SECTION 1 GENERAL REQUIREMENTS AND APPLICATION

1 General

1.1 Application

1.1.1 The requirements of these Rules are specific to ships intended for pleasure cruising, engaged or not engaged in commercial sailing, and with a length not exceeding 100 m.

Such ships are assigned the service notation **yacht** and **charter yacht,** as presented in Ch 1, Sec 2 .

The wording yachts currently used in the present Rules cover both service notations, except otherwise indicated in the relevant Chapters.

Note 1: Yachts hired without crew are not considered as engaged in commercial sailing.

1.1.2 For the purpose of the present Rules, the following definitions apply:

- passengers: every person other than the Master and the members of the crew or other persons employed or engaged in any capacity on board the ship on the business of that ship, or a child under one year old,
- crew: persons employed or engaged in any capacity on board the yacht on the business of that yacht.

1.1.3 The requirements of these Rules cover sailing ships and motor vessels, of monohull type or catamaran type, built in steel, aluminium, composite materials or wood.

The requirements of these Rules do not cover racing yachts.

1.1.4 The present Rules cover the Classification and the Certification processes.

1.1.5 The regulations set forth in the present Rules apply to ships operated in a proper manner by competent and qualified crew according to the environmental, operating and other criteria on which classification is based.

1.1.6 The Society will consider alternatives to the provisions of the Rules provided that they can be demonstrated, through satisfactory service experience or sound engineering analysis, to be equivalent to the overall strength and safety standards set forth in the Rules.

1.1.7 The Society will consider the classification of ships incorporating novel design principles or features, to which the provisions of the Rules are not directly applicable, on the basis of experiments, calculations or other supporting information provided to the Society.

2 Content of Rules

2.1 Summary table

2.1.1 The Parts and Chapters of these Rules containing the requirements specific to yachts are indicated in Tab 1.

Table 1 : Summary Table

Main subject	Reference
Classification notation and processes - Certification	Part A, Chapter 1 to Part A, Chapter 2
Stability and Subdivision	Part A, Chapter 2 (definitions) Part B, Chapter 2 and Part B, Chapter 3
Structure	Part A, Chapter 2 (definitions) Part B, Chapter 4 to Part B, Chapter 10
Machinery	Part A, Chapter 2 (definitions) Part C, Chapter 1
Electricity and Automation	Part A, Chapter 2 (definitions) Part C, Chapter 2 and Part C, Chapter 3
Fire protection, detection and extinction	Part A, Chapter 2 (definitions) Part C, Chapter 4
Materials, welding and working process	Part B, Chapter 11 and Part B, Chapter 12

2.1.2 Whenever necessary or justified, the Society may modify any requirement of the present Rules, lay down new ones and change the application of the Rules.

2.2 Other Regulations

2.2.1 The attention of Owners, designers, builders and other interested parties is drawn to requirements of applicable International Conventions (e.g Load Line, Solas, Marpol, as defined in Ch 2, Sec 1), National Rules and Regulations and other instruments. (Refer to Part A, Chapter 2).

2.2.2 Ship Rules

When "Ship Rules" are mentioned in the present rules, reference is made to the Rules for the Classification of Steel Ships" of the Society. The designer has to contact the Society for information about any amendments to these Rules.

SECTION 2 CLASSIFICATION

1 Principles of classification

1.1 Classification notations

1.1.1 Ships complying with the requirements of these Rules are to comply with the classification requirements indicated in Part A of the Rules for Steel Ships.

1.2 Class symbols

1.2.1 They are assigned class symbols and construction marks as indicated in Part A, Ch 1, Sec 2, [2] and Part A, Ch 1 Sec 2, [3] of the Rules for Steel Ships.

1.3 Additional class notations

1.3.1 Ships complying with the requirements of these Rules may be assigned additional class notations as indicated in Pt A, Ch 1,Sec 2, [6] of the Rules for Steel Ships.

1.4 Navigation notations

1.4.1 Every classed yacht is to be assigned one navigation notation as listed:

- The navigation notation **unrestricted navigation** is assigned to a yacht intended to operate in any area and any period of the year.
- The navigation notation **unrestricted navigation limited to 60 nautical miles** is assigned to a yacht under 300 GT intended to operate only within 60 nautical miles from the shore.

  The designation of the sea condition and the indication of any exemptions are defined in the Annex to the certificate of classification.
- The navigation notation **coastal area** is assigned to a yacht intended to operate only within 20 nautical miles from the shore and with a maximum sailing time of six hours from a port of refuge or safe sheltered anchorage.
- The navigation notation sheltered area is assigned to a yacht intended to operate in sheltered waters, i.e. harbours, setuaries, roadsteads, bay, lagoons and generally calm stretches of water and when the wind force does not exceed 6 Beaufort scale.

1.4.2 The assignment of a navigation notation, including the reduction of scantlings or specific arrangements for restricted navigation notation, is subject to compliance with the requirements laid down in Part B and Part C.

1.4.3 The assignment of a navigation notation does not absolve the Interested Party from compliance with any International or National regulations established by the Administrations for a ship operating in national waters, or a specific area, or a navigation zone.

1.5 Service notations

1.5.1 Ships complying with the requirements of these Rules are assigned one of the service notations **yacht** or **charter yacht**, which is always to be completed by one of the additional service features **motor** or **sailing** as indicated in Part A, Ch 1, Sec 2 of the Rules for Steel Ships:

- **charter yacht-motor** for ships intended for pleasure cruising, engaged in commercial sailing and propelled by a propulsion engine
- **charter yacht-sailing** for ships intended for pleasure cruising, engaged in commercial sailing and fitted with a sail propulsion, including those assisted by auxiliary engine propulsion
- **yacht-motor** for ships intended for pleasure cruising, other than charter yachts and propelled by a propulsion engine
- **yacht-sailing** for ships intended for pleasure cruising, other than charter yachts and fitted with a sail propulsion, including those assisted by auxiliary engine propulsion.

In addition, the service notations **yacht** or **charter yacht** are always completed by one of the following additional service features, as applicable:

- **C** when the hull is made of composite material
- **S** when the hull is made of steel material
- **A** when the hull is made of aluminium material
- **W** when the hull is made of wood material.

Example:

yacht-motor-S

SECTION 3 SURVEYS

1 Principles of surveys

1.1 General

1.1.1 Ships complying with the requirements of this Rule are to comply with the survey requirements indicated in Part A of the Rules for Steel Ships.

Ships constructed with hull material other than steel are also to comply with the additional requirements indicated in [2] and [3].

Ships assigned with the service notation **yacht** are not submitted to annual surveys for hull and machinery.

2 Class renewal survey

2.1 General

2.1.1 The class renewal survey of ships complying with the requirements of this Rule may be carried out according to the normal survey system (SS) or to the continuous survey system (CS) or to the planned maintenance survey system (for machinery) as indicated in Part A, Ch 2, Sec 2, [4] of the Rules for Steel Ships.

2.2 Ships with additional service feature C

2.2.1 An external examination of the coating condition is to be carried out. This examination is to be directed at discovering significant alteration of the coating or contact damages.

2.3 Ships with additional service feature W

2.3.1 For ships built with laminate wood and provided with sheating or coating, an external examination of the protection of edges against water ingress is to be carried out.

For ships built with plank seams and butts, the condition of plank seams, butts and caulking is to be externally examined and renewal is to be carried out as found necessary by the Surveyor.

Where applicable, the timber of the main structural items is to be tapped specially in place where ventilation is poor. When traces of worm or rot are found, the damaged pieces are to be adzed to sound wood or renewed as found necessary by the Surveyor.

2.4 Ships with additional service feature A

2.4.1 Highly stressed areas are to be externally examined and dye penetrant checks are to be carried out, as found necessary by the Surveyor.

Thickness measurements are to be carried out, in areas where chaffing or corrosion may have developed, as found necessary by the Surveyor.

3 Bottom survey

3.1 Ships with additional service feature W

3.1.1 The seams and butts of the garboard and bilges at midship, the keel scarphs and rabbets are to be examined.The same applies to caulking of the underwater parts specially butts and rabbets. The Surveyor may require caulking to be renewed or the hull to be recaulked as found necessary.

For hulls built with planks, a particular attention is to be given to the tightness of the junctions between planks.

The condition of the bolting and fastening and, in general, of metal parts, is to be examined.

If decay or rot is found or if the wood is worn, it is to be renewed as found necessary by the Surveyor.

Where the planking is sheated with composite material, such as fibre reinforced plastic, the edges of planks are to be examined as found necessary by the Surveyor, in order to ascertain that no ingress of water has occurred along them.

3.2 Ships with additional service feature A

3.2.1 The appendages of the hull (hydrofoils, hydrofoil supports, skirt fixations, shaft brackets, as applicable) are to be examined as found necessary by the Surveyor, with particular attention to their fixation to the hull and to the surrounding area specially where deterioration of the hull protection is found.

SECTION 4 EC CERTIFICATION

1 General

1.1 Definition

1.1.1 All yachts put on the European Community (EC) market, and in a given hull length range (2,5 m to 24 m), are requested to be certified against harmonized EC directive.

Exception is made for yachts that are chartered (granted with a service notation **charter yacht** for Classification purpose), that do not fall within the scope of the EC Directive.

Note 1: Refer to EC directive 2003/44, as amended.

1.1.2 Bureau Veritas, acting as Notified Body (NB n° 0062), is empowered to perform such certification, on behalf of EC.

1.2 Application

1.2.1 For yachts having a hull length L_h greater than or equal to 12 m but not greater than 24 m, the design review requested by the EC directive is to be performed with referentials as specified inTab 1.

Note 1: The definition of the hull length L_h is given in EN ISO standard 8666:2002. This definition is also reminded in Ch 2, Sec 1, [2.2.1].

1.2.2 For yachts having a hull length L_h greater than or equal to 2,5 m but not greater than 12 m, the certification is based on EC directive as only referential.

1.2.3 Yachts granted with Classification will be only partly considered as EC directive compliant.

Full compliance with EC directive will request additional safety requirements to be checked by the Society.

The safety requirements of EC Directive versus requirements of Class are shown in Tab 1.

Table 1 : Safety requirements of EC Directive

Req. n°	Subject **(1)**	Referential to be used **(2)** for		
		Class only	EC only	Class + EC
2	**GENERAL REQUIREMENTS**			
2.1	Hull Identification Number (HIN)	NA	B	B
2.2	Builder's plate	NA	B	B
2.3	Protection from falling overboard and means of reboarding	NA	B	B
2.4	Visibility from the main steering position	NA	B	B
2.5	Owner's manual	NA	B	B
3	**INTEGRITY AND STRUCTURAL REQUIREMENTS**			
3.1	Structure	A	A **(3)**	A
3.2	Stability and freeboard	A	B	C
	Subdivision and collision bulkhead	A	B	A
3.3	Buoyancy and flottation	A	A	A
3.4	Openings in hull, deck and superstructure	A	B	A
3.5	Flooding	A	B	A
3.6	Manufacturer's maximum recommended load	NA	B	B
3.7	Liferaft stowage	NA	B	B
3.8	Escape	A	B	C
3.9	Anchoring, mooring and towing	A	NA	A
4	**HANDLING CHARACTERISTICS**			
4.1	Sea trials	A	B	C
5	**INSTALLATION REQUIREMENTS**			
5.1	Engines and engine spaces	A	B	A
5.2	Fuel system	A	B	A
5.3	Electrical system	A	B	A
5.4	Steering system	A	B	C
5.5	Gas system	NA	B	B
5.6	Fire protection	A	B	A
5.7	Navigation lights	A	B	A
5.8	Discharge prevention	NA	B	B

(1) The table is based on EC Directive 94/25

(2) Identification of referentials:
- NA = Not applicable
- A = BV Rules
- B = EC Directive
- C = BV Rules + EC directive

(3) Design categories defined by EC directive are taken into consideration through loads reduction factors, so-called navigation coefficients, defined in Pt B, Ch 4, Sec 2.

SECTION 5 INTERVENTION ON BEHALF OF NATIONAL AUTHORITIES

1 National and International Regulations

1.1 General

1.1.1 The classification of a ship does not relieve the interested party (Shipowner, Building Yard or Designer) from compliance with any requirements issued by Flag Administrations.

1.1.2 When authorised by the Flag Administration concerned, the Society will act on its behalf within the limits of such authorisation. In this respect, the Society will take into account the relevant National Requirements, survey the ship, report and issue or contribute to issue the corresponding certificate.

The above surveys do not fall within the scope of the classification of ships, even though their scope may overlap in part and may be carried out concurrently with surveys for assignement or maintenance of class.

1.1.3 In the case of a discrepancy between the provisions of the applicable International and National Regulations and those of the Rules, normally, the former take precedence. However, the Society reserves the right to call for the necessary adaptation to preserve the intention of the present Rules.

1.1.4 Ch 2, Sec 2, Tab 1, Ch 2, Sec 2, Tab 2 and Ch 2, Sec 2, Tab 3 suggest the cumulative effect of the several National and International Regulations and classification requirements.

SECTION 6 APPLICATION BY TYPE OF YACHTS

1 General

1.1

1.1.1 For guidance purpose, the limits and criteria given in Tab 1 are explicitly considered for the requirements in the various chapters of the present Rules.

Where the indication "No" is mentioned, it means that the relevant Rules requirements are not influenced by the limit or criteria given in the first column.

Where the indication "Yes" is mentioned, its means that the relevant Rules requirements are different depending on the limits or criteria given in the first column. An additional detailed information may be given as table foot note.

Table 1 : Limits and criteria

Item	Hull	Stability	Machinery	Electricity/ Automation	Fire safety
Rules reference	Part B, Chapter 4 to Part B, Chapter 10	Part B, Chapter 3	Part C, Chapter 1	Part C, Chapter 2 to Part C, Chapter 3	Part C, Chapter 4
Types of yachts: - Monohull - Catamarans	Yes	Yes	Yes **(4)**	Yes **(4)**	No
Classification notation - Sheltered area - Coastal area - Unrestricted navigation	Yes	Yes	Yes	No	Yes
Type of propulsion: - Motor - Sail	Yes	Yes	Yes **(4)**	Yes	No
Speed: - Fast - Slow	Yes	No	No	No	No
Hull material: - Steel - Aluminium - Composites - Wood	Yes	No	No	No	Yes
Length **(1)**: - < 24m - ≥ 24m	No	Yes	Yes	Yes	Yes
Number of passengers: - 0 - 12 - 13 - 36 - > 36	No	Yes **(2)**	Yes **(3)**	Yes	Yes
Tonnage: - < 500 GT - ≥ 500 GT	No	No	Yes	Yes	Yes
Installed power (ME: propulsion engines/EP: electrical power) - ≤ 375 kW - > 375 kW	No	No	Yes for ME **(4)**	Yes for EP **(4)**	Yes for EP

(1) Length according to International Rules (Load line). Only 12 passengers benchmark considered.
(2) Only 36 passengers benchmark considered.
(3) Only 12 passengers benchmark considered.
(4) Less stringent requirements for sailing yachts, for catamarans or for power limited to 375 kW.

SECTION 1 DEFINITIONS

1 General

1.1 Application

1.1.1 This Chapter deals with the various possible interactions between the requirements for the Classification of a yacht and the requirements of the Flag Authorities applicable to such a yacht.

2 Definitions

2.1 Definitions used in the present Rules

2.1.1 The general definitions used in the present Rules are given hereafter:

- Administration: Governement of the State whose flag the yacht is entitled to fly
- International Rules: International Rules and Regulations used by Adminstrations as referential, partly or in full

Note 1: See [2.1.2] for the list of main International Rules.

- National Rules: Set of Rules and Regulations of a Flag Administration applicable for the registration of a yacht by this Flag Administration
- Rules: The present set of Rules
- Society: The Classification Society to which the yacht is classed.

2.1.2 The International Rules mentioned in [2.1.1] are mainly:

- Load Line Convention: International Convention on Load Lines, 1966, as amended
- Solas Convention: International Convention for the Safety of the Life at Sea, 1974, as amended
- Marpol Convention: International Convention for the Prevention of Pollution from Ships, 1973, as amended
- EC Directive: Directive 94/25/CE issued by the European Council dated June 16th, 1994, as amended.

2.1.3 Service notations

The service notations **yacht** and **charter yacht** are defined in Ch 1, Sec 2.

It is reminded that:

- the service notation **yacht** is granted to pleasure vessel operating for private used, and/or hired without crew,
- the service notation **charter yacht** is granted to pleasure vessel engaged in commercial sailing, e.g. hired with a crew.

Note 1: A yacht used alternately for private use and for commercial sailing is to be considered with the service notation **charter yacht**.

2.2 Definitions used in the International Rules

2.2.1 The main defintions used in the International Rules are given hereafter:

- Passenger: Every person other than the master and the members of the crew or other persons employed or engaged in any capacity on board the ship on the business of that ship, or a child under one year old
- Passenger ship: Ship which carries more than twelve passengers
- Cargo ship: Any ship which is not a passenger ship
- Length according to International Rules (L_{LL}):

  This length is equal to 96 per cent of the total length on a waterline at 85 per cent of the least moulded depth measured from the top of the keel, or the length from the fore side of the stem to the axis of the rudder stock on that waterline, if that be greater. In yachts designed with a rake of keel, the waterline on which this length is measured shall be parallel to the design water line.

- Length according to EC Directive (L_h):

  This length is to be measured parallel to the reference waterline and yacht centerline as the distance between two vertical planes, perpendicular to the centreplane of the yacht, one plane passing through the foremost part and the other through the aftermost part of the yacht.

  This length includes all structural and integral parts of the yacht, such as wooden, plastic or metal stems or sterns, bulwarks and hull/deck joints.

  This length excludes parts which are normally fixed, such as fixed spars, bowsprits, pulpits at either end of the yacht, stemhead fittings, rudders, outboard motor brackets, outdrives, waterjets and any propulsion units extending beyond the transom, diving and boarding platform, rubbing strakes and permanent fenders. Outdrives, waterjets, other propulsion units and all movable parts shall be measured in their normal operating condition to their maximum lengthwise extension when the craft is underway.

  This length excludes outboard motors and any other type of equipment that can be detached without the use of tools.

- Gross tonnage:

  Gross tonnage as calculated according to Annex 1 of the International Convention on Tonnage Measurement of Ships, 1969.

SECTION 2 APPLICATION

1 General

1.1 Application

1.1.1 The present Rules deal only with requirements for Classification.

Some additional requirements may be requested from the Flag Administration, without being classification requirements.

For guidance, the tables hereafter indicate the possible additional requirements (National Rules or International Rules) that may be requested by the Flag Administration:

- Tab 1 applies to vessels having the service notation **yacht**
- Tab 2 applies to vessels having the service notation **charter yacht** and carrying not more than 12 passengers
- Tab 3 applies to vessels having the service notation **charter yacht** and carrying more than 12 passengers.

1.1.2 Upon request of the ship Owner and with agreement of the Flag Administration, the Society may accept other requirements considered as equivalent, on a case by case basis.

Table 1 : Yacht

Type of vessel	Monohull or Multihull			
Hull materials	Steel or Aluminium or Composites or Wood			
Length according to EC Directive (L_h)	≤ 24 m		> 24 m	
Gross tonnage	< 400 GRT			400 GRT ≤
Number of passengers	All			
Classification Rules	Present Rules			
Regulatory Framing	When State is EC member	When State is not EC member	All situations	All situations
National **(1)**	EC Directive	National Rules	National Rules	National Rules
International (indicated as reference)	EC Directive Marpol Annexes IV and V	No Marpol Annexes IV and V	No Marpol Annexes IV and V	No Marpol Annexes I, IV and V
(1) National Rules may superseed the International Regulatory Framing or may consider totally or partly the International regulatory Framing				

Table 2 : Charter yacht with not more than 12 passengers

Type of vessel	Monohull or Multihull			
Hull materials	Steel or Aluminium or Composites or Wood			
Length according to International Rules (L_{LL})	≤ 24 m	> 24 m		
Gross tonnage	< 400 GRT		400 GRT ≤ < 500 GRT	≥ 500 GRT
Classification Rules	Present Rules			
National Regulatory Framing	National Rules	National Rules	National Rules	National rules
International Regulatory Framing (indicated as reference)	No Marpol Annexes IV and V	Load Line Marpol Annexes IV and V	Load Line + Marpol Annexes I, IV and V	Load Line + Marpol Annex I, IV and V + Solas for Cargo Ships

Table 3 : Charter yacht with more than 12 passengers

Type of vessel	Monohull or Multihull			
Hull materials	Steel or Aluminium or Composites or Wood			
Load line length according to International Rules	≤ 24 m	> 24 m		
Gross tonnage	< 400 GRT		400 GRT ≤ < 500 GRT	≥ 500 GRT
Classification Rules	Present Rules			
National Regulatory Framing	National Rules	National Rules	National Rules	National rules
International regulatory Framing (indicated as reference)	Solas for Passenger Ships + Marpol Annexes IV and V	Load Line + Marpol Annexes IV and V + Solas for Passenger Ships	Load Line + Marpol Annex I, IV and V + Solas for Passenger Ships	Load Line + Marpol Annex 1, IV and V + Solas for Passenger Ships

SECTION 1 APPLICATION

1 General

1.1 Structural requirements

1.1.1 The wording yacht currently used in the present Rules covers both service notations **yacht** and **charter yacht**, except otherwise indicated in the relevant chapters.

1.1.2 The present Part B of the Rules contains the requirements for determination of the minimum hull scantlings and for the intact and damage stability, applicable to all types of yachts as specified in Pt A, Ch 1, Sec 1, [1.1].

1.1.3 Yachts whose hull materials are different than those given in [1.1.2] and ships with novel features or unusual hull design are to be individually considered by the Society, on the basis of the principles and criteria adopted in the Rules.

1.1.4 The strength of yachts constructed and maintained according to the Rules is sufficient for the draught corresponding to the full load draught. The full load draught considered when applying the Rules is to be not less than that corresponding to the assigned intact ship deepest full load waterline.

1.1.5 Where scantlings are obtained from direct calculation procedures which are different from those specified in Part B, Chapter 8 and Part B, Chapter 9, adequate supporting documentation is to be submitted to the Society as detailed in Ch 1, Sec 3.

1.2 Limits of application to lifting appliances

1.2.1 The fixed parts of lifting appliances, considered as an integral part of the hull, are the structures permanently connected by welding or by laminating, depending on hull material, to the ship's hull (for instance crane pedestals, masts, king posts, derrick heel seatings, etc., excluding cranes, derrick booms, ropes, rigging accessories, and, generally, any dismountable parts).

1.2.2 The fixed parts of lifting appliances and their connections to the ship's structure are covered by the Rules.

2 Rule application

2.1 Materials

2.1.1 General

For the purpose of application of the Rules, the yachts are considered as built in following materials:

- steel (ordinary or high tensile)
- aluminium alloys
- composites
- wood (strip planking only).

Yachts built in traditional wooden construction will be specifically considered, on a case by case basis.

2.1.2 Fire protection

Attention is drawn to the selection of building materials which is not only to be determined from strength consideration, but should also give consideration to structural fire protection and associated class requirements (or Flag Administration requirements, where applicable).

2.2 Rules applicable to various ship parts

2.2.1 The various Chapters and Sections of this present Part B are to be applied for the general arrangement and scantling of ship parts according to Tab 1.

2.3 Rules applicable to other ship items

2.3.1 The various Chapters and Sections of this present Part B are to be applied for the general arrangement and scantling of other ship items according to Tab 2.

Table 1 : Part B Rules requirements applicable for the general arrangement and scantling of ship parts

Parts	Applicable Chapters and Sections
	General
General arrangement	Part B, Chapter 2
Stability	Part B, Chapter 3
Design loads and stresses	Part B, Chapter 4 Part B, Chapter 5 Part B, Chapter 6 Part B, Chapter 7
Scantlings	Part B, Chapter 8 Part B, Chapter 9
Materials	Part B, Chapter 11 Part B, Chapter 12

3 Rounding off of scantlings

3.1

3.1.1 Plate thicknesses on metallic hulls

The rounding off of plate thicknesses on metallic hulls is to be obtained from the following procedure:

a) the thickness is calculated in accordance with the rule requirements

b) the rounded thickness is taken equal to the value rounded off to the nearest half-millimeter.

3.1.2 Stiffener section moduli on metallic hulls

Stiffener section moduli as calculated in accordance with the rule requirements are to be rounded off to the nearest standard value; however, no reduction may exceed 3%.

Table 2 : Part B Rules requirements applicable for the general arrangement and scantling of other items

Items	Applicable Chapters and Sections
Anchors and chain cables	Ch 10, Sec 1
Rudders	Ch 10, Sec 2
Windows and sidescuttles	Ch 10, Sec 3
Shaft brackets	Ch 10, Sec 4
Independent tanks	Ch 10, Sec 5
Chain plates	Ch 10, Sec 6
Solid keel for sailing yachts	Ch 10, Sec 7

SECTION 2 SYMBOLS AND DEFINITIONS

1 Units

1.1 Units definition

1.1.1 Unless otherwise specified, the units used in the Rules are those defined in Tab 1.

2 Symbols

2.1

2.1.1 The main symbols are used in the present Rules are:

- L : Rule length, in m, defined in [3.2]
- L_{WL} : Waterline length, in m, measured with the ship at rest in calm water, at the full load displacement, as defined in [3.2]
- L_{LL} : Length according to International Rules as defined in Pt A, Ch 2, Sec 1, [2.2.1]
- L_h : Length according to EC Directive as defined in Pt A, Ch 2, Sec 1, [2.2.1]
- L_{HULL} : Hull length, in m, defined in [3.3]
- B : Moulded breadth, in m, defined in [3.5]
- B_{WL} : Greatest moulded breadth on waterline at draught T, in m, defined in [3.5]
- D : Depth, in m, defined in [3.6]
- T : Full load draught, in m, defined in [3.7]
- Δ : Full load displacement, in tonnes, at draught T, in sea water (density ρ = 1,025 t/m^3).
- C_B : Total block coefficient. For catamarans, C_B is to be calculated for a single hull, assuming Δ equal to one half of the ship's displacement

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

- C_W : Wave height, in m, defined in [3.10]
- V : Maximum speed, in knots, of the yacht
- LCG : Ship's longitudinal centre of gravity
- a_{CG} : Design vertical acceleration, in g, defined in [3.11]
- H_S : Significant wave height, in m, defined in [3.10].

3 Definitions

3.1 Moulded base line

3.1.1 The moulded base line is the horizontal reference line tangent to the upper face of bottom plating at midship.

In the case of yacht with a solid bar keel, the moulded base line is to be taken at the intersection between the upper face of the bottom plating with the solid bar keel at the middle of length L.

Table 1 : Units

Designation	Usual symbol	Units
Ship's dimensions	See [2]	m
Hull girder section modulus	Z	m^3
Density	ρ	t/m^3
Concentrated loads	P	kN
Linearly distributed loads	q	kN/m
Surface distributed loads	p	kN/m^2
Thicknesses	t	mm
Span of ordinary stiffeners and primary supporting members	ℓ	m
Spacing of ordinary stiffeners and primary supporting members	s	m
Bending moment	M	kN.m
Shear force	Q	kN
Stresses	σ, τ	N/mm^2
Section modulus of ordinary stiffeners and primary supporting members	w	cm^3
Section area of ordinary stiffeners and primary supporting members	A	cm^2

3.2 Rule length

3.2.1 The rule length L is equal to L_{WL} where L_{WL} is the waterline length measured with the yacht at rest in calm water, at the full load displacement.

3.3 Hull length

3.3.1 The hull length L_{HULL} is equal to the total hull length, from the extreme foreward part of the hull, excluding any outfitting protusing, and the extreme aft part.

3.4 Ends of rule length L_{WL} and midship

3.4.1 Fore end

The fore end (FE) of the rule length L_{WL} (see Fig 1) is the perpendicular to the full load waterline at the forward side of the stem.

3.4.2 Aft end

The aft end (AE) of the rule length L_{WL} (see Fig 1, is the perpendicular to the full load waterline at a distance L_{WL} aft of the fore end.

3.4.3 Midship

The midship is the perpendicular to the waterline at a distance 0,5L_{WL} aft of the fore end (see Fig 1).

3.5 Breadth

3.5.1 The moulded breadth B, in m, is the greatest moulded breadth measured amidships below the weather deck.

3.5.2 The breadth B_{WL}, in m, is the greatest moulded breadth measured amidships at full load waterline. For catamarans, B_{WL} is the breadth of each hull.

3.6 Depth

3.6.1 The depth D, in m, is the distance measured vertically on the midship transverse section, from the moulded base line to the top of the deck beam at side on the uppermost continuous deck.

3.7 Draught

3.7.1 The full load draught T, in m, is the distance, measured vertically on the midship transverse section, from the moulded base line to the full load waterline.

In the case of ships with a solid bar keel, the moulded base line is to be taken as defined in [3.1].

3.8 Lightweight

3.8.1 The lightweight, in t, is the displacement without cargo, fuel, lubricating oil, ballast water, fresh water and feed water, consumable stores, passengers and crew with their effects, but including liquids in piping.

3.9 Deadweight

3.9.1 The deadweight is the difference, in t, between the displacement, at the summer draught in sea water of density ρ = 1,025 t/m^3, and the lightweight.

3.10 Wave characteristics

3.10.1 The wave height C_W, in m, is the height crest-to-trough of the wave. This wave height is used only for scantling calculation purpose.

3.10.2 The wave height H_S, in m, is the significant wave height ($H_{1/3}$) of the considered sea-state.

3.10.3 The wave lenght L_W, in m, is the distance between two consecutive crests of the wave. This wave length is used only for scantling direct caculation purpose.

3.11 Design vertical acceleration

3.11.1 The design vertical acceleration at LCG, a_{CG} (expressed in g), is to be defined by the designer and corresponds to the average of the 1 per cent highest accelerations in the most severe sea conditions expected, in addition to the gravity acceleration.

3.12 Freeboard deck$^{(m)}$

3.12.1 The freeboard deck$^{(m)}$ is defined in Ch 2, Sec 2, [2.2.1].

3.13 Bulkhead deck

3.13.1 The bulkhead deck is the uppermost deck up to which the transverse watertight bulkheads are carried.

3.14 Superstructure

3.14.1 The superstructure is defined in Ch 2, Sec 2, [2.2.2].

3.15 Superstructure deck

3.15.1 A superstructure deck is a deck forming the upper boundary of a superstructure.

4 Reference co-ordinate system

4.1

4.1.1 The ship's geometry, motions, accelerations and loads are defined with respect to the following right-hand co-ordinate system (see Fig 2):

- Origin: At the intersection among the longitudinal plane of symmetry of ship, the aft end of L and the baseline
- X axis: Longitudinal axis, positive forwards
- Y axis: Transverse axis, positive towards portside
- Z axis: Vertical axis, positive upwards.

4.1.2 Positive rotations are oriented in anti-clockwise direction about the X, Y and Z axes.

Figure 1 : Ends and midship

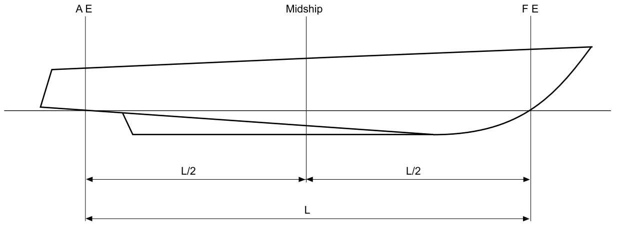
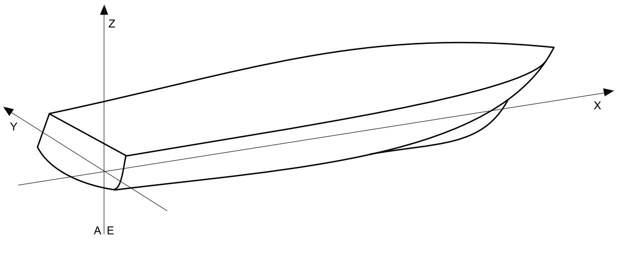


Figure 2 : Reference co-ordinate system



SECTION 4 CALCULATION PROGRAMMES

1 General

1.1 Application

1.1.1 The present Section deals with the various calculation software developed by Bureau Veritas to help checking the requirements of the present Rules.

1.1.2 The list of software is given hereafter, together with their main purpose and scope of application.

Application for these software is to be transmitted to the following internet address:

- MarinesoftwareMail@bureauveritas.com

Information can also be found on the following web site:

- http://www.veristar.com

2 Software

2.1 STEEL

2.1.1 This software allows any type of 2D or 3D beam analysis, for metallic structure.

It includes user-friendly pre-processing for the modelling and post-processing for the bending moments, shear forces, and resulting stresses analysis.

Curved beams may easily be modelled and calculated, using dedicated pre-processing developed separately.

2.2 COMP 2000

2.2.1 This software allows the detailed strength analysis of any type of composites panel or stiffeners, and calculation of strength characteristics of hull girder transverse section, according to Part B, Chapter 9 and to Part B, Chapter 12.

It includes the failure criteria to be considered.

2.3 MARS

2.3.1 Using the appropriate sub-routine, this software allows the calculation of geometrical characteristics of any transverse section of yachts made of metallic materials.

SECTION 5 CONNECTION WITH PART C

1 General

1.1 Application

1.1.1 The present Section deals with the interconnection and the inter linked requirements of Part B and Part C of the present Rules.

1.2 Inter linked requirements

1.2.1 General

Part B of the present Rules deals with the naval architecture of the yacht design (structure and stability). The requirements therein are generally applicable from the very beginning of the Class design review.

Part C of the present Rules deals with the systems fitted on board the yacht, for propulsion, piping and associated functions, for power generation and control and for fire safety.

Attention of designers is drawn on fact that some naval architecture options, that may be decided early in the design process, are directly influencing the design options for systems covered by Part C, or some statutory matters.

The following requirement [1.2.2] outlines the most important such inter linked options.

1.2.2 Inter linked requirements

The most important inter linked options of the various Parts of the Rules are given in Tab 1.

Table 1 : Inter linked requirements

Naval architecture option	Inter linked systems options
Type of hull (mono - multi) Type of propulsion (motor - sail)	Power generation Emergency source
Hull material	Fire safety Piping materials
Watertight bulkheads (distribution and arrangement)	Damage stability
Openings in hull	Damage stability Loadline **(1)**
(1) If relevant	

SECTION 5 INDEPENDENT TANKS

Symbols

L : Rule length as defined in Ch 1, Sec 2, [3.2]

x : Longitudinal position, in m, taken from the aft end AE as defined in Ch 1, Sec 2, [3.4.2].

1 General

1.1 Application

1.1.1 The present section deals with scantlings of independent tanks, in steel, aluminium alloys or composites.

1.2 General

1.2.1 The connections to reinforced hull structures of independent tanks are to be able to withstand the reactions induced by the tank weight.

For that purpose, the dynamic amplification due to behaviour of yacht at sea is to be taken into account for high speed motor yachts as defined in Ch 5, Sec 1, [2] and for monohull sailing yachts. For such yachts, the tank weight is to be taken as W_D, where:

- W_D : Dynamic weight of the tank, taken equal to $(1 + 0{,}4\ a_V)$

  W : Maximum static weight of the tank

  a_V : Vertical acceleration resulting from effect of heave and pitch, equal to:

  $a_v = 2\ .\ x/L\ .\ a_{CG}$, for high speed motor yacht, without being less than a_{CG} , where a_{CG} is defined in Ch 5, Sec 1, [2.1.7]

  $a_v = a_H + a_P$, for monohull sailing yacht , where a_H and a_P are defined in Ch 5, Sec 1, [2.2].

2 Steel and aluminium tanks

2.1 General

2.1.1 In case of gas-oil or diesel-oil aluminium tanks, it is reminded that careful attention is to be paid to welds, as repairs are made very difficult due to degreasing difficulty.

2.2 Plating

2.2.1 The rule thickness of independent tank plates is given, in mm, by the formulae:

$$t = 22,4 \cdot \mu \cdot s \cdot \sqrt{\frac{p}{\sigma_{ad}}}$$

where:

s : Smaller side, in m, of the elementary plate panel

μ : Aspect ratio coefficient of the elementary plate panel, equal to:

$$\sqrt{1,1 - \left(0,5 \cdot \frac{s^2}{\ell^2}\right)}$$

without being taken more than 1, where:

ℓ : Longer side, in m, of the elementary plate panel

p : Design pressure, or testing pressure, in kN/m², given in Ch 7, Sec 1, [5]

σ_{ad} : Rule admissible stress, in N/mm², defined in Ch 4, Sec 3, Tab 2 or Ch 4, Sec 3, Tab 4 whatever the case

Checking of plate thickness against design pressure is to be performed with admissible local bending stress induced by local hydrodynamic loads.

Checking of plate thickness against testing pressure is to be performed with admissible local bending stress induced by tank testing loads.

2.2.2 A local increase in plating thickness is generally required in way of pipe penetration.

2.3 Stiffeners

2.3.1 As a rule, the design section modulus Z, in cm³, of independent tank ordinary stiffeners is given by the formulae:

$$Z = 1000 \cdot \left(1 - \frac{s}{2 \cdot l}\right) \cdot \frac{p \cdot s \cdot l^2}{m \cdot \sigma_{ad}}$$

where:

ℓ : Span of the siffener, in m, measured as indicated in Ch 4, Sec 4, [3]

s : Spacing between siffeners, in m

p : design pressure, or testing pressure, in kN/m², as given in Ch 7, Sec 1, [5]

σ_{ad} : Rule admissible stresses, in N/mm², defined in Ch 4, Sec 3, Tab 2 or Ch 4, Sec 3, Tab 4 whatever the case

Checking of stiffener section modulus against design pressure is to be performed with admissible local bending stress induced by local hydrodynamic loads.

Checking of stiffener section modulus against testing pressure is to be performed with admissible local bending stress induced by tank testing loads.

m : Coefficient depending on end conditions, equal to 12, 10 or 8, as defined in Ch 4, Sec 4, [3.2.5].

2.3.2 As a rule, the design shear area A_{sh}, in cm^2, of independent tanks stiffeners is given by the formulae:

$$A_{sh} = 10 \cdot \left(1 - \frac{s}{2 \cdot l}\right) \cdot \frac{p \cdot s \cdot l}{\tau_{ad}}$$

where:

p, s, ℓ : As indicated in [2.3.1]

τ_{ad} : Rule admissible shear stress, in N/mm^2, as defined in Ch 4, Sec 3, Tab 2 or Ch 4, Sec 3, Tab 4 as appropriate

Checking of stiffener shear area against design pressure is to be performed with admissible local shear stress induced by local hydrodynamic loads.

Checking of stiffener section modulus against testing pressure is to be performed with admissible local shear stress induced by tank testing loads.

2.3.3 The end connections of stiffeners with supporting structures are also to be carefully checked.

2.3.4 In independent tanks made of steel and intended for fresh water or sea water, the fillet welds connecting the stiffeners to the attached plate are to be double continuous fillet welds, to avoid corrosion.

However, in independent tanks made of steel and intended for gas-oil, it is accepted to have intermittent fillet welds.

3 Composites tanks

3.1 General

3.1.1 The mechanical characteristics of the composite laminates used for the tanks is described in Ch 12, Sec 4.

3.2 Plating

3.2.1 The rule scantlings of independent tank in composites material is to be checked according to Ch 9, Sec 3, [7], with

p : Design pressure, or testing pressure, in kN/m^2, given in Ch 7, Sec 1, [5]

SF : Safety coefficients between the applied stresses (see Ch 12, Sec 4, [4]) and the theoretical breaking stresses (see Ch 12, Sec 3, [5]), to be compared with Rule safety factor defined in Ch 4, Sec 3, [5.4].

3.2.2 A local increase in plating laminate is generally required in way of pipe penetration.

3.3 Stiffeners

3.3.1 The rule flexural modulus and shear areas of independent tank composites stiffeners are is to be checked according to Ch 9, Sec 4, [2], with:

p : Design pressure, or testing pressure, in kN/m^2, given in Ch 7, Sec 1, [5]

SF : Safety coefficients between the applied stresses and (see Ch 12, Sec 4, [6]) and the theoretical breaking stresses (see Ch 12, Sec 3, [5]), to be compared with Rule safety factor defined in Ch 4, Sec 3, [5.4].

3.3.2 The end connections of stiffeners with supporting structures are also to be carefully checked.

SECTION 1 GENERAL REQUIREMENTS

1 General

1.1 Characteristics of the materials

1.1.1 The characteristics of the steel or aluminium materials to be used in the construction of ships are to comply with the applicable requirements of the Rule Note NR216 Materials and Welding.

1.1.2 Materials with different characteristics may be accepted, provided their specification (manufacture, chemical composition, mechanical properties, welding, etc.) is submitted to the Society for approval.

1.2 Testing of materials

1.2.1 Materials are to be tested in compliance with the applicable requirements of the Rule Note NR216 Materials and Welding.

1.3 Manufacturing processes

1.3.1 The requirements of this Chapter presumes that welding and other cold or hot manufacturing processes are carried out in compliance with current sound working practice and the applicable requirements of the Rule Note NR216 Materials and Welding:

- parent material and welding processes are to be within the limits stated for the specified type of material for which they are intended
- specific preheating may be required before welding
- welding or other cold or hot manufacturing processes may be need to be followed by an adequate heat treatment.

1.3.2 Requirements for welding and weld connections are given in Ch 11, Sec 2 and Ch 11, Sec 3 .

1.3.3 Qualification of welders

The welders hired by the yard are to be duly qualified and their qualification duly checked, according to the requirements of the Rule Note NR216 Materials and Welding.

1.3.4 Qualification of welding procedures

The welding procedures used for the construction are to be qualified by qualification tests carried out under the Surveyor's supervision, according to the requirements of the Rule Note NR216 Materials and Welding.

SECTION 1 GENERAL REQUIREMENTS

1 General

1.1 Application

1.1.1 The characteristics of composite materials to be used in the construction of yachts within scope of Bureau Veritas classification are to comply with the present Chapter.

1.2 General

1.2.1 The composite's characteristics are directly depending on:

- type of resin
- type of fibre
- type of reinforcement fabric
- type of hull's manufacturing process.

All these particulars are taken into account in this Chapter:

- to characterize composite materials from a mechanical point of view
- to define the Bureau Veritas survey and inspection requested for granting the construction marks ✠ or • and for classing the yacht.

1.2.2 The following steps are to be examined within the scope of the classification of a composite yacht, from a structural point of view:

- Raw materials: homologation or equivalent process to grant the construction marks as defined in Ch 12, Sec 2, [6]
- Theoretical characterization of laminates as defined in Ch 12, Sec 3 (individual layer) and Ch 12, Sec 4 (laminate)
- Mechanical sample tests representative of the hull's structure to compare with theoretical analysis as defined in Ch 12, Sec 5, [4]
- Structure drawings examination, as defined in Ch 1, Sec 3
- Preliminary survey of the yard and survey at work as defined in Ch 12, Sec 5, [2] and Ch 12, Sec 5, [3].

1.2.3 The composite materials considered in this present chapter are basically those made from:

- Thermoset resin's systems
- Glass, carbon or para-aramid based reinforcement fabrics
- Manufacturing processes as lay-ups (spray and hand) or vacuums (infusion) or pre-pregs.

Composite materials made of other resin's systems, fibres or manufacturing processes may be accepted provided their specifications are submitted to the Society for approval.

2 Documents to be submitted

2.1 General

2.1.1 As a rule, the drawings and documents to be submitted for examination are listed in Ch 1, Sec 3, Tab 1.

2.2 Laminate

2.2.1 Following information are to be given on drawings:

- arrangement of laminate for the various structural elements: thickness, definition of the successive layers of reinforcement, mass per square meter in layers of reinforcement, proportion in mass of reinforcement of each layer, directions of roving layers and unidirectional reinforcements, decreasing in thicknesses between layers
- direction of laminate in relation with ship structure
- structure of oil tanks or other liquid tanks which are integrated to the hull
- details of connection between various structural elements and details of attachments to the hull of reinforcing supplementary elements
- pillars.

2.3 Individual layer

2.3.1 However, the technical specifications of suppliers with indication of types, trademarks and references of the resins and gel-coats, reinforcements, and core materials are to be supplied.

These specifications have to give the following information:

- for resins: system (polyester, vinylester or epoxy), density, Young modulus, shear modulus, Poisson coefficient, breaking strength and elongation at break
- for reinforcements (unidirectional reinforcements, woven rovings, chopped strand mats): quality (fibre's type, density with breaking strength of the elementary fibre, Young modulus and Poisson coefficient, in fibre direction and normal to fibre direction), mass per square meter, thickness and eventually weft-warp distribution
- for core materials: type and quality, density, tensile, compression and shear strength and elasticity moduli.

SECTION 2 RAW MATERIALS

1 General

1.1 Application

1.1.1 The mechanical characteristics of composite materials depend on raw materials' characteristics.

1.1.2 The present section gives general "state of the art" information about raw materials.

1.2 Definitions

1.2.1 The present chapter describes the main raw materials used in composite boat building.

The raw materials, used in boat building, are of four main types: resin systems, reinforcements, core materials, adhesives.

1.2.2 Resin systems

Also named matrix, resin systems are thermoset resins (initial liquid, hard and stiff cross linked material that does not return liquid when cured). Resin is used to:

- link reinforcements together
- protect them from impact, moisture and abrasion
- spread loads through reinforcements' layers.

Resin systems dealt with in this Chapter are polyester, vinylester and epoxy systems.

1.2.3 Reinforcements

Reinforcement fabrics are used to improve mechanical characteristics of composite materials.

Reinforcement fabrics may be constructed with interlaced yarns or without interlacing, named respectively woven rovings and stitched rovings.

Reinforcement fabrics dealt in this chapter are made of continuous yarns, manufactured with glass, carbon or para-aramid fibres.

1.2.4 Core materials

Core materials are used in composite sandwich structures to improve global moment of inertia of the whole laminate. Sandwich structures are made of two reinforced faces also named skins, separated by and jointed to a core.

Core materials dealt with in this chapter are synthetic foams, natural cores and honeycombs.

1.2.5 Adhesives

Adhesive materials are generally considered as resin systems, and are used to bond together different composite structures or to bond skins to core in sandwich structures.

2 Resin systems

2.1 General

2.1.1 Manufacturing and curing process

As a general rule, thermoset resin systems used in shipbuilding are obtained from a synthetic resin, also named polymer, made of long unsaturated chains of molecules.

The process, which allows to modify the arrangement of molecular chains from free independent chains to a three dimensional linked chains network, is called polymerisation or curing process.

This chemical reaction is observed where resin goes from its liquid state to its solid state. This reaction is accompanied by a heat discharge and is irreversible for thermoset resins.

The three dimensional network is obtained by different curing processes, according to the type of synthetic resin:

- for polyester and vinylester: by mixing synthetic resin with an unsaturated monomer (e.g. styrene) which creates the chemical links. In this case, the chemical reaction needs a catalyst to start the polymerisation process
- for epoxy: by adding a hardener which promotes the polymerisation process. In this case, macromolecular chains are directly linked to each other.

These two different chemical processes have an important effect on mechanical characteristics of the final resin system and particularly on the volumetric shrinkage during the polymerisation (source of stress concentration in the final composite between resin and fibre).

2.1.2 Glass Transition Temperature (Tg)

Glass Transition Temperature (Tg): the state of polymerisation may be appraised by measuring the Tg. This is the approximate temperature at which number of chemical links between molecular chains is significant to change mechanical properties of a cured resin.

The more polymerized is the resin, which means the greater is the number of chemical links between macromolecular chains, higher is the value of Tg.

Where Tg is measured, it is necessary to indicate the reference of the test method, taking into account that the measured value of Tg may vary from one method to another.

For epoxy resin systems in particular, Tg may be increased after the resin polymerisation by a post cure with an additional rise of temperature.

2.1.3 Speed of polymerisation

The speed of polymerisation process may be controlled:

- either by the amount of accelerators for polyester and vinylester resin systems
- or by the amount of a hardener for epoxy resin systems
- or by a controlled rise of temperature speed.

2.1.4 Resin system reference

The resin systems may be affected by:

- the chemical formulation of polymers used (basic resins, unsaturated monomers, catalysts or hardeners)
- the polymerisation process and the additive products used such as thixotropic or coloured agents.

Due to the above, resins are to be used within the limits fixed by the manufacturer. In this respect, the Surveyor may ask any useful justification to be submitted, such as:

- technical data sheet of resin system in a determined cured condition
- manufacturer guarantee for resin used in naval construction (stability regarding ageing in marine environment, resistance to hydrolysis...)
- type and proportion of catalyst, hardener and accelerator recommended by the manufacturer to be adjusted in the different circumstances of conditions of work (ambient atmosphere, i.e. temperature, relative humidity, dust)
- Type approval certificate for resin system granted by a recognized Society.

Note 1: As a general rule, mechanical tests are to be carried out on a panel laminate representative of the hull structure and polymerisation process as defined in Ch 12, Sec 5, [4].

These mechanical tests aim at examining the final performance of the resin system among others.

2.2 Resin systems type

2.2.1 Polyester system

Polyester resin systems are the result of mixing unsaturated polyester resin with an unsaturated monomer, also called co-polymer, and a catalyst. This reaction is named co-polymerisation.

- Monomer: the unsaturated monomer, generally styrene, is used to reduce the initial viscosity of the resin before polymerisation and to create the chemical links between chains of polyester macromolecules. The chemical reactive sites and so the chemical links are located all along the macromolecular chains of polyester.

  This chemical reaction between polyester and styrene leads to the emission of styrene over, not used in the polymerisation. The global chemical polymerisation is stopped where all the styrene over emission is fully completed or where reactive sites of polyester are fully linked.
- Catalyst: generally of organic peroxyde chemical family, catalyst is used to initiate the reaction between polyester and monomer. It does not take part in the chemical reaction.

  The catalyst proportion and its homogeneous mixing with the polyester/styrene resin before moulding are main parameters.

  Too low proportion of catalyst may result in an incomplete polymerisation reaction, which may affect the mechanical properties of the final laminate. The catalyst proportion is to be defined by the resin manufacturer.
- Accelerator: an accelerator may also be added to control the chemical speed of reaction, according to the workshop environment (temperature for example).

  Because the accelerator has no influence to initiate the polymerisation reaction, as long as there is no catalyst, it may be directly added by the manufacturer in the polyester resin system. This type resin is called pre-accelerated.

The polymerisation is carried out at room temperature and goes with an exothermic heat temperature.

The chemical network after polymerisation may be represented by Fig 1.

Two types of polyester resins are used in boat building: orthophtalic and isophtalic.

The mechanical characteristics and the water absorption resistance of isophtalic are higher than of orthophtalic polyester resin. Isophtalic polyester resin is then generally used for gelcoats and in the first layers located after the gelcoat.

The main physical characteristics of polyester resin systems are:

- a high volumetric shrinkage during polymerisation due to the great number of chemical links along polyester macromolecules and to styrene emission
- a moderate breaking strain due to the location of chemical links along polyester macromolecules
- a water absorption sensitivity due to ester functions in polyester macromolecules.

Figure 1 : Polyester

```
- P - RS - P - P - RS - P - RS - P -
       |           |        |
       S           S        S
       |           |        |
- P - RS - P - P - RS - RS - RS - P -
```

RS= Reactive Sites; P= Polyester; S= Styrene

2.2.2 Vinylester resin systems

Vinylester resin systems have the same polymerisation process than polyester systems.

Unsaturated vinylester resins differ from polyesters primary in their chemical structure by:

- the location of ester groups and reactive sites at ends of vinylester macromolecular chains
- the lower number of ester groups along chains
- the presence of epoxy groups along the chemical structure.

The chemical network after polymerisation may be represented by Fig 2.

The main physical characteristics of the vinylester resin systems are:

- Lower volumetric shrinkage during polymerisation than polyester, due to the lower number of chemical links between macromolecules
- a higher resistance to the water absorption due to the fewer ester functions along macromolecules of vinylester
- a higher breaking strain and ductility than polyester systems due to the location at ends and fewer number of reactive sites along the macromolecule
- high adhesive characteristics due to the presence, in macromolecules, of polarized molecules able to create non-chemical links (hydrogen type) between macromolecules.

Figure 2 : Vinylester

```
- RS - Vi - ................ - Vi - RS -
    |                            |
    S                            S
    |                            |
- RS - Vi - ................ - Vi - RS -
```

RS: Reactive site; Vi: Vinylester; S: Styrene.

2.2.3 Epoxy systems

Epoxy resins are made of long macromolecular chains of polymer with epoxy reactive sites located at ends of these chains. Epoxy resin systems polymerisation may be obtained by:

- mixing epoxy molecular chains with a hardener, generally polyamine or acid anhydride
- and/or rising curing temperature. In this case, epoxy sites may directly react during the polymerisation between each other, without need to add a hardener.

One of the two cases here above is necessary to initiate the reaction; and, in both cases, this chemical reaction is called polyaddition.

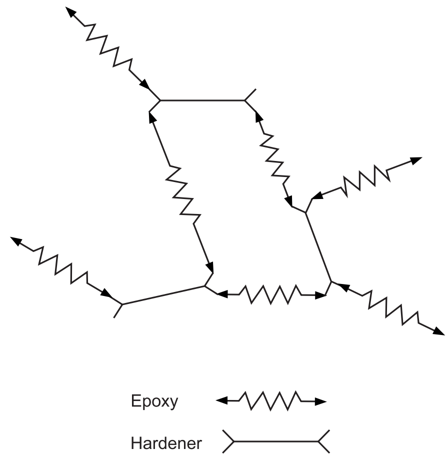
Taking into account that epoxy reactive sites do not need a co-polymer to create chemical links between themselves, the quality of a polymerisation may be increased by a second rise of temperature. This process is named post-cure.

The chemical network after polymerisation of polyepoxyde may be represented as shown in the Fig 3.

The main characteristics of epoxy resins are:

- a low volumetric shrinkage during polymerisation
- a higher breaking strain than polyester and vinylester ones due to the location of the chemical links at macromolecules ends and to the strong resistance of these links
- a high water absorption resistance due to the absence of ester group in the macromolecule
- very high adhesive properties.

Figure 3 : Epoxy



2.3 Homologation of resin systems

2.3.1 General

As a general rule, the resins used in the construction of a yacht are to be certified within the scope of Classification and in particular to assign the construction marks ✠ or •.

This resin system homologation process is described in [6].

2.4 Resins mechanical characteristics

2.4.1 General

As a general rule, the mechanical characteristics of the resin to take into account for laminate calculation are to be given by manufacturer and/or by mechanical test.

2.4.2 The minimum mechanical characteristics are given for information in Tab 1.

3 Reinforcements

3.1 General

3.1.1 As a general rule, the reinforcement fibres need to be arranged into fabric products to make handling possible.

These fabrics are textile structures made from continuous yarns, themselves made from an assembly of monofilaments.

In boat building, continuous yarns and monofilaments are generally named "fibres" and fabrics may also be named "rovings".

The main mechanical characteristics of reinforcement fabrics taken into account in the present chapter depend on:

- fibre type
- yarns' nature
- fabrics' nature.

Table 1 : Resins' mechanical characteristics

	Polyester	Vinylester	Epoxy
Density ρ_m	1,2	1,1	1,25
Poisson coefficient ν_m	0,38	0,26	0,39
Tg (°C)	around 60°	around 100°	between 80° and 150° **(1)**
Tensile Young modulus (MPa) E_m	3550	3350	3100
Tensile or compressive breaking stress (MPa)	55	75	75
Tensile or compressive breaking strain (%)	1,8	2,2	2,5
Shear modulus (MPa) G_m	1350	1400	1500
Shear breaking stress (MPa)	around 50	around 65	around 80
Shear breaking strain (%)	3,8	3,7	5
(1) The actual value of Tg is depending on the polymerisation process used and in particular the temperature used in post-cure			

3.1.2 After fabrication of monofilaments and/or yarns, a surface treatment, named size, is carried on yarns in order to:

- create a cohesion between yarns
- improve the quality of the reinforcement/resin interface
- protect the yarns from manufacturing process.

This size plays a very important part to promote fibre/resin interfacial bond strength. In some cases (carbon and para-aramid fibres), size remains on yarns throughout the fabrics' manufacturing process. In other cases (glass fibre), a first size is applied during yarns' manufacturing to protect monofilaments and a second one is applied during fabric fabrication to improve fibre/resin interface bonding characteristics.

3.1.3 The linear density of a yarn, expressed in tex (g/km), has a direct influence on the strength of a yarn and then on final fabric.

3.1.4 Taking into account that a reinforcement may be affected by the nature of fibre, of yarn, of size or of fabric the Surveyor may ask any useful justification such as technical data sheets of used yarns and/or fabrics to be submitted.

3.1.5 As a general rule, mechanical tests are to be carry out on samples representative of hull laminate structure and polymerisation process as defined in Ch 12, Sec 5, [4].

At this stage, these tests aim at examining performance of yarns and fabrics as well as the fibre/resin interface bond strength.

3.2 Fibre type

3.2.1 Glass

Glass monofilaments are obtained by heating a mixture of silica and alumina up to approximately 1600 °C then by stretching the liquid through a die, made up of holes generally of 5 to 25 µm.

They have the same molecular arrangement than glass plates and then are considered as isotropic materials. It means that the mechanical properties are the same in lengthwise and crosswise directions.

The two main types of glass used in composite shipbuilding are the E and the R types. E-glass is the reference glass, generally used. R-glass has an higher mechanical resistance due to greater percentages of silica and alumina in its chemical composition.

Glass yarns have a standardized designation (ISO 2078), giving following information:

- type of glass
- type monofilament: C for Continuous and D for Discontinuous, commonly and respectively named strand and staple
- diameter of monofilaments in micrometer
- linear density in Tex.

For example, "EC15 800" means E-Glass made from Continuous monofilaments of 15 µm diameter and 800 Tex.

The main physical characteristics of the E-Glass are:

- a good tensile and compressive strength and stiffness
- a relatively poor impact resistance.

The main physical characteristics of R-Glass are the same than E-Glass with an improvement of roughly 20% as well as good interlaminar shear strength properties.

3.2.2 Carbon

Carbon monofilaments are mainly made from Poly-Acrylonitril) (PAN) precursor fibres.

PAN-precursor fibres are first oxidized (between 200°C and 300°C) and then carbonized under inert atmosphere (between 700°C and 1500°C). These steps rearrange the molecular structure into a network of aromatic carbon layers, which are all chemically linked. This chemical process makes the structure different in the lengthwise direction and in the crosswise direction, which explains the orthotropy of carbon monofilaments.

This first stage of fabrication gives the HS Carbon.

This Carbon may undergo an additional stage: a graphitization between 2000°C and 3000°C under inert gaz. This final stage increases the number of aromatic carbon layers and chemical links, which give the monofilaments a higher density and a higher Young modulus. Those types of Carbon are named IM and HM Carbon (respectively Intermediate Modulus and High Modulus).

Another type of Carbon, called Pitch Carbon, is also used in shipbuilding. Pitch-precursor carbon monofilaments are obtained by pitch fusion (between 350°C and 450°C), dying and high stretching. Stretching, which is in addition with the chemical process, gives monofilaments a higher anisotropic molecular arrangement than the HM carbon monofilaments then an even higher Young modulus.

Generally, one has to apply a size to carbon monofilaments in order to improve the quality of reinforcement/resin interface and to protect them from the different steps of reinforcements' fabrication.

The industrial designation of carbon multifilament is as follow. First one gives the type of carbon, then the number of monofilaments into the multifilament, expressed in thousands of monofilaments (e.g. HR-12k Carbon).

The main characteristics of carbon fibres are:

- very high tensile and compressive strength and stiffness
- a very low strength in the normal direction to the fibres' direction
- a relatively poor interlaminar shear strength and impact resistance.

3.2.3 Para-aramid

Aramid (Aromatic ether amid) fibres are organic man-made fibres. Para-aramid is the result of a polycondensation of a polyamine and an aromatic acid around 300°C.

Para-aramid monofilaments are obtained successively by hot-dying, cold-water solidification and "high-speed, high-temperature, dry-air" stretching. Stretching, which is a mechanical process, gives to para-aramid monofilaments a very high-oriented molecular organization in the "fibre" direction. Their behaviour and mechanical properties in transverse and "fibre" directions are then very different.

The main characteristics of the para-aramid fibres are:

- a very high impact resistance
- high tensile strength and stiffness and a poor compressive strength
- a very poor tensile and compressive resistance in transverse direction.

As a general rule, para-aramid are hard to wet by resin systems.

3.2.4 Mechanical characteristics

As a general rule, the mechanical characteristics of fibres to take into account for laminates calculations are to be submitted by manufacturer and/or are given by mechanical tests.

The minimum mechanical characteristics are given in Tab 2 for information.

Table 2 : fibres mechanical properties

		Glass		Carbon			Para-aramid
		E	R	HS	IM **(1)**	HM **(1)**	
Density ρ_f		2,57	2,52	1,79	1,75	1,88	1,45
Tensile in fibre direction	Poisson coefficient ν_f	0,238	0,2	0,3	0,32	0,35	0,38
	Young modulus $E_{f0°}$ (MPa)	73100	86000	238000	350000	410000	129000
	Breaking strain (%)	3,8	4	1,5	1,3	0,6	2,2
	Breaking stress (MPa)	2750	3450	3600	4500	4700	2850
Tensile normal to fibre direction	Poisson coefficient	0,238	0,2	0,02	0,01	0,01	0,015
	Young modulus $E_{f90°}$ (MPa)	73100	86000	15000	10000	13800	5400
	Breaking strain (%)	2,4	2,4	0,9	0,7	0,45	0,7
	Breaking stress (MPa)	1750	2000	135	70	60	40
Compressive in fibre direction	Breaking strain (%)	2,4	2,4	0,9	0,6	0,45	0,4
	Breaking stress (MPa)	1750	2000	2140	2100	1850	500
Shear	Modulus G_f (MPa)	30000	34600	50000	35000	27000	12000
	Breaking strain (%)	5,6	5,6	2,4	3	3,8	4
	Breaking stress (MPa)	1700	1950	1200	1100	1000	500

(1) Taking into account the large diversity of IM and HM carbon, the values presented in this table are given for general guidance only.

3.3 Reinforcement fabrics

3.3.1 General

Usually, reinforcing fibres are arranged into fabric products.

These fabrics may be made by:

- mechanical stitching of fibres (unidirectional fabrics)
- mechanical weaving of fibres (woven fabrics)
- chopped fibre chemically gathered into sheet
- combined fabrics mixing one or other previous described fabric product
- pre-preg fabrics.

Fabrics may be made of different types of fibre, one type of fibre per main fabric direction.

3.3.2 Mechanical characteristics

The mechanical characteristics will be influenced by the fibre type used for fabric products, by the direction and positioning of the fibre in the fabric products, but also by the various distortion of the fibre induced by weaving process, called waviness.

3.3.3 Unidirectionals (UD)

Unidirectionals are fabrics with fibres in one main direction, gathered by mechanical or chemical stitching, respectively with another fibre or a specific adhesive.

The main characteristics of unidirectionals are:

- high tensile and compressive strengths in the fibre direction, due to the high percentage of fibres in fibre direction and also to lack of waviness
- low tensile and compressive strengths in the crosswise fibre direction.

From a theoretical point of view, UD are used as reference for the calculations of elastic coefficients of the other fabric types.

3.3.4 Woven rovings

Woven rovings are made from two sets of fibres criss-crossing, which form a right angle. The one in the weaving direction is named warp, the other one weft. Weaving consists in repeating a basic interlace sequence between warp and weft rovings. This sequence is named basic weave.

The four main weave families used in composite shipbuilding are:

Plains : Each weft fibre passes alternatively under and over each warp fibre. This type of fabric is relatively difficult to drape due to its high stability. The fibres are strongly crisscrossed (high waviness)

Baskets : Similar to plains with an alternative pattern made up of 2 or more weft fibres alternatively interlaced with 2 or more warp fibres (high aviness)

Twills : One or more weft fibres pass alternatively under two or more warp fibres. The main interests of this fabric type are to make easier the drape process and to limit the bend fibre in the weaving process as well as to increase the wet operation, named wetting. This is a moderate waviness fabric

Satins : The weaving pattern is obtained by one or more weft fibres cross several warp fibres and then pass under only one warp fibre. Satins have the same interest than twills with a lower waviness and a higher wetting ability.

As a general rule, the weaving angle between weft and warp is equal to 90°.

The coefficient "woven balance" C_{eq}, indicates for each woven roving the amount of fibre laid in weft and warp direction.

3.3.5 Chopped Strand Mats (CSM)

Chopped strands mats (CSM) are made of fibres chemically gathered to form a web. As fibres are random assembled in the web, there is no main direction. That explains why CSM are considered as isotropic reinforcements.

Mats may be made of fibres shorter than 50mm (Chopped Strand Mats) or longer than 50mm (Continuous Strand Mats).

Chopped Strand Mats mechanical characteristics are low due to the short length of fibres and their non-alignment.

As a general rule, only continuous strands mats (with fibres longer than 50mm) are to be used.

The main characteristics of mats are the nature of fibre, the length of fibres and the area weight.

3.3.6 Combined fabrics

Combined fabrics mainly consist in the assembly by stitching together several reinforcement fabrics as for example:

- woven roving and CSM
- two woven rovings with different orientation (0° for one and 45° for the other) to make a combined fabric with main fibre orientation from -45°, 90°, 0° and 45°
- two UD with orientation equal to -45° and 45° to make a fabric named "bi-bias" or "biax"
- three UD with orientation equal to -45°, 0° and 45° to make a "three directional fabric".

3.3.7 Pre-pregs

The pre-pregs consist in reinforcement fabrics (usually UD, woven roving or combined fabrics) pre-impregnated with a resin system (itself pre-catalysed).

The main advantage of pre-preg fabrics is their accurate resin contents in the reinforcement fabrics.

As a general rule, it is necessary to initiate the polymerisation to activate the chemical reaction by rise in temperature.

3.4 Homologation of reinforcement fabrics

3.4.1 The reinforcements fabrics are to be used within limits fixed by the manufacturer, taking into account the resin systems and laminating process used by the yard.

In this respect, the Surveyor may ask any useful justification to be submitted, such as:

- technical data sheet of reinforcement fabrics, specifying the fibre nature and characteristics
- manufacturer guarantee for the use in shipbuilding.

As a general rule, the reinforcement fabrics in the construction of a yacht are to be certified within the scope of Classification and in particular to assign the construction marks ✠ or •.

The reinforcement fabrics homologation process is described in [6].

4 Core materials

4.1 General

4.1.1 Core materials are used in sandwich composite structures.

The aim of a core material in a composite is to increase the laminate stiffness by increasing its thickness. The core material acts similar to the web of a beam, and so is basically subject to shear forces.

The main characteristics of a core material are low density, shear strength and also capacity to take compressive and shear loading without buckling failure.

Three main families are used as core material:

- foam cores obtained from expanded synthetic resins
- natural material, mainly balsa wood
- manufactured material such as honeycombs.

4.2 Foam cores

4.2.1 General

Foam cores may be manufactured from a large variety of synthetic resins and in a large range of densities and thicknesses.

All the foam cores are to have closed cells to avoid water migration.

The foam cores are to be compatible with resin systems and adhesives used and must withstand to temperature when they are used for pre-pregs process or post-cure process.

Some foam cores need to be heat treated before use to reduce the amount of gassing given when they are submitted to temperature rising during laminating process such as post-cure or pre-preg work.

It is to the manufacturer responsibility to define the process of this operation.

The foam materials are to be used within the limits fixed by the manufacturer and in particular for their compatibility with resin and adhesive systems used and working process when rising temperature is provided.

The purpose of the present subarticle is to describe the main mechanical characteristics of the most used foam cores in shipbuilding.

4.2.2 PVC foam (PolyVinyl Chloride)

The main characteristics of PVC foams are highly resistant to water absorption, to many chemical products and in particular styrene used in polyester and vinylester resin systems.

There are two different types of PVC foams: cross linked PVC and uncross linked PVC (also named linear PVC). The linear PVC foam is more flexible and their mechanical properties are lower than cross linked ones. Cross linked PVC are however more brittle than uncrossed PVC.

4.2.3 PU foam (Polyurethan)

As a general rule, PU foams are only used for lightly loaded structures and as frame or girder formers.

Their mechanical characteristics are relatively low, and the interface between foam and skins may be subject to brittleness with ageing.

4.2.4 PMI foam (Polymethacrylimide)

The PMI foams are used for their high strength and stiffness. They are also used in construction process requiring temperature rising (pre-pregs for example) due to high dimensional stability.

4.2.5 SAN foam (Styrene Acrylo Nitrile)

The main SAN foam characteristic is highly resistant to impact loads.

Their mechanical characteristics are similar to cross linked PVC with higher elongation and toughness.

4.3 Homologation of foam cores

4.3.1 The foam cores are to be used within the limits fixed by the manufacturer.

In this respect, the Surveyor may ask any useful justification to be submitted, such as:

- technical data sheet of foam
- manufacturer guarantee regarding work process.

As a general rule, the foam cores used in the construction of a yacht are to be certified within the scope of Classification and in particular to assign the construction mark ✠ or •.

The foam cores homologation process is described in [6].

4.3.2 As a general rule, mechanical characteristics of the foam cores to take into account for sandwich calculations are to be given by manufacturer and/or are given by mechanical tests.

For information only, the standard mechanical characterisitcs of different types of foam cores in relation to their density are given in Tab 3.

Table 3 : Foams

	Voluminal mass (kg/m^3)	Modulus			Breaking Stresses			Poisson coefficient ν_{12} , ν_{21}
		Tensile E_1 , E_2 (MPa)	Compressive E_3 (MPa)	Shear G_{12} , G_{13} , G_{23} (MPa)	Tensile σ_1, σ_2 (MPa)	Compressive σ_1, σ_2 (MPa)	Shear τ_{12} , τ_{13} , τ_{23} (MPa)	
PVC Linear	50	21	18	8	0,7	0,3	0,3	0,36
	60	29	28	11	0,9	0,4	0,5	0,31
	70	37	38	14	1,1	0,6	0,7	0,27
	80	44	49	18	1,3	0,7	0,8	0,25
	90	52	59	21	1,4	0,9	1,0	0,24
	100	59	69	24	1,6	1,0	1,2	0,23
	110	67	79	27	1,8	1,2	1,3	0,22
	130	82	99	34	2,2	1,5	1,7	0,21
	140	89	109	37	2,4	1,6	1,9	0,21
PVC cross linked	50	37	40	18	1,0	0,6	0,6	0,02
	60	47	51	22	1,4	0,8	0,8	0,05
	70	57	63	27	1,8	1,1	1,0	0,07
	80	67	75	31	2,2	1,4	1,1	0,08
	90	78	88	36	2,5	1,7	1,3	0,09
	100	88	102	40	2,9	1,9	1,5	0,10
	110	98	116	44	3,3	2,2	1,6	0,11
	130	118	145	53	3,9	2,8	2,0	0,12
	140	129	161	57	4,3	3,0	2,2	0,12
	170	159	209	71	5,2	3,8	2,7	0,13
	190	180	243	79	5,8	4,4	3,0	0,13
	200	190	260	84	6,1	4,7	3,2	0,13
	250	241	352	105	7,4	6,0	4,1	0,14
SAN	50	52	29	13	0,9	0,4	0,7	0,11
	60	65	37	16	1,2	0,5	0,8	0,18
	70	78	44	18	1,5	0,6	0,9	0,20
	80	92	50	21	1,7	0,8	1,0	0,19
	90	107	55	23	1,9	0,9	1,1	0,17
	100	122	60	26	2,0	1,1	1,2	0,15
	110	137	64	29	2,2	1,2	1,3	0,12
	130	168	71	34	2,5	1,6	1,5	0,06
	140	184	74	36	2,6	1,8	1,6	0,03
	170	234	83	43	2,9	2,4	1,9	0,03
	190	268	88	48	3,1	2,8	2,1	0,03
	200	285	90	51	3,1	3,0	2,1	0,03
PMI	50	54	59	21	1.9	0.8	0.8	0.4
	60	69	76	24	2.1	1.1	1.0	0.6
	70	84	94	28	2.3	1.5	1.2	0.6
	80	101	112	33	2.6	1.9	1.5	0.7
	90	119	132	39	2.9	2.3	1.8	0.7
	100	137	152	45	3.2	2.7	2.1	0.7
	110	155	173	52	3.6	3.2	2.4	0.6
	130	195	217	71	4.5	4.2	3.1	0.5
	140	215	239	83	5.0	4.8	3.5	0.4
	170	280	311	131	6.8	6.7	4.7	0.2

The values presented in this table are given for general guidance only.

Note 1: τ_{13} and τ_{23} are identical to respectively τ_{IL2} and τ_{IL1}

Table 4 : Balsa

	Voluminal mass (kg/m^3)								
	80	96	112	128	144	160	176	192	240
Young modulus (MPa), parallel to sandwich in-plane E_1 , E_2	23	33	42	51	61	71	80	89	116
Young modulus (MPa), normal to sandwich in-plane E_3	1522	2145	2768	3460	4083	4706	5328	5882	7750
Shear modulus (MPa), normal to sandwich in-plane G_{13} , G_{23}	57	80	103	127	150	174	197	218	286
Shear modulus (MPa), parallel to sandwich in-plane G_{12}	40	55	70	90	105	120	140	150	200
Coefficient ν_{12} , ν_{21}	0,015	0,015	0,015	0,015	0,015	0,015	0,015	0,015	0,015
Breaking compressive (MPa), normal to sandwich in-plane σ_3	3,53	5,12	5,95	8,17	9,69	11,35	12,80	14,32	18,96
Breaking traction (MPa), parallel to sandwich in-plane σ_1 , σ_2	0,28	0,34	0,42	0,51	0,56	0,64	0,69	0,78	1
Breaking compressive (MPa), parallel to sandwich in-plane σ_1 , σ_2	0,48	0,58	0,71	0,87	0,95	1,1	1,17	1,33	1,7
Shear breaking (MPa), through sandwich thickness τ_{13} , τ_{23}	0,94	1,1	1,33	1,62	1,73	1,93	2,05	2,33	2,93
Shear breaking (MPa), parallel to sandwich in-plane τ_{12}	0,7	0,9	1,2	1,5	1,8	2	2,3	2,5	3,4

The values presented in this table are given for general guidance only.
Note 1: τ_{13} and τ_{23} are identical to respectively τ_{IL2} and τ_{IL1}

4.4 Natural materials

4.4.1 General

The natural material used is the wood, and so the mechanical characteristics of wood as core are intrinsically linked to the structure of wood used.

Two main technics are used to make sandwich with wood core which differ from the wood grain orientation in relation to the sandwich plane:

- wood grain running normal to the sandwich plane (balsa). In this case, the wood core behaviour is similar to foams or honeycombs.
- wood grain running parallel to the sandwich plane (cedar for example). In this case, in addition to ensuring stiffness and shear resistance of the sandwich, the wood core directly takes part to the global sandwich bending due to significant stiffness.

4.4.2 Balsa

The main mechanical characteristics of balsa are:

- high compressive and shear strength
- high stability where heated.

Balsa is available in a large range of density and thickness.

Where balsa is used with high density and thickness, the grain may be transversally solicited by the global sandwich bending.

For information, the standard mechanical characteristics of the balsa core material in relation to their density are given in Tab 4.

4.4.3 Red cedar

Red cedar is generally used in typical construction, named "strip planking". With its wood grain running parallel to the sandwich plane, the cedar is also participating to bending stress located perpendicular to the cedar grain where its resistance is weaker.

For information, the main mechanical characteristics of red cedar, for a voluminal mass equal to 350 kg/m^3, are in Tab 5.

Table 5 : Red cedar

Young modulus (MPa), parallel to grain E_1	6000
Young modulus (MPa), perpendicular to grain E_2 , E_3	300
Shear modulus (MPa) G_{12}	350
Shear modulus (MPa) G_{23}	250
Shear modulus (MPa) G_{13}	350
Coefficient ν_{12}	0,47
Coefficient ν_{21}	0,02
Breaking traction (MPa), parallel to grain direction σ_1	40
Breaking traction (MPa), perpendicular to grain direction σ_2	1,5
Breaking compressive (MPa), parallel to grain direction σ_1	25
Breaking compressive (MPa), perpendicular to grain direction σ_2	2,5
Breaking, shear stress (MPa) τ_{12} , τ_{13} , τ_{IL2}	5
Breaking, shear stress (MPa) τ_{23} , τ_{IL1}	10

The values presented in this table are given for general guidance only.

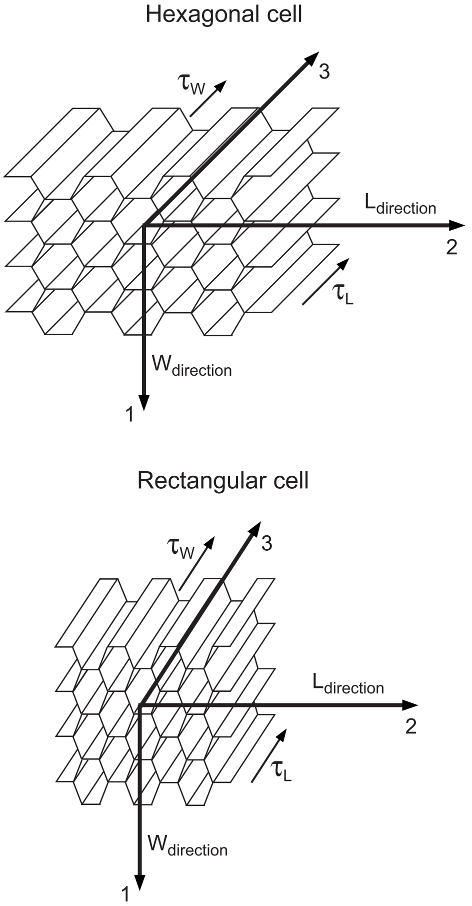
4.5 Honeycombs

4.5.1 General

Honeycombs are cores whose geometry is described as shown in Fig 4. Honeycomb cores are available in a large range of materials (meta-aramid, thermoplastic resins), cell shape and size thickness. The cells' shapes are closely linked to the manufacturing process of the honeycomb.

All these parameters act upon the final mechanical characteristics of the honeycomb core.

Figure 4 : Honeycombs



4.5.2 Thermoplastic honeycombs

The most common polymers used for thermoplastic honeycombs are polyethylen, polycarbonate and polypropylene.

As a general rule, these thermoplastic honeycomb cores have relatively low stiffness and mechanical characteristics and are difficult to bond with the sandwich skins.

The cell shape may be diverse due to the fact that these honeycomb cores are obtained by extrusion process.

The use of thermoplastic honeycombs is submitted to a special examination on a case by case basis due to the important diversity of these cores and their temperature sensitiveness.

Special examination is mainly carried out through mechanical tests to estimate the interface and shear resistance of the core in a sandwich construction.

4.5.3 Meta-aramid honeycombs

The meta-aramid honeycomb cores are obtained from an aramid paper, dipped in resin system.

The density of the aramid paper directly acts upon the shear characteristics while the dip operation in resin acts on the compressive characteristics of the honeycomb.

Note 1: Two honeycombs with same density may differ from a mechanical point of view (shear and compressive stresses) in relation to their respective paper thickness and number of dip operations in resin.

Two main cell shapes are available: hexagonal and rectangular. Second shape is being obtained from the hexagonal one with an over expand mechanical operation.

The main advantage of the rectangular cell shape is its curving ability.

From mechanical characteristics point of view, the two main particulars of honeycomb are:

- shear characteristics are different in the two directions of a honeycomb sheet
- for a given honeycomb, shear stress depends on its thickness.

Honeycomb cores are mainly used with pre-pregs process. Honeycomb sheets need to be heat-treated before use to reduce the amount of gassing where they are submitted to temperature rising during pre-preg process.

This material, relatively difficult to stick to sandwich skins must be dust-free and cleaned before use.

For information, the standard mechanical characteristics of meta-aramid honeycombs in relation to their density, cell size, and thickness are given in Tab 6.

Note 2: The failure mode under traction and compressive stresses along L and W directions as well as in plane shear stresses are not dependent on honeycomb characteristics only but also on the characteristics of the global sandwich laminates (core thickness and skins characteristics).

These failure modes are estimated on a case by case by mechanical tests as defined in Ch 12, Sec 5.

5 Structural adhesives

5.1 General

5.1.1 In the present article, the structural adhesive is used to create a structural connection between:

- two composite structures, already cured, as for example the deck/hull gluing
- one composite structure, already cured, with another element, not cured, as for example the stiffener matting-in with the hull
- two raw materials, as for example, the gluing of the foam core with a sandwich skin
- two elements of different kinds, as for example, the windows / hull assembly.

Table 6 : Meta-aramid honeycombs

Voluminal mass	Hexagonal								
	E_1 (in W direction)	E_2 (in L direction)	G_{12}	G_{13}	G_{23}	ν_{12}	ν_{21}	τ_{13} (in L direction), τ_{IL2}	τ_{23} (in W direction), τ_{IL1}
48	13	16	3	37	25	0,82	0,82	1,2	0,7
50	13,6	17	3,3	39	26	0,82	0,82	1,3	0,75
56	14	18	4,1	46	30	0,82	0,82	1,5	0,85
64	17	20	5	59	38	0,82	0,82	1,8	1
96	21	27	6	87	57	0,82	0,82	3	1,7

Voluminal mass	Rectangular								
	E_1 (in W direction)	E_2 (in L direction)	G_{12}	G_{13}	G_{23}	ν_{12}	ν_{21}	τ_{13} (in L direction), τ_{IL2}	τ_{23} (in W direction), τ_{IL1}
48	105	12,5	1,5	19	36	0,263	0,263	0,75	0,8
50	108	12,8	1,6	19,5	37	0,263	0,263	0,8	0,85
56	114	13	1,9	21	40	0,263	0,263	0,95	0,9
64	135	13,5	2,1	23,5	43,5	0,263	0,263	1,1	1
96	180	15,5	3,3	31	58	0,263	0,263	1,9	1,5

Note 1: The values presented in this table are given for general guidance only. The mechanical characteristics given by the supplier and taking into account the cell size and paper thickness of the honeyycombs are to be taken into account for rules calculations.
Note 2: τ_{13} and τ_{23} are identical to respectively τ_{IL2} and τ_{IL1}

5.1.2 The main mechanical characteristics of a structural gluing joint mainly depends on the following parameters:

- resin systems and additives such as thixotropic agents
- type of the components to be bonded as well as their surface preparation (abrasing, cleaning,...)
- geometry and thickness of the bonded joint
- curing process of the bonded joint.

5.2 Structural adhesive characteristics

5.2.1 The large range of adhesive resin systems, curing adhesive process, type of components to be bonded and the large variety of joint geometry do not permit to define typical mechanical characteristics.

As a general use, the mechanical values to take into account are given by the manufacturer, paying attention to the mechanical type tests context from which the mechanical values are taken from.

5.2.2 As a general rule, a maximum breaking shear stress from 5 N/mm^2 to 10 N/mm^2 (for high performance bonding) is usually considered.

6 Raw materials certification

6.1 Construction marks

6.1.1 Definition

Construction mark refers to the mode of survey of raw materials used in construction of a yacht and is granted in scope of classification.

6.1.2 The possible construction marks are:

- Construction mark ✠ where the principal raw materials are homologated or surveyed at works (or on reception at the yard) by the Society
- Construction mark • where the principal raw materials have not been surveyed by the Society under the terms of one of the previous schemes; in this case, the yard is responsible for ensuring that the raw materials comply with the Society's requirements.

6.1.3 Principle of assignment of construction marks

This article stipulates the arrangements to be adopted in assigning the construction marks ✠ or •.

Materials concerned by certification are:

- gel-coats and laminating resins
- reinforcement fabrics
- core materials for sandwich laminates.

Other materials may occasionally be submitted for Society approval (e.g. adhesives or structural plywoods).

Note 1: The purpose of survey of raw materials by the Society is to ensure compliance with the requirements of the relevant Society's Rules (within the framework of theoretical calculation of the mechanical properties of the composite). However, the findings of such surveys are not to be used as the only basis for the order specification. The Yard must issue a proper specification to its Supplier.

6.2 Assignment of construction mark ✠

6.2.1 General

The construction mark ✠ is assigned when one of the following modes of survey of raw materials is used:

- Homologation of raw materials

- Acceptance of specific mechanical tests carried out on raw materials used for construction
- Homologation already granted by another Society, recognized by Bureau Veritas.

6.2.2 Homologation of successive stages

The homologation of raw materials requests two successive stages:

- Type approval
- Homologation itself.

6.2.3 Type Approval

The Society ensures that certain technical data in the Supplier data sheets comply with the relevant requirements of the Society's Rules.

A test programme, drawn up jointly by the Supplier and the Society, is performed, and the results are examined, so that the declared properties may be confirmed.

For information, the standards' test programme is generally as follows:

- Gel coats:
  - Tensile test (modulus, elongation): ISO 527 or equivalent
  - Moisture absorbency: Standard ISO 62 or equivalent
- Resin:
  - Density: ISO 1675 or equivalent
  - Tensile test (modulus and breaking strength): ISO 527 or equivalent
  - compressive test (modulus and breaking strength): ISO 604 or equivalent
  - Shear test (modulus and breaking strength): ISO 1922 or equivalent
  - Voluminal shrinkage: ISO 3521 or equivalent
  - Glass Transition Temperature: ISO 11357 or ISO 11359 or equivalent
- Reinforcements fabrics:
  - Surface weight: ISO 3374 or equivalent
  - Tensile test: ISO 4604 and ISO 4606 or equivalent
- Prepregs:
  - Glass content: ISO 9782 or equivalent
  - Surface weight: ISO 10352 or equivalent
- Core materials - foams:
  - Density: ISO 845 or equivalent
  - Tensile test (modulus and breaking strength): ISO 1926 or equivalent
  - compressive test (modulus and breaking strength): ISO 844 or equivalent
  - Shear test (modulus and breaking strength): ISO 1922 or equivalent
- Core materials - balsa:
  - Density: ISO 3131 or equivalent
  - Shear strength: ISO 8905 or equivalent
- Core materials honeycombs: Test program to be defined with the Society.

Certain tests may be dropped from this list, and other additional tests requested, depending on the particular use of materials, or experience acquired with such materials.

Reports, issued in the forms stipulated in standards, are submitted to the Society for examination.

Tests are generally done either in laboratories recognized by Bureau Veritas, or in presence of the Surveyor. In the former case, the laboratory reference is stated.

Samples may be taken from the production line or from stocks at the Supplier. Sampling conditions must also be stated by the Supplier.

A type approval certificate is issued for each type of raw material.

6.2.4 Homologation of raw materials

During homologation, the Society checks that the Supplier of mass-produced raw materials is capable of reproducing satisfactory the products examined during type approval. For this purpose, the Supplier must submit documents on the various phases described below, as a basis for survey of the production line by the Surveyor:

- Organisation and means of production of raw materials for homologation
- Procedures for purchase, acceptance testing and storage of various materials used in the manufacture of the products
- Procedures for manufacturing of the products
- Survey procedures used during production phases
- Tests and surveys performed on completion of production.

6.2.5 Acceptance of specific mechanical tests

On a case by case basis, where raw materials are not homologated as defined in [6.3], specific mechanical tests, based on these defined in Ch 12, Sec 5, [4], may be accepted by the Society.

The raw material samples are to be defined in accordance with the Society.

6.3 Assignment of construction mark •

6.3.1 The construction mark • is assigned where one of the forms of survey of raw materials, described in [6.2], is not applied.

In this case, the yard is responsible for ensuring that the materials used in the construction meet the relevant requirements of the Society's Rules.

SECTION 3 INDIVIDUAL LAYER

1 General

1.1 Application

1.1.1 General

The present Section deals with the methodology to estimate the five elastic coefficients and the six breaking stresses requested to define the breaking strength of an individual layer.

The in-plane elastic coefficients to take into account are:

- a longitudinal Young's modulus
- a transverse Young's modulus
- two Poisson's coefficients
- a shear modulus.

The theoretical breaking stresses to estimate are:

- in-plane longitudinal tensile and compressive breaking stresses
- in-plane transverse tensile and compressive breaking stresses
- in-plane shear breaking stress
- interlaminar shear breaking stress.

Two geometric parameters are also to be defined:

- the individual layer's thickness
- the individual layer's density (or weight per surface unit).

1.1.2 Methodology

Coefficients, breaking stresses and geometric parameters defined in [1.1.1] are based on the Society experience and take into account:

- the type of raw material as defined in Ch 12, Sec 2
- the fibre/resin mix ratio
- the laminating and curing processes used for the composite work
- the type of stress in relation to the reinforcement's orientation.

Whatever the type of reinforcement making up the individual layer, the first step of the methodology consists in estimating the elastic coefficients of a unidirectional (UD) fabric having same raw materials and content of fibre than the considered individual layer to calculate.

Where unusual individual layers are used (due to specific raw materials or laminating process), the Society may request mechanical tests to be performed in order to evaluate elastic coefficients and/or breaking stresses and compare them to the present Rule theoretical approach.

1.1.3 Symbols

Symbols used in the formulae of the present Section are:

C_{eq} : Woven balance coefficient for woven rovings. See [3.2.2].

e : Individual layer thickness, in mm

$E_{f0°}$: Longitudinal Young's modulus of fibre, in MPa (see Note 1)

$E_{f90°}$: Transversal Young's modulus of fibre, in MPa (see Note 1)

E_m : Young's modulus of resin, in MPa (see Note 1)

G_f : Shear modulus of fibre, in MPa (see Note 1)

G_m : Shear modulus of resin, in MPa (see Note 1)

m : Total mass per square meter of individual layer, in gr/m^2

M_f : Content in mass of fibre in an individual layer, in %

M_m : Content in mass of resin in an individual layer, in %

P_f : Total mass per square meter of dry reinforcement fabric, in g/m^2

V_f : Content in volume of fibre in an individual layer, in %

V_m : Content in volume of resin in an individual layer, in %

ν_f : Poisson's coefficient of fibre

ν_m : Poisson's coefficient of resin

ρ : Density of an individual layer

ρ_f : Density of fibre

ρ_m : Density of resin.

Note 1: Minimum mechanical characteristics are given, for information only, in Ch 12, Sec 2, Tab 1and Ch 12, Sec 2, Tab 2.

2 Geometrical and physical properties of an individual layer

2.1 fibre/resin mix ratio

2.1.1 The fibre/resin mix ratio of an individual layer can be expressed in:

- mass or volume, and
- resin or reinforcement.

The contents in mass are obtained from the following formulae:

- M_f = fibres' mass (gr/m²)/individual layer's mass (gr/m²)
- M_m = resin's mass (gr/m²)/individual layer's mass (gr/m²)
- V_f and V_m are defined in [1.1.3].

$$V_f = \frac{(M_f / \rho_f)}{(M_f / \rho_f) + ((1 - M_f) / \rho_m)}$$

$$V_m = 1 - V_f$$

$$M_f = \frac{(V_f \times \rho_f)}{(V_f \times \rho_f) + ((1 - V_f) \times \rho_m)}$$

$$M_m = 1 - M_f$$

with all parameters defined in [1.1.3].

2.1.2 The resin/fibre mix ratio is to be specified by the shipyard and depends on the laminating process.

For information only, the common ratio values are given in Tab 1.

2.2 Individual layer's thickness

2.2.1 The individual layer's thickness, in mm, can be expressed from the fibre's content, in mass or in volume, by the following formulae:

$$e = \frac{\left(P_f \cdot \left(\frac{1}{\rho_f} + \frac{1 - M_f}{M_f \cdot \rho_m}\right)\right)}{1000}$$

$$e = \frac{P_f / (V_f \cdot \rho_f)}{1000}$$

with all parameters defined in [1.1.3].

2.3 Mass, voluminal mass and density of an individual layer

2.3.1 The density of an individual layer is obtained by the following formula:

$$\rho = \rho_f \times V_f + \rho_m \times (1 - V_f)$$

with all parameters defined in [1.1.3].

3 Elastic coefficient of an individual layer

3.1 Unidirectionals

3.1.1 Reference axis

The reference axis system for a unidirectional is as follows (see Fig 1):

- 1 : axis parallel to the fibre's direction
- 2 : axis perpendicular to the fibre's direction
- 3 : axis normal to plane containing axis 1 and 2, leading to direct reference axis system.

The reference axis for an elementary fibre is defined as follows (see Fig 2):

- 0° : Longitudinal axis of the fibre
- 90° : Transverse axis of the fibre.

Figure 1 : Reference axis for unidirectionals

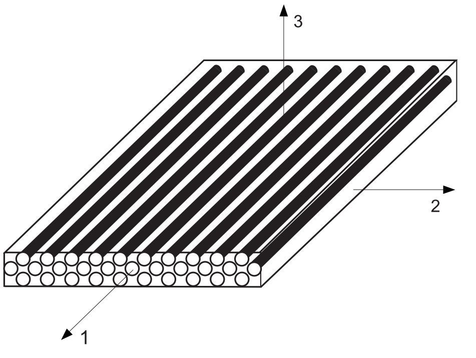
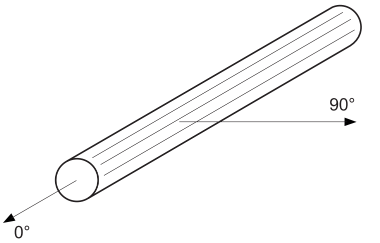


Figure 2 : Reference axis of an elementary fibre



3.1.2 Elastic coefficients

The elastic coefficients of an unidirectional are estimated by the following formulae, with all parameters defined in [1.1.3]:

- Longitudinal Young's modulus E_{UD1}, in MPa:

$$E_{UD1} = C_{UD1} \times (E_{f0°} \times V_f + E_m \times (1 - V_f))$$

- Transverse Young's moduli E_{UD2} and E_{UD3}, in MPa:

$$E_{UD2} = E_{UD3} = C_{UD2} \times \left(\left(\frac{E_m}{1 - \nu_m^2}\right) \times \frac{1 + 0{,}85 \cdot V_f^2}{(1 - V_f)^{1{,}25} + \frac{E_m}{E_{f90°}} \times \frac{V_f}{1 - \nu_m^2}}\right)$$

- Shear moduli, in MPa:

$$G_{UD12} = G_{UD13} = C_{UD12} \cdot G_m \times \frac{1 + \eta \cdot V_f}{1 - \eta \cdot V_f}$$

$$\text{with} \quad \eta = \frac{\left(\frac{G_f}{G_m}\right) - 1}{\left(\frac{G_f}{G_m}\right) + 1}$$

$$G_{UD23} = 0,7 \cdot G_{UD12}$$

- Poisson's coefficients:

$$\nu_{UD13} = \nu_{UD12} = C_{UD\nu} \times (\nu_f \times V_f + \nu_m \times (1 - V_f))$$

$$\nu_{UD21} = \nu_{UD31} = \nu_{UD12} \times \frac{E_{UD2}}{E_{UD1}}$$

$$\nu_{UD23} = \nu_{UD32} = C_{UD\nu} \times (\nu_f' \times V_f + \nu_m \times (1 - V_f))$$

$$\text{with} \quad \nu_f' = \nu_f \cdot \frac{E_{f90°}}{E_{f0°}}$$

The coefficients C_{UD1}, C_{UD2}, C_{UD12} and $C_{UD\nu}$ are experimental coefficients taking into account the specific characteristics of fibre's type. They are given in Tab 2.

Table 1 : Resin / fibre mix ratios (in %)

Laminating Process		V_f	M_f		
			Glass	Carbon	Para-aramid
Hand Lay-up	Mat	from 15 to 20	from 25 to 35	-	-
	Roving	from 25 to 40	from 40 to 60	from 35 to 50	from 30 to 45
	Unidirectional	from 40 to 50	from 60 to 70	from 50 to 60	from 45 to 55
Infusion		45	60	55	50
Pre-pregs		from 55 to 60	from 60 to 70	from 65 to 70	from 60 to 65

Table 2 : Coefficients C_{UD1} , C_{UD2}, C_{UD12} and $C_{UD\nu}$

	E-glass	R-Glass	Carbon HS	Carbon IM	Carbon HM	Para-aramid
C_{UD1}	1	0,9	1	0,85	0,9	0,95
C_{UD2}	0,8	1,2	0,7	0,8	0,85	0,9
C_{UD12}	0,9	1,2	0,9	0,9	1	0,55
$C_{UD\nu}$	0,9	0,9	0,8	0,75	0,7	0,9

3.2 Woven Rovings

3.2.1 Reference axis

The reference axis defined for woven rovings are the same than for unidirectionals with the following denomination:

- 1 : axis parallel to warp direction
- 2 : axis parallel to weft direction
- 3 : axis normal to plane containing axis 1 and 2, leading to direct reference axis system.

3.2.2 Woven balance coefficient C_{eq}

The woven balance coefficient is equal to the mass ratio of dry reinforcement in warp direction to the total dry reinforcement of woven fabric.

3.2.3 Elastic coefficients

The elastic coefficients of woven rovings as individual layers are estimated by the following formulae:

- Young's modulus in warp direction E_{T1}, in MPa:

$$E_{T1} = \frac{1}{e} \cdot \left(A_{11} - \frac{A_{12}^2}{A_{22}}\right)$$

- Young's modulus in weft direction E_{T2}, in MPa:

$$E_{T2} = \frac{1}{e} \cdot \left(A_{22} - \frac{A_{12}^2}{A_{11}}\right)$$

- Out-of-plane Young's modulus E_{T3}, in MPa:

$$E_{T3} = E_{UD3}$$

- Shear moduli G_{12}, G_{23} and G_{13}, in MPa:

$$G_{T12} = \frac{1}{e} \cdot A_{33} \quad \text{and} \quad G_{T23} = G_{T13} = 0,9 \cdot G_{T12}$$

- Poisson's coefficients:

$$\nu_{T12} = \frac{A_{12}}{A_{22}}$$

$$\nu_{T21} = \nu_{T12} \cdot \frac{E_{T2}}{E_{T1}}$$

$$\nu_{T32} = \nu_{T31} = (\nu_{UD32} + \nu_{UD31})/2$$

$$\nu_{T13} = (\nu_{UD23} + \nu_{UD13})/2$$

where:

$$A_{11} = e \cdot (C_{eq} \cdot Q_{11} + (1 - C_{eq}) \cdot Q_{22})$$

$$A_{22} = e \cdot (C_{eq} \cdot Q_{22} + (1 - C_{eq}) \cdot Q_{11})$$

$$A_{12} = e \cdot Q_{12}$$

$$A_{33} = e \cdot Q_{33}$$

with:

$$Q_{11} = E_{UD1}/(1 - (\nu_{UD12} \cdot \nu_{UD21}))$$

$$Q_{22} = E_{UD2}/(1 - (\nu_{UD12} \cdot \nu_{UD21}))$$

$$Q_{12} = (\nu_{UD21} \cdot E_{UD1})/(1 - (\nu_{UD12} \cdot \nu_{UD21}))$$

$$Q_{33} = G_{UD12}$$

Note 1: Parameters with suffix UD are defined in [3.1].

3.3 Chopped Strand Mats

3.3.1 General

A chopped strand mat is made of cut fibres, random arranged and supposed uniformly distributed in space. It is assumed as isotropic material.

3.3.2 Elastic coefficients

Isotropic assumption makes possible to define only three elastic coefficients obtained by the following formulae:

- Young's moduli, in MPa:

$$E_{mat1} = E_{mat2} = \frac{3}{8} \cdot E_{UD1} + \frac{5}{8} \cdot E_{UD2}$$

$$E_{mat3} = E_{UD3}$$

- Poisson's coefficient is as all isotropic materials:

$$\nu_{mat12} = \nu_{mat21} = \nu_{mat32} = \nu_{mat13} = 0,3$$

- Shear moduli, in MPa:

$$G_{mat12} = E_{mat1}/(2 \cdot (1 + \nu_{mat21}))$$

$$G_{mat23} = G_{mat31} = 0,7 \cdot G_{UD12}$$

Where parameter with suffix UD are defined in [3.1].

Note 1: Parameters with suffix UD are defined in [3.1].

3.4 Combined fabrics

3.4.1 Combined fabrics, as defined in Ch 12, Sec 2, [3.3.6], are to be considered as a series of individual layers such as unidirectionals, woven rovings or chopped strand mats. Each component is analysed as defined in [3.1], [3.2] or [3.3] accordingly to type of reinforcement fabric.

4 Rigidity and flexibility of an individual layer

4.1 In-plane characteristics

4.1.1 General

Rigidity and flexibility of an individual layer need to be determined to perform the mechanical calculations of a laminate, made of several individual layers, as defined in Ch 12, Sec 4.

4.1.2 Rigidity

The rigidity $\overline{R}$, defined in the individual layer coordinate system, is as follows:

$$[\sigma]_{1,2} = [\overline{R}] \cdot [\varepsilon]_{1,2}$$

where $[\sigma]$ is the matrix of in-plane stresses, $[\varepsilon]$ is the matrix of in-plane strains and $[\overline{R}]$ local matrix of rigidity.

Or under matrix notation:

$$\begin{bmatrix}\sigma_1\\ \sigma_2\\ \tau_{12}\end{bmatrix} = \begin{bmatrix}\overline{R}_{11} & \overline{R}_{12} & 0\\ \overline{R}_{21} & \overline{R}_{22} & 0\\ 0 & 0 & \overline{R}_{33}\end{bmatrix} \cdot \begin{bmatrix}\varepsilon_1\\ \varepsilon_2\\ \gamma_{12}\end{bmatrix} \quad \text{with} \quad \overline{R} = \begin{vmatrix}\overline{R}_{11} & \overline{R}_{12} & 0\\ \overline{R}_{21} & \overline{R}_{22} & 0\\ 0 & 0 & \overline{R}_{33}\end{vmatrix}$$

Elements of matrix of rigidity are specific to types of reinforcement and define in Tab 3.

4.1.3 Flexibility

The flexibility $\overline{S}$, defined in the individual layer coordinate system, is as follow:

$$[\varepsilon]_{1,2} = [\overline{S}] \cdot [\sigma]_{1,2}$$

where σ and ε are defined in [4.1.2] and $[\overline{S}]$ local individual layer flexibility matrix.

Or under matrix notation:

$$\begin{bmatrix}\varepsilon_1\\ \varepsilon_2\\ \gamma_{12}\end{bmatrix} = \begin{bmatrix}\overline{S}_{11} & \overline{S}_{12} & 0\\ \overline{S}_{21} & \overline{S}_{22} & 0\\ 0 & 0 & \overline{S}_{33}\end{bmatrix} \cdot \begin{bmatrix}\sigma_1\\ \sigma_2\\ \tau_{12}\end{bmatrix} \qquad \overline{S} = \begin{vmatrix}\overline{S}_{11} & \overline{S}_{12} & 0\\ \overline{S}_{21} & \overline{S}_{22} & 0\\ 0 & 0 & \overline{S}_{33}\end{vmatrix}$$

Elements of matrix of flexibility are specific to types of reinforcement and are defined in Tab 4.

5 Individual layer breaking stress criteria

5.1 General

5.1.1 The individual layer breaking criteria are in relation with the elastic coefficients defined in [3], taking into account the type and the direction of the stresses.

5.2 Definitions

5.2.1 Breaking stresses

The individual layer breaking criteria are defined, in MPa, as the maximum breaking stresses of the individual layer in its local coordinate system, and are obtained by the following formulae:

$\sigma_{br1} = \varepsilon_{br1} \cdot E_1 \cdot Coef_{res}$

$\sigma_{br2} = \varepsilon_{br2} \cdot E_2 \cdot Coef_{res}$

$\tau_{br12} = \gamma_{br12} \cdot G_{12} \cdot Coef_{res}$

$\tau_{brIL1} = \gamma_{brIL23} \cdot G_{23} \cdot Coef_{res}$

$\tau_{brIL2} = \gamma_{brIL13} \cdot G_{13} \cdot Coef_{res}$

where :

E_1, E_2, G_{12}, G_{13}, G_{23} : Elastic coefficients defined in [3], in N/mm², for the individual layer considered according to type of reinforcement (unidirectionals, woven rovings, mats)

ε_{br1} : Theoretical breaking strain, in %, in traction or compressive, of an individual layer in the direction 1 of its local coordinate system

ε_{br2} : Theoretical breaking strain, in %, in traction or compressive, of an individual layer in the direction 2 of its local coordinate system

γ_{br12} : Theoretical in-plane breaking shear strain, in %, of an individual layer

γ_{brIL} : Theoretical interlaminar breaking shear strain, in %, of an individual layer

$Coef_{res}$: Coefficient taking into account the adhesive quality of the resin system.

All breaking strains and coefficients are given in Tab 5 or Tab 6, as applicable.

Table 3 : Elements of matrix of rigidity

	For Unidirectionals	For Woven Rovings	For Mats	Core material
$\overline{R}_{11}$	$E_{UD1}/(1 - \nu_{UD12} \cdot \nu_{UD21})$	$E_{T1}/(1 - \nu_{T12} \cdot \nu_{T21})$	$E_{mat}/(1 - \nu_{mat}^2)$	$E_1/(1 - \nu_{12} \cdot \nu_{21})$
$\overline{R}_{22}$	$E_{UD2}/(1 - \nu_{UD12} \cdot \nu_{UD21})$	$E_{T2}/(1 - \nu_{T12} \cdot \nu_{T21})$	$E_{mat}/(1 - \nu_{mat}^2)$	$E_2/(1 - \nu_{12} \cdot \nu_{21})$
$\overline{R}_{12}$	$\nu_{UD21} \cdot E_{UD1}/(1 - \nu_{UD12} \cdot \nu_{UD21})$	$\nu_{T21} \cdot E_{T1}/(1 - \nu_{T12} \cdot \nu_{T21})$	$\nu_{mat} \cdot E_{mat}/(1 - \nu_{mat}^2)$	$\nu_{21} \cdot E_1/(1 - \nu_{12} \cdot \nu_{21})$
$\overline{R}_{21}$	$\nu_{UD12} \cdot E_{UD2}/(1 - \nu_{UD12} \cdot \nu_{UD21})$	$\nu_{T12} \cdot E_{T2}/(1 - \nu_{T12} \cdot \nu_{T21})$	$\nu_{mat} \cdot E_{mat}/(1 - \nu_{mat}^2)$	$\nu_{12} \cdot E_2/(1 - \nu_{12} \cdot \nu_{21})$
$\overline{R}_{33}$	G_{UD12}	G_{T12}	G_{mat12}	G_{12}

Table 4 : Elements of matrix of flexibility

	For Unidirectionals	For Woven Rovings	For Mats	Core material
$\bar{S}_{11}$	$1/E_{UD1}$	$1/E_{T1}$	$1/E_{mat}$	$1/E_1$
$\bar{S}_{22}$	$1/E_{UD2}$	$1/E_{T2}$	$1/E_{mat}$	$1/E_2$
$\bar{S}_{12}$	$-\nu_{UD21}/E_{UD2}$	$-\nu_{T21}/E_{T2}$	$-\nu_{mat}/E_{mat}$	$-\nu_{21}/E_2$
$\bar{S}_{21}$	$-\nu_{UD12}/E_{UD1}$	$-\nu_{T12}/E_{T1}$	$-\nu_{mat}/E_{mat}$	$-\nu_{12}/E_1$
$\bar{S}_{33}$	$1/G_{UD12}$	$1/G_{T12}$	$1/G_{mat12}$	$1/G_{12}$

Table 5 : Theoretical breaking strains, in %

		Strains		Reinforcement fibres type					
				E Glass	R Glass	HS Carbon	IM Carbon	HM Carbon	Para-aramid
Reinforcement fabrics' type	Unidirectionals	Tensile	ε_{br1}	2.7	3.1	1.2	1.15	0.7	1.7
			ε_{br2}	0.42	0.35	0.85	0.65	0.4	0.65
		Compressive	ε_{br1}	1.8	1.8	0.85	0.65	0.45	0.35
			ε_{br2}	1.55	1.1	2.3	2.3	2.1	2
		Shear	γ_{br12}	1.8	1.5	1.6	1.7	1.8	2
			γ_{br13}, γ_{brIL2}	1.8	1.5	1.6	1.7	1.8	2
			γ_{br23}, γ_{brIL1}	2.5	1.8	1.9	1.85	1.8	2.9
	Woven	Tensile	ε_{br1}	1.8	2.3	1	0.8	0.45	1.4
			ε_{br2}	1.8	2.3	1	0.8	0.45	1.4
		Compressive	ε_{br1}	1.8	2.5	0.85	0.8	0.5	0.42
			ε_{br2}	1.8	2.5	0.85	0.8	0.5	0.42
		Shear	γ_{br12}	1.5	1.5	1.55	1.6	1.85	2.3
			γ_{br13}, γ_{brIL2}	1.8	1.8	1.55	1.6	1.85	2.9
			γ_{br23}, γ_{brIL1}	1.8	1.8	1.55	1.6	1.85	2.9
	Mats	Tensile	ε_{br1}	1.55	NA	NA	NA	NA	NA
			ε_{br2}	1.55	NA	NA	NA	NA	NA
		Compressive	ε_{br1}	1.55	NA	NA	NA	NA	NA
			ε_{br2}	1.55	NA	NA	NA	NA	NA
		Shear	γ_{br12}	2	NA	NA	NA	NA	NA
			γ_{br13}, γ_{brIL2}	2.15	NA	NA	NA	NA	NA
			γ_{br23}, γ_{brIL1}	2.15	NA	NA	NA	NA	NA

Table 6 : Coefficient $Coef_{res}$

Resin systems		
Polyester	Vinylester	Epoxy
0.8	0.9	1

5.2.2 As a general Rule, the mechanical characteristics of the individual layer are also depending on the laminating process. To simplify the breaking criteria, the influence of the process is taken into account by means of a dedicated safety coefficient defined in Ch 4, Sec 3, [5.4.1].

5.2.3 Other maximum breaking stresses of an individual layer may be taken into account, provided that representative mechanical tests are submitted to the Society.

The elastic coefficients and theoretical individual layer breaking criteria may be computed by the Bureau Veritas dedicated software, as defined in Ch 1, Sec 4.

SECTION 1 GENERAL REQUIREMENTS

1 General

1.1 Application

1.1.1 General

All yachts may be assigned class only after it has been demonstrated that their stability is adequate. Adequate stability means compliance with standards laid down with the requirements specified in the relevant chapters taking into account the yacht's size and type. See Tab 1.

1.1.2 Approval of the Administration

Evidence of approval by the Administration concerned may be accepted for the purpose of Classification, if demonstrated that their requirements are at least equal to those defined in the relevant chapter of these rules.

2 Examination procedure

2.1 Documents to be submitted

2.1.1 List of documents

For the purpose of the examination of the stability, the following documents are to be submitted:

- lines plan
- general arrangement plan. In addition for sailing yachts, a general arrangement plan showing the sails lowered on the rigging and masts
- capacity plan indicating the volume and position of the centre of gravity (coordinates X, Y, Z), of all compartments and tanks and the free surfaces
- hydrostatic tables or curves
- lightship particulars
- trim and stability booklet
- when applicable, damage stability calculations.

Table 1 : Application

Length	Navigation notation		
	Sheltered area	Coastal area	Unrestricted navigation
$L_{LL} \leq 24m$	Ch 3, Sec 2	Ch 3, Sec 2	Ch 3, Sec 2
$L_{LL} > 24m$	Ch 3, Sec 2	Ch 3, Sec 2	Ch 3, Sec 2 and Ch 3, Sec 3 **(1)**

(1) May be exempted from damage stability for yacht having the navigation notation **unrestricted navigation limited to 60 nautical miles**.

2.1.2 Documents for approval

The report of the inclining experiment, the trim and stability booklet and when applicable the damage stability calculations are to be submitted for approval.

2.1.3 Provisional documentation

Provisional stability documentation based on the estimated lightship particulars should be submitted for examination.

2.1.4 Final documentation

Final stability documentation based on the results of the inclining experiment or the lightweight check is to be submitted for examination.

When the difference between the estimated values of the lightship and those obtained from the inclining experiment or the lightweight check is less than:

- 2% for the displacement and
- 1% of the length between perpendiculars for the longitudinal position of the centre of gravity

and the determined vertical position of the centre of gravity is not greater than the estimated vertical position of the centre of gravity, the provisional stability documentation may be accepted as the final stability documentation.

2.2 Inclining experiment/lightweight check

2.2.1 Definitions

The following definitions are used in the present Chapter:

a) Lightship

The lightship is a yacht complete in all respects, but without consumable, stores, and crew and effects, and without any liquids on board except for machinery and piping fluids, such as lubricants and hydraulics, which are at operating levels

b) Inclining experiment

The inclining experiment is a procedure which involves moving a series of known weights, normally in the transverse direction, and then measuring the resulting change in the equilibrium heel angle of the yacht. By using this information and applying basic naval architecture principles, the yacht's vertical centre of gravity (VCG or KG) is determined

c) Lightweight check

The lightweight check is a procedure which involves auditing all items which are to be added, deducted or relocated on the yacht at the time of the inclining experiment so that the observed condition of the yacht can be adjusted to the lightship condition. The weight and longitudinal, transverse, and vertical location of each item are to be accurately determined and recorded. The lightship displacement and longitudinal centre of gravity (LCG) can be obtained using this information, as well as the static waterline of the yacht at the time of the ligthweight survey as determined by measuring the freeboard or verified draughts marks of the yacht, the yacht's hydrostatic data and the sea water density.

2.2.2 General

The inclining experiment or the lightweight check is to be attended by a Surveyor of the Society. The Society may accept inclining experiment or lightweight check attended by a member of the Flag Administration.

After completion, the yacht is subject to an inclining experiment. In some particular cases as described in [2.2.4], the Society may accept a lightweight check.

2.2.3 Inclining experiment

The inclining experiment is required in the following cases:

- any new yacht, after its completion, except for the cases specified in [2.2.4]
- any yacht, if deemed necessary by the Society, where any alterations are made so as to materially affect the stability.

2.2.4 Lightweight check

The Society may allow a lightweight check to be carried out in lieu of an inclining experiment in the case of:

a) An individual yacht, provided basic stability data are available from the inclining experiment of a sister ship and a lightweight check is performed in order to prove that the sister ship corresponds to the prototype yacht. In such case the Society is satisfied when the result of the lightweight check shows a deviation from the displacement of the prototype yacht not greater than 2%, and not greater than 1% of the length between perpendiculars for the longitudinal position of the centre of gravity. The final stability data to be considered for the sister ship in terms of displacement and position of the centre of gravity are those of the prototype

b) On a case by case basis and subject to the agreement of the flag Administration, provided that:
   - a detailed list of weights, and the positions of their centre of gravity is submitted
   - a lightweight check is carried out, showing accordance between the estimated values and those determined
   - adequate stability is demonstrated in all the loading conditions reported in the trim and stability booklet.

2.2.5 Detailed procedure

A detailed procedure for conducting an inclining experiment is included in Ch 3, App 1. For the lightweight check, the same procedure applies except as provided for in Ch 3, App 1, [1.1.8].

SECTION 2 INTACT STABILITY

1 General

1.1 Information to the Master

1.1.1 Stability booklet

Each yacht is to be provided with a stability booklet, approved by the Society, which contains sufficient information to enable the Master to operate the yacht in compliance with the applicable requirements contained in this Section.

Where any alterations are made to a yacht so as to materially affect the stability information supplied to the Master, amended stability information is to be provided. If necessary the yacht is to be re-inclined.

Stability data and associated plans are to be drawn up in the official language or languages of the issuing country. If the languages used are neither English nor French, the text is to include a translation into one of these languages.

The format of the trim and stability booklet and the information included are specified in Ch 3, App 2.

1.2 Permanent ballast

1.2.1 If used, permanent ballast is to be located in accordance with a plan approved by the Society and in a manner that prevents shifting of position. Permanent ballast is not to be removed from the yacht or relocated within the yacht without the approval of the Society. Permanent ballast particulars are to be noted in the yacht's stability booklet.

1.2.2 Permanent solid ballast is to be installed under the supervision of the Society.

2 Design criteria for all type of yachts

2.1 General intact stability criteria

2.1.1 General

The intact stability criteria specified from [2.1.2] to [2.1.5] are to be complied with for the loading conditions mentioned in Ch 3, App 2, [1.2].

However, the lightship condition not being an operational loading case, the Society may accept that part of the above-mentioned criteria are not fulfilled.

2.1.2 GZ curve area

The area under the righting lever curve (GZ curve) is to be not less than 0,055 m·rad up to θ = 30° angle of heel and not less than 0,09 m·rad up to θ = 40° or the angle of down flooding θ_f if this angle is less than 40°. Additionally, the area under the righting lever curve (GZ curve) between the angles of heel of 30° and 40° or between 30°and θ_f, if this angle is less than 40°, is to be not less than 0,03 m rad.

Note 1: θ_f is an angle of heel at which openings in the hull, superstructures or deckhouses which cannot be closed weathertight submerge. In applying this criterion, small openings through which progressive flooding cannot take place need not be considered as open (see Ch 3, App 2, [1.3.3]).

2.1.3 Minimum righting lever

The righting lever GZ is to be at least 0,20 m at an angle of heel equal to or greater than 30°.

2.1.4 Angle of maximum righting lever

The maximum righting arm is to occur at an angle of heel preferably exceeding 30° but not less than 25°.

When the righting lever curve has a shape with two maximums, the first is to be located at a heel angle not less than 25°.

In cases of yachts with a particular design (multihull for example), the Society may accept an angle of heel θ_{max} less than 25° but in no case less than 10°, provided that the area "A" below the righting lever curve is not less than the value obtained, in m.rad, from the following formula:

$A = 0,055 + 0,001\ (30° - \theta_{max})$

where θ_{max} is the angle of heel in degrees at which the righting lever curve reaches its maximum.

2.1.5 Initial metacentric height

The initial metacentric height GM_0 is not to be less than 0,15 m.

3 Severe wind and rolling criterion (weather criterion)

3.1 Scope

3.1.1 This criterion supplements the stability criteria given in [2.1] for yachts of a length L_{LL} greater than 24 m. The more stringent criteria of [2.1] and the weather criterion are to govern the minimum requirements.

3.1.2 Tab 1 can be used for the correspondence between Beaufort scale and wind pressure.

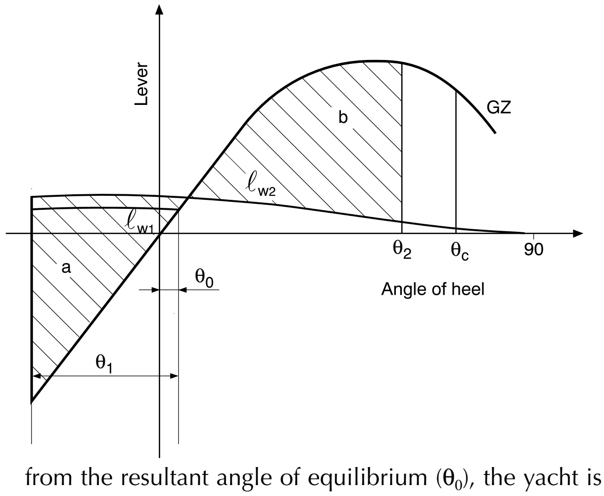
3.2 Weather criterion for motor yachts and sailing yachts with lowered sails

3.2.1 Assumptions

The ability of a yacht to withstand the combined effects of beam wind and rolling is to be demonstrated for each standard condition of loading, with reference to Fig 1 as follows:

- the yacht is subjected to a steady wind pressure acting perpendicular to the yacht's centreline which results in a steady wind heeling lever (ℓ_{w1})

Figure 1 : Severe wind and rolling



- from the resultant angle of equilibrium (θ_0), the yacht is assumed to roll owing to wave action to an angle of roll (θ_1) to windward
- the yacht is then subjected to a gust wind pressure which results in a gust wind heeling lever (ℓ_{w2})
- free surface effects, as described in [4], are to be accounted for in the standard conditions of loading as set out in Ch 3, App 2, [1.2].

3.2.2 Criteria

Under the assumptions of [3.2.1], the following criteria are to be complied with:

- the area "b" is to be equal to or greater than area "a", where:

  a : area above the GZ curve and below ℓ_{w2}, between θ_R and the intersection of ℓ_{w2} with the GZ curve

  b : area above the heeling lever ℓ_{w2} and below the GZ curve, between the intersection of ℓ_{w2} with the GZ curve and θ_2

- the angle of heel under action of steady wind (θ_0) is to be limited to 16° or 80% of the angle of deck edge immersion, whichever is less.

3.2.3 Heeling levers

The wind heeling levers ℓ_{w1} and ℓ_{w2}, in m, referred to in [3.2.2], should vary as the square cosine function of the yacht heel and should be calculated as follows:

$$\ell_{W1} = \frac{PAZ}{1000g\Delta}$$

and

$\ell_{W2} = 1{,}5\ell_{W1}$

where:

P : Is according to Tab 2

A : Projected lateral area in m², of the portion of the yacht above the waterline

Z : Vertical distance in m, from the centre of A to the centre of the underwater lateral area or approximately to a point at one half the draught

Δ : Displacement in t.

g = 9,81 m/s²

Table 1 : Beaufort scale

Beaufort	Wind pressure, in N/m²
4	19 - 41
5	42 - 71
6	72 - 118
7	119 - 177
8	178 - 255
9	256 - 363
10	364 - 491
11	492 - 648

Table 2 : Wind pressure

	$L_{LL} \le 70$ m	$L_{LL} > 70$ m
Unrestricted navigation	reduced pressure according to [3.2.4]	504 N/m²
Restricted navigation	reduced pressure according to [3.2.4]	reduced pressure subject to the agreement of the Administration

3.2.4 Calculation of the wind pressure

For yachts with a length equal or lesser than 70 m, the wind pressure P, in t/m², is to be calculated according to the following formulae:

$$P = 0{,}0514\left(\frac{Z-T}{10}\right)^{1/3}$$

where :

Z : Vertical distance in m, from the centre of A to the centre of the underwater lateral area or approximately to a point at one half the draught

T : Mean moulded draught in m, of the yacht.

3.2.5 Angles of heel

For the purpose of calculating the criteria of [3.2.2], the angles in Fig 1 are defined as follows:

θ_0 : Angle of heel, in degrees, under action of steady wind

θ_1 : Angle of roll, in degress, to windward due to wave action, calculated as follows:

$$\theta_1 = 109kX_1X_2\sqrt{rs}$$

θ_2 : Angle of downflooding θ_f in degrees, or 50° or θ_c , whichever is less

θ_f : Angle of heel in degrees, at which openings in the hull, superstructures or deckhouses which cannot be closed weathertight immerse. Small openings though which progressive flooding cannot take place need not be considered as open (see Ch 3, App 2, [1.3.3])

θ_c : Angle in degrees, of second intercept between wind heeling lever ℓ_{w2} and GZ curves

$\theta_R = \theta_0 - \theta_1$

X_1 : Coefficient defined in Tab 3

X_2 : Coefficient defined in Tab 4

k : Coefficient equal to:

k = 1,0 for a round-bilged yacht having no bilge or bar keels

k = 0,7 for a yacht having sharp bilge

for a yacht having bilge keels, a bar keel or both, k is defined in Tab 3

OG : Distance in m, between the centre of gravity and the waterline (positive if centre of gravity is above the waterline, negative if it is below)

T_1 : Mean moulded draught in m, of the yacht

$r = 0,73 \pm 0,6\ (OG)/T_1$

s : Factor defined in Tab 4.

Note 1: The angle of roll θ_1 for yachts with anti-rolling devices is to be determined without taking into account the operations of these devices.

Note 2: The angle of roll θ_1 may be obtained, in lieu of the above formula, from model tests or full scale measurements.

The rolling period T_R, in s, is calculated as follows:

$$T_R = \frac{2CB}{\sqrt{GM}}$$

where:

$$C = 0,373 + 0,023\frac{B}{T_1} - 0,043\frac{L_W}{100}$$

The symbols in the tables and formula for the rolling period are defined as follows:

L_W : Length in m, of the yacht at the waterline

T_1 : Mean moulded draught in m, of the yacht

A_K : Total overall area in m^2 of bilge keels, or area of the lateral projection of the bar keel, or sum of these areas, or area of the lateral projection of any hull appendages generating added mass during yacht roll

GM : Metacentric height in m, corrected for free surface effect.

Intermediate values are to be obtained by linear interpolation from values given in Tab 3 to Tab 4.

3.3 Weather criterion for sailing yachts

3.3.1 For all the operational loading conditions of Ch 3, App 2, [1.2], the wind moment based on the three sailing combinations as described in [3.3.2], has to be calculated according to [3.3.4]. Each condition has to comply with the criteria listed in [3.3.5].

3.3.2 The three sailing combinations which have to be investigated are:

- full sails
- intermediate sails
- reduced sails.

3.3.3 The wind force should be calculated as follows:

$F = 1/2\ C_s\ \rho\ A\ V^2$

Table 3 : Values of coefficient X_1

B/T_1	X_1
≤ 2,4	1,00
2,5	0,98
2,6	0,96
2,7	0,95
2,8	0,93
2,9	0,91
3,0	0,90
3,1	0,88
3,2	0,86
3,4	0,82
≥ 3,5	0,80

Table 4 : Values of coefficient X_2

C_B	X_2
≤ 0,45	0,75
0,50	0,82
0,55	0,89
0,60	0,95
0,65	0,97
≥ 0,70	1,00

Table 5 : Values of coefficient k

$\frac{A_K \times 100}{L \times B}$	k
0,0	1,00
1,0	0,98
1,5	0,95
2,0	0,88
2,5	0,79
3,0	0,74
3,5	0,72
≥ 4,0	0,70

Table 6 : Values of factor s

T_R	s
≤ 6	0,100
7	0,098
8	0,093
12	0,065
14	0,053
16	0,044
18	0,038
≥ 20	0,035

where:

F : Wind force, in N

C_s : Shape coefficient. Without specific available data, this coefficient has to be taken equal to 1,1

ρ : Air mass density, equal to 1,222 kg/m^3

A : Projected area of all the exposed surfaces, in square metres

V : Maximum wind speed, in m/s, for which the yacht is able to operate for each specific combination of sails as described in [3.3.2].

3.3.4 The wind moment is the force F as calculated in [3.3.3], multiplied by the heeling lever Z. The heeling lever Z is the vertical distance in m, from the centre of A to the centre of the underwater lateral area or approximately to a point at one half the draught.

The wind heeling lever is calculated as follows:

$\lambda = \lambda(0)\ (\cos\theta)^2$

where λ(0) is the wind heeling lever at 0°.

3.3.5 Criteria

Under the assumptions of [3.3.4], the following criteria are to be complied with:

- the metacentric height corrected by the free surface effects, has to be greater or equal to 0,30 m
- the angle of the static heel due to the effect of wind has to be limited to 20° or 90% of the immersion of the deck, whichever is less
- the rigthing lever GZ is to be at least 0,50 m at an angle of heel equal to or greater than 50°
- the area above the wind heeling lever λ and below the GZ curve, between the angle of static wind heel and the downflooding angle, has to be at least equal to 0.065 mrd.

4 Effects of free surfaces of liquids in tanks

4.1 General

4.1.1 For all loading conditions, the initial metacentric height and the righting lever curve are to be corrected for the effect of free surfaces of liquids in tanks.

4.2 Consideration of free surface effects

4.2.1 Free surface effects are to be considered whenever the filling level in a tank is equal or less than 98% of full condition. Free surface effects need not be considered where a tank is nominally full, i.e. filling level is above 98%. Nevertheless, in order to take into account the consumption of consumable just after departure, the requirement of [4.2.2] has to be considered.

4.2.2 In calculating the free surfaces effect in tanks containing consumable liquids, it is to be assumed that for each type of liquid at least one transverse pair or a single centreline tank has a free surface and the tank or combination of tanks taken into account are to be those where the effect of free surface is the greatest.

4.3 Water ballast tanks

4.3.1 Where water ballast tanks are to be filled or discharged during the course of a voyage, the free surfaces effect is to be calculated to take account of the most onerous transitory stage relating to such operations.

4.4 GM_0 and GZ curve corrections

4.4.1 The corrections to the initial metacentric height and to the righting lever curve are to be addressed separately as indicated in [4.7.2] and [4.7.3].

4.4.2 In determining the correction to the initial metacentric height, the transverse moments of inertia of the tanks are to be calculated at 0 degrees angle of heel.

4.4.3 The righting lever curve may be corrected by any of the following methods:

- correction based on the actual moment of fluid transfer for each angle of heel calculated
- correction based on the moment of inertia, calculated at 0 degrees angle of heel, modified at each angle of heel calculated.

4.4.4 Whichever method is selected for correcting the righting lever curve, only that method is to be presented in the yacht’s trim and stability booklet. However, where an alternative method is described for use in manually calculated loading conditions, an explanation of the differences which may be found in the results, as well as an example correction for each alternative, are to be included.

4.5 Remainder of liquid

4.5.1 The usual remainder of liquids in the empty tanks need not be taken into account in calculating the corrections, providing the total of such residual liquids does not constitute a significant free surface effect.

5 Icing

5.1 Application

5.1.1 For any yacht operating in areas where ice accretion is likely to occur, adversely affecting a yacht's stability, attention is to be paid to the effect of the ice. The Society reserves its right to request additional calculations on a case by case basis.

SECTION 3 DAMAGE STABILITY

1 General

1.1 Application

1.1.1 The damage stability requirements of this Section are to be applied to yachts having a classification notation **unrestricted navigation** and a length L_{LL} greater than 24 m.

Yachts having the navigation notation **unrestricted navigation limited to 60 nautical miles** as defined in Pt A, Ch 1, Sec 2 may be exempted from damage stability requirements.

2 Assumptions

2.1 Description of the damage

2.1.1 Standard of damage

The damage should occur anywhere along the yacht's length except in way of a watertight bulkhead.

2.1.2 Extent of damage

A circular damage of 1,0 m along the side shell has to be considered from the baseline up to the level of the waterline.

2.2 Method of calculation

2.2.1 Lost buoyancy method

The damage stability calculations have to be performed using the lost buoyancy method (constant displacement).

2.3 Permeabilities

2.3.1 General

For the purpose of the damage stability calculations, the following permeabilities have to be considered:

- 0,95: accomodation or voids
- 0,85: machinery
- 0,60: stores
- 0 or 0,95: for liquids, whichever results in the more se vere requirements.

2.4 Inclining moment

2.4.1 The moment due to the wind pressure should be considered as follows:

- a wind pressure of 120 N/m^2 is to be applied
- the area applicable is to be the projected lateral area of the yacht above the waterline corresponding to the intact condition

  For sailing yachts, the sails should be considered lowered
- the moment arm is to be the vertical distance from a point at one half of the mean draught corresponding to the intact condition to the centre of gravity of the lateral area.

2.5 Damage stability criteria

2.5.1 The following damage stability criteria have to be complied with:

a) in the case of symmetrical flooding due to compartment arrangement, a positive residual metacentric height is to be at least 50 mm as calculated by the constant displacement method

b) in the case of unsymmetrical flooding, the angle of heel is not to exceed 7°. For multihull yacht, an angle of heel up to 10° may be accepted

c) the deck line should not be submerged at the equilibrium

d) the minimum range of the positive residual righting lever curve is to be at least 15° beyond the angle of equilibrium

e) the area under the righting lever curve is to be at least 0,015 m.rd measured from the angle of equilibrium to the lesser of the angle at which progressive flooding occurs, and 22° measured from upright

f) a residual righting lever is to be obtained within the range of positive stability taking into account the heeling moment due the wing pressure, as calculated by the formula:

$$GZ = \frac{Hw}{D} + 0,04$$

where:

H_w : Wind heeling moment as calculated in [2.4.1], in t.m

D : Displacement, in t

GZ : Righting lever, in m.

However, in no case is this righting lever to be less than 0,1 m.

APPENDIX 2 TRIM AND STABILITY BOOKLET

1 Trim and stability booklet

1.1 Information to be included in the trim and stability booklet

1.1.1 General

A trim and stability booklet is a stability manual, to be approved by the Society, which is to contain sufficient information to enable the Captain to operate the yacht in compliance with the applicable requirements contained in the Rules.

The format of the stability booklet and the information included vary depending on the yacht type and operation.

1.1.2 List of information

The following information is to be included in the trim and stability booklet:

- a general description of the yacht, including:
  - the yacht's name and the Society classification number
  - the yacht type and service notation
  - the class notations
  - the yard, the hull number and the year of delivery
  - the moulded dimensions
  - the draught corresponding to the summer load line (defined in Ch 1, Sec 2, [3.7]
  - the displacement corresponding to the above-mentioned draught
- clear instructions on the use of the booklet
- general arrangement and capacity plans indicating the assigned use of compartments and spaces (stores, accommodation, etc.)
- a sketch indicating the position of the draught marks referred to the yacht's perpendiculars
- hydrostatic curves or tables corresponding to the design trim, and, if significant trim angles are foreseen during the normal operation of the yacht, curves or tables corresponding to such range of trim are to be introduced. A clear reference relevant to the sea density, in t/m^3, is to be included as well as the draught measure (from keel or underkeel)
- cross curves (or tables) of stability calculated on a free trimming basis, for the ranges of displacement and trim anticipated in normal operating conditions, with indication of the volumes which have been considered in the computation of these curves
- tank sounding tables or curves showing capacities, centres of gravity, and free surface data for each tank
- lightship data from the inclining experiment, as indicated in Ch 3, Sec 1, [2], including lightship displacement, centre of gravity co-ordinates, place and date of the inclining experiment, as well as the Society approval details specified in the inclining experiment report. It is suggested that a copy of the approved experiment report be included

  Where the above-mentioned information is derived from a sister ship, the reference to this sister ship is to be clearly indicated, and a copy of the approved inclining experiment report relevant to this sister ship is to be included
- standard loading conditions as indicated in [1.2] and examples for developing other acceptable loading conditions using the information contained in the booklet
- intact stability results (total displacement and its centre of gravity co-ordinates, draughts at perpendiculars, GM, GM corrected for free surfaces effect, GZ values and curve, criteria as indicated in Ch 3, Sec 2, reporting a comparison between the actual and the required values) are to be available for each of the above-mentioned operating conditions. The method and assumptions to be followed in the stability curve calculation are specified in [1.3]
- damage stability results (total displacement and its maximum permissible centre of gravity height, draughts at perpendiculars, GM, GM corrected for free surfaces effect, GZ values and curve, criteria as indicated in Ch 3, Sec 3, reporting a comparison between the actual and the required values) are to be available for each of the above-mentioned operating conditions. The method and assumptions to be followed in the stability curve calculation are specified in [1.3]
- maximum KG or minimum GM curve or table which can be used to determine compliance with the applicable intact and damage stability criteria when applicable
- information about openings (location, tightness, means of closure), pipes or other progressive flooding sources. the opening used for the calculation of the down flooding angle has to be clearly identified
- information concerning the use of any special cross-flooding fittings with descriptions of damage conditions which may require cross-flooding, when applicable
- any other necessary guidance for the safe operation of the yacht, in particular, limitations regarding maximum allowable wind pressure as calculated in Ch 3, Sec 2, [3]
- a table of contents and index for each booklet.

1.2 Loading conditions

1.2.1 The standard following loading conditions are to be included in the trim and stability booklet:

- yacht in the fully loaded departure condition with full stores and fuel and with full number of passengers with their luggage
- yacht in the fully loaded arrival condition, with full number of passengers and their luggage but with only 10% stores and fuel remaining.

1.3 Stability curve calculation

1.3.1 General

Hydrostatic and stability curves are normally prepared on a designed trim basis. However, where the operating trim or the form and arrangement of the yacht are such that change in trim has an appreciable effect on righting arms, such change in trim is to be taken into account.

1.3.2 Superstructures, deckhouses, etc. which may be taken into account

Enclosed superstructures complying with Ch 1, Sec 2 may be taken into account.

1.3.3 Angle of flooding

In cases where the yacht would sink due to flooding through any openings, the stability curve is to be cut short at the corresponding angle of flooding and the yacht is to be considered to have entirely lost its stability.

Small openings such as those for passing wires or chains, tackle and anchors, and also holes of scuppers, discharge and sanitary pipes are not to be considered as open if they submerge at an angle of inclination more than 30°. If they submerge at an angle of 30° or less, these openings are to be assumed open if the Society considers this to be a source of significant progressive flooding; therefore such openings are to be considered on a case by case basis.

SECTION 2 DESIGN LOADS

1 Definitions

1.1 Local loads

1.1.1 Local loads are pressures or forces which are directly applied to the individual structural members such as plating panels, ordinary stiffeners and primary supporting members.

1.1.2 Local loads considered in the present Rules are:

- still water local loads, constituted by the hydrostatic external sea pressures and hull weight distribution
- wave local loads, constituted by the external sea pressures due to waves and the inertial pressures and forces induced by the ship accelerations
- dynamic local loads, constituted by the slamming pressures on the bottom hull (induced by the vertical ship motions) and by impact pressure on the side shell (induced by sea impact on the hull)
- punctual loads, constituted by localized efforts exerted on ship's structure, such as, e.g., loads induced by standing rigging and main sail sheet.

1.1.3 Test loads are local loads constituted by pressures exerted during hydrostatic tests of spaces intended to carry liquids.

1.2 Hull girder loads

1.2.1 Hull girder loads (still water, wave and dynamic) are forces and moments which result as effects of local loads acting on the ship as a whole and considered as a beam.

1.2.2 Hull girder loads considered in the present Rules are:

- still water hull girder loads, resulting from the effect difference in downwards ship weights and upwards buoyancy forces throughout the length of the ship
- wave hull girder loads, induced by the added or substracted buoyancy forces along the float induced by incident waves on the float
- rigging induced global, constitued by all the loads exerted by the standing rigging on the float.

2 Application criteria

2.1 Fields of application

2.1.1 The wave induced and dynamic loads defined in this Chapter corresponds to an operating life of the ship equal to 20 years.

2.1.2 The still water, wave induced and dynamic loads defined in this Chapter are to be used for the determination of the hull girder strength and structural scantlings. These loads are not to be amplified by any safety factor, such safety factor being included in admissible stress levels given in Ch 4, Sec 3.

3 Navigation coefficients

3.1 General

3.1.1 Navigation coefficients depending on navigation notation defined in Pt A, Ch 1, Sec 2 are given in Tab 1.

3.1.2 In scope of application of the present Rules for specific purposes (e.g. evaluation of conformity in scope of EC directive for recreational craft), navigation coefficients depending on navigation may be taken into account.

Such coefficients are given in Tab 1.

Table 1 : Navigation coefficients

Navigation notation	Navigation coefficient n
Unrestricted navigation Design category A and B (EC Directive)	1,00
Coastal area Design category C (EC Directive)	0,90
Sheltered area Design category D (EC Directive)	0,80

SECTION 1 GENERAL

1 Definitions

1.1 Global loads

1.1.1 Global loads are made of forces and bending moment on the hull girder, resulting from application of local loads throughout the ship.

1.1.2 The different global loads (also named hull girder loads) are defined in Ch 4, Sec 2, [1.2].

1.2 Sign conventions of vertical bending moments and shear forces

1.2.1 The sign conventions of bending moments and shear forces at any ship transverse section are as shown in Fig 1, namely:

- the vertical bending moment M is positive when it induces tensile stresses in the strength deck (hogging bending moment); it is negative in the opposite case (sagging bending moment)
- the vertical shear force Q is positive in the case of downward resulting forces preceding and upward resulting forces following the ship transverse section under consideration ; it is negative in the opposite case.

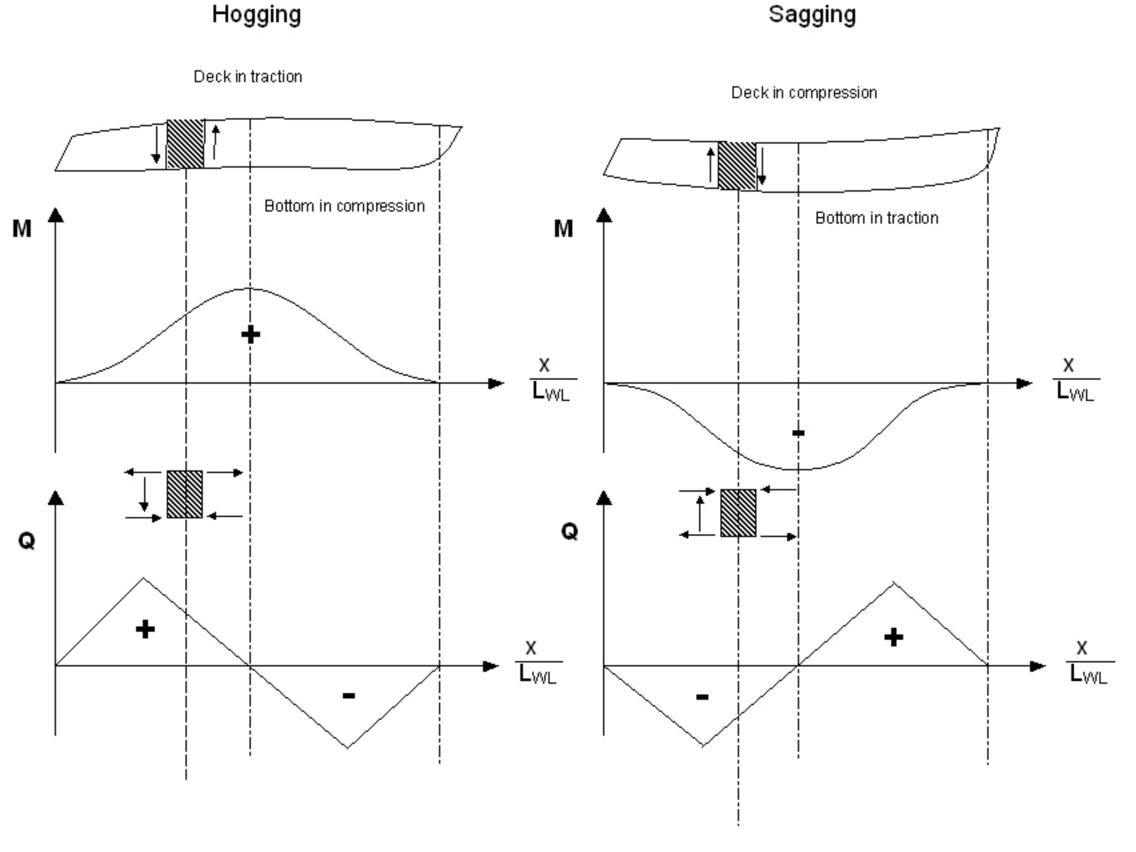
1.2.2 The resulting forces correspond to the difference between the vertical sea pressure and the vertical forces applied to the hull.

1.3 Application

1.3.1 As a rule, the global loads are to be taken into consideration in the following situations:

- yacht with important length (superior to 40 m), or
- sailing yacht, of monohull or multihull type, having important compression force induced by the mast and important forces induced by standing rigging, or
- ship having large openings in decks or significant geometrical structure discontinuity at bottom or decks, or
- ship with transverse framing system, or
- ship with deck structure made of small plate thicknesses and large spacing of secondary stiffeners.

Figure 1 : Sign conventions for shear forces Q and bending moments M



SECTION 3 SPECIFIC GLOBAL LOADS

1 General

1.1 Application

1.1.1 The specific global loads of this Section are applicable to sailing yacht (monohull or catamaran) and to catamarans (sailing yachts or motor yachts).

1.1.2 The multihulls with more than two floats are not covered by the present Section and are to be submitted to a special examination.

1.1.3 Other requirements may be considered for such specific global loads, in case of yachts having unusual particulars.

2 Rig loads

2.1 General

2.1.1 The rig global loadings described in that Section are generally to be considered for yachts featuring:

- a sailing configuration where mast, stays, shrouds and backstay induce significant loads in the hull girder
- a deck with large openings or significant structural discontinuity
- a deck with transverse framing system.

2.1.2 The rig global loads inducing a hull girder bending effect are to be combined with still water and wave global loads as indicated in Ch 6, Sec 4.

2.1.3 The rig loads to be considered in the present Section are the forces induced by the standing rigging:

- stays
- vertical shrouds and lower shrouds
- backstay.

The loads induced by the standing rigging during normal navigation conditions are to be indicated by the Yard and/or by the Designer, for the various navigation conditions taking account of:

- sails reduction versus apparent wind speed
- sails configuration for all wind heading from head wind to down wind.

2.1.4 The combination calculations are carried out without any trim and list.

2.1.5 The Society reserves the right to determine the rig loads from the sizing of the shrouds. In such case, the forces are corresponding to the breaking strength of the shroud under consideration, divided by a coefficient of 2,5 (this coefficient is generally the safety factor on breaking strength used for the design of shrouds in the scantling riggings).

The Society may consider a different value for this coefficient, on a case by case basis, upon satisfactory justification given by the Yard and/or the Designer.

2.2 Sailing monohull with one mast

2.2.1 The maximum hull girder bending moment M_{RIG}, in kN.m, induced by the standing rigging, is the mean value of fore rig induced hull girder bending moment M_{RIGF} and aft rig induced hull girder bending moment M_{RIGA}, defined as follows:

- where only the forestay is loaded:

  $M_{RIGF} = F_E \sin\alpha_E \, L_E$

- where only the baby stay is loaded:

  $M_{RIGF} = F_{BE} \sin\alpha_{BE} \, L_{BE}$

- where both the main stay and the baby stay are loaded simultaneously:

  $M_{RIGF} = F_E \sin\alpha_E \, L_E + F_{BE} \sin\alpha_{BE} \, L_{BE}$

- $M_{RIGA} = M_P + M_{V1} + M_{D1}$

  where:

  $M_P = F_P \sin\alpha_P \, L_P$

  $M_{V1} = F_{V1} \, L_{V1}$

  $M_{D1} = F_{D1} \sin\alpha_{D1} \, L_{D1}$

The symbols are shown on Fig 1, where:

F_P : Load on backstay, in kN

F_{V1} : Load on vertical shroud, in kN

F_{D1} : Load on lower shroud, in kN

F_E : Load on forestay, in kN

F_{BE} : Load on baby stay, in kN

α_I : Angle from the horizontal, in °, as shown on Fig 1

L_I : Horizontal distance from mast foot, in m, as shown on Fig 1.

2.2.2 The maximum hull girder vertical shear force Q_{RIG}, in kN, induced by the standing rigging, is the mean value of fore rig induced hull girder vertical shear force Q_{RIGF} and aft rig induced hull girder vertical shear force Q_{RIGA}, defined as follows:

- where only the main stay is loaded:

  $Q_{RIGF} = F_E \sin\alpha_E$

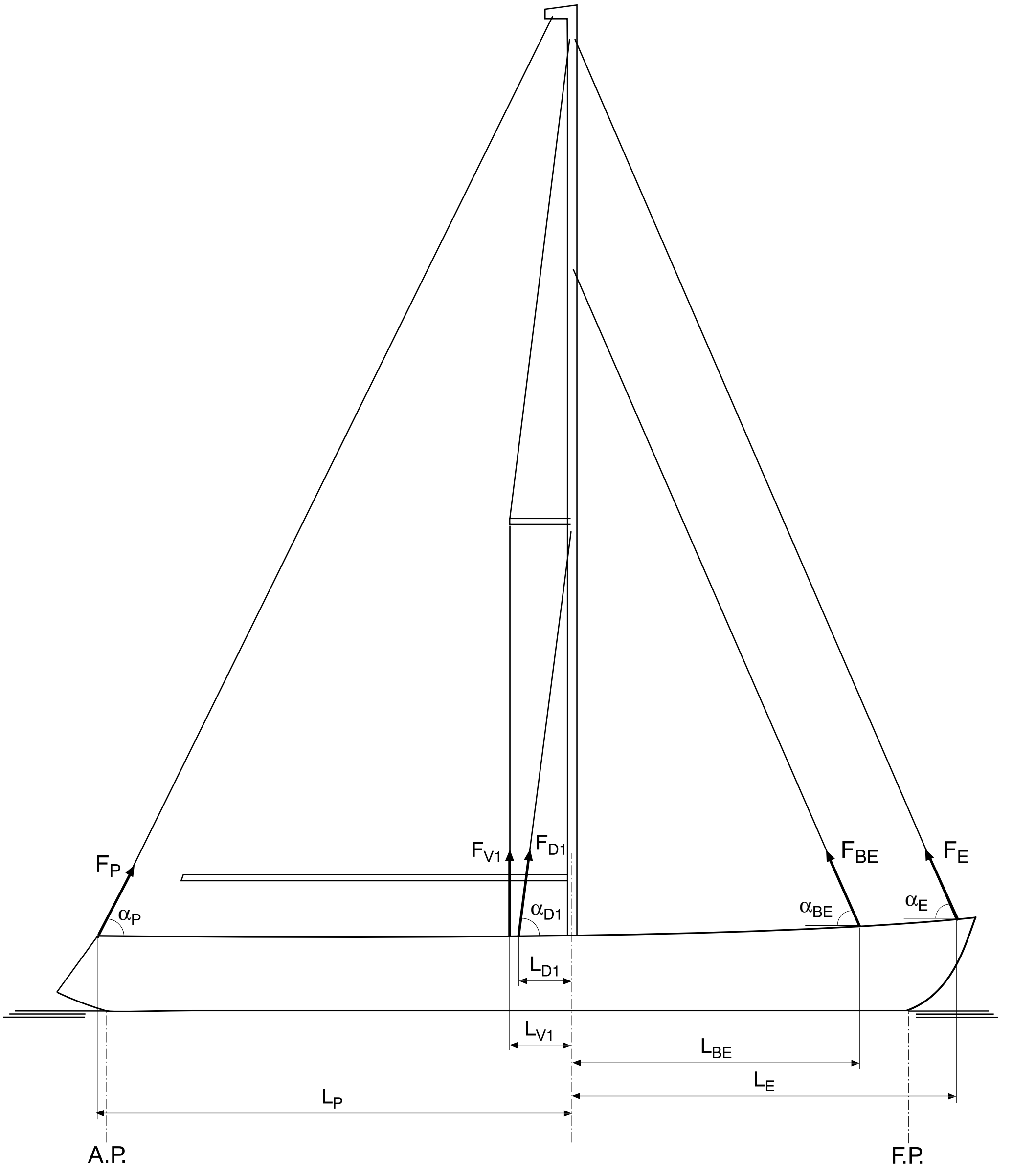
- where only the baby stay is loaded:

  $Q_{RIGF} = F_{BE} \sin\alpha_{BE}$

- where both the main stay and the baby stay are loaded simultaneously:

  $Q_{RIGF} = F_E \sin\alpha_E + F_{BE} \sin\alpha_{BE}$

Figure 1 : Rig loads designation



- $Q_{RIGA} = Q_P + Q_{V1} + Q_{D1}$

  where:

  $Q_P = F_P \sin \alpha_P$

  $Q_{V1} = F_{V1}$

  $Q_{D1} = F_{D1} \sin \alpha_{D1}$

The symbols are defined in [2.2.1].

2.3 Sailing monohull with several masts

2.3.1 In case of sailing monohull with more than one mast, the hull girder bending moments and shear forces induced by the standing rigging are determined from a direct calculation.

This calculation is to be carried out with following assumptions:

- the hull is considered as a series of beams of constant inertia, fixed in way of each mast (see Fig 3)
- this beam is vertically loaded by the various forces exerted by the standing rigging (see Fig 2).

The hull girder is then analysed by steps, bending moments and shear forces being calculated individually for each span between masts.

The hull girder rig bending moments and shear forces are generally calculated in way of each mast.

The design value of the hull girder rig bending moment in way of each mast is the mean value of the bending moments calculated either side of the mast under consideration.

The design value of the hull girder rig shear force in way of each mast is the mean value of the shear forces calculated either side of the mast under consideration.

2.3.2 The actual distribution of hull girder bending moments and shear forces may be calculated by means of beam analysis.

2.3.3 Where the top of masts are attached to each other by an horizontal shroud, the rig loads will be subject to special examination.

Figure 2 : Rig loads designation for sailing yachts with several masts

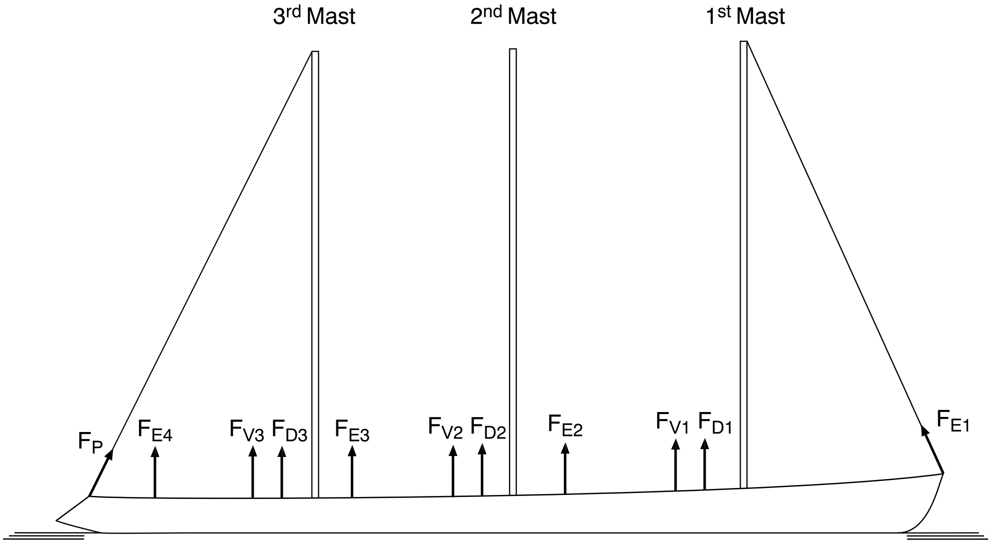
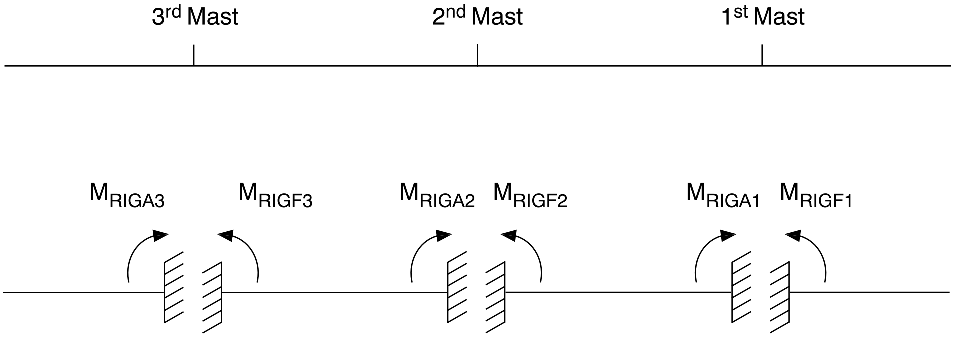


Figure 3 : Hull girder analysis



2.4 Sailing catamarans with one mast or more than one mast

2.4.1 General

The rig loads considered in the present sub-article may induce:

- a global vertical bending moment
- a global torsional connecting moment (rig torque).

The loads induced by the standing rigging during normal navigation conditions are to be indicated by the Yard and/ or by the Designer, for the various navigation conditions taking account of:

- sails reduction versus apparent wind speed
- sails configuration for all wind heading from head wind to down wind.

The Society reserves the right to determine the rig loads from the sizing of the shrouds. In such case, the forces are corresponding to the breaking strength of the shroud under consideration, divided by a coefficient of 2,5 (this coefficient is generally the safety factor on breaking strength used for the design of shrouds in the scantling riggings).

The Society may consider a different value for this coefficient, on a case by case basis, upon satisfactory justification given by the Yard and/or the Designer.

2.4.2 Vertical bending moment induced by rig

The hull girder bending moment induced by the standing rigging, M_{RIG} , is to be calculated according to sub-article [2.2].

2.4.3 Torque induced by rig

The rig loads considered in the present requirement are the rig forces that induce a torsional connecting moment in the cross deck between the floats. These forces are non-symetrical with respect to longitudinal axis, and are:

- the forces exerted by the vertical shrouds and lower shrouds
- the forces exerted by the backstay.

The hull girder torsque bending moment induced by the standing rigging, M_{RIGT} , is equal to:

$$M_{RIGT} = F_{V1}\ L_{V1}' + F_{D1}\ L_{D1}'\ \sin\alpha_{D1} + F_P\ L_P'\ \sin\alpha_P$$

where L_{V1}', L_{D1}' and L_P' are the horizontal distances from respectively vertical shroud chain plate, lower shroud chain plate and side backstay chain plate to cross deck center of rotation, determined as indicated in Ch 8, Sec 2 for steel and aluminium yachts, or Ch 9, Sec 2 for composites yachts.

3 Loading induced by deck diving into waves (broaching)

3.1 General

3.1.1 This type of loading corresponds the situation where the catamaran sails in quartering head seas and has the fore end of the floats burying themselves into the encountered waves.

3.1.2 The assumptions considered to determine the corresponding global loads are the following one:

- 10° longitudinal trim
- 10° tranverse list
- 1g broaching horizontal deceleration
- the float getting the bigger broaching effect is submerged from the extreme fore end to the forward part of the forward cross deck structure.

3.2 Loads and stresses

3.2.1 Vertical and horizontal forces to be applied on the fore part of the floats, in kN, are defined as follows.

The vertical force F′, in kN, induced by Archimedian overpressure resulting from the deck diving, is to be calculated according to the following formula:

$$F' = \frac{1,8 \cdot 9,807 \cdot \Delta \cdot d \cdot \sin 10^{\circ}}{\delta_1 + \delta_2}$$

The horizontal force F″, in kN, induced by Archimedian overpressure resulting from the deck diving, is to be calculated according to the following formula:

$F'' = F' \cos 80°$

where:

Δ : Full load diplacement, in T, of the catamaran

d : Horizontal distance between the extreme fore end of each float and the forward part of the forward cross beam

δ_1, δ_2 : Sinkages, in m, of a point located at mid-distance between the extreme fore end of each float and the fore stem of the forward cross deck structure (at d/2)

$$\delta_1 = \frac{3}{8} \cdot L_{WL} \cdot \tan 10^{\circ}$$

$$\delta_2 = \frac{1}{8} \cdot L_{WL} \cdot \tan 16^{\circ}$$

L_{WL} : Length of each float, in m, at full load waterline.

3.2.2 Load distribution

The distribution of the loads on the fore part of the floats may be considered as linear load applied according to Fig 4.

3.2.3 For non conventional loaction of the fore part of the cross deck between hulls, the Society may decide to consider another load distribution, on a case by case basis.

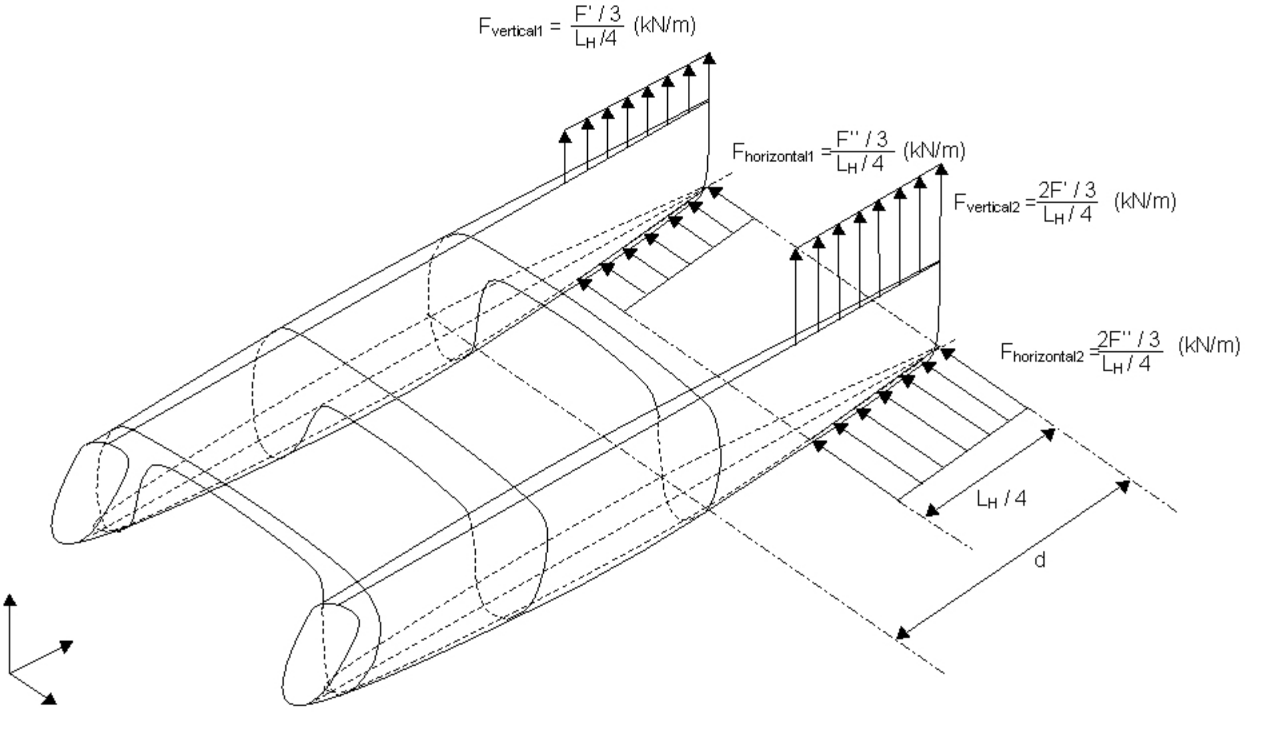
3.2.4 Bending moment M_E and shear force Q_E

The bending moments and shear forces induced in the cross deck by this type of loads are to be determined according to Ch 8, Sec 2 for steel or aluminium yacht and Ch 9, Sec 2 for composite yacht.

3.2.5 Admissibles stresses

The admissible stresses to be considered for the cross deck scantlings under this type of loading are defined in Ch 4, Sec 3.

Figure 4 : Loading of catamarans due to digging in



SECTION 1 HYDRODYNAMIC LOADS

Symbols

C_W : Wave height defined in [1.1.3]

L_W : Wave length, defined in [1.1.3]

X_I : Wave load coefficient, defined in [2.2.1] and in Tab 1

B_W : Breadth at waterline. For catamarans, see Fig 3

ℓ : Distance between internal sideshells of catamaran at waterline, defined in Fig 3

p_s : Sea pressure defined from [2] to [4]

p_{smin} : Minimum pressure on side shell as defined in [2.3]

p_{sumin} : Minimum pressure on superstructure as defined in Tab 3

p_{dmin} : Minimum pressure on deck as defined in [3.1.2].

1 Sea pressure

1.1 General

1.1.1 The local loads induced by the sea pressure on any point of the outside shell are the combined action of the hydrostatic pressure and the pressure induced by waves.

1.1.2 The hydrostatic pressures are calculated with full load condition.

1.1.3 The pressure induced by waves is given as a function of:

- the wave height C_W, in m, equal to:

  $C_W = 10 \log (L_W) - 10$

  without being taken less than 3m, where:

  L_W : Wave length equal to 0,5 ($L_{WL} + L_{HULL}$)
- a wave load coefficient X_i, defined inTab 1, and depending on the longitudinal location and on the type of yacht.

1.1.4 Bottom area

The bottom area is the part of the hull located below the full load waterline (see Fig 1).

1.1.5 Side shell area

The side shell area is the part of the hull located above the full load waterline.

1.2 Bottom and side shell

1.2.1 Bottom sea pressure for monohull

For monohull, sea pressure on bottom is considered uniform on the bottom area in any transverse section.

1.2.2 Side shell sea pressure for monohull

For monohull, side shell sea pressure are derived from the bottom sea pressure, taking into account the vertical distance z between the calculation point and the full load waterline in the considered transverse area (see Fig 2).

1.2.3 Bottom and side shell sea pressure for catamaran

In case of catamarans, the sea pressure for bottom and side shell are calculated taking account of a vertical distance between load point and base line, as shown on Fig 3.

2 Pressure on bottom and side shell

2.1 General

2.1.1 In any point, the design sea pressure to be taken into account for platings, secondary stiffeners and primary stiffeners is given in [2.2]

Figure 1 : Definition of bottom area for monohulls

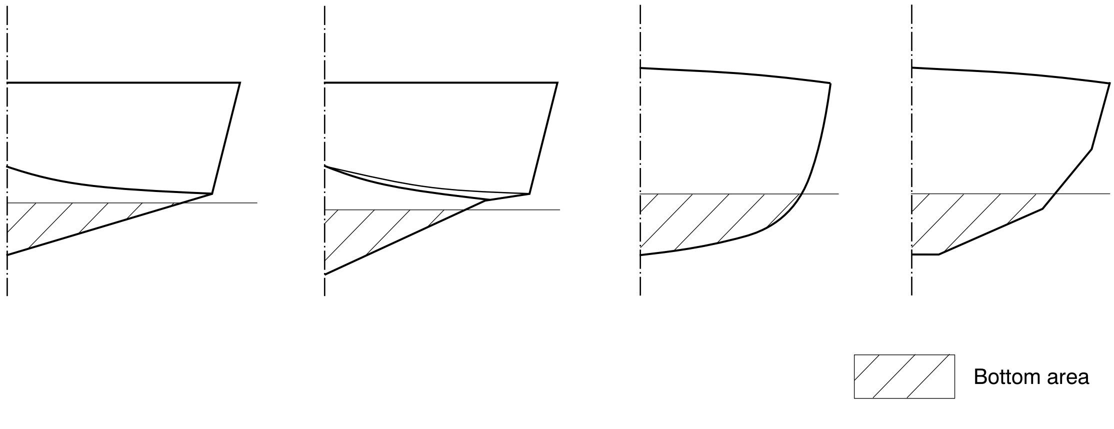


Figure 2 : Vertical distance z for monohull

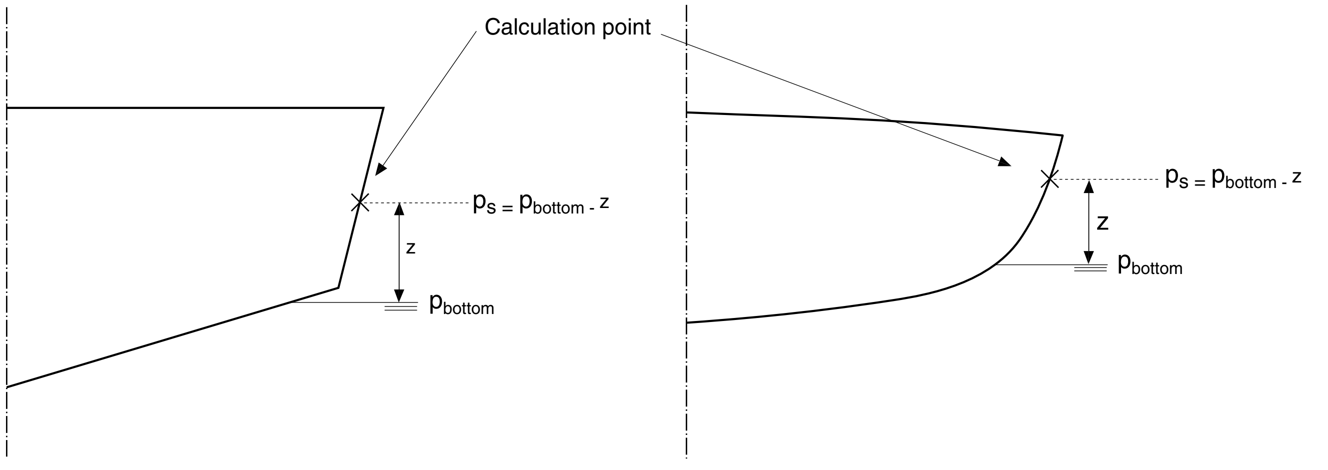
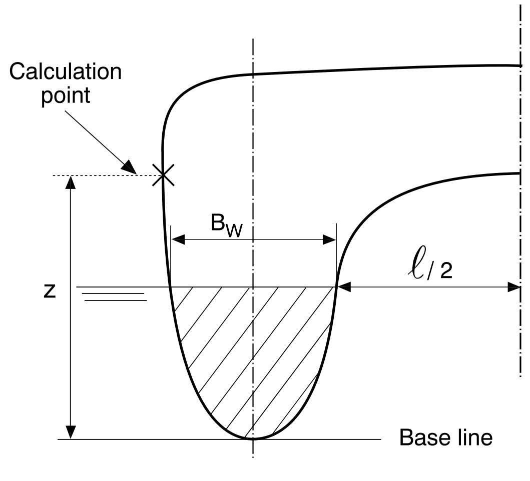


Figure 3 : Vertical distance z for catamarans



2.2 Sea pressure

2.2.1 For all types of yachts, the sea pressure in any point of the bottom and side shell, in kN/m², is defined by the following formula:

$$P_S = 9{,}807\,n\left[T + \left(\frac{C_W}{X_I} + h_2\right) - z\right]$$

where:

n : Coefficient depending on the navigation notation, as given in Pt B, Ch 4, Sec 2

T : Full load draught, in m

C_W : Wave height, defined in [1.1.3], in m

X_I : Wave load coefficient shown on Fig 4, and defined in Tab 1

z : Vertical distance from calculation point to the full load waterline (monohull) or to the base line (catamarans). For monohull, bottom pressure is calculated with z = 0

h_2 : Distance in m, equal to:

- for monohull: $h_2 = 0$
- for bottom or external side shell of catamarans: $h_2 = 0$
- for internal side shell of catamaran and inner side of cross deck of catamaran:

$$h_2 = \frac{B_W\left(T + \frac{C_W}{X_I}\right)C_B}{\ell}$$

where:

B_W : Breadth at full load waterline at considered transverse section (see Fig 3)

ℓ : Distance between internal side shells at waterline at considered transverse section, in m, as defined in Fig 3

C_B : Block coefficient defined in Ch 1, Sec 2, [2.1.1].

Table 1 : Wave load coefficients

Type of yachts	Area 4 **(1)** X_4	Area 3 **(1)** X_3	Area 2 **(1)** X_2	Area 1 **(1)** X_1
Monohull motor yacht	2,8	2,2	1,9	1,7
Monohull sailing yacht	2,2	1,9	1,7	1,4
Multihull motor yacht	2,8	2,2	1,9	1,4
Multihull sailing yacht	2,5	2,2	1,7	1,1
(1) See Fig 4 for definition of areas.				

Figure 4 : Load areas and coefficient X_i for the external side shell and bottom sea pressure

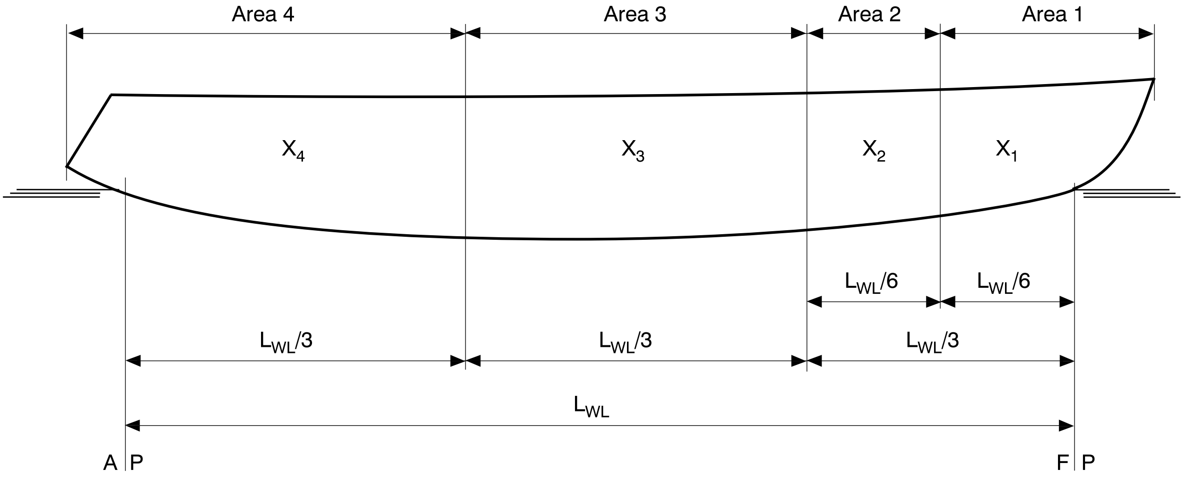
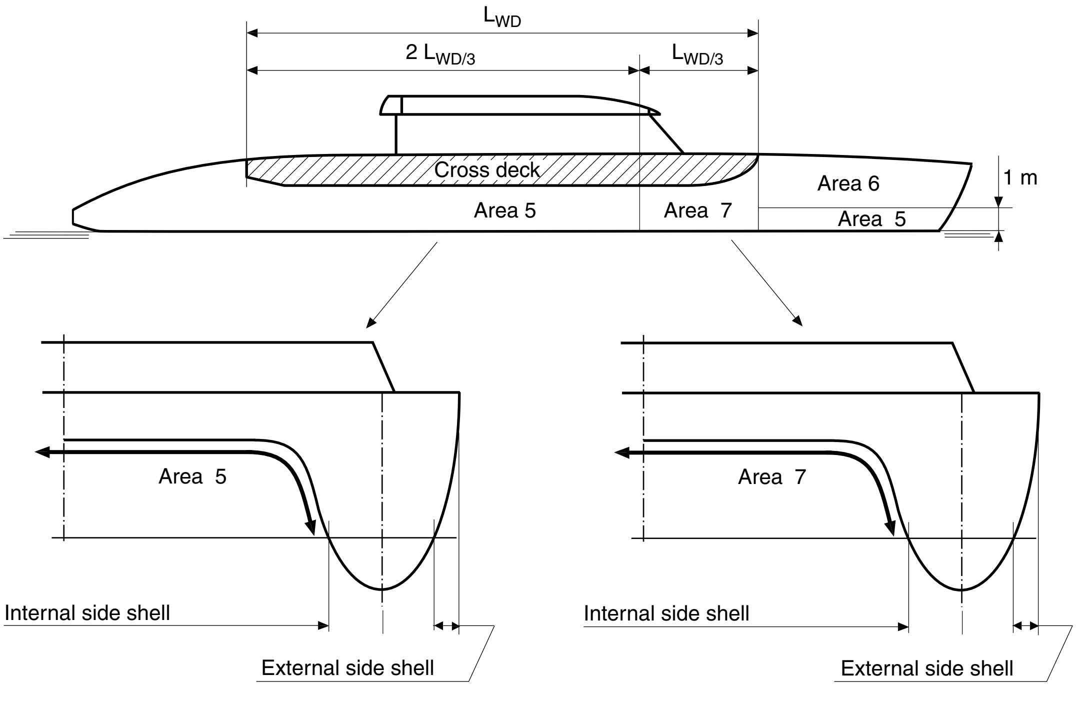


Figure 5 : Load areas for the impact pressure on internal side shell on catamaran



2.3 Impact pressure on side shell

2.3.1 General

The impact pressure given hereafter is to be considered as a minimum pressure on side shell and is to be taken into account only for plating and secondary stiffeners located on side shell area as defined in [1.1.5].

Impact pressure on side shell represents the local wave impact load and is locally distributed like a water column of 0,6 m diameter. The admissible stresses or the safety coefficients to be considered are given in Ch 4, Sec 3.

2.3.2 Monohull

In any point of the side shell of monohull, the impact pressure p_{smin}, in kN/m², is to not be less than:

- in areas 1 and 2 as defined in Fig 4 (from fore perpendicular to $L_{WL}/3$ aft of fore perpendicular), between the full load waterline and 1 m above:

  $p_{smin} = 80 \ n \ K_2$

- elsewhere:

  $p_{smin} = 50 \ n \ K_2$

where:

n : Coefficient depending on the navigation notation, as given in Ch 4, Sec 2

k_2 : $K_2 = 0,455 - \left(0,35 \cdot \dfrac{u^{0,75} - 1,7}{u^{0,75} + 1,7}\right)$

with:

$K_2 \geq 0,50$ for plate panel

$K_2 \geq 0{,}45$ for stiffener,

and:

$u = 100\ s / S_r$

S_r : reference area, m^2, equal to:

$$S_r = 0{,}7\frac{\Delta}{T}$$

For catamaran, Δ in the above formula is to be taken as half the craft displacement

s : Surface of the elementary plate panel or surface of the plate panel supported by the stiffener, in m^2

T : Full load draught, in m.

2.3.3 Catamaran

In any point of the external side shell of catamaran, the impact pressure p_{smin}, in kN/m^2, is to not be less than:

- in areas 1 and 2, as defined in Fig 4 (from fore perpendicular to $L_{WL}/3$ aft of fore perpendicular), between the full load waterline and 1 m above: $p_{smin} = 80\ n\ K_2$
- elsewhere, $p_{smin} = 50\ n\ K_2$

where:

n, K_2 : As defined in [2.3.2]

In any point of the internal side shell and the underside of cross deck of catamarans, the impact pressure p_{smin}, in kN/m^2, is to be not less than:

- in area 5 as defined in Fig 5: $p_{smin} = 80\ n\ K_2$
- in area 6 as defined in Fig 5: $p_{smin} = 50\ n\ K_2$
- in area 7 as defined in Fig 5: $p_{smin} = 120\ n\ K_2$

where:

n, K_2 : As defined in [2.3.2].

3 Pressure on decks

3.1 Exposed decks

3.1.1 The sea pressure on any point of exposed deck, in kN/m^2, is to be not less than the greater of the sea pressure given hereafter and the minimum pressure given in [3.1.2]:

$$P_s = (p_0 - z_D 9{,}807)\varphi_1 n$$

where:

φ_1 : Reduction coefficient depending of the location of the considered deck with respect to the full load waterline:

- $\varphi_1 = 1{,}00$ for freeboard deck(m), as defined in Ch 2, Sec 2, [2.2.1]
- $\varphi_1 = 0{,}75$ for the first deck just above the freeboard deck(m), as defined in Ch 2, Sec 2, [2.2.1]
- $\varphi_1 = 0{,}50$ for the decks above

n : Navigation coefficient as as defined Ch 4, Sec 2

p_0 : Sea pressure on bottom in the considered area, in kN/m^2, calculated according to [2.2.1] with $z = 0$

z_D : Vertical distance, in m, between the deck at side at the considered transverse section and the full load waterline (for monohull) or the baseline (for catamaran).

3.1.2 The pressure given in [3.1.1] is to be not less than the following minimal sea pressure p_{dmin}, in kN/m^2:

- in areas 1 and 2, as defined in Fig 4 (from fore perpendicular to $L_{WL}/3$ aft of fore perpendicular):

  $p_{dmin} = 15\ n\ \varphi_1$
- in areas 3 and 4 (elsewhere):

  $p_{dmin} = 10\ n\ \varphi_1$

where:

φ_1, n : As defined in [3.1.1].

3.2 Accommodation decks

3.2.1 The pressure on accommodation decks is to be not less than:

- $p_s = 5\ kN/m^2$, in large spaces (lounges, cinema, restaurant, kitchens, etc)
- $p_s = 3\ kN/m^2$, in cabins
- $p_s = 10\ kN/m^2$, in technical spaces and machinery spaces.

3.3 Superstructure deck

3.3.1 The pressure on exposed and accommodation superstructure decks are to be not less than the values given in [3.1] and [3.2].

However, when an exposed superstructure deck is not directly exposed to green seas effect, the pressure on this deck is to be taken not less than:

- $p_S = 5\ kN/m^2$ for decks accessible to passengers or crew members.
- $p_S = 3\ kN/m^2$ for decks not accessible to passengers or crew members.

4 Pressure on superstructures

4.1 General

4.1.1 In any point, the design pressure is to be taken as the sea pressure given in [4.2], without being taken less than the minimum pressure given in [4.3].

4.2 Sea pressure

4.2.1 The design pressure to be considered for scantlings of fore walls, side walls and aft walls of superstructures and deckhouses, in kN/m^2, is to be not less than:

$$p_S = 7 \cdot a \cdot c \cdot n \cdot (b \cdot f - z_S)$$

where:

a : Coefficient as given in Tab 2

c : Coefficient equal to:

- for monohull - motor yacht:

  $c = 0,3 + 0,7\ b_i / B_i$

- for monohull - sailing yacht: $c = 1,0$
- for catamarans (sailing or motor): $c = 0,5$

where:

B_i : Breadth of hull at the considered longitudinal location

b_i : Breadth of superstructure or deck-house at the considered longitudinal location

Table 2 : Coefficient a

Location		a
Front wall	First tier	$2,0 + L_{WL}/ 120$
	2nd tier and above	$1,0 + L_{WL}/ 120$
Aft wall		$0,5 + L_{WL} / 1000$
Side walls		$0,5 + L_{WL} / 150$

n : Navigation coefficient as defined Ch 4, Sec 2, [3]

b : Coefficient equal to:

- in areas 1 and 2 as defined in Fig 4 (from fore end to $L_{WL}/3$ aft of fore perpendicular): $b = 1,5$
- in areas 3 and 4 (elsewhere): $b = 1,0$

f : Coefficient equal to:

$f = -2\ L_W^2 / 8000 + 0,1\ L_W - 1$

L_W : Wave length, in m, as defined in [1.1.3]

z_S : Vertical distance, in m, between the full load waterline and the calculation point, located as follows:

- for plating: mid-height of the elementary plate panel
- for stiffeners: mid-span.

4.3 Minimum pressures

4.3.1 As a rule, the design pressures to be considered for scantling of plating and supporting members of superstructures are to be not less than the minimum pressures p_{smin} given in Tab 3.

4.3.2 When the front wall is sloped aft, the front wall pressures values (sea pressures and minimum pressure) can be multiplied by cos a, where a is the angulation between z axis and straight line tangent to superstructure as shown on Fig 6.

5 Pressure in tanks

5.1 General

5.1.1 Scantlings of watertight bulkeadings of tanks are to be determined with design pressures given in Tab 4.

Tank testing conditions are also to be checked with testing pressures given in Tab 4.

Figure 6 : angulation of superstructures

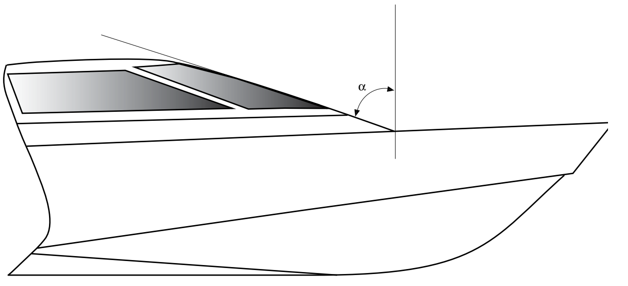


Table 3 : Minimum pressures

Type of wall	Location	p_{sumin} (in kN/m²)
Unprotected front wall	Lower tier, areas 1 and 2	21
	Lower tier, areas 3 and 4	15
	Upper tiers	10
Protected front wall or side walls	Lower tier	10
	Upper tiers	7
Unprotected aft wall	Lower tier, area 4	10
	Lower tier, areas 1, 2 and 3	7
	Upper tiers	7
Protected aft wall	Anywhere	5
Note 1: Areas are defined in Fig 4.		

Table 4 : Tank design and testing pressures

Type of tanks	Design pressure, in kN/m²	Testing pressure, in kN/m²
Water ballast Fresh water tank	$p_S = 11\ [(z_{AP} - z_{TOP}) + z_1]$	$p_T = 11\ (d_{AP} + z_1)$ without being less than p_V
Gas-oil or Fuel-oil tank	$p_S = 11\ [(z_{AP} - z_{TOP}) + z_1]$	$p_T = 11\ (d_{AP} + z_1)$ or $p = 10\ (2,4 + z_1)$ whichever is the greater, without being less than p_V

Note 1:

z_{TOP} : Z co-ordinate, in m, of the top of the tank

z_{AP} : Z co-ordinate, in m, of the moulded deck line of the deck to which the air pipes extend

d_{AP} : Vertical distance, in m, between the top of the tank and the top of the air pipe

z_1 : Vertical distance, in m, between the calculation point and the top of the tank

p_V : Safety pressure of valves, if applicable, in bar.

6 Pressure on bulkheads

6.1 General

6.1.1 Two types of watertight bulkheads are covered by the present Article :

- ordinary watertight bulkheads, fitted to partition the yacht into watertight compartments for damage stability purposes. The design pressure on such bulkheads is given in [6.1.3],
- watertight bulkheads forming boundary of a liquid capacity (Gas-oil, water ballast, fresh water, etc). The design pressure on such bulkheads is given in [5].

6.1.2 Non-watertight bulkheads are not subject to any design lateral pressure.

6.1.3 Scantlings of ordinary watertight bulkeads are to be determined with design pressures given in Tab 5.

However, in case of special arrangement of watertight bulkheads, the Society may request specific analysis and determination of design pressures to be used.

Table 5 : Watertight bulkheads design pressure

Type of bulkheads	Design pressure, in kN/m^2
Watertight bulkhead other than collision bulkhead	$p_S = 10 (1.3T - z) > 0$
Collision bulkhead	$p_S = 10 (D - z) > 0$
Note 1:	
T : Full draught, in m,	
z : Z co-ordinate, in m, of the calculation point	
D : Depth as defined in Ch 1, Sec 2, [3.6]	

SECTION 2 BOTTOM SLAMMING LOADS

1 General

1.1 Slamming loads

1.1.1 As a rule, bottom slamming loads given in the present Section, in kN/m², are applied to the following types of ships:

- high speed motor yacht of monohull and multihull type
- sailing yachts of monohull type.

1.1.2 Slamming loads sustained by plating and ordinary stiffeners may be considered as uniform pressures.

1.2 Slamming areas

1.2.1 As a rule, bottom slamming loads are to be calculated at following areas:

- high speed motor yacht of monohull type: bottom area, from centreline to upper limit of bilge or hard chine, and from transom to fore end
- sailing yacht of monohull type: bottom area, from centreline to waterline at side, and from centre of gravity of the keel or the bulb keel to fore end
- motor yacht of multihull type: bottom area, from centreline of each hull to upper limit of bilge or hard chine, and from transom to fore end.

2 High speed motor yacht of monohull or multihull type

2.1 Plating and stiffeners

2.1.1 If slamming is expected to occur, the slamming pressure, in kN/m², considered as acting on the bottom of hull is to be not less than:

$$p_{sl} = 70 \cdot \frac{\Delta}{S_r} \cdot K_1 \cdot K_2 \cdot K_3 \cdot a_{CG}$$

where:

Δ : Displacement, in tonnes. For catamaran, Δ in the above formula is to be taken as half of the craft displacement

S_r : Reference area, in m², equal to:

$$S_r = 0,7 \cdot \frac{\Delta}{T}$$

For catamaran, Δ in the above formula is to be taken as half the craft displacement

K_1 : Longitudinal bottom slamming pressure distribution factor (see Fig 1):

- for $x/L < 0,5$: $K_1 = 0,5 + x/L$
- for $0,5 \le x/L \le 0,8$: $K_1 = 1,0$
- for $x/L > 0,8$: $K_1 = 3,0 - 2,5\ x/L$

where x is the distance, in m, from the aft perpendicular to the load point

K_2 : Factor accounting for slamming area, equal to:

$$K_2 = 0,455 - 0,35 \cdot \frac{u^{0,75} - 1,7}{u^{0,75} + 1,7}$$

with:

- $K_2 \ge 0,50$ for plating
- $K_2 \ge 0,45$ for ordinary stiffeners
- $K_2 \ge 0,35$ for primary stiffeners

$$u = 100 \cdot \frac{s}{S_r}$$

where s is the area, in m², supported by the element (plating or stiffener). For plating, the supported area is the spacing between the stiffeners multiplied by their span, without taking for the latter more than three times the spacing between the stiffeners

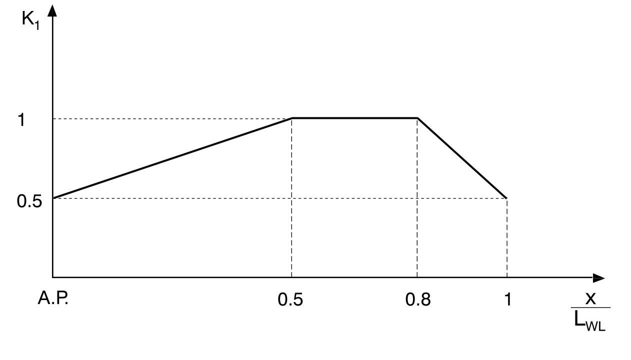
K_3 : Factor accounting for shape and deadrise of the hull, equal to:

$$K_3 = (50 - \alpha_d)/(50 - \alpha_{dCG}) \le 1$$

where α_{dCG} is the deadrise angle, in degrees, measured at LCG and α_d is the deadrise angle, in degrees, between horizontal line and straight line joining the edges of respective area measured at the longitudinal position of the load point; values taken for α_d and α_{dCG} are to be between 10° and 30°

a_{CG} : Design vertical acceleration at LCG, defined in Ch 5, Sec 1, [2.1.7].

Figure 1 : K_1 distribution factor



3 Sailing yachts of monohull type

3.1 Plating and stiffeners

3.1.1 The slamming pressure, in kN/m², considered as acting on the bottom of hull is to be not less than:

$$p_{sl} = 70 \cdot \frac{\Delta}{S_r} \cdot K_2 \cdot K_3 \cdot a_v$$

where:

Δ : Displacement, in tonnes

S_r : Reference area, m², equal to:

$$S_r = 0,7 \cdot \frac{\Delta}{T}$$

K_2 : Factor accounting for slamming area, equal to:

$$K_2 = 0,455 - 0,35 \cdot \frac{u^{0,75} - 1,7}{u^{0,75} + 1,7}$$

with:

- $K_2 \geq 0,50$ for plating
- $K_2 \geq 0,45$ for ordinary stiffeners
- $K_2 \geq 0,35$ for primary stiffeners

$$u = 100 \cdot \frac{s}{S_r}$$

where s is the area, in m², supported by the element (plating, stiffener, floor or girder). For plating, the supported area is the spacing between the stiffeners multiplied by their span, without taking for the latter more than three times the spacing between the stiffeners

K_3 : Factor accounting for shape and deadrise of the hull, equal to:

$$K_3 = (50 - \alpha_d)/(50 - \alpha_{dCG}) \leq 1$$

where α_{dCG} is the deadrise angle, in degrees, measured at LCG and α_d is the deadrise angle, in degrees, between horizontal line and a reference line defined in Fig 2 at the transversal section considered; α_d is not to be taken greater than 50 degrees

a_v : Total vertical acceleration resulting from the sum of heave and pitch acceleration (refer to Ch 5, Sec 1, [2.2.4]).

3.1.2 As a rule, the slamming pressure is to be calculated along the ship, from center of gravity of the keel or the bulb keel to fore part of ship.

Longitudinal location of calculation points can be taken as indicated in Fig 3. The value of the total vertical acceleration a_v is to be calculated at each calculation point P_i.

Figure 2 : Deadrise angle

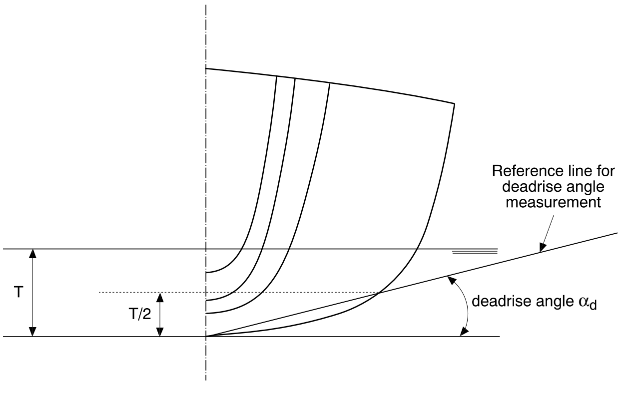
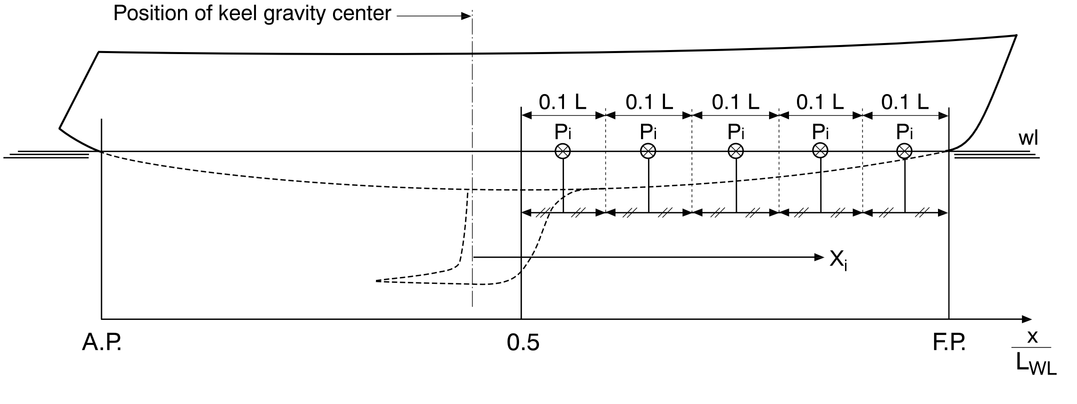


Figure 3 : Calculation points for slamming pressure



SECTION 1 GENERAL

1 Application

1.1 General

1.1.1 The requirements of the present chapter are applicable to structural members of hull and superstructures of yachts and charter yachts built in composite (totally or partly).

SECTION 1 GENERAL REQUIREMENTS AND APPLICATION

1 General

1.1 Application

1.1.1 Chapter 1 applies to the design, construction, installation, tests and trials of main propulsion and essential auxiliary machinery systems and associated equipment, pressure vessels, piping systems, and steering and manoeuvring systems installed on board classed yachts, as indicated in each Section of this Chapter and as far as class is concerned only.

Where the word yachts is used in the subsequent chapter, it means yachts and charter yachts.

1.1.2 In the present Chapter, length reference to 24 m means:

- for yacht: Hull length, L_h, as defined in EC Directive (EN ISO standard 8666:2002) reminded in Pt A, Ch 2, Sec 1, [2.2.1]
- for charter yacht: Length according to International Rules, L_{LL}, as defined in Pt A, Ch 2, Sec 1, [2.2.1].

1.2 Statutory requirements

1.2.1 Attention is to be paid to any relevant statutory requirements of the National Authority of the country in which the yacht is to be registered, as stated in Part A.

In particular, no specific requirements related to prevention of marine pollution are included in the present Rules.

1.3 Documentation to be submitted

1.3.1 Before the actual construction is commenced, the Manufacturer, Designer or yacht builder is to submit to the Society the documents (plans, diagrams, specifications and calculations) requested in the relevant Sections of this Chapter.

1.4 Definitions

1.4.1 Engine space

On yachts of less than 24m in length, the engine space is the space or compartment of the yacht containing main or auxiliary engine(s).

1.4.2 Machinery spaces

On yachts of 24 m in length and over, machinery spaces are machinery spaces of category A and other spaces containing propulsion machinery, boilers, oil fuel units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air conditioning machinery, and similar spaces, and trunks to such spaces.

1.4.3 Machinery spaces of category A

On yachts of 24 m in length and over, machinery spaces of category A are those spaces and trunks to such spaces which contain either:

a) internal combustion machinery used for main propulsion, or

b) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW, or

c) any oil-fired boiler or oil fuel unit, or any oil-fired equipment other than boilers, such as inert gas generators, incinerators, etc.

1.4.4 Fuel oil unit

Fuel oil unit is the equipment used for the preparation of fuel oil for delivery to an oil fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine, and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 0,18 N/mm^2.

1.4.5 Continuity of service

The Shipyard is to give special consideration to the reliability of single essential propulsion components. This may require a separate source of propulsion power sufficient to give the yacht a navigable speed, especially in the case of unconventional arrangements.

2 Design and construction

2.1 General

2.1.1 The machinery, pressure vessels, associated piping systems and fittings are to be of a design and construction adequate for the service for which they are intended and are to be so installed and protected as to reduce to a minimum any danger to persons on board, due regard being paid to moving parts, hot surfaces and other hazards.

The design is to have regard to materials used in construction, the purpose for which the equipment is intended, the working conditions to which it will be subjected and the environmental conditions on board.

2.2 Materials, welding and testing

2.2.1 General

Materials, welding and testing procedures are to be in accordance with the requirements of the Rule Note NR216 Materials and Welding and those given in the other Sections of this Chapter. In addition, for machinery components fabricated by welding the requirements given in [2.2.2] apply.

Table 1 : Inclination of yacht

Installations, components	Angle of inclination (degrees) **(1)**			
	Athwartship		Fore and aft	
	static	dynamic	static	dynamic
Main and auxiliary machinery	15	22,5	5	7,5
Safety equipment, e.g. emergency power installations, emergency fire pumps and their devices Switch gear, electrical and electronic appliances **(4)** and remote control systems	22,5 **(2) (3)**	22,5 **(2) (3)**	10	10

(1) Athwartship and fore-and-aft inclinations may occur simultaneously.
(2) In sailing yachts, auxiliary engines must operate satisfactorily after being heeled to a larger angle of 30° a long time.
(3) In sailing yachts, where main and/or auxiliary engines are intended to supply energy to a yacht sailing heeled a long time, the subject engines must operate satisfactorily to an angle of 30°.
(4) Up to an angle of inclination of 45° no undesired switching operations or operational changes may occur.

2.2.2 Welded machinery components

Welding processes and welders are to be approved by the Society in accordance with the Rule Note NR216 Materials and Welding, Chapter 5.

References to welding procedures adopted are to be clearly indicated on the plans submitted for approval.

Joints transmitting loads are to be either:

- full penetration butt-joints welded on both sides, except when an equivalent procedure is approved
- full penetration T- or cruciform joints.

For joints between plates having a difference in thickness greater than 3 mm, a taper having a length of not less than 4 times the difference in thickness is required. Depending on the type of stress to which the joint is subjected, a taper equal to three times the difference in thickness may be accepted.

T-joints on scalloped edges are not permitted.

Lap-joints and T-joints subjected to tensile stresses are to have a throat size of fillet welds equal to 0,7 times the thickness of the thinner plate on both sides.

In the case of welded structures including cast pieces, the latter are to be cast with appropriate extensions to permit connection, through butt-welded joints, to the surrounding structures, and to allow any radiographic and ultrasonic examinations to be easily carried out.

Where required, preheating and stress relieving treatments are to be performed according to the welding procedure specification.

2.3 Vibrations

2.3.1 Shipyards and manufacturers are to give special consideration to the design, construction and installation of propulsion machinery systems and auxiliary machinery so that any mode of their vibrations shall not cause undue stresses in this machinery in the normal operating ranges.

2.4 Operation in inclined position

2.4.1 Main propulsion machinery and all auxiliary machinery essential to the propulsion and the safety of the yacht are, as fitted in the yacht, be designed to operate when the yacht is upright and when inclined at any angle of list either way and trim by bow or stern as stated in Tab 1.

The Society may permit deviations from angles given in Tab 1, taking into consideration the type, size and service conditions of the yacht.

Machinery with a horizontal rotation axis is generally to be fitted on board with such axis arranged alongships. If this is not possible, the Manufacturer is to be informed at the time the machinery is ordered.

2.5 Ambient conditions

2.5.1 Machinery and systems covered by the Rules are to be designed to operate properly under the ambient conditions specified in Tab 2, unless otherwise specified in each Section of this Chapter.

Table 2 : Ambient conditions

AIR TEMPERATURE	
Location, arrangement	Temperature range (°C)
In enclosed spaces	between 0 and +45 **(2)**
On machinery components, boilers In spaces subject to higher or lower temperatures	According to specific local conditions
On exposed decks	between –25 and +45 **(1)**

WATER TEMPERATURE	
Coolant	Temperature (°C)
Sea water or, if applicable, sea water at charge air coolant inlet	up to +32

(1) Electronic appliances are to be designed for an air temperature up to 55°C (for electronic appliances see also Part C, Chapter 2).
(2) Different temperatures may be accepted by the Society in the case of yachts intended for restricted service.

2.6 Power of machinery

2.6.1 Unless otherwise stated in each Section of this Chapter, where scantlings of components are based on power, the values to be used are determined as follows:

- for main propulsion machinery, the power/rotational speed for which classification is requested
- for auxiliary machinery, the power/rotational speed which is available in service.

2.7 Astern power

2.7.1 Where power exceeds 5 kW, means for going astern is to be provided to secure proper control of the yacht in all normal circumstances.

The main propulsion machinery is to be capable of maintaining in free route astern at least 70% of the maximum ahead revolutions for a period of at least 30 min.

For main propulsion systems with reversing gears, controllable pitch propellers or electrical propeller drive, running astern is not to lead to an overload of propulsion machinery.

During the sea trials, the ability of the main propulsion machinery to reverse the direction of thrust of the propeller is to be demonstrated and recorded (see also Ch 1, Sec 10).

2.8 Safety devices

2.8.1 Where risk from overspeeding of machinery exists, means are to be provided to ensure that the safe speed is not exceeded.

2.8.2 Where main or auxiliary machinery including pressure vessels or any parts of such machinery are subject to internal pressure and may be subject to dangerous overpressure, means are to be provided, where practicable, to protect against such excessive pressure.

2.8.3 Where applicable, main internal combustion propulsion machinery and auxiliary machinery are to be provided with automatic shut-off arrangements in the case of failures, such as lubricating oil supply failure, which could lead rapidly to complete breakdown, serious damage or explosion.

The Society may permit provisions for overriding automatic shut-off devices.

See also the specific requirements given in the other Sections of this Chapter.

2.9 Fuels

2.9.1 Fuel oils employed for engines and boilers are, in general, to have a flash point (determined using the closed cup test) of not less than 60°C. However, for engines driving emergency generators, fuel oils having a flash point of less than 60°C but not less than 43°C are acceptable.

For yachts assigned with a restricted navigation notation, or whenever special precautions are taken to the Society's satisfaction, fuel oils having a flash point of less than 60°C but not less than 43°C may be used for engines and boilers, provided that, from previously effected checks, it is evident that the temperature of spaces where fuel oil is stored or employed will be at least 10°C below the fuel oil flash point at all times.

Fuel oil having flash points of less than 43°C may be employed on board provided that it is stored outside machinery spaces and the arrangements adopted are specially approved by the Society (see also Ch 4, Sec 9).

3 Arrangement and installation on board

3.1 General

3.1.1 Provision is to be made to facilitate cleaning, inspection and maintenance of main propulsion and auxiliary machinery, including boilers and pressure vessels.

Easy access to the various parts of the propulsion machinery is to be provided by means of metallic ladders and gratings fitted with strong and safe handrails.

Spaces containing main and auxiliary machinery are to be provided with adequate lighting and ventilation.

3.2 Gratings

3.2.1 Gratings in engine rooms, if any, are to be metallic, divided into easily removable panels.

3.3 Bolting down

3.3.1 Bedplates of machinery are to be securely fixed to the supporting structures by means of foundation bolts which are to be distributed as evenly as practicable and of a sufficient number and size so as to ensure proper fitting.

Where the bedplates bear directly on the inner bottom plating, the bolts are to be fitted with suitable gaskets so as to ensure a tight fit and are to be arranged with their heads within the double bottom.

Continuous contact between bedplates and foundations along the bolting line is to be achieved by means of chocks of suitable thickness, carefully arranged to ensure a complete contact.

The same requirements apply to thrust block and shaft line bearing foundations.

Particular care is to be taken to obtain levelling and general alignment between the propulsion engines and their shafting (see also Ch 1, Sec 2, [7]).

3.3.2 Chocking resins are to be type approved.

3.3.3 Where stays are provided for fixing the upper part of engines to the yacht's structure in order, for example, to reduce the amplitude of engine vibrations, such stays are to be so designed as to prevent damage to these engines further to deformation of the shell plating in way of the said stays. The stays are to be connected to the hull in such a way as to avoid abnormal local loads on the structure of the yacht.

3.4 Safety devices on moving parts

3.4.1 Suitable protective devices on access restrictions are to be provided in way of moving parts (flywheels, couplings, etc.) in order to avoid accidental contact of personnel with moving parts.

3.5 Gauges

3.5.1 All gauges are to be grouped, as far as possible, near each manoeuvring position; in any event, they are to be clearly visible.

3.6 Ventilation in engine or machinery spaces

3.6.1 Engine or machinery spaces are to be sufficiently ventilated so as to ensure that when machinery or boilers therein are operating at full power in all weather conditions, including heavy weather, a sufficient supply of air is maintained to the spaces for the operation of the machinery.

This sufficient amount of air is to be supplied through suitably protected openings arranged in such a way that they can be used in all weather conditions, taking into account Regulation 19 of the 1966 Load Line Convention.

Special attention is to be paid both to air delivery and extraction and to air distribution in the various spaces. The quantity and distribution of air are to be such as to satisfy machinery requirements for developing maximum continuous power.

The ventilation is to be so arranged as to prevent any accumulation of flammable gases or vapours.

3.7 Hot surfaces and fire protection

3.7.1 Surfaces, having temperature exceeding 60°C, with which the crew are likely to come into contact during operation are to be suitably protected or insulated.

Surfaces of machinery with temperatures above 220°C, e.g. steam, thermal oil and exhaust gas lines, silencers, exhaust gas boilers and turbochargers, are to be effectively insulated with non-combustible material or equivalently protected to prevent the ignition of combustible materials coming into contact with them. Where the insulation used for this purpose is oil absorbent or may permit the penetration of oil, the insulation is to be encased in steel sheathing or equivalent material.

Fire protection, detection and extinction are to comply with the requirements of Part C, Chapter 4.

3.8 Machinery remote control, alarms

3.8.1 For remote control systems of main propulsion machinery and essential auxiliary machinery and relevant alarms and safety systems, the requirements of Ch 3, Sec 2 apply.

4 Tests and trials

4.1 Works tests

4.1.1 Equipment and its components are subjected to works tests which are detailed in the relevant Sections of this Chapter. The Surveyor is to be informed in advance of these tests.

Where such tests cannot be performed in the workshop, the Society may allow them to be carried out on board, provided this is not judged to be in contrast either with the general characteristics of the machinery being tested or with particular features of the shipboard installation. In such cases, the Surveyor is to be informed in advance and the tests are to be carried out in accordance with the provisions of the Rule Note NR216 Materials and Welding relative to incomplete tests.

All boilers, all parts of machinery, all steam, hydraulic, pneumatic and other systems and their associated fittings which are under internal pressure are to be subjected to appropriate tests including a pressure test before being put into service for the first time as detailed in the other Sections of this Chapter.

4.2 Trials on board

4.2.1 Trials on board of machinery are detailed in Ch 1, Sec 10.