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IEEE Recommended Practice for Electric Installations on Shipboard

Sponsor

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of the
IEEE Industry Applications Society

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Foreword

(This foreword is not a part of IEEE Std 45-1977, Recommended Practice for Electric Installations on Shipboard.)

Recommended Practice for Electric Installations on Shipboard, IEEE Std 45-1977 constitutes the chief undertaking of the Marine Transportation Committee of the IEEE Industry Applications Society.

Due to the differences between the requirements of the various classification societies and the insurance companies in regard to electric installations on shipboard, and the lack of any accepted standard engineering practice for marine installations, the AIEE* 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 the 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, and 1971.

This edition includes many significant additions, changes, and deletions. Following is a listing of a portion of the reworked subjects:

Sections dealing with cable have been extensively revised. Cable Construction, Section 18, includes new materials, construction details, testing procedures, and the introduction of several new types of cable. Cable Application, Section 19, includes major changes to current-carrying capacities, effects of exceeding single-banked racks, and use of unarmored cables. Cable Installation, Section 20, includes changes to cable support spacing, water tight penetration methods, and cable splicing.

Medium voltage systems have been added in this edition. Standard voltages recognized in Section 14 include 2.4 kV and 4.16 kV. Switchboards, Section 17, and Control Apparatus, Section 27, include new recommendations dedicated to medium voltage equipment.

Notable changes also will be found in Section 17, regarding arrangement of switchboard equipment; Section 21, regarding branch circuit cable loading; Sections 17 and 23, regarding bus bar phase sequencing; and Section 23, regarding use of nonmetallic boxes.

Recommendations for illumination have been added to Lighting Equipment, Section 33.

The sections devoted to signal, interior communications, alarms, electronic communications, and navigation equipment, Section 37 through 41, have been revised to reflect current state of the art methods and systems.

Recommendations for treatment of electrical circuits in hazardous areas have been revised in Section 43.

In the Appendixes, tables have been modified to agree with revised text. Fault current decrement conversion factor curves have been added for use in preparing short circuit calculations for ac systems.

It should be noted that the sections under Introduction have been revised to reflect more accurately the scope of the standard, and the sections under Definitions and General Recommendation have been revised to agree with IEEE Std 100-1972 (ANSI C42.100-1972) Dictionary of Electrical and Electronics Terms.

It is intended that subsequent significant changes to the standard are to be made available to the purchaser as supplements or revised pages. Purchaser should fill out and return the attached card.

*In 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 (IEEE).

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IEEE Recommended Practice for Electric Installations on Shipboard

Introduction

1. General

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 IEEE standards are referenced in the text. Other IEEE standards should be followed to the extent applicable.

Attention is directed to the fact that regulations for electric installations on shipboard are promulgated by Governmental Regulatory Agencies, the Intergovernmental Maritime Consultative Organization, and Classification Societies. Such regulations have been given due consideration in these recommendations, but there are areas where differences are expressed. Reference should always be made to those regulations which may be applicable to the design.

1.2 Vessel Classification. The Government Inspection Agency has divided vessels into the following groups:

- Group No 1—Ocean-going vessels which navigate on any ocean or the Gulf of Mexico 20 mi or more off shore.
- Group No 2—Ocean-going vessels which navigate on any ocean or the Gulf of Mexico but less than 20 mi off shore.
- Group No 3—Vessels navigating 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.

1.3 Applicability. These recommendations have been prepared primarily for application to all passenger and cargo vessels of groups 1, 2, and 3. However, this standard should apply generally to all marine electrical installations in order to assure a consistently high standard of design, apparatus, and installation.

1.4 Plans. Every vessel should be provided with plans giving the complete and detailed information as to circuits, cable sizes, loads, protective device settings, etc, for all systems. A manufacturer's name, size, type, rating, catalog number, or similar identification for all electrical equipment on the vessel should also be provided for the vessel's operating personnel. A one line diagram of the ship's distribution system should be permanently installed so as to be accessible at all times to the engineering personnel.

1.5 Usual Service Conditions. Installations should be suitable for the following usual general conditions of shipboard marine service:

(1) Continuous condition of exposure to severe moisture and salt laden atmosphere, high wind velocity, and ice formation encountered at sea.

(2) Roll, pitch, and vibration of a vessel under way. Installations should be suitable for momentary 30 degrees roll and 10 degrees pitch and permanent inclination of 15 degrees athwartship and 5 degrees fore and aft.

(3) Safe and reliable operation of electric systems and equipment on shipboard, which directly affect the safety of a vessel and life at sea.

(4) Equipment conforming to these standards should be suitable for operation at its standard rating, provided that the temperature of the cooling air (ambient temperature) does not exceed:

(a) 40°C in quarters, passages, etc.

(b) 50°C in machinery spaces, boiler rooms, engine rooms, generator rooms, and other spaces containing heat sources of considerable magnitude.

1.6 Other Conditions Which May Affect Design and Application. Where special conditions exist they should be brought to the attention of those responsible for the design and applica-

tion of the equipment. Examples of such conditions are:

- (1) Exposure to damaging fumes or vapors, excessive or abrasive dust, steam, salt spray, etc.
- (2) Exposure to abnormal vibration, shocks, or tilting.
- (3) Exposure to excessively high or low temperatures.
- (4) Exposure to unusual transportation or storage conditions.
- (5) Unusual operating duty, frequency of operation, difficulty of maintenance, poor waveform, unbalanced voltage, special insulation requirements, etc.
- (6) Exposure to flammable atmospheres. See Section 43.

Definitions and General Recommendations

2. General Definitions¹

2.1 cargo vessel. A vessel that carries solids or liquids as freight, and no more than twelve (12) passengers.

2.2 quarters. Where used in these recommendations, those spaces provided for passengers or crew, as specified, which are actually used for berthing, mess spaces, offices, private baths, toilets and showers, and lounging rooms, smoking rooms, and similar spaces.

2.3 machinery spaces. Where used in these recommendations, those spaces which are primarily used for machinery of any type or equipment for the control of such machinery, as boiler, engine, ship's service generator, and evaporator rooms.

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

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

¹In Sections 2 to 14 that portion in parenthesis is added by the Marine Transportation Committee and by IEEE nomenclature is identified as "discussion."

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

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

2.8 hertz (Hz). The unit of frequency, one cycle per second.

2.9 single-phase circuit. A circuit energized by a single alternating electromotive force.

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

2.10 three-phase circuit. A combination of circuits energized by alternating electromotive forces which differ in phase by one-third of a cycle (120 degrees).

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

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

- (1) as a percent of synchronous speed;
- (2) as a decimal fraction of synchronous speed;
- (3) directly in revolutions per minute.

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

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

2.14 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.

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

2.16 capacitor. A device, the primary purpose of which is to introduce capacitance into an electric circuit.

Capacitors are usually classified, according to their dielectrics, as air capacitors, mica capacitors, paper capacitors, etc.

2.17 capacitance (capacity). That property of a system of conductors and dielectrics which 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.

2.18 reactor. A device, the primary purpose of which is to introduce reactance into a circuit.

A reactor is a device used for introducing reactance into a circuit for purposes such as motor starting, paralleling transformers, and control of current.

2.19 reactance. The reactance of a portion of a circuit for a sinusoidal current and potential difference of the same frequency is the product of the sine of the angular phase difference between the current and potential difference times the ratio of the effective potential difference to the effective current, there being no source of power in the portion of the circuit under consideration. The reactance of a circuit is different for each component of an alternating current. If

$$e = E_{1m} \sin(\omega t + \alpha_1) + E_{2m} \sin(2\omega t + \alpha_2) + \dots$$

and

$$i = I_{1m} \sin(\omega t + \beta_1) + I_{2m} \sin(2\omega t + \beta_2) + \dots$$

then the reactances, X_1 , X_2 , etc, for the different components are

$$X_1 = \frac{E_{1m} \sin(\alpha_1 - \beta_1)}{I_{1m}} = \frac{E_1 \sin(\alpha_1 - \beta_1)}{I_1}$$

$$X_2 = \frac{E_{2m} \sin(\alpha_2 - \beta_2)}{I_{2m}} = \frac{E_2 \sin(\alpha_2 - \beta_2)}{I_2}$$

etc.

NOTE: The reactance for the entire periodic current is not the sum of the reactances of the components. A definition of reactance for a nonsinusoidal periodic current has not yet been agreed upon.

2.20 semiconductor rectifier. A semiconductor rectifier cell is 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 recti-

fier stack is a single columnar structure of one or more semiconductor rectifier cells.

2.21 direct-current 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 direct-current commutating machines are direct-current generators, motors, synchronous converters, boosters, balancers, and dynamotors.

2.22 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.

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

2.24 induction machine. An asynchronous ac machine which 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.

2.25 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.

2.26 corrosion-resistant parts.

(1) *General.* 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.

(2) *Corrosion-resisting materials.* Silver, corrosion-resisting steel, copper, brass, bronze, copper-nickel, certain nickel-copper alloys, and certain aluminum alloys are considered satisfactory corrosion-resisting materials within the intent of the foregoing.

(3) *Corrosion-resistant treatments.* The following treatments, when properly done and of a sufficiently heavy coating, are considered

satisfactory corrosion-resistant treatments within the intent of the foregoing.

Electroplating of:

Cadmium	Nickel
Chromium	Silver
Copper	Zinc

Sherardizing

Galvanizing

Dipping and painting. (Phosphate or suitable cleaning, followed by the application of zinc chromate primer or equivalent.)

(4) *Application*. These provisions should apply to the following components:

(a) *Parts*. Interior small parts which are normally expected to be removed in service, such as bolts, nuts, pins, screws, cap screws, terminals, brushholder studs, springs, etc.

(b) *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.

(c) *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 which would be seriously damaged or rendered ineffective by corrosion.

2.27 flame-retarding. Flame-retarding materials and structures 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.

NOTE: Compliance with the requirements of the preceding paragraph should be determined with the apparatus and according to the methods described in the Underwriters' Laboratories Standards for the materials and structures unless specific applicable tests are invoked in these recommendations.

2.28 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.

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

3. Generator Classification

3.1 electric generator. A machine which transforms mechanical power into electric power.

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

3.3 stabilized shunt-wound generator. A stabilized shunt-wound generator is the same as the shunt-wound type, except that a series field winding is added, of such proportion as not to require equalizers for satisfactory parallel operation. The voltage regulation of this type of generator is to comply with that given for shunt-wound generators.

3.4 compound-wound generator. A dc generator which has two separate field windings: one, supplying the predominating excitation, is connected in parallel with the armature circuit and the other, supplying only partial excitation, is connected in series with the armature circuit and of such proportion as to require an equalizer connection for satisfactory parallel operation.

3.5 magnetoelectric generator. An electric generator, in which the magnetic flux is provided by one or more permanent magnets.

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

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

3.8 synchronous generator. A synchronous alternating-current machine which 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.)

3.9 single-phase synchronous generator. A generator which produces a single alternating electromotive force at its terminals. It delivers

electric power which pulsates at double frequency.

3.10 polyphase synchronous generator. A generator whose ac circuits are so arranged that two or more symmetrical alternating electromotive forces with definite phase relationships are produced at its terminals. Polyphase synchronous generators are usually two-phase, producing two electromotive forces displaced 90 electrical degrees with respect to one another, or three-phase, with three electromotive forces, displaced 120 electrical degrees with respect to each other. (Polyphase generators as used for marine service are generally three-phase. For special cases they may be two-phase.)

3.11 inductor type synchronous generator. A generator in which the field coils are fixed in magnetic position relative to the armature conductors, the electromotive forces being produced by the movement of masses of magnetic material.

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

3.13 brushless exciter. An ac (rotating armature type) exciter whose output is rectified by a semiconductor device to provide excitation to an electric machine. The semiconductor device would be mounted on and rotate with the ac exciter armature.

3.14 brushless synchronous machine. A synchronous machine having 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 with its exciter has no collector, commutator, or brushes.

4. Motor Classification

4.1 electric motor. A machine which transforms electric power into mechanical power.

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

4.3 shunt-wound motor. A direct-current motor in which the field circuit and armature circuit are connected in parallel.

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

4.5 series-wound motor. A commutator motor in which the field circuit and armature circuit are connected in series. (It operates at a much higher speed at light load than at full load.)

4.6 compound-wound motor. A direct-current motor which 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. (The characteristics as regards speed and torque are intermediate between those of shunt and series motors.)

4.7 induction motor. An alternating-current motor in which a primary winding on one member (usually the stator) is connected to the power source and a polyphase secondary winding or a squirrel-cage secondary winding on the other member (usually the rotor) carries induced current.

4.8 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.

4.9 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.)

4.10 synchronous motor. A synchronous machine which transforms electric power into mechanical power.

NOTE: Unless otherwise stated, it is generally understood that a synchronous generator (or motor) has field magnets excited with direct current.

4.11 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.

4.12 amortisseur. A permanently short-circuited winding 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. This winding when used in salient-pole machines sometimes includes bars which do not pass through the pole shoes, but are supported in the interpolar spaces between the pole tips.

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

5. Converters

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

5.2 motor-generator set. A machine which consists of one or more motors mechanically coupled to one or more generators.

5.3 synchronous converter. A converter which combines both motor and generator action in one armature winding and is excited by one magnetic field. It is normally used to change alternating-current power to direct-current power.

5.4 rectifier. A converter in which the direction of average power flow is from the ac circuit to the dc circuit.

5.5 direct-current balancer. A machine which 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.

5.6 power inverter. A converter unit in which the direction of average power flow is from the dc circuit to the ac circuit.

5.7 static converter. A unit that employs static rectifier devices such as semiconductor rectifiers or controlled rectifiers (thyristors) transistors, electron tubes, or magnetic amplifiers to change ac power to dc power or vice-versa.

6. Motor Speed Classification

6.1 constant-speed motor. A motor, the speed of normal operation of which is constant or practically constant. For example, a synchronous motor, an induction motor with small slip, or an ordinary dc shunt-wound motor.

6.2 multispeed motor. A motor which 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.

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

6.4 base speed of an adjustable-speed motor. The lowest speed obtained at rated load and rated voltage at the temperature rise specified in the rating.

6.5 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.

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

7. Ventilation of Machines

7.1 open machine. A machine having ventilating openings which permit passage of external cooling air over and around the windings.

7.2 self-ventilated machine. A machine which has its ventilating air circulated by means integral with the machine.

7.3 separately ventilated machine. A machine which has its ventilating air supplied by an independent fan or blower external to the machine.

7.4 enclosed self-ventilated machine. A machine having openings for the admission and discharge of the ventilating air, which is 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 to them.

NOTE: Such ducts or pipes, if used, must have ample section and be so arranged as to furnish the specified volume of air to the machine, otherwise the ventilation will not be sufficient.

7.5 enclosed separately ventilated machine. A machine having openings for the admission and discharge of the ventilating air, which is 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.

7.6 totally enclosed machine. A machine so enclosed as to prevent the exchange of air between the inside and outside of the case, but not sufficiently enclosed to be termed airtight.

7.7 totally enclosed fan-cooled machine. 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.

8. Enclosure of Equipment

8.1 general-purpose enclosure. An enclosure which primarily protects against accidental contact and slight indirect splashing but is neither dripproof nor splashproof.

8.2 semiprotected enclosure. An enclosure in which all of the openings, usually in the top half, are protected as in the case of a "protected enclosure," but the others are left open.

8.3 protected enclosure. An enclosure in which all openings are protected with wire screen, expanded metal, or perforated covers.

NOTE: A common form of specification for "protected enclosure" is: "The openings should not exceed $\frac{1}{2}$ square inch in area and should be of such shape as not to permit the passage of a rod larger than $\frac{1}{2}$ inch in diameter, except where the distance of exposed live parts from the guard is more than 4 inches the openings may be $\frac{3}{4}$ square inch in area and must be of such shape as not to permit the passage of a rod larger than $\frac{3}{4}$ inch in diameter."

8.4 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.

8.5 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 degrees 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.

8.6 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 degrees from the vertical cannot enter the enclosure either directly or by striking and running along a surface.

8.7 waterproof enclosure. An enclosure constructed so that any moisture or water leakage which may occur into the enclosure will not interfere with its successful operation. In the case of motor or generator enclosures, leakage which 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.

8.8 oilproof enclosure. An enclosure constructed so that oil vapors, or free oil not under pressure, which may accumulate within the enclosure will not prevent successful operation of, or cause damage to, the enclosed equipment.

8.9 explosionproof enclosure. An enclosure designed and constructed to withstand an explosion of a specified gas or vapor which may occur within it, and to prevent the ignition of the specified gas or vapor surrounding the enclosure by sparks, flashes, or explosions of the specified gas or vapor which may occur within the enclosure.

NOTE: Explosion-proof apparatus should bear Underwriters' Laboratories approval ratings of the proper class and group consonant with the spaces in which flammable volatile liquids, highly flammable gases, mixtures, or highly flammable substances may be present.

8.10 dusttight enclosure. An enclosure constructed so that dust cannot enter the enclosing case.

8.11 watertight enclosure. An enclosure constructed so that a stream of water from a hose not less than 1 in in diameter under a head of 35 ft from a distance of 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 1 in.

8.12 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.

8.13 submersible enclosure. An enclosure constructed so that the equipment within it will operate successfully when submerged in water under specified conditions of pressure and time.

9. Torque Classifications

9.1 locked-rotor torque. The minimum torque of a motor which it will develop at rest for all angular positions of the rotor, with rated voltage applied at rated frequency.

9.2 pull-out torque. The maximum sustained torque which a synchronous motor will develop at synchronous speed with rated voltage applied at rated frequency and with normal excitation.

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

9.4 torque margin. The increase in torque above rated torque to which a propulsion system may be subjected without the motor pulling out of step with the generator.

10. Duty Classification

10.1 continuous duty. A requirement of service that demands operation at a substantially constant load for an indefinitely long time.

10.2 intermittent duty. A requirement of service that demands operation for alternate periods of (1) load and no load; or (2) load and rest; or (3) load, no load and rest; such alternate intervals being definitely specified.

11. Control Apparatus and Switchgear

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

11.2 full magnetic controller. An electric controller having all of its basic functions performed by devices, which are operated by electromagnets.

11.3 semi-magnetic controller. An electric controller having only part of its basic functions performed by devices which are operated by electromagnets.

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

11.5 drum controller. An electric controller which utilizes a drum switch as the main switching element.

NOTE: A drum controller usually consists of a drum switch and a resistor.

11.6 starter. An electric controller for accelerating 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.)

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

11.8 autotransformer starter. A starter which 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.

11.9 across-the-line starter. A device which 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.

11.10 master switch. A switch which domi-

nates the operation of contactors, relays, or other remotely operated devices.

11.11 resistor. A device the primary purpose of which is to introduce 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.)

11.12 overcurrent protection (overload protection). The effect of a device operative on excessive current² to cause and maintain the interruption of current flow to the device governed.

11.13 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.

11.14 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 reestablishment of the main circuit on return of voltage.

11.15 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.

11.16 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.

11.17 overload relay. An overcurrent relay which 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.

11.18 step-back relay. A relay which 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.

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

11.20 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, or a combination of both.

11.21 rated continuous current. The designed limit in rms amperes or direct-current amperes which a switch or circuit breaker will carry continuously without exceeding the limit of observable temperature rise.

11.22 circuit breaker interrupting rating (rated interrupting current). The highest rms current at a specified operating voltage which a circuit breaker is required to interrupt under the operating duty specified and with a normal frequency recovery voltage equal to the specified operating voltage.

NOTE: The current is the rms value, including the dc component, at the instant of contact separation as determined from the envelope of the current wave. Where limited by testing equipment, the maximum tolerance for normal frequency recovery voltage is 15 percent of the specified operating voltage.

(For dc breakers the rated interrupting current is the maximum value of direct current.)

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

11.24 indicating circuit. That portion of the control circuit of a control apparatus or system which carries intelligence to visual or audible devices which indicate the state of the apparatus controlled.

12. Insulation

12.1 Definition of Insulation System. An insulation system is an assembly of insulating materials in a particular type of equipment. The class of the insulation system may be desig-

²(but not necessarily on short circuit)

nated 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.

12.2 Preferred Insulation System Classifications. The preferred insulation system classifications are classes A,B,F,H,C, or 105,130,155, 180, or greater than 220, and as designated by the equipment standard.

12.3 Restriction on the Use of Porcelain or other Brittle Materials. Porcelain or other brittle materials shall not be used for lamp sockets, receptacles, fuse blocks, etc. where the material is rigidly fastened by machine screws or equivalent.

13. Types of Circuits

13.1 lighting branch circuit. A circuit supplying energy to lighting outlets only. (Lighting branch circuits also may supply portable desk or bracket fans, small heating appliances, motors of $\frac{1}{4}$ horsepower (186½ W) and less, and other portable apparatus of not over 600 W each.)

13.2 appliance branch circuit. A circuit supplying energy to one or more outlets to which appliances are to be connected; such circuits to have no permanent connected lighting fixtures not a part of an appliance.

13.3 motor branch circuit. A branch circuit supplying energy only to one or more motors and associated motor controllers.

13.4 communication circuits. Circuits used for audible and visual signals and communication of information from one place to another, within or on the vessel.

13.5 feeder. A set of conductors originating at a main distribution center and supplying one or more secondary distribution centers, one or more branch-circuit distribution centers, or any combination of these two types of equipment.

(Bus tie circuits between generator and distribution switchboards, including those between main and emergency switchboards, are not considered as feeders.)

13.6 branch circuit. That portion of a wiring system extending beyond the final overcurrent device protecting the circuit.

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

13.8 lighting outlet. An outlet intended for the direct connection of a lampholder or a lighting fixture.

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

13.10 receptacle outlet. An outlet where one or more receptacles are installed.

13.11 attachment plug. A device which, by insertion in a receptacle, establishes connection between the conductors of the attached cord and the conductors connected permanently to the receptacle.

13.12 distribution center. A point at which is located equipment consisting generally of automatic overload protective devices connected to buses, the principal functions of which are subdivision of supply and the control and protection of feeders, subfeeders, or branch circuits, or any combination of feeders, subfeeders, or branch circuits.

13.13 switchboards and panels. A generator and distribution switchboard receives energy from the generating plant and distributes directly or indirectly to all equipment supplied by the generating plant.

A subdistribution switchboard is essentially a section of the generator and distribution switchboard (connected thereto by a bus feeder and remotely located for reasons of convenience or economy) which distributes energy for lighting, heating, and power circuits in a certain section of the vessel.

A distribution panel receives energy from a distribution or subdistribution switchboard and distributes energy to energy-consuming devices or other distribution panels or panelboards.

A panelboard is a distribution panel enclosed in a metal cabinet.

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

13.15 vital services. Vital services are normally considered to be those required for the safety of the ship and its passengers and crew. These may include propulsion, steering, navigation, firefighting, emergency lighting, and communications functions. Since the specific identification of vital services is influenced by the type of vessel and its intended service, this matter should be specified by the design agent for the particular vessel under consideration.

14. Nature of Supply

14.1 Standard Systems. The following systems of distribution are recognized as standard:

- (1) Two-wire with single-phase alternating current, or direct current.
- (2) Three-wire with single-phase alternating current, or direct current.
- (3) Three-phase three-wire, alternating current.
- (4) Three-phase, four-wire, alternating current.

14.2 Standard Voltages. The following voltages are recognized as standard:

	Alternating Current (volts)	Direct Current (volts)
Lighting	115	115
Power utilization	115-200-220-230 440-460-2300-4000	115 and 230
Generators	120-208-230-240 450-480-2400-4160	120 and 240

14.3 Standard Frequency. A frequency of 60 Hz is recognized as a standard for all ac lighting and power systems.

14.4 Selection of Voltage and Distribution System.

(1) *Alternating Current.* For small vessels having little power apparatus, 120 V, three-phase generators may be used, with 115 V, three-phase distribution for power and lighting. As an alternative lighting feeders may be

single-phase, balanced at the generator and distribution switchboard to provide approximately equal load on the three phases.

For vessels with considerable power apparatus (particularly for intermediate-size vessels), generators may be 230 V, three-phase or 240 V, three-phase; the power utilization at 220V or 230V, three-phase, respectively; and lighting distribution 115V, three-phase, derived from transformers. As an alternative, generators may be three-phase, four-wire, 208/120 V. Power and lighting should be at 200/115V, three-phase.

For all vessels of a size and type which require a dual voltage system, first consideration should be given to the application of 450V or 480V generators with power utilization at 440V or 460V, three-phase, respectively, and lighting distribution at 115V, three-phase, three-wire or 120/208V, three-phase, four-wire, derived from transformers.

For vessels having very large electrical system requiring higher voltage power generation, consideration should be given to generating first at 4160V or at 2400V with some power utilization at 4000V or 2300V, three-phase, respectively, with lower utilization voltages to be derived from transformers.

Either grounded or ungrounded ac electrical systems may be used for the above listed standard systems, except that in the case of the 450V or 480V, three-phase systems, first consideration should be given to the use of an ungrounded system. Where a grounded system is applied, the method of grounding should be in accordance with 21.41.

(2) *Direct Current.* For vessels having little power apparatus, 120 V generators are recommended with 115 V light and power distribution systems.

Where an appreciable amount of power apparatus is to be considered, 240/120 V, three-wire generators and 230 V power distribution system and 230/115 V three-conductor lighting feeders should be selected. Branch circuits from lighting panelboards should be 115 V two-wire.

14.6 Balancer Sets—Use of. Balancer sets should not be used for obtaining 120 V from 240 V two-wire dc generators.

Equipment and Installation

15. Generating Sets

15.1 Installation and Location. Generating sets should be located in a dry well-ventilated place. They should not be installed in the immediate proximity to water and steam piping, etc, and should be protected from dripping water, oil, etc. In cases where the shaft will be located athwartship the manufacturer should be so advised. There should be at least 18 in between the set and surrounding objects to provide accessibility, and 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 approved fireproof material.

15.2 Generating Sets for Ship's Service—Number and Size. In determining the capacities and number 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 generating sets should be sufficient to provide one spare generating set (one set not in operation) at all times, including in port. The combined normal capacity of the operating generating sets should be at 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.

In selecting the capacity of an ac generating plant particular attention should be given to the starting current of squirrel-cage motors forming a part of the system. With one generating set held in reserve as a spare, the remaining generator sets operating in parallel and initially carrying minimum load necessary for operating the ship, should have sufficient capacity with respect to the largest idle motor on the ship so that the motor can be started and the voltage drop occasioned by its starting current will not cause any already running motor to stall or control equipment to drop out.

15.3 Exciters. Each ac generator should have an exciter of sufficient capacity to provide excitation when the alternator is carrying 150 percent rated current at 0.5 lagging power factor, for two minutes, and maintain the voltage within 7.5 percent of rated voltage. The source of excitation should have characteristics best suited for the voltage regulating system and should conform to all applicable recommendations.

15.4 Generating Sets—Emergency. In addition to the foregoing, Government Regulatory Agencies require the installation of a diesel-engine-driven generating set, or storage batteries, or both, located above the bulkhead deck or above the freeboard deck, whichever is higher, and outside the machinery compartment. 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 approved "structural insulation" or other approved material. This protection should be such as to be capable of preventing an excessive temperature rise in the space containing the emergency source of electric power, or vital components thereof, for a period of at least one hour 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 20 s with the cooling water, lubricating oil, and air supply at a temperature of 32°F. Gas turbine-driven generators may also be used.

The capacity of the generating sets and storage batteries for the various groups of vessels is given in Section 36. Gasoline and semi-diesel engines are not recommended for the operation of emergency generators. The fuel used shall have a flash point of not less than 110°F.

When emergency storage batteries are supplied, appropriate means should be furnished for providing power from these batteries to alternating-current loads, such as a synchronous converter.

15.5 Generator Windings. Ship's service alternating-current generators should be wound for three-phase 60 Hz and 80 percent power factor.

Where ac generators are to operate in parallel, they should be equipped with amortisseur windings.

In the case of dc installations where the load does not fluctuate appreciably, shunt-wound generators without voltage regulators or stabilized shunt-wound generators may be used in lieu of compound-wound generators. In the case of installations where the load is apt to fluctuate appreciably, shunt-wound generators should be used in the interest of substantially constant voltage.

Unless otherwise specified, all three-wire dc generators should be designed for 25 percent unbalanced current.

In order to promote uniformity of practice for two-wire compound-wound dc generators, it is recommended that the series field terminal be negative.

15.6 Voltage Regulation.

15.6.1 General. Voltage regulators should be of a type and construction capable of withstanding shipboard conditions and should be designed to be unaffected by normal engine-room vibration. Separate units should be provided for each generator when voltage regulators are required.

15.6.2 AC Generators. Taking into account the combined effect of the speed regulation of the prime mover, the performance of the voltage regulating equipment and the characteristics of the generator system performance should be as set forth below. Means should be provided to divide the reactive power properly between generators, when it is intended that two or more generators will be operating in parallel.

15.6.2.1 Cargo and Similar Vessels.

(1) *Single Generator* (no reactive droop compensation). The settled voltage for any increasing or decreasing load between zero and full load at rated power factor should not vary at any point more than plus or minus 1 percent of rated generator voltage from a median value halfway between the highest and lowest points attained.

(2) *Two or More Generators with Reactive Droop Compensation.* With the reactive droop compensation adjusted for a voltage droop of not more than 4 percent of rated voltage for a reactive load change from zero to 60 percent of the continuous kVA rating of the generator,

the system performance should be such that the average curve drawn through a plot of the settled voltage versus load for any increasing or decreasing load between zero and full load at rated power factor, droops no more than 4 percent of rated voltage and no recorded point varies more than plus or minus 1 percent of rated generator voltage from the average curve.

15.6.2.2 Passenger Vessels. For passenger vessels, the combined system should meet the requirements for cargo vessels. In addition, the distribution system should be arranged so that ship auxiliary power loads will produce minimum flicker in the lighting circuits.

15.6.2.3 Emergency Generating Set (no reactive droop compensation). The system performance should be such that the settled voltage for any increasing or decreasing load between zero and full load at rated power factor should not vary at any point more than plus or minus 2½ percent of rated generator voltage from a median value halfway between the highest and lowest points attained.

15.6.3 DC Generators.

15.6.3.1 Shunt-wound or stabilized shunt-wound generating 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 over 8 percent when the load is gradually reduced from 100 percent load to 20 percent load and so that there will be a drop in voltage of not more than 12 percent when the load is gradually increased from 20 percent load to 100 percent load, based on applicable percent speed regulation (drop in speed from no load to full load) or the prime mover. For each condition the field rheostat should be set for normal rated voltage at the beginning of each test. When lighting loads are supplied directly by the ship's service generator, a voltage regulator should be supplied for each generator which regulator should effect a regulation of the supply voltage to the system not in excess of that required for compound-wound generators covered in 15.6.3.2.

15.6.3.2 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 percent load with voltage within 1 percent of rated voltage, it should give at full load a voltage within 1½ percent of rated voltage. The average of the ascending and descending voltage regulation curves between 20 percent load and full load should not vary more than 3 percent from rated voltage.

15.6.3.3 In addition to meeting the requirements of either 15.6.3.1 or 15.6.3.2, the voltage regulation of a three-wire generator should be such that when operating at rated current on the heavier loaded side, with either positive or negative lead, with rated voltage between the positive and negative leads and a current of 25 percent of the generator current rating in the neutral wire, the resulting difference in voltage between the positive and neutral leads and negative and neutral leads should not exceed 2 percent of the rated voltage between the positive and negative leads.

In the preceding, the speed regulation curve of the prime mover should not vary more than 1 percent from a straight line drawn between the speeds at 20 percent load and 100 percent load.

The voltage regulation and compounding tests should be made at the works of the electrical manufacturer in accordance with his standard testing practice, using an approximately straight-line speed regulation from 20 percent to 100 percent, in amount as specified by the prime mover builder.

If shunt or stabilized shunt-wound generators are to be paralleled when they are units of sets containing larger generators which are also to be paralleled, the following regulation should be met: When the direct-current load on the smaller unit is gradually reduced from 100 percent to 20 percent, the direct-current voltage regulation should be not more than 12 percent, based on a speed regulation of the applicable percent on the prime mover. The prime mover speed regulation is based on varying the combined load on the prime mover from zero to 100 percent.

15.7 Parallel Operation. Generating sets should be capable of operating successfully in parallel. Successful parallel operation is attained if the load on any generator does not differ more than plus or minus 15 percent of its rated kilowatt load from its proportionate share, based on the generator ratings, of the combined load, for any steady-state condition in the combined

load between 20 percent and 100 percent 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 percent 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:

(1) The generators should be at normal operating temperatures.

(2) The speed of the generators should be constant or slightly decreasing with increase in load with the change in speed approximately proportional to load.

(3) For compound-wound machines, the voltage drop at rated full-load current across the series field circuit (including field and cables to main bus) of all machines should be made equal, by the insertion of resistance if necessary.

For compound-wound direct-current machines, series field equalizer connections are required. 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, but in no case should the cross-sectional area of the longest equalizer lead from a generator be less than the area of that generator's main leads.

15.8 Successful Commutation Defined. Successful commutation is attained if neither the brushes nor the commutator is burned or injured in an acceptance test; or in normal service to the extent that abnormal maintenance is required. The presence of some visible sparking is not necessarily evidence of unsuccessful commutation.

15.9 Prime Movers. Generating sets may be driven by steam engines either of the turbine or reciprocating type, by gas turbines, or by diesel engines. 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 percent. Each prime mover should in addition, be under the control of an efficient operating governor capable of limiting the speed, when full load is suddenly removed, to at least 5 percent less than that of the over-

speed trip setting. The overspeed trip should also be equipped with a means for manual tripping.

Where a turbine prime mover is also fitted to utilize auxiliary exhaust, it should be provided with a properly arranged automatic shutoff, and where provision is made for extraction of steam, positive means should be provided for preventing a reversal of flow to the turbine.

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

For turbine-driven direct-current generating sets which will operate in parallel, each should be provided with a switch which, upon functioning of the overspeed device, will trip the generator circuit breaker.

15.10 Motor-Generator Sets—Overspeed Protection. Motor-generator sets having dc motors, driving ac or dc generators which will operate in parallel with other units and which are of a frame size corresponding to a rating of 15 hp or 10 kW, 1750 rpm or above, should be provided with overspeed protection. This preferably should be obtained by a mechanical attachment which will trip the circuit breaker in the case of a generator, or the feeder circuit breaker in the case of a motor. If it is not practicable to use a direct mechanical overspeed device in the case of a dc motor driven set, protection may be obtained by a relay in the shunt field which will open the line contactor in the motor starter in case of loss of motor shunt field.

15.11 Mountings. The generator and its driving unit should be mounted on a common support to insure proper alignment. Care should be exercised to secure a rigid foundation. Where a bedplate is used, each unit comprising the set should be provided with ample supporting feet secured to the bedplate.

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

15.13 Insulation of Windings. Stator coils of ac generators and all assembled armatures and also the armature coils for open-slot dc construction should be immersed in insulating varnish and baked. All field coils should be treated with varnish or other insulating compound while being wound, or impregnated

and baked. The finished winding should be water and oil resistant.

Abnormal brush wear and ring or commutator maintenance may occur on motors or generators with even a slight amount of silicone insulation, especially if the machine is enclosed. Special consideration must be given to these problems if silicone is used on motors and generators.

15.14 Lubrication. All ship service generating sets should lubricate and operate satisfactorily when permanently inclined to an angle of 15 degrees athwartship and 5 degrees fore and aft, and arranged so that they will not spill oil under a vessel roll of 30 degrees each side of the vertical and 10 degree pitch. In cases where the shaft will be located athwartship, the manufacturer should be so advised. All prime movers for ship service generating sets (not emergency sets) depending on 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 37.27.

Emergency generator sets should lubricate and operate satisfactorily when permanently inclined to an angle of 30 degrees athwartship and 10 degrees fore and aft. Units depending upon forced lubrication should be provided with an audible alarm device to sound on loss of oil pressure while running.

15.15 Corrosion-Resistant Parts. To prevent deterioration and corrosion of interior bolts, nuts, pins, screws, terminals, brush-holder studs, springs, etc, and such other small parts as would be seriously damaged and rendered ineffective by corrosion, these should be made of corrosion-resistant material or steel suitably protected against corrosion. Steel springs should be treated to resist moisture in such a manner as not to impair their spring quality. See 2.26.

15.16 Terminal Arrangements. See Section 23.3 for terminal lugs on incoming cables.

15.16.1 Generators 50 kW and Above.

15.16.1.1 Side Location. Generators should be provided with either: (1) an insulating terminal board having secured terminals to which the lugs of the incoming cables can be readily

fastened, or (2) terminal leads, suitably secured to the generator frame, and provided with approved connectors to permit ready connection of the incoming cables.

The generator terminals should be enclosed in a drip-proof terminal box so constructed that the incoming cables can be led individually through an insulating cover screwed or bolted to the bottom, or through a metal strip at least $\frac{1}{4}$ in thick. If the cables enter through the bottom, ordinary clearance holes are recommended. If the cables enter through the top, individual terminal tubes should be used.

15.16.1.2 Top Location. Generators should be provided with terminal arrangements as recommended in 15.16.1.1 enclosed in a drip-proof box having top and side sections at least $\frac{1}{4}$ in thickness through which the individual cables can be entered through terminal tubes.

15.16.1.3 Bottom Location. Generators should be provided with strap terminals, secured to an insulating block, to which the connections, or straps, of the incoming cables can be fastened. The terminal arrangement should be protected against accidental contact and mechanical damage.

15.16.2 Generators Below 50 kW. Generators may be provided with a drip-proof conduit box with removable cover plate, in place of the terminal board described in 15.16.1.1(1) above. The generator cables should be secured inside the conduit box. The arrangement should be such as to permit ready connection of the incoming cables.

15.17 Nameplates. The following minimum information should be given on the rating nameplates of corrosion-resistant material:

- (1) Marine (name of apparatus).
- (2) Manufacturer's name on generator, prime mover, and reduction gear (if any).
- (3) Manufacturer's serial number on generator, prime mover, and reduction gear (if any).
- (4) Manufacturer's type and frame designation on generator, prime mover, and reduction gear (if any).
- (5) Output: in kVA for ac generator; in kW for dc generator.
- (6) Voltage rating.
- (7) Kind of rating, continuous, short time, and continuous with 2 h, 25 percent overload.
- (8) Temperature rise at rated load. For generators having a 2 h, 25 percent overload, the

temperature rise at the end of the 2 h overload should also be given.

(9) Revolutions per minute at rated load for generator and prime mover if not direct connected.

(10) Amperes at rated load.

(11) Frequency at rated load, for ac generator.

(12) Number of phases, for ac generator.

(13) Power factor, for ac generator.

(14) Excitation voltage at rated load, for ac generator.

(15) Excitation current in amperes at maximum continuous rating and at overloads, if applicable, for ac generator.

(16) Shunt, stabilized shunt, or compound, for dc generator.

(17) Steam and exhaust pressures and superheat for prime movers; cylinder size and stroke for reciprocating engines; and cycles, cylinder size and stroke for diesel engines.

15.18 Tests. Sufficient tests should be made at the manufacturer's works to insure that the machine is in accordance with these Recommendations. When a machine is a duplicate of one already completely tested, only such check tests need be made as may be necessary to demonstrate that the machine operates successfully. Spare rotors and armatures should be given regular insulation voltage and dynamic balance tests, but need not be given any running test.

Tests shall be in accordance with the following:

(1) For synchronous machines—IEEE Std 115-1965 Test Procedure for Synchronous Machines.

(2) For direct-current machines—IEEE Std 113-1973 Test Code for Direct-Current Machines.

15.19 Limits of Temperature Rises. The temperature rise of each of the various parts of ac generators when tested in accordance with the rating should not exceed the values given in Table A3. All temperatures are to be measured by the method indicated in the table.

In order to determine accurately the temperature in ac generating sets of 500 kVA and above, when access to coils is difficult, as in the case of generators equipped with closed ventilating systems, embedded temperature detectors should be provided in the stator windings.

Temperature rise of each of the various parts of dc generators when tested in accordance

with the rating should not exceed the values given in Tables A1 and A28.

Balance coils for three-wire dc generators, when mounted separately from the machines, should not exceed temperature rises, as given in Table A28.

15.20 Ambient Temperature. Generators should be designed for an ambient temperature of 50°C; except in cases where generators are provided with enclosed ventilating systems with coolers designed to maintain 40°C ambient temperature under the worst conditions of operation, and in cases where the generator is located in 40°C ambient temperature, the generator ambient temperature may be taken as 40°C and the temperature rises increased 10°C over those recommended in Table A3 for ac generators and Tables A1 and A28 for dc generators.

When enclosed ventilating systems with coolers are supplied a thermometer should be installed to measure the temperature of the air leaving the cooler.

15.21 Insulation—Voltage Tests. The dielectric strength of the insulation of ac generators should be tested by the continuous application of alternating electromotive force of two times normal plus 1000 V for 1 min between all windings, except field windings, and ground, and between phases. The dielectric strength of the fields of the generators should be tested by the continuous application of alternating electromotive force of 10 times the excitation voltage, but in no case less than 1500 volts, between field brush rigging and ground, and between field brush rigging of opposite polarity.

The dielectric strength of the insulation of dc generators should be tested by a continuous application of alternating emf of twice normal plus 1000 volts for one minute between all circuits and ground; between shunt winding and other windings; between brush rings of opposite polarity; and between armature windings of generators, if provided with two commutators.

15.22 Space Heaters. Space heaters should be supplied integral with all generators as tabulated below. These heaters should be energized at any time that the temperature of the windings or metal parts of the generator are lower than the ambient temperature.

These heaters should meet the following recommendations.

15.22.1 Location. The heaters should be placed in such location that warm air will pass over the windings and commutator. This movement of warm air may be accomplished by convection or forced circulation.

NOTE: For small generators the heaters may be mounted on the outside of the frame to supply heat to the interior of the generator by conduction.

15.22.2 Type. Heater units should be sealed against absorption of moisture and have terminals available for connecting to the supply feeder. (See 17.14.)

15.22.3 Size. The following table shows recommended size of heater in terms of generator weight, excluding shaft:

Weight of Generator Pounds	Watts Space Heater Size
0 - 1000	None
1000 - 3000	250 - 500
3000 - 6000	500 - 1000
6000 - 10000	1000 - 1250
Above 10000	100 Watts/1000 lb (220 Watts/1000 kg)

15.23 Spare Parts. Spare parts should be provided as required by the applicable Classification Societies.

15.24 Spare Parts Stowage. Storage space or spaces should be provided with the necessary bins, etc, for stowing electric spare parts which are carried on board the vessel. Spare rotors and armatures should be protected and provided with means for obtaining insulation resistance without disturbing the protective enclosure; and should be stored in a vertical position. Insulated parts, such as coils, should be protected against moisture and rodents, and should be stored in a room in which the temperature is maintained fairly constant. Coils should be stored so their original form will be maintained. All exposed rubbing surfaces, such as bearings, should be protected against corrosion and damage, and should not be allowed to come in contact with wood or other hygroscopic substances.

16. Storage Batteries

16.1 General. This part of the Recommendations relates to storage batteries which are installed permanently in position, and not to batteries of the portable type.

In general, storage batteries may be of lead-acid or of nickel-alkaline type, due consideration being given to the suitability for any specific application.

16.2 Construction and Assembly. Batteries should be constructed to withstand all conditions incident to installation on shipboard, particularly the strain imposed by rolling up to 30 degrees, pitching and vibration of the vessel, and exposure to severe moisture and salt-laden atmosphere. Plates should be of rigid construction, and should be designed for the least practicable shedding of active material.

Lead plates should be from $\frac{1}{8}$ to $\frac{1}{4}$ in thick depending on the service and plate dimensions, except that batteries for diesel engine starting only may be of the thin type, 0.080 to $\frac{1}{8}$ in thick.

The specific gravity of acid electrolyte, with the battery in fully charged condition, should be from 1.210 to 1.220 at a temperature of 25°C. Diesel engine starting batteries may have electrolyte of 1.270 to 1.285 specific gravity if the intended operation of the vessel is not in tropical areas.

Cells should be assembled in trays of suitable material and rigid construction, equipped with handles for convenient lifting. The number of cells in a tray will depend on the weight and on the space available for installation. The weight of trays, preferably, should not exceed about 250 pounds.

Each tray should be provided with a durable nameplate securely attached, bearing the maker's name and type designation, the ampere hour rating at some specific rate of discharge (preferably that corresponding to the duty for the specific application) and, for lead batteries, the specific gravity of the electrolyte when the battery is fully charged.

Intercell connections and terminals for connections between trays and for external wiring should be suitable for the maximum current to be carried. For diesel engine cranking batteries with very high discharge rate this may require copper inserts in posts or other special provision.

16.3 Installation and Arrangement. Batteries should be located where they are not exposed to excessive heat, extreme cold, spray, steam, or other conditions which would impair performance or accelerate deterioration. Batteries for emergency service, including emergency

diesel engine cranking, should be located where they are protected as far as practicable from damage due to collision, fire, or other casualty.

Alkaline batteries and lead acid batteries should not be installed in the same compartment or enclosure. In addition, on every vessel where both alkaline and lead acid storage batteries are installed, a separate set of necessary maintenance tools and equipment for each battery type should be provided.

A large storage battery, such as for emergency lighting, should be installed in a room assigned to the battery only, but may be installed in a suitable deck box if no room is available. No appliances subject to sparking should be installed in a battery room unless of the explosion-proof type.

Batteries of moderate size (20 to 36V), such as those for engine cranking, communications supply, etc, will be preferably installed in the space with the emergency lighting battery. However, such batteries may be installed in a battery locker (or lockers) in the emergency generator room, machinery space, or other suitable location. Batteries should not be installed in sleeping quarters.

Small batteries of 12 V or less for emergency radio supply, etc, should each be installed in a battery box located as desired, except that it should not be within six feet of radio apparatus or other delicate equipment which would be made inoperative by slight corrosion from battery gases.

Cranking batteries should be located as closely as practicable to the engine or engines served, to limit voltage drop in cables with the high current required.

Batteries should be arranged to permit ready access for inspection, testing, watering, and cleaning. Shelves in battery rooms should be not more than 30 in deep. There should be at least 12 in, preferably 15 to 18 in, clear space above the levels of the filling openings. Trays should be readily removable for repair or replacement.

Shelves in battery rooms or lockers for acid batteries should have a watertight lining of sheet lead of $\frac{1}{16}$ in minimum thickness, not less than 3 in deep. For alkaline batteries, the shelves should be similarly lined with steel, not less than $\frac{1}{32}$ in thick. Alternatively, a battery room may be fitted with a watertight lead (steel for alkaline batteries) pan over the entire deck, carried up not less than 6 in on all sides.

Deck boxes should be lined in accordance with the above alternative method. Boxes for small batteries should be lined to a depth of 3 in consistent with the methods previously described.

Battery trays should be securely chocked with wood strips or equivalent to prevent movement. Each tray should be fitted with nonabsorbent insulating supports, not less than $\frac{3}{4}$ in high on the bottom, and with similar spacer blocks at the sides, or with equivalent provision to assure $\frac{3}{4}$ in space all around each tray for circulation of air.

The interior of all battery compartments, including shelves and other structural parts therein, should be painted with corrosion-resistant paint.

16.4 Ventilation. All rooms, lockers, and boxes for storage batteries should be arranged and ventilated to avoid accumulation of flammable gas. Particular attention should be given to the fact that the gas involved is lighter than air, and will tend to accumulate in any pockets at the top of the space. When batteries are arranged in two or more tiers, all shelves except the lowest should have not less than 2 in space, front and back, for circulation of air.

All battery rooms should be adequately ventilated. Natural ventilation may be employed if ducts can be run directly from the top of the room to the open air above, with no part of the cut more than 45 degrees from vertical. If natural ventilation is impracticable, mechanical exhaust ventilation should be provided with intake at the top of the room. Fans should be capable of completely changing the air in the battery room in not more than two minutes. Interior surfaces of ducts and fans should be painted with corrosion-resisting paint. Adequate openings for air inlet should be provided near the floor.

Battery lockers should, if practicable, be ventilated similarly to battery rooms by a duct led from the top of the locker to the open air or to an exhaust ventilation duct, but, in machinery spaces and similar well-ventilated compartments, the duct may terminate not less than 3 ft above the top of the locker. Louvers or equivalent should be provided near the bottom for entrance of air.

Deck boxes should be provided with a duct from the top of the box, terminating at least 4 ft above in a goose neck, mushroom head, or

equivalent to prevent entrance of water. Holes for air inlet should be provided on at least two opposite sides of the box. The entire deck box, including openings for ventilation, should be sufficiently weathertight to prevent entrance of spray or rain.

Boxes for small batteries require no ventilation other than openings near the top to permit escape of gas.

16.5 Battery Rating. The capacity of any battery should be adequate for its application and duty, considering the time and rate of discharge.

The capacity of batteries for emergency lighting and power should be as stated in Section 36. Where the voltage of the emergency lighting system is the same as that of the general lighting, battery voltage at rated rate of discharge, should be not more than 105 percent of generator voltage when fully charged and not less than 87.5 percent at the end of rated discharge.

Batteries for diesel engine cranking should have a maximum output sufficient to assure break-away torque at the lowest expected temperature, and capacity for not less than $1\frac{1}{2}$ min of cranking at a speed sufficient to assure starting and of sufficient capacity to provide at least six starts consecutively without recharging.

16.6 Charging Facilities. For floating service, or for any other condition where the load is connected to the battery while it is on charge, the maximum battery voltage should not exceed a safe value for any connected apparatus. A voltage regulator should be used for any application where safe voltage cannot otherwise be assured. The voltage characteristics of the generator, or generators, which will operate in parallel with the battery must be suitable for each application.

Where a low-voltage battery is floated on the line with a resistor in series, all connected apparatus must be capable of withstanding line voltage to ground.

Where the voltage of an emergency lighting battery is the same as the ship's dc supply, the battery may be arranged for charging in two equal sections, a charging resistor being provided for each. Alternatively, a booster generator may provide charging voltage. With either method, the arrangement of automatic transfer switching should be such that emergency supply is available whether the battery is on charge or not.

Except as otherwise provided below, the charging facilities for any battery should be such that the battery can be completely charged in not more than 8 h without exceeding a safe charging rate. Low-voltage batteries provided in duplicate for communications supply (one in service, the other on charge) should be charged at a rate commensurate with the average discharge rate.

For batteries which normally stand idle for long periods, trickle charging to neutralize internal losses should be provided, where practicable.

The charging equipment for all batteries with a voltage more than 20 percent of line voltage should provide automatic protection against reversal current.

16.7 Overload Protection. Fuses may be used for the protection of emergency lighting storage batteries instead of circuit breakers up to and including 600 A rating.

17. Switchboards

17.1 Installation and Location. The switchboards should be installed in a dry place, away from the vicinity of steam, water, and oil pipes and should be so located as to be accessible from the front and rear. The space in the rear of the switchboard should be ample to permit maintenance, in general, not less than 24 in in the clear, except that this may be reduced to 18 in in way of stiffeners and frames. Where practicable, access from both ends should be provided. The space in front of the switchboard should be unobstructed and ample for operation, maintenance, and removal of equipment, in general not less than 36 in for low-voltage switchboards and greater as required for medium-voltage switchboards. Clearances should be provided for current-carrying parts to ground per 17.11. Switchboards should be installed on a base which rises above the adjacent deck plating; but to avoid excessively high foundations, consideration may be given to protecting the lower portion of the switchboard by watertight barriers and suitable drains. An insulating mat or grating should be provided on the deck in front and rear of the switchboard extending the entire length and of sufficient width to suit the operating space. Tie rods or braces to the ship's structure may be utilized as needed.

When the space in the rear of the switchboard is accessible to unauthorized personnel, an enclosure should be provided. The enclosure may be made of expanded metal sheets or solid metal sheets with suitable ventilating louvers with doors arranged for locking. Where this arrangement is not feasible, enclosure sheets or grille may be mounted on the switchboard framework. Enclosure covers mounted on the switchboard framework may be bolted on, easily removable, hinged, or arranged for sliding as determined by the conditions of the particular installation. Grille work should be sectionalized at panel joints.

17.2 Construction for Low-Voltage (600V) Switchboards. All switchboards should be of the dead-front type where the voltage is in excess of 48 V and arranged to provide ready access to devices for replacement and maintenance. The front panel sections upon which are mounted instruments, relays, switches, or other devices having numerous wiring connections should be hinged unless the arrangement of the rear mounted equipment is such as to permit ready access from the rear without undue hazard to the operator. Hinged panel sections should also be provided when such panel sections are in front of and are the principal means of access to apparatus mounted within the switchboard structure requiring periodic inspection, adjustment, or maintenance. Hinged panels exceeding a height of 45 in or a width of 24 in, should be provided with panel positioners. This equipment includes control or protective relays, air circuit breakers, and automatic bus transfers. Bolted on, easily removable panel sections should be provided in front of apparatus which is mounted on the switchboard framework and which either does not require periodic inspection, adjustment, or maintenance, or which should be removed from the switchboard for such inspection, adjustment, or maintenance. Small stationary sections may be used for mounting such equipment as field rheostats, field switches, and indicator lights, if access is provided for maintenance from the rear or through adjacent hinged or removable sections.

All switchboards should include drip-proof covers for the top and protective covers for the ends of the structure. The end covers should be made of sheet steel provided with ventilating louvers or grilles when required and should extend from the front to the rear of the struc-

ture. The covers on the top of the structure should be bolted on, easily removable. Side covers may be made a permanent part of the structure when removal is not required for maintenance or access purposes.

Insulating material such as panels, bases, bus, and connection supports should be made of impregnated ebony asbestos, laminated phenolic material, or the equivalent. The insulating material should be of high dielectric and mechanical strength and moisture resistant. Metal panels may be used provided all current-carrying parts are properly insulated.

A nonconducting hand rail or rails attached to the front of the switchboard or panels should be provided; a horizontal rail is preferred. Nonconducting guard rail protection should also be provided at the rear of all switchboards.

Terminal blocks should be provided on the framework closely adjacent to the wire loop to hinged panels for disconnecting these wires. Terminal blocks, properly marked, should be provided for all outgoing instrument and control wires and for connecting from one shipping section of the switchboard to another, except for instrument shunt leads or meter shunt leads.

Metal cases of instruments or other devices should be grounded. The switchboard framework should also be grounded.

All small wiring for instrument and control circuits should not be smaller than #14 AWG (American Wire Gauge) stranded and should be flame-retardant and capable of passing vertical flame test per Section 31 of ANSI C33.80-1975, Safety Standard for Thermoplastic-Insulated Wires (UL 83-April 1972), 600 V insulated wire type TA, TBS, or SIS per ANSI C1-1975 (National Electrical Code), article 310-13. Connections to hinged panels should be with the extra-flexible type.

All groups of small wiring should be adequately secured to the switchboard panels or framework in such a manner as to prevent chafing, cutting of the insulation, or excessive motion caused by vibration. All power cables should be secured adequately to prevent motion caused by vibration and to withstand the maximum calculated short-circuit current.

All levers, handles, hand wheels, interlocks, and their connecting links, shafts, and bearings for the operation of switches and contactors should be of such proportions that they will

not be broken or distorted by manual operation.

17.3 Construction for Medium-Voltage (5kV) Metal-Clad Switchboards. Metal-clad switchboards should be used for medium-voltage class systems. Generally, the construction should be similar to that described in 17.2 for low-voltage class switchboards but with the following additional features:

Metal-clad switchboards should be provided with metal barriers between primary sections of adjacent units and between major primary sections of each circuit. Primary sections are: the bus compartment; the primary entrance compartment; the removable element compartment; the potential transformer(s) compartment; and the control transformer(s) compartment. To minimize the possibility of communicating faults between primary sections, the barriers between primary section should have no intentional openings. Automatic shutters should be provided in the stationary structure to prevent accidental contact with live parts of the primary circuit when the circuit breaker is in the test position, disconnected position, or has been removed. Primary or power-carrying bus, conductors, and connections should be covered with a flame-retardant (where practicable) insulating material throughout. Each conductor shall have an insulating covering that by itself will withstand the maximum rated line-to-line voltage between the conductor and outside surface of the insulating covering for a period of 1 min. Where possible, joints should be completely covered by insulating material at the factory; for joints which must be made on shipboard, insulating material should be supplied for application in accordance with the switchboard manufacturers instructions.

Mechanical interlocks should be provided on metal-clad switchboards as follows:

(1) To prevent moving the circuit breaker to or from the connected position when the switching device is in the closed position.

(2) To prevent closing the switching device unless the primary disconnecting devices are in full contact or are separated by a safe distance.

(3) Means should be provided for positively holding the circuit breaker in place in the housing when it is in either the connected or test position. When a separate disconnected position is provided with the door closed, the circuit breaker should be positively held in this position.

(4) To prevent the disconnection of and access to fuses on the primary side of control power transformers unless the secondary circuit is open.

(5) Circuit breakers equipped with stored energy mechanisms should be designed to prevent the release of the stored energy unless the mechanisms have been fully charged. Interlocks should be provided in the housing to prevent the complete withdrawal of the circuit breaker from the housing when the stored energy mechanism is in the fully charged position. In lieu of the interlock, a suitable device may be provided which prevents the complete withdrawal of the circuit breaker until the closing function is blocked.

Instruments, meters, relays, secondary control devices, and their wiring should be isolated by grounded metal barriers from all primary circuit elements with the exception of short lengths of wire such as at instrument transformer terminals.

The door through which the circuit interrupting device is inserted into the housing may serve as an instrument or relay panel and may also provide access to a secondary or control compartment within the housing.

Potential transformers and their fuses should be mounted in a separate compartment with means for disconnecting from the primary circuit before access can be obtained to either the transformer or its primary fuses. Provision should be made for disconnecting or automatically grounding the secondary circuits when disconnecting the primary circuit. Provision should be made for momentarily grounding the primary of potential transformers during the disconnecting operation.

Small wiring connections between the housing and the circuit breaker should be provided with means for automatic disconnection when the circuit breaker is moved from the connected position and to reinstate them in the test position unless means are provided to sustain control connections between connected and test positions.

One set of test jumpers or their equivalent should be provided for each installation to complete all secondary connections for test in the disconnected position.

Metal-clad switchgear should be enclosed in drip-proof enclosures equipped with front hinged panels with hand-operated latches and bolted rear covers. Ducts or grilles for venting

exhaust gases should be so constructed as to prevent foreign materials from entering the breaker.

17.4 Device Design Characteristics. The design of all current-carrying devices or parts of switchboards should conform to the latest standards specified in the related sections of IEEE standards except as these characteristics may be modified herein.

All devices should be capable of withstanding shipboard vibration without damage or faulty operation and should operate successfully when inclined at an angle of 30 degrees in any direction from the vertical.

All switching devices, applied on or operated from power switchboards, should have a rated capacity at least as great as the maximum continuous current rating of the apparatus controlled. For apparatus having an overload rating of 30 min or more, all switching devices should have a rated capacity at least as great as the overload rating. For apparatus having high short-time current ratings, all switching devices should have a capacity of such value that the devices will not exceed a safe temperature rise.

All electrical indicating instruments should be in accordance with the requirements of ANSI C39.1-1972, Requirement for Electrical Analog Indicating Instruments. All instruments should be of the switchboard type except those for battery charging equipment may be of the panel type having an accuracy class of 2.0 or less. The switchboard-type instruments should preferably be of the 250 degree nominal scale type.

Voltmeter scales should be based on the voltage systems used on the vessel as follows:

Range of System Voltage	Voltmeter Scale
115-120	0-150
220-240	0-300
440-480	0-600
2400	0-3000
4160	0-5250

Ammeter scales should be of sufficient range to indicate maximum current under normal operating conditions and should indicate not less than 110 percent to 150 percent of the normal current rating for circuits which are not subjected to other than momentary overload. For circuits that may be subject to 25 percent

overloads, the ammeter scale should be a minimum of 135 percent of normal current.

Voltage regulator elements should be provided with enclosing cases to protect them from damage.

Double-throw switches of the open type (live-front) mounted within the switchboard enclosure should preferably be mounted horizontally. Where vertically mounted, they should be provided with suitable means for retaining blades in the "open" position in accordance with article 380-6 of ANSI C1-1975, National Electrical Code.

Feeder and branch circuits should be connected to the fuse end of switches and coil end of circuit breakers. When a switch or links are provided to disconnect the generator circuit breaker from the bus or when the generator circuit breaker is of the draw-out type, generator connections may be made to either end of the breaker.

Corrosion-resistant parts should be in accordance with 2.26.

17.5 Circuit Breakers. The current rating of circuit breakers should be the value of current the breakers will carry continuously without exceeding the specified temperature rise. Low-voltage power circuit breakers may be equipped with overcurrent trip devices of the electromechanical or static type. The overcurrent devices may be equipped with time overcurrent trips (long time or short time, or both), instantaneous trips or combination trip units.

The time overcurrent trips should be adjustable on power circuit breakers but need not be adjustable on molded-case circuit breakers.

Medium-voltage class circuit breakers normally utilize separate electromechanical or static-type relays for overcurrent sensing but direct acting overcurrent units may be used. Separate relays should be the three-phase type. Control power for tripping circuit breakers should be from a battery source with an automatic charger or capacitor type storage ac circuit breaker trip units may be used.

Arcing contacts, except those used in molded case circuit breakers, should be easily renewable. All circuit breakers should be of the trip-free type.

All circuit breakers of the molded-case type should be mounted or arranged in such a manner that the breaker may be removed from the front without disconnecting the copper or cable connections or deenergizing the supply to

the breaker. Use of plug-in or draw-out type breakers which do not require use of an insulated wrench for removal is preferred.

For all other requirements, circuit breakers and knife switches should conform with the latest requirements of the Underwriters' Laboratories Standard except for the calibration of thermal trip circuit breakers which should be calibrated for an ambient temperature of 50°C as recommended in 17.6.

17.6 Temperatures. Switchboard apparatus primarily designed for use in a maximum ambient temperature of 40°C may be used in a 50°C ambient temperature provided that the primary contacts and joints are silver surfaced or equivalent and provided that normal operation does not result in total temperatures in excess of:

- 90°C for class 90 insulation
- 105°C for class 105 insulation
- 130°C for class 130 insulation
- 155°C for class 155 insulation.

In addition to these limits on insulating materials, the temperature rises specified in other IEEE or ANSI Standards for various switchboard parts and devices will also apply for these switchboard applications in a 50°C ambient temperature.

Circuit breakers of the molded-case thermal type should be calibrated or ambient compensated for an ambient temperature of 50°C.

17.7 Arrangement of Switchboard Equipment. The devices which are operated or observed from the front of the switchboard should be arranged to provide the greatest degree of safety and convenience for operating personnel. Molded-case circuit breakers may be mounted vertically or horizontally. If mounted horizontally, the center line of 400 A frame and larger circuit breakers should not be mounted higher than 72 in above the bottom of the switchboard. When interrupting devices such as air circuit breakers are mounted one above the other, there should be adequate spacing for the arcing or otherwise protective barriers installed. Barriers should also be provided, if necessary, to prevent arcing to other adjacent equipment.

A minimum clearance of 4 in between live parts and the bottom of the switchboard shall be maintained.

Particular attention should be given to the arrangement of buses and connections to pro-

vide space for cables and accessibility for making cable connections.

In general, all fuses except for instrument and control circuits, should be accessible from the front of the switchboard.

When rheostats or other devices that may operate at high temperatures are mounted on the switchboard, they should be so located or isolated by barriers and naturally ventilated to prevent excessive temperature of copper or adjacent devices. When this cannot be accomplished, the rheostat or other device should be mounted separate from the switchboard.

On ac switchboards, the synchroscope and synchronizing lamps should be located so as to be readily visible from the position at which the operator controls the incoming generator. Voltage adjusting rheostats should be located close to their respective generator voltmeters. The frequency meter should be visible from the prime mover speed control switches.

If voltage regulators and their accessories for two or more generators are located in the same section of the switchboard, the devices for each generator should be isolated by a barrier.

Buses and primary connections should be arranged so that, for three-phase assembled switchboards, the phase sequence is A, B, C, and for direct-current assembled switchboards, the polarities are positive, neutral, negative, front to back, top to bottom, and left to right, as viewed from the front of the switchboard.

17.8 Protective Functions. The following automatic protective functions should be provided:

17.8.1 Protection — General. Refer to 21.30.

17.8.2 Generator Protection.

17.8.2.1 General. Molded-case circuit breakers may be used in place of power circuit breakers for generators rated less than 25 kW, and not arranged for parallel operation.

The generator circuit breaker should be provided with a device connected so that it will be tripped under the conditions described in 15.14.

17.8.2.2 Alternating-Current Generators.

(1) *Generator Overload, Short Circuit, and Reverse Power.* Generators should be protected by means of trip-free low-voltage power circuit breakers having long-time overcurrent trip units, or by medium-voltage circuit breakers and overcurrent relays with long-time pickup characteristics. The pickup setting of the long-time overcurrent trip should not exceed 115

percent of the generator rating for continuous rated machines and should not exceed 15 percent above the overload for special rated machines.

Generator low-voltage circuit breakers should also have short time-delay trips. For medium-voltage circuit breakers, the overcurrent relay short-time feature may not be required if the long-time characteristic provides the needed protection. Where three or more generators are operated in parallel, the generator breakers should also have instantaneous trips which are set at a value in excess of the maximum short-circuit contribution of the individual generator.

In order to provide the maximum obtainable degree of protection for the generator, the overcurrent trips should be set at the lowest values of current and time which will comply with the recommendations of Section 21.30.

When two or more generators are to operate in parallel, each generator should be protected against reverse power flow. If reverse power relays are used which may operate at very low values of power reversal, a time-delay feature should be incorporated to prevent the tripping of breakers during switching operations.

17.8.2.3 Direct-Current Generators.

(1) *Generator Overload and Short Circuits.*

Generators should be protected by means of trip-free power circuit breakers having inverse time overcurrent instantaneous trips as shown in Figs A1 to A10. The time overcurrent trip should be set at a value not to exceed 115 percent of the generator rating for continuous rated machines and at a value not to exceed 15 percent above the overload rating for 125 percent 2 h overload or special rated machines. All generator circuit breakers should be provided with an instantaneous trip set below the maximum generator short-circuit current to reduce the likelihood of, and minimize the damage from, commutator flashover. In order to provide the maximum obtainable degree of protection for the generator, the instantaneous trip should be set at the lowest value of current which will coordinate with the trip settings of feeder or backup circuit breakers supplied by the generator (see Section 21.30).

(2) *Generator Neutral Overcurrent.* Provision should be made to indicate overcurrent in the neutral of three-wire generators by means of a relay and alarm system. The relay should be set to function at a value of current equivalent to 25 percent of the rating of the

generator or at a value not exceeding the rating at the generator neutral. No overload trip feature should be provided on the neutral pole of the generator circuit breaker, but the neutral pole should operate simultaneously with the other poles of the generator circuit breaker.

(3) *Generator Reverse Current.* Where generators are operated in parallel, the generator breakers should be provided with a reverse-current trip which will operate to trip the breaker on current reversals of sufficient magnitude to cause injurious effects on the machine or prime mover. The reverse-current device should operate on reversals of 15 percent or greater of generator rating for diesel driven generators, and of 5 percent or greater for turbine driven generators. Reverse-current relays may be provided to trip the generator breaker in lieu of direct-acting reverse-current trip attachments.

When reverse-current relays are used which may operate at very low values of power reversal, a time feature should be incorporated to prevent the tripping of breakers during switching operations. The time features may be obtained by using a time undervoltage device to trip the circuit breaker.

(4) *Generator Overspeed.* The generator circuit breaker should be provided with an undervoltage device connected so that it may be tripped from an overspeed attachment on the generator or prime mover. The undervoltage device should trip all poles of the circuit breaker. (See 15.9 and 15.10.)

17.8.3 Feeder Cables—Overload and Short-Circuit Protection. For each distribution circuit, a switch or circuit breaker, with a pole for each conductor, should be provided except for three-phase grounded systems where the grounded conductor need not be opened. Fused switches may be used up to 200A; circuit breakers, of the molded-case or the power type, should be used and are preferred for all circuits. Overcurrent protection should be provided for all ungrounded conductors. Fuses should not be, and circuit breaker overload trips need not be, provided for the neutral conductor of a three-wire dc grounded system.

17.8.4 Control Circuits—Overload and Short-Circuit Protection. All control circuits except those listed in the following paragraph should be protected by fuses, one in each line, located as closely as possible to the source of power.

No fuses should be installed in any circuit where the opening of the fuse might introduce

a hazard in operation, such as:

- electric propulsion control circuits;
- circuit breaker tripping control circuits;
- supply circuits for voltage regulators.

NOTE: On electric propulsion installations involving especially complex control circuits and a considerable amount of grouped wiring, consideration may be given to the use of protective fuses. The capacity of the fuses should be several times the normal current of the circuits protected so that they will function only on fault currents.

17.8.5 Potential Circuit Overcurrent Protection. Each conductor for potential circuits to instruments, pilot lamps, and ground detector lamps should be protected by fuses.

In addition, potential transformers, provided they are not installed in any circuit where the opening of a fuse would introduce a hazard to operation, should be protected for short circuit by fuses in the primary only. If instruments are connected to the secondaries of potential transformers that are also connected to reverse power relays, the instruments should be fused in a manner that does not affect the reverse power relays in the event of a fuse opening. The transformer and its primary fuse protection should be designed so that in the event of short circuit on the secondary side the primary fuse will open. The primary fuse size should be no greater than 6A.

NOTE: The potential transformer should operate satisfactorily with a temperature rise of 30°C based on an ambient temperature of 55°C.

17.8.6 Steering Gear Feeder Circuit Breaker. The steering gear feeder circuit breaker, in quantity as required, should be of the instantaneous-trip-only type, and should provide contacts to operate on audible alarm located at the principal control station in accordance with 28.3.1.

17.8.7 Shore Power Feeder Protection. When a shore power feeder is installed, a circuit breaker with a pole for each conductor should be provided for connecting it to the switchboard bus and should preferably be mounted on the front of the switchboard. An indicating light should indicate when power is available from shore.

17.9 Grounding of Instrument Transformers. The secondary windings of instrument transformers should be grounded.

17.10 Grounding Three-Wire Dual-Voltage DC Systems. The neutral connection of three-wire

230/115 V dc systems should be solidly grounded at the generator switchboard with a center zero ammeter in the ground connections. The center zero ammeter should be equipped with a shunt, having a full scale reading of 150 percent of the neutral current rating of the largest generator and marked "plus" and "minus" to indicate the polarity of grounds.

The ground connection should be made in such a manner that it will not prevent checking the insulation of the generator to ground before the generator is connected to the bus.

No direct ground connection should be provided at the emergency switchboard, but the neutral bus or buses (temporary and final) of the emergency switchboard should be solidly and permanently connected to the neutral bus of the main generator switchboard. The capacity of this neutral conductor should be the same as that of the positive and negative conductors. No interrupting device should be provided in the neutral conductor of the bus tie feeder connecting the two switchboards.

17.11 Bus Bars and Connections. All switchboards should be fitted with copper or aluminum bus bars and connections applied on the basis of the cross section required for the circuit ampere rating, except as noted herein. Provisions should be made for withstanding mechanical strains imposed by inrush current and available system short-circuit currents.

Connections should be provided with silver- or tin-plated contacts. Plating should not show a tendency to peel off under normal operating conditions.

The bus size should be selected on the basis of limiting the bus bar temperature rise to 50°C at rated current. Table A27 may be used in determining the necessary bus bar size.

Buses should be designed on the basis of generator capacity and feeder loads. For a single generator, the generator bus should have a capacity equal to the continuous rating of the generator plus any overload rating in excess of 30 min duration. For more than one generator with all generating capacity feeding through one section of the bus, the capacity of the bus for the first generator should be the same as for a single-generator installation. For each subsequent generator, the bus capacity should be increased by 80 percent of the continuous rating of the added generator. The capacity of con-

nection buses for each generator unit should be equal to the continuous rating of the generator plus any overload rating in excess of 30 min duration. In order to limit the size of bus for generators, it is recommended that consideration be given to the location of generator panels in the center or at each end of the switchboard.

If the aggregate generator capacity connected to a ship's service generator switchboard exceeds 3000 kW, the switchboard bus should be subdivided into at least two sections. The connections of the generators and any other duplicated distribution services should be divided equally between the sections as far as is practicable. The bus sectionalizing device may be a bolted splice connection, an automatic or non-automatic circuit breaker, or other suitable device.

For feeder switchboards, the buses should have a capacity of not less than 75 percent of the combined full-load rated current of all loads including 50 percent of the rated installed or design reserve spare breaker capacity. The capacity of the feeder buses need not be greater than the generator buses which supply them. Bus connections to individual feeder circuit breakers should be designed on the basis of the frame rating of the breakers when the frame rating is 600 A or less. For frame ratings above 600 A, the bus connections should not be less than the breaker trip rating.

For certain high-current capacity installations, the use of copper or aluminum channel bus bars or an arrangement of rectangular bars with an increased spacing between bars may offer an appreciable reduction in cross-section requirements. Such arrangements should be used where practicable. All bus bars should be accurately formed, and all holes should be made in a manner which will permit bus bars and connections to be fitted into place without being forced.

Bus bars, connection bars, and wiring on the back of the switchboard should be arranged so that maximum accessibility is provided for cable connections. Consideration should also be given to the arrangement of cables so they may be connected to the switchboard in an orderly manner. The electrical clearance between parts of opposite polarity and between live parts and ground should conform to article

384-26 of ANSI C1-1975, National Electrical Code.

Bolts, nuts, and washers used to maintain contact on bus and connection bars should be of nonferrous material or of steel, with a corrosion-resistant treatment of 2.26.

Current-carrying nuts should be made of a copper alloy having adequate conductivity and should be of sufficient size to provide the necessary area to carry circuit current without exceeding the temperature rise normally specified for copper. Current-carrying nuts should be plated and compatible with the connections. For high-capacity buses in excess of 4000 A, consideration should be given for the use of nonmagnetic-type bus hardware to prevent excessive temperatures at joints and connections.

All nuts and connections should be fitted with efficient locking devices to prevent loosening due to vibration. All bus and connection bars should be liberally supported to prevent vibration and to withstand available short-circuit stresses.

Current and potential transformers, etc, should be rigidly supported.

In order to prevent excessive heating on ac installations, no magnetic material should be located between phase conductors.

17.12 Wire and Conductor Terminal Lugs. All wire and conductor (cable) connections for power and lighting circuits external to the switchboard should preferably be connected to devices or buses by means of solderless terminal lugs in accordance with ANSI C33.5-1975 (Underwriters Laboratories Std UL486-Nov 1975), Safety Standard for Wire Connectors and Soldering Lugs. All terminal connectors for external connections should be located at the rear of the switchboard and located where they are accessible for cable connections.

17.13 Nameplates. Each switchboard should be fitted with a nameplate stating that it has been constructed for marine application and should give the manufacturer's name. Nameplates of nonabsorbent and corrosion-resistant material should be provided for each piece of apparatus to clearly indicate its service. Nameplates for feeders and branch circuits should include the circuit designation and the size of the fuses or

circuit breaker trip calibration required for the circuit.

17.14 Minimum Equipment for Generator Switchboards.

17.14.1 For Alternating-Current Generators.

Drawout or plug-in generator circuit breaker for each generator.

An ammeter for each generator with a selector switch to read the current of each phase.

A voltmeter for each generator with a voltmeter switch to connect the voltmeter to each phase of the generator and to one phase of the bus. One of these voltmeter switches should provide also for reading each phase voltage of the shore connection.

An indicating wattmeter for each generator.

A temperature detection instrument with a selector switch for each generator rated 400 kW and above.

A pilot lamp permanently connected to the generator side of the circuit breaker of each set of incoming generator leads.

Control for each prime mover speed for paralleling.

A switch to supply generator space heater of each generator.

When two or more generators are to operate in parallel, a reverse power protective device should be provided for each generator.

A frequency meter with selector switch to connect to any generator.

A synchroscope and synchronizing lamps with selector switch to provide for paralleling in any combination.

A voltage regulator, unless internal with the exciter, complete with all accessories for each generator.

A switch for cutting out the regulator and for transferring from automatic to manual control mode for each generator.

An automatic control rheostat for each generator.

A manual control rheostat for each generator.

For generators when not excited from unique rotating or static exciters and when the generator field may be disconnected, a double pole field switch with discharge clips and resistor for each generator.

Ground detection means for each bus of the switchboard.

For ungrounded systems, three ground lamps and a normally closed spring return-to-normal

switch or push button in the ground connection. For grounded systems, a ground current ammeter, ammeter switch, and current transformer if required in the ground connection point circuit.

Necessary current and potential transformers.

Test receptacles for use with portable instruments are recommended for the larger switchboards.

NOTE: Refer to 21.41 for additional switching requirements applicable to grounded systems.

17.14.2 For Direct-Current Generators. The following should be supplied.

A drawout or plug-in generator circuit breaker for each generator.

Alternately, generator disconnecting switch or links may be used with a stationary air circuit breaker.

An ammeter for each two-wire generator or two ammeters for each three-wire generator, one in positive line and one in negative line.

An ammeter for neutral ground connection for each three-wire generators.

A voltmeter for each generator with voltmeter switch depending on the type of generator for connecting the voltmeter to indicate generator voltage, positive to negative, positive to neutral, and neutral to negative, bus voltage positive to negative. One of these voltmeter switches should provide also for reading shore connection voltage, positive to negative, positive to neutral, and neutral to negative.

A pilot lamp permanently connected to the generator side of each set of incoming generator leads.

When two or more generators are to operate in parallel, a reverse current protective device should be provided for each generator.

A field rheostat for each generator.

NOTE: Refer to 21.41 for additional switching speed generators, a switch for cutting out the regulator should be provided. When used with variable speed generators, no cutout switch or adjustable field rheostat should be included, unless specified.

17.15 Emergency and Communication Switchboards.

17.15.1 General. These may be separate switchboards, but consideration should be given to providing a single switchboard for the two services. The switchboard or boards should conform to all applicable requirements of 17.1 through 17.14 and 17.16, except that no neutral current ammeter is to be provided, and

should also provide the features described below. Suggested means of providing these features are indicated in Figs A11 to A15, but the detailed description and diagrams are not to be considered as being restrictive or as prohibiting variations to suit special cases.

17.15.2 Alternating-Current Switchboards. Except for differences arising from the fact that the emergency generator will be of the alternating-current type while the emergency battery will necessarily supply direct current, the switchboards will be similar to those described below for dc switchboards.

If there is no continuous load inherently requiring dc supply, the storage battery may be charged by a motor-generator or rectifier taking power from the alternating-current buses. Bus transfer arrangements should be essentially as described for dc switchboards except that the connections must permit satisfactory supply of all loads on the temporary emergency buses from the three-phase final emergency buses or from the storage battery. For suggested arrangements, see Fig A16.

If there is any continuous dc load, there should be a separate dc bus normally supplied from a motor-generator set or rectifier with a separate automatic switch for transfer to battery, if required. Alternatively, this bus may be supplied from a battery that is charged from the final emergency bus through a motor-generator or rectifier of capacity suitable for the continuous direct-current load and battery charging. Emergency lighting and other temporary emergency loads which will operate on either alternating or direct current should be arranged for automatic transfer from the final emergency bus to the battery bus. Protection should be provided against discharge of the battery into supply circuits. Normal operation should be restored automatically upon restoration of main supply or establishment of emergency generator supply after failure of main power.

17.15.3 Direct-Current Switchboards.

17.15.3.1 Cargo Vessels of 1600 Gross Tons and Over. See 36.2 and Figs A11, A12, and A13, with accompanying notes for suggested alternative arrangements. Generally, a single panel will serve both the emergency and interior communication circuits. Suggested connections of the low-voltage system are shown in Fig A15.

17.15.3.2 Passenger Vessels of Less Than 1600 Gross Tons. See 36.6 and Figs A13 and A15, with accompanying notes.

17.15.3.3 Passenger Vessels of 1600 Gross Tons and Over. See 36.4 and Fig A14, with accompanying notes for suggested connections. The emergency switchboard distribution panels should have two sets of buses. The “final emergency” bus should normally be supplied by the bus feeder from the ship’s service switchboard. The “temporary emergency” bus should normally be supplied from the final emergency bus through a bus transfer switch and should be automatically transferred to the storage battery upon failure of power.

Charging equipment, with suitable indicating instruments, should be provided for the emergency battery and for the engine starting battery, if one is supplied.

The communication panels should be provided with any or all of the following buses depending on the needs of the service:

- (1) 120/240 V bus connected directly to the final emergency bus.
- (2) 120 V or 120/240 V bus connected directly to the temporary emergency bus.
- (3) 24 V bus supplied from duplicate storage batteries (see Fig A15).
- (4) 120 V single-phase ac bus supplied either from one of duplicate motor-generator sets through a double-throw generator selector switch; or from dc/ac electronic converters.

If any of the ac circuits are among those classed in 36.4 as temporary emergency circuits, the dc/ac motor-generator or electronic converter should be supplied from the battery bus and arranged for continued operation upon failure of main power. An ac voltmeter, ammeter, and frequency meter should be provided. The master switches for motor-generator starting and the motor and generator field rheostats should be mounted on the switchboard.

17.15.3.4 All Classes of Vessels. All automatic bus transfer switches should preferably be of the latched type with coils energized only at the moment of operation. They should transfer to emergency supply when the main voltage is reduced to from 75 to 85 percent of normal value and, if arranged for automatic retransfer, should return to main supply when the main voltage is from 85 to 95 percent of normal value.

See Section 16 for general requirements applicable to storage battery installations.

All emergency switchboards supplied by a diesel engine or gas turbine driven generator, except those of very small rating, should be arranged to feed back to the ship’s service switchboard all available power from the emergency generator. The feedback arrangement should be interlocked switches or circuit breakers that prevent paralleling the emergency with the ship service generators except for momentary transfer of loads.

General alarm feeder circuits, when fed from the interior communication bus, should be connected directly to the bus through fuses only.

All feeders and branch circuits when served from a combination consisting of a two-wire and three-wire source, should be two-wire circuits.

17.16 Dielectric Withstand-Voltage Test.

(a) *Factory Dielectric Withstand Tests.* The standard factory withstand dielectric test voltage for all switching and interrupting apparatus should be as follows:

Voltage Rating (volts)		Withstand Test (rms voltage)
up to 120	ac	1500
121– 600	ac	2200
601–1200	ac	5000
1201–2400	ac	15 000
2401–4760	ac	19 000
125– 300	dc	1500
301– 600	dc	2200

All apparatus and devices in the power circuit should be mounted in the normal location during the tests, but removable drawout mounted circuit breakers need not be tested in the assembly if they are tested separately. Where the standards for devices other than the switching or interrupting devices call for a lower test voltage, such devices as potential transformers may be disconnected during the dielectric test. Such devices should be individually tested in accordance with their applicable standards.

For the control wiring, a 60 Hz test voltage, 1500 V to ground, shall be applied for 1 min after all circuit grounds have been disconnected and all circuits are wired together with small bare copper wire to short-circuit coil windings.

Dielectric withstand tests should be made at

the factory under the temperature and humidity conditions normally obtained under conditions of testing with appropriate correction factors applied as outlined in IEEE Std 4-1968 (ANSI C68.1-1968) Techniques for Dielectric Test.

The alternating-current test voltage for the Power Frequency Withstand Dielectric Tests should have a crest value equal to 1.41 times the rms test value specified above. The wave shape shall be as close to a sine wave as practicable. The frequency shall not be less than the rated frequency of the apparatus tested. The tests should be made phase-to-phase and phase-to-ground. The test voltages should be applied for 1 min.

(b) *Shipboard Dielectric Withstand Tests.* When dielectric withstand tests are to be made on switchboards after installation in the ship, the assembly may be tested at 0.75 times the test values given above.

18. Cable Construction

18.1 Copper Conductors.

18.1.1 General. The conductors should be of soft annealed copper wire. All conductors should be tinned or alloy-coated where necessary to assure compatibility with primary insulation.

18.1.2 Composition. Conductors should be manufactured in accordance with the latest issue of the following Standard Specifications of the American Society for Testing and Materials (ASTM):

ASTM B3	soft or annealed copper wire;
ASTM B33	tinned soft or annealed copper wire for electrical purposes;
ASTM B189	lead-coated or lead alloy-coated soft copper wire for electrical purposes;
ASTM B8	concentric-lay-stranded copper conductors, hard, medium-hard, or soft;
ASTM B174	bunch-stranded copper conductor for electrical conductors.

18.1.3 Stranding. The construction requirements and nominal resistances of standard Class B concentric conductors may be found in Table A7. Combination stranded conductors or compressed stranded conductors may be substituted for concentric stranded conductors.

The construction requirements of extra-flexible stranded conductors for portable cords (See 19.6.1) should conform to Sections 3, 4, and 5 of the latest issue of ANSI C33.1-1975 (Underwriters' Laboratories Std 62-July 1975) Safety Standard for Flexible Cord and Fixture Wire.

18.1.4 Conductor Shielding. Conductor shielding should be used on conductors of cables rated 5kV with Types E and X insulation and is not required for Type AV.

18.1.4.1 Conductor shielding is a conducting material at least 2.5 mils thick applied over the surface of the conductor. It may be conducting nonmetallic tape, conducting compound, or combination thereof.

18.1.4.2 Extruded conductor shielding should have a maximum volume resistivity of 5000 Ω -cm at 25°C temperature and 50 000 Ω -cm at the rated temperature of the insulation (See 18.2.1) and should meet the following requirements when tested according to procedure in IPCEA S-68-516 (1976) for Type E or S-66-524 (1971) for Type X:

elongation after air oven at 121°C	
$\pm 1^\circ\text{C}$ for 168 h, minimum, percent	100
brittleness temperature, not warmer than	-10°C.

18.1.5 Separator. Where required to insure free stripping, a suitable separator tape may be applied to the conductor.

18.2 Insulation.

18.2.1 General. The insulation should be one of the following types:

Insulation Type Designation	Maximum Conductor Temperature °C
T polyvinyl chloride	75
E ethylene propylene rubber	85
X cross-linked polyethylene	85
M mineral (MI)	85*
S silicone rubber	100
AV asbestos-varnished cloth	100

*A maximum conductor temperature of 250°C is permissible for special applications; standard end fittings may be used provided the temperature does not exceed 85°C at the end fittings. However, when the temperature at the end fittings is higher than 85°C, appropriately rated end fittings are required.

18.2.2 Properties. The physical and electrical properties of Type E, X, S, and T insulation materials should meet the requirements of

Table A9. The physical and electrical properties of Type M and AV should meet the requirements of the following subsections.

18.2.2.1 Type M—Mineral (MI). Mineral insulation should be calcined, highly compressed, refractory mineral, so processed and proportioned as to yield the cable properties hereinafter described in 18.14.

18.2.2.2 Type AV—Asbestos-Varnished Cloth. The insulation shall consist of a composite wall of asbestos and varnished cloth layers, with separator tapes optional between adjacent dissimilar layers.

(1) *Varnished cloth.* The insulation should consist of either varnished cotton tapes or varnished polyester-glass tapes meeting the dimensional, electrical, and physical requirements of IPCEA Publication S-65-375 (1966). The varnished cloth tapes should be suitable for continuous operation at a conductor temperature not exceeding 100°C when flanked by inorganic mineral fiber layers and should be of high quality, substantially free from blisters and other imperfections.

The tapes should be helically wrapped on the cable and should be of such width that they shall lie smoothly and be as free from wrinkles as is practical. A slipper compound, applied between alternate layers of tape should be viscous and nonhardening and should have no deleterious effect on the varnished tapes, the conductor, or other components of the cable assembly. The compound should be applied so as to exclude, as far as practical, air and moisture and to form with the varnished cloth tapes a firm, semiflexible wall of insulation.

The cloth of varnished cotton tape should consist of uniformly woven cotton and the number of threads per inch should be not less than 60 × 55. Methods of sampling and testing should be in accordance with ASTM D-295-70. The cloth of varnished polyester-glass tape should consist of uniformly woven polyester and glass fiber. The polyester fiber should be in the warp direction with no less than 30 ends per inch, and the glass fiber should be in the fill direction with no less than 26 ends per inch. Methods of sampling and testing should be in accordance with ASTM D-2400-70. The varnish coating should be pliable and should not show cracks readily visible to the unaided eye when the varnished cloth tape is doubled upon itself.

The average thickness of the individual varnished cloth tapes should be between 6 and 13

mils. The thickness of any individual tape should not vary from average more than plus or minus 20 percent, but in no case should the tolerance exceed plus or minus 1.5 mils.

The tensile strength of the varnished cloth tape, when tested lengthwise, should meet the following requirements:

tensile strength before application of the cable:

minimum psi 3000.

tensile strength after removal from the cable:

minimum psi 2400.

The varnish coating of the varnished cloth tapes should not be materially softer or more tacky after heating for 15 min in petrolatum at 150°C, determined according to IPCEA S-65-375(1966).

The average dielectric strength of varnished cloth tapes removed from the completed cable should not be less than 800 V/mil when measured according to IPCEA S-65-375(1966) or ASTM D-295-70.

(2) *Felted asbestos.* The asbestos insulation should consist of felted asbestos fiber impregnated with a saturating compound. Asbestos should consist of best quality, long fiber chrysotile asbestos, commercially free from foreign particles. The raw asbestos, prior to saturation, should retain not less than 80 percent of its original weight when ignited in accordance with ASTM D-1918-72. The magnetic rating (MR) of the asbestos or inorganic fiber raw material should not exceed 2 when determined in accordance with ASTM D-1118-72. Felted asbestos should be processed to form a smooth uniform thickness.

The impregnant for felted asbestos should be heat and moisture resistant and the resultant saturated felted wall should not propagate flame.

(3) *Alternate to felted asbestos.* In places where felted asbestos is specified, alternative materials may be employed as options: (1) impregnated glass roving, (2) impregnated asbestos tape, (3) impregnated glass-reinforced asbestos tape. Impregnation should be as for felted asbestos. Impregnated glass roving should be closely wound, leaving no visible gaps. Impregnated tapes should be of the width best suited for the particular diameter, and should be wound helically with butt or overlap construction. Butt construction should not be used where the wall of the asbestos insulation

is composed of only one tape. Impregnated roving or tapes should exhibit not less than 70 percent retention of original weight after ignition according to ASTM D-1918-72. The total wall thickness of impregnated roving or tapes should be not less than that required for felted asbestos, Table A13. Where impregnated roving or tapes are employed on individual conductors, effective measures should be employed to prevent unravelling.

18.2.3 Thickness of Insulation. The average thickness of thermoset, thermoplastic, and combinations of asbestos with varnished cloth insulation should conform to the values given in Tables A10 and A13. The minimum thickness at any point should not be less than 90 percent of the average value.

18.3 Tapes. Where binder or separator tapes are called for, a polyester film tape or compound filled tape should be used. Binder tapes should be flame-retardant as necessary to permit cables to meet the flammability tests of 18.13.5.

Where a compound filled tape is used, the tape should be made from cloth treated on one or both sides with an insulating compound. Thickness of tape should not be less than 0.010 in.

18.4 Braids.

18.4.1 Marker Braid. Marker braid used for conductor identification should be of rayon or glass as required. It should be treated with a flame retardant finish.

18.4.2 Braid over Silicone Insulation. Silicone rubber insulated conductors should be covered with glass or asbestos braids.

18.5 Conductor Identification. Where conductor color coding is specified, the identification may be made either by colored conductors or separate tapes, or by printing the color nomenclature on the insulation or its covering.

Conductor identification of distribution cables, when colored conductors are used, should be as follows:

- two conductors — black, white
- three conductors — black, white, red
- four conductors — black, white, red, blue.

Conductor identification of control and signal cables should follow the color sequence of Table A26.

18.6 Cabling. Conductors or pairs should be cabled in concentric layers. The direction of lay for adjacent layers should be reversed.

18.7 Fillers. Fillers should be moisture-resisting, compatible with other cable components, and capable of being compressed in the cabling operation so as to exclude, as far as possible, all voids. Fillers should be used as required to give the completed cable a substantially circular cross section.

18.8 Marker. Cable identification should be provided by including a marker under the cable jacket. The marker material should be suitable for its service. The marker tape should give the following information at regular intervals:

- (1) manufacturer;
- (2) applicable specification and its edition;
- (3) year of manufacture;
- (4) voltage rating;
- (5) type designations (see 18.27).

18.9 Moisture-Resisting Jacket.

18.9.1 General. The jacket should be black thermoplastic Type T or black thermosetting Type N or CP complying with the requirements of Table A11.

18.9.2 Composition and Construction. The jacket should provide a combination of the following basic properties that are properly proportioned to obtain the properties listed below:

- (1) flame retardance
- (2) stability under long continued exposure to elevated temperatures
- (3) absence of noticeable odor at cable operating temperatures
- (4) flexibility at low temperatures (that is, cold bend qualities)
- (5) stability under exposure to oil and water
- (6) stability under exposure to sunlight.

18.9.3 Jacket Thickness. The average thickness of moisture-resisting jackets should be as shown in Table A12. The minimum thickness at any point should not be less than 80 percent of the values shown.

18.10 Armor.

18.10.1 General. Armor should be of the basket-weave type.

18.10.2 Basket Weave. The armor should consist of wires laid closely together, flat and

parallel, and forming a basket weave that should firmly grip the cable. The wire should be 0.0126 inches in diameter, plus or minus 0.0005 in, and should be free from cracks, splits, or other flaws. The wire should be either commercial bronze or aluminum. The weave should be either the "one over-one under" or the "two over-two under" type. The selection of the number of ends per carrier and the number of carriers per braider should be such as to produce a basket weave with a braid angle and coverage within the following limits:

Diameter over Jacket (inches)	Percent Coverage		Braid Angle (°)	
	Min	Max	Min	Max
up to 0.600	88	94	30	60
0.601 to 1.000	88	94	35	60
1.001 to 1.500	88	94	40	70
1.501 to 2.000	88	94	45	70
2.001 and over	88	94	50	80

where the percent coverage = $(2F - F^2) \times 100$ and

$$F = \frac{NPd}{\sin a}$$

where a is the angle of braid with axis of cable:

$$\tan^{-1} a = \frac{2\pi DP}{C}$$

- d diameter of individual braid wires, in inches;
- C number of carriers;
- D diameter of cable under armor, in inches;
- N number of wires per carrier;
- P picks per inch of cable length.

The maximum number of ends per carrier should conform to the following:

Cable Diameter under Armor (inches)	Maximum Number of Ends per Carrier	
	"one over- one under"	"two over- two under"
0 to 0.400	8	5
0.401 to 0.800	12	8
0.801 to 1.500	15	10
1.501 and larger	20	10

18.10.3 Aluminum Armor. Aluminum armor braid should be Alclad 5056 or aluminum alloy 5056 having a minimum tensile strength of 50 000 psi and a minimum elongation of 2 percent in 10 in.

18.10.4 Commercial Bronze Armor. Commercial bronze armor braid should be annealed 90-10 bronze, Copper Development Association (CDA) alloy number 220.

18.11 Paint. Cables should not be painted except 5000 V types which should be painted yellow.

18.12 Dimension Tolerances. The measured maximum overall diameter of the finished cable should not be larger than given in Tables A19 through A25.

A minus tolerance of not more than 10 percent is permitted on the overall dimension. For cables having an overall diameter of less than 0.400 in, the minus tolerance need not be less than 0.040 in.

18.13 Tests on Finished Cable.

18.13.1 High Voltage. Each reel of finished cable should be tested and successfully withstand for a period of 5 min the high-voltage ac test potential given in Tables A15 and A16, as applicable. The ac potential should be applied between conductors and between conductors and ground for the time specified. Test should be in accordance with IEEE Std 4-1968 (ANSI C68.1-1968), Techniques for Dielectric Tests.

18.13.2 Insulation Resistance. Each reel of finished cable should be tested and should have an insulation resistance measured between each conductor and ground, of not less than that given in Tables A14 and A17. The current should be measured after a 1 min electrification with a continuous direct-current potential of not less than 100 V nor more than 500 V, the conductor being negative to ground. If the test is made at a temperature different from 15.5°C, the measured value should be multiplied with the proper correction factor as given in Table A18.

18.13.3 Bending Test (Type AV). A 10 ft sample of finished cable from each cable production run should be capable of being bent, at 25°C, 180 degrees around a mandrel of the following diameters:

Conductor Insulation Thickness (inches)	Mandrel Size (Multiple of Cable Diameter)	
	Conductor Size up to 500 MCM	Conductor Size 500 MCM and larger
up to 0.125	8	8
0.126 to 0.200	8	10
0.201 to 0.315	10	12

The sample should then be straightened and bent 180 degrees in opposite direction around the same mandrel. This cycle should be repeated, making a total of four bending operations.

The cable should be so held as not to revolve around its own axis during bending. After the bending test, the sample should be able to successfully withstand for a period of 5 min a voltage equal to 150 percent of the full reel test voltage given in Table A15.

18.13.4 Drip Test (Type AV). One 3 ft section of completed cable from each cable production run should be suspended in a vertical position in an oven maintained for a period of not less than 18 h at 95°C. No material should drip or exude from the end of the cable during the test.

18.13.5 Flammability Test. All cable constructions should be flame retarding as defined by acceptable performance in the flammability test of this paragraph. The following cables are considered typical for the purpose of this test and satisfactory performance of these cables will comprise acceptance of other cables of the same construction.

- (1) Distribution cables, 600V: AWG #6, three conductors.
- (2) Distribution cables, 5kV: AWG #6, three conductors.
- (3) Control cables: AWG #12 or #14, seven conductors.
- (4) Signal cables: AWG #18, seven pairs.

Six lengths of unarmored cable of the same type and size shall be arranged in a single layer in a vertical tray with a separation of $\frac{1}{2}$ the cable diameter between each cable. The group of 6 cables shall be centered in the tray.

The tray shall be a ladder-type, made of cold-rolled steel, 3 in deep and approximately 8 ft high. The tray may be bolted to a length of steel angle (or equivalent) for support.

The samples shall be fastened in the tray by suitable nonmetallic cable ties except at the

very top of the ladder where steel wire should be used for support.

The burner¹ shall be mounted horizontally behind the tray, 18 inches from the bottom of the vertical tray, midway between the tray side rails and so that the burner face is 3 inches behind the closest surface of the cables.

Under dynamic conditions, the air pressure shall be 4.3 ± 0.5 cm of water at the supply side of the Venturi mixer and the propane gas flow shall be adjusted so that an even steady flow rate is maintained for the entire 20 min test duration. The flow setting is to allow the proper weight of gas to be consumed with respect to the heating value of the fuel as provided by the supplier.

The flame created is to be approximately 14 to 16 in high with a flame temperature between 1600 F and 1750 F at a point 3 in from the burner face, centered and $1\frac{1}{4}$ above the center line of the burner. The potential heating value of the flame with the above setting would be approximately 70 000 BTU/h.

The following data shall be recorded after the flame has been allowed to burn for 20 min: (1) length of time of afterburn, (2) overall distance of damage to the jacket above the level of the burner, and (3) overall distance of damage to the individual conductors above the level of the burner.

The cable may be destroyed in the area of flame contact, but shall not propagate the flame. The cable is considered to be flame-retardant if the damage to the cable (blistering or charring of the jacket) does not reach the top of the 8 ft samples.

Cable Types

The construction details below are developed for armored cable. Unarmored cable may be used as stated in 19.10.

18.14 Mineral-Insulated Metal Sheathed Cable (Table A21).

18.14.1 Type MI mineral-insulated metal-sheathed cable is composed of one or more solid copper conductors insulated with a highly compressed refractory magnesium oxide insulation, firmly enclosed in a liquid-tight and

¹The flame source to be used shall be an American Gas Furnace Co., 10 in wide, 11-55 drilling, ribbon-type burner (Cat No 10x11-55) with air-gas American Gas Furnace Co. Venturi mixer, Cat No 14-18 (2 psig maximum pressure) with means for controlling the air and gas mixture to regulate the heat input in BTU.

gas-tight seamless copper tube sheathing. Type MI cables are rated 600 V and shall conform to the following:

18.14.1.1 Conductors. Conductors should be solid, uncoated, annealed copper complying with ASTM Specification B4 or B5, and should have nominal cross-sectional areas as listed in Table A21.

18.14.1.2 Insulation. Insulation should be finely divided, highly compressed refractory magnesium oxide.

18.14.1.3 Metal Sheath. The metal sheath should be a round continuous seamless copper tube to provide mechanical protection and a moisture seal and an adequate path for grounding purposes.

18.14.1.4 Conductor Arrangement. In single-conductor cables, the conductor and sheath should be essentially concentric. In multiconductor cables, all conductors should be parallel and radially symmetrical about the cable longitudinal axis.

18.15 Single-Conductor Asbestos Varnished Cloth-Insulated, Jacketed, and Armored (Tables A13, A12, A20).

Types: SAVIA, SAVIB

First: Stranded conductor.

Second: Wall of felted impregnated asbestos or asbestos tapes.

Third: Separator, optional when asbestos tapes are used.

Fourth: Varnished cloth insulation.

Fifth: Separator, optional when asbestos tapes are used.

Sixth: Wall of felted impregnated asbestos or asbestos tapes.

Seventh: Type T, CP, or N jacket.

Eighth: Basket-weave armor.

18.16 Two- or Three-Conductor Asbestos Varnished Cloth-Insulated, Jacketed, and Armored (Tables A12, A13, A20).

Types: DAVIA, DAVIB

TAVIA, TAVIB

First: Stranded conductor.

Second: Wall of felted impregnated asbestos or asbestos tapes.

Third: Separator, color coded.

Fourth: Varnished cloth insulation.

Fifth: Separator, optional when asbestos tapes are used.

Sixth: Wall of felted impregnated asbestos or asbestos tapes.

Seventh: Two to three conductors cables with suitable fillers.

Eighth: Belt of felted impregnated asbestos or asbestos tapes.

Ninth: Separator, optional.

Tenth: Type T, CP, or N jacket.

Eleventh: Basket-weave armor.

18.17 Single-, Two-, or Three Conductor, 5000 V, Asbestos Varnished Cloth-Insulated, Jacketed, and Armored (Tables A13, A12, A23).

Types: SAVIA-5kV SAVIB-5kV

DAVIA-5kV DAVIB-5kV

TAVIA-5kV TAVIB-5kV

Construction of single-conductor cable is same as Section 18.15 and of two- and three-conductor cables as Section 18.16 except for increased insulation as listed in Table A13.

Paint: Finished cable should be painted yellow.

18.18 Single-Conductor, Thermoset or Thermoplastic Insulated, Jacketed, and Armored (Tables A10, A12, A19).

Types: SXIA, SXIB

SEIA, SEIB

STIA, STIB

First: Stranded conductor tin- or alloy-coated where necessary to assure compatibility with insulation.

Second: Insulation, Type X, E, or T.

Third: Type T, CP, or N jacket.

Fourth: Basket-weave armor.

18.19 Two-, Three-, or Four-Conductor, Thermoset or Thermoplastic Insulated, Jacketed, and Armored (Tables A10, A12, A19).

Types: DXIA, DXIB TXIA, TXIB FXIA, FXIB

DEIA, DEIB TEIA, TEIB FEIA, FEIB

DTIA, DTIB TTIA, TTIB FTIA, FTIB

First: Stranded conductors tin- or alloy-coated where necessary to assure compatibility with insulation.

Second: Insulation: Type T; Type E or X with covering of N, CP, or jacket type T. Individuals color coded.

Third: Two, three, or four conductors cabled with fillers.

Fourth: Binder tape.

Fifth: Type T, CP, or N jacket.

Sixth: Basket-weave armor.

18.20 Three-Conductor, Thermoset Insulated, Jacketed, and Armored, 5000 V (Tables A10, A12, A22).

- Types:* TXIA-5kV TEIA-5kV
TXIB-5kV TEIB-5kV
- First:* Stranded conductors tin- or alloy-coated where necessary to assure compatibility with overlying material.
- Second:* Conductor shield of conducting nonmetallic tape or extruded compound, or both.
- Third:* Insulation: Type X or E with covering of N, CP, or jacket type T. Individuals color coded.
- Fourth:* Three conductors cabled with fillers.
- Fifth:* Binder tape.
- Sixth:* Type T, CP, or N jacket.
- Seventh:* Basket-weave armor.
- Eighth:* Paint. Finished cable should be painted yellow.

18.21 Single-Conductor, Silicone Insulated, Jacketed, and Armored (Tables A10, A12, A19).

- Types:* SSIA, SSIB
- First:* Stranded copper conductor.
- Second:* Insulation, type S.
- Third:* Glass or asbestos braid with finishing coat.
- Fourth:* Separator tape.
- Fifth:* Type T jacket.
- Sixth:* Basket-weave armor.

18.22 Two-, Three-, or Four-Conductor, Silicone Insulated, Jacketed, and Armored (Tables A10, A12, A19).

- Types:* DSIA TSIA FSIA
DSIB TSIB FSIB
- First:* Stranded copper conductor.
- Second:* Insulation, type S.
- Third:* Glass or asbestos braid with finishing coat pigmented to provide conductor identification.
- Fourth:* Two, three, or four conductors cables with suitable fillers where required.
- Fifth:* Binder tape.
- Sixth:* Type T jacket.
- Seventh:* Basket-weave armor.

18.23 Control Cable-Multiconductor, Thermoset-Insulated, Jacketed, and Armored (Tables A12, A24).

- Types:* C14XIA C14XIB
C16XIA C16XIB
C18XIA C18XIB
- First:* Stranded conductors, AWG Nos 14, 16, or 18.
- Second:* Insulation, type X, thickness 0.030 in, color coded (Table A26).
- Third:* Required number of conductors cabled with fillers where necessary.
- Fourth:* Binder tape.
- Fifth:* Type T, CP, or N jacket.
- Sixth:* Basket-weave armor.

18.24 Control Cable-Multiconductor, Thermoplastic Insulated, Jacketed, and Armored (Tables A12, A24).

- Types:* C14TIA C14TIB
C16TIA C16TIB
C18TIA C18TIB
- First:* Stranded conductors, AWG Nos 14, 16, or 18.
- Second:* Insulation, type T, thickness 0.030 in, color coded (Table A26).
- Third:* Required number of conductors cabled with fillers where necessary.
- Fourth:* Binder tape.
- Fifth:* Type T jacket.
- Sixth:* Basket-weave armor.

18.25 Signal Cable, Twisted Pair, Thermoplastic Insulated, Jacketed, and Armored (Tables A12, A25).

- Types:* TP16TIA TP16TIB
TP18TIA TP18TIB
TP20TIA TP20TIB
- First:* Stranded conductors, AWG Nos 16, 18, or 20.
- Second:* Type T insulation, thickness 0.025 in. Color code one conductor in each pair (Table A26).
- Third:* Two conductors twisted together with a maximum lay length of 2.5 in to form a pair.
- Fourth:* The required number of pairs cabled with fillers where necessary.

- Fifth:* Binder tape.
Sixth: Type T jacket.
Seventh: Basket weave armor.

18.26 Signal-Cable, Twisted-Pair, Shielded, Thermoplastic-Insulated, Jacketed, and Armored (Tables A12, A25).

- Types:* TPS16TIA TPS16TIB
 TPS18TIA TPS18TIB
 TPS20TIA TPS20TIB
- First:* Stranded conductors AWG # 16, 18, or 20.
- Second:* Type T insulation, thickness 0.025 in.
- Third:* Two conductors twisted together with maximum lay length of 2.5 in to form pair with stranded tinned drain wire in one interstice.
 16 and 18 AWG pairs — # 20 AWG drain wire
 20 AWG pairs — # 22 AWG drain wire.
 Color code one conductor in each pair (Table A26).
- Fourth:* Shielded by a polyester supported aluminum foil tape spirally wrapped with foil face inward. Nominal thickness polyester 0.0005 in, aluminum foil 0.00035 in.
- Fifth:* The required number of shielded pairs cabled with fillers where necessary.
- Sixth:* Binder tape.

- Seventh:* Type T jacket.
Eighth: Basket-weave armor.

18.27 Cable Designations. The following cable designations should be used in connection with the cables described in 18.14 to 18.26 inclusive. The designations are made up of letters and number signifying to the extent shown below the service, number of conductors, types of insulation, moisture-resistant jacket, armor, and conductor size.

Specific types include the following additions to the designations shown in the "Legend."

The wire size of distribution cables is designated by adding to the cable symbol the circular mil size in thousands, thus:

DTIB-4 = No 14 (4110 CM), two-conductor, thermoplastic-type T-insulated, moisture-resistant jacket, and bronze armored.

SAVIA-250 = 250 000 CM, single conductor, asbestos varnished cloth insulated, moisture-resistant jacket, and aluminum armor.

For 5000 V rated cables a suffix, -5kV, is added to the symbol.

The wire size of control and signal cable types is designated by inserting the AWG size immediately following the service symbol. The number of conductors of control, and the number of conductor pairs of signal cable, is added to the cable designation, thus:

C14TIB-20 = 20 conductor control cable, AWG No 14, thermoplastic-insulated, jacketed, and bronze armor.

TP18TIA-10 = 10 twisted pair signal cable, AWG # 18, thermoplastic-insulated, jacketed, and aluminum armor.

Legend

	Cable Type		Insulation		Jacket		Armor
S	Single Conductor-Distribution	E	Ethylene Propylene Rubber	I	Moisture-Resistant Jacket, Type T, CP, or N	A	Aluminum
D	Double Conductor-Distribution	X	Cross-Linked Polyethylene			B	Bronze
T	Three-Conductor-Distribution					(None)	Unarmored
F	Four-Conductor-Distribution	T	Polyvinyl Chloride				
C	Control	AV	Asbestos-Varnished Cloth				
TP	Signal (Twisted Pair)						
TPS	Shielded Signal (Twisted Pair Shielded)	M	Mineral				
		S	Silicone				

Section Number	Type	Designation
18.14	Single Conductor, Mineral Insulated	SM
18.14	Two Conductor, Mineral Insulated	DM
18.14	Three Conductor, Mineral Insulated	TM
18.14	Four Conductor, Mineral Insulated	FM
18.14	Seven Conductor, Mineral Insulated	MM
18.15	Single Conductor, Asbestos-Varnished Cloth Insulated, Jacketed, Aluminum Armor	SAVIA
18.15	Single Conductor, Asbestos-Varnished Cloth Insulated, Jacketed, Bronze Armor	SAVIB
18.16	Two Conductor, Asbestos-Varnished Cloth Insulated, Jacketed, Aluminum Armor	DAVIA
18.16	Two Conductor, Asbestos-Varnished Cloth Insulated, Jacketed, Bronze Armor	DAVIB
18.16	Three Conductor, Asbestos-Varnished Cloth Insulated, Jacketed, Aluminum Armor	TAVIA
18.16	Three Conductor, Asbestos-Varnished Cloth Insulated, Jacketed, Bronze Armor	TAVIB
18.17	Single Conductor, Asbestos-Varnished Cloth Insulated, Jacketed, 5kV, Aluminum Armor	SAVIA-5kV
18.17	Single Conductor, Asbestos-Varnished Cloth Insulated, Jacketed, 5kV, Bronze Armor	SAVIB-5kV
18.17	Two Conductor, Asbestos-Varnished Cloth Insulated, Jacketed, 5kV, Aluminum Armor	DAVIA-5kV
18.17	Two Conductor, Asbestos-Varnished Cloth Insulated, Jacketed, 5kV, Bronze Armor	DAVIB-5kV
18.17	Three Conductor, Asbestos-Varnished Cloth Insulated, Jacketed, 5kV, Aluminum Armor	TAVIA-5kV
18.17	Three Conductor, Asbestos-Varnished Cloth Insulated, Jacketed, 5kV, Bronze Armor	TAVIB-5kV
18.18	Single Conductor, X-Linked Polyethylene Insulated, Jacketed, Aluminum Armor	SXIA
18.18	Single Conductor, X-Linked Polyethylene Insulated, Jacketed, Bronze Armor	SXIB
18.18	Single Conductor, Ethylene Propylene Rubber Insulated, Jacketed, Aluminum Armor	SEIA
18.18	Single Conductor, Ethylene Propylene Rubber Insulated, Jacketed, Bronze Armor	SEIB
18.18	Single Conductor, Thermoplastic Polyvinyl Chloride Insulated, Jacketed, Aluminum Armor	STIA
18.18	Single Conductor, Thermoplastic Polyvinyl Chloride Insulated, Jacketed, Bronze Armor	STIB
18.19	Two Conductor, X-Linked Polyethylene Insulated, Jacketed, Aluminum Armor	DXIA
18.19	Two Conductor, X-Linked Polyethylene Insulated, Jacketed, Bronze Armor	DXIB
18.19	Two Conductor, Ethylene Propylene Rubber Insulated, Jacketed, Aluminum Armor	DEIA
18.19	Two Conductor, Ethylene Propylene Rubber Insulated, Jacketed, Bronze Armor	DEIB
18.19	Two Conductor, Thermoplastic Polyvinyl Chloride Insulated, Jacketed, Aluminum Armor	DTIA
18.19	Two Conductor, Thermoplastic Polyvinyl Chloride Insulated, Jacketed, Bronze Armor	DTIB
18.19	Three Conductor, X-Linked Polyethylene Insulated, Jacketed, Aluminum Armor	TXIA
18.19	Three Conductor, X-Linked Polyethylene Insulated, Jacketed, Bronze Armor	TXIB
18.19	Three Conductor, Ethylene Propylene Rubber Insulated, Jacketed, Aluminum Armor	TEIA
18.19	Three Conductor, Ethylene Propylene Rubber Insulated, Jacketed, Bronze Armor	TEIB
18.19	Three Conductor, Thermoplastic Polyvinyl Chloride Insulated, Jacketed, Aluminum Armor	TTIA
18.19	Three Conductor, Thermoplastic Polyvinyl Chloride Insulated, Jacketed, Bronze Armor	TTIB
18.19	Four Conductor, X-Linked Polyethylene Insulated, Jacketed, Aluminum Armor	FXIA
18.19	Four Conductor, X-Linked Polyethylene Insulated, Jacketed, Bronze Armor	FXIB
18.19	Four Conductor, Ethylene Propylene Rubber Insulated, Jacketed, Aluminum Armor	FEIA
18.19	Four Conductor, Ethylene Propylene Rubber Insulated, Jacketed, Bronze Armor	FEIB
18.19	Four Conductor, Thermoplastic Polyvinyl Chloride Insulated, Jacketed, Aluminum Armor	FTIA
18.19	Four Conductor, Thermoplastic Polyvinyl Chloride Insulated, Jacketed, Bronze Armor	FTIB
18.20	Three Conductor, X-Linked Polyethylene Insulated, 5kV, Aluminum Armor	TXIA-5kV
18.20	Three Conductor, X-Linked Polyethylene Insulated, 5kV, Bronze Armor	TXIB-5kV
18.20	Three Conductor, Ethylene Propylene Rubber Insulated, Jacketed 5 kV Aluminum Armor	TEIA-5kV
18.20	Three Conductor, Ethylene Propylene Rubber Insulated, Jacketed 5 kV Bronze Armor	TEIB-5kV
18.21	Single Conductor, Silicone Insulated, Jacketed, Aluminum Armor	SSIA
18.21	Single Conductor, Silicone Insulated, Jacketed, Bronze Armor	SSIB
18.22	Two Conductor, Silicone Insulated, Jacketed, Aluminum Armor	DSIA
18.22	Two Conductor, Silicone Insulated, Jacketed, Bronze Armor	DSIB
18.22	Three Conductor, Silicone Insulated, Jacketed, Aluminum Armor	TSIA
18.22	Three Conductor, Silicone Insulated, Jacketed, Bronze Armor	TSIB
18.22	Four Conductor, Silicone Insulated, Jacketed, Aluminum Armor	FSIA
18.22	Four Conductor, Silicone Insulated, Jacketed, Bronze Armor	FSIB

Section Number	Type	Designation
18.23	Control, Thermoset Insulated, Jacketed, Aluminum Armor	CXIA
18.23	Control, Thermoset Insulated, Jacketed, Bronze Armor	CXIB
18.24	Control, Thermoplastic Insulated, Jacketed, Aluminum Armor	CTIA
18.24	Control, Thermoplastic Insulated, Jacketed, Bronze Armor	CTIB
18.25	Signal, Twisted Pairs, Thermoplastic Insulated, Jacketed, Aluminum Armor	TPTIA
18.25	Signal, Twisted Pairs, Thermoplastic Insulated, Jacketed, Bronze Armor	TPTIB
18.26	Signal, Shielded Twisted Pairs, Thermoplastic Insulated, Jacketed, Aluminum Armor	TPSTIA
18.26	Signal, Shielded Twisted Pairs, Thermoplastic Insulated, Jacketed, Bronze Armor	TPSTIB

19. Cable Application

19.1 General. The cable constructions listed in Section 18 are designed for installation and use in a marine environment for the services defined herein. A variety of constructions are detailed permitting a selection of conductor insulations, jacket types, and ampacities for the general usage distribution-type cables. Cable constructions intended for other specific applications and different voltages are also included. The applications of the various types are defined below.

These cables are designed particularly to meet the recognized special environmental, installation, and reliability requirements of marine service. The design and characteristics of any cables used other than those defined in this Section should be carefully evaluated to assure a total cable equivalency with respect to flame retardance, conductor material and temperature rise, insulation characteristics and life, and jacket flexibility and resistance to adverse marine installation and service conditions.

19.2 Distribution Cables (600 V) (See 18.14-18.16, 18.18, 18.19, 18.21, 18.22). These cables should be used for the distribution of power up to their voltage rating throughout the system, and may be used in lighting, communication, control, and electronic circuits as desired.

19.3 Distribution Cables (Medium Voltage, 5000 V) (See 18.17; 18.20). These cables should be used for the distribution of two- or three-wire direct current and for three-phase alternating-current power up to their voltage rating.

19.4 Control Cables (600 V) (See 18.23, 18.24). These cables should be used for control, indicating, communication, electronic, and similar circuits where multiple parallel conductor cables are required. Conductor size selection should be made with particular attention to voltage drop considerations.

19.5 Signal Cables (300 V) (See 18.25, 18.26). These cables should be used for signal transmission where twisted pairs of conductors are desired. One of the two designs provides a drain (ground) wire and a shield for each twisted pair.

19.6 Special Service Requirements. Cables, cords, and wires required for applications not otherwise defined should be in accordance with the following.

19.6.1 Portable Cords, Jacketed, Two-, Three-, or Four-Conductor. These cords should be used only for connection of portable lamps and appliances and other equipment not suitable for fixed wiring and should conform to the requirements of Type SJ, SJO, or SJT and, for hard service, to Type S, SO, or ST as specified by ANSI-C33.1-1975 (Underwriters Laboratory Std UL 62-July 1975), Safety Standard for Flexible Cord and Fixture Wire. Portable cords and cables, as specified by MIL-C-915, may also be used. Ampacities of cords and cables should be as defined by the National Electric Code or the Naval Cable Comparison Guide (NAVSEA 0981-052-8090) as applicable.

19.6.2 Coaxial Cables. These cables should be selected in accordance with MIL Specification MIL-C-17.

19.6.3 Switchboard Wiring. See 17.2.

19.6.4 Wires. Component insulated wiring should be selected from a recognized commercial standard or military specification MIL-W-16878 with particular attention to the effects of vibration, moisture, ambient temperature, and other adverse conditions as contaminants and oils which may be present.

19.6.5 Special Applications. Flexible cables used for special applications such as elevators and cranes should meet an appropriate Underwriters Laboratory Standard, MIL Specification, or IPCEA Standard S68-516.

19.7 Alternating-Current Applications. In general, multiple-conductor cable should be used for all alternating-current lighting and power circuits. All phase wires of any circuit should be contained in a single cable to neutralize induction except as noted below.

If the rating of any circuit is such that the current is greater than the rated capacity of any one multiple-conductor cable, two or more multiple-conductor cables may be connected in parallel. One conductor of each phase of the circuit should be contained in each cable.

Where the use of multiple-conductor cable will involve a difficult or undesirable arrangement or where the use of single-conductor cables will not incur heating of adjacent equipment or structure, single-conductor cables may be used for relatively short runs within a single compartment.

19.8 Ampacities. The current-carrying capacities of the various cable types are tabulated in the following Tables:

Distribution:	Table A6
Control:	Table A24.
Signal:	Table A25.

Ampacities should be adjusted as noted to suit the ambient temperature in which the cable is installed if it differs from 50°C. Distribution type cable ampacities in Table A6 are for single banked rack installations. Double banking of distribution type cables should be avoided.

Mineral-insulated cable ampacities are tabulated in Table A21.

19.9 Ambient Temperature. The use of the various conductor insulations are restricted to the following maximum ambient temperatures:

Type	T—50°C
	E—60°C
	X—60°C

S—70°C
AV—70°C
MI—See Section 19.11.

19.10 Armor. The use of armored cable as defined in Section 18 is recommended for all types except type MI.

Cables as described herein may be used without armor, if desired, provided special precautions are observed. Unarmored cables are more subject to damage during handling and installation, particularly to the watertight jacket, unless care is exercised to avoid excessive pulling-in force, tearing of the jacket by pulling over metal or burrs, reduction of the jacket thickness by sliding against metal or other cables, rupture or cracking by sharp bends, and similar handling problems. Unarmored cables also require greater protection from weld splatter during construction.

19.11 Mineral-Insulated Metal Sheathed Cable. Type MI cable may be used up to 600 V for any service defined for the cables in Section 18 except where twisted pairs of conductors are required. Special fittings are required at the conductor terminations which determine the permissible conductor temperature and the allowable ampacity. The sheath of the MI cable if exposed to destructive corrosion conditions should be protected against detrimental effects by suitable corrosion-resistant material.

20. Cable Installation

20.1 General. For alternating-current installations, to avoid undesirable inductive effect, all of the following precautions should be observed in installations of single-conductor cable as described in Section 19:

(1) There should be no closed magnetic circuit around single-conductor cable unless it encloses all conductors of the circuit.

(2) Magnetic material between conductors should be avoided.

(3) Single conductors parallel to a steel bulkhead or other extensive surface of magnetic material should be separated therefrom by at least 2 in.

20.2 Cable Continuity and Grounding. All cables should be continuous between terminations, however, splicing is permitted under certain conditions (See 20.11). For any cable

provided with a metallic sheath or armor, the sheath should be continuous from outlet to outlet and should be grounded at each end except that for final subcircuits the sheath may be grounded at the supply end only. Sheathed or armored cables entering nonwatertight boxes or wiring devices should have the sheath or armor secured outside the box by means of a clamp, attached by locknut to, or screwed into the box.

20.3 Cable Locations. Cables of every description should be located with a view to avoiding spaces where excessive heat and gases may be encountered such as galleys, firerooms, and pumprooms; also spaces where exposed to damage such as cargo spaces and exposed sides of deck houses. Cables should not be located in cargo tanks, ballast tanks, fuel tanks, or water tanks except to supply equipment and instrumentation specifically designed for such locations and whose functions require it to be installed in the tank. Such equipment might include submerged cargo pumps and associated control devices, cargo monitoring instrumentation and underwater navigation systems. For cables associated with hazardous areas see Section 43.

Unless unavoidable, cables should not be located behind or embedded in structural heat insulation and where they pass through such insulation each cable should be protected by a continuous pipe, preferably fitted with a watertight stuffing tube at each end. For wiring entering refrigerated compartments the pipe should be of heat-insulating material (fiber or phenolic tubing) joined to the bulkhead stuffing tube or a section of such material should be inserted between the bulkhead stuffing tube and the metallic pipe. Where cables are installed behind paneling, all connections should be readily accessible, and the location of concealed connection boxes should be indicated.

Wireways should preferably not be run through refrigerated cargo spaces.

Generator cables should not be located in bilges unless no other run is practicable.

Cables in resistor rooms or in spaces occupied by resistors should be so arranged that their location directly over resistors is held to a minimum.

20.4 Cable Protection. All cables in bunkers and where particularly liable to damage such

as locations in way of cargo ports, hatches, tank tops and where passing through decks should be specifically protected by removable metal coverings, angle irons, or other equivalent means. Horizontal pipes or equivalent used for cable protection should have $\frac{1}{4}$ in diameter holes for drainage every 5 ft.

20.5 Cable Support. Cables where installed in groups should be supported, preferably in metal hangers, arranged as far as practicable to permit painting surrounding structure without undue disturbance of the installation. Distribution cables grouped in a single hanger should be limited to single banking, except under the limitations in Note 6 of Table A6. Control and signal cables should preferably be single banked but may be double banked only with other cables of these types.

Cables run in hangers should be strapped at every hanger on vertical runs and at not less than every fourth hanger on horizontal runs, except at turns of horizontal runs the cables should be strapped at each hanger. Clips or straps used for cable support should each be secured by two screws except that clips for supporting one cable, #10 AWG twin or smaller, may be of the one-screw type. Metallic band strapping used for cable support should be secured by metal buckles or other suitable methods. Metallic banding should be steel, a minimum of $\frac{5}{8}$ in wide by 0.015 in thick and corrosion treated if not a corrosion-resistant material. Except as noted in 20.12 and 102.10(4) cable supports should be spaced not more than 24 in apart.

Metal supports should be designed to secure cables without damage to armor or insulation and should be so arranged that the cable will bear for a length of at least $\frac{1}{2}$ in.

20.6 Cables—Radius of Bends. Armored cables should not be bent to a radius of less than 8 cable diameters. Unarmored cables may be bent to a radius of 6 diameters. For MI cables see 20.12.

20.7 Cables Through Bulkheads, Decks, Beams, Etc. Where cables pass through watertight decks or bulkheads, a watertight penetrator or watertight stuffing tubes, capable of taking packing, should be employed.

Multicable penetrators (See 2.28) may be used for passage of cables through nonwatertight bulkheads.

Where cables pass through nonwatertight bulkheads, beams, etc, a suitable bushing should be used of such a type as will permit drawing of the cable without damage. When the thickness of the bulkhead or web is $\frac{1}{4}$ in or more the bushing may be omitted but the edges of the holes should be rounded.

Where cables pass through fire boundaries, arrangements should be made to ensure that the integrity of the bulkhead is not impaired. Nonmetallic stuffing tubes should not be used in such penetrations.

20.8 Cable—Pulling-in Force. No cable should be drawn into wireways where the required pull exceeds twenty times the weight of the cable within the wireway, and no appliance should be used which will damage the braid or armor.

20.9 Cable—Ratproofing. During the installation of cables due consideration should be given to the feasibility of ratproofing as required by the U.S. Public Health Service.

20.10 Holes for Cables. The size of holes required for the installation of the cables for various systems should be such that they will not affect the structural strength of the various members through which they pass. However, if the size or position of the hole is such that the strength of the structural member is affected, suitable reinforcing of the structural member should be provided.

20.11 Cable Splicing (600 V or less). A cable for 600 V or less may be spliced under the following conditions:

(1) A cable installed in a structural subassembly may be spliced to a cable installed in another structural subassembly.

(2) For a vessel receiving alterations, a cable may be spliced to extend a circuit.

(3) A cable of exceptional length may be spliced to facilitate its installation.

(4) A cable may be spliced to replace a damaged section of the cable if before replacing the damaged section the remainder of the cable is determined to be in good mechanical and electrical condition.

Splices should be accessible. Cables for repeated flexing service should not be spliced.

Cable splicing should consist of a conductor connector, replacement cable insulation, re-

placement cable jacket, and reestablishment of electric continuity in the armor of armored cable. Splicing should be performed as follows:

(1) Conductors should be joined using a pressure type butt connector, listed by Underwriters' Laboratories, under UL Std 486 (Wire Connectors and Soldering Lugs). A one-cycle compression tool should be used.

The connection in cables of more than one conductor should be staggered in such a way that the connector for each conductor is in no way contiguous to the connector of an adjacent conductor. The connection in single conductor cable should be made equidistant from both ends of the splice. The conductor insulation should be removed no more than necessary to accept the connector.

(2) Conductor replacement insulation should have the same or a greater thickness than that of the cable insulation, and should have thermal and electrical properties of the cable insulation. Conductor replacement insulation should be centered over the connector and be at least $2\frac{1}{2}$ in longer than the connector.

(3) Replacement cable jacket should be centered over the splice and overlap the existing cable jacket by at least 2 in. The replacement cable jacket should be of such a diameter and be installed in such a way as to make a watertight seal with the existing cable jacket and should have physical properties that are the same as or equivalent to those of the cable jacket.

(4) Electrical continuity of the armor of armored cable should be reestablished by a jumper of wire or braid or by replacement armor of the same metal as the cable armor. The method of securing the replacement armor or jumper should not exert more pressure than is necessary to establish adequate electrical contact.

20.12 Mineral-Insulated Metal Sheathed Cable, Type (MI). Mineral-insulated metal sheathed cable should be securely supported by straps, hangers, or similar fittings, so designed and installed as not to injure the cable sheath. Cable should be secured at suitable intervals to support the cable and insure against effects of vibration, etc, except where run in conduit.

In wet locations, the entire wiring system, including all boxes and fittings used therewith, should be made watertight and the cable