



GUIDE FOR

WIND ASSISTED PROPULSION SYSTEM INSTALLATION

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**American Bureau of Shipping
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Foreword

ABS recognizes the increasing capability of energy saving devices and supports improvements in energy efficiency in marine and offshore operations. A wind assisted propulsion system utilizes wind thrust to reduce vessel fuel consumption. This Guide outlines the requirements for the installation of a wind assisted propulsion system onboard a vessel.

IMO has recognized wind assisted propulsion technology and its potential impact on energy savings and has included the effects of wind propulsion into the Energy Efficiency Design Index (EEDI) calculation in MEPC.1/Circ. 815, in which wind assisted propulsion technology is considered a method of reducing main engine power requirements.

This Guide is applicable to two modern wind assisted propulsion technologies: Flettner rotors and wing sails (including rigid sails and soft sails). These technologies use the wind thrust generation and automatic control system to optimize thrust force generation based on wind conditions. These systems differentiate themselves from conventional sails in that they possess greater efficiency, smaller windage area, and automatic control systems.

These technologies are continuously evolving. Alternative arrangements, designs and technologies may be acceptable on a case-by-case basis, provided they can be demonstrated, through either satisfactory service experience or a systematic evaluation based on sound engineering principles, to meet the overall requirements of this Guide.

The effective date of this Guide is the first day of the month of publication.

Users are advised to check periodically on the ABS website www.eagle.org to verify that this version of this Guide is the most current.

We welcome your feedback. Comments or suggestions can be sent electronically by email to rsd@eagle.org.



GUIDE FOR

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SECTION 1 General

1 Introduction

The scope of this Guide applies to vessels that utilize wind assisted propulsion systems to serve as auxiliary propulsion but not replace conventional propulsion. This Guide focuses on two primary wind assisted propulsion technologies: Flettner rotors and wing sails (including rigid sails and soft sails).

This Guide provides classification requirements for wind assisted propulsion systems on marine vessels. The Guide is to be used in conjunction with the *ABS Rules for Building and Classing Marine Vessels*.

2 Scope and Application

The installation of a wind assisted propulsion system is to be considered as an auxiliary propulsion system that augments the primary propulsion system. Thus, the vessel must be fully operable and in full compliance with applicable ABS Rules with main propulsion means only. Other types of applications will be considered on a case-by-case basis.

At a minimum, a vessel having a wind assisted propulsion system installed is to comply fully with the minimum class requirements prescribed in Section 1, Table 1 and applicable Rules. The optional notation **Wind-Assisted** may be assigned at the request of the owner for an installation complying with these minimum class requirements.

The optional **Wind-Assisted+** notation may be assigned if the vessel complies with the additional requirements listed in Section 1, Table 1.

TABLE 1
Relevant Requirements for Wind-Assisted and Wind-Assisted+ Notations

<i>Requirements</i>	<i>Guide Reference</i>	<i>Minimum Class Requirements for Wind-Assisted Notation</i>	<i>Wind-Assisted+ Notation</i>
Structure			
Foundation structure	3/2.3.1	Yes	Yes
Wind assisted propulsion system support structure members and thrust generating members	2/2.1	No	Yes
Materials			
Foundation structure materials	3/2.4	Yes	Yes
Wind assisted propulsion system support structure members and thrust generating members materials	2/2.2	No	Yes
NDT Testing for welds on foundation structure	4/2.2	Yes	Yes
NDT Testing for welds on wind assisted propulsion supporting structure members and thrust generating members	4/2.2	No	Yes
Stability	3/3	Yes	Yes
Bridge Visibility	3/4.1	Yes	Yes
Radar Blind Sector	3/4.2	Yes	Yes
Navigation Light	3/4.3	Yes	Yes

TABLE 1 (continued)
Relevant Requirements for Wind-Assisted and Wind-Assisted+ Notations

<i>Requirements</i>	<i>Guide Reference</i>	<i>Minimum Class Requirements for Wind-Assisted Notation</i>	<i>Wind-Assisted+ Notation</i>
Maneuverability	Section 5	Yes	Yes
Anchoring and Mooring Equipment	3/6	Yes	Yes
Electrical and Control Systems Integration	3/7	Yes	Yes
Equipment Certification	Section 2, Table 1	Refer to Section 2, Table 1	Refer to Section 2, Table 1
Installation in Hazardous Areas	3/8	Yes	Yes
Crew Safety	3/9.1	Yes	Yes
Fire Safety	3/9.2	Yes	Yes
Lightning Protection	3/9.3	Yes	Yes
Survey	Section 4	Refer to Section 4	Refer to Section 4

When Type Approval for a wind assisted propulsion system is requested, applicants should contact ABS for the approval process. For ABS Type Approval Program requirements, please refer to Appendix 1-1-A3 of the *ABS Rules for Conditions of Classification (Part 1)*.

3 Alternative Standards

Wind assisted propulsion systems may comply with the requirements of an alternative standard, in lieu of the requirements in this Guide, if the standard can achieve an equivalent level of safety. The wind assisted propulsion system is subject to design review, survey during construction, and testing, as applicable.

4 Terms and Definitions

Apparent Wind. The wind measured from a moving object, which is the combination of the true wind and the wind induced by the vessel movement (see Section 1, Figure 1).

Drive Systems. The machinery that drives the operation motions of the wind assisted propulsion system. Typical drive systems include electrical or hydraulic motors with control systems.

Flettner Rotor. A type of wind assisted propulsion system that usually features a rotating cylinder/rotor to generate thrust from wind force by the Magnus effect.

Foundation Structure. The stationary part of the installation that is designed to transfer forces and moments experienced by the wind assisted propulsion systems to the deck structures on the vessel, as shown in Section 1, Figure 2. Support structure members could be considered as part of the wind assisted propulsion system or part of the hull structural foundation. A ratio of 1:2 for the diameter of the tub to the height of the tub, measured from the deck to the base of the wind assisted propulsion system, is the dividing line between the wind assisted propulsion system and the hull structural foundation.

Magnus Effect. An observable phenomenon in which a lift force is generated on a rotating cylindrical or spherical object when in a fluid stream.

Shipboard Installation. The process of installing and integrating a wind assisted propulsion system on board the vessel.

Support Structure Members. The primary support members of the wind assisted propulsion systems that transfer the load from the thrust generating members to the foundation structures, as shown in Section 1, Figure 2.

Thrust Generating Members. The structural members for the thrust generation of a wind assisted propulsion system, as shown in Section 1, Figure 2. For example, the thrust generating member of a Flettner Rotor is the rotating cylinder. The thrust generating member of a wing sail is the sail itself.

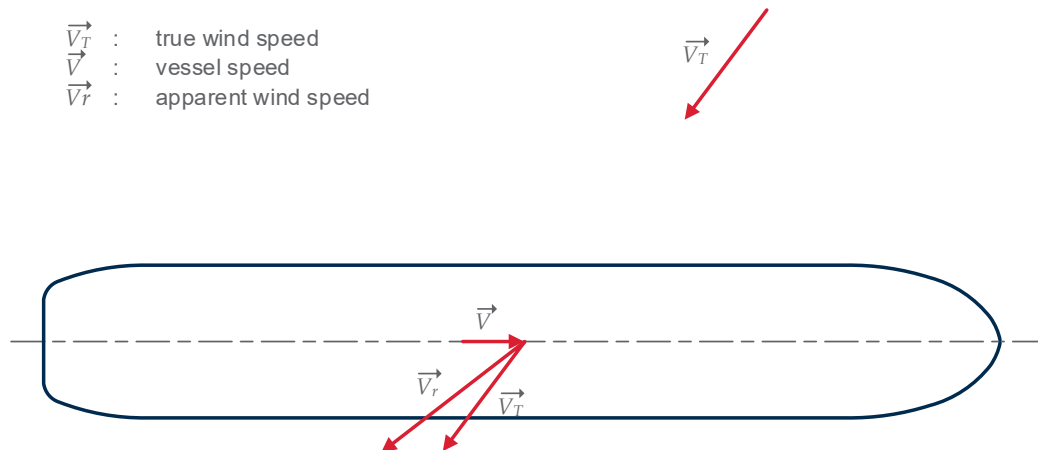
True Wind. The wind measured from a motionless object fixed to the ground.

Wind Assisted Propulsion System. An assembly leveraging wind energy for generating thrust force to assist the propulsion of a ship. It includes supporting structure members, thrust generating members, and drive system.

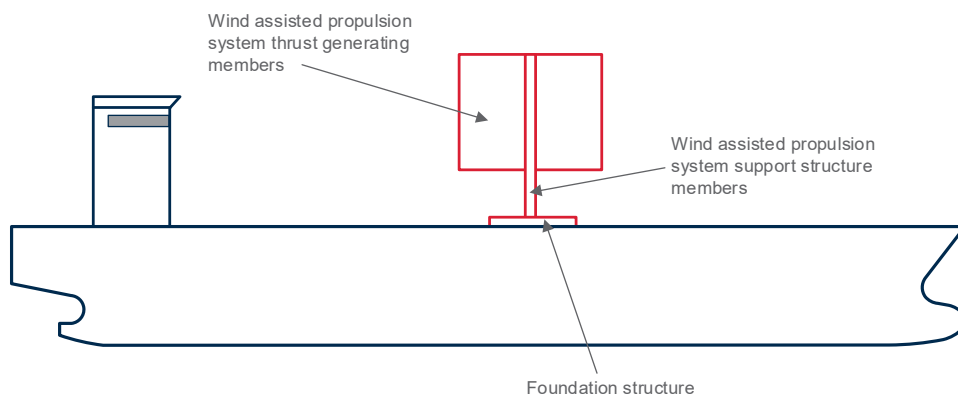
Wing Sail. A type of wind assisted propulsion system that utilizes the pressure difference formed by the air flowing into and across the sail surface to propel the ship forward. By the type of material used, wing sails can be categorized into:

- *Soft Sails.* Usually made of plastic fibers or similar
- *Rigid Sails.* Usually made of metal or composite materials

**FIGURE 1
Apparent Wind**



**FIGURE 2
Structure Components Definition for Wind Assisted Propulsion Systems**



5 Symbols and Abbreviations

ABS:	American Bureau of Shipping
EEDI:	Energy Efficiency Design Index
IMO:	International Maritime Organization
MARPOL:	International Convention for the Prevention of Pollution from Ships
SOLAS:	International Convention on the Safety of Life at Sea
COLREG:	Convention on the International Regulations for Preventing Collisions at Sea

6 Documentation and Plans to be Submitted for Review

6.1 For Minimum Class Requirements and Wind-Assisted Notation

As a minimum, the following drawings and documents associated with the wind assisted propulsion systems and shipboard installation are to be submitted to ABS for review:

- i)* Wind assisted propulsion system specifications
- ii)* Arrangement of wind assisted propulsion system
- iii)* Structural drawings of the foundation structure
- iv)* Materials specifications for the foundation structure
- v)* NDT inspection plan and records for steel welds on foundation structure
- vi)* Applicable loads for normal operation conditions and survival conditions used for design of foundation structure, in accordance with Subsection 3/2
- vii)* General arrangement of the wind assisted propulsion system installation
- viii)* Shipboard foundation structure drawings and scantling calculations taking into consideration the maximum reactions and overturning moments established in the load analysis report, including deck reinforcement details, specifications of materials and joint details, as part of ship structure drawings, as applicable
- ix)* Stability booklet
- x)* Line of sight plan
- xi)* Radar blind sector plan
- xii)* Maneuvering booklet
- xiii)* Anchoring and mooring equipment specifications
- xiv)* Power supply system
- xv)* Integration plan of electrical systems with the onboard power supply
- xvi)* Integration plan of wind assisted propulsion system control, alarm, monitoring and safety systems with shipboard system
- xvii)* Onboard personnel protection plan
- xviii)* Lightning protection plan
- xix)* Survey plans

At a minimum, the following drawings and data are to be submitted for review and kept on board for easy reference by the crew and the attending Surveyor:

- i)* Maintenance manual for wind assisted propulsion system
- ii)* Operation manual for wind assisted propulsion system. As a minimum, the operation manual is to include:
 - Description of chain of command with general responsibilities during normal operation
 - All relevant operational conditions and operational window of the wind assisted propulsion system, including operation under different environmental conditions, and measures for emergency shut-off
 - Measures for vessel maneuvering both with and without the wind assisted propulsion system actively running under operating conditions representative of the vessel's operation, including the operation limits of the system and measures under extreme conditions
 - Description of any inherent operational limitations for each mode of operation and for each change in mode of operation
 - Procedure for emergency shutdown of the wind assisted propulsion system
 - Procedures and a list of tools to change the wind assisted propulsion system from normal operation mode to survival mode in case of control system failure under heavy environmental conditions
 - Procedures and a list of tools to restore the wind assisted propulsion system after power failure or emergency shutdown
 - Ice alert procedures, if applicable.
- iii)* Testing procedures of wind assisted propulsion system, including sea trial/commissioning procedures

6.2 For Wind-Assisted+ Notation

In addition to the drawings and documents in 1/6.1, the following are to be submitted for the **Wind-Assisted+** notation:

- i)* Structural drawings and details of wind assisted propulsion system assembly (including support structure members and thrust generating members)
- ii)* Materials specifications for all structural members
- iii)* NDT inspection plan records for steel welds on support structure members and thrust generating members, if applicable
- iv)* Detailed structural load analysis report and loads used for structural design of supporting structure members and thrust generating members
- v)* Slewing ring drawings, along with static strength calculations and details, if applicable
- vi)* Plans and data for driving machinery including associated gears.
- vii)* Dimensions, materials, welding details, as applicable, of all torque-transmitting components (shafts, gears, clutches, couplings, coupling bolts, etc.) and all load bearing components (shaft bearings, cable lifter, sheaves, drums, bed-frames, etc.) of the wind assisted propulsion system.
- viii)* Electrical system diagrams with components specification
- ix)* Control, alarm, monitoring, and safety systems
- x)* Hydraulic piping system diagram along with system design pressure, relief valve arrangement and settings, bill of materials and typical pipe joint details, if applicable

7 References

7.1 ABS Rules and Guides

ABS Rules for Building and Classing Marine Vessels (Marine Vessel Rules)

ABS Rules for Building and Classing Mobile Offshore Units (MOU Rules)

ABS Guide for Certification of Lifting Appliances (Lifting Appliance Guide)

ABS Guide for Buckling and Ultimate Strength Assessment for Offshore Structures

ABS Guide for Vessel Maneuverability

ABS Guide for Nondestructive Inspection of Hull Welds

7.2 Other References

International Convention for the Safety of Life at Sea, SOLAS

MEPC.1/Circ. 815 2013 Guidance on Treatment of Innovative Energy Efficiency Technologies for Calculation and Verification of the Attained EEDI, IMO

International Convention for the Prevention of Pollution from Ships, MARPOL



SECTION 2 Wind Assisted Propulsion Systems

1 General

This Section provides the additional requirements that are applicable to the **Wind-Assisted+** notation.

A wind assisted propulsion system is considered a non-essential service in accordance with 4-8-1/7.3.3 of the *Marine Vessel Rules*. The criteria for wind assisted propulsion systems in this Section are applicable to features that are permanent and can be verified by plan review, calculation, physical survey, or other appropriate means.

2 Wind Assisted Propulsion System Structure

2.1 Structural Design

The structural drawings of the wind assisted propulsion system are to be reviewed by ABS.

It is the manufacturer's responsibility to submit the loads used for the design of all the structural members of the wind assisted propulsion system. The structure of the wind assisted propulsion system is to be designed to withstand all the vessel operating conditions and survival conditions in accordance with Subsection 3/2.

As a minimum, the load cases are to include the cases in 3/2.1.2 for all the structural members. A detailed load analysis report showing the calculation steps of each load component is to be submitted for review.

The possibility of fatigue damage due to cyclic loading is to be considered in the design of the support structure members of the wind assisted propulsion system in accordance with the relevant sections of the *Marine Vessel Rules* or other recognized standards.

2.2 Materials

The materials used in the construction of the wind assisted propulsion system are to be suitable for the intended service conditions. The materials used in the construction of the wind assisted propulsion system are not required to be manufactured at steel works approved by ABS and tests are not required to be conducted in the presence of an ABS Surveyor. Material certificates are to be provided at the request of an ABS Surveyor, in accordance with Chapter 2, Section 3 of the *Lifting Appliances Guide*.

3 Drive Systems

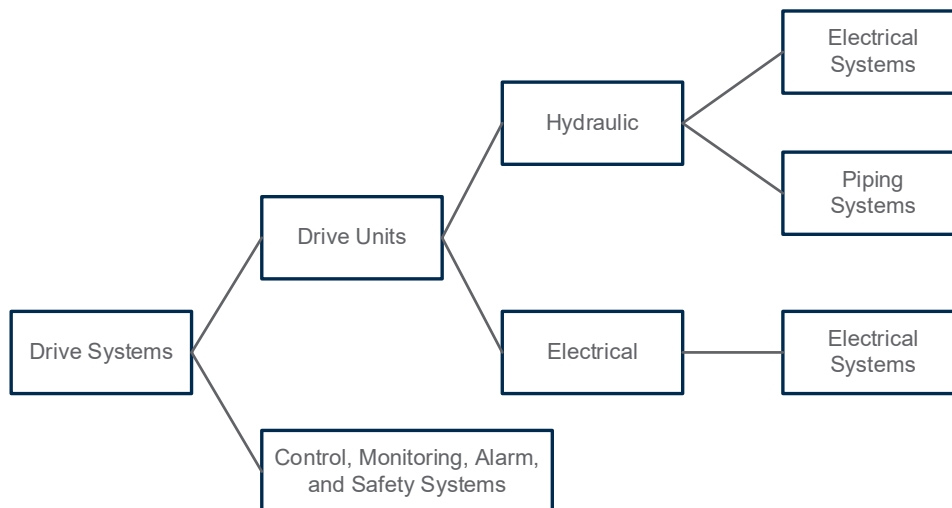
3.1 General

Detailed specifications of all the equipment used in wind assisted propulsion systems are to be included in the submitted equipment specifications, including but not limited to drive units, control systems, cables, and piping arrangements. In general, the machinery of wind assisted propulsion systems consists of drive units for the thrust generating mechanism and the control system. Depending on the system type, the drive unit may be electrical drive or hydraulic drive (see Section 2, Figure 1 for typical components based on system types). The wind assisted propulsion system is to be arranged such that its failure will not interrupt the power supply to equipment necessary for the propulsion, steering, and safety of the vessel, in accordance with 4-8-2/3.11 of the *Marine Vessel Rules*.

The electrical systems for wind assisted propulsion systems are to be in accordance with Part 4, Chapter 8 of the *Marine Vessel Rules* applicable to non-essential systems. Where installed, hydraulic systems, including the piping systems, are to be in accordance with Part 4, Chapter 6 of the *Marine Vessel Rules*.

The main source of power for the wind assisted propulsion system, regardless of drive unit type, is from the vessel. The integration of the electrical systems during the wind assisted propulsion system installation is to be in accordance with Part 4, Chapter 8 of the *Marine Vessel Rules* and Section 3 of this Guide.

FIGURE 1
Components of the Drive Systems



3.2 Electrical Drive Units

When applicable to the **Wind-Assisted+** notation, electrical drive units delivering rotation torque to the wind assisted propulsion system are to be designed in accordance with 4-8-3/3 of the *Marine Vessel Rules*. Electrical motors and motor controllers rated 100 kW (135 hp) and over are to be certified by ABS in accordance with Section 2, Table 1. When gears are fitted, they are to meet the requirements of Section 4-3-1 of the *Marine Vessel Rules*. Gears rated 100 kW (135 hp) and over are to be certified by ABS in accordance with Section 2, Table 1.

3.3 Hydraulic Drive Units

When applicable to the **Wind-Assisted+** notation, hydraulic drive units delivering rotation torque to the wind assisted propulsion systems are to be certified by the Surveyor at the manufacturers’ plant in accordance with 4-6-1/7.3 of the *Marine Vessel Rules*. In addition to the required tests from the ABS Rules, hydraulic motors are to be designed based on applicable pressure vessel and piping standards for pressure retaining components, allowable stress for torque components, and recognized standards for seals. The certification requirements are to be in accordance with Section 2, Table 1.

3.4 Certification of Drive Units

Section 2, Table 1 contains the certification details for wind assisted propulsion system machinery components. The components are to be reviewed and surveyed on a vessel-specific basis if not Type Approved.

TABLE 1
Certification Details for Wind Assisted Propulsion System Machinery Components

<i>Machinery Component</i>	<i>ABS Type Approval Tier for Notation Wind-Assisted (See 1-1-A4 of ABS Rules for Conditions of Classification)</i>	<i>ABS Type Approval Tier for Notation Wind-Assisted+ (See 1-1-A4 of ABS Rules for Conditions of Classification)</i>	<i>Marine Vessel Rules Reference</i>
1. Electrical motors \geq 100 kW (135 hp)	1	4/5	4-8-3/3
2. Electrical motors < 100 kW (135 hp)	1	1	4-8-3/3
3. Electrical Motor Controllers \geq 100 kW (135 hp)	1	4/5	4-8-3/5.11.1
4. Electrical Motor Controllers < 100 kW (135 hp)	1	1	4-8-3/5.11.1
5. Gears Rated Power \geq 100 kW (135 hp)	1	4/5	4-3-1
6. Gears Rated Power < 100 kW (135 hp)	1	1	4-3-1
7. Hydraulic motors	1	4/5	4-6-1/7.3
8. Control, monitoring alarm and safety systems, including computers, programmable logic controllers, etc.	1	4/5	4-9-3/9.3.4, 4-9-3/11.9, 4-9-9/13.1

3.5 Swing (Slewing) Mechanism

Where fitted, swing (slewing) mechanisms are to be powered to rotate the mast in the most unfavorable wind conditions. Slewing rings are to comply with 2-2/5.13 of the *Lifting Appliance Guide*.

Swing (slewing) mechanisms are to be provided with at least a static brake.

Total installed static braking capacity is to be sufficient to hold the mast in the most unfavorable wind conditions.

3.6 Other Mechanical Components

The other mechanical components are to be designed and tested in accordance with a recognized standard. Results are to be made available to the Surveyor upon request.

4 Control, Monitoring, Alarm, and Safety Systems

Control, monitoring, alarm, and safety systems are to comply with the requirements of Sections 4-9-2 and 4-9-3 of the *Marine Vessel Rules*, as applicable for Category I systems, in accordance with 4-9-3/Table 1 of the *Marine Vessel Rules*. The following design and arrangements are to be submitted for review:

- i) Control system design and arrangement
- ii) Emergency stop system arrangement
- iii) Alarm and monitoring system arrangement

4.1 Certification of Control Systems

When applicable to the **Wind-Assisted+** notation, certification of the control, monitoring, and safety systems is to be in accordance with Section 2, Table 1.



SECTION 3 Vessel Design

1 General

This Section provides the minimum class requirements for vessels having wind assisted propulsion systems installed. Vessels fully complying with the requirements in this Section may be assigned the optional **Wind-Assisted** notation, at the request of the owner.

2 Structural Strength and Materials

It is the manufacturer's responsibility to submit the loads used for the design of the foundation structure of the wind assisted propulsion system. The foundation structure of the wind assisted propulsion system is to be designed to withstand the loads experienced by the wind assisted propulsion system from all the vessel operating conditions and survival conditions.

As a minimum, the load cases are to include the cases in 3/2.1.2 for the foundation structure.

2.1 General

2.1.1 Wind Effect

In the structural design, only the apparent wind speed, as defined in Subsection 1/4, is to be applied, unless specified otherwise.

The mean value of the wind speed recorded over 1 minute in a given direction is to be used.

The gust factor, G_p , is to be determined by the manufacturer and included in defining the maximum normal operating wind condition for the wind assisted propulsion system. A gust factor of 1.16 may be used if no manufacturer-suggested value exists.

2.1.2 Operating Modes

2.1.2(a) Normal Operation Condition. The normal operation condition is to be submitted for review, including the maximum operating wind speeds with wind direction based on the vessel's heading direction and the corresponding sea state with the vessel motion induced by the sea state.

Loads to be considered in the analysis of the wind assisted propulsion system structures under normal operation condition, as applicable, are:

- i) Loads due to vessel's motions
- ii) Loads due to wind
- iii) Loads due to snow and ice, as applicable

Hull girder loads are to be considered unless the allowable stress is reduced in accordance with 3-2-20 Table 2 footnote 4 of the *Marine Vessel Rules*.

The analysis of the wind assisted propulsion system and foundation structures is to be based on the worst combination considering load phase of the above loads.

The design wind speed under the normal operation condition is not to be less than:

$$V_{DN} = V_{MO} \times G_f$$

where

- V_{DN} = design wind speed under normal operation condition
 V_{MO} = maximum operating wind speed under normal operation condition
 G_f = gust factor in accordance with 3/2.1.1

The effects of the vertical distance from the water surface to the location of the wind assisted propulsion system are to be included and considered in the analysis. In absence of specific details, the definition in 3/2.1.2(b) may be used.

2.1.2(b) Survival Conditions. The survival conditions are the most severe environmental conditions that the vessel with wind assisted propulsion system may be considered to encounter. Under survival conditions, the environmental conditions have exceeded the operating window and the wind assisted propulsion system is out of service.

The manufacturer is to determine the survival conditions and submit to ABS for review. The effects of gusts and vertical distance from the water surface to the location of the wind assisted propulsion system are to be included and considered in the analysis. The survival condition submissions are to include data on wind condition and corresponding sea state.

Loads under survival condition are to be submitted for review and considered in the structural design of the wind assisted propulsion system. The load calculations for survival conditions are to include:

- i) Loads due to wind
- ii) Loads due to vessel motions
- iii) Loads due to snow and ice, as applicable
- iv) Loads due to green sea

Hull girder loads are to be considered unless the allowable stress is reduced in accordance with 3-2-20/Table 2 footnote 4 of the *Marine Vessel Rules*.

The analysis of the wind assisted propulsion system and foundation structure is to be based on the worst combination considering load phase of the above loads. Detailed load considerations are shown in 3/2.2.

The true wind speed considered in survival conditions for unrestricted service vessels is defined below, and vessel speed is also to be considered accordingly to derive the maximum apparent wind speed for structural design:

$$V_y = V_H * (y/H)^{1/7}$$

where

- y = height above the still-water level at the center of area of the wind assisted propulsion system thrust generating member
 V_y = wind speed at height y
 V_H = wind speed at the reference height H of 15.3 m (50 ft) above still-water level. For survival condition, V_H is not to be less than 51.5 m/s (100 kn), or the design wind speed of the vessel, whichever is greater
 H = reference height of 15.3 m (50 ft)

2.2 Load Considerations

This section includes the details of the loads acting on the wind assisted propulsion system and foundation structure to be included in the structural design load calculations. The calculations of all the loads are to be reviewed and approved by ABS.

2.2.1 Wind Loads

The maximum wind-induced loads are to be specified by the manufacturer and submitted, including the wind directions which induce the maximum loads, for both normal operation condition and survival conditions in accordance with 3/2.1.2.

Loads due to wind may be determined by:

- i) *Normal Operation Condition.* The wind load under normal operation condition is to be defined by the designer based on the thrust generating mechanism for the specific type of wind assisted propulsion system, including the lift and drag forces. Appropriate consideration of gust factor and the vertical distance from the water surface is to be applied in the wind load calculations in accordance with 3/2.1.2(a).
- ii) *Survival Condition.* True wind speed as defined in 3/2.1.2(b) is to be used in the calculations. The form drag is to be considered in the calculation, under the most unfavorable conditions of wind angle and projected area of the wind assisted propulsion system. The calculation method is to be submitted for review. In the absence of specific calculation methods, the methodology provided in 2-2/5.19 of the *Lifting Appliance Guide* may be used as a minimum.

2.2.2 Gravitational and Inertial Loads

Loads due to vessel motion are the loads excited by the motion of the vessel and the self-weight of the wind assisted propulsion system. The loads due to vessel motions are to be submitted. The acceleration values are to be determined for the vessel under consideration.

- i) For bulk carriers and tankers, the calculation of accelerations in 5A-1-4-3 of the *Marine Vessel Rules* may be used as a minimum.
- ii) For container vessels, the calculation of accelerations in 6/3.7 of the *ABS Guide for Certification of Container Securing Systems* may be used as a minimum.
- iii) Alternatively, ABS may consider direct calculations of vessel accelerations or values obtained from model tests. In such cases, accelerations are to be determined with a reference service life of 20 years. As the base case, the IACS Recommendation No. 34 wave scatter diagram for the North Atlantic is to be applied for unrestricted service.

2.2.3 Loads due to Snow and Ice

The manufacturer and the relevant parties are to agree to the level of consideration given to ice loads. Where ice loads are to be included in the load consideration, the impact of icing on both structural design and intact stability is to be determined and submitted by the manufacturer. In absence of specific details, the weight of ice in accordance with 3-3-A3/11.11 of the *Marine Vessel Rules* may be used as a minimum.

2.2.4 Green Sea Loads

The green sea load is to be included in the load consideration for survival condition. The calculation is to be in accordance with 5A-1-4-5/4.3 of the *Marine Vessel Rules*.

2.3 Structural Design

Allowable Stress. The manufacturer is to demonstrate through analysis that the stresses for the strength members of the wind assisted propulsion system subjected to the combined loads under both the normal operating conditions and the survival conditions as defined in 3/2.1 do not exceed the allowable stresses in accordance to 3-2-20/Table 2 of the *Marine Vessel Rules*.

Buckling Strength. Strength members subjected to axial compression or combined loads, such as axial compression and bending moment, are to be assessed in accordance with the requirements of 2-2/5.7 of the *Lifting Appliance Guide* and the *ABS Guide for Buckling and Ultimate Strength Assessment for Offshore Structures*.

Fatigue Strength. The possibility of fatigue damage due to cyclic loading is to be considered in the design of the foundation structure and support structure members of wind assisted propulsion system in accordance with the relevant sections of the *ABS Marine Vessel Rules* or other recognized standards. As a minimum, the wind assisted propulsion system foundation to deck connection is to be evaluated.

Special consideration will be given on a case-by-case basis for non-metallic materials used in the structural members.

2.3.1 Wind Assisted Propulsion System Foundation Structure

As a minimum class requirement and where the **Wind-Assisted** notation applies, the foundation structure members are to be designed for the maximum reaction forces and moments due to the most severe combination of load cases defined in 3/2.1 and using the allowable stress defined in 3-2-20/Table 2 of the *Marine Vessel Rules*.

The hull structures supporting the wind assisted propulsion system foundation are also to be designed to resist the same combination of loads using the allowable stress defined in 3/2.3 and reinforced in accordance to 5A-1-11-4/4 of the *Marine Vessel Rules* and Section 3-2-15 of the *Marine Vessel Rules*.

The detailed design and installation plan of the wind assisted propulsion system foundation is to be submitted for review.

2.4 Materials

The material properties of steel used in the foundation structure members and the material certification requirements are to be in accordance with the *ABS Rules for Materials and Welding (Part 2)*.

The material properties of aluminum alloys used in all the structure members are to be in accordance with Chapter 5 of the *ABS Rules for Materials and Welding (Part 2)*.

Composite material for the building of the wind assisted propulsion system is to be in accordance with Chapter 6 of the *ABS Rules for Materials and Welding (Part 2)* or a recognized industry standard.

3 Stability

3.1 Intact Stability

The intact stability of the vessel can be affected by the aerodynamic and inertia forces due to the installed wind assisted propulsion system. The operation of the wind assisted propulsion system (for example, change of rotation speed of Flettner rotors, change of angle of rigid sails) may also change the heeling force of the vessel. Therefore, the effect of additional heeling forces due to the operation of the wind assisted propulsion systems is to be considered in the assessment of intact stability. It is to be demonstrated that the vessel has sufficient intact stability under the worst combination of design load cases, as per 3/2.1.2, with the wind assisted propulsion system operating and not operating, in accordance with 3-3-1/3 of the *Marine Vessel Rules*. The largest possible windage area is to be considered in the stability calculation.

3.2 Damage Stability

The additional projected lateral area and weight due to the wind assisted propulsion system are to be included in the damage stability calculations in accordance with Section 3-3-1 of *Marine Vessel Rules*, as applicable.

4 Navigation Safety

4.1 Bridge Visibility

It is to be demonstrated that the vessel with the wind assisted propulsion system deployed satisfies the bridge visibility requirement under all operating situations, in accordance with Part 3, Chapter 6 of the *Marine Vessel Rules* and SOLAS Chapter V, Regulation 22. Where compliance is impractical, alternatives will be considered on a case-by-case basis in association with the flag Administration.

4.2 Radar Blind Sector

Where ABS issues the Cargo Ship Safety Equipment Certificate (or equivalent based on vessel type) on behalf of the flag State, it is to be demonstrated that the radar blind sector requirement is complied with. Where ABS does not issue this certificate, the radar blind sector information is to be provided to the flag State and evidence of flag State acceptance is to be provided to ABS. Details of the IMO requirements on radar blind sector can be found in IMO SN.1/Circ.271 and MSC.192(79).

4.3 Navigation Lights

The installation of the wind assisted propulsion system is not to violate the requirements for blockage of navigation lights and is to comply with the requirements in the latest IMO COLREG convention or the flag State interpretation of the convention.

Where a helicopter deck is fitted on the vessel, the installation of the wind assisted propulsion system is to be in accordance with the obstruction, marking and lighting requirements for the helicopter deck in the *ABS Guide for the Class Notation Helicopter Decks and Facilities (HELIDK and HELIDK(SRF))*.

5 Maneuverability

The maneuverability of the vessel may be influenced by the wind assisted propulsion system. It is to be demonstrated that the installed steering equipment and main propulsion system can counteract all the operating effects within the operating range.

If the vessel has the **MAN** or **MAN-A** notation, re-evaluation of vessel maneuverability at sea trials is required in accordance with the *ABS Guide for Vessel Maneuverability*.

The operation manual is to document measures for vessel maneuvering both with and without the wind assisted propulsion system actively running under operating conditions representative of the vessel's operation, including the operation limits of the system and measures under extreme conditions.

The maneuverability of the vessel is to be verified at sea trials in accordance with 4/3.2.

6 Anchoring and Mooring Equipment

The additional side projected area and weight introduced by the installation of the wind assisted propulsion system are to be considered during the equipment number (EN) determination for anchoring and mooring equipment.

For new construction vessels, the calculation is to be in accordance to Section 3-5-1 of *Marine Vessel Rules*.

For vessels being converted or modified, the required equipment is to be as follows:

- i) Where the Equipment Numeral (EN) is increased by one number, no change is required.
- ii) Where the Equipment Numeral (EN) is increased by two numbers, the existing equipment may be accepted provided additional chain of the existing diameter is fitted. This additional chain must meet the length requirement for the new Equipment Numeral, and the mass of the additional chain must compensate for the increase in mass of the anchors required by the new Equipment Numeral. (Alternatively, the existing anchor chain, size and length, may be accepted subject to replacement when worn down to the limits permitted for the size required by the new EN. However, in such cases, new bower anchors are to be fitted.)
- iii) Where the Equipment Numeral (EN) is increased by more than two numbers, new equipment is required. It is to be confirmed by ABS that the anchor windlass can withstand the increased load and chain size, or if new anchor windlass equipment is required to meet the revised requirement.

7 Electrical and Control Systems

It is to be demonstrated that the vessel can provide sufficient electrical power for the operation, control, and monitoring of the wind assisted propulsion system without compromising the safety and operation of the vessel. The electrical systems and electrical equipment requirements for the wind assisted propulsion system installation are to be applied according to Part 4, Chapter 8 of the *Marine Vessel Rules*. A detailed electrical system integration plan between the drive units of the wind assisted propulsion system and the shipboard power supply system is to be submitted for review.

7.1 Electrical Load Analysis

The power demand of the wind assisted propulsion system is to be considered in the electrical load analysis of the vessel.

7.2 Control, Monitoring, Alarm, and Safety System Integration

The installation of the automated control systems is to be in accordance to Part 4, Chapter 9 of the *Marine Vessel Rules*.

The control, monitoring, alarm, and safety systems are to be designed to counteract the different operational and environmental conditions to which the vessel is subjected. A manually-operated emergency shutdown system is to be provided for the wind assisted propulsion system in case of control system failure. The operation manual is also to include the procedures and tools to manually shut down the wind assisted propulsion system in case of control system failure under heavy environmental conditions.

The safety systems are to be designed to prevent the system from exceeding its safe operating window during operation. If the wind assisted propulsion system has additional survival arrangements for extreme environmental conditions besides system shutdown, the control, monitoring, alarm, and safety systems are to provide enough warning ahead of time to allow the wind assisted propulsion system to transition from the operating arrangement into the survival arrangement. A manually operated system is to be provided to transition the wind assisted propulsion system from the operating arrangement to the survival arrangement in case of control system failure. The operation manual is also to include the procedures and tools to transition the wind assisted propulsion system from normal operation arrangement to survival arrangement in case of control system failure under heavy environmental conditions.

The safety system is to be designed to limit the consequence of failures and the wind assisted propulsion system is to be constructed based on the fail-safe principle.

8 Installation in Hazardous Areas

When the location for the installation of the wind assisted propulsion system is within a hazardous area as defined in 4-8-4/27 of the *Marine Vessel Rules*, the requirements in Section 4-8-4 of the *Marine Vessel Rules* are to be complied with.

9 Safety

9.1 Crew Safety

Measures are to exist to protect the crew from the potential hazards from the moving and rotating parts of the wind assisted propulsion system by providing safe passage. If no measure exists, the installation is to be made in accordance to 3-2-17/3 of the *Marine Vessel Rules*.

9.2 Fire Safety

The machinery space where the drive units for the wind assisted propulsion system is installed is considered "Other Machinery Space". The fire protection arrangements are to be in accordance with 4-7-2/1.7 of the *Marine Vessel Rules*.

9.3 Lightning Protection

Wind assisted propulsion systems are to be protected from lightning in accordance with 4-8-5/9.7 of the *Marine Vessel Rules*.



SECTION 4 Surveys and Testing

1 General

This Section provides the survey requirements for a vessel fitted with a wind assisted propulsion system. These requirements are in addition to the requirements for survey specified in other applicable ABS Rules and/or Guides. See *ABS Rules for Survey After Construction (Part 7)*.

As minimum class requirements, and where the **Wind-Assisted** notation is applicable, vessels having wind assisted propulsion systems installed are to fully comply with the minimum survey requirements in this Section.

Where the **Wind-Assisted+** notation is applicable, the vessels are to also comply with the additional requirements in this Section for the **Wind-Assisted+** notation. The ABS Surveyor will witness tests during In-Plant, During-Construction and Annual Surveys. The particulars of these tests and examinations will be entered on the applicable certificates.

Before installation onboard a vessel, all wind assisted propulsion systems are to be tested and examined by the system manufacturer. The person performing the testing and examination is to be duly authorized by the manufacturer.

2 Certification and Testing

As a minimum class requirement and where the **Wind-Assisted** notation applies, before being taken into use, the foundation structure of the wind assisted propulsion system is to have been tested and examined by the manufacturer. The person performing the testing and examination is to be duly authorized by the manufacturer.

The materials used for foundation structure of the wind assisted propulsion system are to be sourced from approved mills and are to be certified by ABS.

The manufacturer is to establish and maintain a quality control system to confirm that all ABS requirements, including design approval, materials, verification, fabrication workmanship, and nondestructive testing, are complete.

The quality control system is to provide sufficient details of manufacturing and inspection so that that manufacturer's inspections are performed at appropriate stages of fabrication. In the event of noncompliance, fabrication is to be delayed for rectification.

The quality control system is to fully document welding procedures and qualifications of welding personnel. The quality control system is also to detail the procedures and qualifications of nondestructive testing personnel to be employed in all stages of fabrication and manufacture. The manufacturer's quality control system is to provide confirmation that required heat treatments have been performed.

Where the **Wind-Assisted+** notation applies:

- i) All wind assisted propulsion systems, including all load bearing support structural members are to be surveyed during construction. Surveys of the wind assisted propulsion system during construction are required to the extent necessary for the Surveyor to determine that the details, including structures, material, mechanical components, welding, and workmanship are acceptable to ABS and are in accordance with the approved drawings.
- ii) The Surveyor is to have access to all material test certificates. All in-plant testing of the wind assisted propulsion system structural components or assembled components is to be witnessed and reported on by the attending Surveyor.
- iii) The welding procedures are to be submitted to and approved by ABS.

2.1 Certification of Drive Units

Each electrical motor over 100 kW (135 hp) and covered by the **Wind-Assisted+** notation is to be certified based on design review in accordance with Section 2, Table 1 and routine tests performed in accordance with 4-8-3/3 of the *Marine Vessel Rules* in the presence of a Surveyor.

Each hydraulic motor covered by the **Wind-Assisted+** notation is to be certified based on design review in accordance with Section 2, Table 1 and routine tests performed in accordance with 4-6-1/7.3 of the *Marine Vessel Rules* in the presence of a Surveyor.

When applicable to the **Wind-Assisted+** notation, other components associated with drive units are to be certified and tested in accordance with Section 2, Table 1. Where a slewing ring is fitted, surveys at the plant of the slewing ring manufacturer are required, and certification is to be done in accordance with Chapter 2 of the *Lifting Appliances Guide*.

2.2 Nondestructive Testing (NDT)

As a minimum and where the **Wind-Assisted** notation is applicable, NDT is to be conducted on the critical steel structure welds on the foundation structure of the wind assisted propulsion system in accordance with the *ABS Guide for Nondestructive Inspection of Hull Welds* or other recognized codes. The areas to be nondestructively inspected and methods of inspection are to be submitted together with the design plans.

Where the **Wind-Assisted+** notation is applicable, NDT is also to be conducted on the critical steel structure welds on the support structure members and thrust generating members in accordance with the *ABS Guide for Nondestructive Inspection of Hull Welds* or other recognized codes. The areas to be nondestructively inspected and methods of inspection are to be submitted together with the design plans. The minimum extent of NDT to be carried out is shown in Section 4, Table 1.

Volumetric NDT techniques include Radiographic Testing (RT) and Ultrasonic Testing (UT). Surface NDT techniques include Magnetic Particle Inspection (MPI), Penetrant Testing (PT), Eddy Current (EC), or Alternating Current Field Measurement (AFM).

The method and extent of nondestructive testing for slewing rings is to be specified by the slewing ring manufacturer. After hardening and finishing, bearing ring raceways are to be inspected by surface NDT along their entire length. Bearing rings are to be 100% ultrasonically tested for internal defects, and the manufacturer is to certify that the materials are free from detrimental defects which may impair the performance of the slewing ring. The Surveyor is to be provided with records of NDT inspections. Additional inspections may be requested at the discretion of the Surveyor.

TABLE 1
Nondestructive Testing (NDT) of Steel Structure Welds

<i>Weld Location</i>	<i>Extent and Type of NDT</i>
Critical circumferential welds in the foundation structure and support structure members Transition pieces between foundation structure and support structure members Transition pieces between the structural members and the slewing ring, if applicable	100% Volumetric NDT plus 100% Surface NDT of all Complete Joint Penetration (CJP) welds, where welded plate thickness is ≥ 8.0 mm ($5/16$ inch); and 100% MPI of all fillet welds, where plate thickness is ≥ 8.0 mm ($5/16$ inch)
Other critical welds of support structure members and thrust generating members	20% Volumetric NDT plus 100% Surface NDT of all CJP welds, where plate thickness is ≥ 8.0 mm ($5/16$ inch); and 10% Surface NDT of all fillet welds, where plate thickness is ≥ 8.0 mm ($5/16$ inch).
Other welded connections	Random Volumetric NDT of CJP welds and Surface NDT of fillet welds, only if considered suspect by the attending Surveyor during construction.

* Note: NDT procedures and acceptance criteria are to at least satisfy the *ABS Guide for Nondestructive Inspection of Hull Welds*.

3 Surveys During Construction

3.1 Shipboard Installation and Operation Tests

The following items are to be verified by the attending Surveyor:

- i) *Installation and Arrangements.* Wind assisted propulsion systems are to be installed in accordance with the approved drawings. The following items are to be verified by the attending Surveyor:
 - Visual inspection of supporting structure members and deck connection
 - Nondestructive testing (NDT) per 4/2.2
- ii) *Testing.* Wind assisted propulsion system testing is to follow the approved testing procedures and is to include at least the following items:
 - a) As a minimum and where the **Wind-Assisted** notation applies:
 - Tests of all the alarms and safety functions
 - Automatic safety shutdown operation
 - Emergency shutdown operation
 - Inspection of lightning protection measures
 - Correct operation of fire detection system and fire extinguishing systems, where provided
 - b) Where the **Wind-Assisted+** notation applies:
 - General examination of machinery, piping, and electrical equipment (see Section 3)
 - Operational tests of machinery, electrical units, and control systems
- iii) Where the **Wind-Assisted+** notation applies, for wind assisted propulsion systems fitted with slewing rings, prior to mounting of the mast, the Surveyor is to witness flatness checks and surface finish requirements to verify compliance with the manufacturer's specifications for the following:
 - Attachment area for slewing ring
 - Slewing ring
 - Mounting flange on pedestal

Shimming or surface leveling compounds are not to be used to attain the required level of flatness of the mounting surfaces.

During installation, bolts are to be pretensioned by controlled means. Pretensioning, by bolt torque or by hydraulic tensioning device, is to be in accordance with the bearing manufacturer's instructions, which are to be submitted for review. Elongation of the bolts is to be measured to verify pretensioning.

At least 10 percent of the bolts are to be randomly selected and measured to the satisfaction of the attending Surveyor.

Once the wind assist propulsion system has been mounted, a "Rocking Test" taken in accordance with the bearing manufacturer's instructions is to be conducted and the results are to be documented and made available to the attending Surveyor during periodic survey.
- iv) *Operation and Maintenance Manual.* The attending Surveyor is to verify the availability of the operation manual and maintenance manual on board the vessel.

3.2 Sea Trials

The sea trial testing of the wind assisted propulsion system is to be carried out following the approved sea trial/commissioning procedures under a wind condition corresponding to the design wind speed in accordance with 3/2.1.2(a). Where the wind condition is considered impractical, the wind condition for sea trial testing may be reduced but is subject to approval by ABS.

3.2.1 Minimum Requirement and where **Wind-Assisted** Notation is Applicable

The following aspects are to be verified during the sea trial testing:

- i) The wind assisted propulsion system is able to respond to change of wind conditions as designed, including emergency situations. During the sea trial, the entire wind assisted propulsion system installation is to be operated in the presence of the Surveyor to demonstrate its reliability and sufficiency to function satisfactorily under operating conditions and its freedom from dangerous vibrations and other detrimental operating phenomena at speeds within the operating range. Based on the sea trial, the following information of the vessel is to be updated and provided on board, in accordance with 4-1-1/9 of the *Marine Vessel Rules*:
 - a) Stopping time
 - b) Vessel headings and distances recorded on sea trials, and
 - c) For vessels with multiple propellers, ability to navigate and maneuver with one or more propellers inoperative
- ii) The normal operation of the vessel is not adversely impacted by the operation of the wind assisted propulsion system, including maneuverability and stability. For the details of recording the maneuvering information from the sea trial, IMO Resolution A.601(15) may be referred to.
- iii) Other tests and requirement outlined in Subsection 3/5, “Maneuvering”

3.2.2 Control System Interaction Trials for **Wind-Assisted+** Notation

The interactions between the wind assisted propulsion system and the main propulsion and steering systems, and the control system response is to be conducted following the submitted trial plan from the manufacturer.

4 Surveys After Construction

For requirements for surveys after construction, see the *ABS Rules for Survey After Construction (Part 7)*.

4.1 Annual Surveys

4.1.1 Where **Wind-Assisted** Notation is Applicable

The following are to be included during the Annual Survey as a minimum and where the **Wind-Assisted** notation is applicable:

- i) Visual inspection of the foundation structure members of the wind assisted propulsion system for deformation, excessive wear, corrosion, fractures, or damage
- ii) Function test of the safety systems for the wind assisted propulsion system, including emergency stops, locks or release systems for extreme conditions, alarms, and fire detection systems, where fitted

4.1.2 Where **Wind-Assisted+** Notation is Applicable

Additionally, where the **Wind-Assisted+** notation is applicable, the following are also to be included during the Annual Survey:

- i) Visual inspection of the supporting structure members and other structural members of the wind assisted propulsion system for deformation, excessive wear, corrosion, fractures, or damage

- ii) Operation test of the wind assisted propulsion system and the associated control system(s)
- iii) The slewing ring, where applicable, is to be examined for slack bolts, damaged bearings and deformation or fractured weldments. Rocking Tests, in accordance with the bearing manufacturer's instructions, are to be taken every six months. The results of these tests are to be recorded for review by the attending surveyor at each Annual Survey.
- iv) Visual examination and operational test of wind assisted propulsion system machinery and gears including drive, clutches, brakes and slewing machinery.

4.2 Special Periodical Surveys

At intervals of five years, in addition to the requirements of the Annual Survey in 4/4.1, wind assisted propulsion system foundation structures with built-up sections with multiple layered plates, are to have sufficient surface NDE conducted on any laminated sections for the Surveyor to verify that the sections are tightly adhered to prevent buckling and inter-layer corrosion. Weld repairs are to be conducted only in accordance with manufacturer's welding procedures.

Where the **Wind-Assisted+** notation applies, the wind assisted propulsion system support structure members fitted with slewing rings, if applicable, are to undergo following testing and examination:

- i) The ABS surveyor is to examine slewing ring, including bolting arrangements and foundation, for slack bolts, damaged bearings, and deformed or fractured weldments.
 - Pretensioning of slewing ring bolts is to be verified as required by the manufacturer's onboard documentation.
 - All slewing ring bolts are to be tested (such as hammer testing or torque verified) to ascertain their soundness and tightness.
 - Dismantling and drawing out of slewing ring bolts need not be carried out for examination unless considered suspect by the attending Surveyor.
 - Any bolts found to be suspect by the Surveyor are to be removed and examined by NDE.
- ii) The ABS Surveyor is to witness a Rocking Test.
 - The Rocking Test is to be performed in accordance with the bearing manufacturer's recommendations or procedures. If the results of the Rocking Test or grease samples indicate potential bearing wear in excess of the manufacturer's recommendation, the bearing is to be opened for internal examination or replaced.
- iii) A grease sample is to be taken from the slewing ring bearing for analysis.
 - The grease sample is to be obtained and analyzed in accordance with the slewing ring bearing manufacturer's recommendations.
 - In the absence of other methods, the grease analysis for particulates is to be performed as per ASTM D1404.

