Wind Propulsion Systems

February 2021

Rule Note
NR 206 DT R01 E

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BUREAU VERITAS MARINE & OFFSHORE

GENERAL CONDITIONS

1. INDEPENDENCE OF THE SOCIETY AND APPLICABLE TERMS

1.1 The Society shall remain at all times an independent contractor and neither the Society nor any of its officers, employees, servants, agents or subcontractors shall be or act as an employee, servant or agent of any other party hereto in the performance of the Services.

1.2 The operations of the Society in providing its Services are exclusively conducted by way of random inspections and do not, in any circumstances, involve monitoring or exhaustive verification.

1.3 The Society acts as a services provider. This cannot be construed as an obligation bearing on the Society to obtain a result or as a warranty. The Society is not and may not be considered as an underwriter, broker in Unit's sale or chartering, expert in Unit's valuation, consulting engineer, controller, naval architect, designer, manufacturer, shipbuilder, repair or conversion yard, charterer or shipowner; none of the above listed being relieved from any of their expressed or implied obligations as a result of the interventions of the Society.

1.4 Only the Society is qualified to apply and interpret its Rules.

1.5 The Client acknowledges the latest versions of the Conditions and of the applicable Rules applying to the Services' performance.

1.6 Unless an express written agreement is made between the Parties on the applicable Rules, the applicable Rules shall be the Rules applicable at the time of entering into the relevant contract for the performance of the Services.

1.7 The Services' performance is solely based on the Conditions. No other terms shall apply whether express or implied.

2. DEFINITIONS

2.1 **"Certificate(s)"** means classification or statutory certificates, attestations and reports following the Society's intervention.

2.2 **"Certification"** means the activity of certification in application of national and international regulations or standards ("Applicable Referential"), in particular by delegation from different governments that can result in the issuance of a Certificate.

2.3 **"Classification"** means the classification of a Unit that can result or not in the issuance of a classification Certificate with reference to the Rules. Classification (or Certification as defined in clause 2.2) is an appraisement given by the Society to the Client, at a certain date, following surveys by its surveyors on the level of compliance of the Unit to the Society's Rules and/or to Applicable Referential for the Services provided. They cannot be construed as an implied or express warranty of safety, fitness for the purpose, seaworthiness of the Unit or of its value for sale, insurance or chartering.

2.4 **"Client"** means the Party and/or its representative requesting the Services.

2.5 **"Conditions"** means the terms and conditions set out in the present document.

2.6 **"Industry Practice"** means international maritime and/or offshore industry practices.

2.7 **"Intellectual Property"** means all patents, rights to inventions, utility models, copyright and related rights, trade marks, logos, service marks, trade dress, business and domain names, rights in trade dress or get-up, rights in goodwill or to sue for passing off, unfair competition rights, rights in designs, rights in computer software, database rights, topography rights, moral rights, rights in confidential information (including know-how and trade secrets), methods and protocols for Services, and any other intellectual property rights, in each case whether capable of registration, registered or unregistered and including all applications for and renewals, reversions or extensions of such rights, and all similar or equivalent rights or forms of protection in any part of the world.

2.8 **"Parties"** means the Society and Client together.

2.9 **"Party"** means the Society or the Client.

2.10 **"Register"** means the public electronic register of ships updated regularly by the Society.

2.11 **"Rules"** means the Society's classification rules (available online on veristar.com), guidance notes and other documents. The Society's Rules take into account at the date of their preparation the state of currently available and proven technical minimum requirements but are not a standard or a code of construction neither a guide for maintenance, a safety handbook or a guide of professional practices, all of which are assumed to be known in detail and carefully followed at all times by the Client.

2.12 **"Services"** means the services set out in clauses 2.2 and 2.3 but also other services related to Classification and Certification such as, but not limited to: ship and company safety management certification, ship and port security certification, maritime labour certification, training activities, all activities and duties incidental thereto such as documentation on any supporting means, software, instrumentation, measurements, tests and trials on board. The Services are carried out by the Society according to the Rules and/or the Applicable Referential and to the Bureau Veritas' Code of Ethics. The Society shall perform the Services according to the applicable national and international standards and Industry Practice and always on the assumption that the Client is aware of such standards and Industry Practice.

2.13 **"Society"** means the classification society **'Bureau Veritas Marine & Offshore SAS'**, a company organized and existing under the laws of France, registered in Nanterre under number 821 131 844, or any other legal entity of Bureau Veritas Group as may be specified in the relevant contract, and whose main activities are Classification and Certification of ships or offshore units.

2.14 **"Unit"** means any ship or vessel or offshore unit or structure of any type or part of it or system whether linked to shore, river bed or sea bed or not, whether operated or located at sea or in inland waters or partly on land, including submarines, hovercrafts, drilling rigs, offshore installations of any type and of any purpose, their related and ancillary equipment, subsea or not, such as well head and pipelines, mooring legs and mooring points or otherwise as decided by the Society.

3. SCOPE AND PERFORMANCE

3.1 Subject to the Services requested and always by reference to the Rules, and/or to the Applicable Referential, the Society shall:

- review the construction arrangements of the Unit as shown on the documents provided by the Client;
- conduct the Unit surveys at the place of the Unit construction;
- class the Unit and enter the Unit's class in the Society's Register;
- survey the Unit periodically in service to note whether the requirements for the maintenance of class are met.

The Client shall inform the Society without delay of any circumstances which may cause any changes on the conducted surveys or Services.

3.2 The Society will not:

- declare the acceptance or commissioning of a Unit, nor its construction in conformity with its design, such activities remaining under the exclusive responsibility of the Unit's owner or builder;
- engage in any work relating to the design, construction, production or repair checks, neither in the operation of the Unit or the Unit's trade, neither in any advisory services, and cannot be held liable on those accounts.

4. RESERVATION CLAUSE

4.1 The Client shall always: (i) maintain the Unit in good condition after surveys; (ii) present the Unit for surveys; and (iii) inform the Society in due time of any circumstances that may affect the given appraisement of the Unit or cause to modify the scope of the Services.

4.2 Certificates are only valid if issued by the Society.

4.3 The Society has entire control over the Certificates issued and may at any time withdraw a Certificate at its entire discretion including, but not limited to, in the following situations: where the Client fails to comply in due time with instructions of the Society or where the Client fails to pay in accordance with clause 6.2 hereunder.

4.4 The Society may at times and at its sole discretion give an opinion on a design or any technical element that would 'in principle' be acceptable to the Society. This opinion shall not presume on the final issuance of any Certificate nor on its content in the event of the actual issuance of a Certificate. This opinion shall only be an appraisement made by the Society which shall not be held liable for it.

5. ACCESS AND SAFETY

5.1 The Client shall give to the Society all access and information necessary for the efficient performance of the requested Services. The Client shall be the sole responsible for the conditions of presentation of the Unit for tests, trials and surveys and the conditions under which tests and trials are carried out. Any information, drawing, etc. required for the performance of the Services must be made available in due time.

5.2 The Client shall notify the Society of any relevant safety issue and shall take all necessary safety-related measures to ensure a safe work environment for the Society or any of its officers, employees, servants, agents or subcontractors and shall comply with all applicable safety regulations.

6. PAYMENT OF INVOICES

6.1 The provision of the Services by the Society, whether complete or not, involves, for the part carried out, the payment of fees thirty (30) days upon issuance of the invoice.

6.2 Without prejudice to any other rights hereunder, in case of Client's payment default, the Society shall be entitled to charge, in addition to the amount not properly paid, interest equal to twelve (12) months LIBOR plus two (2) per-cent as of due date calculated on the number of days such payment is delinquent. The Society shall also have the right to withhold Certificates and other documents and/or to suspend or revoke the validity of Certificates.

6.3 In case of dispute on the invoice amount, the undisputed portion of the invoice shall be paid and an explanation on the dispute shall accompany payment so that action can be taken to resolve the dispute.

7. LIABILITY

7.1 The Society bears no liability for consequential loss. For the purpose of this clause consequential loss shall include, without limitation:

- Indirect or consequential loss;
- Any loss and/or deferral of production, loss of product, loss of use, loss of bargain, loss of revenue, loss of profit or anticipated profit, loss of business and business interruption, in each case whether direct or indirect.

The Client shall defend, release, save, indemnify, defend and hold harmless the Society from the Client's own consequential loss regardless of cause.

7.2 Except in case of wilful misconduct of the Society, death or bodily injury caused by the Society's negligence and any other liability that could not be, by law, limited, the Society's maximum liability towards the Client is limited to one hundred and fifty per-cent (150%) of the price paid by the Client to the Society for the Services having caused the damage. This limit applies to any liability of whatsoever nature and howsoever arising, including fault by the Society, breach of contract, breach of warranty, tort, strict liability, breach of statute.

7.3 All claims shall be presented to the Society in writing within three (3) months of the completion of Services' performance or (if later) the date when the events which are relied on were first discovered by the Client. Any claim not so presented as defined above shall be deemed waived and absolutely time barred.

8. INDEMNITY CLAUSE

8.1 The Client shall defend, release, save, indemnify and hold harmless the Society from and against any and all claims, demands, lawsuits or actions for damages, including legal fees, for harm or loss to persons and/or property tangible, intangible or otherwise which may be brought against the Society, incidental to, arising out of or in connection with the performance of the Services (including for damages arising out of or in connection with opinions delivered according to clause 4.4 above) except for those claims caused solely and completely by the gross negligence of the Society, its officers, employees, servants, agents or subcontractors.

9. TERMINATION

9.1 The Parties shall have the right to terminate the Services (and the relevant contract) for convenience after giving the other Party thirty (30) days' written notice, and without prejudice to clause 6 above.

9.2 The Services shall be automatically and immediately terminated in the event the Client can no longer establish any form of interest in the Unit (e.g. sale, scrapping).

9.3 The Classification granted to the concerned Unit and the previously issued Certificates shall remain valid until the date of effect of the termination notice issued, or immediately in the event of termination under clause 9.2, subject to compliance with clause 4.1 and 6 above.

9.4 In the event where, in the reasonable opinion of the Society, the Client is in breach, or is suspected to be in breach of clause 16 of the Conditions, the Society shall have the right to terminate the Services (and the relevant contracts associated) with immediate effect.

10. FORCE MAJEURE

10.1 Neither Party shall be responsible or liable for any failure to fulfil any term or provision of the Conditions if and to the extent that fulfilment has been delayed or temporarily prevented by a force majeure occurrence without the fault or negligence of the Party affected and which, by the exercise of reasonable diligence, the said Party is unable to provide against.

10.2 For the purpose of this clause, force majeure shall mean any circumstance not being within a Party's reasonable control including, but not limited to: acts of God, natural disasters, epidemics or pandemics, wars, terrorist attacks, riots, sabotages, impositions of sanctions, embargoes, nuclear, chemical or biological contaminations, laws or action taken by a government or public authority, quotas or prohibition, expropriations, destructions of the worksite, explosions, fires, accidents, any labour or trade disputes, strikes or lockouts.

11. CONFIDENTIALITY

11.1 The documents and data provided to or prepared by the Society in performing the Services, and the information made available to the Society, will be treated as confidential except where the information:

- is properly and lawfully in the possession of the Society;
- is already in possession of the public or has entered the public domain, other than through a breach of this obligation;
- is acquired or received independently from a third party that has the right to disseminate such information;
- is required to be disclosed under applicable law or by a governmental order, decree, regulation or rule or by a stock exchange authority (provided that the receiving Party shall make all reasonable efforts to give prompt written notice to the disclosing Party prior to such disclosure).

11.2 The Parties shall use the confidential information exclusively within the framework of their activity underlying these Conditions.

11.3 Confidential information shall only be provided to third parties with the prior written consent of the other Party. However, such prior consent shall not be required when the Society provides the confidential information to a subsidiary.

11.4 Without prejudice to sub-clause 11.1, the Society shall have the right to disclose the confidential information if required to do so under regulations of the International Association of Classifications Societies (IACS) or any statutory obligations.

12. INTELLECTUAL PROPERTY

12.1 Each Party exclusively owns all rights to its Intellectual Property created before or after the commencement date of the Conditions and whether or not associated with any contract between the Parties.

12.2 The Intellectual Property developed by the Society for the performance of the Services including, but not limited to drawings, calculations, and reports shall remain the exclusive property of the Society.

13. ASSIGNMENT

13.1 The contract resulting from to these Conditions cannot be assigned or transferred by any means by a Party to any third party without the prior written consent of the other Party.

13.2 The Society shall however have the right to assign or transfer by any means the said contract to a subsidiary of the Bureau Veritas Group.

14. SEVERABILITY

14.1 Invalidity of one or more provisions does not affect the remaining provisions.

14.2 Definitions herein take precedence over other definitions which may appear in other documents issued by the Society.

14.3 In case of doubt as to the interpretation of the Conditions, the English text shall prevail.

15. GOVERNING LAW AND DISPUTE RESOLUTION

15.1 These Conditions shall be construed in accordance with and governed by the laws of England and Wales.

15.2 Any dispute shall be finally settled under the Rules of Arbitration of the Maritime Arbitration Chamber of Paris ("CAMP"), which rules are deemed to be incorporated by reference into this clause. The number of arbitrators shall be three (3). The place of arbitration shall be Paris (France). The Parties agree to keep the arbitration proceedings confidential.

15.3 Notwithstanding clause 15.2, disputes relating to the payment of the Society's invoices may be submitted by the Society to the *Tribunal de Commerce de Nanterre*, France, or to any other competent local Court, at the Society's entire discretion.

16. PROFESSIONAL ETHICS

16.1 Each Party shall conduct all activities in compliance with all laws, statutes, rules, economic and trade sanctions (including but not limited to US sanctions and EU sanctions) and regulations applicable to such Party including but not limited to: child labour, forced labour, collective bargaining, discrimination, abuse, working hours and minimum wages, anti-bribery, anti-corruption, copyright and trademark protection, personal data protection (https://personaldataprotection.bureauveritas.com/privacypolicy).

Each of the Parties warrants that neither it, nor its affiliates, has made or will make, with respect to the matters provided for hereunder, any offer, payment, gift or authorization of the payment of any money directly or indirectly, to or for the use or benefit of any official or employee of the government, political party, official, or candidate.

16.2 In addition, the Client shall act consistently with the Bureau Veritas' Code of Ethics and, when applicable, Business Partner Code of Conduct both available at https://group.bureauveritas.com/group/corporate-social-responsibility/operational-excellence.

RULE NOTE NR 206

NR 206

Wind Propulsion Systems

February 2021

Section 7 Running Rigging Structure

SECTION 1 GENERAL

1 Application

1.1 General

1.1.1 The present Rule Note is applicable to wind propulsion systems fitted on board ships.

Wind propulsion systems mean wind propulsion technologies that directly transfer mechanical propulsion forces from wind to the ship's structure.

The types of wind propulsion system considered in the present Rule Note, including standing rigging and/or running rigging (see [2.2]), are detailed in [2.1].

1.1.2 It is considered that apart from the wind propulsion system, the ship is self-propelled with power of propulsion enabling to proceed at a speed not less than 7 knots.

Note 1: The speed of the ship is to be determined using procedures deemed suitable by the Society.

For example: speed of at least 7 knots is attained during propulsion trials according to ISO 19019 "Sea-going vessels and marine technology - Instructions for planning, carrying out and reporting sea trials", where conditions of wind and sea state are in accordance with ISO 15016 "Ships and marine technology - Guidelines for the assessment of speed and power performance by analysis of speed trial data".

1.1.3 The present Rule Note is also applicable to the part of the base ship affected by the installation of wind propulsion systems such as:

- stability
- arrangement
- hull structure
- electrical installations
- automation
- fire safety
- rudder and steering gear
- equipment in chain and anchors.

1.1.4 Ships fitted with a wind propulsion system meeting the requirements of the present Rules may be assigned the following additional class notations **WPS1** or **WPS2**, as defined in Sec 2, [2.2]:

- **WPS1** for wind propulsion system including standing part only,

  These propulsion systems are intended to assist the conventional propulsion in specific weather conditions to reduce the consumption of conventional ships.

- **WPS2** for wind propulsion system including standing and running part.

1.1.5 Exclusion

The Society reserves the right, for any reason of specific design, construction or materials, to exclude the sail system from the scope of the wind propulsion system.

In such case, the sail system can be subject to approval or certification, see Sec 3.

1.2 Scope

1.2.1 The present Rule Note defines set of requirements covering the followings:

- Requirements for granting an additional class notation **WPS1** or **WPS2** to a ship fitted with a wind propulsion system complying with the requirement of this Rule Note (see Sec 2)
- Certification of equipments and accessories associated to the wind propulsion system (see Sec 3 and App 2)
- Materials and equipment used for the construction of wind propulsion systems (see Sec 4)
- Design conditions and loads considered for the wind propulsion system (see Sec 5)
- Scantling check of the standing rigging structure (see Sec 6) and the running rigging structure (see Sec 7)
- Assessment of the drive systems (see Sec 8)
- Assessment of the parts of the ship affected by the propulsion systems (see [1.1.3] and Sec 9).
- Sea trials, initial inspection and testing (see Sec 10)
- In-service surveys (see Sec 11)

Guidelines for energy efficiency design index (EEDI) calculations are provided in App 1.

1.2.2 Upon request of the Designer or Builder, the Society may carry out specific certification at different development stages (approval in principle, design, construction …) as defined in Sec 3.

These individual certification steps could be considered for the final classification of the wind propulsion systems.

1.3 Risk analysis

1.3.1 Depending on the type of the wind propulsion system, risk analysis (as defined in [2.4]) may be required to determine the critical conditions that the system is capable to withstand.

When required by the risk analysis, the accidental conditions are to be evaluated, see Sec 5, [3.4].

1.3.2 Risk analysis reports

When risk analysis is performed, a detailed report for risk analysis with a detailed follow-up report of actions and mitigation measures taken in response to risk analysis findings are to be submitted to the Society for information.

Note 1: Risk analysis reports are considered for information only, to ensure that findings and conclusions of the risk analysis are properly taken into account for the design of the wind propulsion system.

1.4 Operating manual and maintenance instruction manual

1.4.1 Operating manual

Wind propulsion system is to operate within conditions as given by the operating manual, see Sec 5, [1.2].

The operating manual is to be kept available on board the ship.

1.4.2 Maintenance plan

Wind propulsion system is to be maintained in accordance with the maintenance plan, see Sec 11, [1.1.2].

The maintenance instruction manual is to be provided on board the ship.

1.5 Applicable rules

1.5.1 Unless otherwise specified, the reference to other Rules of the Society are listed in Tab 1.

Table 1 : Reference to other Rules of the Society

Reference	Rule
NR467	Rules for the classification of steel ships
NR600	Hull structure and arrangement for the classification of cargo ships less than 65 m and non-cargo ships less than 90 m
NR216	Rules on materials and welding for the classification of marine units
NR266	Requirements for survey of materials and equipment for the classification of ships and offshore units
NR546	Hull in composite materials and plywood, material approval, design principles, construction and survey
NR561	Hull in aluminium alloys, design principles, construction and survey

2 Definitions

2.1 Wind propulsion system types

2.1.1 The following types of wind propulsion systems are considered in the present Rule Note:

- Modern rig:

  Rig with one or further masts supporting mainsail and headsails, equipped with or without spreaders and supported by transverse shrouds and forestay and backstays. The sails are trimmed to the wind by the running rigging.

- Traditional rig:

  Rig with further masts supported by transverse and longitudinal standing rigging shrouds, with yards supporting square sails and with headsails. The sails are trimmed to the wind by the running rigging.

- Free-standing rig:

  Rig that doesn't rely on shrouds and stays to keep the masts up. As a rule, self supporting rigs have only headsail trimmed to the wind by the running rigging. The mast can be fixed or turned by rotation.

- Free standing rotating rig:

  Free rotating mast with integral rigid boom extending fore and aft of the mast supporting the sail tacks. The sails are trimmed to the wind by rotation of the mast.

- Modern square-rig:

  Free-standing and rotating masts with curved yards rigidly connected to the mast. The sails furl into the mast and are trimmed to the wind by the rotation of the mast.

- Wing sail:

  Wing, reefable or not, fixed to a free rotating mast with as a general rules integral long boom. The wing sails are trimmed to the wind by rotation of the mast.

- Kite rig:

  Kite not supported by mast and trimmed to the wind by kite control lines.

- Rotor sail:

  Free-standing rotor generating an aerodynamic lift force.

- Suction wings:

  Orientable wing with internal ventilated system to use boundary layer suction effect.

Wind propulsion system can be telescopic, articulated, tilted.

Other type of wind propulsion devices are to be examined on a case by case basis by the Society.

2.2 Standing and running rigging

2.2.1 Standing rigging

The standing rigging means the masts and all the equipment and accessories permanently fixed to the mast and to the hull used to support the wind propulsion system (see Tab 2).

It includes elements essential to the overall integrity and safety of the wind propulsion system.

2.2.2 Running rigging

The running rigging means the rigging elements used for setting, furling, shaping, trimming and controlling the wind propulsion system and accessories fixed to the hull used to support these elements (see Tab 2).

It includes elements the failure of which might induce only localised effects.

Table 2 : Standing and running rigging

Wind propulsion system	Standing rigging	Running rigging **(1)**
Modern rig	Masts, shrouds, fore and back stays, running backstays, cable turnbuckles, spreaders	Booms, sail sheets and halyards, winches, clutch, sheaves
Traditional rig	Masts, shrouds, fore and back stays, running backstays, cable turnbuckles	Yards, sail sheets, winches, clutch, sheaves
Free standing rig	Mast	Booms, sail sheets and halyards, winches, clutch, sheaves
Free standing rotating rig	Mast and integrated long boom, fore stay, back and running backstays when provided	Sail sheets, winches, clutch, sheaves, mast rotating system **(2)**
Modern square-rig	Mast and yards, yard shrouds	Mast rotating system **(2)**
Wing sail	Mast and integrated long boom	Wing sail halyards, mast rotating system **(2)**, flap rotation system, telescopic system
Kite	Kite tension ropes, sheaves, winch	Kite control lines with its sheaves and dedicated winches
Rotor sail	Rotating cylinder	Cylinder rotating system **(2)**
Suction wings	Wing mast	Air suction system, flap rotation systems, wing body rotation system **(2)**

(1) Elements essential for the integrity and safety of the wind propulsion system, are to be considered in the scope of the additional class notation **WPS1**

(2) When the slewing ring is part of a set of an automatic release system to avoid wind overload on the wind propulsion system considered for the scantling of the standing rigging, the slewing ring scantling is to be checked within the scope of the additional class notation **WPS1**

2.3 Ship hull areas

2.3.1 The ship hull areas are the hull areas supporting the reaction forces and moments induced by the standing and running rigging.

These areas are mainly the local hull structure reinforcement in way of:

- mast step
- pad eyes and chain plates
- main and fore sheet track rails
- winches and clutch
- sheave supports.

2.4 Risk analysis

2.4.1 Risk analysis is a structured method involving:

- identification of hazards related to the ship, installation or equipment
- estimation of hazard probabilities or frequencies
- estimation of hazard consequences.

2.4.2 HAZID - Hazard Identification

The HAZard IDentification (HAZID) is a structured method for identifying hazards, threats and consequences affecting assets, environment, human life or economy.

It consists of a brain-storming workshop with designer and client personnel engineering disciplines about project management, commissioning and operations.

2.4.3 HAZOP - Hazard and Operability Study

A HAZard and OPerability (HAZOP) study, also known as process hazard analysis (PHA), is a well-proven, structured, team-based method for process hazard identification commonly used during the process design phase or for proposed modifications.

HAZOP makes detailed examination of the process and engineering intention of new or existing facilities to assess the potential hazards from operating outside of the intended design, or malfunction of individual items of equipment and their consequential effects on the facility as a whole.

SECTION 2 CLASSIFICATION REQUIREMENTS

1 General

1.1 Application

1.1.1 The present Section defines the process within the scope of classification of ships fitted with a wind propulsion systems.

The general principles of Classification are detailed in NR467, Pt A, Ch 1, Sec 1.

The purpose of Classification notations are defined in NR467, Pt A, Ch 1, Sec 2

The general conditions of assignment, maintenance and withdrawal of Class are given in NR467, Part A, Chapter 2.

2 Additional class notations WPS1 and WPS2

2.1 General

2.1.1 In accordance with the requirements of NR467, Pt A Ch 1 Sec 2, Classification of ships complying with the requirements of this Rule Note results in assignment of an additional class notation **WPS1** or **WPS2**, completed by a construction mark.

Ships fitted with a wind propulsion system complying with requirements of this Rule Note are eligible for assignment of one of the following additional class notations:

WPS1 when the ship is fitted with a wind propulsion system including standing part only (see [2.2]).

WPS2 when the ship is fitted with a wind propulsion system including standing and running part (see [2.3])

2.2 Additional class notation WPS1

2.2.1 For Ship fitted with a wind propulsion system including standing part only, granting of **WPS1** means the compliance with the requirements of the present Rule Note on:

- standing rigging part of the wind propulsion system
- global hull structure, and the local hull structure supporting the forces and moments induced by the standing rigging
- mast rotating system and its equipment, the system of measurement of the strain gauge and all the systems provided as automatic release systems to avoid wind overload on the wind propulsion system when taken into account for the scantling of the standing rigging as defined in Sec 6
- systems playing an essential part in the safety and integrity of the wind propulsion system.

2.3 Additional class notation WPS2

2.3.1 For Ship fitted with a wind propulsion system including standing and running part, granting of **WPS2** means the compliance with:

- the requirements listed in [2.2.1] on standing rigging part, and
- the requirements of the present Rule Note on:
    - running rigging part of the wind propulsion system
    - global hull structure, and the local hull structure supporting the forces and moments induced by the running rigging
    - systems playing an essential part in the operation and performance of the wind propulsion system.

2.4 Construction marks

2.4.1 In accordance with the provisions of NR467, Pt A, Ch 1, Sec 2 the construction marks ✠, ✠̲ or • are associated with the additional class notations **WPS1** and **WPS2**.

example: ✠ **WPS1**

The construction mark identifies the procedure under which the wind propulsion system and its main equipment have been surveyed for the initial assignment of the class.

2.4.2 The mark ✠ is assigned to the relevant part of the wind propulsion system, when it has been surveyed by the Society during construction. The Society:

- approves the plans and the documentation as required by the Rules
- proceeds with the appraisal of the design of materials and equipment used in the construction of the wind propulsion system and their inspection at works
- carries out surveys, attends tests and trials provided for in the Rules, or obtains appropriate evidence to satisfy itself that the scantlings and construction meet the rule requirements in relation to the approved drawings.

2.4.3 The mark ✠̲ is assigned to the wind propulsion system surveyed by an another IACS member during its construction and classed after construction according to the following requirements:

- approval of the plans and documentation as required by the Rules (these drawings are to be marked with the stamps of the IACS member by which they were approved upon construction)
- examination of materials inspection certificates, construction survey attestations, test certificates at works for equipment and accessories
- survey of the wind propulsion system (the extent of this survey depends on the existing conditions of certification, on the general maintenance conditions and on the age of the wind propulsion system. As a rule, general

tests are not required if the existing certification for these tests (tests prior to first use and/or quinquennial renewal of tests) is valid.

2.4.4 The mark • is assigned to the wind propulsion system where the procedure for the assignment of classification is other than those detailed in [2.4.2] and [2.4.3], but however deemed acceptable by the Society.

2.5 Classification process for the initial assignment of class

2.5.1 Document to be submitted

The documents to be submitted for information or for approval prior to granting **WPS1** or **WPS2** are listed in Tab 1 and Sec 8, Tab 2.

Table 1 : Documents to be submitted

Item	I/A **(1)**	Document	**WPS1**	**WPS2**
1	I	General structural arrangement of the wind propulsion system with all necessary data for a good understanding of the functioning of the system	X	X
2	A	Operating manual including, operational contractual conditions with limit meteorological conditions (wind and sea state)	X	X
3	I	Definition and description of the various safety devices to prevent from a possible sail overload	X	X
4	I	General arrangement of the ship	X	X
5	I	Deck loading plans	X	X
6	I	Aerodynamic test results in wind-tunnel, when relevant	X	X
7	I	Risk analysis, when relevant	X	X
8	A	All the drawings necessary to define the standing rigging structure specifying the materials and the connections between the different elements of the standing rigging	X	X
9	A	All the drawings necessary to define the running rigging structure specifying the materials and the mechanical characteristics of the different elements of the running rigging		X
10	I	The shrouds and stays pre-tensioning values, where applicable, specifying the pre-tensioning control process at construction and in operation	X	X
11	A	Halyard and sheet ropes characteristics and sail furling devices		X
12	A	Chain plates, pad eyes... supporting the forces reactions induced by the standing rigging	X	X
13	A	Winch, clutch, sheet track rails, sheave supports characteristics... supporting the forces reactions induced by the running rigging		X
14	A	Local hull structure reinforcements in way of ship hull areas as defined in Sec 1, [2.3], specifying the forces reactions induced by the running rigging (winch, clutch, sheet track rails, sheave supports...)	X	X
15	A	Ship hydraulic and electrical installations intended to power the operating running rigging system when applicable (see also Sec 8, Tab 2)		X
16	A	Mast rotating system and its equipment, system of measurement of the strain gauge and all systems provided as automatic release systems to avoid wind overload on the wind propulsion system when taken into account for the scantling of the standing rigging as defined in Sec 6 (see also Sec 8, Tab 2)	X	X
17	A	All the drawings necessary to define the general arrangement of the electrical and hydraulic installations when applicable (see also Sec 8, Tab 2)		X
18	I	Scantling justification documents **(2)**: • forces reaction calculation results on the standing and, when applicable, on the running rigging indicating the considered loads and calculation methods • computer calculations , reference of used softwares, details of the model specifying the model geometry, the boundary conditions, the loading methods, etc...	X	X
19	A	Maintenance and inspection manual	X	X

(1) I: for information; A: for approval

(2) Justifications may be based on recognized experimental results, recorded on similar structures and possibly corrected to take into account minor variations of some parameters, effects of which have been suitably evaluated.
In that case, the tested structures, the test conditions, methods and results are to be clearly defined, and variations in the parameters and their effects on the structure are to be justified

2.5.2 Approval of drawings

The structural arrangement of wind propulsion system drawings, and the drawings showing the sail automatic control and monitoring systems, safety systems, electrical and hydraulic systems are to be submitted to the Society for checking the compliance with the present Rule Note.

As a rule, modifications of the approved plans regarding items covered by classification are to be submitted. This is specially valid for equipment or accessories covered by the class notation.

The Society may also call for additional information according to the specific nature of the ship to be classed.

2.5.3 Appraisal of the materials and inspection at works

The requirements for the manufacture, inspection and certification of steel and aluminium materials used for standing rigging building (mast, boom, spreaders, etc...) are defined in NR216 Rules on materials and welding for the classification of marine units.

The requirements for the manufacture, inspection and certification of composite materials used for standing rigging building (mast, boom, spreaders, etc...) are defined in NR546 "Hull in composite materials".

2.5.4 Appraisal of equipment and accessories and inspections at works

The requirements for appraisal of equipment and accessories and inspections at works are defined in Sec 4.

2.5.5 Survey of material and equipment

Requirements for Survey of Materials and Equipment are defined in App 2.

2.5.6 Installation on board

The requirements for tests after fitting on board are defined in Sec 10.

2.5.7 Sea trials

The requirements for the sea trials are defined in Sec 10.

2.6 In-Service Surveys

2.6.1 Classed ship are submitted to surveys for maintenance of Class. Requirements for Annual survey and Class renewal survey requested for maintenance of notations **WPS1** and **WPS2** are detailed in Sec 11.

SECTION 3 CERTIFICATION REQUIREMENTS

1 Certification of equipment and accessories

1.1 General

1.1.1 Certifications of equipment and accessories concerned by the class notation **WPS1** or **WPS2** are to be carried out within the scope of the wind propulsion system classification according to Sec 4, [5].

Certification of equipment and accessories may be also carried out within the scope of certification by modules (see Article [2]).

2 Certification principles

2.1 Approval in principle (AIP)

2.1.1 AIP is a flexible process, adapted to early certification stages and applicable to innovative project as soon as pilot studies are completed. AIP confirms that the outline project does not present any contradiction either with the state of art or with the applicable rules.

2.1.2 The AIP is based on qualitative studies (no independent calculations) in accordance with the objectives chosen by the Client.

For example, AIP may have the following objectives:

- to establish the design code to comply with
- to verify that the design is feasible, achievable, and contains no technological showstoppers that may prevent the design from further development
- to verify that the design is deemed to be suitable for the conditions of use (environmental conditions, ship, etc.)
- to verify that the design is deemed to be suitable for use in all phases of operation including design, manufacturing, transportation, installation, operation (navigation) and maintenance
- provide recommendations to fulfil through the following phases of the project.

2.1.3 As a first step, the Society and the Client need to define the scope and extent of the AIP:

- objectives (see [2.1.2])
- rules and regulations to be considered for the review
- scope of the AIP (list of submitted documentation).

2.2 Design Approval

2.2.1 Design approval is relevant when the project developing studies are sufficiently advanced. At this stage, the main areas covered by certification are reviewed. Main structure and equipment drawings have been approved.

2.2.2 The Design Approval is based on qualitative/quantitative studies (independent calculation may be performed by the Society).

It allows implementation on a given project without significant risk of:

- major compliance issue with applicable Rules & Regulations
- major qualification issue.

2.3 Product Approval

2.3.1 The product approval is mainly based on test campaigns. It can be carried out on the basic materials, representative sampling and the mast manufacturing process, the shrouds and the fixing systems, the winches, the cylinders

These tests are to be based on the BV standards or equivalent.

2.4 Type Approval

2.4.1 Type Approval is applicable for the "generic part" of a standard commercial wind propulsion system, considering a series of units of common design and manufacture.

2.4.2 The type approval is based on qualitative/quantitative studies, tests and survey. Its purpose is to include:

- confirmation that the wind propulsion system is designed, documented and manufactured in conformity with design assumptions and technical requirements
- demonstration provided by the Applicant that it is possible to install, operate and maintain the wind propulsion system in accordance with the design documentation
- check of wind propulsion system according to specified environmental conditions, corresponding to a specific load envelope.

3 Certification of rigging

3.1 Approval in principle (AIP)

3.1.1 Approval In Principle (AIP), is applicable to innovative projects from the early stages of design,

3.1.2 AIP is to confirm that outline project doesn't present any show stopper nor contradiction with the present note.

3.1.3 An AIP can be carried out on the basis of the calculation note. It makes possible to consolidate the design assumptions or to specify the technical points to be defined later on:

- loadings: wind, sea conditions, method of calculating loads, etc.
- the basic materials for the wind propulsion system (fibers, resins, etc.): names of suppliers, any certifications to be provided, etc.
- scantling criteria: materials resistance, safety coefficients, etc.
- manufacturing processes, contents, etc., identification of subcontractors
- the assembly of mast if built in different parts.

3.2 Design Approval (DA)

3.2.1 Design approval is to confirm that the wind propulsion system is designed, documented in conformity with requirements of the present note.

3.3 Type Approval (TA)

3.3.1 Type Approval is to confirm that the wind propulsion system is designed, documented and manufactured in conformity with requirements of the present note.

Demonstration that it is possible to install, operate and maintain the wind propulsion system in accordance with requirements is required.

3.4 Project Approval (PA)

3.4.1 Project Approval is to confirm for a specific ship that the wind propulsion system and if needed particular foundation design meet requirements of the present note, governed by specific conditions of the base ship.

Certification confirms that ship base conditions (stability, electrical system, manoeuvrability...) conform with those defined in the design documentation.

SECTION 4 MATERIAL AND EQUIPMENT

1 General

1.1 Application

1.1.1 The characteristics of the following materials and equipment used in the construction of wind propulsion systems are to comply with the present Section based on the granted additional class notation **WPS1** or **WPS2**:

- materials used for the construction of mast, boom, spreader, yards, cylinder for rotor sail or suction wings and rotating systems when relevant
- rope materials used for the mast rigging (steel wire rope, steel rod, synthetic fibres) and their terminals and accessories (turnbuckle, …)
- rope and accessories for running rigging (sail sheets and halyards, sheaves, padeyes, winches,…)
- hydraulic system equipment when relevant (piping, hydraulic station, hydraulic jacks,…)
- electrical system and automation system when relevant.

1.2 Corrosion

1.2.1 General

Structures and components constituting the wind propulsion system are to be protected against corrosion damage in sea water atmosphere, using selected material as little sensitive as possible to corrosion, combined with additional protective measure through coating or painting, if necessary.

1.2.2 Corrosion addition

A corrosion addition is to be considered, if necessary:

- in special areas subjected to mechanical wastage due to abrasion (e.g. moving parts, access)
- when the concerned structural members are left unprotected
- when the structural members are not sufficiently protected against corrosion
- in area of difficult maintenance and inspection.

1.2.3 Plan for corrosion protection

An overall plan for the corrosion protection scheme is to be prepared.

Corrosion protection scheme is to stated the complete characteristics of coatings, primers and paints adapted to the nature of material and the location of the component to be protected.

Surfaces are to be prepared in accordance with manufacturer's specifications. In particular, they are to be free from any trace of oxide and grease.

1.3 Temperature

1.3.1 General

Requirements of the present Rule Note are based on a design air temperature not less than −10°C. Other cases are to be subject to special consideration of the Society.

1.3.2 Air temperature

Air temperature is to be taken as the mean air temperature of the coldest day (24h) of the year of area of operation. Where no particular value is specified, the following air temperature is considered:

- 0°C for wind propulsion system not intended to operate in cold area
- −10°C for wind propulsion system intended to operate in cold areas.

2 Construction materials

2.1 Steel

2.1.1 General

Materials used during construction are to comply with the applicable requirements of NR216 Materials and Welding.

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

2.1.2 The present requirements presume that welding and other cold or hot manufacturing processes are carried out in compliance with current sound working practice and with the applicable requirements of NR216 "Materials and Welding", in particular:

- 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 need to be followed by an adequate heat treatment.

2.1.3 Stainless steels are considered by the Society on a case-by-case basis.

2.1.4 Steel grades

As a rule, the steel grades to be used for manufacturing structural elements are defined in Tab 1 according to the plate thickness.

Table 1 : Steel grade for plates

Plate thickness t, in mm	Hull steel grade
$t \le 20$	A or AH
$20 < t \le 25$	B or AH
$25 < t \le 40$	D or DH
$40 < t$	E or EH

2.1.5 Mechanical properties

a) Tab 2 gives the mechanical characteristics of steels to be generally used in the construction.

Note 1: For carbon steel materials, Young's modulus is taken equal to 206000 N/mm² and Poisson's ratio is taken equal to 0,3.

b) Higher strength steels other than those indicated in Tab 2 are considered by the Society on a case-by-case basis. In such a case, a detailed technical specification stating the manufacturing process, mechanical and chemical characteristics, utilization conditions (ability for welding and forming) and the possible heat-treatments is to be submitted to the Society.

c) Where normal tensile loads induce out-of-plane stress greater than 0,5 R_{eH} in steel plates:

- for plates with t < 15 mm, ultrasonic testing is to be performed
- for plates with t ≥ 15 mm, Z-quality steel is to be used or ultrasonic testing is to be performed, in order to prevent laminar tearing

The ultrasonic testing is to be performed, before and after welding, on the area of the plate located within 50 mm or t, whichever is the greater, around the weld, in accordance with NR216 Materials and Welding, Ch 2, Sec 1, [11].

Table 2 : Mechanical properties of steels

Steel grades $t \le 100$ mm	Minimum yield stress R_{eH}, in N/mm²	Ultimate minimum tensile strength R_m, in N/mm²
A-B-D-E	235	400 - 520
AH32-DH32 EH32-FH32	315	440 - 570
AH36-DH36 EH36-FH36 EH36CAS-FH36CAS	355	490 - 630
AH40-DH40 EH40- FH40 EH40CAS-FH40CAS	390	510 - 660
EH47 EH47CAS	460	570 - 720
Note 1: Ref.: NR216 Materials and Welding, Ch 2, Sec 1, [2]		

2.1.6 Design yield stress for scantling structure check

The design yield stress R_y, in N/mm² to be considered for the scantling structure check is to be taken equal to:

$$R_y = \min\left(R_{eH}, \frac{R_m}{1,2}\right)$$

where:

R_{eH}, R_m : Yield stress at 0,2% strain and ultimate tensile stress as defined in [2.1.5]

2.1.7 Steels for forging and casting

Mechanical and chemical properties of steels for forging and casting to be used for structural members are to comply with the applicable requirements of NR216 Materials and Welding.

Steels of structural members intended to be welded are to have mechanical and chemical properties deemed appropriate for this purpose by the Society on a case by case basis.

The steels used are to be tested in accordance with the applicable requirements of NR216 Materials and Welding.

2.1.8 Low temperature air

For ships intended to operate in areas with low air temperatures (–10°C or below), e.g. regular service during winter seasons to Arctic or Antarctic waters (known as the Polar Regions), the materials in exposed structures are to be selected based on the design temperature, to be taken as defined in NR467 Steel Ships, Pt B, Ch 4, Sec 1.

For this purpose, the grade of steel to be used for wind propulsion system elements is to be considered as Class II (See NR467, Pt B, Ch 4 Sec 1, [2.5]).

2.2 Aluminium

2.2.1 General

Aluminium alloys used during construction are to comply with the applicable requirements of NR216 Materials and Welding.

Aluminium alloys are to be tested in compliance with the applicable requirements of NR216 Materials and Welding.

2.2.2 Aluminium alloys

a) As a rule, the aluminium alloys used for the construction are as follows:

- For rolled or extruded products:
  - series 5000: aluminium-magnesium alloy
  - series 6000: aluminium-magnesium-silicon alloy
- For cast products:
  - aluminium-magnesium alloy
  - aluminium-silicon alloy
  - aluminium-magnesium-silicon alloy

b) Influence of welding on mechanical characteristic:

Welding heat input lowers locally the mechanical characteristics $R_{p0,2}$ and R_m of aluminium alloys hardened by work hardening (series 5000 other than condition O) or by heat treatment (series 6000).

Consequently, where necessary, a drop in the mechanical characteristics of welded structures, with respect to those of the parent material, is to be considered for the structure calculation.

Note 1: As a general rule the heat affected zone (HAZ) is to be taken extending over 25 mm on each side of the weld axis.

c) Aluminium alloys of series 5000 (rolled or extruded):

Aluminium alloys of series 5000 in condition O (annealed) are not subject to a drop in mechanical strength in the welded areas.

Aluminium alloys of series 5000 other than condition O are subject to a drop in mechanical strength in the welded areas. The mechanical characteristics to be considered are normally those of condition O.

d) Aluminium alloys of series 6000:

Aluminium alloys of series 6000 are subject to a drop in mechanical strength in the vicinity of the welded areas.

The mechanical characteristics to be considered in this HAZ are normally indicated by the supplier.

When no information is provided by the supplier, the values given in Tab 4 may be used.

e) Unless otherwise agreed, the Young's modulus for aluminium alloys is equal to 70000 N/mm² and the Poisson's ratio equal to 0,33.

2.2.3 Design yield stress for scantling structure check

The design yield stress R_y, in N/mm² to be considered for the scantling structure check is to be taken equal to the minimum specified yield stress of the parent metal in welded condition $R'_{p0,2}$, in N/mm², but not to be taken greater than 70% of the minimum specified tensile strength of the parent metal in welded condition R'_m , in N/mm²

where:

$R'_{p0,2} = \eta_1 R_{p0,2}$

$R'_m = \eta_2 R_m$

$R_{p0,2}$: Minimum specified yield stress, in N/mm², of the parent metal in delivery condition

R_m : Minimum specified tensile stress, in N/mm², of the parent metal in delivery condition.

η_1 and η_2 are given in Tab 3.

Table 3 : Aluminium table for welded construction

Aluminium alloy	η_1	η_2
Alloys without work-hardening treatment (series 5000 in annealed condition O or annealed flattened condition H111)	1	1
Alloys hardened by work hardening (series 5000 other than condition O or H111)	$R'_{p0,2}/R_{p0,2}$	R'_m / R_m
Alloys hardened by heat treatment (series 6000) **(1)**	$R'_{p0,2}/R_{p0,2}$	0,6

(1) When no information is available, coefficient η_1 is to be taken equal to the metallurgical efficiency coefficient β defined in Tab 4.

Note 1:

$R'_{p0,2}$: Minimum specified yield stress, in N/mm², of material in condition O

R'_m : Minimum specified tensile stress, in N/mm², of material in condition O

Table 4 : Metallurgical efficiency coefficient β

Aluminium alloy	Temper condition	Gross thickness, in mm	β
6005 A (Open sections)	T5 or T6	$t \leq 6$	0,45
		$t > 6$	0,40
6005 A (Closed sections)	T5 or T6	All	0,50
6061 (Sections)	T6	All	0,53
6082 (Sections)	T6	All	0,45

2.2.4 Low temperature air

For ships intended to operate in areas with low air temperatures (–10°C or below), the aluminium alloys to be employed are to be agreed by the Society.

2.3 Composite materials

2.3.1 General

The characteristics of the composite materials are to comply with the applicable requirements of NR546 "Hull in Composite Materials" in particular for the:

- raw materials analysis
- individual layers and laminate analysis.

Raw materials and laminates are to be tested in compliance with the applicable requirements of NR546 "Hull in Composite Materials".

2.3.2 Mechanical properties

The design review of the scantling of elements built in composite materials consists in checking the actual safety coefficients, equal to the ratio between the theoretical breaking stresses of the elementary layers of the laminate and the actual applied local stresses.

The values of the theoretical breaking stresses are defined in the NR546, Sec 5, [5].

Breaking stresses directly deduced from mechanical tests may be taken over from the theoretical breaking stresses defined in NR546 if mechanical test results are noticeably different from expected values.

2.3.3 Air temperature

a) General:

Attention is to be paid to the value of the Tg (glass transition temperature) of the composite material, primarily dependant on resin type and post-cure process.

As a rule, the value of Tg is to be at least greater than the air temperature provided in service increased with 15° to 20°.

b) Low temperature air:

For ships intended to operate in areas with low air temperatures (–10°C or below), the composite materials to be employed are to be agreed by the Society.

2.3.4 UV protection

UV protection by gel coat or painting and protection in way of fretting wear are to be provided.

2.4 Other materials

2.4.1 Other materials may be considered on a case by case basis by the Society.

3 Construction and testing

3.1 Welding

3.1.1 General

The general requirements for fabrication by welding (welding consumables and welding procedures) for steel and aluminium alloys are defined in NR216 Materials and Welding.

The scantling, preparation, execution and inspection of steel welded connections are defined in NR467, Pt B, Ch 11, Sec 1.

The scantling, preparation, execution and inspection of aluminium alloys welded connections are defined in the Rule Note NR561 "Hull in Aluminium Alloys", Sec 3.

3.1.2 Structural category

As a rule, a program of weld inspection is to be submitted to the Society, based on the following structural element categories:

- Second category:

  Second category elements are structural elements of minor importance, the failure of which might induce only localised effects.

  e.g. walkways and accesses,

- First category:

  First category elements are main load carrying elements essential to the overall structural integrity of the unit.

  e.g. winch foundation, mast pedestal, main platform,

- Special category:

  Special category elements are parts of first category elements located in way or at the vicinity of critical load transmission areas and of stress concentration locations.

  e.g. connecting parts of mast pedestals to main structure, tilt axis and its foundation.

3.1.3 General plan of weld testing

A plan specifying the areas to be examined and the extent of testing and the quality levels, with reference to the NDT procedures to be used, is to be submitted to the Society for approval.

The lengths of weld and the location of welds to test are to be defined on a case by case basis taking into account the following criteria:

- structural category defined in [3.1.2]
- welds in high stressed areas
- fatigue sensitive areas
- other important structural elements
- welds which are inaccessible or very difficult to inspect in service
- suspected problem areas.

3.2 Bolting

3.2.1 When standardized bolts are used for connections of standing rigging elements, the screws and nuts are to be of the steel quality grades defined in Tab 5 in accordance with the requirements of the ISO 898. For the screws, this table specifies also the tensile strength R and the minimum yield stress R_e which are to be taken into account in strength calculations.

The threading of screws is to be formed by rolling.

Table 5 : Steel quality grade marks for screws and nuts

Quality grade marks for screws	6.8	8.8	10.9	12.9
Tensile strength of screws, in N/mm^2	600	800	1 000	1 200
Yield stress (minimum) of the screws, in N/mm^2	480	640	940	1 080
Quality grade marks for nuts	6	8	10	12
Note 1: Alternatively, other steel quality grades defined by national standards may be accepted.				

3.2.2 The designation symbol of the steel quality grade mark is to be indicated on each screw and nut used.

3.2.3 For assemblies with pre-stressed high strength bolts, the quality grade marks of the screws are to be 8.8 or 10.9 and the quality grade marks of the nuts 8 or 10 respectively. The quality of the washers are to be appropriate to the quality grade marks of the screws and nuts.

Screw threading is to be obtained by rolling, exclusive of any other process.

An attestation for conformity of the bolts and screws with recognized national or international standards may be required.

Note 1: Applications for use of bolts with screws of 12.9 quality grade mark will be subject to special consideration.

3.3 Riveting for aluminium element

3.3.1 General

The conditions of riveting of aluminium alloy elements are defined in NR561, Sec3.

The aluminium alloy rivets characteristics are to be as defined in NR216, Ch 3, Sec 2.

As a rule, the rivet joints scantling are examined on a case by case basis by direct calculation approach.

Depending on the stress level of the riveting joints, an inspection program is to be determined in accordance with the Society.

3.4 Adhesive joint

3.4.1 General

The following technical specifications of suppliers are to be specified:

- adhesive system type and trade mark
- density, Young modulus, shear modulus, Poisson coefficient
- breaking strength and elongation at break in tensile and shear.

In addition, the following parameters are to be defined:

- type of the components to be bonded as well as their surface preparation (abrasion, cleaning...) and surface treatment
- geometry and thickness of the bonded joint
- service temperature range
- service humidity range
- curing process of the bonded joint.

3.4.2 Structural gluing joint characteristics

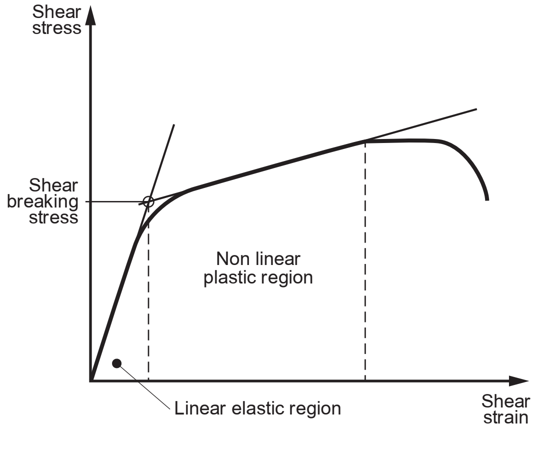
As a rule, the value of the shear breaking stress to be considered is to be taken equal to the minimum value of the:

- initial shear yield stress, in N/mm^2, of the bonding resin specified by the manufacturer, corresponding to the initial yield stress on a substrate equivalent to the examined components, or
- theoretical breaking stress value τ_{IL}, in N/mm^2, of the first layer of the components bonded together.

The shear breaking stress may be determined on the basis of shear stress-strain curve as the intersection of a line tangent to the linear elastic region and a line tangent to the non linear plastic region of the curve (see Fig 1). This curve is to be defined taking into account the maximum air temperature provided in service.

Other values of shear breaking stress deduced from mechanical tests representative of the gluing joint parameters may be considered by the Society where deemed necessary.

Figure 1 : Initial yield stress



3.4.3 Mechanical tests

a) General:

   Mechanical tests are to be carried out for structural gluing joints. The type of tests and the tests temperature ranges are to be defined at the satisfaction of the Society. The type and preparation of adherent, the application of adhesive and the curing process of test samples are to be representative of the hull construction process.

   The type and preparation of adherent, the application of adhesive and the curing process of test samples are to be representative of the construction process.

   The characteristics of the sample tests (geometry and thickness of the gluing joint, stiffness of the adherends) are to be as much as possible representative of the actual joint to be characterized.

b) Documents to be submitted:

   A test program specifying the considered mechanical tests and the number of specimen to be tested is to be submitted to the Society.

   A technical report including the forces/displacements curves is to be submitted to the Society.

4 Rigging elements

4.1 Shrouds and stays (fore, back and running backstays)

4.1.1 The following material specifications of shrouds and stays and their accessories (end fittings, turnbuckle, stay tensioner...) are to be submitted for information:

- steel wire cable: Composition and type of strand, grade, diameter
- rod cable: material, diameter
- carbon cable: type of fibre and resin
- synthetic cable: type of fibre.

4.1.2 For all type of cables, the following information are to be submitted:

- arrangement details of end fittings, turnbuckle, stay tensioner...
- humidity, corrosion, UV and chafe protections
- maximum breaking and safe working loads,
- load strain curve of shroud and stay
- expected service life and maintenance process and survey.

Impact protection are to be provided, particularly for fibre cables, when objects hitting standing rigging may occur.

4.1.3 Steel wire cables and fibre cables are to be in accordance with the requirements of NR216 “Materials and Welding” or other recognized standard.

A programme of tests and examination, based on the requirements of NR216 or recognized standard is to be submitted to the Society for approval.

4.1.4 Control of pre-tensioning

Arrangements to control in service the pre-tensioning applied to the standing rigging by turnbuckles, stay tensioners or equivalent systems are to be justified by the Designer.

4.2 Mats slewing ring

4.2.1 A calculation note and an attestation from the slewing ring manufacturer, fixing the maximum permissible values for overturning moment and vertical force in the working conditions is to be submitted according to Sec 7, [3.2.3], item b).

A BV product certificate is required with invitation of the Surveyor of the Society to attend the tests in addition to the manufacturer's document.

Raw materials data sheets of the main elements of the slewing ring including data such as chemical composition and mechanical properties are to be submitted.

4.3 Winches

4.3.1 Winches and testing procedures are to be in accordance with the requirements of the Rules of the Society, such as NR526, Chapter 2, Section 6 or recognized standards.

Note 1: NR526 Rules for the certification of lifting appliances onboard ships and offshore units.

4.3.2 Construction drawings of winches are not required when standardized production is concerned, provided references of use in service are supplied to the Society satisfaction.

When prototype is concerned, a technical file is to be submitted for information. This file is to include a detailed technical specification, an operating manual, a general drawing, the constructional drawings of the main items and complete calculations of the Manufacturer. The test programme contemplated is to be submitted for approval.

4.3.3 The following main winch capacity are to be submitted:

- rated line pull (RP): Line tension, in kN, that the winch can haul at a specified layer and in a safe manner
- brake capacity: Minimum rated holding force, in kN, of the static brake system at the reeled layer for which the RP is specified
- required nominal force: Line pull force that the winch can haul at the outer winding layer, in normal service conditions, when the drum rotates at its maximum service speed (nominal recovery speed) in order to satisfy the intended performance
- pulling capacity limiter: Capacity value of the device that prevents the winch to pull-in a load in excess of its rated or allowed overload capacity.

4.4 Ropes for running rigging elements

4.4.1 The following material specifications of ropes are to be submitted for information:

- type of material and composition
- rope construction (braided or unidirectional fiber for core, type of cover)
- minimum breaking and safe working loads, elongation
- expected service life.

4.4.2 Ropes are to be in accordance with the requirements of recognized standard.

4.4.3 A programme of tests and examination, based on the requirements of NR216 or recognized standard is to be submitted to the Society for approval.

For proof load tests provided in the programme of tests, the minimum proof load is to be greater than 1,5 SWL, where SWL as defined in Sec6.

Breaking test may be required on case by case basis.

4.5 Sheaves

4.5.1 Sheaves construction and testing procedures are to be in accordance with the requirements of recognized standards.

4.5.2 A programme of tests and examination is to be submitted to the Society for approval.

For proof load tests provided in the programme of tests, the minimum proof load is to be greater than 1,5 SWL, where SWL as defined in Sec 6.

Breaking test may be required on case by case basis.

4.5.3 Safe working load for sheave

The safe working load of sheaves is to be defined as given in Sec 7. As a rule, this safe working load is defined for an angle by which the block turns the rope equal to 180°. When it is not the case, the value of the considered angle is to be defined with the value of the safe working load.

4.6 Mast interface equipment with standing or running rigging elements

4.6.1 Construction drawings of mast interface equipment are not required when standardized production is concerned, provided references of use in service are supplied to the Society satisfaction

For non-standard mast interface equipment, a technical file is to be submitted. This file is to include a detailed technical specification and scantling criteria.

4.6.2 A programme of tests and examination is to be submitted to the Society for approval.

For proof load tests provided in the programme of tests, the minimum proof load is to be greater than 1,5 SWL, where SWL as defined in Sec 6 for standing rigging element or in Sec 7 for running rigging element.

Breaking test may be required on case by case basis.

4.7 Ship hull interface equipment with standing or running rigging elements

4.7.1 Chain plates and pad eyes construction and testing procedures are to be in accordance with the requirements of the Rules of the Society or recognized standards.

4.7.2 A programme of tests and examination is to be submitted to the Society for approval.

For proof load tests provided in the programme of tests, the minimum proof load is to be greater than 1,5 SWL, where SWL as defined in Sec 6 for standing rigging element or in Sec 7 for running rigging element.

Breaking test may be required on case by case basis.

4.7.3 Standardized equipment

Construction drawings of chain plates and pad eyes are not required when standardized production is concerned, provided references of use in service are supplied to the Society satisfaction.

4.7.4 Non-standardized equipment

For non-standard pad eyes, a technical file is to be submitted for information. This file is to include a detailed technical specification and scantling criteria (material characteristics, shear tear out, diametrical bearing pressure, welding...).

4.8 Other equipments

4.8.1 The present sub-article covers all the equipment such as cleats, travelers, shackles...

The following material specifications of these equipments are to be submitted for information:

- type of material and composition
- maximum breaking and safe working loads
- expected service life.

4.8.2 These equipments are to be in accordance with the requirements of recognized standard.

4.8.3 A programme of tests and examination is to be submitted to the Society for approval.

For proof load tests provided in the programme of tests, the minimum proof load is to be greater than 1,5 SWL, where SWL as defined in Sec6.

Breaking test may be required on case by case basis.

5 Equipment and materials certification requirements

5.1 General

5.1.1 A general document including the following informations covering the different rigging equipments (standing rigging elements within the scope of class notation **WPS1** and standing and running elements within the scope of class notation **WPS2**) is to be submitted to the Society for examination:

- recognised standards considered
- type of tests and documents stating the tests results
- type of certification process and certificate granted.

5.1.2 Certification requirements

Within the scope of the class notations **WPS1** and **WPS2** the materials and equipment used in the construction of wind propulsion systems are to be inspected and tested in relation to their use at the manufacturer's works in the presence of a Surveyor of the Society according to App 2.

The certification results in issuance of test and survey certificates.

As an alternative, tests and checks carried out in compliance with international or national standards may be accepted if they are considered as equivalent to the requirements of the present Rule Note.

SECTION 5 DESIGN CONDITIONS AND LOADS

1 General

1.1 Application

1.1.1 This Section provides the design conditions and design loads for structural and safety checks. The load combinations are to be derived from the load scenarios specified as a combination of design conditions defined in [3].

This Section uses the concept of design load scenarios to specify consistent design load sets which cover relevant operating modes.

1.2 Operating manual

1.2.1 The operating manual is to incorporate a dedicated section containing information relating to:

- all design conditions on which the design of wind propulsion system is based
- all permissible limits and operational restrictions for wind propulsion system operation
- operational instruction for safe operation of the wind propulsion system.

2 Definitions

2.1 Wind

2.1.1 True wind

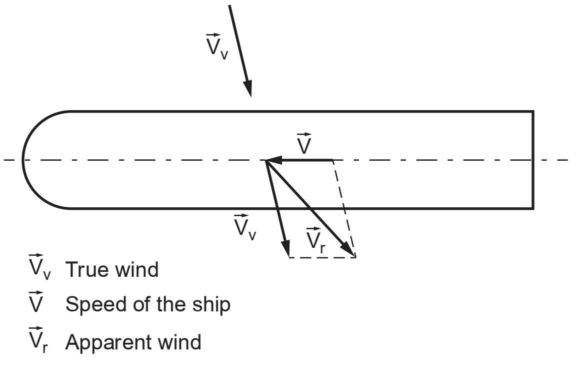
True wind is the wind measured on a solid body motionless with respect to the ground (see Fig 1).

2.1.2 Apparent wind

Apparent wind is the wind measured on a moving solid body (for instance a ship), and is the result of the combination of the true wind and the wind induced by the own speed of the solid body.

Note 1: It is the effect of the apparent wind which acts as wind propulsion of a ship, and thus it is the only one to be taken into consideration for structure scantlings purposes.

Figure 1 : Apparent wind



2.1.3 Wind speed

Wind speed is speed of the wind measured at specified height above the sea level and averaged over a representative period, in m/s (see Fig 2).

In the present Section, the wind speed is defined as the wind speed measured at the highest point of the wind propulsion system, unless otherwise specified.

Note 1: The wind speed of gust is generally averaged over 3 seconds.

The wind speed of constant wind is generally averaged over 10 minutes and should not to be less than 1 minute.

$$V = \frac{1}{T}\int_0^T V(t)dt$$

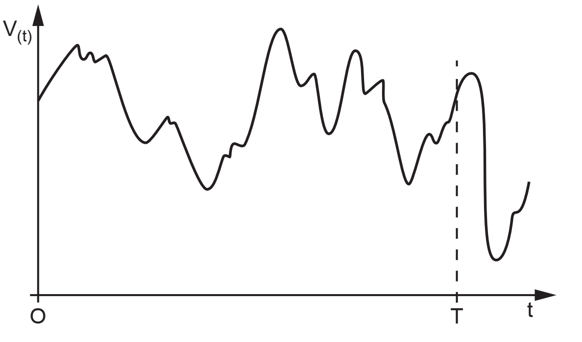
Note 2: The wind speed sensors play an essential part in so far as they allow to evaluate the weather conditions encountered with respect to the scantlings conditions of the system.

They are to be fitted at the upper part of the wind propulsion system and suitably located in order to avoid recording interference components of wind speed, such as:

- natural acceleration of flow in soft sails
- forced acceleration behind turbines
- turbulence in proximity to wing (especially at wing tip).

The measures are to be made continuously and corrected so as to reduce the momentarily steady overspeeds due to the ship rolling and pitching.

Figure 2 : Watched wind speeds



3 Design conditions

3.1 General

3.1.1 Design conditions on the basis of which the safety and structural checks are performed cover all conditions of the wind propulsion system's life entering under the scope of the Society.

A design condition is defined by the combination of the following main conditions:

- environmental conditions
- operating conditions
- system conditions.

Table 1 : Environmental conditions

Conditions	Normal	Extreme	Accidental	Fatigue
Wave probability level	specified by the designer if unknown $p = 10^{-5}$	$p = 10^{-8}$	specified by the designer	$p = 10^{-2}$
Apparent wind speed **(1)**	specified by the designer	100 kn **(2)** (51,44 m/s)	specified by the designer	specified by the designer
(1) gust factor included **(2)** wind speed as measured at 10m above sea water level				

3.2 Environmental conditions

3.2.1 Environmental conditions are external conditions due to wind, sea-state and ice when relevant. Two main categories are defined:

- normal environmental conditions which occur frequently during the life of the wind propulsion system.
- extreme environmental conditions which are the upmost severe conditions that the wind propulsion system may encounter. Environmental conditions are described in Tab 1.

Note 1: Guidance may be found in NI 638 "Guidance for Long-term Hydro-structure Calculations" which defines environmental conditions that the unit will encounter during its lifetime.

3.2.2 Wind

Wind conditions correspond to the description of wind on the wind propulsion system. They are defined by maximum wind speeds together with their direction.

Except where otherwise specified, the term wind mentioned in the present note concerns the apparent wind as measured at the highest point of the wind propulsion system and includes gust effect.

a) Normal wind:

Normal wind conditions correspond to the normal wind that may be encountered while the wind propulsion system is in sailing operating condition.

They are to be specified by the Designer in term of maximum wind speed, including gust effect.

b) Extreme wind:

Extreme wind conditions correspond to maximum wind conditions that may be encountered. Under such conditions, the wind propulsion system is normally in an out-of-operation mode.

They are to be defined by the Designer in term of maximum wind speed taken not less than 100 knots including gust effect.

Note 1: It is the Designer responsibility to determine the suitable gust factor. In any case, this value is to be not less than 1,25 and need not to be greater than 1,45.

Note 2: When relevant (e.g. height not less than 25m), true wind speed is to be described by wind speed profile given by the following exponential variation law:

$$V(z) = V\left(\frac{z}{10}\right)^{\alpha}$$

where:

$V(z)$: True wind speed at height z, in m/s

α : Wind shear exponent, generally to be taken as:
- 0,14 for normal wind
- 0,11 for extreme wind, with V(z) not to be less than 51,44 m/s in extreme conditions

V : True wind speed measured at 10 m above the sea level, in m/s

z : Height above the sea level, in m.

3.2.3 Sea-state

Sea-state correspond to the description of wave.

a) Normal sea-state:

Normal sea-state corresponds to sea-state to be obtained as the most probable the ship may experience during its operating life, for a probability level of:

- 10^{-5} for strength assessment, when sea state are not defined by wave height limitation
- 10^{-2} for fatigue assessment.

b) Extreme sea-state:

Extreme sea-state corresponds to sea-state to be obtained as the maximum the ship may experience during its operating life, for a probability level of 10^{-8}.

3.2.4 Snow and ice

Snow and icing are to be considered for wind propulsion system liable to operate in areas of snow and glazed frost.

In particular, verification of the stability of the base ship, intact and damage is to be performed taking into account the possible over-loads due to ice and snow accumulation.In order to perform the stability calculation, the following amount of ice may be used:

- 30 kg per square metre on exposed weather decks and gangways
- the projected lateral area of discontinuous surfaces of rail, sundry booms, spars (except masts) and rigging of ships having no sails and the projected lateral area of other small objects are to be computed by increasing the total projected area of continuous surfaces by 5% and the static moments of this area by 10%.

Different amount of ice corresponding to local regulations or areas of navigation may be used instead of the above values.

3.3 Operating conditions

3.3.1 Sailing operating conditions

Sailing operating conditions correspond to the situation where the wind propulsion system is working.

3.3.2 Out of operation conditions

Out of operation conditions correspond to the situation where the wind propulsion system is inoperative. According to the type of sails, its configuration is so arranged that it induces wind forces as small as possible on structures, for example:

- soft sail entirely furled
- feathered turbosails in the wind's eye with aspiration stopped
- stopped flettner rotors
- windsails folded and/or trimmed in such a way the combination lift/drag is as small as possible.

3.4 System conditions

3.4.1 Intact conditions

Intact conditions correspond to the normal system condition of wind propulsion system.

3.4.2 Accidental conditions

Accidental conditions correspond to abnormal system condition where the wind propulsion system is under unplanned configuration that result in activation of protection system and/or includes accidental loads.

Accidental conditions are identified following HAZID and HAZOP outcomes results (See Sec 1, [1.3]).

4 Design loads

4.1 General

4.1.1 Overall loads

As a rule, the overall loads to be considered for the different design navigation conditions are to include:

a) Lift and drag loads induced by apparent wind with gusts effect, specifying the associated combination of the wind propulsion system configurations and the wind angle of attack.

b) Reactions forces on mast and boom induced by halyards or hooks, main sheet...

c) Pre-tensioning forces, when applicable, provided in rigging elements (shrouds, stays…)

d) Longitudinal, vertical and transversal inertia loads induced by ship motions.

Generally speaking, loads created by the hull girder deflection are negligible compared to the others, and are not taken into account. Anyhow, for particular arrangements, the Society may require that such loads be duly considered.

4.1.2 Loads induced by wind

The overall loads exerted and their distribution on the structure of the wind propulsion system as defined in [4.1.1], item a), b) and c) are to be defined by the Designer and dully documented.

Note 1: The design wind speed to be considered for the model loading is to be defined as in [3.2.2] taking into account:

- the apparent wind speed, including gust effect, measured at the highest point of the wind propulsion system, generally averaged over 3 seconds.
- the wind speed profile when applicable.

4.1.3 Loads based on a maximum moment of heel

When a maximum moment of heel is considered as a maximum measuring device to define the sailing operating conditions, this moment may be considered for the determination and the distributions of the wind forces to be applied to the standing rigging and may be considered as maximum loading.

In this case, the measuring devices and the measures taken to limit the wind loads on the standing rigging are to be defined and are to fulfil the general requirements defined in Sec 8.

Limitations of sailing operating conditions are to be detailed in the operating manual (see [1.2.1]).

4.2 Inertia loads induced by ship motions

4.2.1 Dynamic forces

The dynamic forces applied to the main elements of the wind propulsion system to take into account for the scantling checks are:

$F_{W,X,i} = M_i \, a_{X\text{-env}}$ in x direction

$F_{W,Y,i} = M_i \, a_{Y\text{-env}}$ in y direction

$F_{W,Z,i} = M_i \, a_{Z\text{-env}}$ in z direction

where:

$F_{W,X,i}$, $F_{W,Yi}$, $F_{W,Zi}$: Dynamic forces in x, y and z direction respectively, in kN

M_i : Mass of the equipment considered, in tons

a_i : Accelerations, in m/s^2

To be defined by the Designer in the different design conditions.

Note 1: The x, y and z directions are defined with respect to the coordinate system detailed in NR467, Pt B, Ch 1, Sec 2, [4].

4.2.2 Load cases

As a rule, the design conditions to be selected in order to maximize the combined acceleration values of the longitudinal, transversal and vertical accelerations are to be the followings:

a) Head sea (angle of incidence equal to 180°)

b) Beam sea (angle of incidence equal to 90°)

c) Forward oblique sea conditions (angle of incidence equal to 120°).

4.2.3 Envelope acceleration guidance values for preliminary assessment

When the values of the accelerations are not available from the Designer, the following guidance of envelope acceleration values may be considered for preliminary assessment of seagoing monohull displacement ships of conventional shape, speed and proportions:

- the envelope longitudinal acceleration $a_{X\text{-env}}$, the envelope transverse acceleration $a_{Y\text{-env}}$, and the envelope vertical acceleration $a_{z\text{-env}}$, in m/s², are to be taken as the envelope accelerations for equipment defined in NR646, Pt B, Ch 5, Sec 3, [3.3]

Note 1: NR646 Tentative Rules for structural assessment of steel ships.

- for normal environmental conditions limited by a maximum significant wave height, H_s, as defined by the Designer, the wave parameter H used to calculate the above accelerations and defined in NR646, Pt B, Ch 5, Sec 3, [2], is to consider the coefficients A_0, A_1, A_2, e_1, e_2 as given in Tab 2.
- the values of the longitudinal, transverse and vertical accelerations at any point are obtained from the formulae in Tab 3 for head sea, beam sea and oblique sea load cases.

Other types of ships will considered by the Society on a case by case basis.

Note 2: For the ship motions and accelerations calculation according to NR646, metacentric height GM and roll radius of giration k_r are to be deduced from the actual loading conditions considered. When GM and K_r are unknown, these values may be taken as defined in NR646.

Table 2 : Wave parameter H coefficients for strength assessment when sea state conditions are limited by H_s

H_s **(1)**	A_0	A_1	e_1	A_2	e_2	L_c
≤ 1,0 m	0,07	1,28	2,45	0,3	1,59	161
≤ 1,5 m	0,12	1,29	2,42	0,31	1,64	186
≤ 2,0 m	0,16	1,27	2,42	0,30	1,65	206
≤ 2,5 m	0,21	1,27	2,38	0,31	1,69	223
≤ 3,0 m	0,25	1,29	2,38	0,32	1,71	239
≤ 3,5 m	0,29	1,34	2,41	0,33	1,71	255
≤ 4,0 m	0,33	1,35	2,41	0,33	1,78	267
≤ 4,5 m	0,38	1,40	2,45	0,35	1,78	284
≤ 5,0 m	0,42	1,44	2,45	0,37	1,75	296
≤ 5,5 m	0,46	1,44	2,46	0,37	1,79	308
≤ 6,0 m	0,49	1,48	2,46	0,39	1,75	321
≤ 6,5 m	0,53	1,48	2,45	0,39	1,76	331
≤ 7,0 m	0,57	1,48	2,42	0,40	1,79	339
≤ 7,5 m	0,60	1,49	2,42	0,42	1,83	349
(1) H_s : Maximum significant wave height, in m, associated to the operating condition as defined by the Designer.						

Table 3 : Guidance of acceleration for load combinations

Direction	Ship type	Load case		
		Head sea	Beam sea	Oblique sea
a_X- Longitudinal	Ro-ro and passenger ships	0,6 $a_{X\text{-env}}$	0	$a_{X\text{-env}}$
	other ships	$a_{X\text{-env}}$		0,6 $a_{X\text{-env}}$
a_Y - Transverse	all ships	0	$a_{Y\text{-env}}$	0,6 $a_{Y\text{-env}}$
a_Z - Vertical	all ships	± a_{Zenv}	± $a_{Z\text{-env}}$	± $a_{Z\text{-ev}}$
Note 1: $a_{X\text{-env}}$, $a_{Y\text{-env}}$ and $a_{Z\text{-env}}$ are the envelope longitudinal, transverse and vertical accelerations as defined in [4.2.3].				

SECTION 6 STANDING RIGGING STRUCTURE

1 General

1.1 Application

1.1.1 The requirements of the present Section are applicable for:

- the scantling check of the standing rigging within the scope of the additional class notation **WPS1** as defined in Sec 2, [2.2.1].
- the scantling check of the standing rigging within the scope of the additional class notation **WPS2** as defined in Sec 2, [2.3.1].

The components and constituents of a standing rigging are defined in Sec 1, [2.2.1] and Sec 1, Tab 2 according to the type of wind propulsion system considered.

1.1.2 The different materials considered in the present Rules are:

- steel (ordinary or high tensile)
- aluminium alloys
- composites
- for shrouds, stays...: Steel wire rigging, steel rod rigging and synthetic rigging.

Element of standing rigging built with other materials are to be specifically considered on a case by case basis.

1.2 Documents to be submitted

1.2.1 In addition to the present Section, documents to be submitted for guidance, approval or examination and the scantling justification documents are listed in Sec 2, [2.5].

2 Structure calculation approach

2.1 Loads

2.1.1 Partial safety factors for loads

The overall loads exerted and their distribution on the standing rigging structure of the wind propulsion system to be taken into account in the 3D calculation model defined in [2.2] are to be as per Sec 5 increased by a partial safety factor α as defined in Tab 1.

2.1.2 Partial safety factor for loads - Fatigue approach

For fatigue calculation analysis, the partial safety factors α as defined in Tab 2 is to be taken into account in the 3D model's defined in [2.2].

2.1.3 Partial safety factors for loads based on a maximum moment of heel

When the overall loads induced by wind are defined on the basis of a maximum moment of heel as defined in Sec 5, [4.1.3], the partial safety factors α as defined in Tab 1 are to be considered.

Table 1 : Partial safety factor α for loading conditions - General case

Conditions			Sea state	Overall loads			
Environmental	Operating	System		Lift and drag loads induced by wind **(1)**	Reactions forces on mast and boom **(2) (3)**	Ship motions induced loads **(4)**	
						Mass	Acceleration
Normal	Sailing	Intact	10^{-5}	1,3 **(5)**	1,1	1,05 **(6)**	1,3
		Accidental	10^{-5}	1,1 **(7)**	1,1 **(7)**	1,05 **(6) (7)**	1,3 **(7)**
Extreme	Out of operation	Intact	10^{-8}	1,1	1,1	1,05 **(6)**	1,1
		Accidental	10^{-8}	1,1 **(7)**	1,1 **(7)**	1,05 **(6) (7)**	1,1 **(7)**

(1) Lift and drag loads induced by wind and their distribution induced by apparent wind with gusts effect, specifying the associated combination of the wind propulsion system configurations and the wind angle of attack.
(2) Reactions forces on mast and boom induced by halyards or hooks, main sheet...
(3) Pre-tensioning forces, when applicable, provided in rigging elements (shrouds, stays…).
(4) Longitudinal, vertical and transversal inertia loads induced by ship motions.
(5) When automatic release systems approved by the Society are provided to avoid wind overloads on the wind propulsion systems, a value of 1,15 may be considered.
(6) When weight report including sufficient margin is available, a value of 1,0 may be considered.
(7) Accidental loads are to be defined on a case by case basis by risk analysis (HAZID or HAZOP), if requested. Provided risk mitigation are taken, lower value of α may be considered by the Society on a case by case basis.

Table 2 : Partial safety factor α for loading conditions - Fatigue approach

Conditions			Sea state	Overall loads **(1)**			
Environmental	Operating	System		Lift and drag loads induced by wind **(2) (3)**	Pre-tensioning forces **(4)**	Ship motions induced loads **(5)**	
						Mass	Acceleration
Normal	Sailing	Intact	10^{-2}	1,0	1,1	1,05	1,0

(1) Accidental loads are to be defined on a case by case basis by HAZID or HAZOP analysis, if requested.
(2) Lift and drag loads induced by wind and their distribution induced by apparent wind with gusts effect, specifying the associated combination of the wind propulsion system configurations and the wind angle of attack.
(3) Reactions forces on mast and boom induced by halyards or hooks, main sheet...
(4) Pre-tensioning forces, when applicable, provided in rigging elements (shrouds, stays…).
(5) Longitudinal, vertical and transversal inertia loads induced by ship motions.

2.2 Structure calculation methods

2.2.1 General

The scantling check of the standing rigging is to be carried out on the basis of a 3D finite element calculation model submitted by the Designer.

As a rule, the model is to be built from:

- a non-linear calculation approach for the check of the global standing rigging scantling to take into account the large deflections of the structure
- linear element:
  - for standing rigging components submitted to bending and/or compression loads (mast, boom...): shell element
  - for stiffeners reinforcement of mast, boom...: beam element or shell element to represent the web and the flange when deemed necessary by the Society (stiffener submitted to local bending or with a wide web height or flange width)
  - for standing rigging components submitted to tensile load only (shrouds, stays...): rod element.

Note 1: Non-linear elements may be required for specific components of the standing rigging (synthetic shroud and stays for example) when deemed necessary by the Society).

Other calculation approach may be considered by the Society on a case by case basis.

2.2.2 Finite element model

a) The shell elements mesh are to follow the stiffening system of the modelled standing rigging components considered as far as practicable, hence representing the actual plate panels between local reinforcements. As a rule:

- the size of elements is to be not greater than 100 mm and the aspect ratio of shell elements is generally not to be greater than 2, and in no case greater than 4.
- angles of quadrilateral elements are to be greater than 60° and less than 120°.
- Angles of triangular elements are to be greater than 30° and less than 120°

When a fine mesh is necessary for the analysis of structural details, the size of the elements in the area of interest is not to be greater than 50 mm and the extend of the refined area is to be at least of 10 elements in any direction around its centre.

The rod elements are to be representative of the mechanical characteristics and behaviour of the standing rigging components considered.

b) As a rule, the hull girder elastic deflection is not to be taken into account. However, if these deflections may affect the force reactions in the standing rigging, particularly in the shroud and stay pre-tensioning values considered for the calculations, the global hull structure deflection is to be considered for the calculation of the forces distribution in the standing rigging calculation.

2.2.3 Document to be submitted

A document setting the hypothesis considered for the calculation model is to be submitted by the Designer for examination. This document is to include:

- a complete representative standing rigging model geometry specifying for the different members contributing to the overall strength of the standing rigging their main characteristics (materials, mechanical characteristics, scantling)
- the orientation of the shell element co-ordinate system in relation to the reference co-ordinate system of the model
- the boundary conditions applied to the model (rotation and translation)
- the loads distribution induced by sails, boom, halyards, stays supporting head sails.
- the pre- tensioning forces provided in shrouds, stays,
- the reference of the finite element analysis programs used by the Designer.

2.2.4 Loading model

The loading of the model is to be in accordance with [2.1].

2.3 Calculation results

2.3.1 Documents to be submitted

A calculation report is to be submitted by the Designer for examination and has to include, for the different sailing operation conditions expected to occur, the following informations, as applicable, in relation with the type of wind propulsion system considered:

- global deflection of the standing rigging
- reaction forces and moments in way of the boundary conditions
- forces in the elements modelled with rods
- stresses in the element modelled with shell elements.

2.3.2 When deemed necessary, the effect of rotation acceleration (starting and braking) on service for rotating mast is to be considered.

3 Stress analysis

3.1 General

3.1.1 The stress analysis approach defined in the present Article is to be corrected to take into account the stress concentrations in way of the attachment of rigging fittings and structural discontinuities.

3.2 Stress analysis in shell elements made of steel and aluminium

3.2.1 Stress components

Stress components are generally identified with respect to the element co-ordinate system. The following stress components to be considered and calculated at the centroid of each element are:

- the normal stresses σ_1 and σ_2 in the directions of element co-ordinate system axes
- the shear stress τ_{12} with respect to the element co-ordinate system axes

3.2.2 Stress calculation

The maximum stresses and buckling stresses are to be calculated as follow:

a) Maximum stress calculation:

The Von Mises equivalent stress, σ_{eq}, in N/mm², is to be derived as follows:

$$\sigma_{eq} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 + 3\tau_{12}^2}$$

Where σ_1, σ_2 and τ_{12} are defined in [3.2.1].

b) Local buckling stress calculation:

Where the buckling panel is meshed by several finite elements, the stresses of the buckling panel are obtained by the following methodology:

- for each finite element, the stresses ($\sigma_{x\,e}^*$, $\sigma_{y\,e}^*$, τ_e^*) expressed in the element co-ordinate system are projected in the co-ordinate system of the buckling panel to obtained the stresses ($\sigma_{x\,e}$, $\sigma_{y\,e}$, τ_e).
- for the buckling panel, the stresses are calculated according to the following formula:

$$\sigma_x = \frac{\sum_i^n A_i \sigma_{x\,e_i}}{\sum_i^n A_i} \geq 0 \qquad \sigma_y = \frac{\sum_i^n A_i \sigma_{y\,e_i}}{\sum_i^n A_i} \geq 0$$

$$\tau = \frac{\sum_i^n A_i \tau_{e_i}}{\sum_i^n A_i} \geq 0$$

where:

$\sigma_{x\,ei}$, $\sigma_{y\,ei}$: Stresses, in N/mm², of the finite element i, taken equal to 0 in case of tensile stress

τ_{ei} : Shear stress, in N/mm², of the plate finite element i

A_i : Area, in mm², of the plate finite element i.

The applied equivalent stress W_{act}, in N/mm², is to be derived as follow:

$$W_{act} = \sqrt{\sigma_x^2 + \sigma_y^2 + \tau^2}$$

c) Column buckling stress calculation:

For mast shored up with shrouds and stays resulting in global compressive force on the mast, a column buckling check is to be carried out taking into account, for each parts of the mast between transversal support, the compressive forces deduced from the calculation.

The uniform compression stress, in N/mm², in the mast element is to be taken equal to:

$$\sigma_C = 10\frac{P}{A}$$

where:

P : Compressive force, in kN, deduced from the calculation

A : Cross section, in cm², of the mast element considered.

3.3 Stress analysis in shell elements made of composite materials

3.3.1 General

The general calculation principle of composite panel is defined in NR546 “Hull in Composite Materials”.

3.3.2 Stress components

Two main approaches are considered:

- a stress analysis in each individual layer of the composite panel ("ply by ply" analysis) in order to determine the following stresses in relation to the individual layer fibre direction:
  - main stresses (tensile, compressive and shear stresses), and
  - combined stresses.
- a stress analysis in the whole laminate panel in order to check the buckling behaviour of the composite panel.

3.3.3 Stress calculation

a) Main stresses:

The main stresses are to be calculated as follow:

- main tensile or compressive stresses σ_1 in the longitudinal direction of the fibre, mostly located in:
  - 0° direction of unidirectional tape
  - 0° and 90° directions of woven roving when the set of fibres are interweaved
- main tensile or compressive stresses σ_2 in the perpendicular direction of the fibre, mostly located in:
  - 90° direction of unidirectional tape or combined fabrics when the set of fibres are stitched together without criss-crossing of fibre
- main shear stresses parallel to the fibre located in the plane of the individual layer (τ_{12}) and/or between each individual layer (τ_{IL1} and τ_{IL2}, also designated as inter-laminar shear stresses).

b) Combined stresses:

- combined stresses calculated according to the Hoffman criterion as defined in NR546, Sec 2.

Note 1: Other combined stress criterion may be considered by the Society on a case by case.

c) Local buckling stresses:

- compression stresses in the longitudinal and transverse directions of the panel or structure element
- shear stresses in the plane of the panel or structure element.

d) Column buckling stress:

For mast shored up with shrouds and stays resulting in compressive force on the mast, a column buckling check is to be carried out taking into account, for each parts of the mast between transversal support, the compressive forces deduced from the calculation.

The uniform compression stress, in N/mm², in the mast element is to be taken equal to:

$$\sigma_C = 10\frac{P}{A}$$

where:

P : Compressive force, in KN, deduced from the calculation

A : Cross section, in cm², of the mast element considered.

3.4 Stress analysis in stiffeners made of steel and aluminium

3.4.1 Stiffeners modeled by beam

The equivalent stress, in N/mm², to take into account at the middle of the element length is to be taken equal to:

$$\sigma_{eq} = \sqrt{\sigma_x^2 + 3\tau^2}$$

where:

σ_x : $\sigma_x = \sigma_a + \sigma_b$

σ_a : Axial stress induce by the global bending and compressive forces applied to the mast.

σ_b : Bending stress induced by the local loads applied to the stiffener where applicable

τ : Shear stress induced by the local loads applied to the stiffener where applicable.

3.4.2 Stiffeners modelled by shell element

The stress analysis in the web and the flange is to be carried out as defined in [3.2].

3.5 Stress analysis in stiffeners made of composite materials

3.5.1 Stiffeners modeled by beam

The global stress σ_A and the longitudinal strain ε_{Aref}, in %, in the stiffener modeled by beam are to be deduced from the 3D model.

The global stress σ_{Ai}, in N/mm², and strain ε_{Ai}, in %, in the basic elements of the stiffener (associated plate, web and flange) in the longitudinal axis of the stiffener are to be calculated as follow:

$$\sigma_{Ai} = \frac{E_i}{100}\varepsilon_{Aref}$$

$$\varepsilon_{Ai} = \frac{100}{E_i}\sigma_{Ai}$$

where:

E_i : Main moduli of the basic element of the stiffener, in the longitudinal axis of the stiffener, in N/mm², as defined in NR546 Ships in Composite, Sec 6.

The local stresses, in N/mm², in each layer of the laminates of the basic elements, in their local axes, are to be calculated according to NR546 Ships in Composite, Sec 7 [3.2].

3.5.2 Stiffeners modeled by shell element

The stress analysis in the web and the flange is to be carried out as defined in [3.3].

3.6 Stress analysis in rod element

3.6.1 The axial stress σ_{axial}, in N/mm2, is to be calculated based on the axial loads at the middle of the element length.

4 Scantling check for standing rigging components

4.1 Scantling check in shell element model

4.1.1 Shell elements made in steel and aluminium alloys

a) Yield criteria:

The Von Mises equivalent stress σ_{eq} defined in [3.2.2], item a) is to be in compliance with the following formula:

$$\sigma_{eq} \le \frac{R_y}{\gamma_m \gamma_R}$$

where:

- R_y : Minimum yield stress, in N/mm², as defined in Sec 4
- γ_m : Material factor to be taken equal to 1,02
- γ_R : Resistance factor to be taken equal to 1,2.

b) Local buckling criteria:

The buckling acceptance criteria is defined as follow:

$$\eta_{act} = \frac{W_{act}}{W_u} \le \eta_{all}$$

where:

- W_{act} : Applied equivalent stress, in N/mm², defined in [3.2.2] b)
- W_u : Equivalent buckling capacity, in N/mm², to be taken as:

$$W_u = \sqrt{\sigma'^2_{cx} + \sigma'^2_{cy} + \tau'^2_c}$$

- σ'_{cx}, σ'_{cx}, τ'_c : Ultimate buckling stress, in N/mm², calculated by the finite element software. These values are to be documented by the Designer.
- η_{all} : Allowable buckling utilisation factor equal to:

  $\eta_{all} = 1/(\gamma_m \gamma_R)$
- γ_m : Material factor to be taken equal to 1,02
- γ_R : Resistance factor to be taken equal to 1,6.

Note 1: For standing structure element that do not affect the overall standing rigging integrity from buckling point of view, the factor γ_R may be taken equal to 1,2.

For plate stiffened panel, η_{act} may be defined as follow:

$$\eta_{act} = \frac{W_{act}}{W_u} = \frac{1}{\gamma_c}$$

where:

- γ_c : Minimum stress multiplier factors γ_{ci} at plate limit state for each of the different limit states as calculated according to the following interaction formulae as defined in NI615:

$$\left(\frac{\gamma_{c1}\ \sigma_x\ S}{\sigma'_{cx}}\right)^{e_0} + \left(\frac{\gamma_{c1}\ \sigma_y\ S}{\sigma'_{cy}}\right)^{e_0} + \left(\frac{\gamma_{c1}\ |\tau|\ S}{\tau'_c}\right)^{e_0} - \Omega = 1$$

with:

$$\Omega = B\left(\frac{\gamma_{c1}\ \sigma_x\ S}{\sigma'_{cx}}\right)^{e_0/2}\left(\frac{\gamma_{c1}\ \sigma_y\ S}{\sigma'_{cy}}\right)^{e_0/2}$$

- when $\sigma_x \ge 0$ (compressive):

$$\left(\frac{\gamma_{c2}\ \sigma_x\ S}{\sigma'_{cx}}\right)^{2/\beta_p^{0.25}} + \left(\frac{\gamma_{c2}\ |\tau|\ S}{\tau'_c}\right)^{2/\beta_p^{0.25}} = 1$$

- when $\sigma_y \ge 0$ (compressive):

$$\left(\frac{\gamma_{c3}\ \sigma_y\ S}{\sigma'_{cy}}\right)^{2/\beta_p^{0.25}} + \left(\frac{\gamma_{c3}\ |\tau|\ S}{\tau'_c}\right)^{2/\beta_p^{0.25}} = 1$$

- $\frac{\gamma_{c4}\ |\tau|\ S}{\tau'_c} = 1$

Note 2: In the present formula, compressive and shear stresses are to be taken as positive, tension stresses are to be taken as negative.

Note 3: NI615 “Buckling assessment of plated structures”.

- σ_x, σ_y, τ : Normal and shear stresses applied on the plate panel, in N/mm², deduced from the calculation and to be taken as defined in [3.2.2] b)
- σ'_{cx} : Ultimate buckling stress, in N/mm², in the direction parallel to the longer edge of the buckling panel, as defined in NI615, Sec 5
- σ'_{cy} : Ultimate buckling stress, in N/mm², in the direction parallel to the shorter edge of the buckling panel, as defined in NI615, Sec 5
- τ'_c : Ultimate buckling shear stresses, in N/mm², as defined in NI615, Sec 5
- γ_{c1}, γ_{c2}, γ_{c3}, γ_{c4} : Stress multiplier factors at plate limit state for each of the above different limit states.

  γ_{c2} and γ_{c3} are to be considered only when $\sigma_x \ge 0$ and $\sigma_y \ge 0$, respectively
- S : Partial safety factor to be taken as:
  - for structure exposed to local concentrated loads: S = 1,1
  - for other cases: S = 1,0
- B, e_0 : Coefficients given in Tab 3.

c) Column buckling criteria:

For mast shored up with shrouds and stays resulting in global compressive force on the mast, a column buckling check is to be carried out taking into account, for each parts of the mast between transversal support, the compressive forces deduced from the calculation.

The compression stress σ_c is to be in compliance with the following formula:

$$\sigma_C \le \frac{\sigma_{CB}}{\gamma_m \gamma_R}$$

where:

- γ_m : Material factor to be taken equal to 1,02
- γ_R : Resistance factor to be taken equal to 1,6

Note 4: For standing structure element that do not affect the overall standing rigging integrity from buckling point of view, the factor γ_R may be taken equal to 1,2.

σ_{CB} : Critical column buckling, in N/mm² in the mast element submitted to compression, in N/mm², calculated by the finite element software and documented by the Designer or obtained from the following formulae:

$$\sigma_{cB} = \sigma_{E1} \quad \text{for} \quad \sigma_{E1} \le \frac{R_{eH}}{2}$$

$$\sigma_{cB} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E1}}\right) \quad \text{for} \quad \sigma_{E1} > \frac{R_{eH}}{2}$$

σ_{E1} : Euler column buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_{E1} = \pi^2 E \frac{I}{A(f\ell)^2} 10^{-4}$$

I : Moments of inertia, in cm⁴, of the mast element with regard to the main axis of the mast

A : Cross-sectional area, in cm², of the mast element

ℓ : Span, in m, of the mast element between lateral support with regard to the main axis of the mast

f : Coefficient taking into account the boundary conditions of the mast element ends in way of the transversal supports and to be taken equal to:

- for both end fixed: f = 0,5
- for both ends pinned: f = 1
- for one both fixed and the other pinned: f = 0,71.

Table 3 : Coefficient B and e_0

Applied stresses	B	e_0
$\sigma_x \ge 0$ and $\sigma_y \ge 0$	$0,7 - 0,3\ \beta_p / \alpha^2$	$2/\beta_p^{0,25}$
$\sigma_x < 0$ or $\sigma_y < 0$	1,0	2,0

Note 1:
β_p : Plate slenderness parameter taken as:

$$\beta_p = \frac{b}{t_p}\sqrt{\frac{R_{eH\_P}}{E}}$$

b : Length of the shorter side of the plate panel, in m
t_p : Thickness of the plate panel, in mm.

4.1.2 Shell elements made in composite materials

a) General:

The structure scantling criteria are based on the actual safety coefficients equal to the ratio between:

- for main stresses and combined stresses: the theoretical breaking stresses of each individual layers of laminates (as defined in NR546, Sec 5) and the actual stresses deduced from the calculation (see item b) and item c))
- for buckling stresses: the critical buckling stress of the whole laminate (as defined in NR546, Sec 6), and the actual stresses deduced from the calculation.

b) Main stresses in individual layers:

The main stresses in each ply are to be in compliance with the following criteria:

$$\frac{\sigma_{bri}}{\sigma_{iapp}} \ge SF$$

where:

σ_{bri} : In-plane theoretical individual layer breaking stresses defined in NR546, Sec 5, [5]

σ_{iapp} : In-plane individual layer applied stresses

SF : Minimum stress criterion in layers to be taken equal to:

$$SF = C_V\ C_F\ C_R$$

C_V, C_F, C_R: Partial safety coefficients as per item f)

c) Combined stresses in individual layers:

The safety factor for the combined stresses in each ply is to be in compliance with the following criteria:

$SF_{CS} \ge SF_{CSiapp}$

where:

SF_{CSiapp}: Actual combined stress applied in layer as calculated in NR546, Sec 2, [1.3.3].

SF_{CS} : Minimum safety coefficient equal to:

$$SF_{CS} = C_V\ C_F\ C_{CS}$$

C_V, C_F, C_{CS}: Partial safety coefficients as per item f).

d) Local buckling stresses:

The local buckling stresses in the whole laminate are to be in compliance with the following criteria:

$$\frac{\sigma_c}{\sigma_A} \ge SF_B$$

where:

σ_c : Ultimate buckling stress, in N/mm², calculated by the finite element software. These values are to be documented by the Designer.

σ_A : Compressive stress applied to the whole laminate considered calculated according to [3.3.3], item c)

SF : Minimum stress criterion in layers to be taken equal to:

$$SF_B = C_V\ C_F\ C_{Buck}$$

C_V, C_F, C_{Buck}: Partial safety coefficients as per item f)

e) Column buckling stresses:

For mast shored up with shrouds and stays resulting in global compressive force on the mast, a column buckling check is to be carried out taking into account, for each parts of the mast between transversal support, the compressive forces deduced from the calculation.

The global buckling stresses in the whole laminate are to be in compliance with the following criteria:

$$\frac{\sigma_{cg}}{\sigma_A} \ge SF_B$$

where:

σ_{cg} : Critical global buckling stress to be taken equal to:

$$\sigma_{cg} = \pi^2 \frac{[EI]}{A(f\ell)^2} 10^{-6}$$

σ_A : Compressive stress applied to the whole laminate considered calculated according to [3.3.3], item c)

ℓ : Span, in m, of the mast element between lateral support with regard to the main axis of the mast

f : Coefficient taking into account the boundary conditions of the mast element ends in way of the transversal supports and to be taken equal to:

- for both end fixed: f = 0,5
- for both ends pinned: f = 1
- for one both fixed and the other pinned: f = 0,71.

A : Global transverse section of the pillar, in mm²

[EI] : Global bending rigidity of the pillar in its main axis, in N/mm².

SF_B : Minimum stress criterion in layers to be taken equal to:

$SF_B = C_V\ C_F\ C_{Buck}$

C_V, C_F, C_{Buck}: Partial safety coefficients as per item f)

f) Partial safety coefficients:

The partial safety factors are to be taken at least equal to:

- ageing effect factor C_V:

  C_V takes into account the ageing effect of the composites and is generally taken equal to 1,1.

- fabrication process factor C_F:

  C_F takes into account the fabrication process and the reproducibility of the fabrication and is generally taken equal to:

  C_F = 1,10 in case of a prepreg process

  C_F = 1,15 in case of infusion and vacuum process

- type of stress factor C_R:

  C_R takes into account the type of stress in the fibres of the reinforcement fabrics and is generally taken equal to:

  - for tensile or compressive stress parallel to the continuous fibre of the reinforcement fabric:

    C_R = 2,1 for unidirectional tape, bi-bias, three-unidirectional fabric

    C_R = 2,4 for woven roving

  - for tensile or compressive stress perpendicular to the continuous fibre of the reinforcement fabric:

    C_R = 1,25 for unidirectional tape, bi-bias, three-unidirectional fabric

  - for shear stress parallel to the fibre in the elementary layer and for interlaminar shear stress in the laminate:

    C_R = 1,6 for unidirectional tape, bi-bias, three-unidirectional fabric

    C_R = 1,8 for woven roving

- combination stress factor C_{CS}:

  C_{CS} = 1,7 for unidirectional tape, bi-bias, three-unidirectional fabric

  C_{CS} = 2,1 for the other types of layer

- buckling factor C_{BUCK}:

  C_{BUCK} = 1,45

Note 1: For standing structure element that do not affect the overall standing rigging integrity from buckling point of view, the factor C_{BUCK} may be taken equal to 1,1.

4.2 Scantling check for stiffener elements modeled by beam

4.2.1 Stiffeners made in steel and aluminium

a) Maximum stresses:

The Von Mises equivalent stress σ_{eq} defined in [3.4.1] is to be in compliance with the following formula:

$$\sigma_{eq} \le \frac{R_y}{\gamma_m \gamma_R}$$

where:

R_y : Minimum yield stress, in N/mm², as defined in Sec 4

γ_m : Material factor to be taken equal to 1,02

γ_R : Resistance factor to be taken equal to 1,2.

b) Buckling stresses:

The global column buckling stress and the local buckling stress of the basic elements of the stiffener (flange, web and associated plating) are to be checked taking into account the axial stress induced by the bending and compressive forces applied to the mast and the acceptance criteria γ_m and γ_R defined in [4.1.1], item b).

4.2.2 Stiffeners made in composite materials

a) Maximum stresses and combined stresses:

The maximum stresses and the combined stresses in the basic elements of the stiffener (associated plate, web flange) are to fulfil the requirements defined in [4.1.2], item b) and item c).

b) Buckling stresses:

Where deemed necessary by the Society, the column buckling stress and the local buckling stress of the basic elements of the stiffener (flange, web and associated plating) are to be checked taking into account the acceptance criteria defined in [4.1.2], item d) and item e).

4.3 Scantling check for stiffeners modeled by shell elements

4.3.1 Stiffeners made in steel and aluminium

The scantling check is to be as defined in [4.1.1].

4.3.2 Stiffeners made in composite materials

The scantling check is to be as defined in [4.1.2].

4.4 Scantling check for shrouds, stays...

4.4.1 General

The present Sub-article is to be considered for wire and their terminal accessories (end fittings, turnbuckles...).

4.4.2 Scantling check

The minimum breaking force (MBF), in KN, of shrouds, stays... and their terminal accessories is to comply with the following criteria:

$MBF \geq \eta.F$

where:

MBF : Minimum breaking load defined in Sec 7

F : The SWL of the cable and terminal accessories, to be taken at least equal to the maximum static tension, in kN, deduced from the model calculations as defined in [2]

η : Safety factor defined in Tab 4.

Table 4 : Safety factor η

Type of cable and terminal accessories	Safety factor η
Steel wire	3,0
Steel rod	2,5
Carbone	3,0
PBO	4,0

5 Scantling check for standing rigging component connections

5.1 Welding and weld connections

5.1.1 As a rule, the general requirements for the preparation, execution and scantling of welded connections are to be in accordance with the principles defined in the NR 467 Steel ships, Pt B, Ch 11, Sec 1.

5.1.2 The main principles of weld connections between main elements of the standing rigging are:

- fillet welds of butt welding are to be continuous and of full penetration type
- the throat thickness of the double fillet welds on fillet weld T connections is to be in general neither lower than 3,5 mm nor higher than 0,7 times the thickness of the thinnest plate of the assembly. Full penetration welds may be required for heavy stressed elements.

Other arrangements may be examined on a case by case basis.

5.1.3 When fillet weld scantling are determined by direct calculation, the fillet weld scantling is to be based on the scantling criteria defined in the present Section for the considered plates of the assembly.

5.2 Bolting connections

5.2.1 General

As a rule, the arrangement and scantling of bolted connections are to be checked by direct calculation and are to comply with a recognized standard.

5.2.2 The effective cross-sectional area (nominal stress area) to be taken into account for the bolting connection scantling, in mm², of the threaded part of a bolt is to be taken as equal to the following value:

$$S_b = \frac{\pi}{4}(d_b - 0,94p)^2$$

where:

d_b : Nominal bolt diameter, in mm

p : Thread pitch, in mm.

If the diameter of the screw body is less than d_b – 0,94p the nominal stress area of the bolt is to be taken as equal to the cross-sectional area of the screw body.

If the thread pitch is not indicated, it is assumed that it is an ISO metric threading complying with the ISO standard 898-1 of which are specified in Tab 5 according to the nominal diameter of the bolt.

5.2.3 The tightening of bolts is to be checked by suitable means and the pre-stress applied is to be between 70% and 90% of the yield stress of the bolts used.

When the tightening is checked by measuring the torque applied, then the value of this torque is to be specified. If the value, in daN.m, is not included between the minimum value C_{min} and the maximum value C_{max}, given hereunder, relevant explanations may be requested:

$C_{min} = 0,14\ 10^{-4}\ S_b\ d_b\ R_e$

$C_{max} = 0,16\ 10^{-4}\ S_b\ d_b\ R_e$

where:

S_b : Nominal stress area, in mm², of the bolt as per [5.2.2]

d_b : Nominal diameter, in mm, of the bolt

R_e : Yield stress, in N/mm², of the bolt corresponding to its steel quality grade (see Sec 4, [3.2]).

Here above values for tightening torques are valid for bolts (screws, nuts and washers) suitably cleaned, without dust or rust, and slightly oiled.

Note 1: Bolt tightening for bolted connections on composite materials are to examined on a case by case basis.

Table 5 : ISO metric thread value of thread pitch

Nominal diameter d_b of the bolt, in mm			Thread pitch (coarse thread) p, in mm
10			1,50
12			1,75
14	16		2,00
18	20	22	2,50
24	27		3,00
30	33		3,50
36	39		4,00

5.3 Riveting connections

5.3.1 As a rule, the arrangement and scantling of riveting connections are to be checked by direct calculation and are to comply with a recognized standard.

5.4 Gluing connections

5.4.1 General

As a rule, adhesive structure connections are examined by direct calculation taking into account the shear force applied to the adhesive joints deduced from the model calculation, the surface of the joint, and the gluing joint characteristics determined as defined in Sec 4, [3.4].

Where gluing structure connection are submitted to tension or out of plane forces (cleavage, peel...) due to the joint geometry, or where adhesive with shear elongation at break greater than 10% are used, the gluing structure connection is to be examined on a case by case basis.

5.4.2 Scantling check

The safety factor equal to the ratio between the theoretical shear breaking stresses of the gluing joint defined in Sec 4, [3.4.2] and the actual applied shear stress in the connection is to fulfil the following condition:

$SF \geq 2{,}4\ C_t\ C_v\ C_F\ C_{t^\circ} \geq 4$

where:

C_t : Safety factor considered for the shear breaking stress as determined by mechanical tests according to Sec 4, [3.4.2]and Sec 4, [3.4.3].

C_t is to be taken equal to 1,2.

C_V : Factor taking into account the ageing effect, to be taken at least equal to 1,2.

Note 1: When the joint is directly exposed to UV and/or water, the value of C_v is to be determined by ageing tests

C_F : Factor taking into account the gluing process and post control and generally taken as follows:

- C_F = 1,25 in case of manual process
- C_F = 1,15 in case of a vacuum process, infusion or equivalent

Note 2: The post control plan is to be submitted to the Society.

C_{t° : Factor taking into account the temperature in service condition, to be taken equal to:

- C_{t° = 1 when the joint is tested in laboratory with the min/max temperature provided in service
- C_{t° = 1,2 when the mechanical characteristics of the joint at the min/max temperature provided in service are deduced from technical data sheets submitted by the adhesive supplier.

6 Scantling check for interface components between mast and standing rigging elements

6.1 General

6.1.1 The interface components between mast and standing rigging (tangs or equivalent devices) are to fulfil the present Article.

6.1.2 Scantling check

Scantling check of the tangs or equivalent devices are to be based either on the breaking load of the component or the SWL of the equipment, to be taken at least equal to the maximum load in the standing rigging elements fixed to the component deduced from the calculation approach defined in [2].

a) Scantling based on breaking load:

The scantling check of the tang or equivalent devices based on the breaking load is to fulfil the following criteria:

$MBF \geq \eta . F$

where:

MBF : Minimum breaking load of the tang or equivalent devices

F : Maximum static tension in the standing rigging element fixed to the tang, in KN, deduced from the model calculation as defined in [2]

η : Safety factor to be taken not less than:

- 3,5 for creeping-sensitive component
- 2,4 for non creeping-sensitive element.

b) Scantling based on calculation approach:

The scantling check of the tang or equivalent device based on calculation approach is to fulfill the following criteria:

$$\sigma_{eq} \leq \frac{R_y}{\gamma_m \gamma_R}$$

where:

R_y : Minimum yield stress, in N/mm², as defined in Sec 4

γ_m : Material factor to be taken equal to 1,02

γ_R : Resistance factor to be taken equal to:

- 2.1 for creeping-sensitive component
- 1.45 for non creeping-sensitive element

σ_{eq} : Von Mises equivalent stress, in N/mm².

For components built in composite materials, the main stresses and the combined stresses are to comply the criteria defined in [4.1.2] item b) and item c) respectively with SF and SF_{CS} increased by 25%.

7 Scantling check for interface components between ship hull and standing rigging elements

7.1 General

7.1.1 The interface components between the ship hull and the standing rigging elements (chain plate, pad eye or equivalent devices) are to fulfil the requirements defined in [6].

The references loads to be considered for the scantling of chain plate, pad eye or equivalent devices are defined in [6.1.2].

Local ship hull reinforcement are to be as defined in Sec 9, [4].

8 Deflection

8.1 Maximum horizontal deflection

8.1.1 When relevant, the acceptability of deflections are to be considered under operating conditions. Acceptability criteria are to be defined by the Designer.

9 Vibration

9.1 General

9.1.1 The main origins of vibratory excitation sources of the wind propulsion system are:

- ship induced sources:
  - mechanical propulsion installation
  - hydraulic or electric energy production installation
  - mechanical installations inherent to wind propulsion system (ventilators, turbines, etc...).
- external sources
  - variations of wind instantaneous speeds
  - induced vibratory phenomenon (for instance Van Karman vortices)
  - motion of the very ship induced by sea effects.

It is to the builder's responsibility to evaluate, if deemed necessary, the resonance risk of the structure of wind propulsion system, and the possible vibratory level.

10 Fatigue

10.1 General

10.1.1 It is to the Builder's responsibility to carry out an assessment of the fatigue capacity of the propulsion structure and critical structure details under fluctuating stresses.

The critical details identified by the fatigue analysis are to be submitted to appropriate inspections and maintenance in-service to be defined in a plan of inspection within the scope of the maintenance of class defined in Sec 11.

SECTION 7 RUNNING RIGGING STRUCTURE

1 General

1.1 Application

1.1.1 General

The requirements of the present section are applicable for the scantling check of the running rigging within the scope of the additional class notation **WPS2** as defined in Sec 2, [2.2.1].

The components and constituents of a running rigging are defined in Sec 1, [2.2.2] and Sec 1, Tab 2 according to the type of wind propulsion system considered.

1.2 Documents to be submitted

1.2.1 General

The documents to be submitted to define the general arrangement of the running rigging are defined in Sec 2, [2.5.2] and Sec 2, Tab 1.

A general arrangement drawing of the running rigging specifying the following informations is to be submitted:

- positions of winches, cleats and clutches
- positions of tracks, padeyes
- arrangement of sail sheets and halyards specifying the change of angles in way of blocks
- details of deck connection of fixed elements (blocks, padeyes, winches...).

A table is to be submitted specifying the forces applied to the here above elements in the different wind propulsion system configurations associated to the wind angle of attack deduced from the calculations defined in [2].

1.2.2 For each running rigging elements, the following documents are to be submitted to the Society for information:

- technical specifications as defined in Sec 4
- manufacturer's documents stating the results of the tests performed on the equipment and product certificate
- structure drawings of elements such as boom, mast rotating systems, wing orientable systems… when applicable.

2 Calculation methods

2.1 General

2.1.1 The forces applied to the different running rigging elements, deduced from the calculation approach defined in Sec 6 or equivalent taking into account the different wind propulsion system configurations associated to the wind angle of attack, are to be submitted by the Designer.

The maximum static forces considered in the present Section are to be calculated taking into account the partial safety factor α for loading conditions defined in Sec 6.

2.2 Sheave

2.2.1 Load on sheave block

As a rule, the load on sheave block is to be determined on the basis of vectorial composition of force exerted by the rope taking into account the angle by which the block turns the rope.

The maximum load on a sheave block is obtained for an angle equal to 180° and is equal to 2 times the tensile rope force.

3 Scantling check for running rigging elements

3.1 General

3.1.1 Minimum breaking force (MBF)

The minimum breaking force of an element is the static force in kN, corresponding to its minimum load which causes its breaking.

As a rule, when Safe Working Load (SWL) of an element is defined as [3.1.2] the minimum breaking load is to be not less than 2 SWL.

3.1.2 Safe Working Load (SWL)

The safe working load of an element is the maximum load which may be carry by this element in operation.

3.1.3 Reference loads

The reference load to consider for the scantling check of the running rigging element are to be based either on:

a) for sail sheets and halyards, clutch, sheaves: the breaking load of the element (for sail sheets and halyards, clutch, sheaves…), or the SWL to be taken at least equal to the maximum load in the element deduced from the calculation approach defined in [2].

b) for winch: the brake value for winch

c) for boom and mechanical elements of mast rotating systems: the loads deduced from the calculation approach defined in [2] for boom, mechanical elements of mast rotating systems.

Note 1: Long boom integrated to the mast for free standing rotating rig and wing sail systems are to be considered as standing rigging and are to be examined according to Sec 6.

3.2 Scantling criteria for running rigging elements

3.2.1 Scantling based on breaking load

The scantling check of the elements defined in [3.1.3], item a) is to fulfil the following criteria:

$MBF \geq \eta.F$

where:

MBF : Minimum breaking force, in kN, of the considered element defined in [3.1.1]

F : The SWL of the equipment to be taken at least equal to the maximum static tension, in KN, deduced from the model calculation as defined in [2]

η : Safety factor to be taken not less than:

- 3,1 for creeping-sensitive elements
- 2,1 for non creeping-sensitive elements

Note 1: For fiber ropes of materials other than polyester and HMPE (High Modulus Polyethylene), the minimum values of safety factors are to be increased in the rope itself (i.e. not including other parts of the line) by 10%.

3.2.2 Scantling based on brake value

The design of the winches and equivalent equipments is based on the brake capacity in service conditions.

The minimum brake capacity of the winch is to be at least equal to the values defined in Tab 1.

Table 1 : Minimum braking force

RP, in kN **(1)**	Minimum braking force, in kN **(2)**
RP < 200	1,50 RP
200 ≤ RP ≤ 500	1,20 RP + 60
RP > 500	1,32 RP

(1) Line tension, in kN, deduced from [2.1.1]
(2) Minimum rated holding force, in kN, of the static brake system at the reeled layer for which the RP is specified.

3.2.3 Scantling based on the calculation approach

a) General:

The scantling check of the running rigging elements examined on the base of the loads deduced from the calculation approach defined in [2] is to be carried out by direct calculation according to the scantling criteria defined in Sec 6, [6.1.2], item b) with a resistance factor γ_R to be taken equal to:

- 2.1 for creeping-sensitive component
- 1.3 for non creeping-sensitive element.

For components built in composite materials, the main stresses and the combined stresses are to comply the criteria defined in Sec 6, [4.1.2], item b) and item c) respectively with SF and SF_{CS} increased by 10%.

b) Slewing ring

An attestation from the ring manufacturer fixing the maximum permissible values for overturning moment and vertical force in the working conditions is to be submitted to the Society.

These values are not to be lower than those calculated according to calculation approach defined in Sec 6, [2] increased by 10%.

The connections of the slewing ring with the mast and the hull support is to be documented specifying the bolt pre-stressing values and the local reinforcement in the composite parts.

When the slewing ring is part of a set of an automatic release system to avoid wind overload on the wind propulsion system considered for the scantling of the standing rigging, the slewing ring scantling is to be checked within the scope of the additional class notation **WPS1**.

4 Scantling check for interface components between running rigging elements and mast or ship hull

4.1 General

4.1.1 The interface components between running rigging components and mast or ship hull are to fulfil the criteria defined in [3].

Local ship hull reinforcements are to be as defined in Sec 9, [4].

SECTION 8 DRIVE SYSTEMS

1 General

1.1 Application

1.1.1 The present Section applies to drive systems of the wind propulsion system. It includes the drive unit with all the machinery and electrical equipment/systems used to operate, control and monitor the wind propulsion system.

Drive systems include the following types:

- electrical drive
- hydraulic drive.

1.1.2 According to the additional classification notation **WPS1** or **WPS2** to be granted to the ship, the present Section applies to the following:

- For ships assigned with notation **WPS1**:
  - Drive systems playing an essential part in the safety and integrity of the wind propulsion system
- For ships assigned with notation **WPS2**:
  - Drive systems, considered for the notation **WPS1**, playing an essential part in the safety and integrity of the wind propulsion system
  - Drive systems playing an essential part in the use of the wind propulsion system.

1.1.3 Wind propulsion system control includes the following modes:

- full automatic
- remote operated from navigation bridge
- locally hand-operated.

1.1.4 Applicable requirements

Drive systems are to comply with the applicable requirements according to Tab 1.

1.2 Documents to be submitted

1.2.1 The documents listed in Tab 2 are to be submitted, as a minimum, for approval or for information.

Table 1 : Applicable requirements

Item	Rule Reference
Main principles	• Article [2]
Machinery	• Article [3] • NR467, Pt C, Ch 1
Electrical installations	• Article [4] • NR467, Pt C, Ch 2
Automation	• Article [5] • NR467, Pt C, Ch 3

2 Main design principles

2.1 General

2.1.1 Machinery essential for the control and safety of the wind propulsion system shall be provided with effective means for its operation and control.

2.1.2 Drive system is to be designed so that any damage to pump, motor, monitoring system, electrical or hydraulic fluid supply will not cause the wind propulsion system to be out of control and thus endanger the life of operators or of the personnel

2.1.3 Fail-to-safety principle

Control, alarm and safety systems are to be based on the fail-to-safety principle

2.1.4 Type approved products

The drive system and its components, as indicated in NR467, Pt C, Ch 2, Sec 15, are to be chosen from among the list of type approved products.

Case by case approval may also be granted at the discretion of the Society, based on submission of adequate documentation and subject to the satisfactory outcome of any required tests.

2.1.5 Environmental conditions

The drive system is to be designed to operate satisfactorily in the environment in which it is located. The environmental conditions are described in NR467, Pt C, Ch 2, Sec 2.

2.1.6 Essential services

Essential service is intended to mean a service necessary for a ship to proceed at sea, be steered or manoeuvred, or undertake activities connected with its operation, and for the safety of life, as far as class is concerned.

Examples of equipment for essential services are given in Tab 3.

2.2 Power sources

2.2.1 Loss of any power source (hydraulic, pneumatic, electric) is to be signalled by a specific alarm.

2.2.2 Except where alternative arrangement is equivalent, power sources are to be duplicated (compressed air reducing valves and filters, electric supply contactors and feeders, hydraulic oil pumps).

2.2.3 In case of a total loss of the usual means of control, some appropriate last emergency facilities are to be given in order to possibly secure all the sail equipment in a safe position.

Table 2 : Documentation to be submitted for drive systems

No.	I/A	Documentation
General arrangement and operating principles		
1	I	The general specification for the automation of the wind propulsion system, including: • specification of the safety devices • specification of the mechanical propulsion plant.
2	I	The general operating principles of the wind propulsion system, including: • description of modes of control (at open sea, in manoeuvre) • description of possible combinations of the various means of propulsion • description of propeller - sail coordination • modes of propulsion power sharing within the wind propulsion system and the main engine.
3	A	The detailed specification of the essential service systems
4	A	The list of components used in the automation circuits, and references (Manufacturer, type, etc.)
5	I	Instruction manuals
6	A	The diagrams of the supply circuits of automation systems, identifying the power source
7	I	List of computerized systems as mentioned in NR467, Pt C, Ch 3, Sec 3, [1.2.1]
8	I	Software Registry as mentioned in NR467, Pt C, Ch 3, Sec 3, [4.3.1], including specification of the data processing hardware and description of the application software
Monitoring and alarms		
9	I	FMECA (failure mode effects and criticality analysis) of the system components (for instance, as per the document IEC 812 - 1985)
10	I	Test program and procedures for control, alarm and safety systems
11	A	Location and arrangement of the control stations, including a general diagram showing the monitoring and/or control positions for the various installations, with an indication of the means of access and the means of communication between the positions as well as with the engineers
12	A	The list of monitored parameters for alarm/monitoring and safety systems
13	A	Sensor list and data sheets, with justification of their qualification for the sea-going environmental conditions
14	I	Explanatory note on sensor location and duplication, where necessary
15	A	Note on the analog sensor signal processing
16	A	Alarm list and alarm system specification
17	A	Diagram of the engineers' alarm system
18	A/I	Documentation and test attendance for based computer systems as mentioned in NR467, Pt C, Ch 3, Sec 3, Tab 2

Table 3 : Examples of essential services

Description of service	**WPS1**	**WPS2**
Mast rotating system	**(1)**	X
Mast lashing system	X	X
Winches used for standing rigging	X	X
Winches used for running rigging	**(1)**	X
Monitoring and safety devices/systems	X	X
Control system of wind propulsion system	**(1)**	X
Fire detection and alarm system	X	X
Emergency shut-down systems having an impact on essential services	X	X
Mast tilting system	X	X
Navigation lights, aids and signals	X	X
Main lighting system for those parts of the wind propulsion system normally accessible to and used by the personnel	X	X
Hydraulic pumps supplying the above equipment	**(1)**	X
Auxiliary services supplying the above equipment (lubricating oil pumps, cooling water pumps)	**(1)**	X
(1) When system is used as safety guard		

3 Machinery

3.1 General

3.1.1 Safety devices on moving parts

Suitable protective devices on access restrictions are to be provided in way of moving parts in order to avoid accidental contact of personnel with moving parts.

3.2 Hydraulic systems

3.2.1 Hydraulic installations are to comply with the applicable requirements of NR467, Pt C, Ch 1, Sec 3 and NR467, Pt C, Ch 1, Sec 10.

3.2.2 Hydraulic equipment are to be duly protected against

- overpressure
- oil pollution (abrasive particles)
- corrosion
- accidental shocks.

3.2.3 The design pressure of piping system is the pressure considered by the manufacturer to determine the scantling of the system components. It is not to be taken less than the maximum working pressure expected in this system or the highest setting pressure of any safety valve or relief device whichever is the greater.

Note 1: Maximum working pressure is to be determined according to loads defined in Sec 5 and load cases defined in Sec 6, Tab 1.

Special attention is to be paid on accidental case resulting in high transient working pressure so that the safety valve or relief device, is not reacting,

3.2.4 Scantlings of cylinder shell

The minimum thickness t of the steel cylindrical shell of luffing or slewing hydraulic cylinders is given, in mm, by the following formula:

$t = pD / (2K - p)e$

where:

p : Design pressure, in MPa

D : Inside diameter of the cylinder, in mm

e : Efficiency of welded joint equal to 1 in general, specially considered by the Society depending on the service and the manufacture procedure.

K : Permissible stress, in N/mm^2

Where not otherwise specified, the permissible stresses K, may be taken as the minimum of the values obtained by the following formulae:

- $K = R_{m,20} / A$
- $K = R_S / B$

A, B : Coefficients of utilisation defined in Tab 4.

$R_{m,20}$: Minimum tensile strength at ambient temperature (20°C), in N/mm^2

R_S : Minimum between R_{eH} and $R_{p\,0.2}$ at the design temperature T, in N/mm^2.

The thickness obtained is net thickness, as it does not include any corrosion allowance. The thickness obtained by the above formulae is to be increased by 0,75mm.

The Society reserves the right to increase the corrosion allowance value in the case of vessels exposed to particular accelerating corrosion conditions. The Society may also consider the reduction of this factor where particular measures are taken to effectively reduce the corrosion rate of the vessel.

Irrespective of the value calculated by the formulae, the thickness t is not to be less, in mm, than the following:

$t = 3 + D/1500$

No corrosion allowance needs to be added to the above value.

Note 1: The formula of t is applicable if the ratio external diameter/inside diameter is equal to or less than 1,5, if not the cylinder is subject to special consideration.

Table 4 : Coefficients of utilisation

	A	B
Steel	2,7	1,8
Cast steel	3,4	2,3
Nodular cast iron	4,5	3,5
Aluminium	4	1,5

3.2.5 Scantlings of cylinder heads

The thickness of the bottom and of the head of the cylinder is to comply with the applicable requirements of NR467, Pt C, Ch 1, Sec 3, [2.7].

3.2.6 Scantlings of piston rods

Scantlings of piston rods are to be checked for buckling according to the following strength criterion:

$\omega\sigma_c \le 0,55\ R_e$

where:

σ_c : Compression stress, in N/mm^2

R_e : Yield stress, in N/mm^2, considered in calculations of cylinder rod resistance.

ω : Buckling coefficient determined with the following formula:

- $\omega = 1$ where $\lambda < 30\ (235/R_e)^{1/2}$
- $\omega = B + \sqrt{B^2 - A}$ otherwise

where:

$A = 112,8 \times 10^{-6}\ \lambda^2\ R_e/235$

$B = 0,5(A + 1) + \zeta(\sqrt{A} - 0,2)$

λ : Slenderness ratio equal to the following value:

$$\lambda = 100\ell\sqrt{\frac{S}{I}}$$

ℓ : Effective length of buckling equal to twice the maximum reach of cylinder rod

S : Cross sectional area, in cm^2

I : Moment of inertia, in cm^4, of the considered cross-section

ζ : Coefficient equal to the following value:

- ζ = 0,1 for closed cross-section beams (tubes. box beams, etc.)
- ζ = 0,17 for open cross-section beams (lattice beams, angle bars, I, T or U-shape sections, etc

3.2.7 Testing pressure

a) Hydraulic cylinders

The hydraulic cylinders, the functions of which are the luffing, slewing or tilting of the boom, mast, balestron are to be submitted to an hydraulic test under a pressure at least equal to 1,5 times the design pressure.

b) Pumps

The pumps are to be submitted to a hydraulic test under the conditions as per NR467, Pt C, Ch 1, Sec 10, i.e. at a test pressure P_H , in MPa, equal to the following value:

- $P_H = 1,5\ P$ when $P \leq 4$
- $P_H = 1,4\ P + 0,4$ when $4 < P \leq 25$
- $P_H = P + 10,4$ when $P > 25$

where P is the design pressure, in MPa.

3.2.8 Pressure pipes are to satisfy the applicable requirements of NR467, Pt C, Ch 1, Sec 10. Flexible pipes are to be of approved type as per requirements of NR467 Pt C, Ch 1, Sec 10.

3.3 Pneumatic equipment

3.3.1 Design is to be established on the same basis as hydraulic equipment.

3.3.2 It is to be demonstrated that level of safety is not less than that which would be achieved by hydraulic equipment ensuring same functions and performances.

4 Electrical installations

4.1 General

4.1.1 Hazardous areas

As far as practicable, electrical installations intended for the wind propulsion system should not be located in hazardous areas (defined in Sec 9, [1.1.1]).

Where due to the operational requirements, some electrical equipment is located in hazardous areas zone 1 or zone 2, it has to comply with the requirements for such equipment in hazardous areas, as defined in NR467, Pt C, Ch 2, Sec 1.

4.1.2 Degrees of protection

Electric motors, equipment and cables are to be duly protected against:

- overcurrent
- ingress of liquids, depending on their location
- ingress of solid foreign bodies, depending on their intended use
- moisture and corrosion in sea water atmosphere
- accidental shocks, depending their on location.

The index of protection against ingress of liquids and solid bodies of electrical equipment, in relation to their location is generally that specified in NR467, Pt C, Ch 2, Sec 3, Tab 2.

5 Automation

5.1 General

5.1.1 When automatically controlled, the system is not to increase significantly the bridge operator tasks.

5.1.2 Operating modes selection

The operating mode selection is to be made from the navigating bridge.

5.1.3 Failure behaviour

The automation system is to have non-critical behaviour in the event of power supply failure, faults or restoration of operating condition following a fault. If a redundant power supply is used, it must be taken from an independent source.

5.1.4 Failure alarm

Failure of automation systems is to generate an alarm.

Detailed indication, alarm and safety requirements regarding automation systems for individual machinery and installations are to be found in tables located in:

- NR467, Part C, Chapter 1, and in
- NR467, Part F, Chapter 3 (for ships granted with a notation **AUT**).

5.1.5 Power supply

The conditions of power supply to be considered are defined in NR467, Pt C, Ch 3, Sec 1, [3.2].

5.2 Remote control

5.2.1 The design of the remote control system is to be such that in case of its failure an alarm will be given.

5.2.2 Supply failure (voltage, fluid pressure, etc.) in wind propulsion system remote control is to activate an alarm at the control position.

Where the vessel, the cargo and the sails are so sized and combined that a total or partial trouble in the control system may result in endangering the ship, some suitable automatic safety arrangements are to be made, such as:

- self automatic sail furling
- self orientation of sails in the less wind-resistant position.

The case of wind assistance during the manoeuvre will specially be considered.

Table 5 : Monitoring - Alarms

	Parameters	Alarms	Others
Sails	Automatic safety furling, folding or equivalent action	X	
	Overload	X	
Hydraulics	Oil tank level	Low	Auto start of stand-by pump
	Oil pressure	Low	
		Very low	
	Oil temperature	High	
Pneumatics	Air pressure	Low	
Electrical equipment	General supply voltage	Low	
	Instrumentation supply voltage (sensors, alarms, computers)	Low	
	Instrumentation supply insulation	Low	
	Tripping of any computer watch dog	X	

5.2.3 Propulsion machinery orders from the navigation bridge shall be indicated in the main machinery control room, and at the manoeuvring platform.

Indicators are to be fitted for:

- wind propulsion system inclination indicator, when relevant (e.g. tilt up mast)
- wind speed indicator
- alarm system with clear text indicating the failure of:
  - general failure of the control system
  - failure in the power system
  - failure of the stability system.

5.2.4 The control shall be performed by a single control device for each independent wind propulsion system, with automatic performance of all associated services, including, where necessary, means of preventing overload of the propulsion machinery.

Where multiple wind propulsion system are designed to operate simultaneously, they are to be controlled by one control device.

5.2.5 The main propulsion machinery shall be provided with an emergency stopping device on the navigation bridge which shall be independent of the navigation bridge control system.

In the event that there is no reaction to an order to stop, provision is to be made for an alternative emergency stop. This emergency stopping device may consist of a simple and clearly marked control device, for example a push-button. This fitting is to be capable of putting the wind propulsion system in the less wind resistant position or sail furling, whatever the cause of the failure may be.

5.3 Alarm system

5.3.1 General

Alarm systems are to meet the requirements given in NR467, Pt C, Ch 3, Sec 2, [7].

Tab 5 gives some non-restrictive recommendations.

5.4 Safety systems

5.4.1 The safety systems are intended to protect the wind propulsion system against either casual or exceptional overload due to environmental conditions.

They include devices such as circuit breakers, safety\ valves, sail furling equipment, etc.

5.4.2 Safety devices or systems are to operate separately from the control and alarm systems. Their operation shall give a suitable alarm.

5.4.3 Safety system failures

A safety system is to be designed so as to limit the consequence of failures. It is to be constructed on the fail-to-safety principle.

The safety system is to be of the self-check type; as a rule, failure within the safety system, including the outside connection, is to activate an alarm.

5.4.4 Safety system activation

The safety system is to be activated automatically in the event of identified conditions which could lead to damage of associated machinery, system or structural part such that:

- normal operating conditions are restored (e.g. by the starting of the standby unit), or
- the operation of the wind propulsion system is temporarily adjusted to avoid overloading (e.g. by reducing the tension in the sail sheets or kite tension line), or
- the wind propulsion system is protected, as far as possible, from critical conditions by arranging the wind propulsion system is an appropriate configuration that it induces wind forces as small as possible on structures (e.g. by furling the soft sails, stopping flettner rotors, folding or trimming the windsails in such a way the combination lift/drag is as small as possible).

5.4.5 Safety system monitoring

When the safety system has been activated, it is to be possible to trace the cause of the safety action. This is to be accomplished by means of a central or local indication.

When a safety system is made inoperative by a manual override, this is to be clearly indicated at corresponding control stations.

Automatic safety actions are to activate an alarm at predefined control stations.

5.4.6 Shutdown

For shutdown systems of machinery, when the system has stopped a machine, the latter is not to be restarted automatically before a manual reset of the safety system has been carried out.

5.4.7 Testing

The safety systems are to be tested in accordance with the requirements in NR467, Pt C, Ch 3, Sec 6.

5.5 Interconnection and relationship with the mechanical propulsion plant

5.5.1 In the automatic mode, the power sharing is to be automatically achieved, nevertheless the choice of the adjustment parameters may be left to the operator who may prefer for instance fuel savings instead of sailing time savings, or reciprocally, according to the situation and the nautical conditions.

5.5.2 Time delayed alarm

When the automatic power load sharing “sails - main engine” is in service, a time delayed alarm given to the navigation bridge, is to be provided in case the engine operating load remains too low during an excessive period of time. Alternatively, similar arrangements may be provided by the application software.

5.5.3 Overload alarm

Where a possibility to cancel the automatic co-ordination sails - engine(s) exists, a dedicated overload alarm of the engines is to be provided.

5.5.4 Manoeuvre

In case of “crash astern” manoeuvre, it may be required, according to the ship and sail type, that optimal sail control be automatically achieved.

SECTION 9 BASE SHIP REQUIREMENTS

1 General

1.1 Definitions

1.1.1 Hazardous area

Hazardous area as defined in IEC 60092-502 means an area in which an explosive gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.

2 Arrangement

2.1 General

2.1.1 Location of wind propulsion system

Wind propulsion system is to be so located and protected as to reduce to a minimum any danger to personnel, due regard being paid to moving parts or other hazards. Adequate provisions should be made to facilitate cleaning, inspection and maintenance.

Due attention is to be given to the underside of the wind propulsion system which should be clear of passing wave crest.

2.1.2 Configuration of wind propulsion system

When the wind propulsion system is inoperative, it is to be possible to secure it and its configuration is to be so arranged that it induces wind forces as small as possible on structures.

3 Stability

3.1 General

3.1.1 Purpose of the stability check

The purpose of stability verifications specified in the present note is to ensure adequate residual stability when considering unfavourable effects which may result from wind actions on the wind propulsion system.

The Society approves the intact stability files and should occasion arise damage stability ones, taking into consideration the criteria determined by the Flag Authorities and/or the Society, both according to the type of wind propulsion and service notation of the ship.

The Society may accept stability approvals and checking made by the Administration or any Organisation duly recognized by the latter. In such a case, the documents which demonstrate that checking and approvals have been made are to be submitted.

3.1.2 Icing

For any ship having an Ice class notation (see NR467, Pt F Ch 8) or operating in areas where ice accretion is likely to occur, effect of icing-up of all or parts of the wind system on ship stability is to be examine as given in NR467, Pt B, Ch 3, Sec 2, [6].

3.2 Intact stability

3.2.1 Wind propulsion system configurations

The different wind propulsion system configurations which provide unfavourable effects resulting from wind actions are to be considered.

For wind propulsion system of rig type, at least, the following three sailing combinations are to be investigated:

- full sails
- intermediate sails
- reduced sails.

3.2.2 Weather criterion

The ability of a ship to withstand the combined effects of beam wind and rolling should be demonstrated for each standard condition of loading as defined in NR467, Pt B, Ch 3, Sec 2, [3] considering the different wind propulsion system configurations defined in [3.2.1].

4 Structural assessment

4.1 General

4.1.1 The ship foundation structure elements in way of the standing and running members are to be designed taking into account the reaction forces and moments induced by the wind propulsion system according to the present Article.

The local hull structure to be considered are defined in Sec 1, [2.3].

4.2 Loads

4.2.1 The loads to be considered are the most severe combination of loads deduced from the 3D finite element model submitted by the Designer according to Sec 6.

4.3 Local ship hull reinforcement

4.3.1 General

When the local ship hull structure in way of the wind propulsion system foundation contributes to the hull girder strength, the normal stresses in the hull girder induced by still and wave global bending moments and, when applicable, induced by the wind propulsion system arrangement in operation, are to be combined with the local stresses for the local reinforcement structure check.

4.3.2 Ship hull reinforcement - Hull in steel or aluminium

a) Scantling check:

The bending, tensile and shears stresses in the local hull reinforcement and fillet welding in way of the standing and running members are to be obtained through direct calculation analysis.

The Von Mises equivalent stress, σ_{eq}, in N/mm², is to be derived as follows:

$$\sigma_{eq} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 + 3\tau_{12}^2}$$

where:

σ_1, σ_2 : Normal local and global hull girder stresses in the directions of the reinforcement element co-ordinate system axes

τ_{12} : Shear stress with respect to the reinforcement element co-ordinate system axes.

The Von Mises equivalent stress σ_{eq} is to be in compliance with the following formula:

$$\sigma_{eq} \leq \frac{R_y}{\gamma_m \gamma_R}$$

where:

R_y : Minimum yield stress, in N/mm², as defined in Sec 4

γ_m : Material factor to be taken equal to 1,02

γ_R : Resistance factor to be taken equal to 1,45.

b) Connection scantling check

- Welding connections:

  As a rule, the general requirements for the preparation, execution and scantling of welded connections are to be in accordance with the principles defined in the NR467, Pt B, Ch 11, Sec 1.

  A plan specifying the NDT procedures of the connection welds according to Sec 4, [3.1.3] is to be submitted to the Society for approval.

- Bolting and riveting connections:

  Bolting and riveting connections are to be examined on a case by case basis according to Sec 6, [5.2] and Sec 6, [5.3].

4.3.3 Ship hull reinforcement - Hull in composite materials

a) Scantling check

The bending, tensile and shears stresses in the local hull reinforcement in way of the standing and running members are to be obtained through direct calculation analysis.

The main approach considered is based on a stress analysis in each individual layer of the composite panel ("ply by ply" analysis) in order to determine the following stresses in relation to the individual layer fibre direction:

- main stresses (tensile, compressive and shear stresses), and
- combined stresses.

The main stresses and the combined stresses are to comply the criteria defined in Sec 6, [4.1.2] items b), c) and d) respectively with SF and SF_{CS} and SF_B increased by 25%.

b) Connection scantling check

- Bolting and riveting connections:

  Bolting and riveting connections are to be examined on a case by case basis according to Sec 6, [5.2] and Sec 6, [5.3].

- Gluing connections:

  Adhesive structure connections are examined by direct calculation taking into account the shear force applied to the adhesive joints, the surface of the joint, the gluing joint characteristics according to Sec 6, [5.4] taking into account a safety coefficient SF increased by 25%.

4.4 Strength check of the global hull girder

4.4.1 General

When the wind propulsion system arrangement induces significant global hull girder bending moments and shear forces, these moments and forces are to be combined with the still and wave global hull girder loads to carry out the strength check of the hull girder structure.

The values of the global bending moments and shear forces induced by the wind propulsion system arrangement in operation are to be defined by the Designer. These values may be calculated on the basis of the moments and forces deduced from the 3D finite element model defined in Sec 6 reduced by 30%.

The strength check of the hull girder structure is to be carried out as defined in the Rules for the classification of ships of the Society.

4.5 Vibrations

4.5.1 Attention is drawn to the necessity to evaluate the effects of vibration of the wind propulsion system on the ship structure, see Sec 6, [9].

If deemed necessary, the Society reserves the right to ask for a justification of fatigue strength.

5 Hull outfitting

5.1 Rudder

5.1.1 Strength and performance

The main steering gear and rudder stock are to be:

- of adequate strength and capable of steering the ship at maximum ahead service speed
- capable of putting the rudder over from 35° on one side to 35° on the other side with the ship at its deepest seagoing draught and running ahead at maximum ahead service speed,

in the different operating conditions defined in Sec 5, [3.3].

5.1.2 Rudder scantling

The rudder scantling is to be as defined in NR467, Pt B, Ch 9, Sec 1.

The rudder force C_R is to take into account the reaction force induced by the moment generated by the transverse forces from wind propulsion system and anti-drift forces. This reaction force is to be defined by the Designer.

5.2 Keel and leeboard

5.2.1 The structure of keels and leeboards necessary for maintaining the yacht's stability are reviewed on a case-by-case basis.

The weight of the keel or leeboard, the maximum ship heeling angles and the hydrodynamic anti-drift forces on keel or leeboard are to be submitted by the Designer.

The structure is to be checked taking into account a Von Mises equivalent stress σ_{eq} in compliance with the following formula:

$$\sigma_{eq} \le \frac{R_y}{\gamma_m \gamma_R}$$

where:

R_y : Minimum yield stress, in N/mm², as defined in Sec 4

γ_m : Material factor to be taken equal to 1,02

γ_R : Resistance factor to be taken equal to 1,9.

5.2.2 The hull structure local reinforcements in way of keel and leeboard are to be checked according to [4.3.2] taking into account a resistance factor γ_R equal to 1,9.

These reinforcements are to be examined in way of keel and leeboard necessary for maintaining the yacht's stability and also for anti-drift keel and leeboard fitted to the hull. In this case, the reaction forces applied to the hull structure are to be defined by the Designer.

5.3 Equipment in anchors and chains

5.3.1 General

The equipment in chain and anchor for temporary mooring of ship is to be determined taking into account the hypothesis calculation approach defined in NR467 or NR600, as applicable.

In addition, the forces due to the wind on the standing rigging is to be considered according to [5.3.2].

5.3.2 Force on standing rigging

The theoretical static force induced by wind applied on the standing rigging, in kN, is defined according the following formula for each mast:

$$F_m = \frac{1}{2}\rho\left(C_{xm} h_m b_m + C_{xi}\sum \ell_i d_i 10^{-3}\right)V^2 10^{-3}$$

where:

ρ : Air density, equal to 1,22 kg/m³

V : Speed of the wind, in m/s, as defined in the Rules of the Society defined in [5.3.1]

C_{xm} : Mast or rotor sail drag coefficient to be taken equal to:
- 0,5 for cylindrical mast or rotor
- 0,22 for streamlined mast or wing mast.

Note 1: Other drag coefficient may be taken into account if duly justified.

h_m : Height, in m, of the mast or rotor

b_m : Breadth, in m, of the mast or rotor

C_{xi} : Shroud drag coefficient to be taken equal to 1,2

ℓ_i : Length, in m, of mast shrouds (lower and upper, fore and backstay)

d_i : Diameter, in mm, of shrouds.

For ship having several masts or rotors, the total static force induced by wind applied on the standing rigging is to be taken equal to the sum of the forces F_m of each mast or rotors and its standing rigging.

5.3.3 Equipment in chain and anchor

The equipment in chain and anchor is to be determined as follow:

a) For ships for which the equipment is covered by NR600:

On the basis of the dynamical force F_{EN} in KN calculated as defined in NR600 increased by $2.F_m$, where F_m is the static force defined in [5.3.2]

b) For other ships:

On the basis of the equipment number EN calculated as defined in NR467 increased by the following value EN_m:

$EN_m = 9{,}5.F_m$

where F_m is the static force defined in [5.3.2].

6 Fire safety

6.1 General

6.1.1 When require by risk analysis outputs, exposed surfaces are not to give rise to smoke or toxic or explosive hazards at elevated temperatures, this being determined in accordance to the Fire Test Procedures Code.

6.1.2 Machinery spaces containing the drive unit of the wind propulsion system are considered as other machinery spaces for fire protection arrangements in accordance with NR467, Part C, Chapter 4.

Depending on the outputs of risk analysis or if deemed necessary by the Society, additional requirements may be considered on a case by case basis.

7 Electrical installation

7.1 General

7.1.1 Power supply

When the ship main power plant is used to supply the wind propulsion system, it shall have sufficient power to run simultaneously:

- the wind propulsion system at its maximum rated load
- the essential services (as defined in Sec 8, [2.1.6])
- the ballast system, when relevant.

7.1.2 Hazardous area

Electric and wiring are not to be installed in a hazardous area unless essential for operational purposes or safety enhancement, they are of certified safe type for use in the area.

7.2 Lightning protection and earth protection

7.2.1 Earthing definition

The earth connection to the general mass of the hull of the base ship in such a manner as will ensure at all times an immediate discharge of electrical energy without damage.

7.2.2 A protective system is to be fitted to structure of non metallic construction or having a substantial number of non-metallic members. The lightning and earthing system is to be designed in accordance with the requirements of IEC60092-401.

SECTION 10 SEA TRIALS, INITIAL INSPECTION AND TESTING

1 General

1.1 Application

1.1.1 This Section covers shipboard tests, both at the quay and during sea trials.

Note 1: Reference is made to Sec 4, [5] and App 2 for materials and components used in the construction of wind propulsion systems to be inspected and tested in relation to their use at the manufacturer's works.

1.1.2 Shipboard tests are intended to demonstrate that the wind propulsion system is functioning properly.

1.1.3 A comprehensive list of the shipboard tests intended to be carried out is to be submitted to the Society.

For each test, the following information is to be provided:

- scope of the test
- acceptable wind speed range, when applicable
- relevant ship speed range, when applicable
- parameters to be recorded.

1.1.4 The tests are to be witnessed by a Surveyor.

The final test results and reports are to be submitted to the Society for examination.

2 Tests after fitting

2.1 General

2.1.1 After fitting, the wind propulsion system installations are submitted to the tests considered as necessary to check the good operational conditions.

Such tests are carried out at quay, when possible, or, if not, at sea.

2.1.2 A detailed programme of tests is to be approved by the Society. It is to include. in particular, the following tests:

- dielectric and insulation tests of the electric circuits
- test of each alarm channel
- test of any safety device, such as safety valves, automatic furling equipment limit switches
- test of the various modes of automatic use
- test of the last emergency control
- test of behaviour in case of black out and of possible automatic restarting (for ships assigned with a notation **AUT**).

2.1.3 Tests of piping system

Except otherwise permitted by the Society, all piping systems are to be leak tested under operational conditions after completion on board.

3 Sea trials

3.1 General

3.1.1 Global demonstrative trial is to be carried out at sea according to an approved programme to check that the wind propulsion system is satisfactory from the operation and control point of view.

3.1.2 Sea trial normally includes a period of navigation time under each of the navigation modes, including the emergency ones. The good working of the safeguards is also to be verified.

3.1.3 A demonstration of the behaviour of the ship under sails when a "black-out" occurs, and a "crash-astern" manoeuvre are also to be achieved, stopping distances and wind speed are to be noted for crew information purpose.

3.1.4 If it is impossible to carry out these trials under maximum service conditions or other determining provided conditions, the performance of only preliminary tests in the presence of the Surveyor may be allowed, the remaining trials being carried out afterwards. However, the trials of good running and safety is to be performed on the preliminary tests.

3.2 Functional tests

3.2.1 During sea trials, piping systems including associated monitoring and control devices, are to be subjected to functional tests at the nominal power of the machinery. Operating parameters (pressure, temperature, consumption) are to comply with the values recommended by the equipment manufacturer.

SECTION 11 IN-SERVICE SURVEYS

1 General

1.1 Application

1.1.1 Ships granted with an additional class notation **WPS1** or **WPS2**, are submitted to class renewal surveys (see NR467, Pt A, Ch 2, Sec 2, [4.1]) and annual surveys (see NR467, Pt A, Ch 2, Sec 2, [5]) to record that the ship in service meets the conditions for maintenance of Class (see NR467, Part A, Chapter 2).

The particular requirements relating to these notation are defined in [2] for the class renewal surveys and in [3] for the annual surveys.

It is the Owner' responsibility to apply for the requested surveys with a view to avoiding any inconvenience likely to result from the suspension or withdrawal of class

1.1.2 Maintenance plan

As a rule, a maintenance plan is to be submitted to the Society for information.

The repairs and criteria to replace equipment or accessories are defined in each case at Society Surveyor' satisfaction.

1.2 Preparation of the surveys

1.2.1 In order to allow a correct examination of the propulsion system, it is necessary to check that all the elements of it are accessible in good safety conditions.

A basket or an equivalent system is to be provided.

1.2.2 Should sails control and manoeuvring systems be included in the additional notation **WPS1** or **WPS2** (for instance: furling or reefing systems), it is necessary to check that it is possible to use them during the survey without difficulty, according for instance to wind direction and speed, power supply and any other factor which may influence the survey.

1.2.3 The laying down of the mast(s) may be requested for the survey, if the Society considers that otherwise the examination cannot be carried out satisfactorily.

2 Class renewal survey

2.1 General

2.1.1 As a rule, the scope of examination is applicable to metallic system.

In the case of the use of particular materials (aluminium alloys, plastic reinforced with fiberglass or other fiber, sandwich panels,...) an adapted programme of inspection is to be carried out, after approval by the Society.

2.1.2 For internal controls, endoscope, x-rays or any other usable means can be accepted.

2.1.3 The extent of the survey is defined in:

- [2.2] and [2.4] for ships granted with notation **WPS1**
- [2.2], [2.3] and [2.4] for ships granted with notation **WPS2**.

2.2 Standing rigging

2.2.1 Systematic dismantlings may be required by the Society, depending on maintenance programme, at the Surveyor' satisfaction.

As a rule, a mast and its standing rigging are to be entirely dismantled once every five years. This duration may be modified after a probationary period determined on case by case basis by the Society.

2.2.2 Mast or rotor structure

The examination of mast or rotor structure, including spreaders if applicable, consists of:

- extensive visual examination of the masts or rotor and of their assembling zones (welded, riveted zones).
- extensive visual examination of all the connecting elements. Additional examinations and non destructive tests may be required by the Surveyor.
- thorough visual examination of the rigging connection elements.
- control of the internal corrosion of the structure.
- control of the structure of the lower part of the masts: additional controls and/or non-destructive tests are to be carried out to check the good behaviour of the base of the masts (connections to the decks).
- control of equipment fittings on the masts or rotors.

The extent of the non-destructive tests is determined by the Surveyor taking into account the general maintenance conditions and previous test results.

The Surveyor may require an examination of the uprightness of the spreaders. The sags are to be compared with the previous or initial data.

2.2.3 Connection fittings and ropes

The examination consists of:

- Visual examination of the connection fittings: turnbuckles, forks, chainplates, etc...
- Visual examination of the wire ends (about 10% of the wire lengths) to check the absence of corrosion cracks or broken wires.

  The forestay wire ropes are to be carefully examined, especially if furling systems are fitted:

  - upper and lower ends
  - wire areas on which furling system bearings are supported.

2.2.4 Control of pretensioning

If the standing rigging installation has been examined by the Society for precise working conditions (pretensioning, fitting of additional movable forestays or backstays) the Surveyor is to be able to check that these working conditions are complied with.

Should any doubt arise, additional tests and/or measurements may be required.

2.3 Running rigging

2.3.1 Examination of running rigging includes:

- general examination of related items (halyards, sheets, blocks...), in accordance with the programme of maintenance
- non-destructive tests on mounting and slewing rings to detect possible cracks.

2.3.2 Moving elements

Moving elements are to be dismantled at the Surveyor' satisfaction.

As a rule, the following elements are to be removed:

- every hinged connection to allow checking of the state of pins and bearings
- several fixing bolts of the mounting and slewing rings of rotative systems to check their state.

The replacement of the removed bolts (screws, nuts and washers) is recommended.

2.3.3 Manoeuvring system

Examination of manoeuvring system, for example furling or reefing system, consists of an extensive examination to detect any abnormal wearing, clearance:

- checking of external and internal state of the furling rods (paint or cathodic protection, corrosion, residual thickness,...)
- checking of the state of the connections of the furling rods, (for riveted or glued connections, it may be required to dismantle some of the elements to check the general condition of the system)
- checking of the state of the bearings:
  - end bearings (stay) are to be dismantled at each survey. If not possible, tests are to be carried out at the Surveyor' satisfaction
  - intermediate bearings: depending on the type.

2.3.4 Sails

When the sails are within the scope of the notation, additional examination may be required in accordance with the programme of maintenance.

2.4 Drive system

2.4.1 Depending on the type of drive systems, inspections are to be carried out to check:

- the working condition of the systems
- the working condition of the safety devices
- the working condition of the automated control system if such an equipment is provided.

This inspection is to be carried out in accordance with the requirements of the automation programme.

3 Annual survey

3.1 General

3.1.1 The annual survey programme is detailed in:

- [3.2] for wind propulsion systems less than 18 months old, and
- [3.3] for other wind propulsion systems.

Should any doubt arise as to the maintenance of the state of the wind propulsion system, further examination and testing may be conducted if considered as necessary by the Surveyor

3.1.2 Preparation of surveys

The requirements for the preparation of survey are described in [1.2].

3.2 Systems less than 18 months old

3.2.1 The extent of the annual survey of wind propulsion systems less than 18 months old is defined in [2.1] to [2.4].

3.3 Systems 18 months old or more

3.3.1 The extent of the annual survey of wind propulsion systems of 18 months old or more is defined in:

- [3.3.2], [3.3.4] and [3.3.5] for ships granted with notation **WPS1**

  [3.3.2], [3.3.3], [3.3.4] and [3.3.5] for ships granted with notation **WPS2**.

3.3.2 Standing rigging

As a rule, the programme of survey consists of:

- visual examination of all the concerned parts
- additional examinations at the Surveyor' satisfaction on areas highly stressed or subject to severe working conditions (corrosion, vibrations,...).

3.3.3 Running rigging

As a rule, the programme of survey consists of:

- visual examination of all the elements and connections of the concerned items.

  Moving elements are to be dismantled at the Surveyor' satisfaction.
- operating tests.

3.3.4 Drive system

The extent of annual survey of drive system as described in [2.4] is applicable.

3.3.5 Additional examinations depending on items within the scope of the notation **WPS1** or **WPS2**, may be required at the Surveyor' satisfaction.

APPENDIX 1 GUIDELINES FOR CALCULATION OF ENERGY EFFICIENCY DESIGN INDEX (EEDI)

1 General

1.1 Application

1.1.1 General

The attained Energy Efficiency Design Index (EEDI) is a measure of ships' performance in term of energy efficiency and calculated using a formula given by IMO EEDI Calculation guidelines.

Regulations in context of IMO MARPOL Annex VI, require the application of EEDI calculation depending on ship category and propulsion systems. For ships meeting the criteria, the attained EEDI is to be calculated and fulfill mandatory value (i.e. required EEDI).

1.1.2 Wind propulsion systems are technologies that reduce the CO2 emissions of ships due to propulsion power of main engines and shaft motors if any. In the EEDI calculation, these effects are taken into account as a deduction of CO2 emissions in relation to available effective power propulsion of the wind propulsion system,

Note 1: Wind propulsion systems may also contributing to reduce CO_2 emissions through the auxiliary power reduction by increasing the production of electricity by shaft generators (hydro generation).

In this case, the effects are taken into account as a reduction of CO2 emissions in relation to the mechanical energy for auxiliary engine.

1.1.3 Documentation

Main texts on EEDI determination in relation to wind propulsion systems are:

- IMO Convention MARPOL Annex VI Prevention of air pollution from ships Chapter 4 Regulation on energy efficiency for ships
  - regulation 20 Attained Energy Efficiency Design Index (Attained EEDI)
  - regulation 21 Required EEDI.
- IMO EEDI Calculation guidelines: MEPC.308(73) 2018 Guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships.
- IMO EEDI Survey guidelines: MEPC.1/Circ.855/Rev.2 - 14 January 2019 - Guidelines on survey and certification of the energy efficiency design index (EEDI).
- IMO MEPC.1/Circ. 815 - 2013 - Guidance on treatment of innovative energy efficiency technologies for calculation and verification of the attained EEDI.

2 Calculation of effects of wind propulsion systems

2.1 General

2.1.1 Wind propulsion systems impact the CO2 emission of the ship. Considering these effects, the EEDI of the ship (without wind propulsion system) considers the saving CO2 emissions due to the presence of wind propulsion system.

2.1.2 Emission savings

The amount of CO_2 savings is calculated as the product of the available effective power of wind propulsion system with specified fuel consumption of main engine and conversion factor between fuel consumption and CO_2 emission:

$CO_{2\ savings} = (f_{eff}.P_{eff}) \times (C_{FME}.SFC_{ME})$

2.2 Wind propulsion power

2.2.1 Available effective power of wind propulsion systems

Available effective power is effective power delivered by the specified wind propulsion system. It is defined in overall EEDI calculation as the product of effective power P_{eff} and availability factor f_{eff}. as defined in the EEDI calculation.

For wind propulsion system, the available effective power, may be formulated according to the additional wind propulsion power gained by the use of wind propulsion system, P_{wind_add}, subtracted by the power requirement for its operation, P_{wind_req}:

$(f_{eff}.P_{eff}) = P_{wind\_add} - P_{wind\_req}$

Note 1: Innovative energy efficiency technologies (Category B-2) can be used at their full output only under limited condition. The setting of availability factor (f_{eff}) should be less than 1,00.

2.2.2 Additional wind propulsion power

The additional wind propulsion power gained by the use of wind propulsion system, P_{wind_add} is defined as:

$P_{wind\_add} = F_{Vref} \times V_{ref} \times 1/\eta_T$

Where:

V_{ref} : Ship speed, in m/s, as defined in EEDI calculation guidelines

η_T : Total efficiency of main drives at 75% of rated installed power of main engines

if unknown, $\eta_T = 0,7$

F_{Vref} : Force of the wind propulsion system for ship speed V_{ref}, determined considering a global wind probability matrix and a wind propulsion system force matrix defined here below.

The global wind probability matrix contains data of the global wind power on the main global shipping routes based on a statistical survey of worldwide wind data, see Tab 1

Note 1: The main global shipping network is a network of global shipping routes with the highest frequency of journeys.

The wind propulsion system force matrix is specific to a wind propulsion system. Every wind propulsion system has a distinctive force characteristic dependent on ship speed, wind speed and the wind angle relative to heading. The force characteristic can be expressed in a two dimensional matrix, holding elements for any combination of wind speed and wind angle relative to heading for a given ship speed V_{ref}, see Tab 2.

Note 2: The wind propulsion system force matrix may be determined from model testing, land-based full-scale tests or CFD calculations.

Note 3: Performance test for the specific type of wind propulsion system are required to validate the wind propulsion force matrix.

The wind angle is the wind relative to the ship's heading at 10 m above the sea level subdivided into 72 sectors of 5° steps (0°, 5°,... 355°).

Note 4: Although the directions of a wind observed on a given site are not regularly distributed within 360°, the present Note considered that wind angle and wind speed are two independent parameters.

The wind direction is the North-oriented direction of the wind measured at 10 m above sea level and is subdivided into eight sectors (North, North-East, East, South-East, South, South-West, West, North-West).

2.3 Power requirement for operation

2.3.1 The power requirement for operation of the wind propulsion system, P_{wind_req}. is to consider the power required to operate the wind propulsion system in the different wind configurations (speed, angle) and the wind probability.

Table 1 : IMO Lay-out of the global wind probability matrix

		Wind angle (°)			
		0	5	...	355
Wind speed (m/s)	< 1	$W_{1.1}$	$W_{1.2}$	...	$W_{1.72}$
	< 2	$W_{2.1}$	$W_{2.2}$	...	$W_{2.72}$
	< 3	$W_{3.1}$	$W_{3.2}$	...	$W_{3.72}$
	...	...	...	...	...
	≥ 25	$W_{26.1}$	$W_{26.2}$	...	$W_{26.72}$

Table 2 : Wind propulsion system force matrix

		Wind angle (°)			
		0	5	...	355
Wind speed (m/s)	< 1	$f_{1.1}$	$f_{1.2}$	...	$f_{1.72}$
	< 2	$f_{2.1}$	$f_{2.2}$	...	$f_{2.72}$
	< 3	$f_{3.1}$	$f_{3.2}$	...	$f_{3.72}$
	...	...	...	...	...
	≥ 25	$f_{26.1}$	$f_{26.2}$	...	$f_{26.72}$

3 Survey and certification

3.1 General

3.1.1 Attained EEDI for a ship with wind propulsion system should be verified in accordance with IMO EEDI Survey Guidelines.

3.2 Preliminary verification at design stage

3.2.1 Preliminary verification includes verification of the EEDI technical file developed by the shipowner of shipbuilder including additional information about the wind propulsion system.

3.2.2 EEDI technical file

The EEDI technical file is to include in addition to IMO EEDI Survey Guidelines, the followings:

- outline of Wind propulsion system
- calculated value of EEDI due to the wind propulsion system
- detailed calculation process of the wind propulsion system:
  - force matrix $F(V_{ref})$
  - results of performance tests
- if relevant, appropriate technical reports on interactions between the different innovative energy efficiency technologies.

3.2.3 Performance tests

Performance tests are to be performed to validate the force matrix of the wind propulsion system.

When technical means are taken to limit the wind propulsion system's load, they should be verified as part of the performance test.

APPENDIX 2 REQUIREMENTS FOR SURVEY OF MATERIALS AND EQUIPMENT

1 Application

1.1 General

1.1.1 This Appendix gives the certification requirements for materials and equipment (generally referred as "products") which are covered by the Class.

1.1.2 The requirements for materials and equipment covered by the Class and used or fitted on board are given in the relevant parts of the present Rules or NR467, as applicable.

1.1.3 For a given project of wind propulsion system, the Builder has to review the items covered by the Class to check that this equivalence of Rules is applicable to this project. The equivalences defined for the Project are to be submitted to Bureau Veritas for acceptance.

1.1.4 The certification scheme of materials and equipment covered by the Class is given in the Society's Rule Note NR320 "Certification Scheme of Materials and Equipment for the Classification of Marine Units".

1.1.5 The particular conditions and requirements expressed by National Flag Authorities, owners, shipyards or manufacturers may lead to additional surveys or other services to be specified and agreed in each case by the concerned parties.

1.2 Explanatory notes, symbols and abbreviations

1.2.1 Symbols used in the table implemented have the following meaning:

C : BV product certificate is required with invitation of the Surveyor to attend the tests unless otherwise agreed, in addition to the manufacturer's document stating the results of the tests performed and/or compliance with the approved type as applicable.

W : Manufacturer's document is required, stating the results of the tests performed and/or stating compliance with the approved type (as applicable).

X : Examinations and tests are required.

Where fitted, each additional index (h, ndt) indicates a specific type of test:

- h : Hydraulic pressure test (or equivalent)
- ndt : Non destructive tests as per Rules.

1.2.2 Column 1 (item name)

Column 1 contains the name of the equipment or component with, eventually, its sub-systems.

1.2.3 Column 2 (design assessment / approval index)

Column 2 contains the design assessment / approval index. The meaning of the letters TA and DA is the following:

TA : Type Approval is required

TA (HBV): Type Approval is required with work's recognition (HBV scheme as per NR320)

DA : Design assessment/Appraisal of the product is required; this one may be carried out as applicable:

- either for a specific unit, or
- using the Type Approval procedure.

Note 1: Where nothing is mentioned in column 3, a design assessment/approval of the specific unit is not required.

1.2.4 Column 3 (raw material certificate)

Column 3 indicates the nature of the document that is to be submitted by the manufacturer or supplier of the concerned raw material.

Note 1: Consistently with the Rules or agreed specifications, this document includes data such as material tests (chemical composition and mechanical properties), non-destructive tests and surface hardness (if hardened).

1.2.5 Columns 4 (examination and testing)

Column 4 indicates that examination and/or testing are required, and are to be carried out by the manufacturer. For the type of examination and/or testing required, reference is to be made to the relevant provisions of the present Rules.

Note 1: As a general rule, even if a cross "X" is not fitted in a cell under column 5, examination and tests during fabrication may be required with invitation/attendance of the Society's Surveyor.

1.2.6 Column 5 (product certificate)

Column 5 indicates the nature of the document to be supplied by the manufacturer of the concerned product.

1.2.7 Column 6 (remarks)

Column 6 indicates the remarks (if any) associated to the concerned equipment or component.

1.3 Notice regarding columns 2 to 6 (product certification)

1.3.1 Column 2, column 3, column 4, column 5 and column 6 summarize the product certification process or steps to be completed by the manufacturer within the scope of Survey of Materials and Equipment at Works by the Society.

Table 1 : Requirements for survey of materials and equipment - Wind propulsion system for ships granted with additional class notations WPS1 or WPS2

Item	Product certification				Remarks
	Design assessment / Approval	Raw material certificate	Examination and testing	Product certificate	
Steel and aluminum (Raw materials)@					(1) Approval as per NR216 and NR480, as applicable (2) Type approval as per NR216 (3) See raw material certification
1 - Steel plates, profiles, bars for mast structure	(1)	C (1)		(3)	
2 - Aluminum alloy plates, profiles, bars for mast structure	(1)	C (1)		(3)	
3 - Filler products for welding (welding consumables)	TA (2)			W	
4 - Aluminum alloy rivets for mast structure	(1)	C (1)		(3)	
5 - Transition joints steel / aluminum alloy	TA (1)	C		C	
6 - Steel castings/forgings	(1)	C (1)	X ndt	(3)	
7 - Aluminum alloy castings	(1)	C (1)	X ndt	(3)	
Laminate composite materials (Raw materials: Composite)	DA (1)		X (2)	C / W (3)	(1) see provisions of NR546 (2) Representative samples of the composite construction is to be tested and qualified as per agreed program; relevant tests to be carried out by a testing laboratory accepted by the Society (3) Document type according to the agreed survey scheme - as per conditions set in the DA
1 - Adhesives assembly	TA HBV		X (2)	W	
2 - Reinforcement fibres	TA HBV			W	
3 - Resin systems	TA HBV			W	
4 - Core materials for sandwiches	TA HBV			W	
5 - Adhesives	TA HBV			W	
6 - Prepreg	TA HBV			W	
Standing rigging					(1) Approval as per NR206 (2) The extent and the nature of the non-destructive examinations are subject to the Society's agreement. (3) According to type of materials (4) Proof load as per NR206 (5) For special bolts (i.e. expansion type), product certificate C is required Notes: Checking of fitting on board
1 - Mast	DA /TA (1)	(3)	X (2)	C	
2 - Shrouds intended for standing rigging: - Steel and fiber ropes - Terminal accessories	DA (1)	W	X (2)	C	
3 - Deck eyeplates, chain plate for standing rigging	DA (1)	(1)	X (2) (4)	C	
4 - Coupling bolts	DA (1)	W	X	C / W (5)	
5 - Bearings	DA	W	X (2)	W	

Item	Product certification				Remarks
	Design assessment / Approval	Raw material certificate	Examination and testing	Product certificate	
Running rigging					
1 - Shrouds intended for running rigging - Steel and fiber ropes -Terminal accessories	DA (1)	W	X (2)	W	(1) Approval as per NR206 (2) Breaking test on specimen as per NR206 (3) For welded construction. The extent and the nature of the non-destructive examinations are subject to the Society's agreement (4) Proof load as per NR206 (5) Tests as per NR206
2 - Deck eyeplates, chain plate for running rigging	DA (1)	W	X (3) (4)	W	
3 - Clutch, shackle, sheaves and other running rigging accessories	DA (1)	W	X (3) (4)	W	
4 - Winches and their accessories for running rigging	DA (1)	W	X (5)	W	
5 - Slewing ring	DA	C	Xndt	C	
Drive unit - Mechanical system					
1 - Reduction gears with transmitted power ≥110 kW	DA / TA	W / C	X h ndt	C	(1) Approval as per NR206 (2) Material as per NR216 (3)For welded construction. The extent and the nature of the non-destructive examinations are subject to the Society's agreement (4) Running test as per agreed program (5) Electrical motors and equipment to be considered as intended 'for essential services'. Survey requirements as per NR266 item K (6) As per Society's agreement. (7) Diesel engines to be type approved as marine engines. Survey requirements as per NR266 item E1 and applicable provisions of NR467, Pt C, Ch 1, Sec 2 (8) Material certificate of small pumps or valve required depending on the type of wind propulsion system.
2 - Reduction gears with transmitted power < 110 kW	DA / TA	W		W	
3 - Winches for rotating and release systems	DA (1)	(2)	X (3) (4)	C	
4 - Hydraulic systems and other component essential for the function of the winch		C	X	C	
5 - Motors and electrical equipment essential for the function of the winch (5)			X	C	
6 - Auxiliary machinery items essential for the function of the wind propulsion system	(6) (7)				
7 - Hydraulic accumulator	DA / TA	W / C	X h ndt	W / C	
8 - Hydraulic cylinders class I	DA / TA	C	X h ndt	C	
9 - Hydraulic motors / pumps belonging to class I and II	DA / TA	W	X h ndt	C	
10 - Hydraulic motors / pumps belonging to class III			X h	W	
11 - Flexible hoses	TA	W	X h	C	
12 - Piping system and fittings		W / C (8)	X h ndt	W / C	

Item	Product certification				Remarks
	Design assessment / Approval	Raw material certificate	Examination and testing	Product certificate	
Drive unit - Electrical system					
1 - Electric motors for essential functions of the wind propulsion system (1)	DA / TA		X	C / W	(1) Electrical motors and equipment to be considered as intended ‘for essential services’. Survey requirements as per NR266 item K.
2 - Cables, Circuit breakers, Contactors	DA / TA			W	
3 - Convertors	DA / TA			C	
4 - Switchboard	DA		X	C	
5 - Other electrical equipment (1)	DA	(1)	(1)	(1)	

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