local vs. global strength and stiffness

The scantling determination method presented in Chapter 14 is based on dimensioning against local loads. Normally, this will result in scantlings, which are adequate also for global loads. Where this is not the case, the dimensioning against global loads shall be assessed, see paragraph 12.5.

12.4.2 Hierarchy of the load carrying elements

When calculating requirements for panels and stiffeners according to Chapter 14, the hierarchy of structure is assumed to adhere to the following principles:

- The panel is supported by secondary stiffeners supported by primary stiffeners as indicated in Figure 12.1
- The primary stiffeners are at least twice as stiff as the secondary stiffeners, i.e:

$$\frac{I_p}{l_p^3} \Big/ \frac{I_s}{l_s^3} \geq 2 \qquad (12.1)$$

- The load is uniformly distributed;
- The edges of the panel are clamped;
- The ends of the stiffeners are fixed.

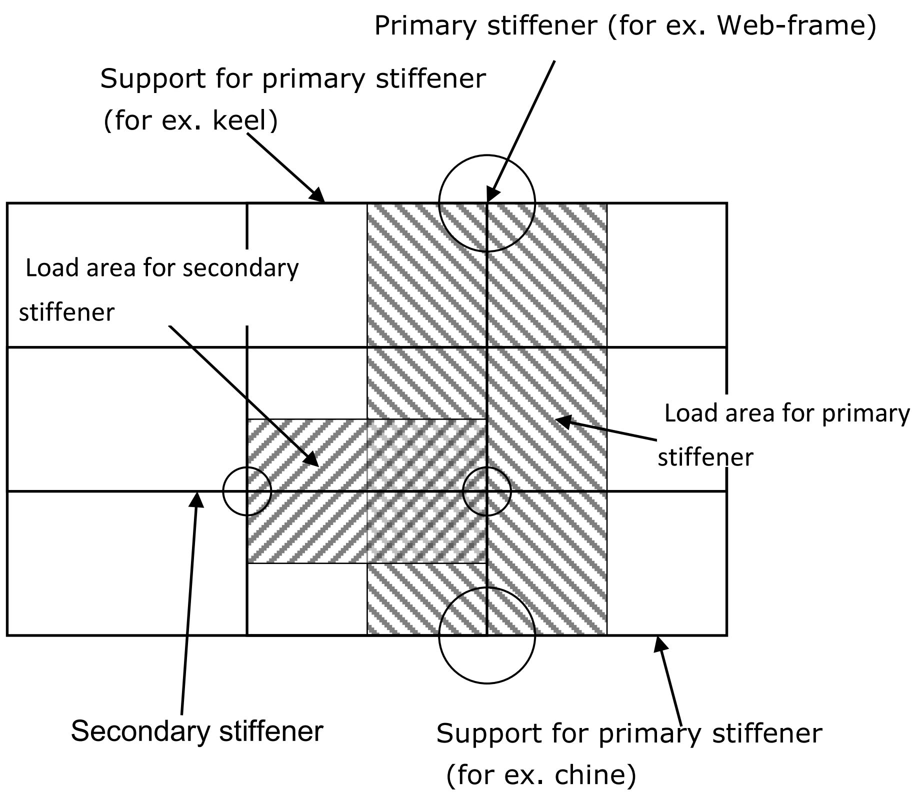


Figure 12.1. Hierarchy of stiffeners.

12.5 Global strength and stiffness

In the following cases also the global strength and stiffness must be investigated:

- If the bottom is only transversely stiffened and its relative speed $V/\sqrt{L_{WL}}>6$
- If there are (large) openings in the deck;
- If the ratio of the hull length to the hull depth $L_H/D_{MAX}>12$

The global strength and stiffness shall be determined according to ISO 12215-6 Annex D. At least the deck shall be checked against buckling (compressive stress in the deck). For craft with only transverse stiffening in the bottom also the strength of the bottom shall be checked.

For multihull craft, the strength shall be assessed in the global load cases given in Chapter 7.

12.6 Structural arrangement

12.6.1 Displacement craft, design category D

Boats in design category D with $V/\sqrt{LWL} \leq 6$, may be stiffened by the keel, gunwale and transverse stiffeners alone. Boats in higher design categories may only be stiffened by transverse framing alone if an assessment of the global strength and stiffness is carried out, see paragraph 12.5.

12.6.2 Planing craft

Boats with $V/\sqrt{LWL} > 6$, should in general have longitudinal stiffening in the bottom. The details of longitudinal stiffeners shall meet the requirements of paragraph 7.

12.6.3 Support for longitudinal stiffeners

The bottom longitudinal stiffeners shall in general be supported by transverse stiffeners such as bulkheads, web frames or deep floors, which are to be designed to carry the load acting on the hull area in question, see Figure 12.1.. The details of transverse stiffeners shall meet the requirements in paragraph 12.7.

12.6.4 Keels, stem and chines

The craft shall have a reinforced keel, stem and chines according to Chapter 14.

12.6.5 Torsional stiffness and -strength

The torsional strength and stiffness is considered adequate if the craft has one of the following items:

- A full deck;
- Tranverse bulkheads;
- A strengthened bulwark.

12.6.6 Superstructure support points

The loads imposed by superstructures shall be led into bulkheads, webframes or other primary structure.

12.7 Hull stiffeners

12.7.1 Continuity and termination of stiffeners

In craft where V /√LWL>6, the bottom longitudinal stiffeners shall be continuous. Terminating of stiffeners on a panel between stiffeners shall be avoided. With the exceptions of paragraph 12.9.2, the ends of stiffeners shall be fastened to other stiffeners

12.7.2 Straightness and local discontinuities of stiffeners

Hull stiffeners shall be as straight as possible. At most 30 degrees are accepted, provided buckling support is arranged at the points where the direction change. Abrupt changes in the cross section of the stiffeners shall be avoided. If the stiffeners have local discontinuities, the transition shall be smooth and corners shall be rounded, radius at least 30 mm.

12.7.3 Safety against buckling

The cross section of stiffeners shall be such that they are not prone to buckling. Stiffeners with one web without flange are not allowed at bottom area. Stiffeners with one web must not be fastened at an angle exceeding 30 degrees relative to the normal against the panel.

12.7.4 Transverse stiffeners

The hull transverse stiffeners such as bulkheads, webframes and deep floors, shall extend from side to side of the hull. When calculating the section modulus requirement of a web frame, the span shall be taken as the distance between chines. However, if the section modulus of the keel meets the requirements in paragraph 14.8, the stiffeners span may be taken as the distance between the chine and the keel.

12.7.5 Floating stiffeners

Arrangements, where stiffeners are not fastened to the bottom (floating stiffener), shall only be used if it is verified that the stiffener is not critical for buckling. This is assessed according to ISO 12215-6, clause 6.3.4.

12.8 Other stiffeners

The stiffening arrangement of decks, superstructures and bulkheads shall comprise of secondary stiffeners supported by primary stiffeners according to the principles in paragraph 12.4.2.

12.9 Construction details

12.9.1 Joining plates of different thickness

The thickness difference between adjacent hull plates shall not exceed 25% of the thicker plate unless the edge of the thicker plate is bevelled.

12.9.2 Fastening and joints of stiffeners

The stiffener including its fastening shall be able to carry the bending moment and shear force in Chapter 14 paragraph 14.8 without exceeding the design stresses given in Chapter 14.

If a stiffener is continuous through a web frame or bulkhead, a bracket is not required at the intersection. If the stiffener is cut off for instance at a watertight bulkhead, the end(s) shall be connected by means of brackets or similar to ensure, that the stiffness and strength of joint corresponds to that of a continuous stiffener.

The ends of stiffeners shall, with the following exceptions, be connected to other stiffeners. Termination of stiffeners within a plate panel is allowed under the following conditions.

(1) In the bottom structure, all design categories, side structure of craft in design category A and B:

- The stiffener ends at an angle of at least 15 degrees relative to a line through the last support point and the stiffener end, or
- The stiffener ends at a stiff area, for instance near the keel or chine;
- In both case the bending and shear stress must not exceed half of the design stress as given in Chapter 14 and
- The end of the stiffener shall be sniped at least 3:1 and
- The distance from the stiffener end to a stiff point is at most 35 mm.

(2) Other applications, all design categories

- The end of the stiffener shall be sniped at least 3:1 and the distance from the stiffener end to a stiff point is at most 35-75 mm

12.9.3 Openings in load-bearing structures

12.9.3.1 General

The effect of openings in load-bearing structures shall be taken into account. Opening shall, where necessary, be supported against buckling at their edges by flanges or similar.

12.9.3.2 Openings in hull stiffeners

With the exceptions given below, openings in hull stiffeners are not allowed, unless it can be shown by calculation that the stiffener meets the requirements of Chapter 14 including the opening.

In the webs, no openings are to be located within 20% of the length of the stiffeners from the support points. In other locations of the webs openings with a height not exceeding 50% of the web height and a length not exceeding 75% of the web height are allowed.

12.9.4 Sharp edges

Sharp edges or notches are not allowed in loaded structures.

12.9.5 Other details

Structures, which accumulate water shall be avoided as far as possible. Locations, where water may accumulate shall be accessible (definition see chapter 31).

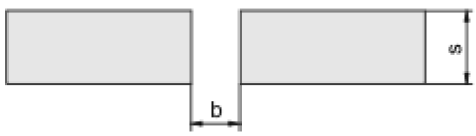
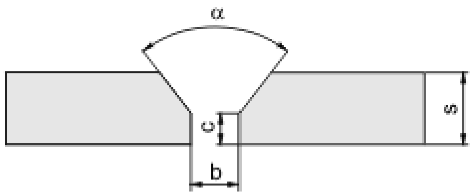
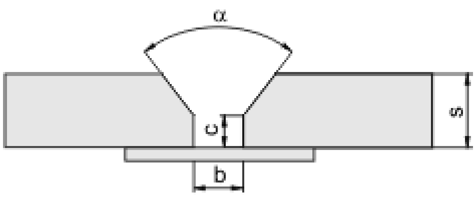
12.9.6 Corrosion

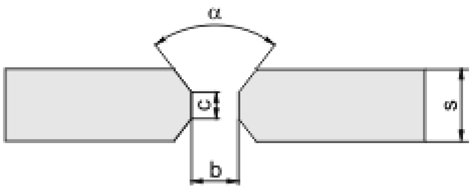
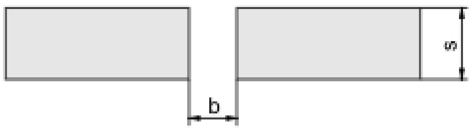
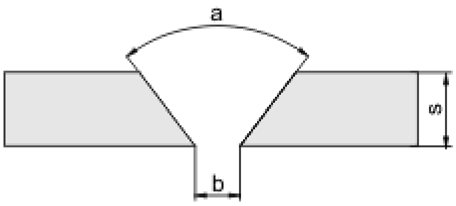
All items fitted to the underwater hull, which are not the same material as the hull, shall be isolated for instance by sealant to avoid crevice corrosion. With the exception of acid-proof steel AISI 316, those items shall also be electrically isolated from the hull. Sacrificial anodes are required if the craft is equipped with an AC shore connection.

12.10 Welding

The weld joint geometry shall be according to Table 12.1.

Table 12.1. Geometry of welding joints

Joint type	Joint dimensions	Comments
MIG		
	s = 1.5...5 mm b = 0...2 mm	Welding from one side only. Back-up strip shall be used.
	s = 5...25 mm b = 0...3 mm c = 1.5...3 mm α = 60...100°	Largest angle recommended for under-up position. Gouging and re-welding shall be carried out.
	s = 8...25 mm b = 3...7 mm c = 2...4 mm α = 40...60°	Smallest joint angle may be used up to 15 mm and with the largest root cap. Vertical position, under-up and side-in require a large root cap.

	s = 12...25 mm b = 0...2 mm c = 3...5 mm α = 50...70°	Specially allowed for automatic welding. Semiautomatic processes may be used in all positions, and gouging shall be performed prior to welding from the other side.
	TIG	
	s < 2 mm	
	s < 4 mm b = 0...2 mm	Welding from one side.
	s = 4...10 mm b = 0...2 mm α = 60...70°	Back-up strip shall be used in a horizontal position.

s= Material thickness, mm

b = Root gap, mm

c = Root face, mm

α = Joint angle, degrees

Welding shall be carried out in accordance with table 12.2. The notations in the table are the minimum requirements.

Table 12.2. Minimum requirements for welding

Application	Design category			
	A	B	C	D
Hull shell plating butt welds s <5 mm	CDB	CDB	CSB	CSB
Hull shell plating butt welds s => 5mm	CDB	CDB	CDB	-

Other plating butt welds s < 5 mm	CSB	CSB	CSB	CSB
Other plating butt welds s => 5 mm	CDB	CDB	CDB	-
Hull chines fillet welds s <5 mm	CDF	CDF	CSF	CSF
Hull chines fillet welds s=>5 mm	CDF	CDF	CDF	-
Other watertight fillet welds	CDF	CDF	CSF	CSF
Engine foundations	CDF	CDF	CSF	-
Brackets, supports for highly loaded items	CDF	CDF	CDF	-
Hull transverse frame ends (also at keel, chine)	CDF	CDF	CDF	CDF
Hull transverse frames at engine foundations	CDF	CDF	CDF	-
Hull transverse frames elsewhere	DF	DF	DF	DF
Hull and other stiffener ends	CDF	CDF	CDF	CDF
Hull and other stiffeners elsewhere	DF	DF	DF	DF

Notations for butt weld types:

CSB = Continuous single-sided butt weld, no back-opening required, back-up strip shall be used in welding of plating, s < 5mm
CDB = Continuous double-sided butt weld, back-opening required, s => 5mm

Notations for filled welds:

CSF = Continuous single-sided fillet weld
CDF = Continuous double-sided fillet weld
DF = Intermittent (staggered or chain) double-sided fillet weld

When hull and deck stiffeners are welded using intermittent welding, the welds shall be at least as long as the break. Shorter welds may be considered for other types of stiffeners that are permitted to be welded with intermittent welds. The length of the weld must never be less than 40% of the joint length. The ends of stiffeners shall always be welded from both sides.

The a-dimension of the weld shall be at least 2.5 mm or (0,35 t+1,5) whichever is greater, where t is the thickness of the plate [mm]. The a-dimension never need to be taken more than 7 mm for plate thicknesses up to 30 mm.

13 ALUMINIUM MATERIALS

13.1 Objective

This chapter presents the aluminium materials suitable for boat building. Mechanical properties for the different alloys and tempers are given. These values are intended for use with the scantlings formulae given in Chapter 14. Provided herein are also guidelines for selection of welding consumables with different base metal combinations.

This chapter is to be used with chapters 7 (design pressures and loads) 12 (design principles, aluminium), 14 (scantlings, aluminium), 15 (production of aluminium boats).

13.2 References

This chapter refers to the following international standards:

- ISO 12215-3. Small craft. Hull construction and scantlings. Part 3: Materials: Steel, aluminium alloys, wood, other materials.
- ISO 12215-5:2008 - Hull construction and scantlings -- Part 5: Design pressures for monohulls, design stresses, scantlings determination

13.3 Documentation

The following documents are needed to verify the requirements of this chapter:

- The material certificates of the plates and profiles
- Material certificate for the welding consumables

13.4 Mechanical properties of aluminium alloys

13.4.1 Group 1. Non-heat treatable alloys

The alloys in this group are used for plates. Examples of commonly used alloys are presented in Table 13.1.

Table 13.1. Example of Group 1 aluminium alloys

Standard marking	Mixture	Condition	σ_U	σ_{UW}	σ_Y	σ_{YW}
EN AW-5052	AlMg2,5	H32	210	170	160	65
EN AW-5052	AlMg2,5	H34	235	170	180	65
EN AW-5754	AlMg3	0/H111	225	190		80
EN AW-5754	AlMg3	H24	240	190	190	80
EN AW-5154A	AlMg3,5	0/H111	215	215	85	85
EN AW-5154A	AlMg3,5	H24	240	215	200	85
EN AW-5086	AlMg4	0/H111	240	240	100	100
EN AW-5086	AlMg4	H34	275	240	185	100
EN AW-5083	AlMg4,5Mn0,7	0/H111	275	275	125	125
EN AW-5083	AlMg4,5Mn0,7	H32	305	275	215	125
AA 5059 Alustar	AlMg5-6	0/H111	330	300	160	160
AA 5059 Alustar	AlMg5-6	H32	370	300	270	160
EN AW-5383	AlMg4,5Mn0,9	0/H111	290	290	145	145
EN AW-5383	AlMg4,5Mn0,9	H32	305	290	220	145

13.4.2 Group 2. Heat treatable alloys

The alloys in this group are used for profiles. Examples of commonly used alloys are presented in Table 13.2.

Table 13.2. Example of Group 2 aluminium alloys

Standard marking	Mixture	Condition	σ_U	σ_{UW}	σ_Y	σ_{YW}
EN AW-6060	AlMgSi	T5, T6	190	95	150	65
EN AW-6061	AlMg1SiCu	T5, T6	260	165	240	115
EN AW-6061	AlMg1SiCu	T5, T6	245	165	205	115
EN AW-6063	AlMg0,7Si	T5	150	100	110	65
EN AW-6063	AlMg0,7Si	T6	205	100	170	65
EN AW-6005A	AlSiMg(A)	T5, T6	260	165	215	115
EN AW-6005A	AlSiMg(A)	T5, T6	250	165	215	115
EN AW-6082	AlSi1MgMn	T5, T6	310	170	260	115
EN AW-6082	AlSi1MgMn	T5, T6	290	170	240	115
EN AW-6106	AlMgSiMn	T6	240	240	195	195

13.4.3 Other alloys

Alloys, which contain copper must not be used

13.5 Welding consumables

The welding consumables used shall be chosen on the basis of base metals to be welded together, as indicated in Table 13.3

Table 13.3. Applicability of welding consumables

Materials to be pieced together	**AlMg2,5 AlMg3**	**AlMg4,5Mn AlMg5**	**Group 2, all mixtures**
Group 2, all mixtures	AlMg5 AlMg4,5Mn AlSi5	AlMg5 AlMg4,5Mn AlSi5	AlSi5 AlMg5 AlMg4,5Mn
AlMg4,5Mn AlMg5	AlMg5 AlMg4,5Mn	AlMg5 AlMg4,5	
AlMg2,5 AlMg3	AlMg5 AlMg4,5Mn AlMg3		

14 SCANTLINGS DETERMINATION, ALUMINIUM

14.1 Objective

This chapter presents the formulae for scantling determination of aluminium craft.

The given formulae are to be used only in conjunction with the design loads given in Chapter 7, using the mechanical properties given in Chapter 13 and the principles regarding the structural arrangement given in Chapter 12.

14.2 References

The scantlings determination method in this chapter is in general that of the ISO 12215-5 - Hull construction and scantlings -- Part 5: Design pressures for monohulls, design stresses, scantlings determination. To ensure that workboat can cope with harsh operating conditions, craft size and speed dependent additions regarding plate thickness against impact loads and corrosion have been added.

14.3 Documentation

To verify that the requirements presented in this chapter are met, the following documentation is required:

- Structural design drawings, including, if appropriate:
    - Longitudinal cross-section;
    - Transverse cross-sections;
    - Welding methods and welding dimensions;
- Material certificates for the plates and profiles used;
- Scantlings calculations showing the rule requirements for different structural members and the attained values.

14.4 List of symbols

Symbols used in several Chapters are given in Chapter 1. In Table 14.1 some symbols used in this Chapter are listed. In addition, there are symbols defined in their context.

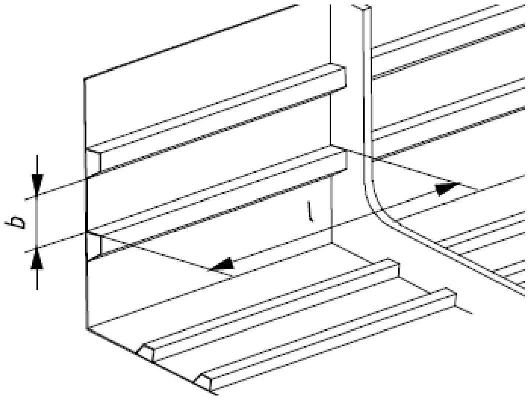
Table 14.1. Symbols used in Chapter 14.

Symbol	Unit	Meaning	Reference
p	kPa	Design pressure	Chapter 7
l	mm	Longer side of panel	
b	mm	Shorter side of panel	
s	mm	Fram spacing, width of design area	
l_U	mm	Span of stiffener	
t	mm	Thickness of panel	
W	cm^3	Section modulus	
σ_d	MPa	Allowable normal stress	Item 14.11

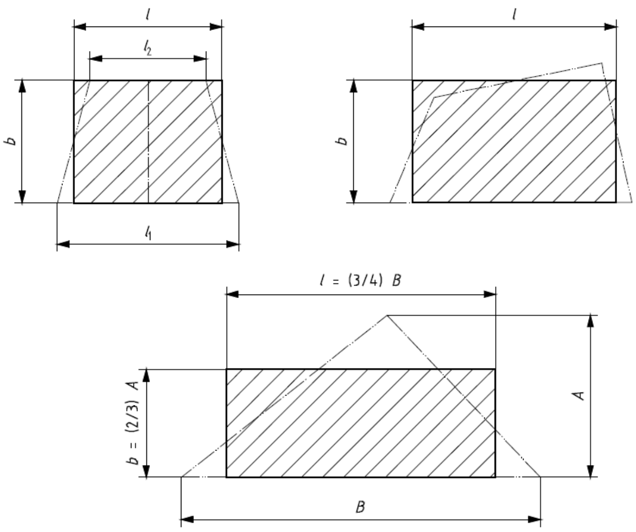
τ_d	MPa	Allowable shear stress	Item 14.11

14.5 Dimension of panels

The dimensions of panels are given for some typical cases in Figure 14.1.



a) Rectangle shaped panel. Note, that l and b are measured to the web of the stiffener.



b) Some other than rectangular shapes

Figure 14.1 Measures *b* and *l* for typical panels

14.6 Scantlings requirements, aluminium panels

The thickness of aluminium plating shall not be less than the greater of formulae 14.1 and 14.2:

$$t \geq b \cdot k_C \cdot \sqrt{\frac{p \cdot k_2}{1000 \cdot \sigma_d}} \text{ [mm]} \qquad (14.1)$$

Where

k_C = curvature correction factor, see 14.7.2
P = design pressure, see Chapter 7.
k_2 = panel aspect correction factor, see. 14.7.3
σ_d = allowable stress, see 14.11.

The plating thickness shall never be less than given by formula 14.2:

$$t_{min} = 1{,}15 \cdot f_1 \cdot \left(t_0 + k_3 \cdot V_{MAX} + k_4 \cdot M_{LDC}^{0{,}33}\right) \text{ [mm]} \qquad (14.2)$$

Where

Factors t_0, k_3 and k_4 can be found in Table 14.2 and factor f_1 from Clause 14.7.1.

Table 14.2. Factors used in formula 14.2

Component	t_0	k_3	k_4
Bottom plate	1,0	0,02	0,1
Side plating and transom	1,0	0	0,1
Cargo deck, load Q [t/m²]	2 + 0,5·Q	0	0

If the clamping of an edge of a panel is less than that of a panel continuing past its edge stiffeners, the thickness requirement must be adjusted to conform to the actual edge clamping.

14.7 Correction factors for panels

14.7.1 Correction for alloy strength

The correction factor f_1 used in the minimum thickness formula takes the strength of the alloy into consideration. The factor shall be determined with the following formula:

$$f_1 = \sqrt{\frac{125}{\sigma_y}} \qquad (14.3)$$

Where

σ_Y = yield strength of alloy, [MPa]

14.7.2 Correction based on panel curvature

The correction factor k_c takes account of the effect the curvature has on the strength of panels; see Table 14.5 with measurements in Fig. 14.2.

Table 14.5. Correction factor for panel on the basis of curvature

c*/*b	***k*C**
0…0,03	1,0
0,03…0,18	1,1 – 3,33 · *c*/*b*
>0,18	0,5

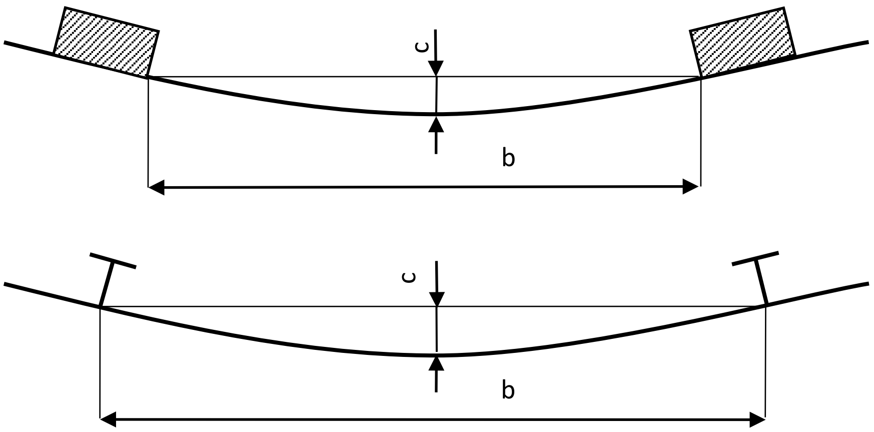


Figure 14.2. Measures needed for curvature correction factor.

14.7.3 Correction based on panel aspect ratio.

Factor k_2 which takes the effect of the panel aspect ratio on the bending stress into consideration, can be found in table 14.4

Table 14.4. Panel aspect ratio correction factor k_2.

Aspect ratio	Correction factor for bending stress
l/b	k_2
>2,0	0,500
2,0	0,497
1,9	0,493
1,8	0,487
1,7	0,479
1,6	0,468
1,5	0,454
1,4	0,436
1,3	0,412
1,2	0,383
1,1	0,349
1,0	0,308

14.8 Stiffeners

14.8.1 Section modulus

The section modulus W of stiffeners, including the effective flange, shall not be less than given by formula 14.4.

$$W \geq \frac{83{,}3 \cdot k_{CS} \cdot p \cdot s \cdot l_U^2 \cdot 10^{-9}}{\sigma_d} \quad [\text{cm}^3] \qquad (14.4)$$

Where

l_U stiffener span, not needed to be taken greater than 330·LH [mm]
k_{CS} correction factor for stiffener curvature, see Table 14.5.

Table 14.5. Stiffener correction factor k_{CS}

c_u/l_u	k_{CS}
0…0,03	1,0
0,03…0,18	$1{,}1 - 3{,}33 \cdot c_U/l_U$
0,18…	0,5

If the end fixity of one or both ends of the stiffener differs from the situation, where a stiffener is continuous over its support points, the required section modulus shall be corrected to correspond to the real end fixity.

14.8.2 Effective flange

For calculating the stiffener's section modulus, the effective flange may be determined using formula (14.5), or in the case of quadratic panels, according to ISO 12215-5 table A.11.

$$b_e = t_s + 60 \cdot t \quad \text{[mm]} \qquad (14.5)$$

Where t_s [mm] is the thickness of the stiffener web.

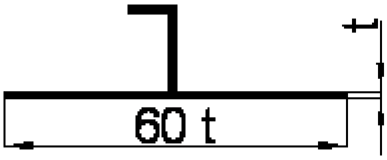


Figure 14.3. Effective flange

14.8.3 Shear area of stiffener webs

The cross-sectional area of the stiffener shear web shall be at least as given by formula 14.6.

$$A_W = \frac{k_{SA} \cdot p \cdot s \cdot l_U}{\tau_d} \cdot 10^{-6} \text{ [cm}^2\text{]} \qquad (14.6)$$

Where

k_{SA} = factor for cross-sectional area.

- k_{SA} = 5 if the stiffener is attached to plating
- k_{SA} = 7.5 for floating stiffeners

τ_d = allowable shear stress for webs [MPa] (see paragraph 14.11).

14.9 Reinforcements

The keel structure shall be appropriately reinforced to withstand the loads of docking and/or trailering. This is considered fulfilled if the requirements for the keel strake thickness and/or section modulus given in Table 14.6 below are met. The plate thickness of the keel strake shall not be less than that given in Table 14.6. If the keel is protected by a profile, the section modulus shall not be less than that given in Table 14.6. When calculating the section modulus for the keel profile, a width of the plate adjacent to the profile equal to 60 times the plate thickness may be included on both sides.

Table 14.6. Plating thickness and section modulus of keel.

Construction element	**Requirement**
Keel strake if no keel profile, b = 10·Lh [mm]	$t_k = 1.5 \cdot t_{min}$ (bottom) see paragraph 14.6.
Section modulus (SM) of the keel	$W_k = 0.85 \cdot m_{LCC} \cdot L_H / 1000$ [cm^3]

In the table above, m_{LC} [kg] is the lightweight of the craft as defined in clause 4.5.1.

If the edge of the deck or the hull/deck joint is the widest part of the craft, they are to be strengthened to withstand loads from collision with piers, docking and handling of the craft ashore. The deck edge or hull/deck joint usually functions as a stiffener for hull topsides. The hull/deck joint shall be watertight for craft in design category A, B and C.

14.10 Highly loaded structures

14.10.1 Engine foundations

Engine foundations shall be strong and stiff enough to carry the weight and loads of the engine. Such loads are:

- Weight of the engine and additional dynamic forces from craft's motion;
- Propulsion force (in cases where no thrust bearing is fitted);
- Torsion from the propeller;
- Vibration.

Engine foundations must be securely fixed primary athwarthship stiffeners like bulkheads or similar at both ends. Foundations shall be supported against buckling and collapsing, especially near engine holding down bolts.

14.10.2 Transoms for outboard and sterndrive engines

The transom design should ensure that the moment, mass forces and thrust from the outboard engine or sterndrive will be transferred into the primary structure without creating excessive stresses.

For engines with big power, the transom shall be engineered using the design loads given in clause 7.11.6

14.10.3 Attachment of mooring and towing

The foundations and fittings for mooring and towing must be dimensioned to withstand design loads as determined in ISO 15084.

14.10.4 Attachment of railings, handholds and lifeline hooking points

Attachment of railings, handholds and lifeline hooking points shall be designed to withstand design loads as determined in ISO 15085.

14.10.5 Attachment of RIB-pontoon

The attachment of the RIB-pontoon to the rigid hull shall be designed to transmit the loads without stress peaks. Special attention shall be paid to the attachment in the bow and stern. The attachment shall be tested according to ISO 6185-3 for craft with a hull length of less than 8 m and ISO 6185-4 for bigger craft, or using a verified method giving the same strength level as the standards mentioned above.

14.11 Design stresses

The design stresses to be used in the equations in chapter 14 are presented in Table 14.7. Mechanical properties for commonly used aluminium alloys can be found in Chapter 13.

Table 14.7. Design stresses

Structural member	Allowed stress, MPa
Panels, normal stress	$\sigma_d = 0{,}6 \cdot \sigma_{UW}$ or $0{,}9 \cdot \sigma_{YW}$
Stiffeners, normal stress	$\sigma_d = 0{,}7 \cdot \sigma_{YW}$
Stiffeners, shear stress	$\tau_d = 0{,}4 \cdot \sigma_{YW}$

Where

σ_{UW} = Tensile strength, welded
σ_{YW} = Yield strength, welded

15 PRODUCTION OF ALUMINIUM BOATS

15.1 Objective

The rules in this chapter deal with the production of aluminium craft. A prerequisite for applying the rules in this chapter is that the raw-materials, the structure and scantlings meet the requirements in Chapters 12, 13 and 14 respectively. The rules apply to individually built boats and, as applicable, to series built boats.

15.2 References

This chapter is partially based on international standard ISO 12215-4 - Small craft — Hull construction and scantlings —Part 4: Workshop and manufacturing.

Reference is made also to the following documents:

- EN 9606-2 Qualification test of welders. Fusion welding. Aluminium and aluminium alloys.
- EN ISO 15614-2 Specification and qualification of welding procedures for metallic materials -- Welding procedure test -- Part 2: Arc welding of aluminium and its alloys
- SFS-EN ISO 10042: Welding. Arc-welded joints in aluminium and its alloys. Quality levels for imperfections.
- SFS-EN 970: Non-destructive examination of fusion welds. Visual examination

15.3 Documentation

To verify the compliance with the requirements in this chapter, a production report for each individual craft is to be prepared. The report shall be readily identifiable by means of the Craft Identification Code, the yards' newbuilding number or similar and shall include the following information as relevant:

- Reference to the used structural drawings, see Chapter 14.
- The material certificates for plates and profiles;
- The names and qualification certificates of the welders which have participated in the welding of the hull;
- Reference to relevant welding procedure specifications (WPS);
- Protocol of visual inspection of welds;
- Reports of radiography and/or other NDT inspection carried out;
- Reports of possible problems encountered and the remedy.

15.4 Workshop conditions

Aluminium plates, profiles, welding consumables and other aluminium materials shall be stored in a dry location separated from other metals.

The workshop shall be essentially clean and there must not be any cutting of other metals during the welding process.

The cutting and welding of aluminium shall be carried out in a dry place under cover, protected from wind and weather.

Welding of aluminium shall not be carried out at temperatures below -5 ^oC. Where the outdoor temperature may fall below 0 ^oC, it shall be possible to heat the workshop.

Workshops where welding is carried out using shield gas shall be free of air draught.

15.5 Materials

It shall be possible to show, with the aid of material certificates, that the plating and profiles which are used in a particular craft, are of the alloy and temper specified on the construction drawings.

The material shall be straight and undamaged, and of the dimensions and alloy as specified on the approved drawings.

15.6 Cutting and forming

Hardened aluminium alloys shall not be formed by the application of heat. Where cold forming is required, care shall be taken to avoid local damage to the material.

When bending plates and profiles, the methods and the bend radius shall ensure that excessive local strain leading to cracks in the material does not occur.

15.7 Welding

15.7.1 Welder’s qualification

Welding shall only be carried out by qualified persons. In craft of design category A and B an official welder's qualification according to EN 9606-2 or equivalent standard is required. For craft of design category C or D, the qualification may be assessed by the beforementioned test or by assessing of the weld quality at the workshop.

In general, MIG or TIG welding methods shall be used. Other methods may be utilised if it can be demonstrated that the results is at least as good as for welds carried out with MIG or TIG.

15.7.2 Welding Procedure Specification

In the manufacturing of craft of design category A and B the welding shall be carried out in accordance with welding procedure specifications (WPS) tried out prior to the construction and which are demonstrated to result in welds with adequate quality. Welding procedure specifications shall be prepared for all relevant joint types, welding positions and material thicknesses and with the welding machines to be used for the construction of the craft. The welding procedure specifications shall be carried out in accordance with the standard EN ISO 15614-2.

For craft of design category C and D no formally approved welding procedure specifications are required.

15.7.3 Surveys

The welds in the hull, deck and other critical structures are to be visually inpected according to EN ISO 970.

In addition, for craft of design category A and B, inspection by radiography shall be carried out for welds in plating. The sampling is to be decided on basis of the visual inspection.

15.7.4 Required weld quality

The quality level of welds in all load-bearing structures shall be at least C according to the standard SFS-EN ISO 10042. This applies to the following items:

For all boats the hull including the following structural members:

- Plating and transom;
- Keel and stem;
- Bulkheads, webframes and stiffeners;
- Engine foundations;
- Possible other stiffeners and foundations.

For fully enclosed boats also:

- Decks and their stiffeners;
- Superstructures and their stiffeners.

16 DESIGN PRINCIPLES, STEEL

16.1 Objective

In this chapter is given requirements for the structural arrangement and the details of the structure. In addition, the principles for the assessment of the structure are defined. The purpose of the requirements presented in this chapter is to ensure that the structural arrangement and details of the craft has been carried out correctly taking into account the special properties of steel and that the procedures for assessing the structure are unambiguous.

This Chapter is to be used in conjunction with Chapter 7 (Design pressures and loads), Chapter 17 (Steel materials), Chapter 18 (Scantlings, steel craft) and Chapter 19 (Production of steel craft)

16.2 References

Requirements in chis chapter are partly based on international standard ISO 12215-6. *Small craft - Hull construction and scantlings -- Part 6: Structural arrangements and details.*

16.3 Principles of structural analysis

16.3.1 Simplified calculation method

If the following conditions are met the scantlings may be analysed using the *simplified calculation method:*

- The structural arrangement is according to paragraph 16.6;
- The assumptions in paragraph 16.4 are valid;
- The craft does not have features, which makes it critical to global loads, see clause 16.5.

The "Simplified calculation method" means that the scantlings are determined using the formulae for panels, stiffeners etc. given in Chapter 18 using the loads in Chapter 7 and the allowable stresses given in Chapter 18.

16.3.2 Direct calculation of stresses and strains

For other cases than those mentioned in clause 16.3.1, general methods of strength of materials shall be followed, for example finite element method. For such analysis, the loads given in Chapter 7 and the design stresses given in Chapter 18 shall be used.

16.4 Assumptions

16.4.1 Assumptions regarding local vs. global strength and stiffness

The scantling determination method presented in Chapter 18 is based on dimensioning against local loads. Normally, this will result in scantlings, which are adequate also for global loads. Where this is not the case, the dimensioning against global loads shall be assessed, see paragraph 16.5.

16.4.2 Hierarchy of the load carrying elements

When calculating requirements for panels and stiffeners according to Chapter 18, the hierarchy of structure is assumed to adhere to the following principles:

- The panel is supported by secondary stiffeners supported by primary stiffeners as indicated in Figure 16.1
- The primary stiffeners are at least twice as stiff as the secondary stiffeners, i.e:

$$\frac{I_p}{l_p^3} / \frac{I_s}{l_s^3} \geq 2 \qquad (12.1)$$

- The load is uniformly distributed;
- The edges of the panel are clamped;
- The ends of the stiffeners are fixed.

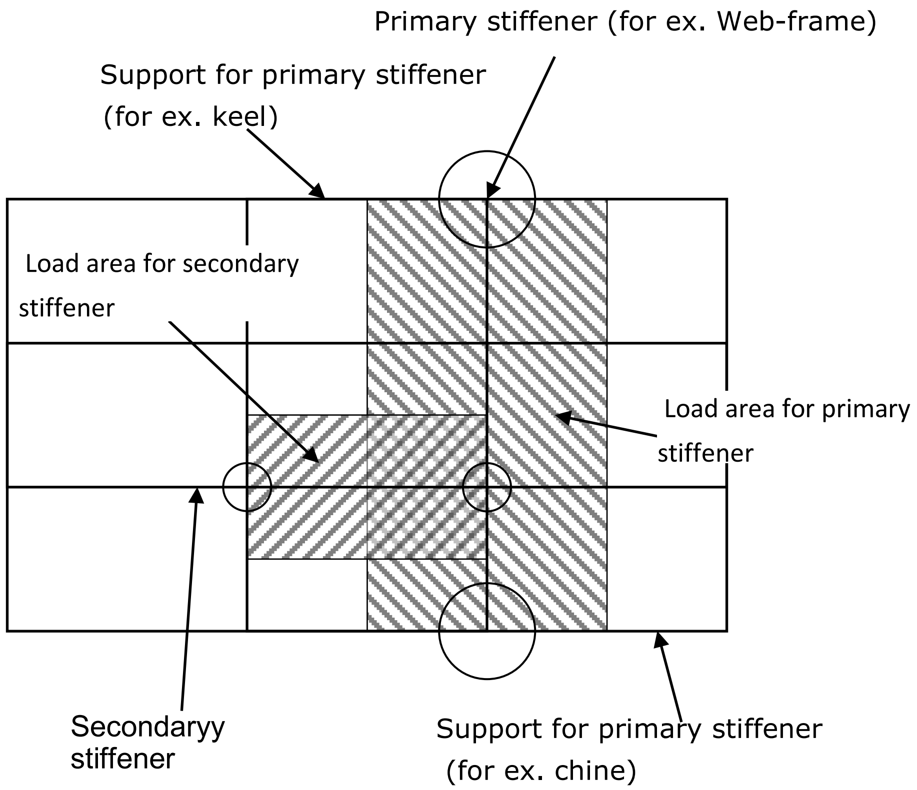


Figure 16.1. Hierarchy of stiffeners.

16.5 Global strength and stiffness

In the following cases also the global strength and stiffness must be investigated:

- If the bottom is only transversely stiffened and its relative speed $V/\sqrt{L_{WL}}>6$
- If there are (large) openings in the deck;
- If the ratio of the hull length to the hull depth $L_H/D_{MAX}>12$

The global strength and stiffness shall be determined according to ISO 12215-6 Annex D. At least the deck shall be checked against buckling (compressive stress in the deck). For craft with only transverse stiffening in the bottom also the strength of the bottom shall be checked.

For multihull craft, the strength shall be assessed in the global load cases given in Chapter 7.

16.6 Structural arrangement

16.6.1 Displacement craft, design category D

Boats in design category D with $V/\sqrt{LWL}\leq6$, may be stiffened by the keel, gunwale and transverse stiffeners alone. Boats in higher design categories may only be stiffened by transverse framing alone if an assessment of the global strength and stiffness is carried out, see paragraph 16.5.

16.6.2 Planing craft

Boats with $V/\sqrt{L_{WL}}>6$, should in general have longitudinal stiffening in the bottom. The details of longitudinal stiffeners shall meet the requirements of paragraph 16.7.

16.6.3 Support for longitudinal stiffeners

The bottom longitudinal stiffeners shall in general be supported by transverse stiffeners such as bulkheads, web frames or deep floors, which are to be designed to carry the load acting on the hull area in question, see Figure 16.1. Principle of load areas. The details of transverse stiffeners shall meet the requirements in paragraph 16.7.

16.6.4 Keels, stem and chines

The craft shall have a reinforced keel, stem and chines according to Chapter 18.

16.6.5 Torsional stiffness and -strength

The torsional strength and stiffness is considered adequate if the craft has one of the following items:

- A full deck;
- Tranverse bulkheads;
- A strengthened bulwark.

16.6.6 Superstructure support points

The loads imposed by superstructures shall be led into bulkheads, webframes or other primary structure.

16.7 Hull stiffeners

16.7.1 Continuity and termination of stiffeners

In craft where $V / \sqrt{L_{WL}} > 6$, the bottom longitudinal stiffeners shall be continuous. Terminating of stiffeners on a panel between stiffeners shall be avoided. With the exceptions of paragraph 16.9.2, the ends of stiffeners shall be fastened to other stiffeners

16.7.2 Straightness and local discontinuities of stiffeners

Hull stiffeners shall be as straight as possible. At most 30 degrees are accepted, provided buckling support is arranged at the points where the direction change. Abrupt changes is the cross section of the stiffeners shall be avoided. If the stiffeners have local discontinuities, the transition shall be smooth and corners shall be rounded, radius at least 30 mm.

16.7.3 Safety against buckling

The cross section of stiffeners shall be such that they are not prone to buckling. Stiffeners with one web without flange are not allowed at bottom area. Stiffeners with one web must not be fastened at an angle exceeding 30 degrees relative to the normal against the panel.

16.7.4 Transverse stiffeners

The hull transverse stiffeners such as bulkheads, webframes and deep floors, shall extend from side to side of the hull. When calculating the section modulus requirement of a web frame, the span shall be taken as the distance between chines. However, if the section modulus of the keel meets the requirements in paragraph 18.8, the stiffeners span may be taken as the distance between the chine and the keel.

16.7.5 Floating stiffeners

Arrangements, where stiffeners are not fastened to the bottom (floating stiffener), shall only be used if it is verified that the stiffener is not critical for buckling. This is assessed according to ISO 12215-6 clause 6.3.4.

16.8 Other stiffeners

The stiffening arrangement of decks, superstructures and bulkheads shall comprise of secondary stiffeners supported by primary stiffeners according to the principles in paragraph 16.4.2.

16.9 Construction details

16.9.1 Joining plates of different thickness

The thickness difference between adjacent hull plates shall not exceed 25% of the thicker plate unless the edge of the thicker plate is bevelled.

16.9.2 Fastening and joints of stiffeners

The stiffener including its fastening shall be able to carry the bending moment and shear force in Chapter 18 paragraph 18.8 without exceeding the design stresses given in Chapter 18.

If a stiffener is continuous through a web frame or bulkhead, a bracket is not required at the intersection. If the stiffener is cut off for instance at a watertight bulkhead, the end(s) shall be connected by means of brackets or similar to ensure, that the stiffness and strength of joint corresponds to that of a continuous stiffener

The ends of stiffeners shall, with the following exceptions, be connected to other stiffeners. Termination of stiffeners within a plate panel is allowed under the following conditions.

1) In the bottom structure, all design categories, side structure of craft in design category A and B:

- The stiffener ends at an angle of at least 15 degrees relative to a line through the last support point and the stiffener end, or
- The stiffener ends at a stiff area, for instance near the keel or chine;
- In both case the bending and shear stress must not exceed half of the design stress as given in Chapter 18 and
- The end of the stiffener shall be sniped at least 3:1 and
- The distance from the stiffener end to a stiff point is at most 35 mm.

2) Other applications, all design categories

- The end of the stiffener shall be sniped at least 3:1 and the distance from the stiffener end to a stiff point is at most 35-75 mm

16.9.3 Openings in load-bearing structures

16.9.3.1 General

The effect of openings in load-bearing structures shall be taken into account. Opening shall, where necessary, be supported against buckling at their edges by flanges or similar.

16.9.3.2 Openings in hull stiffeners

With the exceptions given below, openings in hull stiffeners are not allowed, unless it can be shown by calculation that the stiffener meets the requirements of Chapter 18 including the opening.

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In the webs, no openings are to be located within 20% of the length of the stiffeners from the support points. In other locations of the webs openings with a height not exceeding 50% of the web height and a length not exceeding 75% of the web height are allowed.

16.9.4 Sharp edges

Sharp edges or notches are not allowed in loaded structures.

16.9.5 Other details

Structures, which accumulate water shall be avoided as far as possible. Locations, where water may accumulate shall be accessible (definition see chapter 31).

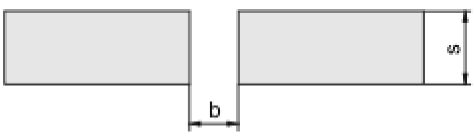
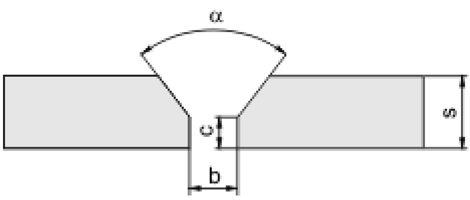
16.9.6 Corrosion

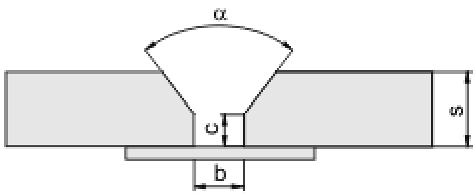
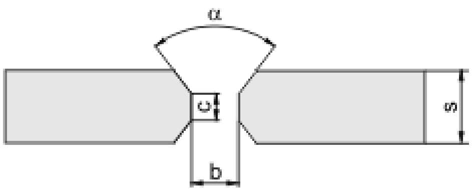
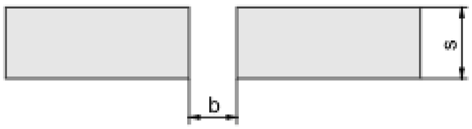
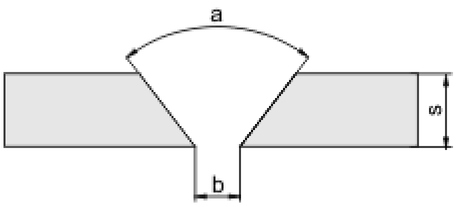
All items fitted to the underwater hull, which are not the same material as the hull, shall be isolated for instance by sealant to avoid crevice corrosion. With the exception of acid-proof steel AISI 316, those items shall also be electrically isolated from the hull. Sacrificial anodes are required if the craft is equipped with an AC shore connection.

16.10 Welding

The weld joint geometry shall be according to Table 16.1.

Table 16.1. Geometry of welding joints

Joint type	Joint dimensions	Comments
	MIG	
	s = 1.5...5 mm b = 0...2 mm	Welding from one side only. Back-up strip shall be used.
	s = 5...25 mm b = 0...3 mm c = 1.5...3 mm □ = 60...100°	Largest angle recommended for under-up position. Gouging and re-welding shall be carried out.

	s = 8...25 mm b = 3...7 mm c = 2...4 mm □ = 40...60º	Smallest joint angle may be used up to 15 mm and with the largest root cap. Vertical position, under-up and side-in require a large root cap.
	s = 12...25 mm b = 0...2 mm c = 3...5 mm □ = 50...70º	Specially allowed for automatic welding. Semiautomatic processes may be used in all positions, and gouging shall be performed prior to welding from the other side.
	TIG	
	s < 2 mm	
	s < 4 mm b = 0...2 mm	Welding from one side.
	s = 4...10 mm b = 0...2 mm □ = 60...70º	Back-up strip shall be used in a horizontal position.

s= Material thickness, mm

b = Root gap, mm

c = Root face, mm

α = Joint angle, deg

Welding shall be carried out in accordance with table 16.2. The notations in the table are the minimum requirements.

Table 16.2. Minimum requirements for welding

Application	Design category			
	A	B	C	D
Hull shell plating butt welds s <5 mm	CDB	CDB	CSB	CSB
Hull shell plating butt welds s => 5mm	CDB	CDB	CDB	-
Other plating butt welds s < 5 mm	CSB	CSB	CSB	CSB
Other plating butt welds s => 5 mm	CDB	CDB	CDB	-
Hull chines fillet welds s <5 mm	CDF	CDF	CSF	CSF
Hull chines fillet welds s=>5 mm	CDF	CDF	CDF	-
Other watertight fillet welds	CDF	CDF	CSF	CSF
Engine foundations	CDF	CDF	CSF	-
Brackets, supports for highly loaded items	CDF	CDF	CDF	-
Hull transverse frame ends (also at keel, chine)	CDF	CDF	CDF	CDF
Hull transverse frames at engine foundations	CDF	CDF	CDF	-
Hull transverse frames elsewhere	DF	DF	DF	DF
Hull and other stiffener ends	CDF	CDF	CDF	CDF
Hull and other stiffeners elsewhere	DF	DF	DF	DF

Notations for butt weld types:

- CSB = Continuous single-sided butt weld, no back-opening required, back-up strip shall be used in welding of plating, s < 5mm
- CDB = Continuous double-sided butt weld, back-opening required, s => 5mm

Notations for filled welds:

- CSF = Continuous single-sided fillet weld
- CDF = Continuous double-sided fillet weld
- DF = Intermittent (staggered or chain) double-sided fillet weld

When hull and deck stiffeners are welded using intermittent welding, the welds shall be at least as long as the break. Shorter welds may be considered for other types of stiffeners that are permitted to be welded with intermittent welds. The length of the weld must never be less than 40% of the joint length. The ends of stiffeners shall always be welded from both sides.

The a-dimension of the weld shall be at least 2.5 mm or (0,35 t+1,5) whichever is greater, where t is the thickness of the plate [mm]. The a-dimension never need to be taken more than 7 mm for plate thicknesses up to 30 mm.

17 STEEL MATERIALS

17.1 Normal strength steel

Unless otherwise specified, steel with a yield strength of 240 MPa is assumed as the basis for the rules. This is referred to as “normal strength steel”. The use of steel grades with better mechanical properties is to be considered separately according to their yield strength and ultimate strength and ultimate strain.

17.2 Steel grades for low temperatures

The use of normal strength steel with normal impact toughness is permitted for commercial craft that do not have an additional “Ice strengthening” notation. For ice-strengthened craft, steel with enhanced toughness in cold temperatures is to be used.

18 SCANTLINGS DETERMINATION, STEEL

18.1 Objective

This chapter presents the formulae for scantling determination of steel craft.

The given formulae are to be used only in conjunction with the design loads given in Chapter 7, using the principles regarding the structural arrangement given in Chapter 16.

18.2 References

The scantlings determination method in this chapter is in general that of the *ISO 12215-5 - Hull construction and scantlings -- Part 5: Design pressures for monohulls, design stresses, scantlings determination.* To ensure that workboat can cope with harsh operating conditions, craft size and speed dependent additions regarding plate thickness against impact loads and corrosion have been added.

18.3 Documentation

To verify that the requirements presented in this chapter are met, the following documentation is required:

- Structural design drawings, including, if appropriate:
  - Longitudinal cross-section;
  - Transverse cross-sections;
  - Welding methods and welding dimensions;
- Material certificates for the plates and profiles used;
- Scantlings calculations showing the rule requirements for different structural members and the attained values.

18.4 List of symbols

Symbols used in several Chapters are given in Chapter 1. In Table 18.1 some symbols used in this Chapter are listed. In addition, there are symbols defined in their context.

Table 18.1. Symbols used in Chapter 18.

Symbol	Unit	Meaning	Reference
p	kPa	Design pressure	Chapter 7
l	mm	Longer side of panel	
b	mm	Shorter side of panel	
s	mm	Fram spacing, width of design area	
l_U	mm	Span of stiffener	
t	mm	Thickness of panel	
W	cm^3	Section modulus	

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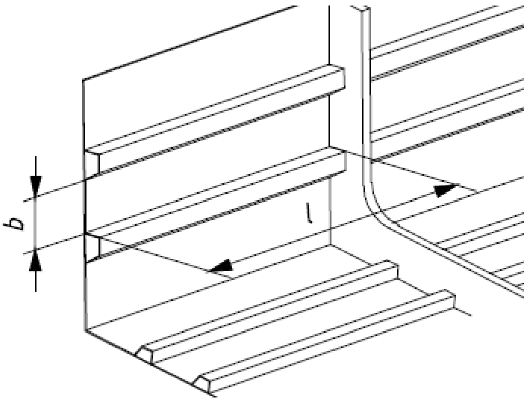
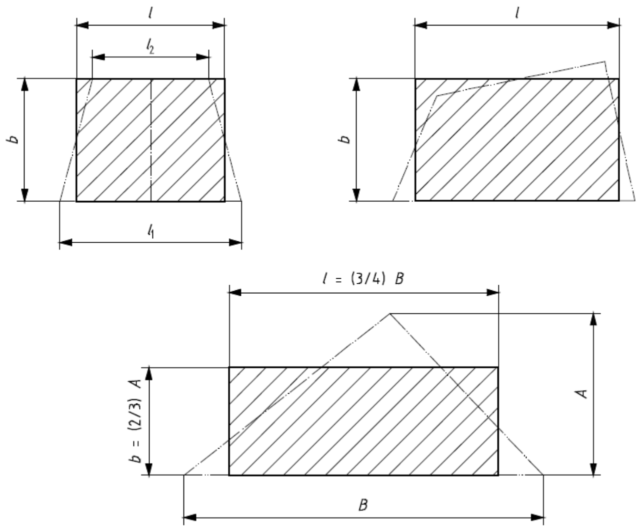
σ_d	MPa	Allowable normal stress	paragraph 18.11
τ_d	MPa	Allowable shear stress	paragraph 18.11

18.5 Dimension of panels

The dimensions of panels are given for some typical cases in Figure 18.1.



a) Rectangle shaped panel. Note, that l and b are measured to the web of the stiffener.



b) Some other than rectangular shapes

Figure 18.1 Measures *b* and *l* for typical panels

18.6 Scantlings requirements, steel panels

The thickness of steel plating shall not be less than the greater of formulae 14.1 and 14.2:

$$t \geq b \cdot k_c \cdot \sqrt{\frac{p \cdot k_2}{1000 \cdot \sigma_d}} \text{ [mm]} \qquad (18.1)$$

Where

k_C = curvature correction factor, see 18.7.2
P = design pressure, see Chapter 7.
k_2 = panel aspect correction factor, see. 18.7.3
σ_d = allowable stress. see 18.11.

The plating thickness shall never be less than given by formula 14.2:

$$t_{min} = 1{,}15 \cdot f_1 \cdot \left(t_0 + k_3 \cdot V_{MAX} + k_4 \cdot M_{LDC}^{0{,}33}\right) \text{ [mm]} \qquad (18.2)$$

Where

Factors t_0, k_3 and k_4 can be found in Table 18.2 and factor f_1 from Clause 18.7.1.

Table 18.2. Factors used in formula 14.2

Rakenneosa	t_0	k_3	k_4
Bottom plater	0,9	0	0,02
Side plating and transom	0,9	0	0
Cargo deck, load *Q* [t/m²]	1,5 + 0,5 · Q	0	0

If the clamping of an edge of a panel is less than that of a panel continuing past its edge stiffeners, the thickness requirement must be adjusted to conform to the actual edge clamping.

18.7 Correction factors for panels

18.7.1 Correction for alloy strength

The correction factor f_1 used in the minimum thickness formula takes the strength of the alloy into consideration. The factor shall be determined with the following formula:

$$f_1 = \sqrt{\frac{240}{\sigma_y}} \qquad (18.3)$$

Where

σ_Y = yield strength of steel alloy, [MPa]

18.7.2 Correction based on panel curvature

The correction factor k_c takes account of the effect the curvature has on the strength of steel panels; see Table 18.3 with measurements in Fig. 18.2.

Table 18.5. Correction factor for panel on the basis of curvature

c/b	***k*c**
0…0,03	1,0
0,03…0,18	1,1 – 3,33 · *c/b*
>0,18	0,5

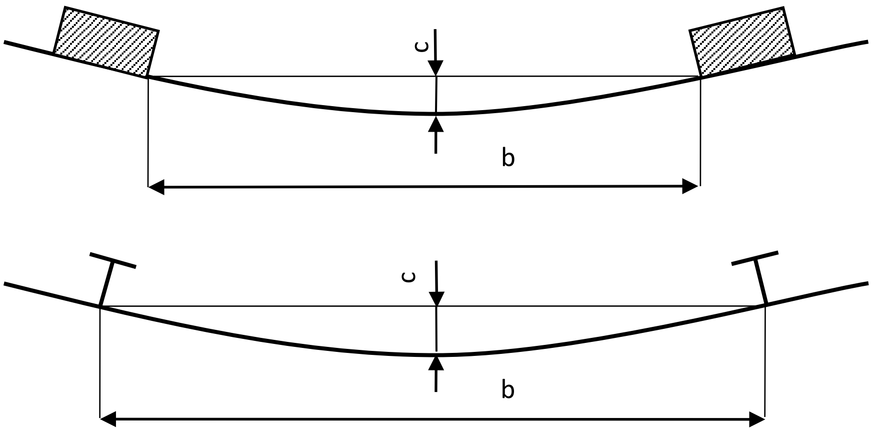


Figure 18.2. Measures needed for curvature correction factor.

18.7.3 Correction based on panel aspect ratio.

Factor k_2, which takes the effect of the panel aspect ratio on the bending stress into consideration, can be found in table 18.4

Table 18.4. Panel aspect ratio correction factor k_2.

Aspect ratio	Correction factor for bending stress
l/b	k_2
>2,0	0,500
2,0	0,497
1,9	0,493
1,8	0,487
1,7	0,479
1,6	0,468
1,5	0,454
1,4	0,436
1,3	0,412
1,2	0,383
1,1	0,349
1,0	0,308

18.8 Stiffeners

18.8.1 Section modulus

The section modulus of stiffeners, including the effective flange calculated according to 6.3, shall not be less than given by formula 18.4.

$$W \geq \frac{83{,}3 \cdot k_{CS} \cdot p \cdot s \cdot l_U^2 \cdot 10^{-9}}{\sigma_d} \quad [\mathrm{cm}^3] \qquad (18.4)$$

Where

l_U stiffener span, not needed to be taken greater than $330 \cdot L_H$ [mm]
k_{CS} correction factor for stiffener curvature, see Table 18.5.
σ_d design stress for steel alloy, [MPa], see clause 18.11

Table 18.5. Stiffener correction factor k_{CS}

c/b	k_{CS}
0…0,03	1,0
0,03…0,18	$1{,}1 - 3{,}33 \cdot c_U/l_U$
0,18…	0,5

If the end fixity of one or both ends of the stiffener differs from the situation, where a stiffener is continuous over its support points, the required section modulus shall be corrected to correspond to the real end fixity.

18.8.2 Effective flange

For calculating the stiffener's section modulus, the effective flange may be determined using formula (18.5)..

$$b_e = t_s + 80 \cdot t \quad \text{[mm]} \qquad (18.5)$$

Where t_s [mm] is the thickness of the stiffener web.

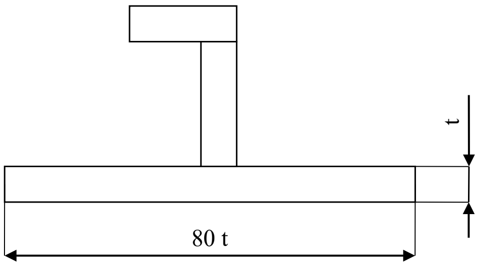


Figure 18.3. Effective flange

18.8.3 Shear area of stiffener webs

The cross-sectional area of the stiffener shear web shall be at least as given by formula 18.6.

$$A_W = \frac{k_{SA} \cdot p \cdot s \cdot l_U}{\tau_d} \cdot 10^{-6} \text{ [cm}^2\text{]} \qquad (18.6)$$

Where

k_{SA} = factor for cross-sectional area.

- k_{SA} = 5 if the stiffener is attached to plating
- k_{SA} = 7.5 for floating stiffeners

τ_d = allowable shear stress for webs, MPa, see 18.11

18.9 Reinforcements

The keel structure shall be appropriately reinforced to withstand the loads of docking and/or trailering. This is considered fulfilled if the requirements for the keel strake thickness and/or section modulus given in Table 18.6 below are met. The plate thickness of the keel strake shall not be less than that given in Table 18.6. If the keel is protected by a profile, the section modulus shall not be less than that given in Table 18.6. When calculating the section modulus for the keel profile, a width of the plate adjacent to the profile equal to 80 times the plate thickness may be included on both sides.

Table 18.6. Plating thickness and section modulus of keel.

Construction element	**Requirement**

Keel strake if no keel profile, b = 10·Lh [mm]	t_k = 1.5· t_{min} (bottom) see Eq.18.2.
Section modulus (SM) of the keel	W_k = 0.85· m_{LCC} · L_H / 1000 [cm^3]

in the table above, m_{LC} [kg] is the lightweight of the craft as defined in clause 4.5.1.

If the edge of the deck or the hull/deck joint is the widest part of the craft, they are to be strengthened to withstand loads from collision with piers, docking and handling of the craft ashore. The deck edge or hull/deck joint usually functions as a stiffener for hull topsides. The hull/deck joint shall be watertight for craft in design category A, B and C.

18.10 Highly loaded structures

18.10.1 Engine foundations

Engine foundations shall be strong and stiff enough to carry the weight and loads of the engine. Such loads are:

- Weight of the engine and additional dynamic forces from craft's motion;
- Propulsion force (in cases where no thrust bearing is fitted);
- Torsion from the propeller;
- Vibration.

Engine foundations must be securely fixed primary athwarthship stiffeners like bulkheads or similar at both ends. Foundations shall be supported against buckling and collapsing, especially near engine holding down bolts.

18.10.2 Transoms for outboard and sterndrive engines

The transom design should ensure that the moment, mass forces and thrust from the outboard engine or sterndrive will be transferred into the primary structure without creating excessive stresses.

For engines with big power, the transom shall be engineered using the design loads given in Chapter 7 Clause 7.11.6.

18.10.3 Attachment of mooring and other highly loaded fittings

The foundations and fittings of mooring and towing must be dimensioned to withstand design loads as determined in ISO 15084.

18.10.4 Attachment of railings, handholds and lifeline hooking points

Attachment of railings, handholds and lifeline hooking points shall be designed to withstand design loads as determined in ISO 15085.

18.10.5 Attachment of RIB-pontoon

The attachment of the RIB-pontoon to the rigid hull shall be designed to transmit the loads without stress peaks. Special attention shall be paid to the attachment in the bow and stern. The attachment shall be tested according to ISO 6185-3 for craft with a hull length of less than 8 m and ISO 6185-4 for bigger craft, or using a verified method giving the same strength level as the standards mentioned above..

18.11 Design stresses

The design stresses to be used in the equations in this chapter are presented in Table 18.7.

Table 14.7. Design stresses

Structural member	Allowed stress, MPa
Panels, normal stress	$\sigma_d = 0{,}6 \cdot \sigma_{UW}$ or $0{,}9 \cdot \sigma_{YW}$
Stiffeners, normal stress	$\sigma_d = 0{,}7 \cdot \sigma_{YW}$
Stiffeners, shear stress	$\tau_d = 0{,}4 \cdot \sigma_{YW}$

where

σ_{UW} = Tensile strength, welded

σ_{YW} = Yield strength, welded

19 PRODUCTION OF STEEL BOATS

19.1 Objective

The rules in this chapter deal with the production of steel craft. A prerequisite for applying the rules in this chapter is that the raw-materials, the structure and scantlings meet the requirements in Chapters 16, 17 and 18 respectively. The rules apply to individually built boats and, as applicable, to series built boats.

19.2 References

This chapter is partially based on international standard *ISO 12215-4 - Small craft — Hull construction and scantlings —Part 4: Workshop and manufacturing.*

Reference is made also to the following documents:

- EN 9606-1. Qualification test of welders. Fusion welding of steel.
- EN ISO 15614-1. Specification and qualification of welding procedures for metallic materials - Welding procedure test - Part 1 : arc and gas welding of steels and arc welding of nickel and nickel alloys.
- ISO 5817. Welding -- Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) -- Quality levels for imperfections
- SFS-EN 970: Non-destructive examination of fusion welds. Visual examination

19.3 Documentation

To verify the compliance with the requirements in this chapter, a production report for each individual craft is to be prepared. The report shall be readily identifiable by means of the Craft Identification Code, the yards' newbuilding number or similar and shall include the following information as relevant:

- Reference to the used structural drawings, see Chapter 18.
- The material certificates for plates, profiles and welding consumables;
- The qualification certificates of the welders which have participated in the welding of the hull;
- Reference to relevant welding procedure specifications (WPS);
- Protocol of visual inspection of welds;
- Reports of radiography and/or other NDT inspection carried out;
- Reports of possible problems encountered during lamination and the remedy;

19.4 Workshop conditions

Steel plates, profiles, welding consumables and other steel materials shall be stored in a dry location to prevent corrosion.

Welding of steel shall not be carried out at temperatures below -5 ^{o}C.

Workshops where welding using shield gas is carried out shall be essentially free of draught.

19.5 Materials

It shall be possible to show, with the aid of material certificates, that the plating and profiles which are used in a particular craft, are of the correct type according to the construction drawings.

The material shall be straight and undamaged, and of the dimensions and alloy as specified on the approved drawings.

19.6 Cutting and forming

Where cold forming is required, care shall be taken to avoid local damage to the material.

When bending plates and profiles, the methods and the bend radius shall ensure that excessive local strain leading to cracks in the material does not occur.

19.7 Welding

19.7.1 Welder's qualification

Welding shall only be carried out by qualified persons. In craft of design category A and B an official welder's qualification according to EN 9606-1 or equivalent standard is required. For craft of design category C or D, the qualification may be assessed by the before mentioned test or by assessing of the weld quality at the workshop.

In general, MIG or TIG welding methods shall be used. Other methods may be utilised if it can be demonstrated that the results are at least as good as for welds carried out with MIG or TIG.

19.7.2 Welding Procedure Specification

In the manufacturing of craft of design category A and B the welding shall be carried out in accordance with welding procedure specifications (WPS) tried out prior to the construction and which are demonstrated to result in welds with adequate quality. Welding procedure specifications shall be prepared for all relevant joint types, welding positions and material thicknesses and with the welding machines to be used for the construction of the craft. The welding procedure specifications shall be carried out in accordance with the standard EN ISO 15614-1. For craft of design category C and D no formally approved welding procedure specifications are required.

19.7.3 Surveys

The welding shall be carried out according to pre-prepared specification.

The welds in the hull, deck and other critical structures are to be visually inspected according to EN ISO 970.

In addition, for craft of design category A and B, inspection by radiography shall be carried out. The sampling is to be decided on basis of the visual inspection.

19.7.4 Required weld quality

The quality level of welds in all load-bearing structures shall be at least C according to the standard ISO 5817. This applies to the following items:

For all boats the hull including the following structural members:

- Plating and transom;
- Keel and stem;
- Bulkheads, webframes and stiffeners;
- Engine foundations;
- Possible other stiffeners and foundations.

For fully enclosed boats also:

- Decks and their stiffeners;
- Superstructures and their stiffeners.

20 RUDDER AND STEERING SYSTEMS

20.1 Objective

The purpose of the rules in this chapter is to ensure proper and safe steering of the craft, while considering her Design Category and maximum speed, and to make sure that the craft can proceed into a safe harbour even when the main steering is out of order.

20.2 References

In this chapter reference is made to the following documents:

- ISO 12215-8 Small Craft – Hull construction and scantlings – Part 8: Rudders
- ISO 8847 Small Craft – Steering gear –Cable and pulley systems
- ISO 9775 Small craft - Remote steering systems for single outboard motors of 15 kW to 40 kW power
- ISO 8848 Small craft – Remote mechanical steering systems

- ISO 10592 Small craft – Hydraulic steering systems
- ISO 4413 Hydraulic fluid power – General rules and safety requirements for systems and their components
- ISO 13929:2001 Small craft – Steering gear – Geared link systems
- ISO 25197 Small craft – Electrical/electronic control systems for steering, shift and throttle
- ISO 23411 Small craft – Steering wheels

20.3 Documentation

For assessment of the requirements given in this chapter the following documentation is required:

- drawings of the rudder and its installation, showing the rudder geometry and construction;
- the materials used;
- measurements for the parts;
- dimensioning calculations showing;
- rudder stock;
- tiller or quadrant connection to the stock; and
- dimensioning of the bearings; and
- conformity declarations for CE-marked components, or approvals of an equivalent requirement level by an accredited inspection body.

20.4 Steering arrangements

20.4.1 Main steering system

The main steering system shall enable proper and safe steering at all speeds considering the Design Category of the craft.

Steering shall normally be accomplished with a fixed steering system, able to produce the required torque or force for proper steering. In craft where manual steering provides sufficient power, remote control is not required.

For craft with the additional notation “Winter navigation” there are additional requirements for the steering system given in Chapter 39.

20.4.2 Emergency steering system

Except for the mentioned cases below, for all craft with remote steering a rapidly available emergency steering system is required. This system shall have proper strength, and enable steering at minimum 4 knots speed, retaining the steering control using the input from one person at a safe force level.

A separate emergency steering system is not required provided:

- the craft has two rudders, each with separate steering system, and can be steered even if either one of the systems is out of order;
- the craft has at least two propulsion units, enabling the craft to be steered even if the main steering system is out of order;
- the craft can be steered in some other way, for example with a bow thruster; or
- the craft has outboard- or sterndrive engine, or waterjet propulsion, and belongs to Design Category C or D.

In case the steering system is electrical, emergency steering is always required.

In connection with emergency steering a dedicated lookout may be used.

The emergency steering shall be assessed in connection with the sea trials (see Chapter 30).

20.4.3 Requirements for steering systems

The steering system components shall be CE-marked according to paragraph 20.2, or be approved by an accredited inspection body using a method ensuring the corresponding safety level.

When using industrial hydraulic components instead of CE-marked components, the installation including its components shall meet the requirements of ISO 4413, and the accredited inspection body shall separately assess the compliance of the system with the referenced standards when inspecting the craft.

The dimensioning of the steering system shall rely entirely on the torque from the rudder or drive unit as calculated in this chapter.

Electrical steering systems shall be approved for marine use by a Classification Society, or shall have CE-marking according to standard ISO 25197.

Cable steering with a single cable must not be used with engine power over 74 kW if the speed of the craft exceeds $7 \cdot \sqrt{L_H}$ knots.

For craft with the additional notation “Winter navigation” there are additional requirements for the steering system given in Chapter 39.

20.5 Rudders

20.5.1 Rudder design, general

The rudder and its parts shall be designed so they can stand the applied loads in all conditions. This includes also light grounding when the craft is stationary, and ice loads for craft intended for such services (see Chapter 39)

Generally, the rudder area shall be sufficient for good control also at low speed in conditions when only one engine is in use.

20.5.2 Fail-safe design

Rudders shall be designed paying attention to grounding, and collision with objects in the water.

This requirement is considered fulfilled if there is a strong skeg or similar in front of the rudder. Alternatively, this can be arranged with local watertight compartmentation, preventing a leak from reaching spaces above the rudder in case the bottom is holed (limited unsinkability, see Chapter 6).

Table 20.1. Rudder stock material properties [MPa]

Material	Compo-sition	σ_y^a *unwelded*	σ_u^a *unwelded*	σ_{yw} *welded*	σ_{uw} *welded*	σ_D^a *unwelded*	σ_{Dw} *welded*	*E* *ESTIMATE*
Stainless steel								
AISI 304	X5 Cr Ni 18.9	195	500	195	195	**195**	**97**	2.05*10^5
AISI 316,316L	X5 Cr Ni Mo 17.2.2	195	500	195	195	**195**	**97**	
AISI 329 Not coldworked	X3 Cr Ni Mo N 27-5-2	500	650	500	500	**325**	**250**	
AISI 329 Coldworked	X3 Cr Ni Mo N 27-5-2	780	900	780	780	**450**	**390**	
17-4 PH, F 16 PH	X5 Cr Ni Cu Nb16.4	720	1000	-	**No welding**	**500**	**-**	
DX45, Uranus[b]	X2 CrNi No N 22.5.3	450	660	450	450	**330**	**225**	
Carbon steel								
E24/A	-	235	400	235	400	**200**	**200**	2.10*10^5
E32-AH 32	-	315	470	315	470	**235**	**235**	
E36-AH 36	-	355	490	355	490	**245**	**245**	
Copper alloys								
Bronze-Mn	-	245	510	-	-	**245**	-	1.10*10^5
Bronze-Ni-Al	-	390	740	-	-	**370**	-	
Monel 400	-	350	550	-	-	**275**	-	1.80*10^5
Monel 500	-	690	960	-	-	**480**	-	

a, Properties in unwelded condition $\sigma_D = \min(\sigma_y; 0.5\sigma_u)$

b, To be welded in a shielding gas (argon)

20.5.3 Rudder dimensioning load

The rudder maximum hydrodynamic force F [N] shall be calculated with formula (20.2) for displacement craft, and (20.3) for planning craft, the larger of these values to be used.

$$F_1 = 1300 \cdot L_{WL} \cdot A \quad \text{[N]} \qquad (20.2)$$

$$F_2 = 465 \cdot \left(\frac{h_r^{\ 2}}{A} \right)^{0,43} \cdot V_{MAX}^{\ \ 1,3} \cdot A \quad \text{[N]} \qquad (20.3)$$

Where A [m^2] is the rudder area, and h_r [m] the rudder blade height.

20.5.4 Spade rudder bending moment and bearing loads

Table 20.2 Centre of pressure height parameter

$c_2 / c_1 = \alpha$	1,00	0,90	0,80	0,70	0,60	0,50	0,40	0,30	0,20
k_b	0,50	0,49	0,48	0,47	0,46	0,44	0,43	0,41	0,39

Where c_2 is the rudder blade upper edge chord, and c_1 the lower chord

The rudder bending arm z_b [m] is

$$z_b = (k_b \cdot h_r) + h_b = h_c + h_b \quad \text{[m]} \qquad (20.5)$$

Where h_b is the distance from the top of the rudder blade to the centre of the neck bearing, and k_b is the height parameter for the centre of pressure location along the rudder blade. The centre of pressure location h_c may also be determined graphically.

Rudder bearing loads for spade rudders. R_U is the carrier bearing load.

$$R_U = F \cdot \frac{z_b}{h_u} \quad \text{[N]} \qquad (20.6)$$

Where h_u [m] is the distance between the carrier and neck bearing centres, and
R_H is the neck bearing load.

$$R_H = R_U + F \quad \text{[N]} \qquad (20.7)$$

Spade rudder bearing stocks shall be dimensioned using the equivalent (combined torque and bending) arm z_{eq} at the centre of the neck bearing

$$z_{eq} = \sqrt{z_b^{\ 2} + 0,75 \cdot r^2} \quad \text{[m]} \qquad (20.8)$$

Where the torsion arm r [m] is calculated with the formula

$r = 0{,}3 \cdot c - u \qquad r > 0{,}1c$ [m] (20.9)

where u [m] is the distance between the rudder stock centre and the rudder leading edge taken at the rudder centre of pressure height.

The dimensioning bending moment for a spade rudder at the centre of the neck bearing is calculated as follows

$$M_{eq} = z_{eq} \cdot F \text{ [Nm]} \tag{20.10}$$

20.5.5 Bending moment and bearing loads for rudders supported at their lower end

The bending moment at the neck bearing is:

$$M_H = F \cdot 0{,}25 \cdot z_b \text{ [Nm]} \tag{20.11}$$

where z_b is the centre of pressure height according to Formula (20.5)

The bending moment in the sole piece:

$$M_s = 0{,}4 \cdot F \cdot L_S \text{ [Nm]} \tag{20.12}$$

Where L_S [m] is the the distance from the sole piece forward end to the rudder stock.

The carrier bearing load:

$$R_U = \frac{M_H}{h_u} \text{ [N]} \tag{20.13}$$

The neck bearing load:

$$R_S = 0{,}35 \cdot F \text{ [N]} \tag{20.14}$$

The pintle bearing load:

$$R_H = F - R_S \text{ [N]} \tag{20.15}$$

The equivalent moment M_{eq} [Nm] assumed to occur in the rudder stock:

$$M_{eq} = \sqrt{M_H{}^2 + 0{,}75T^2} \text{ [Nm]} \tag{20.16}$$

Where M_H is the moment in (20.11) and $T = F \cdot r$ [Nm]

20.5.6 Rudder stock diameter

The diameter d [mm] of a round solid stock to be at least

$$d = 22 \cdot \left(\frac{M_{eq}}{\sigma_D} \right)^{\frac{1}{3}} \quad \text{[mm]} \qquad (20.17)$$

Where σ_D is the rudder stock design stress according to Table 20.1.

This requirement refers to the position where the equivalent moment reaches its maximum. Stocks other than round and solid shall be assessed based on their section modulus. Rudders supported in other ways than shown here above shall be assessed according to ISO 12215-8 except for that the formulas for forces F_1 (20.2), F_2 (20.3), and rudder stock diameter d (20.17) given above shall apply.

20.5.7 Rudder bearings

The rudder bearings and their support arrangements shall be designed for the rudder stock loads at the position in question. The bearing pressure is calculated for the projected area using the actual bearing length.

Table 20.3: Allowed bearing pressures

Material combination	Allowed pressure, σ_D [N/mm^2]
Steel against stainless or bronze	7.0
Steel against white metal, oil lubricated	4.5
Steel against plastic, water lubricated	5.5

20.5.8 Rudder blade

The rudder blade shall stand the dynamic pressure from the water flow rate in the propeller slipstream. The construction shall ensure that the skins do not separate from internal pressure.

The bending and torque moments shall be effectively transmitted to the rudder stock using stiffeners or bracing.

For spade rudders the thickness of the blade at half height hr/2 shall be at least 70 % of the thickness at the top. This requirement may be linearly interpolated from top to bottom.

20.5.9 Plate and profiled rudders

Plate rudders shall have a thickness t_e [mm] at least according to Formula (20.18), and the skin thickness for profiled rudders t_d [mm] at least according to Formula (20.19).

$$t_s = 3 + 0{,}125 \cdot d \quad [\text{mm}] \qquad (20.18)$$

$$t_d = k \cdot t_s \quad [\text{mm}] \qquad (20.19)$$

Where

d [mm] is the required rudder stock diameter

k = 0.46 for carbon steel and aluminium, and

k = 0.33 for stainless steel (AISI 316).

Rudders with skins of FRP shall have at least the same skin thickness as carbon steel or aluminium.

20.5.10 Tillers and quadrants

The rudder torque shall be transmitted to the tiller or quadrant through a keyway connection or equal. The intact diameter of the connection with the given torque T_r [Nm] shall be at least:

$$d_{top} = 1{,}72 \cdot \left(\frac{1750 \cdot T_r}{\sigma_D} \right)^{\frac{1}{3}}, > 0{,}6\, d \quad [\text{mm}] \qquad (20.20)$$

Where $T_r = F \cdot r$ [Nm].

The diameter of the machined stock shall meet the requirement in Formula (20.20) with the diameter taken as the smallest intact diameter to the bottom of the keyway, or as shown in Figure 20.3.

At the carrier bearing the intact diameter of the stock shall be at least 60% of the maximum diameter requirement for the stock, and the diameter requirement increases linearly towards the largest diameter.

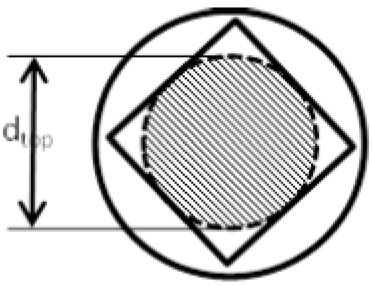


Figure 20.3: Interpretation of the intact diameter for a machined stock

20.5.11 Upper end of rudder stock casing

For preventing entrance of water there shall be a watertight seal or an equal arrangement in the casing.

20.5.12 Rudder sole piece

For rudders supported at their lower end the section modulus SM_S at the forward end of the sole piece where it attaches to the hull shall be at least:

$$SM_s = \frac{1{,}5 M_S}{\sigma_D} \quad [\text{cm}^3] \qquad (20.21)$$

Where σD [MPa] for metals is given in Table 20.1 and for FRP min(0.5σut, 0.5σuc).

The section modulus for the sole piece at the rudder stock shall be at least 60% of the value specified by Formula (20.21)

Between the sole piece attachment forward, and the rudder stock position the sole piece section modulus may be linearly interpolated.

20.5.13 Rudder stock flange bolted connections

For a rudder stock bolted connection the minimum allowed effective bolt circle diameter shall be determined with this formula:

$$d_B = \sqrt{\frac{11 \cdot q \cdot M_{eq}}{(n-1) \cdot (0{,}64 \cdot q)^2}} \quad [\text{mm}] \qquad (20.22)$$

Where M_{eq} is the equivalent moment according to Formula (20.10) for spade rudders, or Formula (20.16) for rudders supported at their lower end, n is the number of bolts, and q the bolt circle width [mm] according to Figure 20.4.

The bolt circle width q shall be at least two times the rudder stock thickness.

The bolts used shall have a minimum breaking strength of 790 Mpa.

The rudder stock flange with connections and welds shall be dimensioned for an equivalent moment Meq using the material properties given in Table 20.1.

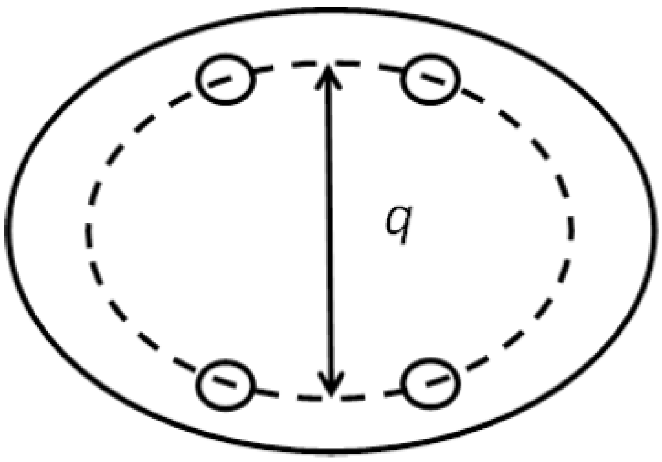


Figure 20.4: Bolt circle width q [mm]

20.5.14 Steering system forces

The steering force K_{RD} for craft with rudders shall be determined with the formula:

$$K_{RD} = 1{,}5 \cdot F \cdot \frac{r}{l_T} \quad \text{[N]} \qquad (20.23)$$

Where *r* is the centre of pressure distance from the rudder stock center, and l_t the tiller length [m].

20.5.15 Steerable propulsion devices

Steering arrangements for steerable propulsion devices shall meet the specifications from both the steering system and propulsion device manufacturers.

20.5.16 Electrical components

The electrical components of the control system located in the control room or engine rooms above the waterline in loaded condition shall be at least IP44, and IPX8 below the loaded condition waterline,

The protection class of the electrical switches of the control system must be at least IP55.

Outdoors, all components involved in the control must have an IPX8 protection class.

21 PROPULSION MACHINERY

21.1 Objective

The objective of the rules in this chapter is to ensure that the machinery installations are made so that the risks of fire and personal injury caused by rotating or hot parts, and unintentional engine stopping are minimized.

21.2 References

In this chapter reference is made to the following documents:

- ISO 8665 Small craft – Marine propulsion reciprocating internal combustion engines – Power measurements
- ISO 9094 Small craft – Fire protection
- ISO 9097-1:2002 Small craft – Electric fans
- ISO 13591 Small craft –Portable fuel systems for outboard motors
- ISO 10088 Small craft – Permanently installed fuel systems and fixed fuel tanks
- ISO 7840 Small Craft – Fire resistant fuel hoses
- ISO 11105 Small craft – Ventilation of petrol engine and/or petrol tank compartments
- ISO 16147 Small Craft – Inboard diesel engines – Engine-mounted fuel and electrical components
- ISO 13297 Small Craft – Electrical systems – Alternating and direct current systems
- IEC 60092-507 Electrical installations in ships part 507 Small vessels
- ISO 16315 Small Craft – Electric propulsion system

21.3 Documentation

For assessment of the requirements given in this chapter the following documentation is required:

- propulsion engine manufacturer, type, and power rating;
- propulsion devices manufacturer and type;
- engine space arrangement drawing, showing
    - location of machinery;
    - doors and hatches;
    - ventilation duct locations and cross sections;
    - cooling system arrangement
    - exhaust system arrangement
- pressure vessel information, if any
- Certificates of conformity for engine exhaust emissions, if required by local legislation

21.4 Application

These rules apply only for unmanned engine spaces.

21.5 Engines

21.5.1 Propulsion engine types

Inboard engines shall be designed and approved for marine use, and be diesel engines or electrical motors.

For outboard engines petrol may be used as fuel.

Outboard engines are approved with the following limitations:

- In Design Category C and D single or multiple outboard engines may be installed;
- If outboard engines are used in Design Category A at least twin installation is required;

Electrical propulsion systems shall meet the requirements in IEC 60092-507 or ISO 16315.

Permanently installed auxiliaries, for example for generating electrical power, shall have diesel engines designed for marine use.

Internal combustion engines shall meet local noise and exhaust emission requirements for commercial traffic, depending on legislation.

21.5.2 Portable auxiliaries

Portable auxiliaries like petrol driven generators, pumps, and hydraulic power units are allowed provided they are used solely on open decks, and are stored in compartments meeting the requirements for petrol storage given in standard ISO 10088.

A portable petrol tank shall have a maximum of 27 liters volume, and meet the requirements in standard ISO 13591.

For small portable petrol engines (<10 kW) where the portable tank volume (27 liters) is not exceeded, the tank may alternatively be integrated into the power unit provided there are safety instructions for the safe procedures to be followed when fuel is filled.

21.5.3 Power ratings

The power for combustion engines shall be declared according to standard ISO 8665.

21.5.4 Redundancy

It shall be possible to maintain the normal use of the propulsion machinery, or restore it to normal also when one essential auxiliary system falls out. Depending on Design Category and engine installation the following essential auxiliary systems shall have a backup:

- fuel feed system (see Chapter 22);
- seawater cooling system (see paragraph 21.8); and
- electrical supply (batteries or generator) (see Chapter 24).

21.5.5 Rolling and pitching

The main propulsion engines as well as all auxiliaries which are important for the safety of the craft shall as installed on board work at heeling angles between 0...15 degrees each way in statical conditions, and between 0...22.5 degrees in dynamic heeling conditions (rolling) with 7.5 degrees of dynamic trim changes each way (pitching) at the same time.

21.5.6 Hot surfaces

Any surface with temperatures exceeding 220°C shall not be located directly below components containing fuel. If necessary, the fuel from joints prone to leaking shall be prevented from reaching hot surfaces by an impermeable barrier to fuel and vapors.

21.6 Power transmission

Engine beds, propeller shafting, flange couplings and other parts of the transmission shall meet the requirements in Chapter 23.

21.7 Engine spaces

21.7.1 Arrangements

Engine spaces shall be separated from the interior of the craft.

All engine parts shall be accessible (definition see Chapter 32) for service and repair. This may be arranged by providing enough space around the engine(s), enabling service and repair in situ. In order to achieve accessibility the removal of non-structural bulkheads and equal is allowed. Alternatively, it should be possible to lift out the engine for bigger overhauls. Accessibility is required for routine service.

Machinery spaces shall be provided with arrangements for the protection of hot surfaces and rotating parts against unintentional contact during in-service maintenance and adjacent aisles.

There must not be any windows in the engine space. Electrical lighting is compulsory.

21.7.2 Installation of outboard engines

For outboard engines with maximum power 15 kW, attached without through bolting, there shall be a transom protection. The protection shall have a ridge at least 5 mm high preventing the engine from sliding off the transom in case its attachments loosen.

Outboard engines with over 15 kW power shall be through bolted to the transom.

In craft with over 15 kW outboard engine(s) there shall be a splash well forward of the engine(s). The well shall have a drain opening. Alternatively, fully enclosed craft, or those having buoyancy for flotation, may have arrangements where the water is immediately drained overboard. Steering cables and fuel hoses penetrations in the well shall meet the requirements in Chapter 3.

The installation of steering systems shall meet the requirements in Chapter 20.

21.8 Cooling systems

21.8.1 General

The rules in this section apply to cooling systems where the cooling is achieved by circulating sea water from a through hull connection through the engine cylinder block, or a heat exchanger, and also to systems where the cooling water is circulated through bottom tanks cooled by the passing sea water (skin tank cooling).

21.8.2 Cooling systems with sea water intake

In Design Category A and B two separate sea water intakes and suction pipes are required. Alternatively, an intake connected to a sea chest having a protective grating may be accepted.

For craft with more than one propulsion engine, one sea water intake per engine is sufficient.

For Design Category C and D craft a single intake and suction pipe is sufficient.

Each intake shall have a strainer, and additionally a filter in the suction pipe. The filter shall be serviceable without the use of tools.

Sea water filters and other cooling system components shall stand at least 100°C working temperature, as well as short fires in the engine space.

Sea water shall be prevented from back flowing into the engine cylinders by a siphon breaking arrangement at the highest point of the cooling water circuit, and if required with a water lock in the exhaust line when the exhaust bend is close to the water surface according to clause 21.9.2.

Sea water cooling circuits shall be equipped with alarm for lack of water.

The through-hulls shall conform with Chapter 3.

21.8.3 Cooling systems without sea water intakes

When the cooling is based on heat exchanging through the bottom of the craft, the exchanger lowest point shall not be below the keel, and the forward part have collision protection.

Skin tank cooling and external heat exchanger sizing and scantlings shall conform with the engine manufacturer’s recommendations.

Skin tank cooling integrated into the hull, and external heat exchangers shall pass a pressure test to 40 kPa for three minutes without any pressure drop.

21.8.4 Cooling system details

The materials used in sea water systems shall be corrosion resistant. Parts shall not be combined so this causes galvanic corrosion.

Cooling circuits shall normally consist of metal tubing. Where flexibility is required short hoses may be used.

Hoses used in cooling system shall stand the expected temperatures (for example meet the requirements in standard ISO 7840).

Hose clamps shall be of stainless steel (AISI 316) or equivalent material.

In cooling system hose connections two stainless clamps shall be used, or alternatively at least one heavy duty super-clamp with two bolts, and over 15 mm width.

21.8.5 Sea chests

The sea chests shall have a service hatch through which the contaminants that come with the sea water can be cleaned.

The strength of the sea chest must correspond to the strength of the hull and be dimensioned with a design pressure of at least 40 kPa.

The overflow edge of the sea chest with the service hatch open must be at least 0.1 m above the fully loaded waterline.

21.9 Exhaust system

21.9.1 General

Each engine shall have a separate exhaust system.

The exhaust system exits and ventilation system intakes shall be located so that exhaust gases are not conveyed into the craft interior.

Exhaust system parts cooled by seawater shall be of corrosion resistant materials. Parts shall not be combined so this causes galvanic corrosion.

The exhaust system back pressure shall not exceed the engine manufacturer's limits.

For dry exhaust systems attention should be paid to high temperature, gas tightness, heat expansion, engine vibrations, and necessary heat insulation.

21.9.2 Prevention of water intrusion

The exhaust shall be designed so that water intrusion into the engine or craft through siphoning or water pressure is avoided.

The entire exhaust outlet including its connection to the exhaust hose shall be at least 100 mm above the fully loaded waterline, or alternatively, if the exhaust outlet is less than 100 mm above the fully loaded waterline, the strength of the outlet pipe shall be equal to that required for the hull in the same location, and the overflow edge height shall be at least 100 mm above the fully loaded waterline.

In watercooled exhaust systems without a water lock or siphon breaker, the overflow edge of the engine exhaust bend shall be at least 350 mm above the fully loaded waterline, and the exhaust line shall be downward-sloping all the way to the outlet located above the fully loaded waterline

If the engine exhaust bend overflow edge is less than 350 mm above the fully loaded waterline, a siphon breaker shall be installed in the cooling water line, additionally the uppermost point of the exhaust line shall be at least 350 mm above the fully loaded waterline, and the exhaust be downward-sloping from this point to the outlet in all loading conditions.

The siphon breaker shall be higher up than the exhaust line, and at least 350 mm above the fully loaded waterline.

The volume of the exhaust line between the engine exhaust bend and the uppermost overflow point of the exhaust line shall be sufficient, and if necessary increased with a water lock, for avoiding water intrusion into the engine.

For engines with integrated exhaust the engine manufacturer's advice should be followed for the height of the engine exhaust bend above the fully loaded waterline, considering all loading conditions.

21.9.3 Insulation

For dry exhaust systems all parts exceeding 60°C shall be thermally insulated for reasons of engine space temperature and crew safety.

Exhaust lines passing through bulkheads and the hull shall be thermally insulated from these items.

21.9.4 Engine space ventilation

The air supply for combustion and engine space cooling shall be sufficient in relation to the power of the engine(s). With the engines running the engine space temperature measured at the level of the engine air intake shall not be more than 15°C over the ambient temperature.

This requirement is considered fulfilled if the engine space natural ventilation is arranged as follows:

- in the engine space bottom third, above bilge water level, there shall be duct(s) for the outgoing air;
- in the engine space top third there shall be duct(s) for the incoming air on the opposite side of the engine space; and
- the total cross section of the ducts shall be at least $7 \cdot P$ [cm^2] where P [kW] is the total engine power.

Alternatively the ventilation may be based on the engine manufacturer's recommendations, provided the engine space temperature requirement above is fulfilled.

Engine space ventilation ducting shall also meet the requirements in standard ISO 11105, meaning that the ventilation of the space shall work also when the engines and forced ventilation are shut off.

For preventing water intrusion into the engine space, the location of the ventilation openings shall meet the requirements in Chapter 3.

The ventilation openings shall be located for avoiding flying spray in waves from getting into the engine combustion air.

In case there is a fire extinguishing system in the engine space (see Chapter 27) requiring the ventilation to be disabled for proper functioning, the ventilation ducting shall be fitted with closing arrangements having controls outside the engine space, enabling locking in both *Closed* and *Open* position.

21.9.5 Material requirements for the exhaust system

Water cooled exhaust hoses shall meet the requirements in SAE J2006, or have Classification Society approval for use in marine exhaust systems. The allowed working temperature for components should be at least 80°C.

Dry exhausts shall be of steel or equivalent material, and have insulation according to Clause 21.9.3.

21.9.6 Arrangements of electrical propulsion

The electric propulsion system must meet the requirements of ISO 16315 or IEC 60092-507.

Electrical propulsion batteries must be in a battery compartment that is ventilated separately outside the craft.

Battery types whose overheating causes an exothermic reaction (eg Li-Ion) shall be in a battery compartment insulated to fire class A60, if the battery capacity exceeds 10 kWh.

The above-mentioned battery compartment must be able to be cooled by water or another substance suitable for the battery type, from outside the compartment in the event of overheating.

Cooling of batteries and electric motors shall be carried out in accordance with the manufacturer's requirements.

21.10 Control and information systems

Propulsion machinery (internal combustion engines) and electric propulsion system shall be controllable from the steering station. The following information shall be displayed at this station if applicable:

- propulsion engine rpm;
- propulsion engine lubricating oil pressure;
- cooling water temperature; and
- alarm for lack of water in wet exhaust systems.
- electrical propulsion status (on / off);
- the operating mode of the hybrid system;
- electric propulsion battery temperature;
- warning of interruption of the cooling circuit of the electric propulsion battery
- warning about overheating of the electric propulsion battery

- electric propulsion battery voltage and low voltage warning
- electric propulsion battery charging and discharging current
- charge level of the electric propulsion battery
- electric propulsion engine power level, or propeller rpm
- warning against overheating of the electric propulsion engine

21.11 Pressure equipment

Pressure equipment shall be assembled, located, maintained, used, and inspected so it does not present a hazard to health, safety, or property. Conformity assessment according to the applicable Law for pressure equipment is verified with Notified Body inspections or other procedures specified in National Regulations for pressure equipment safety.

21.12 Tanks

21.12.1 Strength

Fuel tanks shall meet the requirements in Chapter 22. Waste water tanks shall meet the requirements in Chapter 32. Other tanks, such as for lubricating- or hydraulic oil, or cooling water tanks shall be pressure tested to a level ensuring sufficient safety in relation to the working pressure in the tank, including the static head in an overflow condition. The test pressure P_{TEST} is determined with Formula (21.1)

$$P_{TEST} = 15 \cdot h \text{ [kPa]; min 20 kPa} \qquad (21.1)$$

where h [m] is the vertical distance from the bottom of the tank to the top of the filling or vent line.

21.12.2 Tank materials

Tank materials shall be suitable for the intended use. For fuel tanks the requirements in Chapter 22 shall be met.

22 FUEL SYSTEM

22.1 Purpose

The purpose of the rules in this chapter is to ensure a undisturbed fuel supply, to minimize risk of fire, and to define the means for the prevention of pollution.

NOTE! In Chapters 33...41 there may be further requirements related to additional notations.

22.2 References

In this chapter reference is made to the following documents:

- ISO 10088 Small craft – Permanently installed fuel tanks
- ISO 11105 Small craft – Ventilation of petrol engine and/or petrol tank compartments
- ISO 8846 Small craft – Electrical devices – Protection against ignition of surrounding flammable gases
- ISO 7840 Small craft – Fire resistant fuel hoses
- ISO 13297 Small craft - Electrical systems – Alternating and direct current installations
- ISO 21487 Small craft – Permanently installed petrol and diesel fuel tanks
- ISO 5817 Welding. Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded). Quality levels for imperfections
- ISO 10042 Welding. Arc-welded joints in aluminium and its alloys. Quality levels for imperfections

22.3 Documentation

For assessment of the requirements given in this chapter the following documentation is required:

- fuel system showing
    - location of components
    - information about components
- drawings of fuel tanks showing
    - shape
    - construction
    - scantlings
- test protocols
    - proof pressure test for non CE-marked tanks
    - proof pressure test for fuel system
- certificates of conformity:
    - ignition protected equipment
    - CE-marked components of the fuel system

22.4 Design of fuel systems

The fuel system shall be designed and built so a undisturbed fuel supply is ensured to the propulsion engine(s) and other critical machinery considering the Design Category of the craft.

In Design Category C and D there may be one fuel tank with separate feed and return lines, fuel filter, and water separator. In Design Category A and B one of the following arrangements is required:

- one tank with one feed line equipped with dual filters and by-pass
- one tank with two feed lines (twin engine installation); or
- two tanks

The valves controlling the switching from one feed line to the other shall be easily accessible (see Chapter 31).

Portable fuel tanks (see Chapter 21) are allowed in the following case:

- for small auxiliaries
- for supply for one outboard motor, taking into account a sufficient range of operation.

Petrol fuel tanks shall not be integrated into the hull structure.

22.5 Requirements for spaces containing fuel tanks

Spaces containing fuel tanks shall be tightly separated from enclosed interior spaces (see detailed information in EN ISO 11105 clause 4.4). The spaces shall be ventilated to the open air. The duct for the outgoing air shall be located in the bottom third of the space. The duct for the ingoing air shall be located in upper part of the space. The ducts for the incoming and outgoing air shall primarily be located on opposite sides of the space, however at least 600 mm apart as the space limits allow.

Petrol tanks shall be placed on the deck open to outdoor air, or in a separate compartment. Spaces containing petrol tanks shall have natural ventilation according to ISO 11105.The total cross section of the incoming air duct(s), and the total cross section of the outgoing air duct(s) shall be according to Formula (22.1) in spaces containing petrol tanks.

$$A \geq 33 \cdot \ln (V/0{,}14) \qquad [cm^2] \qquad (22.1)$$

where V [m^3] is the net volume of the space.

In spaces containing petrol tanks only electrical components essential for bilge pumping and fuel system shall be installed. All electrical components installed in spaces containing petrol tanks shall be of the ignition protected type according to standard ISO 8846.

A diesel tank may be located in engine space according to ISO 10088. The diesel tank space shall have a natural ventilation in which the inner diameter of the ventilation ducts is at least 62 mm, or similar area.

22.6 Fuel tanks

22.6.1 Fuel tank arrangements

In diesel oil tanks the connections may be located on the sides provided they have shut-off valves directly at the tank. The shut-off valves shall be protected if there is a risk of structural damage to them.

In petrol tanks all the connections shall be on the top, except for metallic feed or return pipes, which may be attached at the top edge of tank sides or ends, provided they are welded to the tank, and extend upwards above the tank top.

The fuel return pipe shall terminate close to the tank bottom. A small air hole in the return pipe to prevent siphoning is allowed inside the tank

If there is a drain connection in a diesel oil tank, it shall be fitted with a shut-off valve having a plug that can be removed only with tools, or a similar additional protection to prevent fuel leaks.

Each tank shall have an inspection hatch with at least 150 mm diameter. The inspection hatch shall, as a rule, be located on top of the tank, but for diesel oil tanks it may also be on the tank side. There shall be access to the inspection hatch when the tank is in position.

It shall be possible to determine the fuel level and the amount of fuel in each tank.

Transparent external tank level sight glasses are allowed only in diesel oil tanks. They shall be permanently installed, protected against structural damage, and have self-closing shut-off valves which can be opened only manually. Sight glasses connected to the top of a tank, or at the upper edge of tank sides do not need a shut-off valve at that end.

Metal tanks shall be designed and installed so their external surfaces do not trap water.

All fittings on as well as inside the tanks shall be designed and installed so they can not cause damage to the tanks as a result of movement or vibration.

Inside tanks there shall not be any filters.

Prefabricated fuel tanks shall be CE-marked according to standard ISO 21487.

Electrical components in fuel systems shall be installed according to standard ISO 10088, ISO 10133 and ISO 13297.

Integral fuel tanks are allowed only for fuels with a flashpoint over 60°C (for example diesel oil).

22.6.2 Materials

The following requirements refer for tanks made of steel, stainless steel, aluminium, FRP, and polyethylene. FRP tanks shall be made with Class A resins according to standard ISO EN 12215-1, or with other fuel resistant resins.

Diesel fuel tanks located in the engine space shall be of metal.

The welds in metallic fuel tanks shall meet the requirements in standard ISO 12215-6 for the weld details.

22.6.3 Fuel tank construction

CE-marked tanks with a volume less than 200 litres are considered to meet these requirements.

Tanks without CE-marking shall meet the requirements in Table 22.1.

Fuel tanks shall be designed to stand the highest pressure the tank will encounter, considering also dynamic forces.

Tanks with maximum 500 liters volume and meeting the minimum thickness and number of baffles requirements in Table 22.1, are considered to meet the strength requirements.

Tanks with over 500 liters volume shall additionally be assessed using standard ISO 12215-5.

Integral tanks shall additionally be dimensioned and built according to Chapters 7-19 to withstand the hull loads.

Table 22.1: Fule tank material minimum thickness [mm], and number of baffles, V = volume [liters]

Volume, V [l]	**<50**	**50…150**	**150…300**	**300…500**	**>500**
Number of baffles	0	1	2	3	3

Material	**Material thickness [mm]**					**Fuel**
Aluminium 5754	4.0	4.0	5.0	6.0	6.0	Diesel, Petrol
Aluminium 5083	3.0	3.0	4.0	5.0	5.0	Diesel, Petrol
Stainless steel (AISI 316)	1.25	1.5	2.0	3.0	3.0	Diesel, Petrol
Steel	2.0	2..5	3.0	4.0	4.0	Diesel
Hot-dipped galvanized steel (from outside only)	1.5	2.0	2.5	3.5	3.5	Diesel
Hot-dipped galvanized steel (from both sides)	1.5	2.0	2.5	3.5	3.5	Petrol
FRP	4.0	4.5	5.0	5.5	6.0	Diesel
Polyethylene	6.0	7.0	8.0	10	-	Diesel, Petrol

Openings in baffles shall be maximum 30% of the tank cross section at the baffle. Baffles shall not prevent fuel flow along the bottom of the tank, nor air flow along the inside of the tank top. The openings in baffles shall enable cleaning of the tank.

22.6.4 Tank seatings and attachments

The tank seatings and attachments shall stand the loads that occur in the relevant Design Category conditions. The tank attachment shall pay attention to chafe protection. The attachment shall stand the mass forces caused by the downward accelerations used in the hull design pressure determination (see Chapter 7). In other directions the accelerations shall be assumed to be at least 2 g.

Tanks not integrated in the structure shall be installed so there is ventilation around them. Metal tanks shall be at least 25 mm above the bilge pump suction head, or float switch.

Tanks may be foamed in with polymer foam on the following conditions:

- the foam can stand the fuel in question, and the temperature range -40…+60°C;
- metal tanks shall not be foamed in;
- the foam shall not extend to the hull bottom;
- the supporting area is sufficient for carrying the previously mentioned loads.

22.6.5 Testing of fuel tanks

In case the tank has CE-marking, only a system tightness test according to 22.9 “Testing” is made.

The tank shall have all connections and valves installed during the test.

22.6.5.1 Diesel oil tanks

For metal tanks the test pressure is the larger of: 20 kPa, or 1.5 times the maximum possible static head (the vertical distance from the top of the tank to the top of the filler or vent line).

Testing time is 5 minutes. The pressure shall not increase or decrease during the testing. The tank must not leak.

Polyethylene tanks shall use the same test pressures as for metal diesel oil tanks. The testing time is 1 hour when the material density is ≥ 935 kg/m^3, and 5 hours when the density is less than 935 kg/m^3.

Non-metallic tanks in engine spaces shall meet the fire testing requirements in ISO 21487.

22.6.5.2 Petrol tanks

Petrol tanks manufactured in series production shall be pressure-impulse tested according to ISO 21487, or it shall be CE-marked separately. Metallic individually manufactured petrol tanks may alternatively be pressure tested, the test time of is 5 minutes. The test pressure shall be the higher of:

- 30 kPa, or
- $1.5 \cdot h_s \cdot 9.81 + 10$ [kPa].

Where h_s = maximum vertical height of the vent line measured from the top of the tank [m]

The tank shall not break or leak during the test, but permanent deformation is allowed.

Individually manufactured tanks that are tested with pressure test, shall conform the structural requirements for integral tanks in ISO 12215-5, and welding quality class B requirements in ISO 5817 (steel) or ISO 10042 (aluminium).

Non-metallic petrol tanks shall meet the fire testing requirements in ISO 21487.

22.6.6 Marking of fuel tanks

Tanks shall be marked with the net volume [liters] and the fuel to be used.

For craft having additionally CE-marking according to the directive 2013/53/EU, the tanks shall be marked as follows:

Tanks to be permanently marked with at least 3 mm high letters and numbers:

- Tank manufacturer, place and country
- Year made (last two numbers)
- Tank volume [liters]
- For non-metallic tanks the maximum allowed temperature [°C]
- Symbol for the appropriate fuel(s) (per ISO 11192) or the words “Petrol” or “Diesel”.
- Maximum hydrostatic head above the tank [m]
- Maximum allowed test pressure [kPa]
- For fire-tested non-metallic tanks additionally “ISO 21487”

The markings shall be legible when the tank has been installed.

22.7 Fuel system installation

All fuel system parts shall be separately supported, except for small couplings and fittings, as well as short hoses.

All valves and other fittings used or monitored during normal use or in an emergency shall be easily accessible (see Chapter 32). All the other components shall be accessible.

In case there are copper alloy fittings with an aluminium tank, the fittings shall be electrically insulated from the tank for corrosion prevention.

All metallic parts of the fuel system between the filler cap and engine shall be grounded. The grounding cable must not be attached to a spud by jamming it under the hose clamp. If the grounding cable is insulated, the colour shall be yellow-green.

There shall be no petrol fuel system couplings directly above batteries or electrical cabinets.

Spaces containing petrol fuel system couplings shall have ventilation according to ISO 11105, and the electrical devices shall be ignition protected according to ISO 8846.

22.8 Fuel system piping

The filler cap inside diameter to be at least 31.5 mm, and the filler hose at least 38 mm. A separate filler line is required for each tank.

The vent line cross section shall be at least 95 mm^2 and the inside diameter 16 mm. A separate vent line is required for each tank.

The fuel filler and vent lines shall be installed so they drain downwards to the tank.

The fuel filler cap shall be located so overflowing fuel cannot reach the craft interior.

The fuel filler cap and vent line exit shall be at least 400 mm from any ventilation opening or air intake.

The vent line exit or vent line gooseneck shall be installed sufficiently high up, so overflow is avoided during filling, and water can nor enter during normal use. The vent line exit and gooseneck shall be located higher up than the filler cap.

Fuel pipelines shall normally be of steel or copper. Aluminium piping is allowed for diesel oil. Rigid pipes shall be connected to the engine with short flexible fuel hoses.

Fuel hoses shall be accessible for inspection and maintenance.

Fuel hoses in the engine space shall be fire resistant, type A1 or A2 according to standard ISO 7860.

Outside of the engine space hoses of type B1 or B2 may be used.

Fuel feed and return pipes shall have shut-off valves as close to the tank as possible. The valves shall have remote control from an easily accessible location outside the engine space. The valves shall be metallic or fire resistant according to ISO 7840. If feed and return lines are installed so fuel siphoning cannot occur, the shut-off valves are not required.

The fuel feed system shall have a fuel filter, and a water separator. Water collected in the separator shall be recognized visually, or by a sensor with alarm. In outboard installations filtering and water separation may be combined into one unit, then it is not necessary to have visual indication for any water.

For craft in Design Category A and B it shall be possible to clean or replace the filter with the engine running. In the filter pipeline there shall be a vacuum sensor, with indication when cleaning of the filter is due.

he fuel hoses shall be connected to the pipes, spuds or fittings with metallic hose clamps, or swaged end fittings. Hoses with over 25 mm outer diameter shall use two hose clamps for the connections, and the spuds shall be at least 35 mm long to accommodate twin clips.

22.9 Testing

22.9.1 Pressure testing of the system

After installation the fuel system shall be tested for leaks according to standard ISO 10088 Annex A. In Design Category C and D this testing may alternatively be made in connection with sea trials.

The installed system tightness is inspected with a pressure test as follows:

- Test pressure 20 kPa
- Testing time 1.5 s times tank volume in liters, min. 5 minutes, and max. 30 min.
- During the test no leaking in the system is allowed, possible pressure drop to be monitored.
- Filler cap and vent line exits may be plugged.
- The fuel pump at the engine to be disconnected from the feed line, and closed. Other valves and anti-siphon valve to be open during the test.

22.9.2 Fire testing

The fuel system components located in the engine space (for example fuel filters, water separators) shall have been fire tested according to ISO 7840. Non-metallic fuel tanks in the engine space shall have been tested according to ISO 21487. When the fuel pipelines are of metal, their attachments and brackets do not need fire testing.

23 POWER TRANSMISSION

23.1 Objective

The purpose of the rules in this chapter is to ensure correct sizing of the parts of the power transmission in question which do not belong to assemblies for which the equipment supplier takes responsibility, and make sure that the power transmission does not impair the watertightness of the hull.

23.2 References

In this chapter reference is made to the standard ISO 8665 Small Craft – Marine propulsion reciprocating internal combustion engines – Power measurements

23.3 Documentation

For assessment of the requirements given in this chapter the following documentation is required:

- drawing of the propeller shaft line, with the following shown
- propeller shaft including bearings and shaft seal;
- constant velocity joints and other components; and
- material information; and
- propeller shaft sizing calculation

23.4 General requirements

These rules are primarily intended for cases where the power transmission is not supplied as a complete assembly, instead the components are manufactured and chosen one by one by the manufacturer. This rule version deals with propellers on straight shafts as well as waterjet units.

The rules do not specify requirements for propulsion units delivered as assemblies, such as stern drives, water jets, and surface propeller drives. For the installation and use of such units the manufacturer's instructions should be followed. In case such units despite this cause unexpected danger, additional requirements can be given according to the principles presented under clause 23.1 "Objective".

For craft with the additional notation "Winter navigation" the power transmission shall be assessed according to the additional requirements in Chapter 39.

23.5 Engine bearers

Engine bearers shall be designed so they can withstand the forces in the relevant Design Category arising from engine weight, accelerations, propulsion torque, and possibly thrust.

This requirement is considered fulfilled if the bearers are designed according to Chapters 10, 14 and 18, depending on the material used.

23.6 Gearboxes

The gearbox shall be compatible with the propulsion engine

23.7 Requirements for shafting with propeller

23.7.1 Propeller shaft

The diameter of the propeller shaft d [mm] shall meet the engine manufacturer's recommendations, but shall as a minimum meet Formula (23.1)

$$d = 420 \cdot \left(\frac{P}{r \cdot \tau_d} \right)^{\frac{1}{3}} \text{ [mm]} \tag{23.1}$$

where P [kW] is the engine maximum continuous output according to standard ISO 8665, r [1/min] the propeller rpm, and τ_d [N/mm^2] the allowed shear strength given in Table 23.1.

Table 23.1 Propeller shaft and strut material data

Material	Chemical composition	$\sigma_y{}^a$ [MPa]	$\sigma_u{}^a$ [MPa]	$\sigma_D{}^a$ [MPa]	τ_D [MPa]
AISI 304	X5 Cr Ni 18.9	195	500	195	**111**
AISI 316, 316L	X5 Cr Ni Mo 17.2.2	195	500	195	**111**
AISI 329 Not cold worked	X3 Cr Ni Mo N 27-5-2	500	650	325	**185**
AISI 329 Cold worked	X3 Cr Ni Mo N 27-5-2	780	900	450	**256**
17-4 PH, F 16 PH	X5 Cr Ni Cu Nb 16.4	720	1000	500	**285**
DX45, Uranus[b]	X2 Cr Ni No N 22.5.3	450	660	330	**188**
E24/A	-	235	400	200	**114**
E32-AH 32	-	315	470	235	**133**
E36-AH 36	-	355	490	245	**139**
Bronze-Mn	-	245	510	245	**139**
Bronze-Ni-Al	-	390	740	370	**210**
Monel 400	-	350	550	275	**156**
Monel 500	-	690	960	480	**273**
$\tau_D = 0,57\ \sigma_D{}^a$, where $\sigma_D{}^a = min(\sigma_y\ ;\ 0,5\sigma_u)$					

23.7.2 Flexible shaft couplings and constant velocity joints

Flexible shaft couplings equalizing torque and bending or constant velocity joints shall be suitable for the occurring torque and bending according to the manufacturer's recommendations.

23.7.3 Thrust bearings including bearers

Thrust bearings shall be chosen according to the manufacturer's recommendations. Their bearers shall be dimensioned with consideration for maximum propeller thrust, and other loads for example in ice.

23.7.4 Propeller shaft seals

All materials used in shaft seals shall be oil resistant. The entire seal shall stand heating up without leaking significantly.

Propeller shaft penetrations through watertight bulkheads shall be dimensioned so the bulkhead strength, tightness, and possible fire class are not impaired.

23.7.5 Propeller shaft struts

Single arm propeller shaft struts shall be dimensioned so that the section modulus W [cm3] at the hull is at least:

$$W = \frac{l * d^2}{112 \cdot \sigma_u} \text{ [cm}^3\text{]} \qquad (23.2)$$

Where:

- l [mm] is the strut length from the hull to the centre of the shaft
- d [mm] is the shaft diameter
- σu [Mpa] the material breaking strength according to Table 23.1.

Where the strut joins the shaft bearing the section modulus W [cm3] shall be at least 60 % of the above. W at intermediate positions along the strut can be linearly interpolated between these two values.

For double arm struts the section modulus for each shall be 50 % of the requirement in (23.2), when the distance *l* is measured along the perpendicular from the shaft center to the hull, and the angle between the arms is less than 70 degrees.

23.7.6 Propeller shaft bearings

The following requirements are valid for bearings of white metal or equal materials.

The bearing outer diameter shall be at least according to Formula (23.3).

$$t = \frac{d+230}{32} \text{ [mm]} \qquad (23.3)$$

Where *d* [mm] is the actual shaft diameter.

The length of a bearing inside the stern tube shall be at least three times the shaft diameter, and at least two times the shaft diameter in other locations.

23.7.7 Bearing spacing

The maximum distance between bearing centres S [m] shall be taken according to Formula (23.4) for shafts of steel.

$$S = 85 * \sqrt{\frac{d}{85{,}4 * r}} \quad \text{[m]} \qquad (23.4)$$

Where

- d [mm] is the shaft diameter
- r [1/min] is shaft rpm.

When a flexible coupling is used at the gearbox flange the minimum bearing spacing should be according to Table 23.2, but not more than given by Formula (23.4).

Table 23.2: Minimum bearing distance with flexible coupling.

Shaft diameter [mm]	Minimum allowed bearing distance [mm]
25	300
30	400
35	500
40	600
45	700
50	800
55	900
60	1000
70	1100
80	1200

23.8 Requirements for waterjets

For waterjet units the shaft couplings shall meet the requirements in this chapter where applicable.

24 ELECTRICAL INSTALLATION

24.1 Objective

The objective of the rules in this chapter is to provide installation guidelines for electrical installations in commercial craft, for permanently installed d.c. and a.c. systems with nominal voltages Un ≤ 50 V d.c. respective Un ≤ 500 V a.c.

The rules aim to ensure sufficient safety against electric shocks, to minimize the risk of electrical fires, and to enhance the component reliability for distribution of power.

The rules do not refer to internal installations within classed components.

The capacity requirements for electrical propulsion systems are not within the scope of the rules, instead the requirements have to be evaluated case by case. Electrical propulsion system installations are addressed in standard ISO 16315.

Protection against electromagnetic interference refers only to the components used onboard, which should meet IEC 60533 and IEC 60945.

24.2 References

In this chapter reference is made to the following documents:

- ISO 10133 Small craft – Electrical systems – Extra-low-voltage d.c. installations
- ISO 13297 Small craft – Electrical systems – Alternating current installations
- IEC 60092-507 Electrical installations in ships part 507 Small vessels
- ISO 16315 Small craft – Electric propulsion systems

24.3 Documentation

For assessment of the requirements given in this chapter the following documentation is required:

- electrical load balance calculation;
- list of equipment;
- battery capacity calculations;
- electrical distribution main scheme;
- switchboard circuit scheme;
- other electrical schemes if relevant;
- grounding scheme ;
- instructions for service and use of the equipment
- signed declaration of conformity, where references to the rules used, possible exceptions [1)]
- signed test protocols according to paragraph 24.12 Testing [1)]

[1)] the requirement is not applied to small installations, see 24.4.4.

24.4 Definitions

24.4.1 Main electric source, secondary electric source, and emergency electric source

Main electric source means in this connection generators, producing power which enables the craft to operate at sea. The main electric source, i.e. the generator may be powered by the propulsion engine, or an auxiliary engine.

Secondary electric source is a battery or battery bank, whose primary task is to supply electricity to essential consumers when the main electric source is not in use. The secondary electric source can be located in the engine space. Typically the secondary electric source supplying the craft's consumers is the service battery bank, with separate batteries for big consumers (for ex. bow thruster, anchor windlass). Starting batteries are not counted as a secondary electric source.

For craft with the additional notation Passenger transport there are additional requirements for the secondary electric source of electricity in Chapter 34.

Emergency electric source is an independent battery bank outside the engine space, or a generator above the fully loaded waterline, whose purpose is to supply electricity only to the radio communication equipment, emergency lighting, and position-indicating radio equipment during at least two hours (GMDSS). Detailed requirements are given in the TraFi regulation Radio Equipment for Ships (TraFi/5379)

24.4.2 Essential consumers

Essential consumers are all electrical systems needed for the safe navigation of the craft. For example the following, if applicable:

- the propulsion engine systems;
- the steering system;
- running lights;
- bilge pumps;
- radio equipment;
- navigation equipment;
- communication equipment;
- electrically powered doors and hatches
- fire alarm and extinguishing systems; and
- emergency lighting

24.4.3 Main voltage

Main voltage means the voltage supplied by the main electric source.

24.4.4 Small installations, definition

In *Small d.c. installations* the total power of the main electric source of electricity shall be at the most 2 kW (166 Ah 12 V, 83 Ah 24 V) and for the secondary electric source at the most 3 kW (250 Ah 12 V, 125 Ah 24 V).

In *Small a.c. installations* a.c. is not used as the main voltage, the installation has a single phase, and the main fuse is at the most 1 x 16 A.

24.4.5 Easily accessible

Accessible and easily accessible are defined in Chapter 32.

24.5 Application

24.5.1 Electrical installations

The electrical installations for the craft shall be designed and installed according to

IEC 60092-507, except for Small installations.

The additional requirements and exceptions in the text of this chapter shall be followed.

Component manufacturer's specific requirements shall be followed.

24.5.2 Small installations, alternative standards

When an d.c. or a.c. installation meets the definition for small installations, standard ISO 10133 and ISO 13297 may be used instead, but in addition the following paragraphs from this chapter shall always be used:

- 24.3 Documentation
- 24.9 Batteries
- 24.10 Generators and charging equipment
- 24.11 Protection classes for equipment
- 24.12 Testing

24.5.3 Electrical propulsion

The installations for electrical propulsion systems shall be made according to standard ISO 16315.

24.6 General

24.6.1 Selection, planning, dimensioning, and installation

All permanently installed equipment essential for the safe operation of the craft shall be selected and installed so that it is suitable for the craft considering its Design Category and possible special missions.

Electrical appliances and equipment shall be planned and installed so they do not pose any danger to life or property. The risk of arc discharge shall also be considered in connection with the installation of electrical appliances and equipment.

The equipment shall not cause unreasonable electrical or electromagnetical disturbance, and the proper function shall not suffer easily from electrical or electromagnetical disturbance. The appliances shall meet IEC 60533 or IEC 60945 requirements as applicable.

All appliances shall be accessible for operation and service.

The appliances shall be selected and dimensioned for functioning properly considering the accelerations and vibrations of the craft (for example operating in ice), overcoming water, temperature variations, sea water, chemicals, oil, UV-radiation, as well as other circumstances to be expected.

The associated cables and piping shall allow some movement for the appliances and equipment.

24.6.2 Propulsion machinery starting circuit

Only for propulsion engines with less than 100 kW output it is allowed to use the engine block as a conductor in the starting circuit during the starting operation.

24.7 Distribution network

In craft over 15 m with metal hulls all branches of the distribution network shall be fitted with ground-fault circuit interrupters having testing possibility.

All switchboards and consumers shall have a reliable disconnection possibility for service purposes, for example double pole switches or circuit breakers. However, gas alarm, intrusion alarm, heater, and automatic bilge pumps may be connected without disconnection possibility. In this case they shall have their own short circuit protection.

24.8 Electrical generation on board.

24.8.1 The main electric source

The main electric source shall be one or several generators, which can be driven by their own auxiliary engine, or by the main engine.

Craft in Design Category A and B shall have at least two main electric sources, i.e. two generators.

The capacity of each main electric source shall be sufficient for all electrical requirements of the whole craft in all operating conditions.

24.8.2 The secondary electric source

The craft shall have a battery or battery bank to ensure uninterrupted power supply to the essential consumers when the the main electric source of electricity is not in use.

24.8.3 The emergency electric source

The emergency source of electricity supplying the radio equipment related to the GMDSS-system (VHF), the emergency lighting, and the position finding (GPS), shall be independent from the battery bank in the engine space.

24.9 Batteries and battery banks

24.9.1 General

In case the main- and/or auxiliary engine of the craft has electric starting, there shall be both a service battery bank and a starting battery bank.

In normal conditions the starting batteries must not be used for any other purpose than the starting of engines, except for paralleling with the service batteries in exceptional conditions.

For the service and starting batteries there shall be a possibility to connect them in parallel. The service batteries shall be able to function as starting batteries and vice versa.

The service battery bank shall normally supply power to the radio equipment, but additionally there shall be a separate emergency source of electricity for the supply of the radio equipment only.

24.9.2 Battery capacities

The secondary electric source shall have a capacity ensuring that the service batteries can supply the essential consumers of the craft alone, without the main and emergency sources, during at least three hours, when the craft is not in operation, and there is a leak in one compartment corresponding to the bilge pumping capacity, also considering emergency radio traffic, in the applicable alternative situations and circumstances.

The emergency source of electricity shall alone have a capacity able to supply the GMDSS-equipment for at least two hours. Detailed requirements can be found in TraFi regulations for marine radio equipment.

The capacity of starting batteries shall meet the engine manufacturer’s requirements, and additionally be according to Formula (24.1):

$$MCA \geq 200 + 80 \cdot \sqrt[5]{P} \quad [A] \qquad (24.1)$$

where MCA is the battery nominal starting current in 0°C during 30 seconds, and P the nominal power [kW] of the engine to be started.

A fully charged starting battery shall be able to provide six times 10 seconds long starting sequences in 0°C temperature without intermediate charging.

24.9.3 Battery ventilation

When the battery capacity is at most 5 kWh (416 Ah 12 V, 208 Ah 24 V), the batteries shall be installed in a battery trough or box resistant to battery acid, with ventilation in its top part.

When the battery capacity exceeds 5 kWh (416 Ah 12 V, 208 Ah 24 V), the batteries shall be installed in a separate gastight battery space resistant to battery acid, and ventilated to the open air from its top part.

Batteries at most 5 kWh may be installed in crew spaces provided they are in a gastight box or locker with ventilation to the open air from its top part.

The cross section of the ventilation ducts, leading upwards from the top of the battery space, shall be at least 490 mm^2 (corresponds inner diameter of 25 mm).

When the battery space or locker has forced ventilation, battery charging in fast-charging mode shall be interrupted if the ventilation stops. Forced ventilation shall have ignition protected components.

24.9.4 Protection against engine room fire and flooding

In case the batteries are located in the same watertight compartment as the engine space, the batteries shall be protected so that they do not short circuit even if the water level in this compartment rises to the full load waterline.

24.9.5 Attachment of battery installation

The batteries shall be reliably attached, so they can stand forces of at least twice their weight in all directions without moving more than 10 mm. Additionally the installation including cables shall stand the relevant accelerations and vibrations.

24.10 Generators and chargers

It shall be possible to charge the batteries continuously while the craft is in operation.

24.10.1 Charging capacity

The main electric source, i.e. the generators, shall together be able to charge all battery banks within maximum 10 hours to 80% charge level, while the nominal electrical consumption according to the electrical load balance calculation is running simultaneously.

An independent main electric source shall be able to increase the state of charge in the discharged batteries while the maximum electrical consumption is running simultaneously.

The charging current shall be split between the battery banks automatically depending on the state of charge, and loading condition in each bank.

When the craft has a shore power system installed, and the batteries to be charged have a total capacity of more than 2 kWh, the craft shall be fitted with a charger fed from an external electrical network. Its maximum charging current shall be at least 5% of the nominal capacity [Ah] for the batteries to be charged, while the charger at the same time supplies the craft's other electrical services.

24.11 Degree of protection for the equipment

The degree of protection shall meet the requirements in IEC 60092-507, except for small installations, for them the standards ISO 10133 and ISO 13297 shall be used.

24.12 Testing

All electrical systems on board the craft shall be tested before delivery both visually and for proper function according to IEC 60092-507.

- Earthing connection [1)]
- Insulation resistance [1)]
- Load tests for switchboards and control gear [1)]
- Voltage drop for essential equipment
- Proper function of devices and circuits

[1)] This requirement is not applicable to small d.c. installations.

Test protocols shall be made for all tests, and included in the documentation for the craft.

25 INTERIOR

25.1 Objective

The rules in this chapter are to ensure basic convenience and safety for persons on board with regard to toilets, ventilation and supply of fresh water.

25.2 References

In this chapter reference is made to the standard ISO 8099 Small craft – Toilet waste retentionWaste systems, and, in Finland, to the Government regulation on the working environment on board 289/2017

25.3 Documentation

For the verification of the requirements in this chapter a general layout with installations qualifies.

25.4 Toilets

Boats in design categories A and B, where the maximum number of persons (crew+other) exceeds 10, shall be fitted with at least one toilet. Craft without weather tight spaces for accommodation need not comply with this requirement.

Toilet spaces shall have a lockable door and be fitted with lighting. Each toilet space shall have a wash basin with water and drain.

25.5 Ventilation

Accommodation spaces shall be ventilated as to ensure sufficient supply and exhaust of air when doors, side scuttles, windows and similar apertures are closed.

The ventilation apertures for inlet and outlet of air shall be so located as to obtain sufficient ventilation to remove moisture from the interior.

Air intakes shall be located so to minimize the intrusion of fuel fumes and exhaust gases. The exhaust outlet from heaters and engines shall be at least 400 mm.

For natural ventilation, the channels shall be as short and straight as possible.

For natural ventilation, the cross section area for the flow of supply and exhaust channels shall be a minimum of 7.5 cm2 per seat.

In craft fitted with devices having an open flame, or a heater which uses air from the interior for combustion, the air ducts shall be sized on basis of the power of the device and the number of persons. For heaters and cookers a cross sectional area of at least 22 cm2 per kW is required.

A cowl with exhaust into the open air shall be mounted above any cooking appliance. The channel shall be fitted with a ventilation fan.

Toilet spaces shall be provided with a separate exhaust into the open air.

25.6 Fresh water systems

Fresh water tanks shall be readily accessible for cleaning. The tanks shall have an inspection hatch with a diameter of at least 150 mm.

Fresh water tanks shall be capable of being drained through a valve at the lowest point of the tank or through a suction line. The suction line shall end in a well in the bottom of the tank.

25.7 Lighting

The living quarters and work deck must have adequate lighting, taking into account the intended use of the vessel. At the steering point, the lighting must be adjustable steplessly. The lighting must not substantially endanger night vision during working on deck or at steering points.

25.8 Pantry

If the largest displacement exceeds 100 m3, the craft shall be equipped with a pantry.

26 PERSONAL SAFETY

26.1 Objective

The objective of the rules in this chapter is to minimize the risk of falling overboard, to facilitate getting back on board, to minimize the risk of injury caused by unsuitable arrangements on board, to define the emergency routes and emergency exits, and to enable the people on board to find and use the life saving appliances in an emergency.

Note! In Chapters 33...41 there may be additional requirements for the craft type.

26.2 References

In this chapter reference is made to the following documents:

- ISO 15085 Small craft – Man-overboard prevention and recovery
- ISO 9094 Small craft – Fire protection
- ISO 14946 Small craft – Maximum load capacity
- Government regulation on the working environment on board 289/2017 (in Finland)

26.3 Documentation

For assessment of the requirements given in this chapter it is sufficient that the arrangements are shown on the drawings.

26.4 Working deck

26.4.1 Definition

Working deck in this connection means outside areas where people can stand or walk during the normal operation of the craft.

26.4.2 Accessibility

The general arrangement of the craft shall meet the requirements in Chapter 31 (Accessibility and serviceability).

26.4.3 Minimum width of working deck

To facilitate safe moving the working deck shall be near the deck edge, both transversally and longitudinally:

- unrestricted, continuous, and angled at most 15° from the fully loaded waterline (LC2); and
- at least 100 mm wide in Design Category D, 120 mm in Category C, and 150 mm in Category A and B

26.4.4 Working deck continuity

The working decks shall be connected to each other. This may mean passing through interior spaces. In case the height changes, or obstacles need to be bypassed, special rules are applied (see standard ISO 15085 paragraph 4.4).

26.4.5 Prevention of falling overboard

Falling overboard from the working deck is prevented by the implementation of one of the appropriate alternatives in Table 26.1, with possible additional requirements related to the craft type, mission, and Design Category. Different alternatives may be applied to separate craft areas.

Table 26.1. Summary of requirements

Design category	A	B	B	C	C	D
Safety arrangement						
Slip resistant deck areas	x	x	x	x	x	x
Foot-stops	x	x	x			
Handholds on the working deck	x	x	x	x	x	x
Guard-rails and guard-lines	x	x		x		
Hooking points for safety harnesses	x		x		x	
Handholds in high speed craft	x	x	x	x	x	x
Body support in high speed craft and emergency stop	x	x	x	x	x	x
Means of reboarding	x	x	x	x	x	x
Emergency stop	x[b]	x[b]	x[b]	x[b]	x[b]	x[b]

In all Design Categories it is possible to use the requirements of a higher category.

A handhold according to paragraph 4.8 can also be used as hooking point for safety harnesses.

Different alternatives may also be combined provided the Design Category minimum requirements are met. Example: Foot-stop meeting the requirements for handholds, and located less than 300 mm from the working deck outer edge.

[b] Only for craft with open steering position and speed > $10 \cdot \sqrt{L_H}$ or 25 knots

26.4.6 Slip resistant deck areas

Working decks shall be slip resistant. The slip resistant areas must not be continuous, but the distance between slip resistant areas must not exceed 75 mm.

26.4.7 Foot-stops

Foot-stops shall be as near the working deck outer edge as practically possible. Foot-stops are not required at the deck aft edge, nor at gates in the guard-rails.

The top edge of foot-stops shall be at least 25 mm above the adjacent working deck level.

26.4.8 Handholds on working decks

Handholds which are less than 300 mm from the working deck outer edge, shall be at least 500 mm above the deck level, but not higher than an adjacent superstructure. Handholds located more than 300 mm inboard of the working deck outer edge can be at any height. Handholds shall be available at intervals of less than 1.5 meters on the main passageways and on the outer edges of the working deck

26.4.9 Guard-rails, bulwarks and guard-lines

The bulwarks and/or guard-rails shall be at least 750 mm high in craft with a hull length of up to and including 15 m, and 1000 mm in craft longer than 15 m. In the bulwarks or guard-rails there must not be vertical openings exceeding 230 mm below the lower rail. The spacing between the other rails shall be maximum 300 mm.

The same requirements as for guard-rails refer for guard-lines. They shall also meet standard ISO 15085.

Gates or chains in guard-rail openings shall be lockable in closed position.

Guard-lines shall have tensioning possibility.

26.4.10 Hooking points for safety harnesses

Suitable attachment points (see standard ISO 15085) shall be located as follows:

- within 1 m from main entrance hatch or door edge;
- within 2 m from all outside steering positions; and
- within 2 m from winch or strong point required for towing.

The hooking points must not be more than 3 m apart.

The hooking point shall fit within a circle having 15 mm diameter. Also other parts of the craft may work as harness hooking points, although not specifically designed for this, for example handholds.

26.4.11 Seats

There shall be a seat for each person. In Design Category C and D there may alternatively be standing places, for which the same handhold requirements as for seats are applied.

The minimum dimensions for seats shall be as specified in Chapter 1 clause 1.12.1.

The requirements for width and horizontal length do not apply for seats where the person has to sit astride. In craft having a maximum allowed speed exceeding $10 \cdot \sqrt{L_H}$ or 25 knots, pontoons are not allowed as seats.

The seats and their attachment shall be sufficiently strong for the intended conditions of use.

A seat for one person shall stand 1.8 kN force in any direction without breaking, as well as the vertical accelerations according to Chapter 7 paragraph 7.4.

For each seat there shall be at least one handhold.

When the dynamic loading factor according to Chapter 7 paragraph 7.4 exceeds value 4 in fully loaded condition, there shall be arrangements enabling the crew to dampen the accelerations for example by using well padded saddle or spring damped seats.

Damped seats shall be located so their movements do not create risks for the occupant's heads hitting the craft structure.

26.4.12 Handholds in high speed craft

Craft with a top speed exceeding $10 \cdot \sqrt{L_H}$ or 25 knots shall, irrespective of Design Category, have arrangements for supporting the persons on board so the risk of being thrown overboard in tight turns, fast accelerations, or big waves is minimized. When arranging support for the persons on the seats one of the following alternatives shall be used:

- one handhold plus body support according to clause 26.4.13; or
- two handholds arranged so continuous holding on with both hands is possible

Note! One handhold may serve as two handholds, provided it is long enough so the hands can be at least 200 mm apart.

The handholds shall be located in relation to the seat so the person is able to stay in place securely. For a sitting person this means that the handholds shall be at least 0.3 m above the seat, and for a standing person at least 1.0 m above the deck.

A handhold intended for one hand shall stand 1.8 kN force in any direction per user, in case there are more than one user at the same time.

26.4.13 Body support in high speed craft

Craft with a top speed exceeding $10 \cdot \sqrt{L_H}$ or 25 knots where the persons onboard are sitting, shall have working deck seats fitted with body support at least 120 mm high above the solid seat bottom, or in case the seats are padded, above the compressed padding.

The purpose of the body support is to prevent the person primarily from falling overboard, or over a higher located edge.

In case the persons on board are standing or leaning against the seat, the body support can brace only the back of the person.

In case the persons on board are sitting astride on saddle seats the body support can be considered to be given through the knees.

Saddle seats and leaning seats shall have strength equal to single seats.

26.4.14 Emergency stop

Craft with an open steering position and top speed exceeding $10 \cdot \sqrt{L_H}$ or 25 knots shall have an emergency stop for the engine, shutting it off if the driver tumbles from his position.

26.4.15 Means of reboarding

All craft shall have permanently installed ladders or equal for reboarding, enabling a person in the water to climb on board unaided. Ladders which can swing under the craft are not approved. The lowest foot step shall be at least 560 mm below the light service condition waterline. Additionally, there shall be suitable handholds for climbing up to the working deck.

In case a permanent system along the guidelines above is not installed, it shall be demonstrated by a practical test that climbing on board the craft is possible unaided. The test person shall have a dry weight of 85 kg with equipment, with suitable clothing and a life vest during the test.

26.5 Minimizing the risk of injury on board

26.5.1 Doors and passageways

Doors and passageways shall be at least 500 mm wide.

In Finland, the Government regulation on the working environment on board defines that the main passageways shall have a minimum width of 0.6 m and height of 2.03 m. Deviations from the dimensions may be made if it would be structurally unreasonable to comply with them, provided however, that the safety of the crew is not endangered.

26.5.2 Sharp edges

There shall be no sharp edges or protusions which can cause personal injury. On the decks there must not be any stumbling risk.

26.5.3 Securing of heavy objects

Heavy unattached objects shall be secured properly.

26.5.4 Hot surfaces

Hot surfaces shall be protected in case their temperature exceeds 80°C, and their location allows accidental contact with persons on board.

26.5.5 Rotating machinery

Rotating machinery and components shall be protected so injury can be avoided (see also Chapter 21 Propulsion machinery). Lighting in such spaces shall be working with d.c. current.

26.5.6 Falling and loosing balance

In addition to the working deck attention shall also be paid to crew spaces, where the risk of injury shall be kept small by providing handholds and guard-rails if applicable in passageways, stairs and sitting areas.

26.6 Emergency routes and emergency exits

It shall be possible to evacuate people from the interior to the life saving appliances in case of a fire or sinking emergency. In spaces for sleeping or lounging, there shall be at least one emergency route leading to the outside, to the next lounge, or to the stairway leading to the exit or the next lounge. The emergency routes shall meet the following requirements:

- in case there are two emergency routes only one of them may go through the engine space;
- in case the emergency route passes any surface of a cooker or open flame device at less than 750 mm distance, there shall be an alternative emergency route;
- In a closed galley this requirement is not applied if there is a dead end within less than 2 m distance; and
- any emergency route must not pass straight over a cooker or open flame heater.

The distance to the nearest exit shall not exceed $L_H/3$ or 5 m, the smaller applies. The distance shall be measured as the shortest horizontal distance to the centre of the exit from

- the furthest point where a person can stand regardless of headroom; or
- the centre of a berth, whichever is further

Shower- and toilet spaces are considered a part of the cabin or passage into which their doors open, and for them alternative emergency exits are not required;

If the requirements of an emergency route are not met, there shall be another emergency route from the cabin

26.6.1 Emergency exits

All emergency exits in living quarters shall have the following free outlet areas:

- rectangular shape minimum 500 x 500 mm; and
- other shape: the exit to be sufficiently large so that a circle with 500 mm diameter fits through.

Emergency exits shall be easily accessible. Exits opening to the weather deck or open air shall be openable from both in- and outside when they are shut, but not locked.

In case a deck hatch is intended as emergency exit, it shall be fitted with steps, ladders, or stairs. The vertical distance between the uppermost step and the emergency exit shall be at most 1.2 m. These aids shall be permanently installed in the cabin, and marked if not self-evident.

Emergency routes and -doors shall, in case not self-evident, shall be marked with the appropriate ISO- or national symbols.

From the steering cabin there shall be another emergency exit in addition to the main door.

In the design category A and B crafts having no additional notation “Self-righting”, the usability of the emergency exit shall be taken into account also in the situation of capsizing.

26.6.2 Accessibility to life saving appliances

Life saving appliances shall be easily accessible from the weather deck (definition see Chapter 2).

In craft meeting the One compartment subdivision requirements in Chapter 6, the life saving appliances shall be easily accessible in the flotation condition resulting after the filling of any one compartment.

27 FIRE SAFETY

27.1 Objective

The purpose of the rules in this chapter is to identify the fire risks during the operation of the craft, and provide the means of minimizing the consequences of fire. In small craft (LH ≤ 15 m) the main objective is to detect, limit, and extinguish any fire at its outset, and ensure the immediate availability of effective extinguishing means. In larger craft the objective is to additionally limit the use of flammable materials, as well as materials giving off smoke and poisonous gases when burning, and to protect means of escape and emergency routes.

27.2 References

In this chapter reference is made to the following documents:

- The 2000 International Code of Safety for High-Speed Craft (2000 HSC Code)
- IMO MSC/Circ.911, ”Interpretation of fire protection related provisions of the HSC Code”
- Marine equipment directive (2014/90/EU), International Code for Application of Fire Tests Procedures (FTPC) 2010
- ISO 9094 Small Craft – Fire Protection
- ISO 14895 Small craft – Liquid-fuelled galley stoves
- ISO 4589-3 Determination of burning behaviour by oxygen index – Part 3: Elevated-temperature test
- ISO 10239 Small craft – Liquefied petroleum gas (LPG) systems
- ISO 9705 Fire tests – Reaction to fire tests — Room corner test for wall and ceiling lining products
- ISO 5066 Reaction-to-fire tests – Heat release, smoke production and mass loss rate

27.3 Documentation

For assessment of the requirements given in this chapter the following documentation is required:

- Drawings and other documents showing, if applicable:
  - fire resistant bulkheads:
  - the construction and materials for the above;
  - the inherent fire risk areas (engine space, storage of hazardous substances);
  - the galley;
  - emergency exits.
- approval and test protocols for interior materials
- ventilation ducting schemes;
- information about fire extinguishing equipment
  - the manufacturer of the fixed extinguishing system, type, capacity and installation requirements
  - the location of cylinders and orifices; and
  - portable extinguisher type, capacity, and location

27.4 Definitions

In addition to the definitions given in this rule, terms are also defined in standard ISO 9094.

27.4.1 Fire resisting divisions

Fire resisting divisions are divisions enclosed within bulkhead- and deck materials certified according to the Marine equipment directive 2014/90/EU and resisting the fire the prescribed time. Alternatively, prototype bulkheads or -decks can be subject to a fire test procedure according to the FTPC in order to demonstrate equal fire resistance.

27.4.2 Fire resisting materials

Fire resisting materials are materials meeting the Fire Test Procedure Code (FTPC).

27.4.3 Non-combustible material

Non-combustible material is a material which when heated to 750°C does not burn or develop flammable gases in sufficient amounts for ignition according to the Fire Test Procedures Code (HSC Code 7.2.3 and FTPC)

27.4.4 Standard fire test

A *standard fire test* is a test where specimens of the relevant bulkheads, decks, or other constructions are exposed in a test furnace by a specified test method in accordance with the Fire Test Procedures Code (HSC Code 7.2.4)

27.4.5 Steel or other equivalent material

Where the words steel or other equivalent material occur, ”equivalent material” means any non-combustible material, which by itself or due to insulation provided, has structural and integrity properties equivalent to steel at the end of the standard fire test. Such a material is for example aluminium alloy with appropriate insulation (HSC Code 7.2.5)

27.4.6 Low flame-spread

Low frame spread means that the surface will restrict the spread of flame in accordance with the Fire Test Procedures Code (HSC Code 7.2.6)

27.4.7 Fire detection and alarm

Fire detection and alarm means a system that gives an alarm, generally at the main helm position, and is equipped with fire detection.

27.4.8 Fire alarm

Fire alarm means separate alarm units which function locally and independently.

27.5 Firefighting

27.5.1 General arrangements

The bilges where overflowing flammable liquids may collect, shall be accessible for cleaning.

The spaces where petrol- or diesel engines or fuel tanks are located, shall be separated from enclosed accommodation according to the requirements in standard ISO 9094.

Limitations regarding fuel tank materials and testing of the tanks is presented in Chapter 22 clause 22.6.5.

27.5.2 Escape ways and emergency exits

Escape ways and emergency exits shall be arranged according to Chapter 26.

27.5.3 Cooking and heating appliances

The general safety of the installation shall meet standard ISO 9094 and ISO 14895.

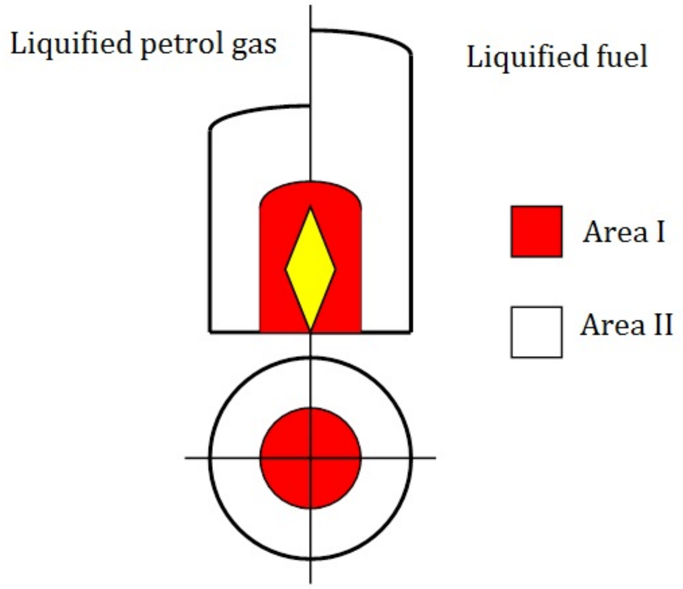


Figure 27.1: The areas with specific requirements for their surface materials

27.5.4 LPG gas installations

LPG gas installations shall meet the requirements in standard ISO 10239.

27.5.5 Ignition protection

Only equipment ignition protected according to standard ISO 8846 shall be installed in spaces where there are any of these:

- a petrol engine or -tank;
- a LPG gas bottle;
- petrol fuel system components;
- LPG gas system components except for connections in accommodation spaces near LPG appliances
- portable petrol tank.

27.6 Requirements for material and arrangements

27.6.1 General

The following spaces are considered fire hazard areas:

- Engine spaces, excluding spaces for small engines ≤120 kW;
- Spaces containing flammable substances (flashpoint below 60°C, does not refer to diesel oil)

A fuel tank space that meets the requirements in Chapter 22 is not regarded as a fire hazard area.

The surroundings of cookers and heaters are treated according to clause 27.5.3.

In fire hazard areas the materials used in the structure or insulation shall be at least fire resisting, the surface against the engine shall not absorb fuel, and the material oxygen index shall be at least 21 according to standard ISO 4589-3 when the surrounding temperature is 60°C.

27.6.2 Fire resisting divisions (for length of hull over 15 m)

Boundary surfaces of fire hazard areas shall be arranged to form fire resisting divisions that are separated from accommodation, working spaces, passages and outside spaces.

The structure shall consist of non-combustible materials (see 27.4.3) or fire resisting materials (see 27.4.2) and insulated with at least 50 mm thick non-combustible mineral wool, having a density of at least 100 kg/m3 or having fire class A-30. Materials tested according to ISO 9075 or ISO 5660 may be accepted here as fire resisting.

Steel surfaces against the open air need not be insulated, unless the surface in question is used in emergency situation such as access to fire pump, escape routes, routes leading to the life raft.

Insulation is not required further down than 300 mm below the waterline.

Penetrations shall be at least approved for A-0 fire divisions (FTPC).

27.6.3 Restrictions to the use of burning materials (for length of hull over 15 m)

When insulation is installed in areas where it may become in contact with a flammable fluid or its vapour, the surface of the insulation must not allow the fluid or vapor to pass through.

For the following surfaces the minimum requirement is low flame-spread:

- the exposed surfaces in closed passages and stairwells;
- bulkheads (including windows) as well as wall and overhead covering in accommodation, control rooms, and helm stations.
- hidden or inaccessible spaces in enclosed corridors or stairways, accommodation spaces, control rooms and helm stations.

Heat- and sound insulation shall be non-combustible or fire resisting on the above mentioned surfaces.

The insulation vapor barrier and glue, or refrigeration tubing attachment insulation need not be non-combustible or fire resisting, but their amount shall be kept as small as practically possible, and their exposed surfaces shall have low flame-spread.

In closed passages or stairwells the exposed surfaces, bulkheads (including windows) as well as wall and overhead covering in accommodation, control rooms and helm stations shall consist of materials which do not produce excessive amounts of smoke and toxic gas when burning, as prescribed by the FTP Code.

27.6.4 Exhaust piping

The exhaust piping shall be designed and arranged to ensure that the exhaust gases are led safely to the open air.

The exhaust pipes shall be arranged so the fire hazard is minimized. For this purpose the exhaust system shall be insulated (this does not refer to wet exhaust systems).

All spaces and structures near the exhaust system, or which may be heated up by the exhaust gases either in normal use or in exceptional conditions, shall be of non-combustible materials, or be protected and insulated with non-combustible materials considering high temperatures.

27.7 Ventilation control

27.7.1 General (for length of hull over 15 m)

It shall be possible to close the inlets and outlets of all ventilation systems from a location outside the ventilated spaces.

27.7.2 Ventilation fan controls

It shall be possible to shut off all fans for the fire hazard areas from a continuously manned control room or helm station outside the ventilated area, and outside the space where the fans are located.

The controls for shutting off the engine space ventilation shall be located separately from the controls for shutting off the ventilation for other spaces.

27.7.3 Fire damper controls (for length of hull over 8 m)

Fire dampers shall be installed in fire resisting spaces, and shall have manual controls operable from both sides of the division where they are installed.

Fire dampers installed in ventilation ducts for basically unmanned spaces (such as engine spaces, stores, and toilet spaces) it is sufficient that the dampers can be closed manually from outside of the spaces.

27.7.4 Deck penetrations (for length of hull over 15 m)

Where ventilations ducts penetrate decks the arrangement shall be such that the deck effectiveness of preventing fire from spreading is not reduced, and that the probability of smoke and hot gases spreading from one space to another is reduced.

27.8 Fire detection- and alarm systems

27.8.1 General

The engine space shall have a fire detection system, with its alarm at the craft main helm position. In other spaces a fire alarm is sufficient in craft below 15 m length.

A fire alarm shall be installed in lounging and accommodation spaces.

27.8.2 Areas to be protected (for length of hull over 15 m)

Fire hazard areas and other enclosed non-manned areas located within crew- and public spaces, such as toilets, stairwells, passages, and escapeways, shall be fitted with automatic smoke detectors connected to the alarm system. In the galley heat detectors may be used.

Propulsion engine spaces shall additionally be fitted with fire detection based on other signs than smoke.

Gas turbines shall be monitored with flame detectors.

27.8.3 Requirements for the system

The required fire detectors, their alarms, and the fire alarms shall be intended for marine use.

All the required permanently installed fire detectors, their alarm systems, and the fire alarms shall be continuously ready for immediate use.

In connection with each fire detector there shall be a clear description of the spaces protected, and where they are located. This is not required if the sensor is integrated into the alarm.

Necessary instructions and spare parts for testing and maintenance shall be supplied.

The sensors shall detect heat, flames, smoke or other combustion gases, or their combinations. Flame detectors shall be used only in addition to smoke and heat detection (see clause 27.8.2).

The fire detection system must not be used for any other purpose, except for the closing of fire doors or equal functions on control panels.

27.8.4 Installation requirements

Where permanently installed fire detection and alarm is required for the protection of spaces, at least one sensor for each space is required, except for stairways, passages, and emergency routes.

The sensors shall be located optimally for detection of fire. They shall not be fitted close to beams or ventilation conduits or other locations where air flow may disturb the proper function of the sensor. Further locations shall be avoided where shock loads or mechanical damage is probable.

Fire detection system electrical cabling shall not be routed through fire hazard areas like the engine space, except where this is necessary for the protection of the spaces in question, or for the connection to the power supply.

27.9 Fire-extinguishing systems – general

Fire hazard areas shall be protected with a fixed fire-extinguishing system, operated from a control station conveniently located for this fire hazard.

In case there is only one engine of 120 kW or less in the engine space, the fire protection can be a portable extinguisher launched through a fire port in the engine casing, according to the requirements in standard ISO 9094.

Other areas to be protected with portable extinguishers.

27.10 Fixed fire-extinguishing systems

27.10.1 Fixed fire-extinguishing system control

A fixed fire extinguishing system shall be operable from the main helm position or, in case this position is more than 5 m away from the protected space, there shall be controls for activating the fire-extinguishing locally.

Automatic fire-extinguishing may be accepted provided the extinguishing agent does not present any danger to people, and the extinguishing does not need other activities, as for example closing of fire dampers, shutting down of engine, or some other intervention necessary for the extinguishing. Solely the release of fire extinguishing agent is not accepted.

The controls for fixed fire-extinguishing systems shall be simple and immediately ready for use. They shall be grouped into as few locations as possible, however so that in case of fire their connection to the protected space is not cut off. In each location there shall be clear instructions to the crew for the use of the extinguishing system.

In case the extinguishing agent is of a suffocating type, or the protected space is large enough for people to enter, a warning signal shall be sounded before the extinguishing agent is released.

In case the engine is able to suck in the extinguishing agent and thereby prevent the extinguishing, it is necessary to shut down the engine before the extinguishing agent is released into the engine space (see ISO 9094).

27.10.2 The amount of extinguishing agent

The amount of extinguishing agent shall be sufficient for the space to be protected. In engine spaces with CO2 –systems the amount of CO2 shall be at least 1.5 kg/m3 of engine space gross volume. The smallest accepted amount is 2 kg. At least half of the gas shall be released into the space during 10 seconds. There shall be arrangements in the space for closing all openings through which air can enter or gas can escape.

Other systems shall be dimensioned according to the manufacturer's instructions. The dimensioning shall take into account possible ventilation ducts if they do not have fire dampers.

27.10.3 Pressure vessels and tubing

The extinguishing agent distribution tubing and the discharge nozzles shall be located for achieving an even distribution of the extinguishing agent.

The installation for all components shall follow the requirements in standard ISO 9094, and the system manufacturer’s instructions.

The pressure vessels and tanks for the storage of extinguishing agent may be located in the engine space or in the space to be protected, in case accidental release of the agent does not present any danger to people.

CO^2-bottles must not be located in the engine space.

The connection between CO^2-bottle valves and system pipelines shall be made with the approved flexible high pressure hoses intended for this purpose.

27.11 Portable extinguishers

27.11.1 Location, type and capacity

Portable extinguishers shall be ready for use, and located visibly so they are immediately available in the case of fire.

Extinguishers may be located in lockers whose door is clearly marked with the appropriate ISO symbol.

The extinguishers shall be located so their function is not restricted by weather conditions, vibration, or other external factors.

It shall be clearly visible if a portable extinguisher has been released.

In control rooms or other spaces containing electrical equipment important for the safety of the craft, the extinguishing agent of portable extinguishers must not conduct electricity nor cause damage to electrical components.

Portable CO_2 –extinguishers may be installed in enclosed accommodation only where there are flammable liquids (for example a galley) or high-voltage equipment, such as electrical motors, batteries, or a main switchboard. A warning text shall be posted near such an extinguisher according to standard ISO 9094.

The maximum permissible capacity of a single portable CO_2 fire extinguisher is 2 kg. There can only be one CO_2 fire extinguisher in an enclosed accommodation space.

The minimum capacity of any extinguisher shall not be smaller than 8A/68B (usually 2 kg) and at least one extinguisher must be 34A/183BC (usually 6 kg).

The capacity B of the portable fire extinguisher required for outboard installation shall be at least P * 0.3 where P is the total power of the outboard engines [kW].

All extinguishers shall meet the requirements in standard EN 3.

27.11.2 Number

The number of portable extinguishers and their location shall be as follows:

- an extinguisher shall be located not more than 2 m (1 m if the craft length of hull is below 10 m) of unobstructed distance from the main helm position;
- an extinguisher shall be located not more than 2 m from a permanently installed cooker, or from any application with an open flame;
- an extinguisher shall be located not more than 3 m distance from an outboard engine or fire port;
- one extinguisher for each 20 m^2 of accommodation area, not more than LH/3 m from the centre of any bed; and
- outside every entrance to engine spaces there shall be an extinguisher suitable for extinguishing a fire in the engine space.

27.12 Fire pumps, waterpipes, hydrants and hoses (for length of hull over 15 m)

Fire pumps and accessories shall be installed for all craft over 15 m length, or alternative efficient extinguishing systems as follows:

- at least one independently powered fire pump is required.
- the fire pump capacity shall be at least 15 m3/h (250 l/min)
- each fire pump shall produce sufficient water pressure for the continuous use of the hydrants.
- the hydrants shall be located so all parts of the craft can be extinguished with water jets from the hydrants.
- All fire hoses shall be of durable materials, and their maximum length approved by the authorities. Fire hoses including the required fittings and tools shall be stored ready for use in easily found locations near the hydrants. Indoors the fire hoses shall be continuously connected to the hydrants.

- there shall be one fire hose for each hydrant.
- all fire hoses shall be fitted with approved dual-mode (spray/jet) nozzles with shut-off valves.

27.13 Miscellaneous

27.13.1 Doors and hatches in fire protected spaces

All openings shall be fitted with permanently installed closing appliances, which shall be at least as fire resistant as the spaces where they are located.

All doors shall be openable from both sides by one person.

27.13.2 Fire protection plan (for length of hull over 15 m)

For craft with a hull length over 15 m length there shall be a fire protection plan permanently posted for captain and crew, where the following locations are clearly shown:

- control stations
- fire resisting spaces
- fire detection and alarms
- sprinkler installations
- fixed and portable extinguishers
- access doors to the spaces
- ventilation system (including information about main fan controls, location of fire dampers as well as the ventilation fan identification numbers for the various compartments)
- location of all control devices.

28 ANCHORING, MOORING AND TOWING

28.1 Objective

The objective of the rules in this chapter is to ensure that the craft is fitted with the proper equipment for mooring, anchoring and temporary emergency towing, taking the intended design category into account.

28.2 References

In this chapter reference is made to the following documents:

- ISO 15084 Anchoring, mooring and towing - Strong points

28.3 Documentation

To verify that the requirements presented in this chapter are met, the following documentation is required:

- Layout of mooring points and equipment;
- Number, weight and type of anchors;
- Type and size of anchor warps and –chains;
- Drawing to determine frontal area of craft.

28.4 Mooring equipment

All craft shall be fitted with at least one mooring cleat or bollard forward and one aft. When two cleats or bollards are fitted forward or aft, they shall be located as near as possible to the deck edge.

At least one cleat or bollard forward and one aft shall be located to facilitate emergency towing.

Cleats and bollards shall be strongly designed and mounted. The cleat or bollard, including its fastening, shall be capable of withstanding a horizontal tensile load P according to formula 29.1. The breaking strength of cleats and bollards need not be greater than the force corresponding to the weight of the vessel at maximum load (m_{LDC}):

$$P = f_{SP}\left(4{,}3 \cdot L_H - 5{,}4\right) < m_{LDC} \qquad \text{[kN]} \qquad (28.1)$$

Appropriate reinforcements shall be provided in the way of cleats and bollards. Bolts, nuts and other mounting details shall be made of corrosion resistant material.

The craft shall be equipped with at least three mooring ropes of a length and minimum breaking strength as per formula 28.2.

$$L_M = 2{,}0 \cdot L_H \qquad \text{[m, kN]} \qquad (28.2)$$

28.5 Anchoring equipment

The anchor weight for traditional anchors is obtained from formula 28.3

$$m_{ANC} = k_{FH}\left(3{,}0 \cdot A_x + \frac{m_{LDC}}{2000}\right) \text{, min 6 kg} \quad \text{[kg]} \qquad (28.3)$$

Where

A_X = frontal area of craft including superstructures, [m^2] in loaded displacement condition (LC2).
k_{FH} = factor for design category, see Table 28.1.

If the anchor is of a type with extra-high holding capacity, e.g. anchors approved by a recognized classification society with the designation "High Holding Power, HHP", the required anchor weight may be reduced by 25%.

If the anchor is of a type approved by a recognized classification society with the designation "Super High Holding Power", the required anchor weight may be reduced by 50%.

The required anchor weight shall be increased by 10% when divided between two anchors.

Each anchor shall have a warp or chain of a length of at least four times the length of hull of the craft.

The breaking strength of the anchor warp/chain shall be at least 80% of formula 29.1 but must not exceed the actual breaking load of the bollard or mooring cleat.

At least one anchor shall be equipped with a short chain of a length according to Formula 28.4:

$$L_{CH} = 0{,}85 \cdot L_H \quad \text{[m]} \qquad (28.4)$$

No chain is required if the anchor warp is leaded rope or similar heavy rope.

The anchor equipment shall be suitably located to facilitate rapid and safe deployment without use of tools.

If the weight of the anchor exceeds 20 kg, there shall be an arrangement to facilitate lifting (windlass).

Table 1. Correction factors for anchor equipment.

Design category	f_{SP}	k_{FH}
A	1,00	1,00
B	1,00	0,90
C	0,90	0,70
D	0,75	0,50

28.6 Towing

The requirements in this chapter covers only temporary towing of the craft by another craft in an emergency situation. Craft, which are intended for towing other craft or floating objects shall meet the requirements in Chapter 35.

29 MAIN HELM POSITION ARRANGEMENTS AND NAVIGATION LIGHTS

29.1 Objective

The objective of the rules in this chapter is to ensure that the visibility at the main helm position is sufficient, the control devices used for the maneuvering of the craft are properly located, and the navigation lights meet the International Regulations.

NOTE! The requirements for special missions in connection with Additional Notations are given in Chapters 33...41. The requirements for high-speed craft seats are given in Chapter 26.

29.2 References

In this chapter reference is made to the following documents:

- Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREGs)
- ISO 11591 Small craft, engine driven – Field of vision from helm
- ISO 11592 Small craft less than 8 m length of hull – Determination of maximum propulsion power rating

29.3 Documentation

For assessment of the requirements given in this chapter a drawing is required, enabling the visibility at the main helm position to be assessed.

29.4 Visibility at the main helm position

29.4.1 General

The main helm position, or other control station, from which the craft is maneuvered, shall be arranged so that the helmsman has sufficient visibility in reference to the speed of the craft. This does not mean that the visibility may be limited in some certain loading condition. In such cases sufficient visibílity shall be ensured by increasing the number of watchmen, and/or reducing the speed of the craft.

The field of visibility is defined *horizontally* (clause 29.4.2) and *vertically* (clause 29.4.3).

The field of visibility is defined in relation to the view point, which corresponds to the eye position.

The *highest and lowest viewpoints* represent the vertical limits.

The field of visibility is assessed with practical tests in light service condition, and fully loaded condition, as well as other possible loading conditions if applicable.

The visibility may be restricted only at the craft planning threshold ± 2 knots, provided however, that the visibility requirement is met, when standing or in some other way, 50 m from the view point to the horizon.

Helm stations which can be used both sitting and standing shall meet the requirements in one of the cases.

In case the craft has several helm stations, at least one of them shall meet the visibility requirements.

29.4.2 Horizontal field of visibility

From the helm station there shall be 112.5° horizontal visibility on the right side of the craft, and 90° on the left side (Figure 29.1, sector A)

When the craft top speed is at most 30 knots in light service condition (loading condition LC1) it is assumed that the horizontal distance between the eyes is 70 mm, and both eyes are open.

When the craft top speed is over 30 knots in light service condition (loading condition LC1) the assessment is made assuming one view point.

In front of the helmsman there shall be a central field of visibility extending from straight forward to 15° to each side. Within this sector there shall not be blind spots simultaneously for both eyes when the head is moved 35 mm in the horizontal direction. (Figure 29.1, sector B).

Additionally, there shall be a field of visibility extending between 90° and 112.5° on the left side, and within this sector there shall not be blind spots if the view point is moved 0.5 m horizontally forward from the normal position (Figure 29.1 sector C).

Aft there shall be a field of visibility 112.5...180° each side of the centreline (Figure 30.1, sector D). In this sector it shall be possible to maintain the visibility without moving sideways more than 0.5 m to each side if the craft is helmed sitting, and 1 m to each side if the craft is helmed in standing position. Visibility to sector D may also be fulfilled with mirrors or other methods.

29.4.3 Vertical field of visibility

Vertically the field of visibility shall extend from the lower border to a line, which at the speed defined in 29.4.1 in the actual load condition is parallel with the water surface and is located at the level of the highest view point (see Figures 29.2 and 29.3).

29.4.4 Requirements

From the view point in question the water surface shall be visible from $4 \cdot L_H$ or 50 m, whichever is smaller, all the way to the horizon, according to the field of visibility defined in 29.4.2 and 29.4.3. This distance to be defined from the limiting structure the in forward direction.

During normal turns the horizon shall be visible according to the horizontal field of visibility sector in 29.4.2.

The number and size of blind spots shall be minimized, so they do not cause a critical reduction of the visibility from the helm station. In unclear cases the visibility shall be assessed according to standard ISO 11591.

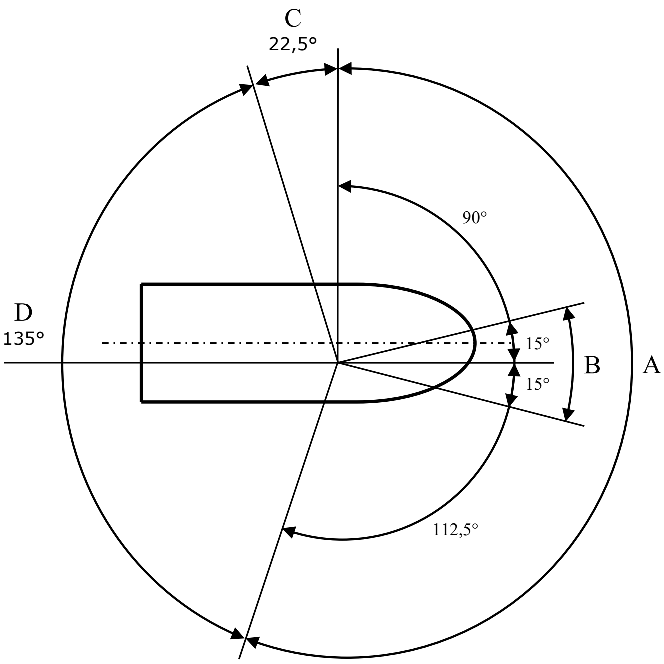


Figure 29.1: Horizontal field of visibility

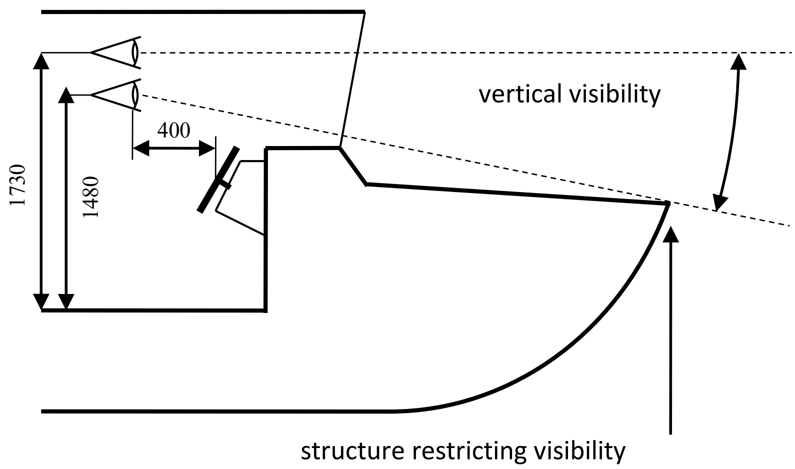


Figure 29.2: Vertical field of visibility when helmsman is standing at the helm

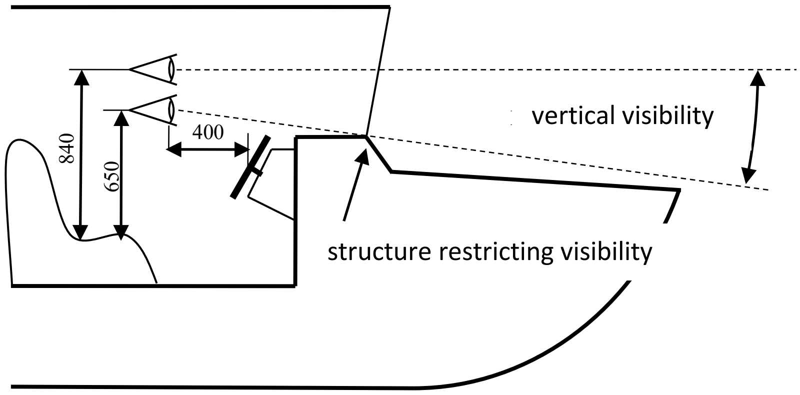


Figure 29.3: Vertical field of visibility when helmsman is sitting at the helm

29.4.5 Illumination

Glare and stray reflections shall be avoided at the helm station. Materials with matte finish shall be used in order to avoid stray reflections.

In areas where illumination is required when the craft is in operation, red lights shall be used in order to help adaptation to night vision.

On decks and outside the helming station the illumination shall be arranged so the safe operation of the craft is not endangered.

29.4.6 Windows

It shall be possible to maintain the visibility through the helm station windows in all weather conditions.

Craft with enclosed helm stations shall have windshield wipers and de-misting at least for the windows in the central field of visibility (see clause 29.4.2).

The windows within the field of visibility shall not be tinted or polarized. Removable sunscreens with slight colour distortion are permitted.

29.5 Control equipment

The main controls for maneuvering and speed, as well as secondary controls such as trim tabs and stern drive angle, shall be located within reach at the helm station.

The compass and other essential instruments shall be located at or be available or readable from the helm station.

In craft with a top speed exceeding 25 knots, it shall be possible to operate all control devices related to steering without taking both hands off the steering wheel at the same time.

29.6 Navigation lights

The craft shall have navigation lights according to COLREGs. Unless the function of lights can be monitored from the helmsman's position, there shall be an indication for each light at the main helm position located inside.

30 HANDLING CHARACTERISTICS AND DETERMINATION OF ENGINE POWER

30.1 Objective

- The objective of the rules in this chapter is to ensure that the performance features are such that:
- the craft can keep a straight course both at low and full speed;
- the craft can avoid a collision with an obstacle in its way;
- the craft can be maneuvered properly also when going astern;
- the craft's propulsion power is not too high in relation to the dynamic stability for holding a straight course and turning at high speed;
- all the above mentioned properties are acceptable considering the loading conditions; and
- the craft can be maneuvered at low speed even when the main steering system is out of order.

30.2 References

The rules in this chapter are based on the requirements in the standard ISO 11592 Small craft – Determination of maximum propulsion power rating, parts 1 and 2.

30.3 Documentation

For assessment of the requirements given in this chapter a sea trial report is required, stating, if applicable:

- the weights on board during the trials;
- the maximum speed achieved;
- the measured turning radiuses;
- an assessment about the function of the emergency steering; and
- other observations referring to the safety of the craft

30.4 Requirements

In Table 30.1 a summary of the requirements is given. Paragraph 30.5 gives a more detailed explanation of the assessment procedure.

Table 30.1: Summary of the requirements related to handling characteristics

Feature	Trials for the determination of engine power and handling characteristic			
	$V_{MAX} \leq 7 \cdot \sqrt{L_{WL}}$		$V_{MAX} > 7 \cdot \sqrt{L_{WL}}$	
	LC1 [1)]	*LC2* [2)]	*LC1*	*LC2*
Keeping a straight course	x	x	x	x
Alternating turns at full speed (zig-zag-test)	x	-	x	-
Turning, normal speed	x	x	x	x
Avoidance test (simple method)	x	-	-	-
Avoidance test (extended method)	-	-	x[3)]	-
Crash stop, an Alternative to avoidance test if $L_H \geq 8.0$ m	-	-	x	-
Quick turn test, an alternative avoidance test if $L_H \geq 8$m	-	-	x	-
Going astern	x	x	x	x
Emergency steering test	When emergency steering is required			

[1)] and [2)] Loading condition LC1 and LC2, see clauses 4.6.2 and 4.6.3
[3)] Reduced speed ≥*0,85* * V_{MAX} is allowed, if a warning sign showing the maximum safe avoidance speed according to standard ISO 11592 is installed.

The requirements for hovercraft are given in Chapter 41.

30.5 Assessment

30.5.1 Loading and weather conditions

The assessment shall be made with the craft in Light condition, and Fully loaded condition, according to Table 30.1.

The avoidance line test and zig-zag- test at full speed are not made in fully loaded condition.

In fully loaded condition the weight distribution both longitudinally and vertically shall be realistic. The floating position shall be as near the loading conditions used for the assessment of stability and freeboard as possible.

All heavy items shall be properly secured during the testing.

The significant wave height during the testing shall not exceed 0.2 m.

30.5.2 Keeping a straight course

All craft shall be able to keep a fairly straight course at full speed in all loading conditions. For craft where purposing or chine walking occurs, it shall be possible to eliminate the dynamic unbalance with the trim tabs only, without active helming or speed reduction.

30.5.3 Alternating turns at full speed (zig-zag-test)

The dynamic stability shall be tested for all craft at full speed in light service condition by turning the wheel to both sides in a suitable rhythm until the craft possibly begins to oscillate by itself.

If oscillation occurs, it shall stop within a reasonable time simply by putting the wheel into centre position, without active helming or speed reduction.

The helmsman shall be particularly alert, and ready to reduce speed if the oscillations tend to increase.

30.5.4 Avoidance test at high speed

The craft shall approach the turning point at high speed, there a sharp 90 degrees turn is initiated. During the turn the craft shall be able to keep the turning radius R between the values given in Formula (30.1) and (30.2) in both directions. The turning radius R corresponds to the distance needed for avoiding a fictitious obstacle;

$$R \leq 6 \cdot L_H \text{ [m]}; \; V_{MAX} < 30 \text{ kn} \qquad (30.1)$$

$$R \leq 6 \cdot L_H + (0{,}1 \cdot L_H + 1{,}2) \cdot (V_{MAX} - 30) \text{ [m]}; \; V_{MAX} \geq 30 \text{ kn} \qquad (30.2)$$

For crafts having L_H < 8 m, the avoidance test is performed at maximum speed V_{MAX}. If the craft does not meet the requirement for turning radius, a reduced speed of 0.85 · V_{MAX} [kn] can be used provided that a warning sign showing the maximum safe manoeuvring speed.

For crafts having L_H ≥ 8 m, the avoidance test is performed at maximum speed V_{MAX} or $V_{T\,MAX}$, whichever is lower. The tests are not performed at speeds exceeding 70 kn.

$$V_{T\,MAX} = 3 \cdot L_H + 24 \text{ [kn]}; \leq 70 \text{ kn} \qquad (30.3)$$

The test speed reduced from the maximum speed to 0.85 · V_{MAX} [kn] is allowed. However, the test shall be passed at least at speed 0.85 · V_{MAX} or $V_{T\,MAX}$, whichever is lower. If a reduced speed is used, a warning sign showing the maximum safe avoidance speed shall be installed at the helm station.

The avoidance test is begun at lower speeds, which is increased until a feel for the craft behaviour as developed.

During the turn it shall be possible to control the direction of the craft. Dangerous instability or broaching tendencies shall not occur. The helmsman shall stay in position.

For slow craft ($V_{MAX} \leq 7 \cdot \sqrt{L_{WL}}$) the compliance may be estimated by observing the wake and comparing the turning radius with some known distance like the length of the craft. This procedure is called the *simple method*.

For high-speed craft ($V_{MAX} > 7 \cdot \sqrt{L_{WL}}$) the compliance shall be evaluated by measuring the turning radius for example with the aid of a track marked with buoys. At least three successful turns shall be made to both sides. This procedure is called the *extended method*.

30.5.5 Quick turn test

Quick turn test is an alternative for $L_H \geq 8$ m crafts to avoidance line test shown in 30.5.4. The craft is operated at full speed at straight course. The steering wheel is turned 180°, or to the maximum of the steering wheel, in 0.5 s or shorter time. The turn is continued until the craft has turned 90°.

During the turn it shall be possible to control the direction of the craft. Dangerous instability or broaching tendencies shall not occur. The helmsman shall stay in position. The test shall be performed to both directions.

30.5.6 Crash stop

The purpose of the crash stop is to determine the distance the craft needs to stop from full speed. This test is an alternative to the avoidance test in 30.5.4 for craft with a hull length of 8 m or larger. The maximum allowed stopping distance is the same as the turning radius requirement for craft with speeds below 30 knots according to Formula (30.1)

30.5.7 Going astern

The craft shall be able to go astern in a straight line, and turn to both sides. It is allowed to use thrusters or equal if required.

Going astern momentarily at 4 knots must not collect water in recesses or on deck affecting stability or water tightness in a dangerous way.

30.5.8 Emergency steering

The proper function of the emergency steering required in Chapter 20 shall be assessed by a practical test.

Conformity is shown if the craft can be steered in a fairly straight line while the speed is at least 4 knots.

31 ACCESSIBILITY AND MAINTENANCE

31.1 Objective

The objective of the rules in this chapter is to ensure that systems and equipment essential for the safe operation of the craft are accessible and operable, and routine maintenance can be carried out without impairing the structure of the craft.

NOTE! Additional requirements may be given for special mission related to class

31.2 References

In this chapter reference is made to the following documents:

- ISO 10088 Small craft – Permanently installed fuel systems and fixed fuel tanks
- ISO 15083 Small craft – Bilge pumping system
- ISO 9094 Small craft – Fire protection
- ISO 12217 Small craft – Stability and buoyancy assessment and categorisation

31.3 Documentation

For the verification of the requirements in this chapter no specific documents are required.

31.4 Definitions

31.4.1 Accessible

"*Accessible*" means a device or system that is capable of being reached for inspection, removal or maintenance without the removal of permanent structures.

31.4.2 Readily accessible

"Readily accessible" means a device or system that is capable of being reached for operation, inspection or maintenance without the use of tools or removal of any structure or any item of portable equipment.

However, a separate closing tool specifically designed only to open and close the closing device in accordance with paragraph 31.6.1 may be used, provided that the closing tool has a storage place where it can always be found.

31.4.3 Without impairing the weather tightness

If a device or system shall be accessible *"Without impairing the weather tightness",* it means one of the following, as applicable:

- In fully enclosed craft (see Chapter 2) the item in question shall be accessible by a person entering through a hatchway of limited size, classified as being "occasionally open at sea"

(definition, Chapter 3) from the weather deck, or from inside a weather tight superstructure or deckhouse.
- Alternatively, in fully enclosed craft, the item in question shall be accessible through suitable openings, which, by virtue of their small size, are regarded as "service openings" (definition, Chapter 3) from outside the space in which it is located.
- Alternatively, in fully enclosed craft, the system and/or equipment in question may be remotely controlled.
- In crafts with buoyancy chambers, and partially decked and open craft (see chapter 2), no requirements are given in this respect.

31.5 Requirements for accessibility and maintenance

Systems and equipment essential for the safe operation of the craft shall be capable of being accessed.

Especially critical systems that are prone to failure at sea are required to be readily accessible.

When located inside the weather tight envelope of a fully enclosed category A craft, and at the same time regarded as particularly critical, some of the systems and equipment are, in addition, required to be accessible without impairing the weather tightness. A summary of the requirements for the accessibility and maintenance of systems and equipment is presented in Table 31.1. The requirements are clarified as needed in clause 6.

Table 31.1. Summary of requirements for accessibility and maintenance of systems and equipment.

Object	Accessibility			Viite
	Accessible	Readily accessible	Without impairing the weathertightness	
Doors and hatchways		x		31.6.1
Anchoring equipment		x		31.6.2
Mooring points and equipment		x		
Lifesaving equipment (lifewests, rafts, fire extinguishers)		x		
Fuel filters		x	x [1)]	31.6.3
Fuel fill, vent and distribution lines	x			
Sea water filters		x	x [1)]	31.6.3
Sea water pump		x	x [1)]	31.6.3
Seacocks		x	x [1)]	31.6.4
Bilge pump strainers	x[2)]	x	x [1)]	31.6.4
Bilge pump lines	x			
Steering gear	x			31.6.5
Emergency steering gear		x		31.6.6
Propeller shaft seals	x			

Hydraulic systems	x			
DC main systems		x	x [1)]	31.6.7

1) Only for craft of design category A

2) For strainers located in weather tight spaces not prone to collect litter or oil

31.6 Clarification of some of the requirements

31.6.1 Doorways and hatchways

Doorways and hatchways leading into the interior, including emergency exits and routes (see Chapter 26), shall be *readily accessible* and operable regardless of possible deck cargo.

For closing devices to *readily accessible* spaces, the separate closing tool must be in a designated and visible, *readily accessible* place from which the closing tool cannot fall overboard or get lost. Alternatively, the closing tool shall be permanently attached to the structures in the immediate vicinity of the closing device. In addition, there must be at least one similar reserve locking tool on board

31.6.2 Anchoring equipment

Anchoring equipment, including chains and warps, shall be *Readily accessible* at all times. This also means that the routes from the steering positions to the anchoring equipment can be used safely regardless of possible deck cargo.

31.6.3 Engine systems

The following systems on the main engine(s) shall be *readily accessible* without impairing the weather tightness of the craft.

- Fuel filters
- Sea water pump impeller
- Sea water filters

In design category A crafts, the systems mentioned above shall also be readily accessible without impairing the weather tightness.

31.6.4 Shut-off valves for seacocks

All shut-off valves for seacocks shall be *readily accessible*. In addition, in design category A only, seacocks located below a level 100 mm above the water line in maximum load condition shall be accessible without impairing the weather tightness of the craft.

31.6.5 Steering gear

The following components of the steering gear shall be accessible for maintenance:

- The hydraulic pump unit;
- The piston unit;
- All valves and joints.

31.6.6 Emergency steering

The arrangements for emergency steering (see Chapter 20) shall be *readily accessible*. In fully enclosed craft the emergency steering system shall be capable of being operated without impairing the weather tightness of the craft.

31.6.7 Electrical systems

On electrical systems the following items shall be readily accessible:

- The battery banks
- Main switches
- Switch boards
- AC distribution cabinets
- Chargers
- Residual current devices
- Main fuses
- Fuses for consumer circuits.

32 PREVENTION OF POLLUTION AND NOISE

32.1 Objective

The objective of the rules in this chapter is to establish the limits to interior noise in craft and to airborne pass-by noise emitted by craft. In addition, the requirements for handling toilet waste is given in this chapter. Further, requirements for handling oil-contamined bilge water is included.

32.2 References

This chapter refers to the following documents:

- ISO 11201 Acoustics – Noise emitted by machinery and equipment - Determination of emission sound pressure levels at a work station and at other specified positions in an essentially free field over a reflecting plane with negligible environmental corrections
- ISO 2923 Acoustics – Measurement of noise on board vessels
- ISO 14509-1 Small craft - Measurement of airborne sound emitted by powered recreational craft - Part 1: Pass-by measurement procedures
- ISO 8099 Small craft – Toilet waste retention systems
- IEC 61672-1 Electroacoustic – Sound level meters – Part 1: Specifications
- IEC 60942 Electroacoustic – Sound calibrators

32.3 Noise on board the craft

This section defines the conditions in and methods by which the ambient noise level is measured in the cockpits of work boats, and the normally allowable level of noise. Measurements must be taken at the position of the driver and also at the position of the assistant driver, when applicable. The same methods may also be applied to other work positions, including monitoring rooms, pantries and workshops. In the following, operator means the driver, navigator or other person working at his or her position.

32.3.1 Test method

The measurement instrument system must comply with the requirements for Class 1 measurement instruments in the standard IEC 61672-1. The measurements must be made using an integrating time-average sound level meter that meets the requirements of the standard IEC 60651. Microphones must be calibrated with a calibrator that meets the requirements of the standard IEC 60942. A windscreen must be used on microphones but its effect on the A-weighted acoustic pressure level may not exceed 0.5 dB in windless conditions.

The circumstances in which the craft is used must be as follows:

- acoustic pressure levels must be measured both at full load and light load;
- propulsion machinery must be running at least 80% of the maximum continuous rating (MCR);
- all auxiliary engines, ventilation devices and equipment that may be running simultaneously in normal conditions must run for the entire duration of the measurement;

- doors and windows must be closed, unless they are kept open in normal use;
- weather conditions must be reported; they must be such that they do not influence the measurement; and
- if further definition of the circumstances of use is needed, they must comply with standard ISO 2923.

The equivalent continuous A-weighted acoustic pressure must be measured with a microphone placed 0.20 m ± 0.02 m from the side of the operator's head. The operator must be standing or sitting in his or her normal working position. Measurements must be taken from both sides of the operator's head and the higher A-weighted acoustic pressure figure LpA [dB(A)] will be recorded.

32.3.2 Test report

The following data must be reported:

- identifying data of the craft and its main and auxiliary engines
- the craft's loading configurations and corresponding attained speeds;
- the measurement area and weather conditions during the measurements;
- the measurement instruments; and
- the equivalent A-weighted pressure level at the locations described in the previous chapter.

32.3.3 Allowable LpA values

Unless otherwise is determined for the craft type in question, the L_{pA} value may not exceed 80 dB(A) in the locations defined under clause 32.3.1.

32.4 Pass-by noise

32.4.1 Objective

For a commercial craft to meet the requirements of the EU recreational craft directive, the airborne noise pass-by emission of the craft must be determined. The noise emission shall be measured in compliance with the standard ISO 14509 as a maximum of the AS-weighted acoustic pressure level. The principal sections of measurement are presented in the following; for details, see the standard ISO 14509.

Measurements are not required in the case of outboard or inboard engine installations if the engines in question have a fixed exhaust manifold and have been type-tested to meet the requirements of the directive. In addition, measurements are not needed if all of the following terms are met:

- the engines have been installed as instructed by the engine manufacturer; and
- the exhaust manifold includes a silencer or silencers that comply with the instructions of the engine manufacturer.
- Froude number does not exceed the value 1.1: $Fn = \frac{V_{MAX}}{\sqrt{g \cdot L_{WL}}} \leq 1{,}1$

- Power-displacement ratio P/Δ, where P = the rated power of the engine under the standard ISO 8665 [kW] and Δ = loaded displacement mass [ton] does not exceed the value 40 kW/ton.

In other cases, measurements must be conducted in compliance with the following section.

32.4.2 Test method

Pass-by noise is measured on both sides of the craft, normally at a distance of 25 m. The measurement instruments must meet the Class 1 instrument requirements presented in the standard IEC 61672-1. The measurements must be made using an integrating time-average sound level meter that meets the requirements of the standard IEC 60651. Microphones must be calibrated with a calibrator that meets the requirements of the standard IEC 60942. A windscreen must be used on microphones but its effect on the A-weighted acoustic pressure level may not exceed 0.5 dB in windless conditions.

The weather conditions, circumstances of use, test track and microphone locations must comply with the standard ISO 14509. The maximum AS-weighted acoustic pressure level during pass-by must be measured. At least two pass-byes must be made for both sides of the craft. The result for both sides is the average of the first two measurement results that are within 1 dB of each other. The maximum AS-weighted acoustic pressure level L_{pASmax} to be recorded is the value for the higher-noise side of the craft.

32.4.3 Allowable acoustic pressure levels L_{pASmax} values

The acoustic pressure level L_{pASmax} may not exceed 75 dB when the craft has a single propulsion engine installed or 78 dB when the craft has two or more propulsion engines.

32.5 Toilet waste

32.5.1 General

If the craft is required to have a toilet, it must have a holding tank equipped with both a pipe going through the bottom and a deck fitting for suction drainage. As an alternative, a chemical toilet may be fitted, with a tank of at least 15 litres, which can be taken ashore for discharge.

32.5.2 Installation of a holding tank for waste water

Waste water holding tanks must be separate and firmly fixed. The minimum capacity of a holding tank is 30 litres. The filling ratio of the tank must be discernible at least when it is ¾ full.

The installation must comply with the standard ISO 8099. The integrity of the system must be verified with tests. When installed, the tank and the pipes, hoses and fittings associated with the system must withstand 20 kPa pressure for a period of 5 minutes without leakage. In addition, the tank must withstand 20 kPa of negative pressure without sustaining permanent deformation. The system must have a means of venting vapours to the outside of the craft.

32.5.3 Hull penetrations

Hull penetrations must have a shut-off valve that can be sealed shut.

32.5.4 Deck fittings for suction drainage

Deck fittings for suction drainage must be placed where they are easily accessible and identified with a marking on the fitting or in its vicinity. The minimum diameter of the fitting is 38 mm.

32.6 Prevention of fuel or lubrication oil leakage

32.6.1 General

The craft must be so constructed that discharge of pollutants (oil, fuel, etc.) overboard is prevented. In particular, there shall be a permanently installed arrangement to collect oil and fuel spill from the engine.

32.6.2 Alternatives for arranging bilge water removal from the engine room

- The part of the bilge underneath the engine(s) has a through or is separated from the rest of the bilge in order to facilitate collection and removal of contamined water. Automatic bilge pumps must not be used from such a compartment. A manual bilge pump shall discharge in a dedicated bilge water tank.
- An automatic bilge pump equipped with an oil separator or bilge water filter. Manual bilge pumps shall discharge in a dedicated bilge water tank or be equipped with oil separator or bilge water filter.
- The engine room bilge is possible to drain with a pump into a fixed or portable container. Automatic bilge pumps are equipped with an oil separator or bilge water filter.

A vessel intended for Finnish inland waters shall not have a system in which treated or filtered oily bilge water from the engine room is automatically discharged into the water.

The oil separators and bilge water filters must be designed for capacity as the connected pump.

The arrangement can also be implemented by some other method which satisfactorily prevents accidental discharges overboard.

33 ADDITIONAL NOTATION “TRANSPORT OF CARGO”

33.1 Objective

In this chapter requirements are given for cargo handling and carrying.

NOTE! Additional requirements on lifting gear are given in Chapter 41!

33.2 Additional notation “Transport of cargo”

The requirements in this chapter is valid for craft where the amount of cargo see Clause 4.5.3, exceeds the value given by formula 33.1:

$$m_{CARGO}=(2{,}5\cdot L_{WL}\cdot B_{WL})^{1{,}5} \text{ kg} \qquad (33.1)$$

If the craft meets the requirements in this chapter, it will be granted the additional notation “Transport of Cargo”.

33.3 Documentation

To verify that the requirements presented in this chapter are met, the following documentation is required:

- Cargo deck layout;
- Stability calculations taking into account the effect of shifting deck cargo.

33.4 Requirements

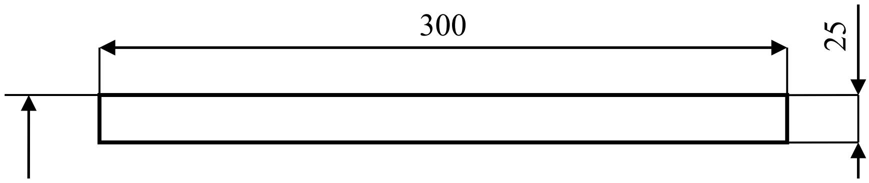
33.4.1 General arrangement

The arrangement of decks shall be such that the intended amount and type of cargo can be safely handled and carried in conditions corresponding to the intended design category. It shall be possible to carry the cargo in such a way that:

- The trim of the vessel is such that water coming onboard will not accumulate on any part of the deck
- The cargo will not block the drainage ports
- The visibility requirements in Chapter 29 are met
- The critical locations and the functions of the vessel are accessible/operable, such as engine room, emergency steering, anchoring, mooring and towing equipment, fire-fighting equipment and life-saving appliances.

33.4.2 Load line mark

The craft shall have a load line mark on both sides amidships. The load line mark shall be according to Figure 1. The upper edge of the mark shall correspond to the draught in fully loaded condition in fresh water.



Draught in fresh water corresponding to “maximum load, departure” condition

Figure 33.1. Load line mark

33.4.3 Load distribution

The load distribution assumed in the calculation of freeboard and stability shall be realistic and in accordance with the principles in paragraph 33.4.1. When the type of cargo is unknown, a specific gravity of 1 t/m3 shall be assumed, and, further, that the cargo is evenly distributed on the cargo deck(s). The vertical centre of gravity of the cargo shall not be taken less than 0,3 m above the deck, unless a limitation is given.

33.4.4 Lashing of cargo

There shall be provision for lashing on decks intended for cargo.

33.4.5 Stability with shifting deck cargo

In the stability assessment according to Chapter 4 it shall be assumed that the athwart ship shift of the total amount of cargo on deck is $B_{CD}/4$, where B_{CD} is the width of the cargo deck in question. If the deck arrangement prevents a shift of this magnitude, a smaller shift may be permitted.

33.4.6 Stability with other types of cargo

The effect of shifting of dry cargo carried in holds, and bulk and liquid cargoes are considered on the basis of the possible potential heeling moment.

33.4.7 Deck cranes, other onboard lifting gear and winches.

Craft fitted with a deck crane shall meet the requirements in Chapter 40. Other onboard lifting gear and winches are assessed on basis on their effect on stability and possible other risks they pose.

34 ADDITIONAL NOTATION “PASSENGER TRANSPORT”

34.1 Objective

The objective of the rules in this chapter is to define additional requirements corresponding to the risks encountered by commercial craft transporting more than 12 passengers.

34.2 Additional Notation *”Passenger Transport”*

The Additional Notation *”Passenger Transport”* can be granted for a commercial craft for which the passenger ship directive is not applied, but is transporting more than 12 passengers who are not part of the crew.

34.3 References

In this chapter reference is made to the following documents:

- Passenger Ships Directive 2009/45/EC
- ISO 15085 Small craft – Man-overboard prevention and recovery
- ISO 8099 Small craft- Toilet waste retention systems
- HSC Code – Chapter 7

34.4 Documentation

For assessment of the requirements given in this chapter the following documentation is required:

- Passenger ship safety information “Safety Plan”;
- Certificates for fire resistant materials as required; and
- Drawings and reports showing compliance with the requirements in paragraphs 34.6…34.16

34.4.1 Scope of application

Within the scope are commercial craft built according to these rules and, under the legislation in force in the country of use, can be assessed on the basis of this Rule. It should be noted, that craft within the scope of the Directive 2009/45/EY are not included.

34.5 General requirements

Craft with the Additional Notation “Passenger Transport” shall in addition to meeting the requirements in the Chapters 1…32 in these rules, also meet the requirements in this Chapter.

34.6 Stability

The craft shall meet the stability requirements for the applied assessment option in Chapter 4, assuming that the centre of gravity for standing persons is 1 m above the deck, and for a sitting person 0.3 m above the seat level. The weight of a person shall be taken as 75 kg in all assessments.

Passenger craft may heel maximally 12 degrees when persons of 75 kg weight are located near the deck edge according to the offset-load test in standard ISO 12217-1, considering the person centre of gravity given in paragraph 34.6. The requirement shall be met with any number of persons right up to the maximum number. The freeboard during the offset-load test shall be at least $0.014 \cdot L_H$ and always over 200 mm measured to the lowest downflooding opening.

Open or partially protected craft are not allowed.

The craft limit of positive stability shall normally be at least 50 degrees. In cases where the GZ-curve area between 30 and 40 degrees is at least 0.03 meter-radians, a limit of positive stability of at least 40 degrees may be allowed.

34.7 Subdivision and water draining arrangements

The craft shall meet the requirements at least for *limited unsinkability* in Chapter 6 paragraph 6.6.

In Design Categories A and B *one compartment damage stability* according to Chapter 38 is required.

The bilge pumping arrangement output and function shall always be tested according to Chapter 6 separately for each compartment.

In each compartment, except for the small spaces in Chapter 6 clause 6.7.2, there shall be a reserve pumping out system which can be controlled outside the pumped out space.

34.8 Fire safety

The fire hazard areas shall be separated according to Chapter 27 clause 27.6.2 from enclosed passenger- and crew areas and from their passages.

In crew- and passenger spaces and their passages the surfaces shall be of low flame-spread type according to Chapter 27 clause 27.4.6.

The craft shall have a fire detection system able to determine the compartment where the fire is.

The fire alarm shall also detect smoke.

34.9 Personal safety

Falling over board shall be prevented according to Chapter 26 with the following additions:

All craft shall be fitted with rails, except for craft with air-filled pontoons in Design Category C and D, where the passengers shall be within the helmsman's field of view, and be seated on saddle seats with front-mounted handholds for both hands.

The rail and its gate, intended to prevent persons from falling over board, or over an upper edge, shall not be removable.

The rail and its gate shall be at least 1000 mm high, and a sphere with 110 mm diameter must not fit through it anywhere from the deck up to 700 mm height.

The rails intended to prevent people from falling over board shall be fitted with at least 25 mm high foot-stops except for where there are gangway gates and passages.

The craft shall be equipped with an arrangement enabling safe disembarking, for example a gangway integrated in the rail.

The gates/gangways shall be arranged so passengers cannot open them accidentally while in the passenger areas without the crew taking notice.

Stairs shall have uniform rise and tread, run in the craft longitudinal direction, and have handrails both sides.

In case the dynamic load factor for the fully loaded craft exceeds 3 calculated according to Chapter 7 paragraph 7.4, there shall be arrangements for reducing the passenger seat vertical accelerations for example with saddle or spring suspended seats.

34.10 Passenger spaces and escapeways

The width of seats shall be at least 0.5 m. The height above the back edge of seats shall be at least 0.9 m. Footwell depth shall be at least 0.75 m measured from the seat backrest.

In the passenger spaces there shall be the same number of seats as the maximum number of persons for the craft. Temporary arrangements or assemblies shall not be counted as seats.

An escapeway located high up shall have permanent a ladder in case its opening is over 1 m above the floor in the evacuated space.

It shall be easy for the passengers to move from the pier to the passenger spaces, and vice versa. The stairs and doors shall be at least 0.75 m wide.

Escapeways, except for stairs and doors, shall be at least 0.8 m wide, including the escapeways for transverse rows of more than four grouped seats.

The area of an escapeway opening shall be at least 0.25 m^2, arranged so a sphere with 0.5 m diameter fits through.

The headroom in passenger spaces and their passages shall be at least 2.03 m. In other crew spaces 1.90 m is required.

Smaller of the heights may be accepted above seats. Height of the doors shall be at least 23.0 m.

The escapeways shall be illuminated and marked with photoluminescent signs according to SFS-ISO 7010 so the passengers can indentify all escapeways, and find the way out.

Escapeways leading to an emergency exit not normally in use, shall be marked with a photoluminescent sign EMERGENCY EXIT.

In crew- and passenger spaces, and deck lounges there shall be illumination and emergency lighting.

The free deck area shall be sufficient for evacuating the craft maximum number of persons from the interior spaces in Design Category A and B.

34.11 Accommodation

In craft with enclosed passenger spaces there shall be at least one toilet, for over 50 passengers at least two toilets.

Spaces closed from the inside shall in an emergency be openable from the outside without breaking anything.

34.12 Electrical system

The craft shall have a *reserve source of electricity* located above the waterline and outside the engine space, able to power the following functions simultaneously for at least three hours without charging:

- Emergency lighting
- Navigation lights
- VHF radio (50 % transmitting, 50 % receiving)
- Navigation electronics
- Alarm- and fire detection systems
- Signalling equipment (at least 20 % use)
- Bilge pumps in engine space

Additionally, the craft shall have an emergency source of electricity powering solely the GMDSS-system

radio equipment according to Chapter 24. In Finland, detailed requirements are given in TraFi regulation Radio Equipment for Ships.

The craft shall have two *main sources of electricity*.

For Design Category A and B having enclosed crew- and passenger spaces, the electrical cables shall be halogen-free.

34.13 Propulsion machinery

There shall be an emergency stop for the craft propulsion machinery at the helm station.

34.14 Fuel system

Fuel with a flashpoint below 60°C (for example petrol) is allowed only for outboard engine installations when the helm station and passenger spaces are entirely in the open.

For inboard engine installations only fuel with a flashpoint over 60°C is allowed (for example diesel oil).

Fuel or flammable oils shall not be carried forward of the collision bulkhead.

34.15 Prevention of pollution and noise

The craft shall meet the requirements for pass-by noise according to Chapter 32 paragraph 32.4.

Enclosed helming and passenger spaces shall meet the requirements for noise on board craft in Chapter 32 paragraph 32.3

Toilets, waste retention, and pump-out systems shall be installed according to standard ISO 8099.

35 ADDITIONAL NOTATION TOWING

35.1 Objective

The objective of this chapter is to define additional requirements for craft engaged in towing operations.

A tugboat is a craft designed for the towing of other craft, log rafts, or other floating objects using a towing hawser, and for this purpose is equipped with a towing hook, winch, bollards or corresponding equipment.

Craft with propulsion power less than 150 kW is not considered a tugboat.

35.2 Additional Notation ”Towing”

Craft meeting the requirements in this chapter will be assigned the Additional Notation ”Towing”.

35.3 Documentation

For assessment of the requirements given in this chapter the following documentation is required:

- A stability calculation according to Chapter 4, where the heeling moment caused by towing is considered; and
- Documentation showing that the towing hawser can be cast off at full load.

35.4 Stability requirements

The stability for tugboats is assessed by plotting the righting and heeling moment curves calculated in the most unfavourable loading condition according to Chapter 4 into the same diagram. Then the area formed above the heeling moment curve between the righting and heeling moment curves shall be at least 0.01 meter radians when calculated up to 40° heeling angle, or to the downflooding angle in case it is less than 40°

35.5 Heeling moment

The heeling moment lever k [m] is calculated according to Formula (34.1)

$$k = \frac{0{,}07C \cdot T \cdot (h \cdot \cos\Phi - 0{,}8r \cdot \sin\Phi + 0{,}5d)}{\Delta} \text{ [m]}$$

(34.1)

where

$C = 4 \cdot l / L_{WL}$, max 1.0*
d = mean draught, [m]
h = the towing point height above the waterline, [m]
ф = heel angle, [degrees]
T = the static bollard pull, [kN]

Δ = displacement [ton]
r = towing hook radial support radius, [m]. If the radius varies, the distance to be used is taken from the hook point of application to the centerline with the pull straight to the side.

For tugboats towing craft which are using their own propulsion engines, or working together with other tugboats, the stability shall be assessed in relation to the pulling power developed by the other craft.

35.6 Special requirements

35.6.1 Towing hawser

It shall be possible to cast off the towing hawser quickly under full load.

The towing hook and hawser hauling-in system shall be dimensioned using the craft maximum bollard pull, with a safety factor of 5 in relation to the breaking load of the used materials.

Person protection during towing work

Windows and doors in front of the towing hook must be protected against the whipping effect caused by the breaking of the towing rope.

35.6.2 Visibility from the helm station

From the helm station there shall be an unobstructed view of the towing hook and towing winch.

36 ADDITIONAL NOTATION “OIL SPILL COMBAT”

36.1 Objective

The objective of this chapter is to define additional requirements for craft engaged in oli spill combat operations, corresponding to the risks these craft are exposed to. Particularly the toxic and flammable components in crude oil requires a higher safety level. However, craft which operate continuously in an environment containing high concentrations of explosive or toxic gases, are outside the scope of these rules.

36.2 Additional Notation ”Oil Spill Combat”

Craft meeting the requirements in this chapter will be assigned the Additional Notation *”Oil Spill Combat”.*

36.3 References

In this chapter reference is made to the following documents:

- ISO 28846 Small craft – Electrical devices – Protection against ignition of surrounding flammable gases
- IEE regulations for the electrical and electronic equipment of ships with recommended practice for their implementation, 6th edition, 1990

36.4 Documentation

For assessment of the requirements given in this chapter the following documentation is required:

- General arrangement drawing with unsafe and safe areas marked; and
- Drawings and documents showing that the requirements in paragraphs 36.5...36.13 are met.

36.5 Scope of application

These rules are applied to craft built to handle, store, and transport oil in connection with an oil spill, i.e. either collecting the oil floating on the water surface, or acting generally in oil recovery.

The rules in this chapter are specifically aimed at larger craft (LH > 15 m), but they may where necessary be applied also to smaller craft.

The scope of application for these rules are limited to oil recovery operations where there are no highly explosive gases. This is considered to be the situation when the flashpoint in the oil spill area is at least 60°C (closed cup test).

36.6 Unsafe and safe areas

36.6.1 Unsafe areas

Unsafe areas are such areas where highly explosive or flammable gases tend to collect. These are:

- Storage tanks for recovered oil;

- Cargo pump spaces;
- Cofferdams and spaces adjacent to the storage tanks for recovered oil;
- Open spaces on deck, where recovered oil may flow;
- Spaces on deck within 3 m from an opening leading into a space on deck;
- Spaces on deck within 3 m from vent openings or hatches from tanks, pump spaces and cofferdams;
- Closed or half open spaces containing cargo piping
- Spaces not having positive pressure ventilation, with direct access from an unsafe area, or having openings to an unsafe area; and
- Any area outside the craft where there is oil pollution (i.e. oil on the water surface).

36.6.2 Safe areas

The areas not mentioned above are considered to be safe in these rules.

36.7 External surface materials

All external surfaces shall be of a non-combustible material, such as steel or aluminium.

36.8 Isolation of unsafe and safe areas

Unsafe and safe areas shall be isolated from each other as far as possible.

36.9 Storage tanks for recovered oil

36.9.1 Arrangement

In case recovered oil will be stored on board the craft, there shall be storage tanks designed for this purpose. The storage tanks for recovered oil shall not be in machinery or accommodation spaces. The tanks shall be isolated from the mentioned spaces by cofferdams, tanks for other purposes, or other dry spaces than accommodation.

36.9.2 Tank openings

All openings to these tanks (fill- and vent line, sounding tube, hatches, etc.) shall be on the open deck.

36.9.3 Tank vents

Tank vent openings shall be located at least 5 m from openings to accommodation or engine spaces, and from uncertified electrical equipment. The tank vent openings shall have flame arrestors.

36.9.4 Pumping systems

The recovered oil shall be handled with a pumping and piping system installed for this purpose.

36.10 Engine installation

36.10.1 Arrangements

Diesel engines including their exhausts, or other equipment which may cause ignition hazards, shall not be installed in unsafe areas.

36.10.2 Cooling system

The propulsion engine cooling system shall be designed for working in oil contaminated water. This can be achieved for example with skin tank cooling, or a scoop system reaching through the oil layer into clean water. In case skin tank cooling is used, particular attention shall be paid to the reduced heat transfer caused by the oil layer. A scoop system shall be sufficiently protected against hitting floating objects.

36.10.3 Exhaust systems

Exits of dry exhaust systems shall be fitted with flame arrestors.

36.11 Ventilation of accommodation spaces

The unsafe and safe areas shall be separated from each other. Ventilation intakes shall be in the safe areas.

At least one entrance to the accommodation shall be in the safe area. Doors and other access openings between safe and unsafe areas shall be kept closed during oil recovery operations.

36.12 Gas detection system

A device for the detection of explosive gases shall be on board.

36.13 Electrical equipment

36.13.1 Certified equipment

Electrical equipment located in unsafe areas shall primarily meet the requirements in IEE regulations for the electrical and electronic equipment of ships with recommended practice for their implementation, 6th edition, 1990, including additions. Alternatively, CE-marked equipment may be used, meeting the requirements in standard ISO 8846 Electrical devices – Protection against ignition of surrounding flammable gases. Electrical bilge pumps shall meet the standard ISO 8849 Electrically operated bilge pumps

36.13.2 Uncertified electrical equipment

It shall be possible to disconnect such electrical equipment located in the unsafe areas from controls in the safe areas during oil recovery operations. None of these shall be:

- Navigation lights;
- Bilge pumps; and
- Other equipment necessary for the safe operation of the craft.

36.13.3 Oil recovery equipment

The electrical supply to oil recovery equipment shall if possible be permanently installed. Both permanently installed and removable oil recovery and pumping equipment as well as separate power sources shall meet the requirements for machinery and electrical equipment.

37 ADDITIONAL NOTATION “SELF-RIGHTING”

37.1 Objective

In this chapter additional requirements are given for craft required to be self-righting after turning fully upside down. The following risks are addressed:

- The craft shall self-righting without any additional actions from any heeling angle.
- The propulsion machinery and its systems shall be able to operate after the craft righted itself.
- Heavy equipment and objects on board shall not move a dangerous amount during the turning.

37.2 Additional Notation ”Self-righting”

Craft meeting the requirements in this chapter will be assigned the Additional Notation ”Self-righting”

37.3 Documentation

For assessment of the requirements given in this chapter the following documentation is required:

- Stability calculation (see Chapter 4) considering the requirements in paragraph 37.4;
- A declaration from the propulsion engine manufacturer that the engine can stand turning upside down without damage;
- A declaration of the heavy objects on board, and their attachment.

37.4 Stability

The righting lever shall be positive for all heeling angles from -180...180°. This requirement shall be met

in all appropriate loading conditions, at least loading conditions LC1, LC2, and LC3 see Chapter 4. Ice load on craft having an additional notation “Winter navigation” is not taken into account in the self-righting stability calculations.

37.5 Propulsion engine and its systems

In case the propulsion engine cannot work in upside down position, there shall be a system stopping the engine automatically if the craft capsizes.

The ingress of water shall be prevented to the extent that it does not endanger the stability of the craft, or the function of the equipment. In addition to the requirements in Chapter 3 the openings always open during operation, such as engine air intake and ventilation, shall be fitted with automatic closing appliances.

37.6 Strength of superstructures

In addition to the scantling pressures given in Chapter 7, the condition when the craft is upside down and the superstructures under water shall be considered. The superstructures shall be dimensioned according to Chapter 10, 14, or 18, depending on the building material, for the largest hydrostatic pressure that occurs at the point under consideration when the craft heels from -180...180°. The pressure shall be determined for each case with the help of the stability calculations.

37.7 Heavy equipment and objects

When the craft heels from -180...180° all equipment and objects shall remain in place. For all objects weighing more than 5 kgs there shall be proper attachments or equal.

37.8 Seating

The seating arrangements shall consider that the craft may turn upside down. The seats shall be fitted with safety belts.

37.9 Operational capability after capsizing and returning to upright

The craft shall after a capsize be fully operational, except for possibly damaged antennas and other sensitive external equipment.

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38 ADDITIONAL NOTATION "ONE COMPARTMENT DAMAGE STABILITY"

38.1 Objective

The objective of this chapter is to ensure that the craft can endure that one watertight compartment is flooded without capsizing and/or sinking.

38.2 Additional Notation "One compartment damage stability"

Craft meeting the requirements in this chapter are assigned the Additional Notation "One compartment damage stability".

38.3 References

In this chapter reference is made to the following document:

- International Convention for the Safety of Life at Sea (SOLAS)

38.4 Documentation

For assessment of the requirements given in this chapter the following documentation is required:

- Drawings showing the following:
  - The watertight subdivision;
  - The structure for watertight bulkheads including WT doors and penetrations;
  - The location of openings leading to watertight compartments, their closing arrangements;
  - Other possible flooding control arrangements;

- Damage stability calculations showing the following:
  - A description of the watertight hull used in the calculations;
  - The lightweight and centre of gravity position;
  - Loading cases (usually the same loading cases as in the stability calculations for the undamaged craft)
  - A description of the damaged conditions;
  - Stability and equilibrium flotation positions after the damage for all loading/damage conditions;
  - Comparison of calculated results with the criteria.

38.5 Definitions

38.5.1 General

The term ”One compartment damage stability” means that the watertight subdivision of the craft is such that the craft can endure that one watertight compartment is flooded without capsizing or sinking, and the flooding does not proceed to other compartments.

38.5.2 Compartment

A space limited by watertight bulkheads, and the length of the space exceeds the minimum length of damage 0.1·LWL.

38.5.3 Bulkhead deck

The *bulkhead deck* is the uppermost deck, or other watertight surface, to which the bulkheads extend.

38.5.4 Margin line

The *margin line* is a (theoretical) line along the craft topside 76 mm below the upper surface of the bulkhead deck.

38.5.5 Space permeability

The *permeability* means how big a part of the compartment volume can be filled with water. Normally the numbers in Table 38.1 are used, but if so desired, the permeability used in the damage stability calculations may also be determined based on the volume of the water displacing items in the space.

38.5.6 Watertight doors and hatches

For the watertight doors and hatches there shall be documentation stating their watertightness. Doors shall be openable and closeable from both sides. Prototypes for doors or hatches shall be tested using a water pressure which can occur when the compartment in question, or the adjacent ones, have filled with water. The closing device shall stand the relevant hydrostatic pressure from both sides.

38.5.7 Initial condition

The craft loading condition before the damage. The initial conditions to be assessed are mentioned in Chapter 4.

38.5.8 Damage condition

A condition where part of the craft watertight compartments are damaged.

38.6 Assumptions for the craft subdivision

The rules for one compartment damage stability are based on the following assumptions for the craft subdivision:

- The craft is divided into watertight compartments primarily with transverse bulkheads extending up to the bulkhead deck, thus preventing flooding from one compartment to another.
- The craft has a collision bulkhead, see Chapter 6.
- The watertight bulkheads are primarily straight, but if this is not the case, SOLAS Part B Chapter II-2 Regulation 7 gives advice for the determination of the extent of flooding.
- Unsymmetrical watertight compartments should better be avoided. In case heeling angle equalization is required using cross-flooding, the arrangement shall be such that no action from the crew is required. Otherwise the advice given in SOLAS Part B Chapter II-1 Regulation 8 for cross-flooding shall be applied.
- The number and size of openings in the watertight bulkheads shall be kept to a minimum.
- Bulkhead penetrations for electrical cables etc. shall be dimensioned for the hydrostatic pressures which can occur in the location in question. Watertight bulkhead penetrations for piping or similar, having open holes in both compartments are not allowed.
- Openings in the bulkhead deck, such as access stairs and hatches, shall be protected with weathertight closing appliances (at least Tightness Level 2 according to Chapter 3 clause 3.6.13). In case such openings are located inside a weather tight superstructure, the opening does not need a closing appliance, unless the same superstructure also protects an opening leading to another compartment.

38.7 Extent of damage

38.7.1 Length of damage

When assessing the craft endurance after damage both side damage and bottom damage shall be considered.

The length of the damage shall be assumed to be $0.1 \cdot L_{WL}$. The damage is assumed to be limited to one watertight compartment, but in case the length of a compartment is less than $0.1 \cdot L_{WL}$, the damage shall be assumed to extend into the next compartment(s) towards the stern.

38.7.2 Bottom damage

The width of the damage for monohulls shall be the same as the beam of the craft, or a smaller width in case this causes a more dangerous damage condition. For catamarans the damage is assumed to affect only one hull.

The vertical extent of the damage shall be assumed to be $0.1 \cdot B_H$. For catamarans the width of the bridge can be deducted from the beam when determining the vertical extent.

Catamaran bridges are assumed to suffer damage only in case the part in question is below the fully loaded waterline when the craft is undamaged.

38.7.3 Side damage

The transverse extent of the side damage shall be assumed to be $0.2 \cdot B_H$ measured from the side perpendicularly to the centreline at the fully loaded waterline. For catamarans the width of the bridge at waterline level can be deducted from the beam when determining the transverse extent. In the vertical direction the damage is assumed to extend upwards from the base line without limitation.

38.8 Permeability coefficients for damaged compartments

The permeability coefficients for damaged compartments shall be taken from Table 38.1, or determined by calculation. The coefficients are applied to both volumes and waterplane areas.

Table 38.1 The space permeability coefficients

Space	Permeability coefficient
Cargo space or store	60
Accomodation	95
Engine space	85
Tanks	0 tai 95 1)
Dry cargo space	70
Car transport space	90
Voids	95

1) Whichever results in the worse result

38.9 Flotation equilibrium position after damage

In the flotation equilibrium position after the damage in calm water in any damage condition specified in paragraph 38.7 and in all applicable loading conditions, the craft shall have sufficient reserve buoyancy and stability, so it meets the following requirements:

- The margin line shall be above water, except for the damaged compartment area, where the margin line may be submerged;
- The freeboard to openings without weather tight closing appliances, through which flooding may progress to undamaged compartments, shall be at least 300 mm;
- The freeboard to openings with weather tight closing appliances shall be positive in all undamaged compartments;
- The craft angle of heel and/or trim shall be at most 10°;
- At the life rafts the freeboard shall be positive;
- The essential life saving appliances, emergency radio equipment, sources of electricity and audible information systems, if any, needed for the evacuation control, shall be in working order.

38.10 Heeling moment

When determining the righting moment lever curve for assessment according to clause 38.10.4, the effect of the offset load moment and wind induced moment acting on the craft shall be assessed separately.

38.10.1 Offset load moment

The offset load moment is the heeling moment arising when all people collect on one side. The offset load moment is determined according to paragraph 4.12, however transfer of deck cargo need not be considered.

38.10.2 Wind induced moment

The wind induced moment shall be calculated in the same way as when assessing the craft stability with wind and waves on the beam in the undamaged condition (see paragraph 4.15).

38.10.3 Alternative to the use of the margin line

In case the craft watertight compartments are such that it is difficult to define the bulkhead deck, or that its use is not appropriate, the flotation equilibrium after flooding shall be assessed as follows: In the equilibrium flotation condition after flooding, the volume of the watertight hull above the waterline shall be at least according to Formula (38.1).

$$V_R = 0.5 \cdot L_H - 2.5\ m^3 \qquad (38.1)$$

The craft shall in other respects meet the requirements for the flotation position specified in paragraph 38.9.

38.10.4 Stability after the damage

The stability in the equilibrium flotation condition after flooding and possible cross-flooding, shall meet the following requirements:

- The stability range to be at least 15°, measured in the equilibrium condition to the smaller of the following angles:
    - heel angle in which flooding to an intact compartment happens
    - capsizing angle
- The maximum righting moment lever must not be smaller than 0.10 m in the heel angle range mentioned above;
- The area under the righting moment lever curve shall be at least 0.015 metreradians measured from the equilibrium angle to the smaller of the following heeling angles:
    - The heeling angle at which flooding to undamaged compartments occur; or
    - 22° measured from the upright position (requirement in the Traficom regulation for commercial craft).
    - capsizing angle

It shall be assumed in the assessment that the offset load moment affects to the craft separately, see paragraph 38.10.

39 ADDITIONAL NOTATION “WINTER NAVIGATION”

39.1 Objective

The objective of the rules in this chapter is to ensure that hull and appendages have enough strength for craft navigating in restricted ice conditions. Further, some other requirements associated with winter navigation are considered. The rules do not address the craft performance in ice breaking tasks.

Here restricted ice conditions mean maximum 20 cm thick solid ice.

39.2 References

In this chapter reference is made to Finnish-Swedish Ice Class Rules

39.3 Symbols

Table 1. Symbols

h = ice thickness [mm]
α = waterline angle [degrees]
β_0 = frame angle [degrees]
P_i = ice pressure [MPa]
F = the linear ice load per metre of contact area [kN/m]
F_{1m} = the linear ice load per metre of contact area corrected for displacement [kN/m]
b = the panel shorter side [mm]
l = the panel longer side [mm]
s = frame spacing [mm]
l_u = stiffener span [mm]
σ_D = design stress [MPa]
m_{LDC} = displacement weight fully loaded [kg]
c_a = correction factor for ice load

Part of the symbols used in this chapter are defined in conjunction with formulas.

39.4 Documentation

For assessment of the requirements given in this chapter the following documentation is required:

- Drawing showing the geometry of the hull and underwater appendages (lines drawing);
- Drawings of the structure in the ice zone;
- Calculations of the ice pressure and the strength of the structure;
- Drawing of the propeller shaft line;
- Drawing of the rudder;
- Drawing of the cooling water system;
- Drawing of closing appliances in the ice zone;
- Drawing of the exhaust line arrangement.

39.5 Definitions

39.5.1 Ice conditions

The assessment of the craft ability to navigate in ice is performed for one of the following cases:

Structural level 1. Maximum 5 cm thick level ice;
Structural level 2. Maximum 10 cm thick level ice;
Structural level 3. Maximum 20 cm thick level ice;

39.5.2 Ice zone

The ice zone is the hull shell area extending aft from the point where the stem and fully loaded waterline cross, the ice thickness h above the fully loaded waterline, and h+100 mm below the light service waterline;

The ice zone further includes:

- From the stem and fully loaded waterline crossing point a 0.3· L_{WL} long, and h+100 mm high area above the fully loaded waterline;
- For displacement craft the whole bottom in a 0.2· L_{WL} long area aft of the fully loaded waterline forward end;
- For planning craft the whole bottom in a 0.6· L_{WL} long area aft of the fully loaded waterline forward end, as well as the chine;
- The area below the fully loaded waterline down to the chine, and transom lower edge.

Butt welded ice reinforced shell plating seams shall not form angles below 135° in relation to the ice field in the transfer area.

The ice zone borders and shell plating bevelled transfer areas are shown in Figure 39.5.

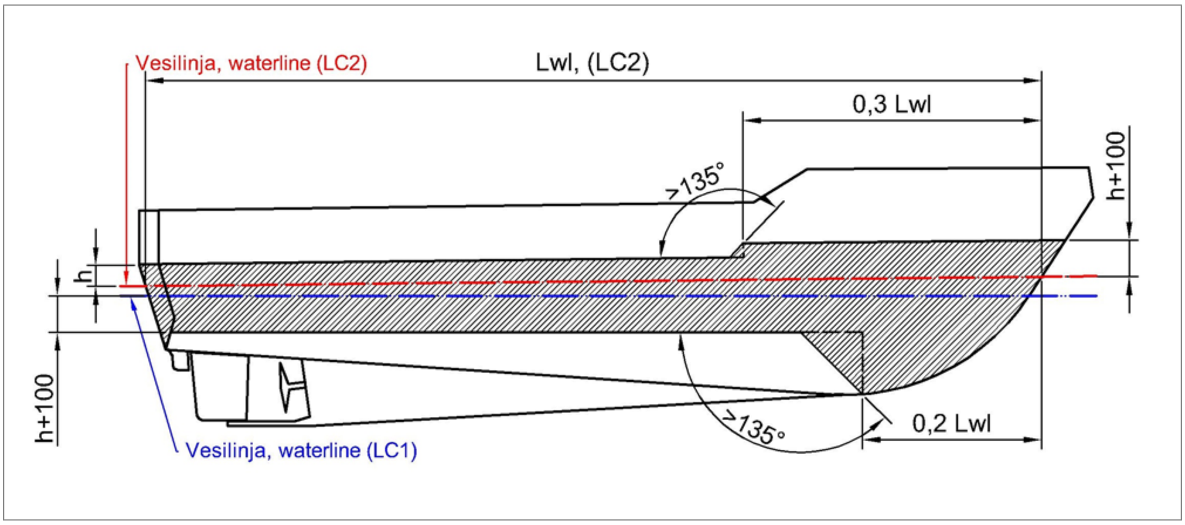


Figure 39.5 Ice zone borders for displacement craft

39.5.3 Ice frame

An ice frame is a stiffener in the ice zone, transferring the ice loads to ice stringers in transversely framed structures, or to web frames in longitudinally stiffened structures.

39.5.4 Ice stringer

An ice stringer is an approximately horizontal major stiffener at the lower and/or upper edges of the ice zone, its purpose is to support ice frames at their upper and/or lower ends.

39.6 Scope of application

39.6.1 Hull type

The structural level 1 or 2 craft shall be a monohull designed for the displacement- or semiplaning speed regime. Craft designed for maximum 5 cm ice may be of planing type.

39.6.2 Hull shape and appendages

The slope of the stem in the ice zone in relation to the horizontal plane shall be at most 60 degrees. For ensuring that the craft is able to go astern in ice the transom or sternpost angle shall equally be at most 60 degrees.

For ensuring the maneuvering properties for Structural level 3 craft the loaded waterline shall be narrower in its aftermost quarter length.

The underwater appendages shall stand ice blocks. Thruster tunnels and water intakes shall be protected by grids.

39.6.3 Propulsion and cooling system

The propulsion for craft with Structural level 2 or 3 shall be an open propeller arrangement meeting the requirements in clause 39.8.7 and 39.8.9. For craft with Structural level 1 waterjet propulsion is allowed.

For Structural level 1 two through hulls with grids and their own raw water filters are approved for cooling water intakes below the ice zone. For Structural level 2 and 3 there shall be closed circuit skin tanks, or a raw water chest to which also the outlet water is led. Raw water filters shall be installed so the crushed ice can be removed from one filter at a time while the engine is running.

39.6.4 Navigation speed

The craft speed in ice fields is limited to 2 m/s (4 knots). In broken ice, or in open water with ice floes the craft may use higher speeds at the discretion of the master. Because several uncertainty factors are involved here, in particular the size of floes, which in practice is impossible to determine from the craft at speed, the rules do not address the maximum allowed speed or the maximum floe size. Further it is assumed that the frame angle is large (> 70°) in the area hitting the floes at planing speeds.

39.6.5 Hull material

The rules refer for steel at all Structural levels. In Structural level 1 or 2 the rules may be applied for aluminium hulls. At Structural level 1 FRP is allowed as hull material, with the limitation, however, that sandwich construction is not allowed in underwater areas, including the ice zone area above the full load water line.

The mechanical properties for the materials are given in Chapter 9 (FRP), 13 (aluminium), and 16 (steel).

39.7 Ice load

39.7.1 The nature of ice load

The ice load is assumed to be a linear load working along the craft ice zone. When the craft proceeds in an ice field, the ice is broken partly by crushing in compression, and partly by bending.

The ice edge in contact with the hull is assumed to exert full load up to 0.6 m length, after that the load drops when the ice field breaks. The height of the ice load is assumed to be the thickness of the entire ice field.

The ice load is in some cases limited by the craft displacement, when the craft climbs up on the ice edge supported by a small contact surface.

It is assumed that ice blocks are hitting the rudder and propeller, but not solid ice.

The ice loads are assumed to depend on the following factors:

- Waterline angle α from the longitudinal direction
- Frame angle β_0 from the vertical direction

- Ice thickness h
- Ice bending strength σ
- Craft speed v

The definition of angles α and β_0 is shown in Figure 39.2. The ice bending strength is assumed to be 500 kPa. The range for both the waterline and the frame angles is 20°...40°. In case the frame angle is less than 20° the calculations shall use 20°, and correspondingly, if the frame angle exceeds 40° the calculations shall use 40°.

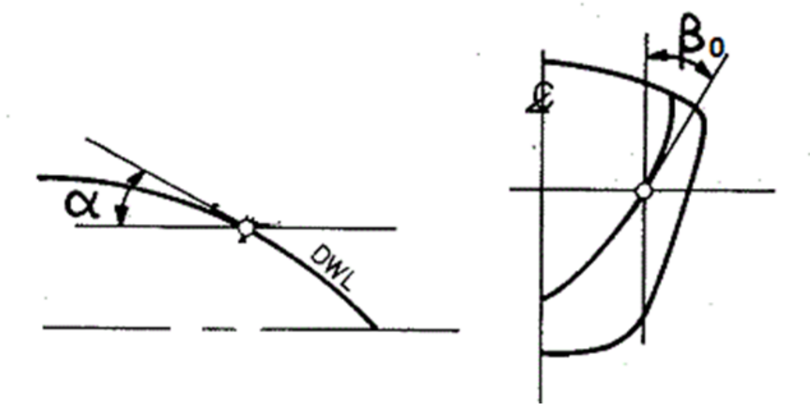
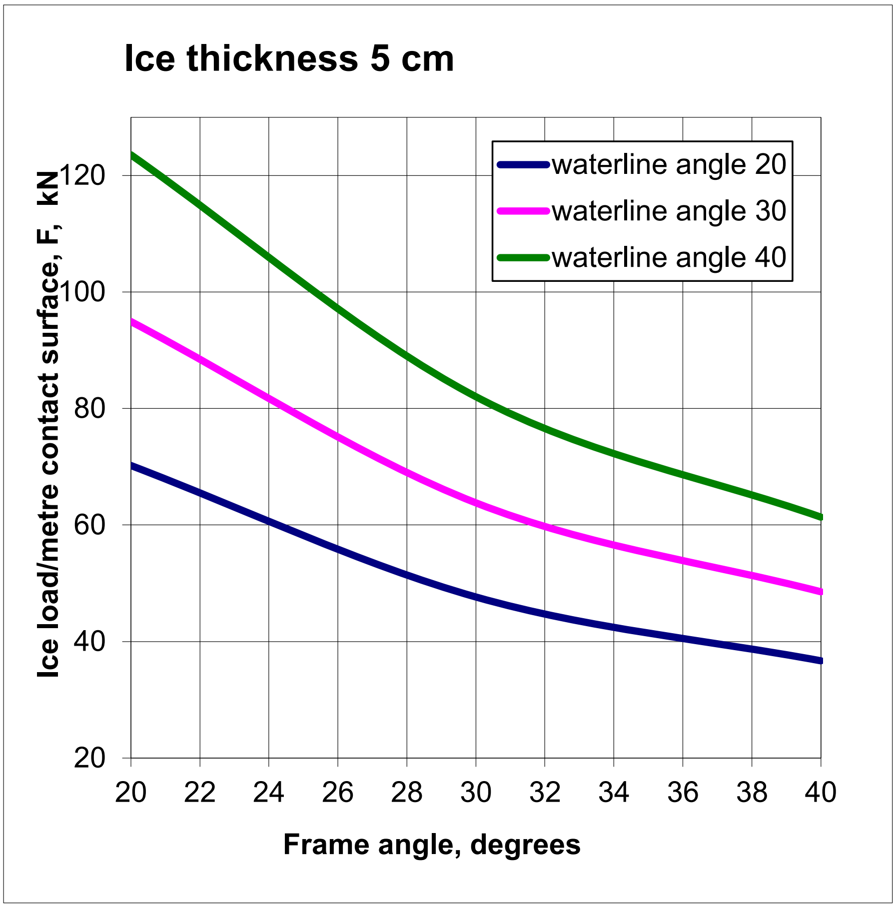
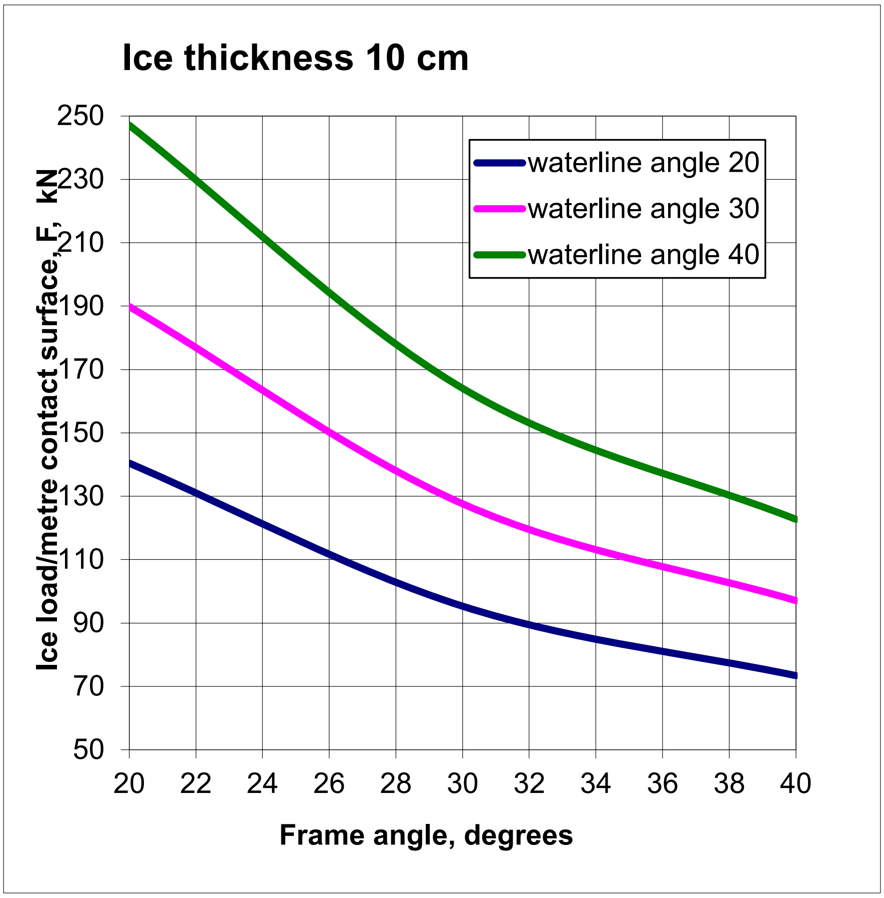


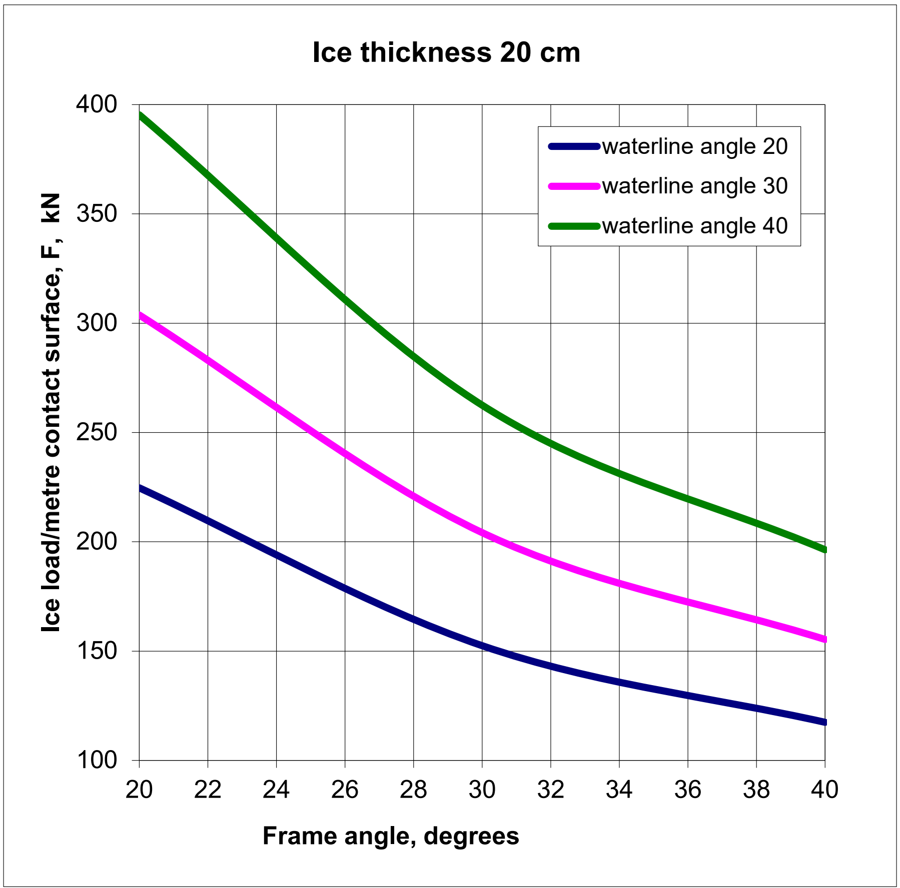
Figure 39.2 Waterline angle and frame angle from buttock

39.7.2 Ice load per contact surface unit length

The ice load per contact surface unit length shall be determined using the curves in Figures 39.3-5.


Ice thickness 5 cm
waterline angle 20
waterline angle 30
waterline angle 40
Ice load/metre contact surface, F, kN
20
40
60
80
100
120
20 22 24 26 28 30 32 34 36 38 40
Frame angle, degrees


Ice thickness 10 cm
Ice load/metre contact surface, F, kN
250
230
210
190
170
150
130
110
90
70
50
20
22
24
26
28
30
32
34
36
38
40
Frame angle, degrees
waterline angle 20
waterline angle 30
waterline angle 40



Figures 39.3 – 39.5. Ice load per meter of contact surface, F for ice thicknesses 5 cm, 10 cm, and 20 cm. Note! In the formulas the ice thickness is given in millimeters!

The ice load per meter under consideration is the smallest of the following:

$$F_{lm} = min\left(F_{max} = \frac{0{,}003 \cdot m_{LDC}}{\cos\alpha \sin\beta_0} \quad ; \quad F\right) \qquad \text{kN} \qquad (39.1)$$

39.7.3 Correction of the load based on contact surface length

The ice load shall be corrected based on contact surface length according to Formula (39.2)

$$c_a = \sqrt{\frac{600}{l_a}} \qquad \text{(max 1,0 ; min 0,35)} \qquad (39.2)$$

Where l_a is to be taken from Table 39.2

Table 39.2.

Structure	Framing system	l_a [mm]
Shell	transverse	*b*
	longitudinal	1.7· b
Ice frames	transverse	*s*
	longitudinal	l_u
Ice stringers	-	Span between bulkheads or equal primary structures, *lu*

39.7.4 Ice pressure

The ice pressure used for the ice zone panel structural design is calculated based on the linear load Flm as follows:

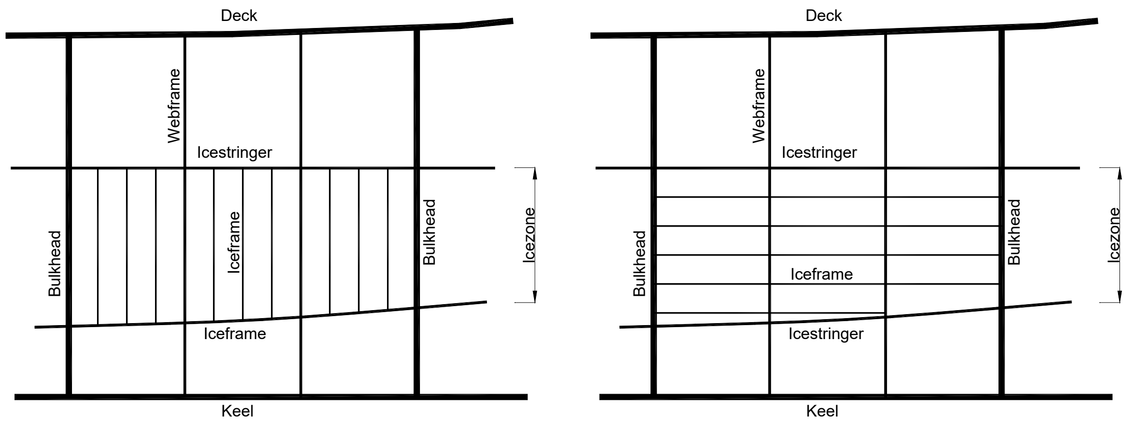
$$P_i = \frac{c_a \cdot F_{lm}}{h} \quad \text{MPa} \quad (39.3)$$

39.8 Structure

39.8.1 Structural arrangements in the ice zone

The structure in the ice zone area is assumed to be an either transversely or longitudinally stiffened hull shell. In a transversely stiffened structure the secondary stiffeners in the ice zone are ice frames placed approximately vertically, and transferring the loads to the ice stringers located at the lower and upper ends of the frames, or to a similar structure (for example a deck).

In a longitudinally stiffened structure the ice zone secondary stiffeners are placed longitudinally, see Figure 39.6.



Transverse framing

Longitudinal framing

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Figure 39.2 Transversely and longitudinally stiffened ice zone

39.8.2 Reinforced areas

Ice reinforcement includes strengthening of the following areas:

- Stem;
- Keel;
- Sharp chines;
- Shell in the ice belt;
- Stiffeners in the ice belt;
- Propeller shaft
- Rudder and steering system

39.8.3 Keel and stem

The keel and stem from the bow to amidships shall be reinforced to stand ice loads at least up to the upper edge of the ice belt. This is considered fulfilled if the keel and stem profile section modulus is at least according to Formula (39.4) below.

The allowed stresses shall, depending on the material, be taken according to Chapter 10, 14, or 18.

$$SM_K = f_0 \cdot m_{LDC} \cdot L_H / \sigma_D \ \ [cm^3] \qquad (39.4)$$

Where:

f_0 = 0.10 for Structural level 1
f_0 = 0.11 for Structural level 2
f_0 = 0.12 for Structural level 3
σ_D = design stress MPa
$\sigma_D = \sigma_y$ for metal
$\sigma_D = \sigma_{UF}/3$ for FRP

When the section modulus for the keel or stem is determined, the effective flange width shall be taken as follows:

FRP:	20 · t,	[mm]
Aluminium:	60 · t,	[mm]
Steel:	80 · t,	[mm]

FRP craft shall have a steel reinforcement for the stem in the ice zone.

For FRP craft reinforced areas the minimum allowed fiber weight W_{min} (Formula 10.9) shall be increased by a factor of 1.2.

39.8.4 Sharp chines

The section modulus of a sharp chine in the ice belt shall meet the Formula (39.5) requirement in the direction of the angle bisector, considering the effective flange according to clause 39.8.3

$$SM = \frac{F_{1m} \cdot c_a \cdot l_u^2}{11 \cdot \sigma_D} 10^{-3} \quad [cm^3] \quad (39.5)$$

where

l_u is the hard chine span in relation to the transverse stiffeners, not to be taken more than 2000 mm in the calculations.

39.8.5 Hull shell

39.8.5.1 Transversely stiffened shell

The required thickness for a transversely stiffened shell is calculated according to Formula (39.6)

$$t = 0{,}667 \cdot b \sqrt{\frac{0{,}75 \cdot f_1 \cdot P_i}{\sigma_D}} + t_C \quad [mm] \quad (39.6)$$

$$f_1 = 1{,}3 - \frac{4{,}2}{\left(h/_b + 1{,}8\right)^2} \quad f_1 \leq 1{,}0 \quad (39.7)$$

Where:

σ_D = design stress:

$\sigma_D = \sigma_y$ for metals;

$\sigma_D = \sigma_{UF}/3$ for FRP;

t_C = addition for wearing and corrosion:

For steel over the whole ice zone +1 mm

For FRP over the length 0.2 L_{WL} from bow +1 mm

39.8.5.2 Longitudinally stiffened shell

The required thickness for a longitudinally stiffened shell is calculated according to Formula (39.8)

$$t = 0{,}667 \cdot b \sqrt{\frac{P_i}{f_2 \cdot \sigma_D}} + t_C \quad [mm] \quad (39.8)$$

Where:

$$f_2 = 0{,}6 + \frac{0{,}4}{h/_b} \quad (39.9)$$

The other definitions are the same as for Formula (39.6)

39.8.6 Frames

39.8.6.1 39.8.6.1 Transverse frames

The section modulus for transverse frames shall be at least

$$SM = \frac{F_{1m} \cdot c_a \cdot s \cdot l_u}{m_t \cdot \sigma_D} 10^{-3} \qquad [cm^3] \qquad (39.10)$$

Where:

m_t = the end restraint of the frame end:

m_t = 4 for simply supported frames

m_t = 6,8 fixed end frames

σ_D = allowed design stress MPa

$\sigma_D = \sigma_Y$ for metal (σY = yield strength)

$\sigma_D = \sigma_{UF}/3$ for FRP (σ_{UF} = flexural breaking strength)

The frame web shear area shall be at least

$$A = \frac{1{,}2 \cdot F_{1m} \cdot c_a \cdot s}{2 \cdot \tau_D} 10^{-2} \qquad cm^2 \qquad (39.11)$$

Where:

τ_D = design shear stress [MPa]

$\tau_D = \sigma_Y/\sqrt{3}$ for metals

$\tau_D = \tau_U/3$ for FRP, τ_u = shear breaking strength in the laminate plane for the stiffener web.

39.8.6.2 Longitudinal frames

The section modulus for longitudinal frames shall be at least

$$SM = \frac{f_3 \cdot F_{1m} \cdot c_a \cdot l_u^2}{m_s \cdot \sigma_D} 10^{-3} \qquad cm^3 \qquad (39.12)$$

Where:

$f_3 = (1 – 0.2 \cdot h/s)$

m_s = Factor taking into account the end fixity:

m_s = 13 for continuous frame ending with brackets

m_s = 11 for continuous frame without brackets

The frame web shear area shall be at least

$$A = \frac{2{,}16 \cdot f_3 \cdot F_{1m} \cdot c_a \cdot l_u}{2 \cdot \tau_D} 10^{-2} \qquad cm^2 \qquad (39.13)$$

Where:

τ_D = design shear stress, [MPa]

$\tau_D = \sigma_Y/\sqrt{3}$ for metals

$\tau_D = \tau_u/3$ for FRP, τ_u = shear breaking strength in the laminate plane for the stiffener web.

39.8.6.3 Ice stringers

Ice stringers are dimensioned in the same way as longitudinal frames while considering the ice pressure reduction coefficient c_a see formula 38.2. In the dimensioning of ice stringers, l_u is the span of the ice stringer between the primary structures, not to be taken more than 2000 mm in the calculations. Ice stringers shall be supported sideways against lateral buckling.

39.8.7 Propeller shaft

The shaft diameter requirement in Chapter 23 shall be multiplied with the following factors

Structural level 1: 1.10
Structural level 2: 1.15
Structural level 3: 1.20

39.8.8 Consideration of side accelerations

The presence of side accelerations shall be considered for the structure and installations.

39.8.9 Reduction and reverse gear

The reduction and reverse gear shall be sized for the shaft end torque considering the following coefficients applied to the engine power:

Structural level 1: 1.25
Structural level 2: 1.35
Structural level 3: 1.50

Additionally, the sizing of the reduction and reverse gear shall be based on the manufacturer's recommendations for ice navigation.

39.8.10 Rudder and steering system

For Structural level 2 and 3 there shall be an ice knife aft of the rudder, able to crush the ice crushing pressure (5 MPa) without exceeding the knife's yield strength.

The steering gear components shall be sized to stand the loads corresponding to the rudder stock yield strength.

For Structural level 2 and 3 there shall be rudder stoppers at the maximum angle.

Rudder stock, rudder, and steering gear including components shall be sized according to Chapter 20 with the following additional factors applied to the force F1:

Structural level 1: 1.50
Structural level 2: 2.00
Structural level 3: 2.50

The force F2 is calculated as presented in Chapter 20, but always at minimum 18 knots speed.

39.8.11 Icing on deck and superstructures

The weight of icing on deck and superstructures shall be considered in the stability calculations, see clause 4.7.5

The structure shall stand the point loads removal of icing without suffering damage.

The dimensioning of the working deck surface shall be based on at least 1 t/m^2 deck load.

40 ADDITIONAL NOTATION "DECK CRANE"

40.1 Objective

In this chapter additional requirements are given for craft equipped with a deck crane.

40.2 Additional Notation "Deck Crane"

Craft meeting the requirements in this chapter are assigned the Additional Notation "Deck Crane".

40.3 Scope of application

The following requirements refer for power-operated deck cranes. This additional notation assumes that the load is lifted in calm water or in a small waves that does not cause the vessel to roll.

40.4 Prevention of overload

40.4.1 Restrictions

The lifting gear shall be arranged so the following is avoided:

- Lifting of loads exceeding the crane designed capacity;
- Large heeling angles resulting from unsuitable combinations of boom length and cargo weight.

40.4.2 Stability

When a deck crane is used, the static heeling angle shall not exceed 10° for any combination of cargo weight and boom length.

At this heel the remaining righting moment lever curve positive area shall be at least 0.01 metreradians.

In case the assessment is done experimentally, the test shall be performed with a short boom in horizontal position. With a load corresponding to the desired maximum lifting moment the heeling angle shall not exceed 10°.

After this the load shall be increased by 20%. With this load there shall not be any signs of insufficient stability, and the static heeling angle must not exceed 15°.

40.4.3 Maximum allowed load

The lifting device shall have a sign stating the maximum allowed load, and addtionally such loads and corresponding arm lengths which in most non-favorable positions cause 10° heel angle in different hoisting directions.

40.5 Documentation of the strength

40.5.1 The strength of the crane

Every lifting device shall have a certificate issued by an accredited testing facility, stating the load for which the device is approved.

40.5.2 The strength of the lifting device attachment

Attachments built of metal shall be dimensioned so that the safety factor to yield is at least 2 and to ultimate strength at least 4. This safety factor does not refer to bolts and other type approved elements coming with the lifting device.

41 ADDITIONAL NOTATION AIR PROPELLED CRAFT

41.1 Objective

The objective of the rules in this chapter is to specify additional requirements and limits for covering the risks that air propelled craft moving on water, ice, snow and land may encounter.

41.2 Additional Notation ”Air propelled craft”

Craft meeting the requirements and limitations in this chapter are assigned the Additional Notation ”Air propelled craft”.

41.3 References

In this chapter reference is made to the following documents:

- ISO 12215-5 Small craft - Hull construction and scantlings – Part 5: Design pressures for monohulls, design stresses, scantlings determination
- ISO 12215-6 Small craft - Hull construction and scantlings – Part 6: Structural arrangements and details
- ISO 12216 Small craft – Windows, portlights, hatches, deadlights and doors. Strength and watertightness requirements
- MCA – The Hovercraft Code

41.4 Documentation

For assessment of the special requirements and exceptions given in this chapter the following documentation is required:

Drawings, test protocols, and reports showing compliance with the requirements in paragraphs 41.6...41.15.

41.5 Scope of application

These rules are applied to craft considered to be hovercraft or hydrocopters according to the following definition:

Hovercraft is a vehicle which during operation is supported by an air cushion, either partly (SES) or fully.

A hydrocopter is a vehicle propelled by an air propeller on ice, land or snow on a fixed hull, and is capable of crossing calm open water sections typically of less than 100 meters, which may have ice flows.

41.6 General requirements

Craft with the Additional Notation ”*Air propelled craft”* shall meet the requirements stated in Chapters 1...32 in these Commercial Craft Rules, as applicable considering the exceptions and additional requirements specified in this chapter.

41.7 Environmental conditions

The requirements stated in this chapter are suitable for Design Category C and D conditions, however, the maximum allowed significant wave height here is 1 m.

Requirements in this chapter are suitable for hydrocopters in calm water.

The air propelled craft shall be tested as fully loaded in the conditions of the aimed use.

41.8 Stability and flotation

The stability for hovercraft may be based on the air cushion, therefore the stability shall be assessed both with air cushion, and without it according to standard ISO 12217-1 to design category D or C

The stability for hydrocopter shall be assessed according to standard ISO 12217-1 to design category D.

41.9 Structure

41.9.1 Scantlings

The structure shall be dimensioned as a displacement motor craft according to standard ISO 12215-5 for Design Category C.

The windows shall meet the strength and water tightness requirements for Design Category C according to standard ISO 12216.

The minimal dry fibre weight (W_{MIN}) and thickness (t_{MIN}) can be determined with the formulas in standard ISO 12215-5 provided the structure otherwise meets the above requirements.

Otherwise the chapters concerning structure and manufacture in this Commercial Craft Rule apply.

41.9.2 Operation on ice

41.9.2.1 On smooth ice

In case the air propelled craft is designed for operation on ice, it shall be ensured that the hovercraft watertight shell is not chafed through.

41.9.2.2 Crossing ice channels

In case the air propelled craft is designed for the crossing of ice channels, it shall be ensured that the uneven surface (ice blocks) does not cause damage to the hovercraft watertight shell.

The loads are difficult to predict, and it needs to be made sure experimentally or by calculation that damage to the contact surfaces does not endanger the hovercraft watertight shell.

41.9.3 Operation on land

In case the hovercraft is designed for operation on land, it shall be made sure experimentally or by calculation that the hovercraft watertight shell is not chafed through, or the craft shall be equipped with wheels, skis or similar arrangements that prevent the watertight shell to get rubbed against soil.

41.10 Propulsion machinery

41.10.1 General

The propulsion machinery shall meet the requirements in Chapter 21, with the exception that also engines designed for aircraft purposes can be accepted.

Petrol fuel can be allowed provided that the engine is installed outside the enclosed hull.

Air propeller and steering fans shall follow the requirements of MCA – The hovercraft Code.

41.10.2 Cooling system

The cooling system shall be approved by the engine manufacturer.

41.11 Personal safety

air propelled craft shall meet the requirements in Chapter 26, further an air propeller shall be protected so it does not cause danger to crew or passengers.

41.11.1 Air propeller protection

An air propeller shall be protected so any part of the human body cannot come into contact with the rotating propeller from the side or deck of the hovercraft. See Figure 41.1.

A protective net shall stand 450 N of external force at any location on an area of 100 x 100 mm without endangering its protective function.

Protection guardrails and fixed hinders shall stand 1.8 kN force in any direction without breaking.

Side or front protection less than 800 mm from the propeller shall not allow a round bar with 50 mm to pass through, and from the openings in this protection there shall be at least 150 mm distance to the propeller swept area. A tight impermeable protection can be closer to the swept area (for example a propeller duct).

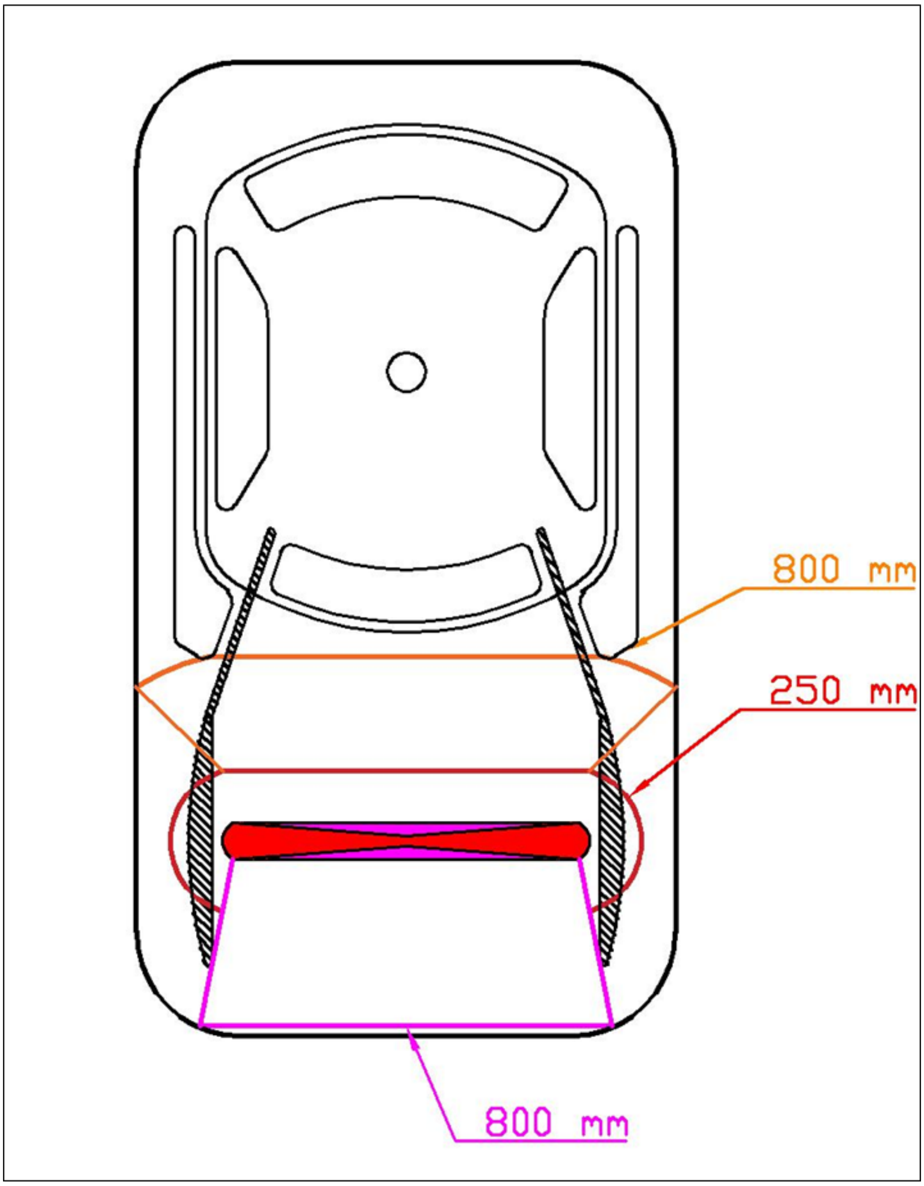
Protection located on the side of the propeller shall be less than 800 mm from the swept area.

There shall be protection in the sector forward of the propeller at least 800 mm from it preventing a person from accidental contact to the propeller. Such an arrangement may be a steeply sloping surface where it is impossible to stand, the outer edge of the hull, or an at least 600 mm high guardrail.

Behind the propeller there shall be an at least 800 mm wide safety area to an at least 600 mm high outer edge of the hull, or alternatively, hinders (f.ex. steering surfaces) behind the sweep area at intervals of not more than 300 mm, and extending at least 300 mm to the rear of the propeller sweep area

Behind the propeller there shall be a warning sign with at least 20 mm high letters:

BEWARE OF THE ROTATING PROPELLER!



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41.12 Fire safety

The engine space shall be fitted with a fixed fire extinguishing system, or alternatively a fire port located at the steering position. In addition to this the requirements in Chapter 27 shall be met.

41.13 Handling characteristics

41.13.1 Air cushion supported

It shall be possible to control and maneuver the hovercraft over smooth ice and over water. If required for turning on glassy ice, it is allowed to deflate the air cushion during a turn. A sudden deflation during a turn must not, however, upset the stability of the hovercraft.

41.13.2 Without air cushion

The hovercraft shall be able to operate in water without an air cushion.

Hydrocopter on ice

It must be demonstrated experimentally or by calculation that the watertight shell does not wear out when operating on ice, and that the watertightness is not compromised by point loads caused by crossing the ice ridges.

The hydrocopter must be able to be controlled and steered on smooth ice and water.

Hydrocopter on land

It shall be demonstrated experimentally or by calculation that the watertight shell does not wear out when operating on land, or the craft shall be equipped with wheels, skis or similar arrangements that prevent the watertight skin to rub against the soil. Sufficient control and steering shall be assessed on land operation, if the hydrocopter is designed for that.

41.14 Noise

A hovercraft must not meet the noise level requirements in Chapter 32.

In a craft not meeting the Chapter 32 requirements for interior noise levels there shall be a warning sign within the view of the pilot reminding about wearing hearing protection.

41.15 User Manual

The User Manual shall explain the hovercraft peculiar features mentioning at least the following:

- Special features related to the maneuvering of the craft:
  - Turning over various surfaces
  - Braking over various surfaces
- Limitations when operating over land
- Limitations for wind speed and significant wave height
- Limitations when crossing ice channels
- Inspection procedures for surfaces subject to wear
- Instructions for hearing protection (if required)
- Service instructions
- Any dangerous issues

Eurofins Guidelines for Commercial craft

Appebdix 1 – Standards, regulations and other sources referenced in the Guidelines for Commercial craft

Chapter 3

- ISO 12216:2018 - Small craft - Windows, portlights and hatches, deadlights and doors - Strength and water tightness
- ISO 12217-1:2017 - Small craft - Stability and buoyancy assessment and categorisation – Part 1: Non-sailing boats of hull length greater than or equal to 6 m
- ISO 11812:2018 - Small craft - Watertight cockpits and quick-draining cockpits.
- ISO 9093-1:2018 - Small craft - Seacocks and through-hull fittings - Part 1: Metallic
- ISO 9093-2:2018 - Small craft - Seacocks and through-hull fittings - Part 1: Non-metallic

Chapter 7

- ISO 6185-3:2018 Inflatable boats - Part 3: Boats with a hull length less than 8 m with a motor rating of 15 kW and greater
- ISO 6185-4:2018 Inflatable boats. Boats with a hull length of between 8 m and 24 m with a motor power rating of 15 kW and greater

Chapter 8

- ISO 12215-6:2008 Small craft – Hull construction and scantlings – Part 6: Structural arrangements and details

Chapter 9

- ISO 12215-1:2018 Small craft – Hull construction and scantlings – Part 1: Materials: Thermosetting resins, glass-fibre reinforcement, reference laminate
- ISO 12215-2:2018 Small craft – Hull construction and scantlings – Part 2: Materials: Core materials for sandwich construction, embedded materials
- ISO 12215-5:2019 Small craft – Hull construction and scantlings – Part 5: Design pressures for monohulls, design stresses, scantlings determination
- ISO 178:2019 Plastics — Determination of flexural properties
- ISO 527-1:2019 Plastics — Determination of tensile properties — Part 1: General principles
- ISO 527-4:1997 Plastics -- Determination of tensile properties -- Part 4: Test conditions for isotropic and orthotropic fibre-reinforced plastic composites
- ISO 527-5:2009 Plastics -- Determination of tensile properties -- Part 5: Test conditions for unidirectional fibre-reinforced plastic composites
- ISO 14126:1999 Fibre-reinforced plastic composites — Determination of compressive properties in the in-plane direction
- ISO 14129:1997 Fibre-reinforced plastic composites — Determination of the in-plane shear stress/shear strain response

- ISO 14130:1997 Fibre-reinforced plastic composites — Determination of apparent interlaminar shear strength by short-beam method
- EN 314-2:1993 Plywood. Bonding quality. Part 2: Requirements

Chapter 10

- ISO 12215-1:2018 Small craft – Hull construction and scantlings – Part 1: Materials: Thermosetting resins, glass-fibre reinforcement, reference laminate
- ISO 12215-2:2018 Small craft – Hull construction and scantlings – Part 2: Materials: Core materials for sandwich construction, embedded materials
- ISO 12215-5:2019 Small craft – Hull construction and scantlings – Part 5: Design pressures for monohulls, design stresses, scantlings determination
- ISO 6185-3:2018 Inflatable boats - Part 3: Boats with a hull length less than 8 m with a motor rating of 15 kW and greater
- ISO 6185-4:2018 Inflatable boats. Boats with a hull length of between 8 m and 24 m with a motor power rating of 15 kW and greater

Chapter 11

- ISO 12215-4:2018 Small craft – Hull construction and scantlings – Part 4: Workshop and manufacturing

Chapter 12

- ISO 12215-6:2018 Small craft – Hull construction and scantlings – Part 6: Structural arrangements and details

Chapter 22

- ISO 10088: 2013 Small craft – Permanently installed fuel systems
- ISO 11105: 2020 Small craft – Ventilation of petrol engine and/or petrol tank compartments
- ISO 8846: 2017 Small craft – Electrical devices – Protection against ignition of surrounding flammable gases
- ISO 7840: 2018 Small craft – Fire resistant fuel hoses
- ISO 13297: 2020 Small craft – Electrical systems – Alternating and direct current installations
- ISO 21487:2012+A2:2015 Small craft – Permanently installed petrol and diesel fuel tanks
- ISO 5817: 2014 Welding. Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded). Quality levels for imperfections
- ISO 10042: 2018 Welding. Arc-welded joints in aluminium and its alloys. Quality levels for imperfections

Chapter 24

- ISO 10133:2017 Small craft – Electrical systems – Extra-low-voltage d.c. installations
- ISO 13297:2018 Small craft – Electrical systems – Alternating current installations
- IEC 60092- 507 2015 Electrical installation in ships part 507 Small vessels
- ISO 16315:2016 Small Craft – Electric propulsion systems

Chapter 25

- ISO 8099-1: 2018 Small craft – Waste Systems

Chapter 26

- ISO 15085: 2003+A2:2018 Small craft – Man-overboard prevention and recovery
- ISO 9094:2017 Small craft – Fire protection
- ISO 14946:2001 Small craft – Maximum load capacity
- 289/2017 Valtioneuvoston asetus työympäristöstä aluksessa

Chapter 27

- The 2000 International Code of Safety for High-Speed-Craft (2000 HSC Code)
- IMO MSC/Circ.911, "Interpretation of fire protection related provisions of the HSC Code"
- Laivanvarustedirektiivi (2014/90/EU)
- International Code for Application of Fire Tests Procedures (FTPC) 2010
- ISO 9094: 2017 Small craft – Fire protection
- ISO 14895: 2016 Small craft - Liquid-fuelled galley stoves
- ISO 4589-3: 2017 Determination of burning behaviour by oxygen index -- Part 3: Elevated-temperature test
- ISO 10239: 2017 Small craft - Liquefied petroleum gas (LPG) systems
- ISO 9705-1: 2016 Reaction to fire tests — Room corner test for wall and ceiling lining products
- ISO 5660-1: 2015 Reaction-to-fire tests - Heat release, smoke production and mass loss rate

Chapter 28

- ISO 15084:2018 Small craft. Anchoring, mooring and towing. Strong points.

Chapter 29

- Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREGs)
- ISO 11591: 2020 Small craft, engine-driven – Field of vision from helm
- ISO 11592-1: 2016 Small craft less than 8m length of hull – Determination of maximum propulsion power rating

Chapter 30

- ISO 11592-1: 2016 Small craft. Determination of maximum propulsion power rating using manoeuvring speed. Part 1: Craft with a length of hull less than 8 m (ISO 11592-1:2016)
- ISO 1192-2:2019 Small craft. Determination of maximum propulsion power rating using manoeuvring speed. Part 2: Craft with a length of hull between 8 m and 24 m

Chapter 31

- ISO 10088: 2017 (2013) Small craft – Permanently installed fuel systems and fixed fuel tanks
- ISO 15083: 2020 Small craft – Bilge pumping system
- ISO 9094: 2017 (2015) Small craft – Fire protection
- ISO 12217: 2017 (2015) Small craft – Stability and buoyancy assessment and categorisation

Chapter 32

- ISO 11201:2010 Acoustics – Noise emitted by machinery and equipment - Determination of emission sound pressure levels at a work station and at other specified positions in an essentially free field over a reflecting plane with negligible environmental corrections
- ISO 2923:1996 Acoustics – Measurement of noise on board vessels
- ISO 14509-1: 2018 Small craft. Airborne sound emitted by powered recreational craft. Part 1: Pass-by measurement procedures (ISO 14509-1:2008)
- ISO 8099-1: 2018 Small craft – Waste Systems
- IEC 61672-1: 2013 Electroacoustics – Sound level meters – Part 1: Specifications
- IEC 60942: 2018 Electroacoustics – Sound calibrators
- Merenkulun ympäristönsuojelulaki 29.12.2009/1672

Chapter 38

- SOLAS Consolidated Edition 2020

Chapter 39

- Jääluokkamääräykset ja niiden soveltaminen. TRAFI/494131/03.04.01.00/2016
- Ice Class Regulations and the Application Thereof. TRAFI/494131/03.04.01.00/2016
- Isklassföreskrifterna och tillämpningen av dem. TRAFI/494131/03.04.01.00/2016

Chapter 41

- ISO 12215-5:2018 Small craft – Hull construction and scantlings – Part 5: Design pressures for monohulls, design stresses, scantlings determination
- ISO 12215-6:2008 Small craft – Hull construction and scantlings – Part 6: Structural arrangements and details
- ISO 12216:2018 Small craft. Windows, portlights, hatches, deadlights and doors. Strength and watertightness requirements
- MCA - The Hovercraft Code