

IEEE Recommended Practice for Electric Installations on Shipboard

Sponsor

**Marine Transportation Committee
of the
IEEE Industry Applications Society**

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IEEE-SA Standards Board

Abstract: Recommendations for the selection and installation of equipment on merchant vessels with electric apparatus for lighting, signaling, communication, power, and propulsion are provided.

Keywords: marine electrical engineering, marine vessels, shipboard systems, ships

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Introduction

(This introduction is not part of IEEE Std 45-1998, IEEE Recommended Practice for Installations on Shipboard.)

IEEE Std 45-1998, IEEE Recommended Practice for Electric Installations on Shipboard, constitutes the chief undertaking of the Marine Transportation Committee of the IEEE Industry Applications Society.

Due to the differences among the requirements of the various classification societies and the insurance companies regarding electric installations on shipboard, and the lack of any accepted standard engineering practice for marine installations, the AIEE¹ in 1913 appointed the Marine Committee (now called Marine Transportation Committee) to take up the preparation of standard marine rules. The first edition was prepared covering two important divisions; namely, fire protection requirements and marine construction requirements. They were adopted by the American Bureau of Shipping and published as Section 37 of their Rules for the building and classing of vessels. As the first edition of the rules did not cover the entire field of use of electricity on shipboard, the Marine Committee of the Institute was continued. The recommendations were considerably amplified in the editions issued in 1920, 1927, 1930, 1938, 1940, 1945, 1948, 1951, 1955, 1958, 1962, 1967, 1971, 1977, and 1983.

This edition has been completely rewritten. It includes many significant additions, changes, and deletions to reflect North American and International marine electrical engineering technology and the latest system design, installation, and test practices necessary to ensure safe and reliable operation.

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¹In 1963 the American Institute of Electrical Engineers (AIEE) merged with the Institute of Radio Engineers (IRE) to become the Institute of Electrical and Electronics Engineers, Inc. (IEEE).

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IEEE Recommended Practice for Electric Installations on Shipboard

1. Overview and general recommendations

1.1 Scope

These marine recommendations are intended to serve as a guide for the selection and installation of equipment on merchant vessels with electric apparatus for lighting, signaling, communication, power, and propulsion. The recommendations define what are considered good present-day engineering practices with reference to the safety of the personnel and of the ship itself as well as reliability and durability of the apparatus. It is recognized that changes and improvements in shipboard requirements may develop which are not specifically covered herein; such changes, if incorporated in the design, should be equal to the safety and reliability levels defined herein and generally in accord with the text of these standards.

Specific nationally recognized standards are referenced in the text. Other standards should be followed to the extent possible.

Attention is directed to the fact that the rules for electrical installations on shipboard are promulgated by the regulatory agencies and the classing societies. Such rules have been given due consideration in these recommendations, but there may be differences among these provisions. Deference should always be made to the regulatory requirements where this standard offers contrary requirements, or where this standard may be silent.

1.2 Purpose

The main purpose of this standard is to provide a consensus of recommended practices in the unique field of marine electrical engineering as applied specifically to ships, shipboard systems, and equipment.

1.3 Vessel classification

Marine vessels and platforms are grouped as following:

- *Group No 1:* Ocean-going vessels that navigate on any ocean or the Gulf of Mexico 20 mi or more off shore.
- *Group No 2:* Ocean-going vessels that navigate on any ocean or the Gulf of Mexico but less than 20 mi off shore.
- *Group No 3:* Vessels navigating on the Great Lakes only.
- *Group No 4:* Vessels navigating bays, sounds, and lakes other than the Great Lakes.
- *Group No 5:* Vessels navigating rivers only.
- *Group No 6:* Fixed and floating offshore petroleum facilities.
- *Group No 7:* Recreational vehicles.

1.4 Applicability

These recommendations have been prepared for application to all vessels in Group 1 through 5. Group Nos 6 and 7 are governed by other standards.

1.5 Documentation

Every vessel should be provided with comprehensive sets of drawings and instruction books that provide complete and detailed information regarding the operation and maintenance of the systems and equipment installed. Drawings for each system should provide cable routing information, cable identification, cable sizes, loads, protective device settings, circuit data, conductor termination details, and material lists. Calculation of fault currents with associated breaker coordination curves should also be provided. Instruction books should include descriptions and illustrations that provide equipment operating instructions, maintenance procedures, test requirements, and spare parts recommendations. A booklet containing the manufacturer's name, size, type, rating, catalog number, or similar identification for all electrical and electronic equipment on the vessel should also be provided for use by shipboard personnel. An as-built one line diagram of the ship's power generation and distribution system should be permanently installed in a location accessible at all times to the engineering personnel.

1.6 Environmental conditions

1.6.1 Normal design and operating conditions

Systems and equipment should be suitable for continuous operation in the following normal conditions of shipboard service:

- a) Continuous exposure to severe moisture- and salt-laden atmosphere, high wind velocity, and ice formation encountered at sea.
- b) Average ambient temperature values of 40 °C (104 °F) in accommodation areas, and similar spaces; 45 °C (113 °F) in main and auxiliary machinery spaces; 50 °C (122 °F) for rotating machinery and propulsion equipment in main and auxiliary machinery spaces containing significant heat sources such as prime movers and boilers; 65 °C (149 °F) in the uptakes of machinery spaces containing prime movers and boilers; all at relative humidities up to 95%. The design value for sea water cooling temperature should be 32 °C (89.6 °F).
- c) Roll and pitch of a vessel underway, as follows:

	Roll		Pitch	
	Static	Dynamic	Static	Dynamic
Ship service equipment	15°	22.5°	5°	7.5°
Emergency equipment	22.5°	22.5°	10°	10°
Switchgear	45°	45°	45°	45°

- d) Vibration of a vessel underway: Electrical equipment should be constructed to withstand at least the following:
- 1) Vibration frequency range of 5–50 Hz with a velocity amplitude of 20 mm/s.
 - 2) Peak accelerations due to ship motion in a seaway of ± 0.6 g for ships exceeding 90 m in length, and ± 1.0 g for smaller ships, with a duration of 5–10 s.

1.6.2 Abnormal design and operating conditions

Special conditions associated with a specific ship design or operating area may exist that require consideration by those responsible for the design and application of electrical systems and equipment. Examples of such conditions are as follows:

- Exposure to damaging fumes or vapors, excessive or abrasive dust, steam, salt spray, etc.
- Exposure to high levels of shock and vibration
- Exposure to excessively high or low temperatures
- Exposure to unusual to flammable atmospheres (See Clause 33)
- Exposure to unusual loading or unloading conditions affecting list and trim
- Unusual operating cycles, frequency of operation, poor power quality, special insulation requirements, stringent or difficult maintenance requirements, etc.

1.7 Equipment construction, testing, and certification

Electrical apparatus and equipment should be constructed and tested in accordance with the requirements of appropriate national and/or international equipment standards. Standards specifically addressing marine requirements should be used whenever applicable. Many appropriate standards are referenced in this document. The apparatus and equipment should be tested and certified by an independent product testing and certification organization that is routinely involved in testing such apparatus or equipment.

1.8 Materials

1.8.1 Corrosion-resistant parts

Where essential to minimize deterioration due to marine atmospheric corrosion, corrosion-resisting materials, or other materials treated in a satisfactory manner to render them adequately resistant to corrosion, should be used. Silver, corrosion-resisting steel, copper, brass, bronze, copper-nickel, certain nickel-copper alloys, and certain aluminum alloys are considered satisfactory corrosion-resisting materials.

The following treatments, when properly performed and of a sufficiently heavy coating, are considered satisfactory corrosion-resistant treatments:

- Electroplating of cadmium, nickel, chromium, silver, copper, or zinc
- Sherardizing
- Galvanizing

- Dipping and painting (phosphate or suitable cleaning, followed by the application of a coating system meeting the requirements of ASTM B117-95¹).

These provisions apply to the following components:

- *Parts*. Interior small parts that are normally expected to be removed in service, such as bolts, nuts, pins, screws, cap screws, terminals, brushholder studs, springs, etc.
- Assemblies, subassemblies, and other units where necessary due to the unit function, or for interior protection, such as shafts within a motor or generator enclosure, and surface of stator and rotor.
- *Enclosures and their fastenings and fittings*. Enclosing cases for control apparatus, outer cases for signal and communication systems (both outside and inside), and similar items together with all their fastenings and fittings that would be seriously damaged or rendered ineffective by corrosion.

1.8.2 Flame-retardant materials

Flame-retardant materials and structures should be used to the maximum extent practicable throughout the vessel. These materials should have such fire-resisting properties that they will not convey flame nor continue to burn for longer times than specified in the appropriate flame test.

Compliance with the requirements of the preceding paragraph should be determined with the apparatus and according to the methods described in appropriate nationally recognized test laboratory standards for the materials and structures being considered, unless specific applicable tests are invoked in these recommendations.

1.9 Insulation

1.9.1 Preferred insulation system classifications

The preferred insulation system classifications are classes 105, 130, 155, 180, 200, 220, and 240 or greater (based upon maximum temperature limits in degrees Celsius), or A, B, F, H, N, R, and C and as designated by the equipment standard. Refer to Tables 5-1, 5-2, 14-1, 17-1, and 34-1 for dc and ac machine and equipment temperature limits applicable to the different insulation classes.

1.9.2 Brittle material

Porcelain or other brittle insulating materials should not be used for lamp sockets, receptacles, fuse blocks, etc., where the material is rigidly fastened by machine screws or equivalent.

1.10 Equipment enclosures

Equipment enclosures of the types defined in 3.7 (except for explosionproof enclosures), should be manufactured and tested in accordance with the requirements of ANSI/NEMA 250-1991 or IEC 60529: 1989.

2. References

This recommended practice shall be used in conjunction with the following publications. When the following standards are superseded by an approved revision, the revision shall apply.

ANSI C39.1-1981 (R 1992), Requirements for Electrical Analog Indicating Instruments.²

¹ Information on references can be found in Clause 2.

ANSI/ASTM D470-93, Standard Methods of Testing Crosslinked Insulations and Jackets for Wire and Cable.

ANSI/ASTM D2671-95, Standard Test Methods for Heat-Shrinkable Tubing for Electrical Use.

ANSI/ASTM D4066-94B Type VIII, Standard Test Methods for Determination of Relative Viscosity, Melting Point, and Moisture Content of Polyamide (PA).

ANSI/ISA-RP 12.6-1995, Wiring Practices for Hazardous (Classified) Locations—Instrumentation, Part I: Intrinsic Safety.

ANSI/NEMA FU1-1986, Low-Voltage Cartridge Fuses.

ANSI/NEMA ICS 1-1993, Industrial Control and Systems General Requirements.

ANSI/NEMA MG 1-1993, Motors and Generators.

ANSI/NEMA 250-1991, Enclosures for Electrical Equipment (1000 Volts Maximum).

ANSI/NFPA 70-1996, National Electrical Code.³

ANSI/NFPA 77-1993, Recommended Practice on Static Electricity.

ANSI/NFPA 99-1996, Standard for Health Care Facilities.

ANSI/NFPA 496-1993, Standard for Purged and Pressurized Enclosures for Electrical Equipment.

ANSI/UL 73-1993, Standard for Safety for Motor-Operated Appliances.

ANSI/UL 197-1993, Standard for Safety for Commercial Electric Cooking Appliances.

ANSI/UL 399-1993, Standard for Safety for Drinking-Water Coolers.

ANSI/UL 471-1995, Standard for Safety for Commercial Refrigerators and Freezers.

ANSI/UL 486A-1991, Standard of Safety for Wire Connectors and Soldering Lugs for Use With Copper Conductors.

ANSI/UL 913-1988, Standard for Intrinsically Safe Apparatus and Associated Apparatus for Use in Class II, and III, Division I, Hazardous Locations.

ANSI/UL 921-1992, Standard of Safety for Commercial Electric Dishwashers.

ANSI/UL 1309-1995, Standard for Safety Marine Shipboard Cable.

ANSI/UL 1581-1991, Reference Standard for Electrical Wires, Cables, and Flexible Cords.

ASTM B3-95, Standard Specification for Soft or Annealed Copper Wire.⁴

² ANSI publications are available from the Sales Department of the American National Standards Institute, 11 West 42nd St., New York, NY 10018 USA.

³ The National Electrical Code is published by the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269. Copies are available from the Sales Department of the American National Standards Institute.

⁴ ASTM publications are available from the American Society for Testing and Materials, 100 Bar Harbor Drive, West Conshohocken, PA 19428 USA.

ASTM B8-95, Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft.

ASTM B33-94, Standard Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes.

ASTM B117-95, Standard Practice for Operating Salt Spray (Fog) Apparatus.

ASTM B172-95, Standard Specification for Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors.

ASTM B173-95, Standard Specification for Rope-Lay-Stranded Copper Conductors Having Concentric-Stranded Members, for Electrical Conductors.

ASTM B174-95, Standard Specification for Bunch-Stranded Copper Conductors for Electrical Conductors.

ASTM B189-95, Standard Specification for Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes.

ASTM D229-96, Standard Test Methods for Rigid Sheet and Plate Materials Used for Electrical Insulation.

ASTM E662-97, Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials.

ASTM F1003-86 (R1992), Standard Specification for Searchlights on Motor Lifeboats.

ASTM F1166-95a, Standard Practice for Human Engineering Design for Marine Systems, Equipment and Facilities.

ASTM G23-96, Standard Practice for Operating Light-Exposure Apparatus (Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials.

CSA C22.1-1994, Canadian Electrical Code Part 1/Seventeenth Edition Safety Standard for Electrical Installations.⁵

CSA C22.2 No. 38-1995, Thermoplastic Insulated Wires and Cables; (Gen. Instr. 1).

Distribution, Power, and Regulating Transformers Standards Collection, 1995 Edition.⁶

ICEA T-28-562-1995, Test Method for Measurement of Hot Creep of Polymeric Insulations.⁷

IEC 60529: 1989, Degrees of protection provided by enclosures (IP Code).⁸

IEEE Std 4-1995, IEEE Standard Techniques for High-Voltage Testing.⁹

⁵ CSA Standards are available from the Canadian Standards Association (Standards Sales), 178 Rexdale Blvd., Etobicoke, Ontario, M9W 1P3, Canada.

⁶ This IEEE standards collection is available from IEEE, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331 USA.

⁷ ICEA documents are available from the Insulated Cable Engineers Association, Inc., P.O. Box 440, South Yarmouth, MA 02663 USA and NEMA Customer Service 1300 North 17th Street, Suite 1847, Rosslyn, VA 22209 USA.

⁸ IEC documents are available from the International Electrotechnical Commission, Case Postale 131, 3, Rue de Varembe, CH-1211, 1211 Genève 20, Switzerland/Suisse.

⁹ IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855 USA.

IEEE Std 43-1974 (Reaff 1991), IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery.

IEEE Std 74-1958 (Reaff 1974), IEEE Standard for Test Code for Industrial Control (600 Volts or Less).¹⁰

IEEE Std 112-1996, IEEE Standard Test Procedure for Polyphase Induction Motors and Generators.

IEEE Std 113-1973, IEEE Guide Test Code for Direct-Current Machines.¹¹

IEEE Std 114-1982, IEEE Standard Test Procedure for Single-Phase Induction Motors.¹²

IEEE Std 115-1995, IEEE Guide: Test Procedures for Synchronous Machines, Part I—Acceptance and Performance Testing, Part II—Test Procedures and Parameter Determination for Dynamic Analysis.

IEEE Std 432-1992, IEEE Guide for Insulation Maintenance for Rotating Electric Machinery (5 hp to less than 10 000 hp).

IEEE Std 444-1973 (Reaff 1992), Standard Practices and Requirements for Thyristor Converters for Motor Drives, Part 1—Converters for DC Motor Armature Supplies.

IEEE Std 519-1992, IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems.

IEEE Std 576-1989, IEEE Recommended Practice for Installation, Termination, and Testing of Insulated Power Cable as Used in the Petroleum and Chemical Industry.

IEEE Std 835-1994, IEEE Standard Power Cable Ampacity Tables.

IEEE Std 1202-1991 (Reaff 1996), IEEE Standard for Flame Testing of Cables for Use in Cable Tray in Industrial and Commercial Occupancies.

IEEE Std C37.20.2-1993, IEEE Standard for Metal-Clad and Station-Type Cubicle Switchgear.

IEEE/ICEA S-135-1962, IEEE/ICEA Power Cable Ampacities—Copper Conductors (ICEA P-46-246).

IES RP-12-1998, Recommended Practice for Marine Lighting.¹³

IMO Resolution A.686 (20 January 1992), Code on Alarms and Indicators.¹⁴

MIL-C-17G, Cables, Radio Frequency, Flexible and Semirigid, General Specification for.¹⁵

MIL-C-24640A, Cable, Electrical, Lightweight for Shipboard Use, General Specification for.

MIL-C-24643A, Cable and Cords, Electrical, Low Smoke, for Shipboard Use, General Specification for.

MIL-HDBK-299-October 1994, Cable Comparison Handbook—Data Pertaining to Electric Shipboard Cable.

¹⁰ IEEE Std 74-1958 has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood, CO 80112-5704 USA, tel. (303) 792-2181.

¹¹ IEEE Std 113-1973 has been withdrawn. Copies can be obtained from Global Engineering.

¹² IEEE Std 114-1982 has been withdrawn. Copies can be obtained from Global Engineering.

¹³ IES publications are available from CSSinfo, 310 Miller Avenue, Ann Arbor, MI 48103 USA.

¹⁴ IMO publications are available from the International Maritime Organization, 4 Albert Embankment, London SE1 7SR, England.

¹⁵ MIL Specifications are available from Standardization Documents Order Desk, Bldg. 4D, 700 Robbins Ave. Philadelphia, PA 19111-5094 USA.

MIL-W-16878F, Wire, Electrical, Insulated, General Specification for.

MIL-W-22759E, Wire, Electrical, Fluoropolymer-Insulated, Copper or Copper Alloy.

NEMA AB1-1975, Molded Case Circuit Breakers.

NEMA SG3-1975, Low-Voltage Power Circuit Breakers.

NEMA ST1-1978, Specialty Transformers (Except General Purpose Type).

NEMA WC 3-1992, Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (ICEA S-19-81).

NEMA WC 5-1992, Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (ICEA S-61-402).

NEMA WC 7-1988, Cross-Linked-Thermosetting-Polyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (ICEA S-66-524).

NEMA WC 8-1988 (R1992), Ethylene-Propylene-Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (ICEA S-68-516).

NES-711 Issue 2, January 1981, Determination of the Smoke Index of the Products of Combustion from Small Specimens of Materials, as modified in MIL-C-24643, paragraph 4.7.27.¹⁶

SOLAS Consolidated Edition, 1997, Consolidated text of the International Convention for the Safety of Life at Sea, 1974, and its Protocol of 1978: articles, annexes and certificates. Incorporating all amendments in effect from 1 July 1997.¹⁷

UL 44-1991, Standard for Safety for Rubber-Insulated Wires and Cables.¹⁸

UL 62-1991, Standard for Safety for Flexible Cord and Fixture Wire.

3. Definitions

3.1 General

3.1.1 Accommodation spaces

Spaces provided for passengers and crew members that are used for berthing, dining rooms, mess spaces, offices, private baths, toilets and showers, lounges, and similar spaces.

3.1.2 Alternating current (ac)

A periodic current with an average value over a period of time of zero. (Unless distinctly specified otherwise, the term refers to a current that reverses at regularly recurring intervals of time and that has alternately positive and negative values.)

¹⁶ NES Standards are available from Procurement Executive, Ministry of Defense, Ship Department, Section TE112, Block G, Foxhill, Bath, England.

¹⁷ SOLAS Publications are available from the International Maritime Organization.

¹⁸ UL standards are available from Global Engineering.

3.1.3 Asynchronous machine

A machine in which the speed of operation is not proportional to the frequency of the system to which it is connected.

3.1.4 Capacitance (capacity)

That property of a system of conductors and dielectrics that permits the storage of electricity when potential differences exist between the conductors. Its value is expressed as the ratio of a quantity of electricity to a potential difference. A capacitance value is always positive.

3.1.5 Capacitor

A device with the primary purpose of introducing capacitance into an electric circuit. Capacitors are usually classified, according to their dielectrics, as air capacitors, mica capacitors, paper capacitors, etc.

3.1.6 Cargo vessel

A vessel that carries bulk, containerized, or roll-on/roll-off dry cargo, and no more than 12 passengers. Research vessels, search and rescue vessels, and tugs are also considered to be cargo vessels in these recommendations.

3.1.7 Cycle

The complete series of values of a periodic quantity that occurs during a period. (It is one complete set of positive and negative values of an alternating current.)

3.1.8 Direct current (dc)

A unidirectional current in which the changes in value (polarity) are either zero or so small that they may be neglected. (As ordinarily used, the term designates a practically nonpulsating current.)

3.1.9 Direct-current (dc) commutating machine

A machine that comprises a magnetic field excited from a dc source or formed of permanent magnets, an armature and a commutator connected therewith. Specific types of dc commutating machines are dc generators, motors, synchronous converters, boosters, balancers, and dynamotors.

3.1.10 Electric coupling

A device for transmitting torque by means of electromagnetic force in which there is no mechanical torque contact between the driving and driven members. The slip type electric coupling has poles excited by direct current on one rotating member, and an armature winding, usually of the double squirrel cage type, on the other rotating member.

3.1.11 Electronics

That branch of science and technology that relates to devices in which conduction is principally by electrons moving through a vacuum, gas, or semiconductor.

3.1.12 Embedded temperature detector

A resistance thermometer or thermocouple built into a machine for the purpose of measuring the temperature.

3.1.13 Frequency

The number of periods occurring in unit time of a periodic quantity, in which time is the independent variable.

3.1.14 Hertz (Hz)

The unit of frequency, one cycle per second.

3.1.15 Induction machine

An asynchronous ac machine that comprises a magnetic circuit interlinked with two electric circuits, or sets of circuits, rotating with respect to each other and in which power is transferred from one circuit to another by electromagnetic induction. Examples of induction machines are induction generators, induction motors, and certain types of frequency converters and phase converters.

3.1.16 Loran

A long-range radio navigational aid of the hyperbolic type whose position lines are determined by the measurement of the difference in the time of arrival of synchronized pulses. (These devices are rapidly being replaced by satellite-based global positioning systems.)

3.1.17 Machinery spaces

Spaces that are primarily used for machinery of any type, or equipment for the control of such machinery, such as boiler, engine, generator, motor, pump and evaporator rooms.

3.1.18 Passenger vessel

A vessel that carries more than 12 persons in addition to the crew.

3.1.19 Radar

A device that radiates electromagnetic waves and utilizes the reflection of such waves from distant objects to determine their existence or position.

3.1.20 Reactance

The imaginary component ($\pm j$, or $\pm 90^\circ$ phase angle) of impedance, where resistance is the real component with a zero phase angle. Reactance appears in two forms, one as a capacitive reactance (X_C) for a capacitor (C), and the other as inductive reactance (X_L) for an inductor (L). The former has the negative 90° phase angle, and the latter a positive 90° angle. Their values can be expressed in the following relationships:

$$X_C = -j \frac{1}{2\pi fC}, \text{ and } X_L = j2\pi fL,$$

where f is the excitation frequency.

3.1.21 Reactor

A device with the primary purpose of introducing reactance into an electric circuit for purposes such as motor starting, paralleling transformers, and control of current.

3.1.22 Semiconductor rectifier

A device consisting of a conductor and semiconductor forming a junction. The junction exhibits a difference in resistance to current flow in the two directions through the junction. This results in effective current flow in one direction only. The semiconductor rectifier stack is a single columnar structure of one or more semiconductor rectifier cells.

3.1.23 Single-phase circuit

A circuit energized by a single alternating electromotive force.

NOTE—A single-phase circuit is usually supplied through two conductors. The currents in these two conductors, counted outward from the source, differ in phase by 180° or a half cycle.

3.1.24 Slip

In an induction machine, the difference between its synchronous speed and its operating speed. It may be expressed in the following ways:

- a) As a percent of synchronous speed
- b) As a decimal fraction of synchronous speed
- c) Directly in revolutions per minute

3.1.25 Synchronous machines

A machine in which the average speed of normal operation is exactly proportional to the frequency of the system to which it is connected.

3.1.26 Tank vessel

A vessel that carries liquid or gaseous cargo in bulk.

3.1.27 Three-phase circuit

A combination of circuits energized by alternating electromotive forces that differ in phase by one-third of a cycle (120°).

NOTE—In practice, the phases may vary several degrees from the specified angle.

3.2 Cable installation

3.2.1 Lug

A wire connector device to which the electrical conductor is attached by mechanical pressure or solder.

3.2.2 Multicable penetrator

A device consisting of multiple nonmetallic cable seals assembled in a surrounding metal frame, for insertion in openings in decks, bulkheads, or equipment enclosures and through which cables may be passed to penetrate decks or bulkheads or to enter equipment without impairing their original fire or watertight integrity.

3.3 Generators

3.3.1 Brushless exciter

An ac (rotating armature type) exciter whose output is rectified by semiconductor devices to provide excitation to an electric machine. The semiconductor devices are mounted on, and rotate with, the ac exciter armature.

3.3.2 Brushless synchronous machine

A synchronous machine that has a brushless exciter with its rotating armature and semiconductor devices on a common shaft with the field of the main machine. This type of machine has no collector, commutator, or brushes.

3.3.3 Compound-wound generator

A dc generator that has two separate field windings. One supplies the predominating excitation, and is connected in parallel with the armature circuit. The other supplies only partial excitation and is connected in series with the armature circuit. It is proportioned to require an equalizer connection for satisfactory parallel operation.

3.3.4 Electric generator

A machine that transforms mechanical power into electric power.

3.3.5 Exciter

The source of all or part of the field current for the excitation of an electric machine.

3.3.6 Homopolar generator

A dc generator in which the magnetic field flux passes in the same direction from one member to the other over the whole of a single air gap area. Characteristically the machines are high-current, low-voltage generators.

3.3.7 Induction generator

An induction machine driven above synchronous speed by an external source of mechanical power.

3.3.8 Inductor type synchronous generator

A generator in which the field coils are fixed in magnetic position relative to the armature conductors. The electromotive forces are produced by the movement of masses of magnetic material.

3.3.9 Permanent magnet generator

An electric generator in which the magnetic flux is provided by one or more pairs of permanent magnets.

3.3.10 Pilot exciter

The source of all or part of the field current for the excitation of another exciter.

3.3.11 Polyphase synchronous generator

A generator whose field circuits are arranged so that two or more symmetrical alternating electromotive forces with definite phase relationships are produced at the terminals. Polyphase synchronous generators are usually two-phase, producing two electromotive forces displaced 90 electrical degrees apart, or three-phase, producing three

electromotive forces displaced 120 electrical degrees apart. (Polyphase generators used for marine services are generally three phase.)

3.3.12 Shunt-wound generator

A dc generator in which the entire field excitation is ordinarily derived from one winding consisting of many turns with a relatively high resistance. This winding is connected in parallel with the armature circuit in a self-excited generator. In a separately excited generator, the winding is connected to the load side of another generator or another dc source.

3.3.13 Single-phase synchronous generator

A generator that produces a single alternating electromotive force at its terminals. It delivers electric power that pulsates at double frequency.

3.3.14 Stabilized shunt-wound generator

Same as the shunt-wound type, except that a series field winding is added. The series field winding is proportioned such that it does not require equalizers for satisfactory parallel operation. The voltage regulation of this type of generator should be the same as shunt-wound generators.

3.3.15 Synchronous generator

A synchronous ac machine that transforms mechanical power into electric power. (A synchronous machine is one in which the average speed of normal operation is exactly proportional to the frequency of the system to which it is connected.)

3.3.16 Variable speed constant frequency generator (VSCF)

An ac generator designed to have a constant frequency output with a variable speed input. This may be accomplished with an induction generator having an ac/ac converter feedback circuit that excites the wound rotor at a frequency to produce a constant frequency output. This may also be accomplished by a synchronous generator whose variable output frequency is fed into a frequency changer that produces a constant output frequency. Basic frequency changers may be of the cycloconverter or dc link type.

3.4 Motors

3.4.1 Adjustable-speed motor

A motor whose speed can be varied gradually over a range of speeds, but when once adjusted remains practically unaffected by the load, such as a dc shunt-wound motor with field resistance control designed for a range of speed adjustments.

3.4.2 Adjustable-varying-speed motor

A motor whose speed can be adjusted gradually, but when once adjusted for a given load will vary with change in load; such as a dc compound-wound motor adjusted by field control or a wound-rotor induction motor with speed control.

3.4.3 Amortisseur winding

A permanently short-circuited winding used for starting induction motors consisting of conductors embedded in the pole shoes of a synchronous machine and connected together at the ends of the poles, but not necessarily connected between poles.

3.4.4 Base speed of an adjustable-speed motor

The lowest speed obtained at rated load and rated voltage at the specified temperature rise.

3.4.5 Breakdown torque

The maximum torque a motor will develop, with rated voltage applied at rated frequency, without an abrupt drop in speed.

3.4.6 Compound-wound motor

A dc motor that has two separate field windings: one, usually the predominating field, connected in parallel with the armature circuit, and the other connected in series with the armature circuit. Speed and torque characteristics are between those of shunt and series motors.

3.4.7 Continuous duty

A requirement of service that demands operation at a constant load for an indefinite period of time.

3.4.8 Electric motor

A machine that transforms electric power into mechanical power.

3.4.9 Induction motor

A polyphase ac motor in which the secondary field current is created solely by induction. The motor operates at less than synchronous speed and less than unity power factor. The operating speed is dependent on the frequency of the power source. It is generally the motor of choice for auxiliary drives.

3.4.10 Intermittent duty

A requirement of service that demands operation for alternate periods (1) load and no load; or (2) load and rest; or (3) load, no load and rest, as specified.

3.4.11 Locked-rotor torque

The minimum torque of a motor developed for all angular positions of the rotor, when at rest, and with rated voltage and frequency applied.

3.4.12 Motor reduction unit

A motor with an integral mechanical means of obtaining a speed different from the speed of the motor.

NOTE—Motor reduction units are usually designed to obtain a speed lower than that of the motor, but may also be built to obtain a speed higher than that of the motor.

3.4.13 Multispeed motor

A motor that can be operated at any one of two or more definite speeds, each being practically independent of the load. For example, a dc motor with two armature windings, or an induction motor with windings capable of various pole groupings.

3.4.14 Pull-out torque

The maximum sustained torque that a synchronous motor will develop at synchronous speed with rated voltage applied at rated frequency and with normal excitation.

3.4.15 Series-wound motor

A dc motor in which the field circuit and armature circuit are connected in series. Speed is inversely proportional to the square root of load torque. Motor operates at a much higher speed at light load than at full load.

3.4.16 Shunt-wound motor

A dc motor in which the field circuit is connected either in parallel with the armature circuit or to a separate source of excitation voltage.

3.4.17 Squirrel-cage induction motor

A motor in which the secondary circuit consists of a squirrel-cage winding suitably disposed in slots in the secondary core.

3.4.18 Squirrel-cage winding

A permanently short-circuited winding, usually uninsulated (primarily used in induction machines) having its conductors uniformly distributed around the periphery of the machine and joined by continuous end rings.

3.4.19 Stabilized shunt-wound motor

A shunt-wound motor that has a light series winding added to prevent a rise in speed, or to obtain a slight reduction in speed, with increase of load.

3.4.20 Synchronous motor

A polyphase ac motor with separately supplied dc field and an auxiliary (amortisseur) winding for starting purposes. The operating speed is fixed by the frequency (f) of the system and the number of poles (p) of the motor. (Synchronous speed (r/min) = $120 f/p$). Thus the speed of the motor can be varied by varying the frequency of the power source. The synchronous motor generally operates at unity power factor and can be used to improve the system power factor. It is generally the motor of choice for ac propulsion systems.

3.4.21 Torque margin

The increase in torque above rated torque to which a motor may be subjected without the motor pulling out of step. This is of particular concern with electric propulsion systems.

3.4.22 Universal motor

A series-wound or a compensated series-wound motor designed to operate at approximately the same speed and output on either a direct- or single-phase alternating current of a frequency not greater than 60 Hz and of approximately the same rms voltage.

3.4.23 Varying-speed motor

A motor whose speed varies with the load, ordinarily decreasing when the load increases, such as a series-wound or repulsion motor.

3.4.24 Wound-rotor induction motor

An induction motor in which the secondary circuit consists of polyphase winding or coils whose terminals are either short-circuited or closed through suitable circuits. (When provided with collector or slip rings, it is also known as a slip-ring induction motor.)

3.5 Converters

3.5.1 Cycloconverter/synchroconverter

A converter using controlled rectifier or transistor devices that has the capability of adjusting the frequency and proportional voltage of the output waveform to provide speed control of motors.

3.5.2 Direct-current balancer

A machine that comprises two or more similar dc machines (usually with shunt or compound excitation) directly coupled to each other and connected in series across the outer conductors of a multiple wire system of distribution, for the purpose of maintaining the potentials of the intermediate conductors of the system, which are connected to the junction points between the machines.

3.5.3 Dynamotor

A form of converter that combines both motor and generator action, with one magnetic field and with two armatures or with one armature having separate windings.

3.5.4 Motor-generator set

A machine that consists of one or more motors mechanically coupled to one or more generators to convert electric power from one frequency to another, or to create an isolated power source.

3.5.5 Power inverter

A component for converting dc power into ac power.

3.5.6 Rectifier

A component for converting ac to dc by inversion or suppression of alternate half cycles.

3.5.7 Static converter/inverter

A unit that employs solid state devices such as semiconductor rectifiers or controlled rectifiers (thyristors), gated power transistors, electron tubes, or magnetic amplifiers to change ac power to dc power, dc power to ac power, or fixed frequency ac power to variable frequency ac power.

3.5.8 Synchronous converter

A converter that combines both motor and generator action in one armature winding and is excited by one magnetic field. It is normally used to change ac power to dc power, or to create an isolated ac power source.

3.6 Rotating machine ventilation

3.6.1 Enclosed self-ventilated machine

A machine that has openings for the ventilating air circulated by means integral with the machine, the machine being otherwise totally enclosed. These openings are so arranged that inlet and outlet ducts or pipes may be connected.

3.6.2 Enclosed separately ventilated machine

A machine that has openings for ventilating air circulated by means external to and not a part of the machine, the machine being otherwise totally enclosed. These openings are so arranged that inlet and outlet duct pipes may be connected to them.

3.6.3 Open machine

A machine that has ventilating openings that permit passage of external cooling air over and around the windings.

3.6.4 Self-ventilated machine

A machine that has its ventilating air circulated by means integral with the machine.

3.6.5 Separately ventilated machine

A machine that has its ventilating air supplied by an independent fan or blower external to the machine.

3.6.6 Totally enclosed fan-cooled machine (TEFC)

A totally enclosed machine equipped for exterior cooling by means of a fan or fans integral with the machine but external to the enclosing parts.

3.6.7 Totally enclosed non-ventilated machine (TENV)

A machine enclosed to prevent the free exchange of air between the inside and outside of the case, but not sufficiently enclosed to be airtight.

3.6.8 Totally enclosed water/air cooled machine (TEWAC)

A totally enclosed machine with integral water-to-air heat exchanger and internal fan to provide closed-loop air cooling of the windings.

3.7 Equipment enclosures

NOTE—NEMA enclosure type designations and IEC enclosure ingress protection (IP) designations are indicated in parentheses, e.g., (NEMA 1) or (IP 11). See Annex A for additional information.

3.7.1 Dripproof enclosure

An enclosure in which the openings are so constructed that drops of liquid or solid particles falling on the enclosure at any angle not greater than 15° from the vertical either cannot enter the enclosure, or if they do enter the enclosure, they will not prevent the successful operation of, or cause damage to, the enclosed equipment (NEMA 2 or 12) (IP 32).

3.7.2 Dustproof enclosure

An enclosure so constructed or protected that any accumulation of dust that may occur within the enclosure will not prevent the successful operation of, or cause damage to, the enclosed equipment (NEMA 5) (IP 54).

3.7.3 Dusttight enclosure

An enclosure constructed so that dust cannot enter (NEMA 4/4X) (IP 66).

3.7.4 Explosionproof enclosure

An enclosure designed and constructed to withstand an explosion of a specified flammable gas or vapor that may occur within it, and to prevent the ignition of flammable gas or vapor in the atmosphere surrounding the enclosure by sparks, flashes, or explosions of the specified gas or vapor that may occur within the enclosure (see Annex A).

NOTE—Explosionproof apparatus should bear a nationally recognized independent testing laboratory approval rating of the proper class and group consonant with the spaces in which flammable volatile liquids, flammable gases, mixtures, or highly flammable substances may be present.

3.7.5 General-purpose enclosure

An enclosure that primarily protects against accidental contact and slight indirect splashing but is neither dripproof nor splashproof (NEMA 1) (IP 11).

3.7.6 Guarded enclosure

An enclosure in which all openings giving direct access to live or rotating parts (except smooth rotating surfaces) are limited in size by the structural parts or by screens, baffles, grilles, expanded metal, or other means to prevent accidental contact with hazardous parts. The openings in the enclosure shall be such that they will not permit the passage of a rod larger than 12 mm (1/2 in) in diameter, except where the distance of exposed live parts from the guard is more than 102 mm (4 in); then the openings may be of such shape as not to permit the passage of a rod larger than 19 mm (3/4 in) in diameter (NEMA 1) (IP 21).

3.7.7 Oilproof enclosure

An enclosure constructed so that oil vapors, or free oil not under pressure, that may accumulate within the enclosure will not prevent successful operation of, or cause damage to, the enclosed equipment (NEMA 13) (IP 65).

3.7.8 Oiltight enclosure

An enclosure constructed so that oil vapors or free oil not under pressure, which may be present in the surrounding atmosphere, cannot enter the enclosure (NEMA 13) (IP 65).

3.7.9 Semi-guarded enclosure

An enclosure in which all of the openings, usually in the top half, are protected as in the case of a “guarded enclosure,” but the others are left open (NEMA 1) (IP 11).

3.7.10 Splashproof enclosure

An enclosure in which the openings are so constructed that drops of liquid or solid particles falling on the enclosure or coming towards it in a straight line at any angle not greater than 100° from the vertical cannot enter the enclosure either directly or by striking and running along a surface (NEMA 3S) (IP 54).

3.7.11 Submersible enclosure

An enclosure constructed so that the equipment within it will operate successfully when submerged in water under specified conditions of submergence depth and time (NEMA 6P) (IP 68).

3.7.12 Waterproof enclosure

An enclosure constructed so that any moisture or water leakage that may occur into the enclosure will not interfere with its successful operation. In the case of motor or generator enclosures, leakage that may occur around the shaft may be considered permissible provided it is prevented from entering the oil reservoir and provision is made for automatically draining the motor or generator enclosure (NEMA 4/4X) (IP 66).

3.7.13 Watertight enclosure

An enclosure constructed so that a stream of water from a hose not less than 25 mm (1 in) in diameter under a head of 10 m (35 ft) from a distance of 3 m (10 ft) can be played on the enclosure from any direction for a period of 15 min without leakage. The hose nozzle shall have a uniform inside diameter of 25 mm (1 in). (NEMA 6) (IP 67).

3.8 Control apparatus and switchgear

3.8.1 Across-the-line starter

A device that connects the motor to the supply without the use of a resistance or autotransformer to reduce the voltage. It may consist of a manually operated switch or a master switch, which energizes an electromagnetically operated contactor.

3.8.2 Automatic starter

A starter in which the influence directing its performance is automatic.

3.8.3 Autotransformer starter

A starter that includes an autotransformer to furnish a reduced voltage for starting a motor. It includes the necessary switching mechanism and is frequently called a compensator or autostarter.

3.8.4 Circuit breaker interrupting rating (rated short-circuit current)

For an unfused circuit breaker, the designated limit of available (prospective) current at which the circuit breaker is required to perform its short-circuit current duty cycle at rated maximum voltage under the prescribed test conditions. This current is expressed as the rms symmetrical value envelope at a time $\frac{1}{2}$ cycle after short-circuit is initiated. (For dc breakers, the rated interrupting current is the maximum value of direct current.)

3.8.5 Constant-torque resistor

A resistor for use in the armature or rotor circuit of a motor in which the current remains practically constant throughout the entire speed range.

3.8.6 Control circuit

The circuit that carries the electric signals of a control apparatus or system directing the performance of the controller but that does not carry the main power circuit.

3.8.7 Electric controller

A device (or group of devices) that serves to govern, in some predetermined manner, the electric power delivered to the apparatus to which it is connected.

3.8.8 Fan duty resistor

A resistor for use in the armature or rotor circuit of a motor in which the current is approximately proportional to the speed of the motor.

3.8.9 Full magnetic controller

An electric controller having all of its basic functions performed by devices that are operated by electromagnets.

3.8.10 Indicating circuit

That portion of the control circuit of a control apparatus or system that carries the results of logic functions to visual or audible devices that indicate the state of the apparatus controlled.

3.8.11 Manual controller

An electric controller having all of its basic functions performed by devices that are operated by hand.

3.8.12 Master switch

A switch that dominates the operation of contactors, relays, or other remotely operated devices.

3.8.13 Molded-case circuit breaker

A circuit breaker assembled as an integral unit in a supporting and enclosing housing of insulating material; the overcurrent and tripping means being of the thermal type, the magnetic type, the electronic type, or a combination thereof.

3.8.14 Overcurrent protection (overload protection)

The effect of a device, operative on excessive current (but not necessarily on short circuit), to cause and maintain

the interruption of current flow to the device governed.

3.8.15 Overload relay

An overcurrent relay that functions at a predetermined value of overcurrent to cause the disconnection of the power supply.

NOTE—An overload relay is intended to protect the motor or controller and does not necessarily protect itself.

3.8.16 Rated continuous current

The designed limit in rms amperes or dc amperes that a switch or circuit breaker will carry continuously without exceeding the limit of observable temperature rise.

3.8.17 Resistor

A device with the primary purpose of introducing resistance into an electric circuit. (A resistor as used in electric circuits for purposes of operation, protection, or control, commonly consists of an aggregation of units. Resistors, as commonly supplied, consist of wire, metal, ribbon, cast metal, or carbon compounds supported by or embedded in an insulating medium. The insulating medium may enclose and support the resistance material as in the case of the porcelain tube type or the insulation may be provided only at the points of support as in the case of heavy duty ribbon or cast iron grids mounted in metal frames.)

3.8.18 Semimagnetic controller

An electric controller having only part of its basic functions performed by devices that are operated by electromagnets.

3.8.19 Solid state controller

An electric controller that utilizes a static power converter as the primary switching device.

3.8.20 Starter

An electric controller that is used to accelerate a motor from rest to normal speed and to stop the motor. (A device designed for starting a motor in either direction of rotation includes the additional function of reversing and should be designated a controller.)

3.8.21 Step-back relay

A relay that operates to limit the current peaks of a motor when the armature or line current increases. A step-back relay may, in addition, operate to remove such limitations when the cause of the high current has been removed.

3.8.22 Temperature compensated overload relay

A device that functions at any current in excess of a predetermined value essentially independent of the ambient temperature.

3.8.23 Undervoltage or low-voltage protection

The effect of a device, operative on the reduction or failure of voltage, to cause and maintain the interruption of power in the main circuit.

3.8.24 Undervoltage or low-voltage release

The effect of a device, operative on the reduction or failure of voltage, to cause the interruption of power to the main circuit, but not to prevent the re-establishment of the main circuit on return of voltage.

3.9 Insulation system

An assembly of insulating materials in a particular type of equipment. The class of the insulation system may be designated by letters, numbers, or other symbols. An insulation system class utilizes material having an appropriate temperature index and operates at such temperatures above stated ambient temperatures as the equipment standard specifies based on experience or accepted test data. The system may alternatively contain materials of any class, provided that experience or a recognized test procedure for the equipment has demonstrated equivalent life expectancy.

3.10 Types of circuits and terms

3.10.1 Appliance branch circuit

A circuit that supplies energy to one or more outlets to which appliances are connected. These circuits have no permanently connected lighting fixtures that are not a part of an appliance.

3.10.2 Attachment plug

A device that, by insertion in a receptacle, establishes connection between the conductors of an attached cord and the conductors connected permanently to the receptacle.

3.10.3 Branch circuit (or final subcircuit)

That portion of a wiring system that extends beyond the final overcurrent device protecting the circuit.

3.10.4 Communication and electronics circuits

Electrical circuits supplying equipment and systems for voice, sound, or data transmission, such as telephone, engine order telegraph, data communication, interior communication, paging systems, wired music systems, fire and general alarm systems, smoke and fire detection systems, closed circuit television, navigational equipment, and microprocessor based automated alarm and control systems.

3.10.5 Controller

A device or group of devices used to control in a predetermined manner the electric power delivered to the apparatus to which it is connected.

3.10.6 Demand factor

The ratio of the operating load demand of a system or part of a system to the total connected load of the system or part of the system under consideration.

3.10.7 Disconnecting means

A device or group of devices used to disconnect the conductors of a circuit from the source of supply.

3.10.8 Distribution center (load center)

Enclosed apparatus that consists of automatic protective devices connected to bus bars, to subdivide the feeder supply and provide control and protection of subfeeders or branch circuits.

3.10.9 Distribution panel

A panel that receives energy from a switchboard or a distribution center and distributes power to energy-consuming devices.

3.10.10 Emergency switchboard

A switchgear and control assembly that receives energy from the emergency generating plant and distributes directly or indirectly to all emergency loads.

3.10.11 Feeder

A cable or set of conductors that originates at a main distribution center (main switchboard) and supplying secondary distribution centers, transformers, or motor control centers. (Bus tie circuits between generator and distribution switchboards, including those between main and emergency switchboards, are not considered as feeders.)

3.10.12 Intrinsically safe circuit

A circuit in which any spark or thermal effect is incapable of causing ignition of a mixture of flammable or combustible material in air under prescribed test conditions. Test conditions generally consider opening, shorting, grounding, or field wiring, along with failures in the circuit. See ANSI/UL 913-1988 for specific information on test conditions.

3.10.13 Lighting branch circuit

A circuit that supplies energy to lighting outlets. A lighting branch circuit may also supply portable desk or bracket fans, small heating appliances, motors of 190 W (1/4 hp) and less, and other portable apparatus of not over 600 W each.

3.10.14 Lighting outlet

An outlet intended for the direct connection of a lamp holder or a lighting fixture.

3.10.15 Motor branch circuit

A branch circuit that supplies energy to one or more motors and associated motor controllers.

3.10.16 Motor control center (MCC)

A group of devices assembled for the purpose of switching and protecting a number of load circuits. The control center may contain transformers, contactors, circuit breakers, protective, and other devices intended primarily for energizing or de-energizing load circuits.

3.10.17 Outlet

A point on the wiring system at which current is taken to supply utilization equipment.

3.10.18 Power (or ship service) switchboard

A switchgear and control assembly that receives energy from the main generating plant and distributes directly or indirectly to all equipment supplied by the generating plant.

3.10.19 Receptacle

A device installed in a receptacle outlet to accommodate an attachment plug.

3.10.20 Receptacle outlet

An outlet where one or more receptacles is installed.

3.10.21 Vital services

Services normally considered to be essential for the safety of the ship and its passengers and crew. These usually include propulsion, steering, navigation, fire fighting, emergency power, emergency lighting, electronics, and communications functions. The identification of all vital services in a particular vessel is generally specified by the government regulatory agencies.

3.11 Automatic or centralized control systems

3.11.1 Centralized control

The local, remote, or programmed operations of more than one equipment or system from one central control station in a common area or room by a broadly skilled operator or supervisory system.

3.11.2 Computer-assisted system

A system that utilizes separate and standalone computers or processors for arithmetic computational and logic functions. All data manipulation and evaluation (e.g., alarm condition annunciation) functions are performed by the system.

3.11.3 Computer-based system

A system that utilizes one or more embedded computers or processors to perform its functions.

3.11.4 Control space

A dedicated area or compartment provided with equipment such as control consoles, gauge boards, control bench boards, switchboards, instrumentation, displays, control switches, communications, and other equipment for the local, remote, or programmed control and monitoring of equipment. The control system equipment may be operated by one or more individuals acting together or independently.

3.11.5 Failsafe

A characteristic where, upon failure or malfunction of a component, subsystem, or system, the output automatically reverts to a predetermined design state of least critical consequence. Typical failsafe states are listed as follows:

Typical failsafe states

System or component	Preferred failsafe states
Cooling water valve	As is or open
Alarm system	Annunciate
Burner valve	Shutdown, limited, or as is an alarm
Propulsion speed control	As is
Feedwater valve	As is or open
Controllable pitch propeller	As is
Propulsion safety trip	As is and alarm

3.11.6 Line replaceable unit (LRU)

The smallest or lowest piece of equipment or subassembly that is replaceable onboard the vessel. Systems and subsystems may contain multiple numbers of LRUs. Typical LRUs include circuit cards, sealed bearings, and drive motors.

3.11.7 Machinery control room

An enclosed or separated space generally located within the machinery spaces that functions as a central control station.

4. Power system characteristics

4.1 Standard systems

The following distribution systems are recognized as standard:

- a) Two-wire with single-phase ac, or dc
- b) Three-wire with single-phase ac, or dc
- c) Three-phase, three-wire, ac
- d) Three-phase, four-wire, ac

4.2 Standard voltages

The following voltages are recognized as standard:

Standard	AC (V)	DC (V)
Power utilization	115-200-220-230-350-440- 460-575-660-2300-3150- 4000-6000-10600-13460	115 and 230
Power generation	120-208-230-240-380-450- 480-600-690-2400-3300- 4160-6600-11000-13800	120 and 240

4.3 Standard frequency

For ac lighting and power systems, 50 Hz and 60 Hz are standard frequencies.

4.4 Selection of voltage and system type

For small vessels having minimal power apparatus (up to 15 kW), 120 V, three-phase or single-phase generators may be used, with 115 V, three-phase or single-phase distribution for power and lighting. Single-phase lighting feeders should be balanced at the switchboard to provide approximately equal load on the three-phase system.

For intermediate size vessels with power apparatus (up to 100 kW), generators may be 230 V, three-phase or 240 V, three-phase; the power utilization at 220 V or 230 V three-phase, respectively; and lighting distribution at 120 V, three-phase, three-wire or, 208/120 V three-phase, four-wire. Power and lighting utilization should be at 200/115 V, three-phase.

For large vessels of a size and type that require a dual voltage system (two systems isolated by transformers operating at different voltages), first consideration should be given to 450 V, 480 V, 600 V, or 690 V generation with power utilization at 440 V, 460 V, 575 V or 660 V, respectively, and lighting distribution at 120 V or 230 V three-phase, three-wire; or 120/208 V, three-phase, four-wire.

For vessels having a very large electrical system requiring higher-voltage power generation, consideration should be given to generating at 6600 V, 4160 V, or 2400 V with some power utilization at 6000 V, 4000 V, or 2300 V,

three-phase, respectively, with lower utilization voltages to be derived from transformers.

For vessels requiring dc power generation, and having little power apparatus, 120 Vdc generators are recommended with a 115 Vdc lighting and power distribution system. Where an appreciable amount of dc power apparatus is provided, 240/120 Vdc, three-wire generators and 230 Vdc power distribution system and 230/115 Vdc three-conductor lighting feeders may be selected. Branch circuits from lighting panelboards should be 115 Vdc two-wire.

4.5 AC power system characteristics

Power distribution systems should maintain the system characteristics described in Table 4-1 under all operating conditions. Power-consuming equipment should operate satisfactorily under the conditions described in Table 4-1, and should be designed to withstand the power interruption, transient, EMI, RFI, and insulation resistance test conditions inherent in the system. Power-consuming equipment requiring a non-standard voltage or frequency for successful operation should have integral power conversion capability. Power-consuming equipment should not have inherent characteristics that degrade the power quality of the supply system described in Table 4-1.

4.6 Power quality and harmonics

Solid-state devices such as motor controllers, computers, copiers, printers, and video display terminals produce harmonic currents due to line-notching during semiconductor device commutation. These harmonic currents may cause additional heating in motors, transformers, and cables. The sizing of protective devices should consider the harmonic current component. Harmonic currents in nonsinusoidal current waveforms may also cause electro-magnetic interference (EMI) and radio frequency interference (RFI). EMI and RFI may result in interference with sensitive electronics equipment throughout the vessel.

Isolation, both physical and electrical, should be provided between electronic systems and power systems that supply large numbers of solid-state devices, or significantly sized solid-state motor controllers. Active or passive filters and shielded input isolation transformers should be used to minimize interference. Special care should be given to the application of isolation transformers or filtering as the percentage of power consumed by solid-state power devices compared to the system power available increases. Small units connected to large power systems exhibit less interference on the power source than larger units connected to the same source. Solid-state power devices of vastly different sizes should not share a common power circuit. Where kilowatt ratings differ by more than 5 to 1, the circuits should be isolated by a shielded distribution system transformer. Surge suppressers or filters should only be connected to power circuits on the secondary side of the equipment power input isolation transformers.

To preclude radiated EMI, main power switchboards rated in excess of 1 kV and propulsion motor drives should not be installed in the same shipboard compartment as ship service switchboards or control consoles.

IEEE Std 519-1992 provides additional recommendations.

Table 4-1—Alternating current (ac) power characteristics (low-voltage systems)

Characteristics	Limits
Frequency a) Nominal frequency b) Frequency tolerances c) Frequency modulation d) Frequency transient: 1) Tolerance 2) Recovery time e) The worst-case frequency excursion from nominal frequency resulting from b), c), and d)1) combined, except under emergency conditions.	50/60 Hz ±3% ½% ±4% 2 s ±5 ½%
Voltage a) User voltage tolerance: 1) Average of the three line-to-line voltages 2) Any one line-to-line voltage, including a)1) and line voltage unbalances b) b) Line voltage unbalance c) Voltage modulation d) Voltage transient: 1) Voltage transient tolerances 2) Voltage transient recovery time e) Voltage spike (peak value includes fundamental) f) The maximum departure voltage resulting from a)1) and d) combined, except under transient or emergency conditions. g) The worst case voltage excursion from nominal user voltage resulting from a)1), a)2), and d)1) combined, except under emergency conditions.	±5% ±7% 3% 5% ±16% 2 s ±2500 V (380–600 V) system; 1000 V (120–240 V) system. ±6% ±20%
Waveform voltage distortion a) Maximum total harmonic distortion b) Maximum single harmonic c) Maximum deviation factor	5% 3% 5%
Emergency conditions a) Frequency excursion b) Duration of frequency excursion c) Voltage excursion d) Duration of voltage excursion: 1) Lower limits (–100%) 2) Upper limit (+35%)	–100 to +12% Up to 2 min –100 to +35% Up to 2 min 2 min

Table 4-1—Alternating current (ac) power characteristics (low-voltage systems) (Continued)

Definitions
1. Frequency a) <i>Nominal frequency</i>: The designated frequency in hertz. b) <i>Frequency tolerance</i>: The maximum permitted departure from nominal frequency during normal operation, excluding transient and cyclic frequency variations. It includes variations caused by load changes, environment (temperature, humidity, vibration, inclination), switchboard meter error, and drift. Tolerances are expressed in percentage of nominal frequency. c) <i>Frequency modulation</i>: The permitted periodic variation in frequency during normal operation that might be caused by regularly and randomly repeated loading. For purposes of definition, the periodicity of frequency modulation should be considered as not exceeding 10 s. $\text{Frequency Modulation (\%)} = \frac{\{f_{\text{maximum}} - f_{\text{minimum}}\}}{\{2 \times f_{\text{nominal}}\}} \times 100$ d) <i>Frequency transient tolerance</i>: A sudden change in frequency that goes outside the frequency tolerance limits, returns to, and remains inside these limits within a specified recovery time after initiation of the disturbance. Frequency transient tolerance is in addition to frequency tolerance limits. e) <i>Frequency transient recovery time</i>: The time period from the start of the disturbance until the frequency recovers and remains within frequency tolerance limits.
2. Voltage a) <i>User voltage tolerance</i>: The maximum permitted departure from nominal user voltage during normal operation, excluding transient and cyclic voltage variations. It includes variations such as those caused by load changes, environment (temperature, humidity, vibration, inclination), switchboard meter error, and drift. b) <i>Line voltage unbalance tolerance (three-phase system)</i>: The difference between the highest and lowest line-to-line voltages. $\text{Line Voltage Unbalance Tolerance (\%)} = \frac{\{E_{\text{maximum}} - E_{\text{minimum}}\}}{\{E_{\text{nominal}}\}} \times 100$ c) <i>Voltage modulation (amplitude)</i>: The periodic voltage variation (peak to valley) or the user voltage that might be caused by regularly or randomly repeated pulsed loading. The periodicity or voltage modulation is considered to be longer than 1 Hz and less than 10 s. Voltages used in the following equation shall be all-peak or all-rms: $\text{Voltage Modulation (\%)} = \frac{\{E_{\text{maximum}} - E_{\text{minimum}}\}}{\{2 \times E_{\text{nominal}}\}} \times 100$ d) <i>Voltage transient</i> 1) <i>Voltage transient tolerance</i>: A sudden change (excluding spikes) in voltage that goes outside the user voltage tolerance limits and returns to and remains within these limits within a specified recovery time longer than 1 ms after the initiation of the disturbance. The voltage transient tolerance is in addition to the user voltage tolerance limits.

Table 4-1—Alternating current (ac) power characteristics (low-voltage systems) (Continued)

Definitions (Continued)	
2)	Voltage transient recovery time: The time elapsed from initiation of the disturbance until the voltage recovers and remains within the user voltage tolerance limits.
e)	<i>Voltage spike</i> : A voltage change of very short duration (less than 1 ms).
3. Waveform	
a)	<i>Total Harmonic Distortion (THD)(of a sine wave)</i> : The ratio in percentage of the rms value of the residue (after elimination of the fundamental) to the rms value of the fundamental.
b)	<i>Single Harmonic (of a sine wave)</i> : The ratio in percentage of the rms value of that harmonic to the rms value of the fundamental.
c)	<i>Deviation Factor (of a sine wave)</i> : The ratio of the maximum difference between corresponding ordinates of the wave and of the equivalent sine wave to the maximum ordinate of the equivalent sine wave when the waves are superimposed in such a way that they make the maximum difference as small as possible.
$\text{Deviation factor (\%)} = \frac{\{\text{maximum deviation}\}}{\{\text{maximum ordinate of the equivalent sine wave}\}} \times 100$	
4. Emergency conditions	
A situation or occurrence of a serious nature that may result in electrical power system interruptions or deviations, such as the occurrence of ship service generator failure and the emergency generator coming on line.	

5. Generating sets

5.1 Installation and location

Generating sets should be located in a dry, well-ventilated place. They should not be installed in immediate proximity to water and steam piping, etc., and should be protected from dripping liquids such as water and oil. Horizontal rotating machines should be installed with the shaft in a fore and aft direction. In cases where the shaft will be located athwartship, special consideration should be given to bearings and lubrication.

The generating sets, and all their auxiliary devices, should be capable of normal operation under the following inclinations (or any combination thereof):

transverse (athwartship), static	15°
roll (each side), dynamic	up to 22.5°
trim (fore and aft), static	5°
pitch (fore and aft), dynamic	up to 7.5°

Emergency installations should operate satisfactorily when the ship is inclined 22.5° and/or when the trim of the ship is 10°.

The location and installation of generating sets should allow access for maintenance and repair. There should be at least 460 mm (18 in) between the set and surrounding objects to provide accessibility. Sufficient room should be provided to permit removal of the rotor or armature.

When diesel engine or gas turbine-driven generating sets are located in deck houses, the enclosing structure should be steel or other fireproof material.

5.2 Generating sets—main or ship service

In determining the number and capacities of generating sets to be provided for a vessel, careful consideration should be given to the normal and maximum demands as well as for the safe and efficient operation of the vessel when at sea and in port. The number and ratings of the main generating sets should be sufficient to provide one spare generating set (one set not in operation) at all times, including in port.

For vessels propelled by electric power and having two or more constant-voltage, constant-frequency, main power generators, the ship service electric power may be derived from this source and additional ship service generators need not be installed, provided that with one main power generator out of service, a speed of 7 kn or one-half of the design speed (whichever is the lesser) can be maintained. The combined normal capacity of the operating generating sets should be least equal to the maximum peak load at sea. If the peak load and its duration is within the limits of the specified overload capacity of the generating sets, it is not necessary to have the combined normal capacity equal to the maximum peak load.

A generator driven by a main propulsion unit (shaft generator) that is intended to operate at constant speed (e.g., a system where vessel speed and direction are controlled only by varying propeller pitch) may be considered to be one of the required ship service generators provided it is able to supply the required power even with the propeller shaft stopped.

Shaft generator installations that do not comply with the above criteria may be fitted in addition to the above required generators provided that an alternative source of electrical power, having a capacity sufficient for the loads necessary for propulsion and safety of the vessel, can be brought on line automatically within 45 s when the shaft generator fails to maintain voltage and frequency within prescribed limits. If shaft generators are employed at

sea, where the shaft speed is not constant, then suitable means of control should be provided so that the speed of the main engine does not drop below the shaft generator critical operating speed until an auxiliary generator is automatically started. This will enable a load transfer to be made to prevent a blackout while not impairing the ability of the vessel to be maneuvered from the navigating bridge.

A single propulsion unit should be connected to only one generator, via a clutch that will enable the generator to be disconnected from the propeller shaft.

In selecting the capacity of an ac generating plant, particular attention should be given to the starting current of ac motors supplied by the system. With one generator held in reserve and with the remaining generator set(s) carrying the minimum load necessary for the safe operation of the ship, the voltage dip resulting from the starting current of the largest motor on the system should not cause any motor already running to stall or control equipment to drop out.

5.3 Generating sets—emergency

Every vessel should be provided with a self-contained emergency source of electric power, generally a diesel engine or gas turbine-driven generator or storage batteries. These emergency sources of power and an emergency switchboard should be located in a space that is above the uppermost continuous deck, aft of the collision bulkhead, outside the main machinery compartment, and readily accessible from the open deck. When a compartment containing the emergency source of electric power, or vital components thereof, adjoins a space containing either the ship's service generators or machinery necessary for the operation of the ship's service generators, all common bulkheads and decks should be protected by structural insulation. This protection should prevent an excessive temperature rise in the space containing the emergency source of electric power, or vital components thereof, for a period of at least 1 h in the event of fire in the adjoining space.

Emergency generating sets should be self-contained and designed to start automatically and assume rated load within 45 s while in their cold condition at a temperature of 0 °C (32 °F). Each emergency generator should be equipped with starting devices with an energy storage capability of at least six consecutive starts. A single source of stored energy, with the capacity for six starts, should be protected to preclude depletion by the automatic starting system, or a second source of energy should be provided for an additional three starts within 30 min. If, after three attempts, the generator set has failed to start, an audible and visual "start failure" alarm should be activated in the main machinery space control station and on the navigation bridge. The starting sequence should be automatically locked-out until an operator can initiate the final three starting attempts from the emergency generator space.

The capacity of the emergency generating sets and storage batteries for the various groups of vessels is given in Clause 26.

The fuel used should have a flash point of not less than 43 °C (110 °F).

When emergency storage batteries are supplied, appropriate means should be furnished for providing power from the batteries to ac loads.

5.4 Voltage regulation

5.4.1 General

Separate voltage regulators should be provided for each generator. Voltage regulation should be automatic and should function under steady-state load conditions between 0% and 100% load at all power factors that can occur in normal use. Voltage regulators should be capable of maintaining the voltage within the range of 97.5% to 102.5% of the rated voltage. A means of adjustment should be provided for the voltage regulator circuit. Voltage

regulators should be capable of withstanding shipboard conditions and should be designed to be unaffected by normal machinery space vibration.

Under overload or short circuit conditions, the generator and voltage regulator together with the prime mover and excitation system should be capable of maintaining a current of such magnitude and duration as required to properly actuate the associated electrical protective devices, with a value of not less than 300% of generator full-load current for a duration of 2 s, or of such additional magnitude and duration as required to properly actuate the associated protective circuit breakers.

5.4.2 AC generators

The combined effect of the speed regulation of the prime mover in accordance with 5.6, the performance of the excitation and voltage regulating equipment and the characteristics of the generator system performance should be as described in the subclauses below. Means should be provided to automatically and proportionately divide the reactive power between generators when two or more generators are operating in parallel.

5.4.2.1 Main or ship service generators

For single-generator operation (no reactive droop compensation), the steady-state voltage for any increasing or decreasing load between zero and full load at rated power factor under steady-state operation should not vary at any point more than $\pm 2.5\%$ of rated generator voltage.

Under transient conditions, when the generator is driven at rated speed at its rated voltage, and is subjected to a sudden change of symmetrical load within the limits of specified current and power factor, the voltage should not fall below 88% nor exceed 112% of the rated voltage. The voltage should then be restored to within $\pm 2.5\%$ of the rated voltage in not more than 1.5 s. In the absence of precise information concerning the maximum values of the sudden loads, the following conditions should be assumed: 150% of rated current with a power factor of between 0.4 lagging and zero to be applied with the generator running at no-load, and then removed after steady-state conditions have been reached.

For two or more generators with reactive droop compensation, the reactive droop compensation should be adjusted for a voltage droop of no more than 4% of rated voltage for a generator. The system performance should then be such that the average curve drawn through a plot of the steady-state voltage vs. load for any increasing or decreasing load between zero and full load at rated power factor, droops no more than 4% of rated voltage and no recorded point varies more than $\pm 1\%$ of rated generator voltage from the average curve.

Isochronous operation of a single generator operating alone is acceptable. However, where two or more generators are arranged to operate in parallel, only one machine should be operating in the isochronous mode unless voltage regulation with isochronous cross-current compensation reactive load-sharing capabilities are provided. Care should be taken when operating machines in parallel in the droop/isochronous modes to ensure that the system minimum load does not decrease below the output set point of the droop machine(s), as this may cause a frequency change in the system and the machine operating in the isochronous mode to motor.

5.4.2.2 Emergency generating set (no reactive droop compensation)

The system performance should be such that the steady-state voltage for any increasing or decreasing load between zero and full load at rated power factor should not vary at any point more than $\pm 3.5\%$ of rated generator voltage between reactive load change from zero to 60% of the continuous kilovoltampere rating of the highest and lowest points attained. For emergency sets under transient conditions, the values may be increased to $\pm 4\%$ in not more than 5 s.

5.4.3 DC generators

5.4.3.1 Shunt-wound or stabilized shunt-wound generating sets

These sets should be designed as to speed regulation and governing of the prime mover and inherent regulation of the generator so that at full-load operating temperature, there will be a rise in voltage of not more than 8% when the load is gradually reduced from 100% load to 20% load and so that there will be a drop in voltage of not more than 12% when the load is gradually increased from 20% load to 100% load, based on applicable percent speed regulation (drop in speed from no-load to full-load) of the prime mover. When testing to verify performance for each condition, the field rheostat should be set for normal rated voltage at the beginning of each test. When lighting loads are supplied by the ship's service generator, a voltage regulator should be supplied for each generator and the regulator should regulate the output voltage to the system equal to that required for compound-wound generators covered in 5.4.3.2.

5.4.3.2 Compound-wound generators

Compound-wound generators should be designed as to governing of prime mover as well as to compounding and regulation of the generator, so that with the generator at full-load operating temperature, and starting at 20% load with voltage within 0.5% of rated voltage, it should give, at full load, a voltage within 1.5% of rated voltage. The average of the ascending and descending voltage regulation curves between 20% and full load should not vary more than 3% from rated voltage.

5.4.3.3 Three-wire generators

In addition to meeting the recommendations of either 5.4.3.1 or 5.4.3.2, the voltage regulation of a three-wire generator should be such that when operating at rated current on the heavier loaded side, with

- a) Either positive or negative load;
- b) Rated voltage between the positive and negative leads; and
- c) A current of 25% of the generator current rating in the neutral wire.

The resulting difference in voltage between the positive and neutral leads and the negative and neutral leads should not exceed 2% of the rated voltage between the positive and negative leads. The speed regulation curve of the prime mover should not vary more than 1% from a straight line drawn between the speeds at 20% load and 100% load.

The voltage regulation and compounding tests should be made at the manufacturer's facility in accordance with standard testing practice, using an approximately straight-line speed regulation from 20% to 100%, at loads specified by the prime mover builder.

If shunt or stabilized shunt-wound generators are part of an electric plant in which larger generators are also installed, and the large and small generators are to be operated in parallel, the following should be met: When the dc load on the smaller unit is gradually reduced from 100% to 20%, the dc regulation should be not more than 12%, based on the applicable speed regulation percentage of the prime mover. The prime mover speed regulation is based on varying combined load on the prime mover from zero to 100%.

Connections for dc machines should be as indicated in Figure 5-1 through Figure 5-10.

5.5 Parallel operation

5.5.1 General

Generating sets should be capable of operating successfully in parallel. Successful parallel operation is attained if the load on any generator does not differ by more than $\pm 15\%$ of its proportionate share of the combined kilowatt

load, based on generator ratings, for any steady-state condition of the combined load between 20% and 100% of the sum of the rated loads of all the generators. The starting point for determination of the foregoing load distribution requirements should be at 75% load with each generator carrying its proportionate share.

When tests are made to determine if successful parallel operation of dc generating sets is obtained, the following should be met:

- a) The generators should be at normal operating temperatures.
- b) The speed of the generators should be constant or slightly decreasing with increase in load with the change in speed approximately proportional to load.
- c) For compound-wound dc machines, series field equalizer connections should be provided.

The ratio of the resistance of the equalizer connections to the resistance of the series field and its connection, both to the point of paralleling, should be no more than 0.5. In no case should the cross-sectional area of the longest equalizer conductor from a generator be less than the cross-sectional area of the generator's main power conductors.

5.5.2 Operation on a grounded system

For generators operated in parallel on a grounded system, the equalizing current resulting from harmonics should not exceed 20% of the current rating of the smallest rated generator.

5.6 Prime movers

Each prime mover should be fitted with an efficient speed regulating governor as well as an automatic overspeed trip. The automatic overspeed trip should function to shut down the unit automatically when the speed exceeds the designed maximum service speed by more than 15%. The overspeed trip should also be equipped with a means for manual tripping. Each prime mover should, in addition, be under control of an efficient operating governor capable of limiting the speed, when full load is suddenly removed, to at least 5% less than that of the overspeed trip setting. The prime mover and regulating governor should also limit the momentary speed variation to 5.5% of the rated speed when 75% of the rated load of the generator is suddenly applied followed by the remaining 25% after an interval sufficient to restore the speed to steady state. The speed should return to within 1% of the final steady-state speed as follows:

Load	Response time	Speed deviation
±75%	2.0 s	5.5%
±100%	5.0 s	7.5%

Emergency generator sets should accept 100% rated kilowatt load in one step.

All sets of 100 kW capacity and above should be provided with a coupling fitted to the rotor or armature shaft.

Each generator should be driven by a separate prime mover that, if used to drive other auxiliary loads, should have sufficient capacity for the total load, unless it is not possible to use the generator and the other auxiliary load simultaneously. Generating sets that operate in parallel should be provided with a switch that trips the generator circuit breaker when the overspeed device is actuated.

5.7 Motor generator sets—overspeed protection

Motor generator sets having dc motors driving ac or dc generators that will operate in parallel with other units and that are of a frame size corresponding to a rating of 11 kW (15 hp), 1750 r/min or above, should be provided with overspeed protection.

5.8 Accessibility

The design of generating sets should provide for accessibility to all parts requiring inspection during operation or disassembling for repairs.

5.9 Mountings

The generator and its driving unit should be mounted on a common rigid sub-base to ensure proper alignment. Each unit comprising the set should be provided with ample supporting feet secured to the sub-base.

5.10 Winding insulation

Table 5-1 and Table 5-2 provide the limits of observable temperature rise for generators for the various insulation classes. Insulating materials and insulated windings should be resistant to moisture, salt air, and oil vapor. All form-wound coils for ac generators, all assembled armatures, and the armature coils for open-slot dc armature construction should utilize vacuum-pressure impregnated solventless epoxy insulation systems. The assembled and wound stators of ac generators and the wound dc armatures for open slot construction should be immersed or flow coated with insulating varnish and baked. All assembled ac machine field coils and wound dc field coils should be treated with epoxy while being wound or vacuum-pressure impregnated with a solventless epoxy insulating material. The finished windings should be water and oil resistant with a Class B temperature rise.

Abnormal brush wear and slipping or commutator maintenance may occur on generators with even a slight amount of silicone insulation, especially if the machine is enclosed. Insulation and construction processes using silicones should be avoided where brushes are installed.

5.11 Lubrication

All generating sets should lubricate and operate satisfactorily without spilling oil, in a 10 s period, under the conditions of inclination, roll, and pitch specified in 5.1. If the shaft is to be located athwartships, the manufacturer should be advised so that any special requirements for this orientation are addressed. All prime movers for main power and ship service generating sets (not emergency sets) that depend upon forced lubrication should be arranged to shut down automatically on loss of oil pressure. The shutting down of the prime mover should cause the tripping of the generator circuit breaker. An alarm system should be provided and arranged to function on low oil pressure as recommended in 27.9.

Emergency generator sets should lubricate and operate satisfactorily when permanently inclined to an angle of 22.5° athwartships and 7.5° fore and aft. Units depending upon forced lubrication should be provided with an audible and visual alarm activated by loss of oil pressure while running.

5.12 Corrosion-resistant parts

Interior bolts, nuts, pins, screws, terminals, brushholder studs, springs, and other small parts that could be damaged by corrosion should be made of corrosion-resistant materials or suitably protected against corrosion. Steel springs should be treated to resist moisture in such a manner as not to impair their spring quality. See 1.8.1.

5.13 Terminal arrangements

Generators should be provided with terminals leads suitably secured to the generator frame and provided with connectors approved by the administration or classification organization to permit ready connection of the