

STANDARD

DNVGL-ST-0511

Edition November 2019

Wind assisted propulsion systems



FOREWORD

DNV GL standards contain requirements, principles and acceptance criteria for objects, personnel, organisations and/or operations.

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Any comments may be sent by e-mail to rules@dnvgl.com

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CHANGES – CURRENT

This is a new document.

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SECTION 1 GENERAL

1.1 Introduction

Wind assisted propulsion systems (WAPS) are re-entering the ship industry. This time mainly to support a reduction in use of conventional (fossil) fuel. This has a positive effect on the energy efficiency index EEDI. Typical WAPS are rotor sails and wing rigs, but also other types are available.

A WAPS may for today's ship arrangements, not replace the main propulsion system, but be used as an add-on when weather conditions are favorable.

1.2 Objective

The objective of this standard is two-fold.

It may serve as an independent technical standard for the design and construction of a wind assisted propulsion unit.

It also serves as procedural and technical basis for wind assisted propulsion systems to be installed on board ships, and more specifically for ships applying for the additional class notation WAPS.

1.3 Scope

The standard provides technical requirements for the design and construction of a wind assisted propulsion unit.

The standard provides procedural requirements to be followed upon certification and classification of a wind assisted propulsion system for installation onboard a ship.

The standard provides physical principles and associated safety considerations in [App.A](#).

Guidance note:

Wind assisted propulsion system technology is under constant development and future technology will reveal other, new systems than explicitly mentioned in [\[1.1.1\]](#), the documentation and technical requirements of this standard may be changed accordingly.

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1.4 Application

This standard is applicable for the design and manufacturing of wind assisted propulsion systems.

This standard is applicable for wind assisted propulsion systems intended for use onboard ships to be classed with DNV GL and having the class notation **WAPS**, see [DNVGL-RU-SHIP Pt.6 Ch.2 Sec.12](#).

1.5 Definitions and abbreviations

Definitions used in this standard and in the related class notation **WAPS** are defined in [Table 1-1](#).

Table 1-1 Definitions

<i>Term</i>	<i>Description</i>
bermudian rig	A fore-and-aft rig that uses triangular sails on a stayed rig with masts and spars
rotor sail	The rotor sail is a rotating cylinder generating an aerodynamic lift force perpendicular to the apparent wind direction. See [A.1.1]
WAPS structure	The WAPS structure is the structural members of the unit itself.

<i>Term</i>	<i>Description</i>
WAPS drive unit	The drive unit is the machinery and electrical installation designed to operate, control and/or monitor the WAPS
wing sail	The wing rig is a 3-dimensional structure equipped with an aerodynamic foil, as opposed to a conventional single pane membrane sail. See [A.1.2] .

Table 1-2 Abbreviations

<i>Abbreviation</i>	<i>Description</i>
AIP	approval in principle
EEDI	energy efficiency design index
IR	inertia loads
OR	other loads
TAC	type approval certificate
TADC	type approval design certificate
WAPS	wind assisted propulsion system(s)
WR	wind loads

SECTION 2 DESIGN OF WAPS UNITS

2.1 General

This section provides design principles and technical requirements for the design of a wind assisted propulsion unit.

2.2 Design principles

2.2.1 Conceptual design

The general concept of a wind assisted propulsion system shall be developed. The concept should address the topics and aspects given in [App.A](#).

2.2.2 Risk assessment

A risk assessment addressing all aspects of design, equipment and operation shall be carried out.

The following aspects shall be included:

- severe weather (storm, ice)
- overspeed
- vibrations
- control system failure
- component failure
- fire
- overload
- static electricity
- human error.

Guidance note:

In order to quantify the resulting risk, it is recommended to perform an FMEA. For certification or classification purposes, a risk assessment is a requirement. See [Sec.3](#).

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2.2.3 WAPS - structure

The WAPS structures shall include:

For a rotor sail:

- The rotor, which includes the cylindrical aerodynamic body or liner and its internal supporting structures and the upper and lower end plate.
- The internal supporting structure as part of the WAPS which transfers the thrust from the rotor to the vessel, e.g. a mandrel.

For a wing rig:

- The wing rig, including the aerofoil body with its external and internal supporting structures, rotating parts of the main bearings, transferring the thrust, to the ship (foundation).

2.2.4 WAPS - drive unit

The drive unit shall be equipped with necessary safety barriers to provide for safe operation in all operating modes.

Guidance note:

Safety barriers should be identified by the mandatory risk assessment; see [2.2.2]. E.g.: Brake and locking mechanism for a rotor sail, or release (unlock) mechanism for wing sail.

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2.3 Materials

DNVGL-RU-SHIP Pt.2 shall be applied.

2.4 Loads

2.4.1 General

This subsection defines the design loads for WAPS and their supporting structures onboard ships and substantiates interference effects between the ship's hull and the WAPS global structural behaviour.

WAPS, similar to a Bermudian rig, and to a limited extent also Wingrigs, shall be dimensioned according to DNVGL-ST-0412, where [2.3] and [2.4] of this standard shall be applied. Other WAPS will be handled on a case-by-case basis.

2.4.2 Environmental conditions

2.4.2.1 General

The design shall take into account the weather conditions, humidity, dust, aggressive media, oil and salt-bearing air, exhaust gases and exhaust gas heat, vibrations and other relevant environmental conditions. See also DNVGL-RU-SHIP Pt.4 Ch.1 Sec.3 [2.2].

WAPS, including auxiliary machinery and electrical installations, shall be dimensioned with respect to temperature and humidity as listed below:

2.4.2.1.1 Enclosed spaces

- air temperature: 0°C to +45°C
- relative air humidity: 80%

2.4.2.1.2 Open deck

- air temperature:
 - WAPS in operation: -10°C to +45°C
 - WAPS out of operation: -25°C to +45°C
- relative air humidity:
 - 80% and influence of salt spray and green sea

2.4.3 Design loads

2.4.3.1 General

For the structural design, all loads acting on the WAPS in operation and in the out of operation state shall be considered.

The WAPS is subject to aerostatic and aerodynamic forces. Additionally, gyroscopic and other inertia effects e.g. weight imbalance during rotation and due to ship motions, shall be part of the design of the rotor.

in operation = WAPS is deployed to generate auxiliary propulsion power

out of operation = WAPS is not generating auxiliary propulsion power; i.e. in harbor mode or when experiencing extreme weather conditions

Loads acting on the structures of WAPS and their supporting structures are categorized as follows:

- regular service loads
- extreme loads.

2.4.3.2 Regular service loads

2.4.3.2.1 Wind loads - WR

Loads excited by wind will be converted to thrust forces supporting the vessel's propulsion and thus will be one of the main design characters. Wind loads shall be considered for the WAPS in operation and out of operation as well as in extreme weather conditions.

Loads on WAPS categorized as regular service loads shall be derived from wind speeds including gust magnification for cases in which the WAPS is in service, i.e. generating assistant propulsion forces. The maximum design wind speed for regular service shall be defined by the designer.

The wind loads shall be determined using aerodynamic relations relevant for the actual WAPS.

The wind load acting on WAPS, shall be calculated from the apparent wind speed, including the effects of gusts with a true wind speed increase of at least 25%.

Technical evidence shall be provided about pertinent lift- and drag-coefficients and how they are used to convert air flow into structural loads.

The onboard wind anemometer and vane measuring the apparent wind speed (and direction) shall be located at a position where the air flow is as undisturbed as possible and where it is representative for the highest elevation sail element.

2.4.3.2.2 Inertia loads - IR

Load effects emerging from the self-weight (mass) and dynamic forces on WAPS, excited due to ship motions in sailing conditions shall be considered. Pertinent acceleration values shall be determined for a particular vessel.

The accelerations determined in [DNVGL-RU-SHIP Pt.3 Ch.4 Sec.3 \[3.3.4\]](#) (envelope accelerations) serve to determine design loads for the structural assessments according to [\[2.5\]](#).

Guidance note:

If the WAPS is designed and manufactured not for a particular vessel, generic conservative assumption should be made.

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2.4.3.2.3 Others - OR

Characteristic loads other than the ones listed shall include, if applicable:

- secondary effects such as precession forces
- interference load effects such as
 - interference of air stream
 - special operating conditions
 - global ship vibrations
 - global ship deformations.

2.4.3.3 Extreme loads

2.4.3.3.1 Wind loads - WE

Extreme wind loads, exceeding the regular service loads, when the WAPS is out of service, shall be derived from the maximum true wind speed.

The maximum true wind speed, v_{we} , shall be calculated as a function of the height according to the following equation:

$$v_{we} = 44 \left(\frac{h_L}{10} \right)^{0.15}$$

, not to be less than 50 m/s.

where:

h_L = height of center of area of WAPS above waterline, in m.

The following calculation of extreme wind pressure is based on a pure drag resistance evaluation.

The form coefficients c_f for elements of the WAPS subjected to extreme wind load may be determined according to [Table 2-1](#).

The wind pressure q_{we} , in N/m^2 , equivalent with the drag resistance, acting on the lateral area of exposed elements of the WAPS shall be accounted for the most unfavourable direction(s) and shall be calculated as per the following equation:

$$q_{we} = 0.625 v_{we}^2 c_f$$

where:

c_f = according to [Table 2-1](#)

Table 2-1 Form coefficients c_f

Component groups	Description	Aerodynamic slenderness ratio l/h or l/d ¹						
		≤ 5	10	20	30	40	≥ 50	
Components	rolled profiles such as I L C T I box profiles square $h < 0.4$ m rectangular $h < 0.5$ m	1.3	1.35	1.6	1.65	1.7	1.8	
	round profiles ² $d \cdot v < 6$ m ² /s	0.7	0.75	0.8	0.85	0.9	1.0	
	$d \cdot v \geq 6$ m ² /s	0.6	0.65	0.7	0.7	0.75	0.8	
	box profiles square $h \geq 0.4$ m rectangular $h \geq 0.5$ m	h/b ¹						
		≥ 2	1.55	1.75	1.95	2.10	2.2	
		1	1.5	1.55	1.75	1.85	1.9	
0.5		1.0	1.2	1.3	1.35	1.4		
	0.25	0.8	0.9	0.9	1.0	1.0		

Component groups	Description	Aerodynamic slenderness ratio l/h or l/d ¹					
		≤ 5	10	20	30	40	≥ 50
Global form coefficients for lattice beams	profiles with flat sides	1.7					
	round profiles ²	1.1					
	$d \cdot v < 6 \text{ m}^2/\text{s}$ $d \cdot v \geq 6 \text{ m}^2/\text{s}$	0.8					
Machine houses, etc.	rectangular, enclosed constructions on a solid bottom plate	1.1					
1) see DNVGL-ST-0377 Figure C-1							
2) v = wind speed according to DNVGL-ST-0377 [4.2.4.5.3]							

2.4.3.3.2 Snow and ice loads - SE

The manufacturer shall specify in agreement with the client if, and to what extent, snow and ice loads shall be considered for individual operating conditions. Where ice accretion shall be considered and no empiric or specified values are available, a general ice accretion of 3 cm thickness shall be assumed for all parts of the construction which are exposed to the weather conditions.

The specific weight of the ice is assumed to be 700 kg/m^3 . The specific weight of snow is assumed to be 200 kg/m^3 .

In the case of ice load, the wind load shall be related to the area increased by ice accretion, if applicable.

2.4.3.3.3 Green sea including spray water - GE

A WAPS shall withstand a design pressure caused by spray water and green sea. Spray water and green sea loads are considered being extreme loads.

- 1) For local scantlings like plates and stiffeners the design pressure shall be determined according to [DNVGL-RU-SHIP Pt.3 Ch.4 Sec.5 \[3.4.1\]](#) and categorized as 'unprotected front wall' with the height of one tier above freeboard deck (2.3 m).
- 2) For a global structure like a rotor foundation the design pressure cumulated for the affected surface shall be determined according to [DNVGL-RU-SHIP Pt.3 Ch.4 Sec.5 \[3.3.1\]](#) and categorized as sides of superstructure.

2.4.3.3.4 Thermal loads TE

Thermal loads for structural elements shall be considered for the defined environmental conditions as given in [\[2.4.2.1\]](#).

2.4.3.3.5 Other extreme loads OE

Wind directional instability (magnitude and rate) may be critical for some type of WAPS and shall be addressed when relevant.

2.4.4 Load combinations

Loads as individually listed in this paragraph shall be considered to occur in combination, as listed in [Table 2-2](#).

If further load combinations are relevant, those shall be considered.

Table 2-2 Load combinations

<i>Loads</i>	<i>Regular loads</i>	<i>Extreme loads</i>					
Load combination case	R1	E1	E2	E3	E4	E5	E6
Wind	WR	WE	WE	WE	WE		
Inertia	IR		IR	IR			
Ice and snow				SE			
Temperatures					TE		
Green sea and spray						GE	
Others	OR						OE

2.4.5 Vibrations

If a WAPS is exposed to vibrations, a vibration analysis shall be carried out and be considered in the structural fatigue analysis.

2.5 Structural calculation principles and design criteria

2.5.1 General

In general, calculations related to structural strength shall be based on DNV GL rules, as applicable. Other international recognized standards may otherwise be used.

2.5.2 Stress calculation for metal components

2.5.2.1 Reference yield strength - general

The strength analyses according to this standard refers to the yield strength of the material as a failure criterion.

For metallic materials without distinct yield strength R_{eH} , the yield strength $R_{p0.2}$ shall be used instead.

To avoid brittle fracture, the materials used shall be sufficiently ductile.

For less ductile materials with a small ratio of ultimate tensile strength R_m over yield strength R_{eH} , additional safety against reaching or exceeding the ultimate tensile strength is stipulated by taking into consideration a reduced value for the yield strength - the reference yield strength σ_{yr} .

R_m = ultimate tensile strength [N/mm²]

R_{eH} = yield strength [N/mm²]

$R_{p0.2}$ = 0.2%-yield strength [N/mm²]

In the case of welded connections, the respective mechanical properties in the welded condition shall be assumed.

2.5.2.1.1 Steels

The reference yield strength σ_{yr} shall be determined as follows:

$$\sigma_{yr} = 0.83 \times R_m \leq R_{eH} \text{ (or } \leq R_{p0.2} \text{)}$$

2.5.2.1.2 Aluminium alloys

If aluminium alloys suitable for seawater according to [DNVGL-RU-SHIP Pt.2 Ch.2 Sec.10](#) are used, the reference yield strength shall be determined as follows:

$$\sigma_{yr} = 0.83 \times (R_{p0.2} + R_m) \leq R_{p0.2}$$

For welded connections, the respective mechanical properties in the welded condition shall be used. If these values are not available, the corresponding values in the soft condition shall be adopted.

2.5.2.2 Permissible stresses

Permissible stresses are defined as follows:

$$\sigma_{perm}, \sigma_{vperm} \leq \frac{\sigma_{yr} \cdot f_m \cdot \gamma_a}{\gamma \cdot \gamma_m}$$
$$\tau_{perm} = \frac{\sigma_{perm}}{\sqrt{3}}$$

Where:

$$f_m = \frac{R_m}{1.5 \cdot \sigma_{yr}} \leq 1$$

γ = 1.48 - stress coefficient for regular loads see [\[2.4.4.2\]](#)
1.22 - stress coefficient for extreme loads, see [\[2.4.4.3\]](#)

γ_m = 1.1 - generic reduction factor for material variance

γ_a = factor accounting for the method of structural analysis

1.0 - for analysis based on engineering first principles (e.g. beam or panel theory) or FE analysis using course mesh, see [DNVGL-RU-SHIP Pt.3 Ch.7 Sec.3 \[4\]](#)

1.22 - for analysis based on FE analysis using fine mesh; addressing local design, see [DNVGL-RU-SHIP Pt.3 Ch.7 Sec.3 \[4\]](#).

2.5.2.3 Structural stresses

Structural stresses are defined as σ , τ and σ_v for all metal components of a WAPS subject to the loads as specified in [\[2.4\]](#). The von Mises stress shall be calculated according to the following formulae:

$$\sigma_v = \sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2 - \sigma_x \cdot \sigma_y - \sigma_x \cdot \sigma_z - \sigma_y \cdot \sigma_z + 3 \cdot \tau_{xy}^2 + 3 \cdot \tau_{xz}^2 + 3 \cdot \tau_{yz}^2}$$

2-dimensional:

$$\sigma_v = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \cdot \sigma_y + 3 \cdot \tau^2}$$

Uniaxial:

$$\sigma_v = \sqrt{\sigma^2 + 3 \cdot \tau^2}$$

Where:

$\sigma_x, \sigma_y, \sigma_z$ axial stresses generated by pure tension, compression and bending

τ = shear stresses generated by pure shear or torsion

2.5.3 Structural safety and acceptance criteria

Structural stresses for all metal components of a WAPS subject to the loads as specified in [2.4] shall not exceed the permissible stresses as defined in [2.5.2.2].

2.5.3.1 General

The following strength analyses shall be carried out, cover the most unfavourable load combination:

- Structural stress, see [2.5.3.3]
- Stability (Buckling), see [2.5.3.4]
- Fatigue, see [2.5.3.5].

2.5.3.2 Structural stress analysis

Structural stresses as defined in [2.5.2.2] shall be determined for the loads and load combinations as listed in [2.4.4] and [2.4.5].

When using analysis techniques involving engineering first principles, stresses from global loads shall be superimposed with those occurring locally, e.g. in way of areas of stress concentrations and/or local load introductions.

2.5.3.2.1 Equivalent stresses

Where normal and shear stresses act simultaneously in a cross-section, the equivalent stress σ_v shall be calculated from the respective allocated stresses.

2.5.3.2.2 Strength criteria

Structural stresses $\sigma_s, \tau_s, \sigma_v$ as defined in [2.5.2.2] - Structural stress shall not exceed permissible stresses as defined in [2.5.2.2].

2.5.3.3 Stability (Buckling)

Buckling calculations shall be conducted according to recognized calculation principles; for example.:

- stability for steel constructions may be conducted according to Eurocode 3 (EN 1993-1-1, EN 1993-1-3, EN 1993-1-6, EN 1993-1-5, EN 1993-1-7)
- stability for aluminium alloy constructions may be conducted according to Eurocode 9 (EN 1999-1-1, EN 1999-1-4, EN 1999-1-5)
- stability for constructions made of austenitic steel may be conducted according to Eurocode 3 (EN 1993-1-4)

When applying Eurocodes for stability checks, the following shall be taken into consideration:

- stability is based on a geometrically non-linear FEA
- instead of safety factor γ_{M1} according to the Eurocode, the value γ_m according to [2.5.2.2] shall be used.
- Instead of the yield strength, the reference yield strength σ_{yr} according to [2.5.2.1] shall be used.

2.5.3.4 Fatigue strength

Fatigue strength calculations shall be carried out in accordance with DNVGL-RU-SHIP Pt.3 Ch.9.

The calculations shall be carried out using the structural stresses as per [2.5.2.2].



Guidance note:

The class guidelines [DNVGL-CG-0127](#) and [DNVGL-CG-0129](#) support the requirements in this chapter and provides detailed procedures for fatigue strength calculations.

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2.6 Operational instructions

Operational instruction for the purpose of safe and reliable handling under all aspects addressed in this standard shall be issued in form of an operational manual.

The operational manual of the unit shall include operational window and restrictions for WAPS operation.

SECTION 3 CLASSIFICATION AND CERTIFICATION

3.1 General

A WAPS including associated structural elements as well as the electrical and machinery installations to operate the WAPS shall be suitable for the intended service as an 'auxiliary propulsion' unit onboard a seagoing ship.

3.2 Classification

3.2.1 Documentation requirements

Documentation related to design and construction of a WAPS shall be submitted as required by [Table 3-1](#)

Table 3-1 Documentation requirements

Object	Documentation type	Additional description	Item reference		
			3.2 ATP	3.4 TADC	3.5 TAC
General					
General arrangement plan of WAPS installation	Z030, C020		AP	AP	AP
Conceptual design	Z050, Z051, Z060, Z070		AP	AP	AP
Gap analysis / risk assessment	G010, Z071		AP	AP	AP
Operational manual	Z161		FI	FI	FI
Rotor sail:					
Rotor general arrangement drawing	C020		AP	AP	AP
Rotor specifications, i.e. size, weights, centre of gravity, materials	C060			AP	AP
Detailed design drawings of structural and safety relevant parts	C030			AP	AP
Material specifications	M030			AP	AP
Component / equipment specifications (i.e. bearings)	C060			AP	AP
Load case report including: <ul style="list-style-type: none"> — definition of load cases — aerostatic loads — aerodynamic loads — rules sea loads — inertia loads 	C040		FI	AP	AP
FEA, if possibilities of engineering 'by first principles' are exceeded	H080			AP	AP
Resonance frequency analysis				AP	AP
Rotational weight balancing procedure			FI	AP	AP

Object	Documentation type	Additional description	Item reference		
Wingrig:					
Wingsail rig general arrangement drawing	C020		AP	AP	AP
Wingsail rig specifications, i.e. size, weights, centre of gravity, materials	C060			AP	AP
Detailed design drawings of structural and safety relevant parts	C030			AP	AP
Material specifications	M030			AP	AP
Component / equipment specifications (i.e. bearings)	C060			AP	AP
Load case report including: — definition of load cases — aerostatic loads — aerodynamic loads — rules sea loads — inertia loads	C040		FI	AP	AP
FEA, if possibilities of engineering 'by first principles' are exceeded	H080			AP	AP
Drive unit	E240, I010, I020				
Drive unit arrangement plan	-		FI	AP	AP
Specification of drive unit components	Z090			FI	AP
Description of integration of drive unit electrical installations into on-board power supply system	E010			FI	AP
Electrical load balance	E040		FI	AP	AP
Short circuit calculation / protection coordination	E150, E200			AP	AP
Electrical or hydraulic engine unit, specification and manufacturer	Z100			FI	AP
Electrical (and hydraulic) circuit diagrams including specification of components	E170			AP	AP
Drive unit detail drawings of structural parts, if not included in 'rotor' or 'rotor foundation', 'spar' or 'spar foundation'	H050			AP	AP
Control system description, systematics and specification, i.e. sensors; arrangement, redundancy, alarms	I020			FI	AP
Emergency stop system description; remote start / stop -fail safe	I020			AP	AP
Implementation into alarm and monitoring system	I200			AP	AP
Instrumentation:					
Control system functional description	I020, I030, I040, I050, I080, I110, I150, I320, Z252		FI	FI	AP
System block diagram (topology)			FI	FI	AP
User interface documentation (possibly part of the user manual)					
Power supply arrangement			FI	FI	AP
Data sheets with environmental specifications			FI	FI	AP

<i>Object</i>	<i>Documentation type</i>	<i>Additional description</i>	<i>Item reference</i>		
List of controlled and monitored points (incl. parameter settings)			FI	FI	AP
Circuit diagrams (with part list)			FI	FI	AP
Software change handling procedure					FI
Test procedure at manufacturer					FI
Ship interference loads:					
(Ship-borne dynamic loads (forced vibration, springing, thruster operation, etc.).)				FI	FI
Inertia effects as installed, in operation					
Testing	Z262, Z266				FI
Fabrication	H130				FI
AP = For approval; FI = For information ACO = As carried out; L = Local handling; R = On request					

For general requirements to documentation, including definition of the info codes, see [DNVGL-CG-0550 Sec.6](#).

For a full definition of the documentation types, see [DNVGL-CG-0550 Sec.5](#).

3.3 Certification services

3.3.1 General

The Society offers different levels of technical assurance in the design and construction processes of WAPS.

3.3.2 Approval in principle - AIP

An approval in principle is an independent assessment of a concept within an agreed framework, led by the Society, by confirming that the design is feasible, and no significant obstacles exist to prevent the concept from being realized.

The basic design and operational concept will be reviewed and approved. The functionality of the system and restrictions of operation will be assessed and approved.

The Society may, on a case-by-case basis, require to perform an AIP for novel designs before engaging in type approval design or other certification activities.

The assessments are following provisions of paragraph [\[2.2.1\]](#), [\[2.2.2\]](#) and [\[3.3.1\]](#) of this standard.

Guidance note:

An AIP is typically carried out at an early stage of a project to confirm its feasibility towards the project team itself, company management, external investors or future regulators.

An AIP is recommended ahead of any further verification or certification, if the concept is (considered) novel.

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3.3.3 Type approval design - TAD

A type approval design certificate is a compliance document issued by the Society. To obtain a type approval design certificate, compliance with documentation requirements in [Table 3-1](#) and requirements of [Sec.2](#) of this standard is required. For general requirements to the type approval process, see [DNVGL-CP-0338](#).

Guidance note:

A type approval design certificate may also be appropriate for a design not representing a series of builds, but a single system or a prototype.

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3.3.4 Type approval - TA

A type approval certificate is a compliance document issued by the Society. To obtain a type approval certificate, compliance with documentation requirements in [Table 3-1](#) and requirements of [Sec.2](#) of this standard is required. For general requirements to the type approval process, see [DNVGL-CP-0338](#).

The scope shall cover:


- design assessment
- production assessment
- survey of at least one sample from production.

3.3.5 Certification requirements

For the services described in [\[3.3.2\]](#), [\[3.3.3\]](#) and [\[3.3.4\]](#), equipment and components being part of the WAPS unit, shall be certified as required by [Table 3-2](#).

Table 3-2 Certification requirements

Object	Certification standard ¹⁾	Additional description	Certificate type		
			2.2 ATP	2.4 TADC	2.5 TAC
Structural material			NA	NA	MC
Electrical equipment		All electrical equipment serving essential or important services shall be delivered with DNV GL product certificate and/or DNV GL type approval certificate as required by DNVGL-RU-SHIP Pt.4 Ch.8 Sec.3 Table 3	NA	NA	PC or TA
Control systems		System shall be handled as important control system as per DNVGL-RU-SHIP Pt.4 Ch.9	NA	NA	PC or TA
Machinery and components			NA	NA	PC or TA
Structural construction			NA	NA	AoM
1) Unless otherwise specified the certification standard is the rules PC = Product certificate, MC = Material certificate, TA = Type approval certificate, AoM = Approval of manufacturer					



For general certification requirements, see [DNVGL-CG-0550 Sec.4](#). For a definition of the certification types, see [DNVGL-CG-0550 Sec.3](#).

APPENDIX A PHYSICAL PRINCIPLES AND SAFETY CONSIDERATIONS

A.1 Physical principles

A.1.1 Rotor sails

A.1.1.1 The rotor sail is a rotating cylinder generating an aerodynamic lift force perpendicular to the apparent wind direction. This force is excited by the pressure difference on windward and leeward side of the rotor, when it rotates. This effect is called the Magnus effect.

The force direction reverses when the rotation reverses.

A.1.1.2 The portion of the resultant force which is pointing in ship's longitudinal direction is the driving force, the portion perpendicular to this is the side force; usually experienced as a parasitic force. This side force causes heeling and possibly also yawing moments, depending on the arrangement of the rotors on-board.

A.1.1.3 The rotors are ineffective as propulsion assistance when the vessel is pointing into the wind direction or running exactly with it, within a certain angle range.

A.1.1.4 When performing a tack or a jibe and the apparent wind direction changes from one tack to the other, the rotation of the cylinders must be reversed to maintain positive driving forces.

A.1.1.5 The rotational speed of the cylinders can be optimized depending on wind speed and -direction, to optimize and/or limit power output.

A.1.1.6 When standing still, the rotor is subject to only the normal lateral drag resistance.

A.1.2 Wing rigs

A.1.2.1 The wing rig is a 3-dimensional structure equipped with an aerodynamic foil, as opposed to a conventional single pane membrane sail. A wingsail can consist of rigid or soft elements spanning the foil's aerodynamic surface. A wingsail can be a single aerodynamic body or equipped with means to vary the camber (e.g. by means of adjustable flaps).

The wingsail is typically mounted around a spar, with which or about which it can rotate for the purpose to adapt to the pertinent wind direction.

Wingsail rigs are typically only supported by its cantilevered foundation and not by standing rigging staying the rig.

A.1.2.2 The portion of the resultant force which is pointing in ship's longitudinal direction is the driving force, the portion perpendicular to this is the side force; usually experienced as a parasitic force. This side force causes heeling and possibly also yawing moments, depending on the arrangement of the rig on board.

A.1.2.3 The wingsail needs to be adjusted in its angle of attack vs. the pertinent apparent wind direction to provide full efficiency.

A.1.2.4 The sails are ineffective as propulsion assistance when the vessel is directly pointing into the wind direction within a certain angle range.

A.1.2.5 When adjusting the wind angle of attack on the sails and when performing a 'tack' or a 'jibe', the wingsail needs to be rotated about its vertical axis.

A.1.2.6 When wingsails are trimmed with their cord aligned with the wind direction, they theoretically only produce drag forces along this direction, no lift forces. This is as long as a situation can be considered stationary and not dynamic.

A.1.3 Wind load sheltering coefficients

General

A.1.3.1 For the determination of wind loads acting on WAPS, it is normally sufficient to use simplified form coefficients. The effect of wind load reductions of areas arranged behind one another may be considered as described in [DNVGL-ST-0377 App.C](#).

A.2 Safety considerations

A.2.1 Operational effects due to aerodynamic forces

A.2.1.1 Due to the resultant aerodynamic side forces, the vessel must cope with a side force and resulting heeling moments.

A.2.1.2 Due to the resultant aerodynamic side forces, the vessel must cope with a certain resultant leeway and possibly also yaw. Depending on the arrangement of the WAPS, part of this action can / shall be compensated by weather helm or lee helm.

A.2.1.3 Due to the fact, that a WAPS is generating aerodynamic forces depending on the wind speed, it is feasible that particularly rolling motions can be influenced by this effect (dampened or amplified, modified amplitude and frequency).

A.2.1.4 Rotor sails: rotating masses are causing a gyroscopic effect. It is feasible that ship motions will be influenced by this effect (dampened or amplified, modified amplitude and frequency).

A.2.1.5 Heeling moments excited by aerodynamic forces can possibly be counteracted using adaptive ballasting systems.

A.2.1.6 Manoeuvrability can be influenced by the above-mentioned effects in an active (possibly improve manoeuvrability by selective action of multiple WAPS) or a passive way (parasitic forces lead to more difficult manoeuvrability).

A.2.1.7 Wingsails: considerations shall be made for the case that a wingsail cannot be 'reefed', i.e. reduced in effective size in heavy weather conditions.

A.2.2 General operational obstructions

A.2.2.1 Due to the existence of large WAPS structures, navigation can be influenced by obstructed view from the navigation deck ('line of sight'). Relevant regulations, i.e. by the IMO or flag state regulations shall be regarded or interpretation or exceptions shall be inquired.

A.2.2.2 Cargo handling may be obstructed by the physical existence of tall over deck structures.

A.2.2.3 Bridge clearance can be influenced by tall over deck structures.

A.2.2.4 Damage on the rotor can obstruct ship's operation and safety of navigation.

A.2.2.5 The vessel and its systems and structures shall cope with occurring permanent heel of the vessel.



APPENDIX B EEDI ENERGY EFFICIENCY CERTIFICATION

B.1 General

The EEDI applies only to certain ship types with certain propulsion systems and only as of a ship type specific critical contract date for a newbuilding system. For ships falling under these criteria the EEDI is mandatory. For these ships the regulations as published by IMO in context to the convention *MARPOL Annex VI Chapter 4* shall be followed. In principle, relevant DNV GL guidelines are set up along the lines of the respective IMO guidelines, however any assessment method that is considered equivalent to the described procedures can be accepted based on sufficient and transparent description and test witnessing.

Guidance can be given separately from the certification program described in this standard.



CHANGES – HISTORIC

There are currently no historical changes for this document.

About DNV GL

DNV GL is a global quality assurance and risk management company. Driven by our purpose of safeguarding life, property and the environment, we enable our customers to advance the safety and sustainability of their business. We provide classification, technical assurance, software and independent expert advisory services to the maritime, oil & gas, power and renewables industries. We also provide certification, supply chain and data management services to customers across a wide range of industries. Operating in more than 100 countries, our experts are dedicated to helping customers make the world safer, smarter and greener.

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