

Guide for

Vibration of Machinery Equipment and Related Structures



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GUIDE FOR

**VIBRATION OF MACHINERY EQUIPMENT AND RELATED
STRUCTURES
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American Bureau of Shipping
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Foreword

This Guide provides vibration measurement requirements and acceptance criteria for vibration levels of local structures, machinery, and equipment for a vessel to obtain the optional classification notation **VIB-M**.

The requirements provided in this Guide are in addition to the mandatory class requirements of the ABS *Rules for Building and Classing Marine Vessels (Marine Vessel Rules)*.

ABS may give special consideration to aluminum structures as well as offshore units and installations to obtain this optional classification notation.

ABS also provides the requirements for vibration for the optional notations related to crew habitability and passenger comfort. See the *ABS Guide for Passenger Comfort on Ships* and the *ABS Guide for Crew Habitability on Ships*.

This Guide becomes effective on 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

VIBRATION OF MACHINERY EQUIPMENT AND RELATED STRUCTURES

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SECTION 1 General

1 Application

This Guide applies to both new construction and existing vessels. Section 2 provides vibration acceptance criteria for local structures as well as machinery and equipment. Section 3 provides requirements for the vibration measurement procedure addressing the instrumentation, measurement conditions and locations as well as data processing and reporting.

2 Scope

This Guide outlines the process and acceptance criteria to obtain the optional classification notation **VIB-M** based on vibration measurements. Compliance with the vibration acceptance criteria is to be verified to the satisfaction of the attending Surveyor through the measurement of the vibration of

- i)* Local structures
 - Structures supporting the main propulsion system or other machinery and equipment, as well as nearby structures
 - Structures in compartments of machinery and equipment that may be affected by the operation of the associated machinery and equipment
- ii)* Machinery and equipment specified in this Guide

Where major modifications to the vessel result in changes to the vibration characteristics of the vessel, new measurements are to be taken to maintain the notation. For sister vessels, measurements are to be carried out for each vessel.

The additional requirements provided in the Guide do not alter the mandatory class requirements of the *ABS Rules for Building and Classing Marine Vessels (Marine Vessel Rules)*.

For aluminum structures as well as offshore units and installations, special consideration by ABS may be required to obtain this optional classification notation.

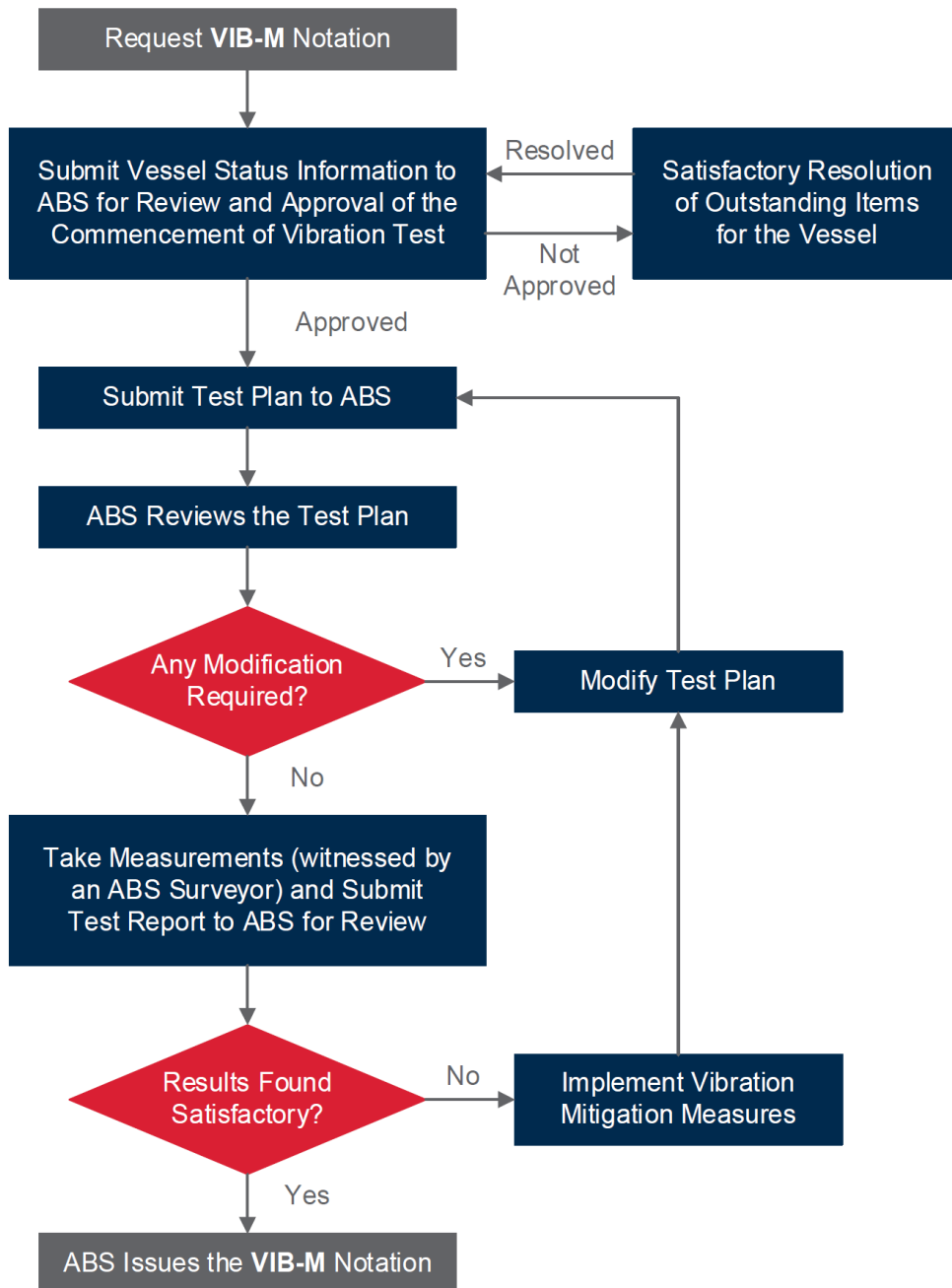
3 Process for Obtaining a Notation

Prior to scheduling vibration testing activities, the vessel's Owner or shipyard is to submit the vessel's operational status information confirming the vessel is fully operational and/or inclusive of all relevant equipment and furnishings to ABS for review.

If the vessel is not fully operational, a complete list of deficiencies of compartments, components and equipment is to be submitted to ABS for review. ABS will make the decision and notify the vessel's Owner or shipyard whether to proceed with the required vibration testing.

Section 1, Figure 1 outlines the process for obtaining the **VIB-M** notation.

FIGURE 1
Process for Obtaining the VIB-M Notation



4 Submission of Documents

The following documents are to be submitted to ABS Engineering for review:

- Vessel Status Information (See Subsection 1/3)
- Test Plan (See Subsection 3/6)
- Test Report (See Subsection 3/7)

5 Terminology

Free-Route. The condition achieved when the vessel is proceeding at a constant speed and course with minimum helm adjustment (± 2 degrees or less) and no throttle adjustment.

Local Structures. Structures including machinery foundation structures and structures in compartments of machinery and equipment that may be affected by the operation of the associated machinery and equipment.

Root Mean Square (RMS) Value. An indication of an equivalent steady state energy contained in an oscillating signal. It can be calculated from a time series of a measured signal or from a frequency spectrum obtained using the Fast Fourier Transform (FFT). Refer to ISO 20283-4 for methodologies of RMS calculations in frequency domain or in time domain.

Severity of Vibration. The peak value of vibration (velocity, acceleration, or displacement) during periods of steady-state vibration.

Windowing. A technique used to minimize the spectral leakage during FFT of random signals. This is accomplished by multiplying the time series of the measured signal with a window function. The window is a symmetric function in time and usually begins and ends with a zero value and has a value of one in the middle.

6 Abbreviations and References

6.1 Abbreviations

ABS	American Bureau of Shipping
AP	Aft Perpendicular
FFT	Fast Fourier Transform
FP	Forward Perpendicular
ISO	International Organization for Standardization
RMS	Root Mean Square
RPM	Revolutions Per Minute
SS	Service Supplier

6.2 References

6.2.1 Application

The international and recognized industry standards form the basis of the requirements in this Guide. Where the requirements in this Guide differ from those in the reference standards, this Guide takes precedence.

6.2.2 List of References

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

ABS Guidance Notes on Risk Assessment Application for the Marine and Offshore Industries

ABS Guidance Notes on Ship Vibration

ISO 20816-1 (2016), *Mechanical vibration – Measurement and evaluation of machinery vibration*

ISO 20283-4, *Mechanical vibration - Measurement on vibration on ships - Part 4: Measurement and evaluation of vibration of the ship propulsion machinery*

SECTION 2 Acceptance Criteria

1 General

This Section provides the vibration acceptance criteria including:

- i) Vibration limits for local structures
- ii) Vibration limits for machinery and equipment

The vibration limits with corresponding frequency ranges in this Section are given as the broadband RMS values, unless otherwise agreed. These limits are only applicable when the equipment is operating within the permissible operating range. Operating restrictions are to be documented.

2 Vibration Limits for Local Structures

The RMS value of the vibration velocity (measured in either vertical, transverse, or longitudinal direction) in the range from 4 Hz to 200 Hz is not to exceed 45 mm/s.

The vibration limits for foundation structures are to be the same as the limits for the mounted equipment.

The severity of vibration induced fatigue damage may vary according to local structural detail, actual stress level, local stress concentration, and material properties of local structures. Fatigue analysis as an alternative may be considered to address the excessive vibration levels that normally are not acceptable.

3 Vibration Limits for Machinery and Equipment

3.1 Main Propulsion Machinery

The vibration of main propulsion machinery can be affected by propeller excitation. The vibration criteria for the main propulsion machinery provided in this Section are not to be exceeded for internally and/or externally excited vibrations.

The vibration limits are provided in Section 2, Table 1 in terms of RMS values with multi-frequency components.

Commentary:

For additional measurements required by the attending Surveyor but not specified in this Guide, the *ABS Guidance Notes on Ship Vibration* or other applicable recognized industry standards may be referred to.

End of Commentary

TABLE 1
Vibration Limits for Main Propulsion Machinery

<i>Propulsion Machinery</i>	<i>Direction</i>	<i>Frequency Range</i>	<i>Velocity Limit (RMS)</i>	<i>Displacement Limit (RMS)</i>
Shaft Line Oil Lubricated Bearing	Lateral, measured on bearings casing/housing	1-200 Hz	7 mm/s	
Slow-Speed Diesel Engines (RPM: less than 200)	All directions, measured on engine block top	1-200 Hz	10 mm/s (vertical) 10 mm/s (longitudinal) 25 mm/s (transverse)	1 mm (vertical) 1 mm (longitudinal) 1.5 mm (transverse)
Diesel Engines (RPM: greater than 200)	All directions, measured on engine block top	4-200 Hz	15 mm/s (fixed mounting) 25 mm/s (resilient mounting)	

3.2 Machinery and Equipment

The machinery and equipment include generators, turbochargers, gears, turbines, motors, centrifugal pumps, compressors, turbochargers, boilers, fans, pipes, and electrical equipment, as applicable. The machinery and equipment required to be measured for this optional notation are those intended for essential services as defined in 4-8-1/7.3.3 of the *Marine Vessel Rules*. A list of these machinery and equipment is given in Appendix 1.

The vibration levels of machinery and equipment are not to exceed the limits specified in Section 2, Table 2 in terms of RMS value for normal operating conditions. In the case where the manufacturer requires more stringent vibration limits for specific machinery or equipment and its foundation, these requirements are to be satisfied.

The vibrations are to be measured for normal operation conditions. All possible restricted operating ranges are to be specified.

TABLE 2
Vibration Limits for Machinery and Equipment

<i>Machinery/Equipment</i>	<i>Measurement Locations and Directions</i>	<i>Frequency Range</i>	<i>Velocity Limit (RMS)</i>	<i>Acceleration Limit (RMS)</i>
Turbochargers ⁽¹⁾	Measured at the casing top at compressor part	4 - 200 Hz	45 mm/s (for below 5 MW) ⁽²⁾	2.5 g (for below 5 MW) ⁽²⁾
			50 mm/s (for 5 to 10 MW) ⁽²⁾	2.0 g (for 5 to 10 MW) ⁽²⁾
			55 mm/s (for above 10 MW) ⁽²⁾	1.5 g (for above 10 MW) ⁽²⁾
Generators driven by diesel ⁽⁷⁾	Measured on the bearings for all directions	4 - 200 Hz	18 mm/s ⁽³⁾	
Electric motors on thrusters	Measured on the bearings for all directions	4 - 200 Hz	18 mm/s ⁽³⁾	

<i>Machinery/Equipment</i>		<i>Measurement Locations and Directions</i>	<i>Frequency Range</i>	<i>Velocity Limit (RMS)</i>	<i>Acceleration Limit (RMS)</i>
Turbines		Measured on the bearings for all directions	4 - 1000 Hz	7 mm/s	
Turbine driven generators		Measured on the bearings for all directions	4 - 1000 Hz	7 mm/s	
Gears		Measured on the bearings for all directions	4 - 1000 Hz	7 mm/s	
Boilers		Measured at rigid part (i.e., cover flanges)	4 - 200 Hz	45 mm/s	
Pipes ⁽⁶⁾		Measured where large vibration amplitude occurs	4 - 200 Hz	45 mm/s	
Compressors (rotary, axial or centrifugal)		Measured on the bearings for all directions	4 – 200 Hz ⁽⁴⁾	7 mm/s (fixed mounting) 10 mm/s (resilient mounting)	
Compressors and pumps (reciprocating)		Measured on the bearings for all directions	4 - 200 Hz	30 mm/s	
Electric motors, separators, motor driven hydraulic pumps, fans driven by non-reciprocating engines		Measured on the bearings for all directions	4 – 200 Hz ⁽⁴⁾	7 mm/s (Internal Vibration) ⁽⁵⁾ 12 mm/s (Forced Vibration) ⁽⁵⁾	
Electronic instrument/equipment	On machinery	Measured where large vibration amplitude occurs	4 - 200 Hz	25 mm/s	
	On bulkheads	Measured where large vibration amplitude occurs	4 - 200 Hz	12 mm/s	
	On masts	Measured where large vibration amplitude occurs	4 - 200 Hz	20 mm/s	

Notes:

- 1 The vibration limit may be increased by 20 percent for non-continuous running in the operating speed range.
- 2 Total power of the cylinders served by each turbocharger.
- 3 Narrowband velocities with RMS above 7 mm/s for the first vibration mode to be investigated.
- 4 The upper limit of frequency range is to be at least 200 Hz, and greater than twice of RPM.
- 5 For the motors vertically mounted, the vibration level at motor top may be increased by 50 percent.
- 6 Those pipes associated with the machinery and equipment intended for essential services.
- 7 For small generator sets, recognized industry standards may be referred to for the limits.

4 Alternatives

Any departure from the acceptance criteria of this Guide may be considered by ABS based on suitable engineering analysis or risk assessment. In such cases, the vibration test results exceeding the limits specified in this Guide are subject to ABS's approval upon a demonstration of acceptable levels of safety in line with the principles of this Guide and recognized industry standards. Based on the risk assessment with consideration of mitigation measures, enhanced monitoring and more frequent inspections may be required for those locations.

Refer to the ABS *Guidance Notes on Risk Assessment Application for the Marine and Offshore Industries* for an overview of risk assessment techniques and additional information.

SECTION 3 Measurements

1 General

This Section provides general requirements for the measurement and evaluation of the vibration. Vibration levels of local structures, machinery, and equipment are to be measured to verify that vibration responses on board do not exceed the vibration limits defined in Section 2. Actual items for measurements are to be determined based on vessel specifications or specific needs.

2 Instrumentation

2.1 General Requirements

Measurements are preferably to be made with an electronic system which produces a permanent record. Provisions are to be made for suitable attenuation control to enable the system to accommodate a wide range of amplitudes. See ISO 20816-1.

2.2 Calibration

Calibration is to be carried out using system calibration or electrical calibration. Recognized industry standards are to be applied for the calibration procedure. Instrument calibration is to be performed every other year or following the calibration interval specified by the manufacturer, whichever interval is shorter.

3 Measurement Conditions

Vibration tests are to be conducted under the following conditions. Any deviation from the below conditions is to be recorded in the report.

3.1 Environmental Conditions

3.1.1 Sea State

The test is to be conducted in a sea state that does not have a significant impact on measurement results. The actual sea state during the vibration measurement is to be clearly stated in the report.

3.1.2 Water Depth

The test is to be conducted in a water depth of not less than five times the draft of the vessel, with machinery running under normal conditions. Where it is not practical to meet the water depth requirements, a shallower water depth may be acceptable provided it can be demonstrated that such water depth will have no significant impact on the measurement. If a vessel normally operates in shallow water, the depth during the test is to be representative of normal operating depths.

3.2 Loading Condition

The vessel is to be ballasted to a displacement and trim as close as possible to normal operating conditions within the ordinary ballasting capacity of the vessel. The propeller is to be fully immersed.

3.3 Course

Tests are to be conducted for free-route runs. During free-route runs, the vessel is to maintain a straight course. Rudder action is to be kept to a minimum.

3.4 Speed and Engine Power

Free-route runs are to be conducted under normal operating conditions of the propulsion system. Data recording of steady-state values is to cover the operational speed range of the engine for main propulsion machinery and associated machinery components. Slow run-up may be required.

3.5 Machinery Operating Condition

All other machinery components are to be run under defined normal operating conditions during the test. Consideration is to be given to other operating conditions that may cause more severe vibration.

Commentary:

Scenarios in normal operating conditions where adjacent equipment and/or systems are in operation concurrently may need to be considered as part of the above requirement.

End of Commentary

4 Measurement Locations

All measurement locations are subject to a walkthrough inspection by the attending ABS Surveyor. At the discretion of the attending ABS Surveyor, additional measurements are to be included for the locations and components that present significant vibrations during the sea trial or vibration test.

4.1 Measurement Locations for Local Structures

Vertical, transverse, and longitudinal measurements are to be taken at the locations of local structures supporting the main propulsion system or other machinery and equipment listed in 2/3.2 as well as the structures in compartments of machinery and equipment that could potentially present significant vibrations.

4.2 Measurement Locations for Machinery and Equipment

Measurement locations for machinery components and equipment are to be in accordance with ISO 20816-1.

5 Data Processing Analysis

Measured data is to be recorded for the displacements, velocities, or accelerations for the appropriate frequency range. The frequency ranges of transducers, signal conditioners, and recording equipment are to be selected to match the frequency components of interest. Refer to Section 2 for corresponding frequency ranges for each item required for the vibration test. Any deviation from the specified frequency range is to be clearly stated in the test report.

For measurements of internal vibration which is self-excited with a single excitation source, such as rotating machinery, amplitudes are constant, and a large sample in time series is not required. For machinery (e.g., main propulsion machinery) where vibration data are excited by mixed sources, the amplitudes could be modulated and random. A sample large enough to account for the randomness is to be taken.

6 Test Plan

Vibration test plans for local structures, machinery, and equipment are to be submitted to ABS for review. A Test Plan serves as the principal means for verifying that the measurements are in compliance with the vibration requirements in this Guide. A list of machinery and equipment as well as the affected local structures required to be measured is to be included in the test plan. This document is to be prepared by the ABS recognized vibration Service Supplier with additional input provided by the designer/builder.

The Test Plan is to include the following items described in this Subsection.

6.1 Drawings

The Test Plan is to include drawings indicating the locations of all vibration sources.

6.2 Testing Personnel

The Test Plan is to provide information about the ABS recognized vibration Service Supplier conducting the test and their recognition certificates.

6.3 Test Conditions

The Test Plan is to document the conditions under which the tests will be performed. More details on documenting the measurement conditions are provided in Subsection 3/3.

6.4 Measurement Locations

All locations where measurements will be taken are to be documented in the Test Plan, in detail, using appropriate drawings. In addition, transducer placement positions are to be indicated. Details on selecting measurement locations are provided in Subsections 2/3 and 3/4.

6.5 Instruments and Data Acquisition

The Test Plan is to provide information regarding the methods and instrumentation to be used for measurement and data recording. Instrumentation specification details are to include the type of instruments to be used, accuracy, calibration, sensitivity, and frequency range.

6.6 Data Analysis

The Test Plan is to provide information regarding the methods, software, and devices/instrumentation to be used for data analysis.

FFT techniques are to be applied to obtain the narrowband vibration levels in frequencies by converting the waveform data in time domain to frequency domain. For the frequency range between 1 Hz and 200 Hz, a resolution of at least 400 spectral lines and a Hanning window are to be used. For frequency range up to 1000 Hz, minimum of 1600 spectral lines resolution with flat top window is to be used.

6.7 Data Collection Sheets

The Test Plan is to provide sample data sheets (in table format) that will be used for reporting the measurement data.

7 Survey

7.1 Initial Survey

The data collection is to be executed by an ABS recognized Service Supplier (SS), for Vibration Measurement, and witnessed by an ABS Surveyor. The test personnel are to complete the Test Report at the time of the survey. Equipment and instrumentation calibration certificates, together with the results of the field setup and calibration check, are to be provided to the ABS Surveyor.

The ABS Surveyor is to verify that the actual vibration measurement is carried out according to the approved measurement plan (see Subsection 3/6), and sign the Vibration Measurement report if the measurement meets the applicable requirements.

The contents of the test report are to at least include:

- Particulars of tested vessel
- Particulars of propulsion-shaft system
- Particulars of main diesel engine or turbine driven plants
- A sketch showing locations of machinery transducers and their directions of measurement as well as the associated vibration limits given in this Guide. Transducer locations for local vibration measurements are to be shown on a separate sketch where the precise location of the transducer is denoted
- Trial conditions during vibration measurements including sea state, wave direction, wind speed/wind direction, vessel heading, water depth, draft at forward perpendicular (FP) and aft perpendicular (AP), and propeller immersion
- Measurement and analysis system including type of measurement instrument, method of analysis, and recording system
- Description of data processing procedures and parameters including frequency resolution, number of spectral lines, and type of windows
- Plots of displacement, velocity, or acceleration amplitudes versus frequency as well as time history data (waveforms) if applicable
- Tables of maximum narrowband RMS values in different directions of all measured locations and corresponding engine RPM or shaft rotational frequency for machinery-excited vibration
- Summary of vibration measurements, including RMS, the excessive measurements, alternative assessment (risk assessment or engineering analysis), and mitigation measures, if applicable

7.2 Annual Survey

See 7-9-47/5.1 of the *ABS Rules for Survey After Construction (Part 7)*.

7.3 Special Periodical Survey

See 7-9-47/5.3 of the *ABS Rules for Survey After Construction (Part 7)*.

APPENDIX 1

List of Machinery and Equipment Intended for Essential Services for Vibration Measurement

TABLE 1
Measurement List for Machinery and Equipment Intended for Essential Services

(Also see 4-8-1/7.3.3 of the *Marine Vessel Rules*)

	<i>Machinery and Equipment item</i>	<i>Application</i>
1	Main Propulsion Machinery	See Section 2, Table 2
2	Steering Gears	
3	Pumps	See 4-8-1/Table 1 (c), (e), (g), (k), (n), and 4-8-1/Table 2 (b), (c), (f), and (m) of the <i>Marine Vessel Rules</i> for those pumps intended for essential service, as applicable
4	Turbines	
5	Turbochargers	
6	Generator driven by diesel engine	
7	Generator driven by Turbine	
8	Electric motors on thrusters	
9	Boilers for essential services	
10	Pipes	Associated with machinery/equipment required to be measured
11	Compressors	- Gas compressor supporting boil-off gas usage as fuel to main propulsion or electric power generation machinery - Starting air and control air compressors
12	Electric motors for power sources supplying essential equipment	
13	Separators	For heavy fuel oil and lubrication oil
14	Fans	- Forced ventilating fans for engine and boiler rooms - Used for maintaining dangerous spaces in a safe condition (See 4-8-1/Table 2 of the <i>Marine Vessel Rules</i>)

	<i>Machinery and Equipment item</i>	<i>Application</i>
15	Electrical equipment	• Ambient temperature control equipment required by 4-8-3/1.17.2 of the <i>Marine Vessel Rules</i> • Navigation equipment on masts • Other equipment identified for essential service depending on the vessel type
16	Machinery/Equipment used for the methods as defined in 5C-8-7/1 of the <i>Marine Vessel Rules</i> on liquefied gas carriers	