

IEEE

No. 45

FEB. 1967

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Recommended Practice
for
ELECTRIC INSTALLATIONS
ON SHIPBOARD

(Effective February 20, 1967)

IEEE No. 45



PUBLISHED BY

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Foreword

"Recommended Practice for Electric Installations on Shipboard", IEEE Standard No. 45, constitutes the chief undertaking of the Committee on Marine Transportation of the Institute of Electrical and Electronics Engineers.

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 Committee on Marine Transportation) 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 Rules were considerably amplified in the editions issued in 1920, 1927, 1930, 1938, 1940, 1945, 1948, 1951, 1955, 1958 and 1962.

The 1966 Marine Transportation Committee personnel follows:

W. A. HALL, <i>Chairman</i> General Electric Co.	J. W. HECK American Bureau of Shipping
H. E. SENDER, <i>Vice Chairman</i> Moore-McCormack Lines, Inc.	D. B. HOOVER Westinghouse Electric Corp.
W. N. ZIPPLER, <i>Secretary</i> Gibbs & Cox, Inc.	W. E. JACOBSEN General Electric Co.
W. L. AITKENHEAD U. S. Coast Guard	V. W. MAYER U. S. Maritime Administration
J. M. APPLE U. S. Department of the Navy	L. R. PARKER Esso International, Inc.
J. A. BRITTON The Atlantic Refining Co.	E. M. ROTHEN Russell & Stoll Co., Inc.
S. B. COHEN Sperry Gyroscope Co.	J. D. SHUSTER J. E. Bowker Associates
R. W. FROST Henschel Corp.	G. O. WATSON Engineering Consultant, England
E. A. GEARY New York Shipbuilding Corp.	G. H. WELCH I-T-E Circuit Breaker Co.
D. GRAY Lloyd's Register of Shipping	J. D. WESTBROOK Newport News Shipbuilding & Dry Dock Co.
G. N. HAUSER Cutler-Hammer, Inc.	M. ZIEV Philadelphia Naval Shipyard
S. A. HAVERSTICK Westinghouse Electric Corp.	

Recommended Practice

for

ELECTRIC INSTALLATIONS ON SHIPBOARD

SECTION 1

GENERAL

1.01 Scope.—These Marine Recommendations have been drawn up to serve as a guide for the equipment of merchant vessels with an electric plant system and electric apparatus for lighting, signaling, communication, power, and propulsion. They indicate what is considered good engineering practice with reference to safety of the personnel and of the ship itself as well as reliability and durability of the apparatus; it is not intended, however, that improvements, which may be developed from time to time, should be excluded.

These Recommendations are intended to supplement the other Standards of the IEEE, which should be followed wherever applicable.

Attention is directed to the fact that regulations for electric installations on shipboard are promulgated by the Government Regulatory Agencies and the American Bureau of Shipping. These Recommendations have given due consideration to all the regulations, but since the above referenced sponsoring bodies frequently modify the requirements to meet changing conditions, reference should always be made to the latest edition of their requirements.

1.03 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 miles or more off-shore.

Group No. 2—Ocean going vessels which navigate on any ocean or the Gulf of Mexico but less than 20 miles 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.

1.05 Vessel Classification Groups Covered Herein

—Since this standard is promulgated only as a recommendation, the general thought in its preparation has been for its application to all passenger and cargo vessels of Groups No. 1, No. 2 and No. 3, but it is believed that many of the recommendations are applicable to all groups of vessels if a high standard electric installation is desired. Certain sections herein, notably Section 36—Emergency Light and Power System, contain recommendations for vessels in Groups Nos. 1 to 5 inclusive.

1.07 Plans.—Every vessel should be provided with plans giving complete and detailed information as to circuits, wire sizes, load, etc., for the light, power,

and communication systems. A symbol list giving the manufacturer's name, size, type, rating, catalog number or similar identification for all the equipment on the vessel should also be provided for the vessel's operating personnel. One-line diagrams of the main switchboard and of the entire ship's distribution system should be permanently installed in locations accessible at all times to the engineering personnel.

1.09 Symbols.—In order to standardize practices of the various design offices, manufacturers, and shipbuilders, the symbols for shipboard electric equipment shown in the Appendix herein are recommended for use on plans furnished in accordance with Subsection 1.07.

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

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

(b) 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.

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

(d) 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.

(1) 40C in quarters, passages, etc.

(2) 50C in machinery spaces (boiler, engine, ship's service generator, and evaporator rooms), and other spaces containing heat sources of considerable magnitude.

1.13 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 application of the equipment. Examples of such conditions are:

(a) Exposure to damaging fumes or vapors, excessive or abrasive dust, steam, salt spray, etc.

(b) Exposure to abnormal vibration, shocks, or tilting.

(c) Exposure to excessively high or low temperatures.

(d) Exposure to unusual transportation or storage conditions.

(e) Unusual operating duty, frequency of operation, difficulty of maintenance, poor wave form, unbalanced voltage, special insulation requirements, etc.

(f) Exposure to explosive mixtures of gases in the following and similar locations:*

- (1) Battery rooms.
- (2) Storage and mixing rooms for paint and allied products.
- (3) Storage rooms for oil, oil lamps, etc.
- (4) Hospital operating rooms (within five feet above deck).
- (5) Areas in which highly volatile motor fuel, such as gasoline, is stored in self-propelled vehicles. (These areas include the entire area below the weather deck and to a height of four feet above the deck on each deck at or above the weather deck, on which vehicles are transported.)
- (6) Cofferdams adjacent to, or access trunks to, compartments or tanks in which volatile liquids or gases are stored.

(7) Similar spaces in which explosive accumulations of gases, mixtures or highly flammable substances may be present.

Cargo Vessels of the Bulk Oil Carrier Type

- (1) The applicable spaces listed above.
- (2) Open deck areas where explosive gases may accumulate.
- (3) Areas under deck houses immediately above tanks.

*Explosionproof equipment only, as approved by the Underwriters' Laboratories for the particular class and group of hazardous location, should be used in spaces where explosive accumulations of flammable dusts, vapors, or gases may exist, except that separately enclosed and ventilated motors or sealed motors with built-in air coolers may be used if approved by the cognizant Government Regulatory Agencies.

DEFINITIONS

SECTION 2*

GENERAL DEFINITIONS

- 2.01 Cargo Vessel.**—A cargo vessel is one that carries solids or liquids as freight, and no more than twelve (12) passengers.
- 2.03 Quarters.**—Quarters, where used in these recommendations, are those spaces provided for passengers and/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.
- 2.05 Machinery Spaces.**—Machinery spaces, where used in these recommendations, are 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.
- 2.07 Direct Current.**—A direct current is 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 non-pulsating current.)
- 2.09 Alternating Current.**—An alternating current is a periodic current the average value of which over a period is zero. (Unless distinctly specified otherwise, the term "alternating current" refers to a circuit which reverses at regularly recurring inter-

vals of time and which has alternately positive and negative values.)

- 2.11 Cycle.**—A cycle is 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.)
- 2.13 Frequency.**—The frequency of a periodic quantity, in which time is the independent variable, is the number of periods occurring in unit time.
- 2.15 Hertz.**—The unit of frequency, one cycle per second.
- 2.17 Single-Phase Circuit.**—A single-phase circuit is 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.

- 2.19 Three-Phase Circuit.**—A three-phase circuit is a combination of circuits energized by alternating electromotive forces which differ in phase by one-third of a cycle, i.e., 120 degrees.

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

- 2.21 Slip.**—The slip of an induction machine is the difference between its synchronous speed and its operating speed and may be expressed in the following ways:

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

(ASA C42 10.91.030)

- 2.23 Embedded Temperature Detector.**—An embedded temperature detector is a resistance thermometer or thermocouple built into a machine for the purpose of measuring the temperature. (ASA C42 10.11.335)

- 2.25 Electronics.**—Electronics is that branch of science and technology which relates to the conduction of electricity through gases or in vacuo.

*Notes 1—In Sections 2 to 14 that portion of the definition appearing ahead of the identification (ASA C42) duplicates the definition of the number shown herein as given in the latest edition of the appropriate part of American Standard C42. That portion in parentheses is added by the Marine Transportation Committee and by IEEE nomenclature is identified as "discussion".

2—IEEE has agreed to use the International System of Units (Symbol SI) as far as practicable in all new publications. Since the revisions to this publication were approved by the Marine Transportation Committee prior to the IEEE ruling, the original units are used in the text but may be translated to the International System of Units by the conversion factors as standardized by IEEE.

2.27 Loran.—A loran is 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.

2.29 Radar.—A radar is a device which radiates electromagnetic waves and utilizes the reflection of such waves from distant objects to determine their existence or position.

2.31 Capacitor.—(Condenser). A capacitor is 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.

2.33 Capacitance.—(Capacity). Capacitance is 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.

2.35 Reactor.—A reactor is 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.

2.37 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 periodic current has not yet been agreed upon.

2.39 Metallic Rectifier.—A metallic rectifier cell is a device, consisting of a conductor and semi-conductor 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. A metallic rectifier stack is a single columnar structure of one or more metallic rectifier cells.

2.41 Direct-Current Commutating Machine.—A direct-current commutating machine comprises a magnetic field excited from a direct-current 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.

(ASA C42 10.21.005)

2.43 Synchronous Machines.—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.

2.45 Asynchronous Machine.—An asynchronous machine is one in which the speed of operation is not proportional to the frequency of the system to which it is connected. (ASA C42 10.01.020)

2.47 Induction Machine.—An induction machine is an asynchronous alternating-current 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. (ASA C42 10.01.025)

2.49 Electric Coupling.—An electric coupling is 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.

2.51 Corrosion-Resistant Parts.—

(a) 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.

(b) 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.

(c) 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

Sheradizing
Galvanizing

Dipping and Painting—Phosphate or suitable cleaning, followed by the application of zinc chromate primer or equivalent.

(d) These provisions should apply to the following:

Parts—Interior small parts which are normally expected to be removed in service, such as bolts, nuts, pins, screws, cap screws, terminals, brush-holder studs, springs, etc.

Assemblies, subassemblies and other units—Where necessary due to the unit function, or for interior protection, such as shafts within a motor or generator enclosure, and surface of stator and rotor.

Enclosures and their fastenings and fittings—Such as enclosing cases for control apparatus and outer cases for signal and communication systems (both outside and inside), and all their fastenings and fittings which would be seriously damaged or rendered ineffective by corrosion.

- 2.53 Flame-Retarding (Flame Resisting).**—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 apparatus and according to the methods described in the Underwriters' Laboratory Standards for the materials and structures.

SECTION 3

GENERATOR CLASSIFICATION

- 3.01 Electric Generator.**—An electric generator is a machine which transforms mechanical power into electric power. (ASA C42 10.01.035)
- 3.03 Shunt-Wound Generator.**—A shunt-wound generator is a direct-current 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.
- 3.05 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 generator is to comply with that given for shunt-wound generators.
- 3.07 Compound-Wound Generator.**—A compound-wound generator is a direct-current 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.
- 3.09 Magnetolectric Generator.**—A magnetolectric generator is an electric generator, in which the magnetic flux is provided by one or more permanent magnets. (ASA C42 10.01.080)
- 3.11 Exciter.**—An exciter is the source of all or part

of the field current for the excitation of an electric machine. (ASA C42 10.036.010)

- 3.13 Pilot Exciter.**—A pilot exciter is the source of all or part of the field current for the excitation of another exciter. (ASA C42 10.36.020)
- 3.15 Synchronous Generator.**—A synchronous generator is 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.)
- 3.17 Single-Phase Synchronous Generator.**—A single-phase synchronous generator is one which produces a single alternating electromotive force at its terminals. It delivers electric power which pulsates at double frequency. (ASA C42 10.01.115)
- 3.19 Polyphase Synchronous Generator.**—A polyphase synchronous generator is one whose alternating-current 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. (ASA C42 10.01.120) (Polyphase generators as used for marine service are generally three-phase. For special cases they may be two-phase.)
- 3.21 Inductor Type Synchronous Generator.**—An inductor type synchronous generator is one 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. (ASA C42 10.01.130)
- 3.23 Induction Generator.**—An induction generator is an induction machine, driven above synchronous speed by an external source of mechanical power. (ASA C42 10.01.135)
- 3.25 Brushless Exciter.**—A brushless exciter is an ac (rotating armature type) exciter whose output is rectified by a semiconductor device to provide excitation to an electric machine.
- 3.27 Brushless Synchronous Machine.**—A brushless machine is 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.

SECTION 4

MOTOR CLASSIFICATION

- 4.01 Electric Motor.**—An electric motor is a machine which transforms electric power into mechanical power. (ASA C42 10.01.145)
- 4.03 Universal Motor.**—A universal motor is 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 cycles per second and of approximately the same rms voltage. (ASA C42 10.01.150)

4.05 Shunt-Wound Motor.—A shunt-wound motor is a direct-current motor in which the field circuit and armature circuit are connected in parallel. (ASA C42 10.01.230)

4.07 Stabilized Shunt-Wound Motor.—A stabilized shunt-wound motor is 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. (ASA C42 10.01.235)

4.09 Series-Wound Motor.—A series-wound motor is a commutator motor in which the field circuit and armature circuit are connected in series. (ASA C42 10.01.240) (It operates at a much higher speed at light load than at full load.)

4.11 Compound-Wound Motor.—A compound-wound motor is 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. (ASA C42 10.01.245) (The characteristics as regards speed and torque are intermediate between those of shunt and series motors.)

4.13 Induction Motor.—An induction motor is 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. (ASA C42 10.01.180)

4.15 Squirrel-Cage Induction Motor.—A squirrel-cage induction motor is one in which the secondary circuit consists of a squirrel-cage winding suitably disposed in slots in the secondary core. (ASA C42 10.01.190)

4.17 Wound-Rotor Induction Motor.—A wound-rotor induction motor is 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. (ASA C42 10.01.185) (When provided with collector or slip rings, it is also known as a slip-ring induction motor.)

4.19 Synchronous Motor.—A synchronous motor is 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.

(ASA C42 10.01.195)

4.21 Motor Reduction Unit.—A motor reduction unit is a motor, with an integral mechanical means of obtaining a speed differing 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.

(ASA C42 10.01.330)

4.23 Amortisseur.—An amortisseur is 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. (ASA C42 10.16.005)

4.25 Squirrel-Cage Winding.—A squirrel-cage winding is 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. (ASA C42 10.16.030)

SECTION 5

CONVERTERS—INVERTERS

5.01 Dynamotor.—A dynamotor is 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. (ASA C42 10.01.385)

5.03 Motor-Generator Set.—A motor-generator set is a machine which consists of one or more motors mechanically coupled to one or more generators. (ASA C42 10.01.405)

5.05 Synchronous Converter.—A synchronous converter is 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. (ASA C42 10.01.375)

5.07 Synchronous Condenser.—A synchronous condenser is a synchronous phase modifier running without mechanical load, the field excitation of which may be varied so as to modify the power factor of the system; or through such modification, to influence the load voltage. (ASA C42 10.01.455)

5.09 Direct-Current Balancer.—A direct-current balancer is a machine which comprises two or more similar direct-current 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. (ASA C42 10.01.460)

5.11 Phase Modifier.—A phase modifier is a machine the chief purpose of which is to supply leading or lagging reactive volt amperes to the system to which it is connected. Phase modifiers may be either synchronous or asynchronous. (ASA C42 10.01.445)

5.13 Power Inverter.—A power inverter is a rectifier unit in which the direction of average power flow is from the direct current circuit to the alternating current circuit. (ASA C42 15.90.060)

5.15 Static Converter.—A static converter is a unit that employs static switching devices such as metallic controlled rectifiers, transistors, electron tubes or magnetic amplifiers.

SECTION 6

MOTOR SPEED CLASSIFICATION

- 6.01 Constant-Speed Motor.**—A constant-speed motor is one 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 direct-current shunt-wound motor. (ASA C42 10.21.005)
- 6.03 Multispeed Motor.**—A multispeed motor is one which can be operated at any one of two or more definite speeds, each being practically independent of the load. For example, a direct-current motor with two armature windings, or an induction motor with windings capable of various pole groupings. (ASA C42 10.21.010)
- 6.05 Adjustable-Speed Motor.**—An adjustable-speed motor is one the speed of which can be varied gradually over a considerable range, but when once adjusted remains practically unaffected by the load; such as a direct-current shunt-wound motor with field resistance control designed for considerable range of speed adjustment.
(ASA C42 10.21.020)
- 6.07 Base Speed of an Adjustable-Speed Motor.**—The base speed of an adjustable-speed motor is the lowest speed obtained at rated load and rated voltage at the temperature rise specified in the rating. (ASA C42 10.21.025)
- 6.09 Varying-Speed Motor.**—A varying-speed motor is one the speed of which varies with the load, ordinarily decreasing when the load increases; such as a series-wound or repulsion motor. (ASA C42 10.21.030)
- 6.11 Adjustable-Varying-Speed Motor.**—An adjustable-varying-speed motor is one the speed of which can be adjusted gradually, but when once adjusted for a given load will vary in considerable degree with change in load; such as a direct-current compound-wound motor adjusted by field control or a wound-rotor induction motor with rheostatic speed control. (ASA C42 10.21.035)

SECTION 7

VENTILATION OF MACHINES

- 7.01 Open Machine.**—An open machine is one having ventilating openings which permit passage of external cooling air over and around the windings. (ASA C42 10.26.005)
- 7.03 Self-Ventilated Machine.**—A self-ventilated machine is one which has its ventilating air circulated by means integral with the machine.
- 7.05 Separately Ventilated Machine.**—A separately ventilated machine is one which has its ventilating air supplied by an independent fan or blower external to the machine.
- 7.07 Enclosed Self-Ventilated Machine.**—An enclosed self-ventilated machine is 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.
- 7.09 Enclosed Separately Ventilated Machine.**—An enclosed separately ventilated machine is 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.
- 7.11 Totally Enclosed Machine.**—A totally enclosed machine is one 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. (ASA C42 10.26.045)
- 7.13 Totally Enclosed Fan-Cooled Machine.**—A totally enclosed fan-cooled machine is 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. (ASA C42 10.26.055)

SECTION 8

ENCLOSURE OF EQUIPMENT

8.01 General-Purpose Enclosure.—A general-purpose enclosure is one which primarily protects against accidental contact and slight indirect splashing but is neither drip proof nor splash proof.

8.03 Semi-Protected Enclosure.—A semi-protected enclosure is one 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.

8.05 Protected Enclosure.—A protected enclosure is one 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 (323 sq. mm) in area and should be of such shape as not to permit the passage of a rod larger than $\frac{1}{2}$ inch (12.7 mm) in diameter, except where the distance of exposed live parts from the guard is more than 4 inches (101.7 mm) the openings may be $\frac{3}{4}$ square inch (484 sq. mm) in area and must be of such shape as not to permit the passage of a rod larger than $\frac{3}{4}$ inch (19 mm) in diameter."

8.07 Dust Proof Enclosure.—A dust proof enclosure is one 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.

8.09 Drip Proof Enclosure.—A drip proof enclosure is one in which the openings are so constructed that drops of liquid or solid particles falling on the enclosure at any angle not greater than 15° from the vertical either cannot enter the enclosure, or if they do enter the enclosure, they will not prevent the successful operation of, or cause damage to, the enclosed equipment.

8.11 Splash Proof Enclosure.—A splash proof enclosure is one in which the openings are so constructed that drops of liquid or solid particles falling on the enclosure or coming towards it in a straight line at any angle not greater than 100° from the vertical cannot enter the enclosure either directly or by striking and running along a surface.

8.13 Waterproof Enclosure.—A waterproof enclosure is one so constructed 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.

8.15 Oil Proof Enclosure.—An oil proof enclosure is one so constructed 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.

8.17 Explosion Proof Enclosure.—An explosion proof enclosure is one which is designed and con-

structed 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.

8.19 Dust Tight Enclosure.—A dust tight enclosure is one so constructed that dust cannot enter the enclosing case.

8.21 Watertight Enclosure.—A watertight enclosure is one so constructed that a stream of water from a hose not less than 1" in diameter under a head of 35' from a distance of 10' can be played on the enclosure from any direction for a period of 15 minutes without leakage. The hose nozzle shall have a uniform inside diameter of 1".

8.23 Oil Tight Enclosure.—An oil tight enclosure is one so constructed that oil vapors, or free oil, not under pressure, which may be present in the surrounding atmosphere, cannot enter the enclosure.

8.25 Submersible Enclosure.—A submersible enclosure is one so constructed that the equipment within it will operate successfully when submerged in water under specified conditions of pressure and time.

SECTION 9

KINDS OF TORQUE

9.01 Locked-Rotor Torque.—The locked-rotor torque of a motor is the minimum torque which it will develop at rest for all angular positions of the rotor, with rated voltage applied at rated frequency. (ASA C42 10.41.010)

9.03 Pull-Out Torque.—The pull-out torque of a synchronous motor is the maximum sustained torque which the motor will develop at synchronous speed with rated voltage applied at rated frequency and with normal excitation. (ASA C42 10.41.035)

9.05 Breakdown Torque.—The breakdown torque of a motor is the maximum torque which it will develop with rated voltage applied at rated frequency, without an abrupt drop in speed. (ASA C42 10.41.040)

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

SECTION 10

DUTY CLASSIFICATION

10.01 Continuous Duty.—Continuous duty is a requirement of service that demands operation at a substantially constant load for an indefinitely long time.

- 10.03 Intermittent Duty.**—Intermittent duty is 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.

SECTION 11

CONTROL APPARATUS AND SWITCHGEAR

- 11.01 Electric Controller.**—An electric controller is 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. (ASA C42 25.20.001)

- 11.03 Full Magnetic Controller.**—A full magnetic controller is an electric controller having all of its basic functions performed by devices, which are operated by electromagnets. (ASA C42 25.20.031)

- 11.05 Semi-Magnetic Controller.**—A semi-magnetic controller is an electric controller having only part of its basic functions performed by devices which are operated by electromagnets. (ASA C42 25.20.036)

- 11.07 Manual Controller.**—A manual controller is an electric controller having all of its basic functions performed by devices which are operated by hand. (ASA C42 25.20.041)

- 11.09 Drum Controller.**—A drum controller is 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.

(ASA C42 25.20.016)

- 11.11 Starter.**—A starter is an electric controller for accelerating a motor from rest to normal speed and to stop the motor. (ASA C42 25.20.061) (A device designed for starting a motor in either direction of rotation includes the additional function of reversing and should be designated a controller.)

- 11.13 Automatic Starter.**—An automatic starter is a starter in which the influence directing its performance is automatic. (ASA C42 20.20.071)

- 11.15 Autotransformer Starter.**—An autotransformer starter is 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. (ASA C42 25.20.086)

- 11.17 Across-the-Line Starter.**—An across-the-line starter is 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.

- 11.19 Master Switch.**—A master switch is a switch which dominates the operation of contactors, relays, or other remotely operated devices. (ASA C42 25.15.046)

- 11.21 Resistor.**—A resistor is 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 imbedded 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.)

- 11.23 Overcurrent Protection.**—

(Overload Protection)—Overcurrent protection is the effect of a device operative on excessive current* to cause and maintain the interruption of current flow to the device governed. (ASA C42 25.50.011)

- 11.25 Undervoltage or Lowvoltage Protection.**—

Undervoltage or lowvoltage protection is 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. (ASA C42 25.50.81)

- 11.27 Undervoltage or Lowvoltage Release.**—

Undervoltage or lowvoltage release is the effect of a device, operative on the reduction or failure of voltage, to cause the interruption of power to the main circuit, but not to prevent the re-establishment of the main circuit on return of voltage. (ASA C42 25.50.036)

- 11.29 Constant Torque Resistor.**—A constant torque resistor is 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.

- 11.31 Fan Duty Resistor.**—A fan duty resistor is 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.

- 11.33 Overload Relay.**—An overload relay is 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.

(ASA C42 25.15.086)

- 11.35 Step-Back Relay.**—A step-back relay is 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 limitation when the cause of the high current has been removed.

- 11.37 Temperature Compensated Overload Relay.**—A temperature compensated overload relay is a device that functions at any current in excess of a predetermined value essentially independent of the ambient temperature.

- 11.39 Molded-Case Circuit Breaker.**—A molded-case circuit breaker is a breaker assembled as an inte-

* (but not necessarily on short circuit)

gral 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.

11.41 Rated Continuous Current.—The rated continuous current of a switch or circuit breaker is the designated limit in rms amperes or direct-current amperes which it will carry continuously without exceeding the limit of observable temperature rise.

11.43 Circuit Breaker Interrupting Rating (Rated Interrupting Current) (Rated Interrupting Capacity).—The rated interrupting current of a circuit breaker is the highest rms current at a specified operating voltage which the 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 direct-current 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.

(ASA C42 20.15.060)

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

11.45 Control Circuit.—The control circuit of a control apparatus or system is the circuit which carries the electric signals directing the performance of the controller but does not carry the main power circuit.

11.47 Indicating Circuit.—The indicating circuit of a control apparatus or system is that portion of its control circuit which carries intelligence to visual or audible devices which indicate the state of the apparatus controlled.

SECTION 12

CLASS OF INSULATING MATERIAL*

12.01 Class O Insulation.—Materials or combinations of materials such as cotton, silk, and paper without impregnation.** Other materials or combinations of materials may be included in this class if by experience or accepted tests they can be shown to be capable of operation at 90 C.

12.03 Class A Insulation.—Materials or combinations of materials such as cotton, silk, and paper when suitably impregnated** or coated or when immersed in a dielectric liquid such as oil. Other materials or combinations of materials may be included in this class if by experience or accepted tests they can be shown to be capable of operation at 105 C.***

* From Table 1-16 of IEEE Standard No. 1, June 1957—General Principles Upon Which Temperature Limits are Based.

** Insulation is considered to be “impregnated” when a suitable substance provides a bond between components of the structure and also a degree of filling and surface coverage sufficient to give adequate performance under the extremes of temperature, surface contamination (moisture, dirt, etc.), and mechanical stress expected in service. The impregnant must not flow or deteriorate enough at operating temperature so as to seriously affect performance in service.

12.05 Class B Insulation.—Materials or combinations of materials such as mica, glass fiber, asbestos, etc., with suitable bonding substances. Other materials or combinations of materials, not necessarily inorganic, may be included in this class if by experience or accepted tests they can be shown to be capable of operation at 130 C.***

12.07 Class C Insulation.—Insulation that consists entirely of mica, porcelain,† glass, quartz, and similar inorganic materials. Other materials or combinations of materials may be included in this class if by experience or accepted tests they can be shown to be capable of operation at temperatures over 220 C.

12.09 Class F Insulation.—Materials or combinations of materials such as mica, glass fiber, asbestos, etc., with suitable bonding substances. Other materials or combinations of materials, not necessarily inorganic, may be included in this class if by experience or accepted tests they can be shown to be capable of operation at 155C.

12.11 Class H Insulation.—Materials or combinations of materials such as silicone elastomer, mica, glass fiber, asbestos, etc., with suitable bonding substances such as appropriate silicone resins. Other materials or combinations of materials may be included in this class if by experience or accepted tests they can be shown to be capable of operation at 180 C.***

SECTION 13

TYPES OF CIRCUITS

13.01 Lighting Branch Circuit.—A lighting branch circuit is a circuit supplying energy to lighting outlets only. (ASA C42 95.11.051). (Lighting branch circuits also may supply portable desk or bracket fans, small heating appliances, motors of ¼ horsepower and less, and other portable apparatus of not over 600 watts each.)

13.03 Appliance Branch Circuit.—An appliance branch circuit is a circuit supplying energy to one or more outlets to which appliances are to be connected; such circuits to have no permanently-connected lighting fixtures not a part of an appliance. (ASA C42 95.11.056).

13.05 Motor Branch Circuit.—A motor branch circuit is a branch circuit supplying energy only to one or more motors and associated motor controllers. (ASA C42 95.11.066).

13.07 Communication Circuits.—Communication circuits are circuits used for audible and visual signals

*** The electrical and mechanical properties of the insulation must not be impaired by the prolonged application of the limiting insulation temperature permitted for the specific insulation class. The word “impaired” is here used in the sense of causing any change which could disqualify the insulating material for continuously performing its intended function whether creepage spacing, mechanical support, or dielectric barrier action.

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

and communication of information from one place to another, within or on the vessel.

- 13.09 Feeder.**—A feeder is 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.)
- 13.11 Branch Circuit.**—A branch circuit is that portion of a wiring system extending beyond the final overcurrent device protecting the circuit. (ASA C42 95.11.046).
- 13.13 Outlet.**—An outlet is a point on the wiring system at which current is taken to supply utilization equipment. (ASA C42 95.11.091).
- 13.15 Lighting Outlet.**—A lighting outlet is an outlet intended for the direct connection of a lampholder or a lighting fixture. (Adapted from ASA C42 95.11.095)
- 13.17 Receptacle Outlet.**—A receptacle outlet is an outlet where one or more receptacles are installed. (ASA C42 95.11.101).
- 13.19 Receptacle.**—A receptacle is a device installed in a receptacle outlet to accommodate an attachment plug.
- 13.21 Attachment Plug.**—An attachment plug is 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. (ASA C42 95.16.006)
- 13.23 Distribution Center.**—A distribution center is 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.
- 13.25 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 sub-distribution 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 sub-distribution 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.
- 13.27 Demand Factor.**—The demand factor of any system or part of a system is the ratio of the

maximum demand of the system or part of a system to the total connected load of the system or of the part of the system under consideration.

SECTION 14

NATURE OF SUPPLY

- 14.01 Standard Systems.**—The following systems of distribution are recognized as standard:

- (a) Two-wire with single-phase alternating current, or direct current.
- (b) Three-wire with single-phase alternating current, or direct current.
- (c) Three-phase three-wire, alternating current.

- 14.03 Standard Voltages.**—The following voltages are recognized as standard:

	Alternating Current	Direct Current
Lighting.....	115 Volts	115 Volts
Power.....	115-220-440	115 and 230
Generators.....	120-230-450	120 and 240

Note: Satisfactory to use 120 volt lamps.

- 14.05 Standard Frequency.**—A frequency of 60 hertz is recognized as a standard for all alternating-current lighting and power systems.

- 14.07 Selection of Voltage and Distribution System**

- (a) A-C—For small vessels having little power apparatus, 120 volt, 3 phase generators may be used, with 115 volt, 3 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 volts, 3 phase; the power distribution 220 volts, 3 phase and lighting distribution 115 volts, 3 phase, derived from transformers. As an alternative, a 120/208 volt, 3 phase, 4 wire system may be used for lighting and power distribution.

For all vessels of a size and type to require a dual voltage system, first consideration should be given to the application of 450 volt generators with power distribution at 440 volts, 3 phase and lighting distribution at 115 volts, 3 phase, 3 wire or 120/208 volts, 3 phase, 4 wire derived from transformers.

Grounded and Ungrounded A-C Electrical Systems—Either type of system may be used for the above listed standard systems, except that in the case of the 450-volt, 3-phase system 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 Subsection 21.81.

- (b) D-C—For vessels having little power apparatus, 120 volt generators are recommended with 115 volt light and power distribution systems.

Where an appreciable amount of power apparatus

is to be considered, 240/120 volt, three-wire generators and 230 volt power distribution system and 230/115 volt three-conductor lighting feeders should be selected. Branch circuits from lighting panel-

boards should be 115 volts two-wire.

14.09 Balancer Sets—Use of.—Balancer sets should not be used for obtaining 120 volts from 240 volt two-wire direct-current generators.

EQUIPMENT AND INSTALLATION

SECTION 15

GENERATING SETS

15.01 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 inches 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.

15.03 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 (i.e., 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.

15.05 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.

15.07 Generating Sets—Emergency.—In addition to the foregoing, Government Regulatory Agencies re-

quire the installation of a diesel-engine-driven generating set and/or storage batteries 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/or 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 seconds with the cooling water, lubricating oil and air supply at a temperature of 32 degrees F. Gas turbine driven generators may also be used.

The capacity of the generating sets and/or 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 (or 43°C).

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

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

Where alternating-current generators are to operate in parallel they should be equipped with amortisseur windings.

In the case of direct-current 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 with voltage regulators, or compound-wound generators should be used in the interest of substantially constant voltage.

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

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

15.11 Voltage Regulation:

General.—Voltage regulators should be of a

type and construction capable of withstanding ship-board conditions and should be designed to be unaffected by normal engineroom vibration. Separate units should be provided for each generator when voltage regulators are required.

(A) 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.

(a) 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.

(b) *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.

(c) *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 $2\frac{1}{2}$ percent of rated generator voltage from a median value halfway between the highest and lowest points attained.

(B) DC Generators

(a) 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) of 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 (b) below.

(b) 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 $1\frac{1}{2}$ 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.

(c) In addition to meeting the requirements of either subparagraph (a) or (b) above, the voltage regulation of a three-wire generator should be such that when operating at rated current on the heavier loaded side, i.e., 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 above, 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.

15.13 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:

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

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

(c) For compound-wound 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.

15.15 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. (ASA C50.4-1955 par. 4-8.9)

15.17 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 overspeed 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.

15.19 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 d-c 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.

15.21 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.

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

15.25 Insulation of Windings.—Stator coils of A.C. generators and all assembled armatures and also the armature coils for open-slot D.C. 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.

15.27 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 Subsection 37.49.

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.

15.29 Corrosion-Resistant Parts.—To prevent deterioration and corrosion of interior bolts, nuts, pins, screws, terminals, brushholder 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 Subsection 2.49.

15.31 Terminal Arrangements.—See Subsection 23.05 for terminal lugs on incoming cables.

(a) *Generators 50 kw and above.*

(1) Side location.

Generators should be provided with either:

(a) an insulating terminal board having secured terminals to which the lugs of the incoming cables can be readily fastened, or

(b) 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 $\frac{1}{4}$ inch 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.

(2) Top location.

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

(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.

(b) *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 (a) 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.

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

(a) Marine (Name of apparatus).

(b) Manufacturer's name on generator, prime mover and reduction gear (if any).

(c) Manufacturer's serial number on generator, prime mover and reduction gear (if any).

(d) Manufacturer's type and frame designation on generator, prime mover and reduction gear (if any).

(e) Output: in kva for ac generator; in kw for dc generator.

(f) Voltage rating.

(g) Kind of rating, continuous, short time, and continuous with 2 hour, 25 percent overload.

(h) Temperature rise at rated load. For generators having a two hour, 25 percent overload, the temperature rise at the end of the two-hour overload should also be given.

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

(j) Amperes at rated load.

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

(l) Number of phases, for ac generator.

(m) Power factor, for ac generator.

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

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

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

(q) 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.

15.35 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 should be made in accordance with American Standard C50, except as recommended below.

15.37 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 6 (Appendix). 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 1 and 2 (Appendix). All temperatures should be measured by thermometer.

Balance coils for three-wire dc generators, when mounted separately from the machines, should not exceed temperature rises, taken by thermometer, as given in Table 2 (Appendix).

15.39 Ambient Temperature.—Generators should be designed for an ambient temperature of 50C; except in cases where generators are provided with enclosed ventilating systems with coolers designed to maintain 40C ambient temperature under the worst conditions of operation, and in cases where the generator is located in 40C ambient temperature, the generator ambient temperature may be taken as 40C and the temperature rises increased 10C over those recommended in Table 6 (Appendix) for ac generators and Tables 1 and 2 (Appendix) 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.

15.41 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 volts for one minute 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.

Tests should be made in accordance with American Standard C50.

15.43 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.

(a) *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.

(b) *Type.* Heater units should be sealed against absorption of moisture and have terminals available for connecting to the supply feeder. (See Subsection 17.23.)

(c) *Size.* The following table shows recommended size of heater in terms of generator weight, excluding shaft:

Weight of Generator in Pounds	Watts of Space Heater
0 - 1000	None
1000 - 3000	250 - 500
3000 - 6000	500 - 1000
6000 - 10000	1000 - 1250
Above 10000	100 Watts/1000bs.

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

15.47 Spare Parts Stowage.—Storage space(s) 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 substance.

SECTION 16

STORAGE BATTERIES

16.01 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.

16.03 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 $\frac{1}{4}$ inch 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 $\frac{1}{8}$ inch 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.

16.05 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, includ-

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

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 explosionproof type.

Batteries of moderate size (20 to 36 volts) 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 volts 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 inches deep. There should be at least 12 inches, preferably 15 to 18 inches, 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 1/16 inch minimum thickness, not less than three inches deep. For alkaline batteries the shelves should be similarly lined with steel, not less than 1/32 inch 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 inches 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 inches consistent with the methods described above.

Battery trays should be securely chocked with wood strips or equivalent to prevent movement. Each tray should be fitted with non-absorbent insulating supports, not less than 3/4 inch high on the bottom, and with similar spacer blocks at the sides, or with equivalent provision to assure 3/4 inch 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.

- 16.07 Ventilation.**—All rooms, lockers and boxes for storage batteries should be arranged and/or ventilated to avoid accumulation of flammable gas. Particular attention should be given to the fact that the gas evolved 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 two inches 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 feet above the top of the locker. Louvres 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 four feet 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.

- 16.09 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 should be as stated in Subsection 36.07. 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 1½ minutes of cranking at a speed sufficient to assure starting and/or be of sufficient capacity to provide at least six starts consecutively without recharging.

- 16.11 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 direct-current 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 hours 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.

- 16.13 Overload Protection.**—Fuses may be used for the protection of emergency lighting storage batteries instead of circuit breakers up to and including 600 ampere rating.

SECTION 17

SWITCHBOARDS

- 17.01 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 inches in the clear, except that this may be reduced to 18 inches 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 and maintenance; in general, not less than 36 inches. Ample clearance should be provided for current-carrying parts to ground. Insulating barriers should be installed in way of ship's structure above the contacts of air circuit breakers if contacts are less than 12 inches from the ship's structure. 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. Where self-supporting switchboards with complete box framing are used, tie rods or braces to the ship's structure may not be 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 solid metal sheets, with suitable ventilating louvers or a grille, extending from the ends of switchboard to the ship's structure 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.

Suitable drip shields should be provided over switchboards when subject to damage by leaks or falling objects.

For cargo vessels (bulk oil carriers) and vessels carrying oil having a flash point of less than 150F, switchboards should not be located in spaces where explosive vapor or gas is normally expected to accumulate.

- 17.03 Construction.**—It is recognized that the dead-front type of switchboard protects against accident or shock, and the use of such switchboards is desirable in certain installations. All ac switchboards should be of the dead-front type where the voltage to ground is in excess of 150 volts. All dc switchboards should be of the dead front type where the voltage to ground or between poles is in excess of 250 volts.

All switchboards, except when main power buses do not exceed 1200 amperes, should be of box frame construction.

All dead-front switchboards should be 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. 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 provided with box frame type structure 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 structure. 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. The surfaces should have a smooth finish and should have beveled edges on the exposed surface of live-front switchboards. Metal panels may be used provided all current-carrying parts are properly insulated.

Insulating panel and base sizes should be determined by the dimensions and operating duty of mounted devices and the thickness should be selected to provide a wide margin of strength. In general, small panels are preferable.

A non-conducting hand rail or rails attached to the front of the switchboard or panels should be provided; a horizontal rail is preferred. Non-conducting 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 be not smaller than 4000 CM and of the extra flexible type for connection to hinged panels and of the flexible type with at least the number of strands required by Table 12 (Appendix), for other than hinged panel wiring. The insulation should be of the flame retarding type.

All groups of small wiring should be adequately secured to the switchboard panels or framework in such a manner as to prevent chafing and excessive motion caused by vibration and should be adequately laced together by cord of sufficient diameter to prevent cutting of the insulation. 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.

17.05 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 thirty minutes 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 the latest issue of ASA Standard C39.1 for switchboard instruments. Instruments should preferably be of the 250 degree nominal scale type.

Voltmeter scales should be adapted to the voltage in use on the vessel and rating of the generators. For 115/120 volt installations, scales should read 0-150 volts. For 230/240 volt installations, scales should read 0-300 volts. For 440/450-volt installations, scales should read 0-600 volts.

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) 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 the 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 drawout type, generator connections may be made to either end of the breaker.

The normal current rating of circuit breakers should be the value of current the breakers will carry continuously without exceeding the specified temperature rise. Circuit breakers may be equipped with time overcurrent trips, instantaneous trips, or trips consisting of both time overcurrent and instantaneous features. Time overcurrent trips, except for breakers of the molded-case, thermal trip type, should be adjustable between 80 and 160 percent of the normal current rating of the breaker (100 percent rating). The time feature of overcurrent trips may be obtained either by mechanical

or thermal means. Time and current adjustment should not be required for molded-case breakers.

Circuit breakers should be capable of easily opening circuits carrying the maximum rated current at rated potential and must be capable of interrupting short circuits within their short-circuit rating.

The arcing and main contacts of circuit breakers should be of simple construction. Arcing contacts, except those used in moulded 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 de-energizing the supply to the breaker. Use of plug-in type breakers which do not require use of an insulated wrench for removal is preferred.

Corrosion-resistant parts should be in accordance with Subsection 2.49.

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 of 50C as recommended in Subsection 17.07.

17.07 Temperatures.—Due to special conditions in some locations on shipboard, it has been found desirable to permit available apparatus primarily designed for use in a maximum ambient of 40C to be used in a 50C ambient. This shipboard practice is permissible provided that the primary contacts and joints are silver surfaced or equivalent and provided that such operation does not result in insulation hottest spot temperatures in excess of:

90C for Class O insulations

105C for Class A insulations

130C for Class B insulations

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

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

17.09 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. Sufficient space should be allowed between devices mounted on the front of panels to minimize the danger of contact with live parts and to guard against the possibility of injury due to the arcing of interrupting devices. 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.

For live-front switchboards it is desirable to maintain a minimum clearance of 8 inches between live parts and the base channel. In no case should the clearance be less than 4 inches.

Particular attention should be given to the arrangement of buses and connections to provide space for cables and accessibility for making cable connections.

In general, all fuses except for instrument and control circuits should be mounted on or be accessible from the front of the switchboard. Fuses should be located adjacent to their associated disconnect switch.

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.

Buses and connections should be arranged so that for alternating current the phase sequence is A, B, C and for direct current the polarity is positive, neutral, and negative from right to left, as viewed from the front of the switchboard; also for alternating current so that the phase sequence is A, B, C and for direct current the polarity is positive, neutral, and negative from top to bottom and from front to rear. Equalizer buses where required for dc switchboards may be located in the most convenient arrangement.

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

(a) *Protection—General.*—Refer to Subsection 21.57.

(b) *Generator Protection.*

(1) General.

Fused switches may be used in place of 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 Subsection 15.27.

(2) Alternating Current Generators.

(i) *Generator Overload, Short Circuit, and Reverse Power.*

Generators should be protected by means of trip free air circuit breakers having long time overcurrent trips. The pick up 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 rating for 125 percent 2-hour overload or special

rated machines. For the actual tripping times to be expected with these pick up settings refer to NEMA Standard SG3-1958.

Generator breakers should also have short time delay trips. 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 instantaneous and short time overcurrent trips should be set at the lowest values of current and time which will comply with the recommendations of Subsection 21.57.

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.

(3) Direct Current Generators.

(i) *Generator Overload and Short Circuits.*

Generators should be protected by means of trip-free air circuit breakers having inverse time overcurrent and instantaneous trips as shown in Figures 1 to 10 (Appendix). 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 hour 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 back-up circuit breakers supplied by the generator. (See Subsection 21.57.)

(ii) *Generator Neutral Overcurrent.*

Provision should be made to indicate overcurrent in the neutral of 3-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 breaker 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.

(iii) *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 per-

cent 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.

(iv) *Generator Overspeed.*

The generator circuit breaker, when furnished, 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 Subsections 15.17 and 15.19.)

(c) *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. All poles should be rigidly connected for simultaneous operation. Fused knife switches may be used up to 200 amperes; circuit breakers, of the molded case or the open type, should be used when greater rating is required, and are preferred for all circuits. Overcurrent protection should be provided for all ungrounded conductors. Fuses of more than 200 ampere rating should not be used except in bus feeder from emergency lighting batteries. Fuses should not be, and circuit breaker overload trips need not be, provided for the neutral conductor of a 3-wire dc grounded system.

(d) *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,

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.

Circuit breaker tripping control circuits,

Supply circuits for voltage regulators,

Steering gear thermal overload indicating light.

(e) *Potential Circuit Overcurrent Protection.*

Each conductor for potential circuits to instruments, pilot lamps and ground detector lamps should be protected by cartridge 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 6 amperes.

Note: The potential transformer should operate satisfactorily with a temperature rise of 45 C based on an ambient temperature of 50 C.

(f) Steering Gear Thermal Overcurrent Indication.

An indicating light, operated by a thermal overload relay in the steering gear motor controller should be provided in accordance with Subsection 28.09.

(g) Shore Power Feeder Protection.

When a shore power feeder is required, 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, with a suitable label plate on the front of the switchboard should indicate when power is available from shore.

(h) Motor-Generator Overspeed Protection.

Motor-generator sets having d-c generators operating in parallel should be provided with overspeed protection as recommended in Subsection 15.19.

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

7.15 Grounding Three-Wire Dual Voltage DC Systems.—The neutral connection of three-wire 230/115 volt direct-current systems should be solidly grounded at the generator switchboard with a center zero ammeter in the ground connection. 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.

7.17 Bus Bars and Connections.—All copper or aluminum bus bars and connections except as noted herein should be applied on the basis of the minimum cross sections required for the circuit ampere rating. Provision should be made for withstanding mechanical strains imposed by inrush currents and system short-circuit currents.

Bus bars and connections should be provided with silver surfaced contacts. The bus size should be selected on the basis of ampere ratings given in Table 32 (Appendix). The silver should be not less than 0.0002 inch thick and should not show a tendency to peel off under normal operating conditions.

The contact surfaces and studs of all power devices to which connections are made should also be silver surfaced. The silver surfacing for those contacts should be of the same thickness and applied in the same manner as described above. For stud connections, the threaded surfaces should have silver applied to a thickness of 0.0004 inch.

Bus bars 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 thirty minutes 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 connection buses for each generator unit should be equal to the continuous rating of the generator plus any overload rating in excess of thirty minutes 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 of switchboards with feeder panels located on each side of the generator units.

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 75 percent of the rated capacity of spare switches or breakers except that the capacity of the feeder buses need not be greater than the generator buses which supply them. Bus connections to individual feeder circuit breakers or switches should be designed on the basis of the frame rating of the breakers or switches when the frame rating is 600 amperes or less. For frame ratings above 600 amperes where loads have been definitely established, it is permissible to supply buses or connections based on breaker 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 the National Electrical Code.

Bolts, nuts and washers used to maintain contact on bus and connection bars should be of non-ferrous material or of steel, zinc electroplated or rendered corrosion-resistant by an equivalent process.

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 silver plated when they are used with connections that are silvered.

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 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.

17.19 Wire and Conductor Terminal Connectors.—

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 connectors. (See also Subsection 23.05.) Solderless terminal connectors should include means to prevent loosening due to vibration. All terminal connectors for external connections should be located at the rear of the switchboard and located where they are accessible for cable connections.

17.21 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 non-absorbent 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.

17.23 Minimum Equipment for Generator Switchboards.

(A) For Alternating Current Generators.—

The following should be supplied for each generator and exciter:

Each generator of 25 kilowatts and above should be protected by an independent arm or trip-free-from-handle circuit breaker with a separate pole for each lead. These should be arranged to open at a predetermined overload and should be provided with an overload time limiting device.

Fused switches may be used in place of circuit breakers for generators rated less than 25 kilowatts.

An unfused generator switch or links which will completely disconnect the generator and the circuit breaker from the bus where more than one generator is used.

The switch or links may be omitted when draw-out or plug-in mounted generator breakers are furnished.

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.

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

Control for prime mover speed for paralleling.

An indicating wattmeter for each generator.

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

Mounting for a field rheostat for each generator and each exciter.

A switch to supply generator space heater.

A double pole field switch with discharge clips and resistor for each generator.

For generators with variable voltage exciters or rotary amplifier exciters, each controlled by a voltage regulator unit acting on the exciter field, and for generators equipped with static excitation and regulating systems, the field switch, the discharge resistor, and the generator field rheostat may be omitted.

A voltage regulator complete with all accessories.

A switch for cutting out the voltage regulator. Pilot lamp as required for direct-current switchboards.

Adequate means for ground detection.

Necessary current and potential transformers.

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

For switchboards controlling generators rated 500 KVA and above, one temperature detection instrument should be provided; also a selector switch for each generator.

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

Power available indicating light for steering gear, unless equivalent indication is provided at the propulsion control station. (See Subsection 28.09.)

Note: Refer to Subsection 21.81 for additional switching requirements applicable to grounded systems.

(B) For Direct Current Generators.—

(a) For All Generators (Two-Wire or Three-Wire).

1—Power available indicating light for steering gear, unless equivalent indication is provided at the propulsion control station. (See Subsection 28.09.)

(b) For Two-Wire Generators.

(1) Two or more Generators arranged for Parallel Operation. (See Figures 1, 5 and 10, Appendix.)

For Each Generator:

1—Generator air circuit breaker

1—Reverse-current attachment or relay

- 1—Undervoltage device for reverse-current and overspeed trip when required
- 1—Generator disconnecting switch or disconnecting links

Note: The switch or links may be omitted when drawout or plug-in mounted generator breakers are furnished.

- 1—Ammeter
- 1—Voltmeter with voltmeter switch for connecting the voltmeter to indicate generator voltage and bus voltage. One of these voltmeter switches should provide also for reading shore connection voltage.
- 1—Lamp receptacle permanently connected on generator side of incoming generator leads
- 1—Mounting for generator field rheostat
- 1—Switch to supply generator space heater

For Each Complete Generator Switchboard:

- 2—Ground lamp receptacles
- 1—Ground lamp switch
- (2) Two or more Generators not arranged for Parallel Operation. (See Figures 2 and 6, Appendix.)

For Each Generator:

- 1—Generator air circuit breaker or fused switch if rated less than 25 kw
- 1—Generator disconnecting switch or disconnecting links
- 1—Ammeter
- 1—Voltmeter
- 1—Lamp receptacle permanently connected on generator side of incoming generator leads
- 1—Mounting for generator field rheostat
- 1—Switch to supply generator space heater

For Each Complete Generator Switchboard:

- 1—Voltmeter switch for connecting one of the generator voltmeters to shore connection
- 2—Ground lamp receptacles
- 1—Ground lamp switch

(c) *For Three-Wire Generators.*

(1) Two or More Generators arranged for Parallel Operation. (See Figures 3, 7 and 9, Appendix.)

For Each Generator:

- 1—Generator air circuit breaker
- 1—Reverse-current attachment or relay
- 1—Undervoltage device for reverse-current and overspeed trip when required
- 1—Generator disconnecting switch or disconnecting links.
- 2—Ammeters per generator, one in positive line and one in negative line
- 1—Voltmeter with voltmeter switch for connecting the voltmeter to indicate generator voltage, positive to negative, positive to neutral, and neutral 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.
- 1—Lamp receptacle permanently connected on generator side of incoming generator leads
- 1—Mounting for generator field rheostat

- 1—Switch to supply generator space heater

For Each Complete Generator Switchboard:

- 1—Ammeter for neutral ground connection
- (2) For Two or More Generators not arranged for Parallel Operation. (See Figures 4 and 8, Appendix.)

For Each Generator:

- 1—Generator air circuit breaker or fused switch if rated less than 25 kw
- 1—Generator disconnecting switch or disconnecting links
- 2—Ammeters per generator, one in positive line and one in negative line
- 1—Voltmeter
- 1—Voltmeter switch for positive to negative, positive or negative to neutral and one of the generator voltmeters to shore connection readings
- 1—Lamp receptacle permanently connected on generator side of incoming generator leads
- 1—Mounting for generator field rheostat
- 1—Switch to supply generator space heater

For Each Complete Generator Switchboard:

- 1—Ammeter for neutral ground connection
- Note—When voltage regulators are used with constant 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.

17.25 Emergency and Communication Switchboards.

(a) *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 preceding Subsections 17.01 to 17.23 inclusive and 17.27, 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 Figures 11 to 15 (Appendix), but the detailed description and diagrams are not to be considered as being restrictive or as prohibiting variations to suit special cases.

(b) *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 direct current switchboards.

If there is no continuous load inherently requiring direct-current supply, the storage battery may be charged by a motor-generator or rectifier taking power from the alternating-current buses, and bus transfer arrangements may be essentially as described for direct-current switchboards except that the connections must be such as will 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 Figure 16 (Appendix).

Any infrequent momentary direct-current load, such as watertight door operating motors, may be supplied from the battery only.

If there is any continuous direct-current load, such as fire screen door holding magnets, there should be a separate direct-current bus normally supplied from a motor-generator, with a separate automatic switch for transfer to battery, if required. As an alternative, the battery may float on the direct-current bus supplied 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 load 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 and normal operation should be restored automatically upon restoration of main supply or establishment of emergency generator supply after failure of main power.

The secondary windings of instrument transformers should be grounded.

(c) *Direct Current Switchboards.*

(1) *Cargo Vessels of 1600 Gross Tons and Over.*

See Subsection 36.03 and Figures 11, 12, and 13 (Appendix), 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 Figure 15 (Appendix).

(2) *Passenger Vessels of Less Than 1600 Gross Tons.*

See Subsection 36.09 and Figures 13 and 15 (Appendix), with accompanying notes.

(3) *Passenger Vessels of 1600 Gross Tons and Over.*

See Subsection 36.07 and Figure 14 (Appendix), 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. Electrical indicating instruments for battery charging equipment need not be of the switchboard type as defined in ASA Standard C39.1. As a minimum, however, they should be in accordance with the requirements of the latest issue of ASA Standard C39.1 for 3½ inch round or rectangular panel instruments.

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

- (a) 120/240 volt bus connected directly to the final emergency bus.
- (b) 120 volt or 120/240 volt bus connected directly to the temporary emergency bus.
- (c) 24 volt bus supplied from duplicate storage batteries (see Figure 15, Appendix).
- (d) 120 volt single-phase alternating-current bus supplied either from one of duplicate motor-generator sets through a double-throw generator selector switch; or from d-c/a-c electronic converters.

If any of the alternating-current circuits are among those classed in Subsection 36.07 as temporary emergency circuits, the d-c/a-c motor-generator or electronic converter should be supplied from the battery bus and arranged for continued operation upon failure of main power. An a-c 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.

(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 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 feed-back arrangement may be bolted links, a locked open switch, or equivalent, and may be installed on the rear of the switchboard. When the feed-back arrangement does not provide a natural interlock against paralleling the ship's service and emergency generators, as in Figure 14 (Appendix), indicating lights in duplicate should be connected to the bus feeder.

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 2-wire and 3-wire source should be 2-wire circuits.

17.27 Insulation—Voltage Tests.—All control and secondary wiring should be insulated for 600 volts. All primary or power connections should be un-insulated except for special installations where insulation is specified, or unless insulation is required to make the equipment comply with the required dielectric test.

The standard test for all switching and control apparatus for systems 61 to 600 volts, should be 1500 volts, for one minute. Where the standards on devices used on these equipments call for a lower test voltage, such devices may be disconnected during the test.

For systems 60 volts or less, the standard test should be 500 volts for one minute.

Voltage tests should be made in accordance with American Standard C68.1.

- 17.29 Spare Parts.**—Spare parts should be provided as required by the applicable Classification Societies. Spare parts should be stowed as provided in Subsection 15.47.

SECTION 18

WIRES AND CABLES—CONSTRUCTION

18.01 Copper Conductors.

(a) *General.*—The conductors should be of soft annealed copper wire. All conductors may be tinned or alloy coated, if desired, but all conductors used with Type R or B insulation should be coated.

(b) *Properties.*—The copper wires, prior to stranding and insulating, should have the physical and electrical properties as listed in Table 11 (Appendix).

(c) *Tinning.*—The continuity of the tin coating, prior to stranding and insulating, should be determined by the sodium-polysulfide test conducted at a temperature between 15.6C and 21C as follows:

Samples should be thoroughly cleaned by immersion in benzine, ether or carbon tetrachloride for at least three minutes, then removed and wiped dry with a clean, soft cloth. The cleaned samples at least 4½ inches long should be immersed in accordance with the following cycle:

First: Immerse for one minute in hydrochloric acid solution having a specific gravity of 1.088 at 15.6C. Wash in clean water and wipe dry with a clean, soft cloth.

Second: Immerse for 30 seconds in sodium-polysulfide solution having a specific gravity of 1.142 at 15.6C. Wash and wipe dry.

Third: Immerse for one minute in hydrochloric acid solution. Wash and wipe dry.

Fourth: Immerse for 30 seconds in sodium-polysulfide solution. Wash and wipe dry.

After the above operation, the samples should be examined to ascertain if copper, exposed through openings in the tin coating, has been blackened. If blackening is revealed at a distance of more than ½ inch from the end of the sample, the sample has failed.

(d) Alloyed Coating

Continuity of Coating

(1) The coating on the wire should be continuous.

(2) The continuity of coating on the wire should be determined on representative samples taken before stranding or insulating. The continuity of coating should be determined by the ammonium persulfate test or by the sodium polysulfide-hydrochloric acid test. In the ammonium persulfate test, the color of the test solution after immersion of the test specimen should be not darker than that of the reference color standard solution. In the sodium polysulfide-hydrochloric acid test the specimens, following the specified immersions, should not show blackening resulting from the exposure of copper through openings in the coating. In case the results obtained in the sodium polysulfide-hydrochloric acid test are not conclusive, the ammonium per-

sulfate test should be employed and the results obtained by this latter test shall be final.

Ammonium Persulfate Test for Continuity of Coating.

(1) Length of Specimens.—The length of test specimens should be determined by substituting the appropriate value of K , as given in Table A, in the following formula:

$$L = K/D$$

where:

L = length of test specimen in inches, and

D = diameter of the coated wire in inches.

In cases where the length of a specimen, determined by the above formula, is such that it cannot be immersed in the specified manner as a single length, it may be divided into shorter sections which will permit complete immersion.

Table A

Wire Diameter inch	K	Quantity of Test Solution, ml
0.460 to 0.321	1.2	150
0.320 to 0.161	0.8	100
0.160 to 0.0810	0.4	50
0.0800 to 0.0400	0.2	25
0.0390 to 0.0030	0.1	12.5

(2) Treatment of Specimens.—The test specimens should be thoroughly cleaned by immersion in benzine, redistilled petroleum ether, or carbon tetrachloride for at least three minutes, then removed and wiped dry with a clean soft cloth. The ends of each specimen should be completely coated with wax to protect the exposed copper. The wax-coated length should not be included in determining the length of the specimen.

(3) Special Solutions:

Test Solution (Ammonium Persulfate).—Dissolve 10 grams of ammonium persulfate (chemically pure crystals containing not less than 95 percent of ammonium persulfate) in 500 milliliters of distilled water. Add 75 milliliters of chemically pure NH_4OH (specific gravity 0.90) and dilute to 1 liter with distilled water. The ammonium persulfate solution should be freshly prepared each day tests are to be conducted and should not be subjected to temperatures above 100F.

Reference Color Standard (Copper Sulfate—Ammonium Hydroxide).—Dissolve 0.100 grams of anhydrous copper sulfate in distilled water, add 75 milliliters of chemically pure NH_4OH (specific gravity 0.90), and dilute to 1 liter.

(4) Procedure.—A specimen of the required length (Paragraph (1)) should be immersed in the quantity of test solution prescribed in Table A, using as the container a test tube of appropriate dimensions. The specimens should be immersed in the test solution at a temperature between 83F and 87F for a period of 15 minutes. The specimen should then be removed, and the test solution compared with an equal depth of the reference color standard contained in a similar test tube. The color comparison should be made by viewing the solutions lengthwise of the test tubes. The color of the test

solution after immersion of the test specimen should be not darker than that of the reference color standard solution.

Sodium Polysulfide—Hydrochloric Acid Test for Continuity of Coating.

(1) **Length of Specimens.**—The test specimens should each have a length of about 6 inches. They should be tagged or marked to correspond with the coil, spool, or reel from which they were cut.

(2) **Treatment of Specimens.**—The test specimens should be thoroughly cleaned by immersion in benzine, redistilled petroleum ether, or carbon tetrachloride for at least 3 minutes, then removed and wiped dry with a clean, soft cloth. The specimens thus cleaned should be kept wrapped in a clean, dry cloth until required for test. That part of the specimen to be immersed in the test solution should not be handled. Care should be taken to avoid abrasion by the cut ends.

(3) **Special Solutions:**

Sodium Polysulfide Solution (specific gravity 1.142).—A concentrated solution should be made by dissolving sodium sulfide crystals in distilled water until the solution is saturated at about 21C (70F), adding about 250 grams of flowers of sulfur per liter, and allowing to stand for at least 24 hours. The test solution should be made by diluting a portion of the concentrated solution with distilled water to a specific gravity of 1.142 at 15.6C (60F). The sodium polysulfide test solution should have sufficient strength to blacken thoroughly a piece of clean, untinned copper wire in 5 seconds. A portion of the test solution used for testing specimens should not be considered to be exhausted until it fails to blacken a piece of clean copper as described above.

Hydrochloric Acid Solution (specific gravity 1.088).—Commercial HCl (specific gravity 1.12) should be diluted with distilled water to a specific gravity of 1.088 measured at 15.6C (60F). A portion of HCl solution having a volume of 180 milliliters should be considered to be exhausted when the following number of test specimens have been immersed in it for two cycles.

Diameter inch	Maximum Number of Specimens to be tested for Two Cycles in 180 milliliters of Acid Solution
0.460 to 0.141	2
0.140 to 0.0851	4
0.0850 to 0.0501	6
0.0500 to 0.0381	10
0.0380 to 0.0301	12
0.0300 to 0.0030	14

(4) **Procedure.**—A length of at least 4½ inches from each of the cleaned specimens should be immersed, in accordance with the following cycles, in test solutions maintained at a temperature between 15.6C and 21C (60F and 70F):

a. The specimen should be immersed for 30 seconds in the sodium polysulfide solution, washed, and then shaken lightly to remove excess water.

b. The specimen should be immersed for 1 minute in the HCl solution, washed, and then shaken lightly to remove excess water.

c. The specimen should be immersed for 30 seconds in the sodium polysulfide solution, washed, and then shaken lightly to remove excess water.

d. The specimen should be immersed for 1 minute in the HCl solution, washed, and then shaken lightly to remove excess water. After the operations described, the specimens should be examined to ascertain whether blackened areas resulting from the action of the sodium polysulfide are present. (Blackening of the coated surface that occurs when the specimen is immersed in the sodium polysulfide solution should disappear during immersion in the HCl solution, leaving blackened areas only where copper is exposed.) In examining specimens, blackening present within 0.5 inch of the cut ends should be disregarded.

(e) **Stranding.**—All stranded conductors, except the extra flexible conductors, should have the individual wires laid up in concentric layers, with adjacent layers in conductors having a nominal cross-sectional area larger than size 8 awg laid in opposite directions.

The number and size of the individual strands should conform to Table 12 (Appendix), for standard concentric conductors and Table 13 (Appendix), for annular conductors.

(f) **Splices.**—No splice should be made in a stranded conductor as a whole. Not more than one of the wires in a stranded conductor of 19 wires or less, nor more than one of the wires in any given layer in a stranded conductor of more than 19 wires should be spliced in any one foot of the conductor.

18.02 Insulation.

(a) **General.**—The insulation should be one of the following types as recommended herein, capable of meeting the detail requirements listed in the following subsections:

Type	Maximum Conductor Temperature
R —Thermosetting Heat Resisting Rubber	75C
B —Thermosetting High Temperature Rubber	85C (alternate for Varnished Cloth)
T —Thermoplastic Polyvinyl Chloride..	75C
V —Varnished Cloth	85C
AV —Asbestos-Varnished Cloth	95C
TA —Asbestos-Thermoplastic	...
M —Mineral (MI)	85C
S —Silicone Rubber	95C

(b) **Properties.**—The physical and electrical properties of the insulation should meet the following requirements:

Type R—Thermosetting Heat Resisting Rubber	
(1) Tensile strength, psi, minimum.....	700
(2) Elongation at rupture, percent, minimum	300
(3) Set in 2 inch gauge length, inches, maximum	¼
(4) After air pressure heat test, 20 hours, at a temperature of 127 ± 1C, at 77-83 psi	
a. Tensile strength, percentage of un- aged value, minimum	50
b. Elongation at rupture, percentage of unaged value, minimum	50

- (5) After oxygen pressure test, 168 hours, at a temperature of $80 \pm 1\text{C}$, at 290-310 psi
 - a. Tensile strength, percentage of unaged value, minimum 50
 - b. Elongation at rupture, percentage of unaged value, minimum 50
- (6) Dielectric constant after 24 hours in distilled water at a temperature of 75C 6.0
- (7) Increase in capacitance, percent, maximum
 - 1 to 14 days 10.0
 - 7 to 14 days 4.0

Type B—Thermosetting High Temperature Rubber

- (1) Tensile strength, psi, minimum..... 600
- (2) Elongation at rupture, percent, minimum 350
- (3) Set in 2 inch gauge length, inches, maximum $\frac{1}{2}$
- (4) After air pressure heat test, 40 hours, at a temperature of $127 \pm 1\text{C}$, at 77-83 psi
 - a. Tensile strength, percentage of unaged value, minimum 50
 - b. Elongation at rupture, percentage of unaged value, minimum..... 50
- (5) After air oven test, 168 hours, at a temperature of $100 \pm 1\text{C}$, at atmospheric pressure
 - a. Tensile strength, percentage of unaged value, minimum 60
 - b. Elongation at rupture, percentage of unaged value, minimum 60
- (6) Increase in capacitance, in distilled water at a temperature of $75 \pm 1\text{C}$, percent, maximum
 - 1 to 14 days 5
 - 7 to 14 days 3

Type T—Thermoplastic Polyvinyl Chloride

- (1) Tensile strength, psi, minimum..... 2000
- (2) Elongation at rupture, percent, minimum 150
- (3) After air oven aging test, 168 hours, at a temperature of $121 \pm 1\text{C}$, at atmospheric pressure
 - a. Tensile strength, percentage of unaged value
 - Maximum 120
 - Minimum 80
 - b. Elongation at rupture, percentage of unaged value, minimum..... 75
- (4) After oil immersion test, 4 hours, at a temperature of $70 \pm 1\text{C}$
 - a. Tensile strength, percentage of unaged value, minimum..... 85
 - b. Elongation at rupture, percentage of unaged value, minimum..... 85
- (5) Heat distortion, at a temperature of $121 \pm 1\text{C}$, percentage of unaged value, maximum 25
- (6) Heat shock, at a temperature of $121 \pm 1\text{C}$ No Cracks
- (7) Cold bend, at a temperature of minus $30 \pm 1\text{C}$ No Cracks
- (8) Increase in capacitance, in distilled water at a temperature of $75 \pm 1\text{C}$, percent, maximum
 - 1 to 14 days 4
 - 7 to 14 days 2

Type V—Varnished Cloth

The varnished-cambric insulation should be of the heat-resisting type suitable for continuous operation at a conductor temperature not exceeding 85C in accordance with Tables 9 and 10 (Appendix).

The varnished cloth insulation should consist of a high grade varnished cloth, substantially free from blisters or other imperfections, with an insulating compound between alternate layers of varnished cambric.

The varnished cloth should be applied in the form of helically wound tapes. The tapes should be of such width that they will lie smoothly and be as free from wrinkles as practicable.

The cloth should be uniformly woven cotton. The number of threads per inch should be not less than 60 by 55.

The varnished coating should be pliable, and should show no cracks visible to the naked eye when the varnished cloth is doubled upon itself.

The thickness of finished varnished cloth should be between the following limits:

Minimum average thickness.....	6 mils
Maximum average thickness.....	13 mils

The thickness of individual tapes should not vary more than 20 percent plus or minus, nor should the variation exceed 1.5 mils.

The varnished cloth, when tested lengthwise, should be capable of meeting the following requirements:

- (1) Tensile strength before application to the cable, psi, minimum 3000
- (2) Tensile strength after removal from finished cable, psi, minimum 2400
- (3) Five samples of the cloth should be heated in air to a temperature of 125C (plus or minus $2\frac{1}{2}\text{C}$) for a period of 150 hours. They should then be exposed to an atmosphere of not more than 65 percent relative humidity at room temperature for not less than 30 minutes and not more than 2 hours. The specimens should then be tested by bending them through not less than 180 degrees around a mandrel having a diameter of 0.125 inch. The varnished films of the specimen should not crack when subjected to this test. Not more than one of the five samples should fail to meet this test.

The insulating compound, applied between alternate layers of varnished cloth so as to exclude as far as practicable air and moisture, should form with the varnished cloth a firm semi-flexible wall of insulation. The compound should be viscous, non-hardening, of slow drying characteristics, and of such a nature as to have no deleterious effect on the varnished cloth or conductor.

Type AV—Asbestos-Varnished Cloth

The varnished cloth insulation should meet the requirements of Type V above.

The asbestos insulation should consist of best quality, long fibre chrysolite asbestos commercially free from foreign particles. It should be well carded to prevent lumps and irregularities in the finished cable.

The asbestos insulation after extraction of impregnating compound should contain not less than 80 percent by weight of asbestos.

The wall of felted asbestos insulation should be applied to form a smooth wall of uniform thickness with the conductor well centered. It should be thoroughly dried and completely saturated with a flame- heat- and moisture-resisting compound.

The thickness of the insulation of component layers should be in accordance with Table 35 (Appendix).

Where felted asbestos is specified, glass roving, impregnated asbestos (or combination of glass and asbestos) tapes may be used as a substitute or alternate.

Where asbestos tapes are used on individual conductors, effective measures should be employed to prevent unravelling of the tapes.

Type TA—Asbestos-Thermoplastic.—(For Communication Cables, Telephone Cables and Switchboard Wire, as indicated in Subsections 18.30, 18.37 and 18.41 respectively.)

The thermoplastic insulation should comply with the thermoplastic specified under Type T above.

The asbestos insulation should comply with the asbestos specified under Type AV above.

Type M—Mineral

Mineral insulation should be calcined, highly compressed, refractory mineral; so processed and proportioned as to yield the cable properties hereinafter described in Section 18.16.

Type S—Silicone Rubber

- | | |
|---|-----|
| (1) Tensile strength, psi, minimum..... | 800 |
| (2) Elongation at rupture, percent, minimum | 250 |
| (3) After air oven test, 168 hours, at a temperature of $200 \pm 2^\circ\text{C}$ | |
| (a) Tensile strength, psi, minimum.... | 500 |
| (b) Elongation at rupture, percent, minimum | 125 |
| (4) Increase in capacitance, in distilled water at a temperature of $75 \pm 1^\circ\text{C}$ percent, maximum | |
| 1 to 14 days | 10 |
| 7 to 14 days | 3 |

The foregoing values are applicable only to nominal wall thicknesses of 0.027" or greater.

(c) **Thickness of Insulation.**—The average thickness of rubber, thermoplastic, varnished-cambric, and combinations of asbestos with varnished cambric or thermoplastic insulation, should conform to the values given in Tables 14 and 35 (Appendix). The minimum thickness at any point should not be less than 90 percent of the average recommended value.

(d) **Tests.**—For test procedures for Types R, B and S rubber insulation refer to IPCEA Publication S-19-81, latest edition.

For test procedure for Type T thermoplastic insulation and Type T thermoplastic jacket and Type N thermosetting jacket refer to IPCEA Publication S-61-402, latest edition.

18.03 Tapes.—Where binder or separator tapes are

called for a film tape of polyethylene terephthalate should be used. For cable with Type S insulation a special binder tape of polyethylene terephthalate film laminated to asbestos or glass fibers should be used.

Where a compound filled tape is called for the tape should be made from cotton cloth having a weight of not less than one pound per four yards based on a width of 36 inches and not less than 56 by 60 threads per inch. The tape should be frictioned on both sides and thoroughly filled with an insulating compound. Tape should not be less than 0.010 inch in thickness.

18.04 Braid.

(a) **General.**—Except for conductors insulated with Type S rubber, the braid used should be one of the following types as recommended under Cable Constructions: (1) Standard braid, or (2) Marker braid.

(b) **Standard braid.**—The standard braid should be closely woven from cotton thread having not less than two plies. The thickness of the braid should be not less than that recommended in Table 15 (Appendix).

(c) **Marker braid.**—Cotton marker braid should be woven from yarn not smaller than No. 40/2 or 18/1. Marker braids for heat- and flame-resisting cables should be rayon or glass as specified in cable constructions.

(d) **Saturation and finish.**—Standard braids, except when used for color coding, should be thoroughly saturated with a moisture-resisting compound and finished with a black or dark colored moisture-resisting and flame-retarding compound. The braid surface should be free from tackiness.

Marker braids and standard braids used for color coding should be saturated in paraffin, except that rayon marker braids used for color coding heat- and flame-resisting communication cables should be treated with a flame-resisting compound and glass marker braid used for color coding heat- and flame-resisting type telephone cables should be treated with a flame-resisting lacquer.

(e) Silicone rubber insulated conductors should be glass braided according to the recommendations of the manufacturer.

18.05 Color Code.—Color coding by means of tapes, braids or colored and striped thermoplastic insulation should conform to Table 16 (Appendix).

Base colors may be obtained by suitable color coatings applied to the insulation surface or by colored insulation.

Tracers should be colored stripes, bands, continuous or broken lines, such as a series of dots and dashes, applied over the base color, or as an integral part of the insulation, longitudinally, annularly, spirally, or in other distinctive patterns.

Whenever more colors than one are required, the first color named in the table should be the background. For telephone pairs, one conductor of each pair should be white. The other conductor should be coded in accordance with the sequence given in Table 16 (Appendix), omitting color No. 2. Tracer

colors should be those enumerated below, the numbers referring to those of "The Standard Color Card of America," Ninth Edition.

White	70,001
Red (Scarlet)	70,080
Blue (Peking)	70,142
Green (Emerald)	70,063
Orange	70,071
Brown (Tobacco)	70,095

Circuit identification in MSIA and MSIB cables should be in accordance with IPCEA Publication S-19-81, par. 5.6.3, Method 3, first sentence only, except that Code should conform to Table 16 (Appendix).

18.06 Cabling.—Conductors or pairs should be cabled in concentric layers; the direction of lay for adjacent layers should be reversed.

18.07 Fillers.—Fillers should be saturated with a moisture-resisting saturant and be capable of being compressed in the cabling operation so as to exclude as far as possible all voids.

18.08 Marker.—Cable identification should be provided by including a marker under the cable sheath. The marker material should be suitable for its service. Marker threads in lieu of tape may be used for cables smaller than 0.300 inch diameter under the cable sheath. The marker tape should give the following information at regular intervals:

- (a) Manufacturer
- (b) Applicable specification and its edition
- (c) Year of Manufacture

18.09 Moisture Resisting Jacket.

(a) *General.*—The jacket should be constructed of a solid wall of lead or thermoplastic or thermosetting compound to a thickness as given in Table 17 (Appendix) for lead sheath. (Thermosetting jackets should not be used for cables having thermoplastic insulation.)

(b) The composition and construction of the jacket should provide a combination of the following basic properties that are properly proportioned for the particular purpose intended:

- (1) Resistance to flame.
- (2) Stability under long continued exposure to elevated temperatures.
- (3) Absence of noticeable odor at cable operating temperatures.
- (4) Deformability at low temperatures (i.e., cold bend qualities).
- (5) Stability under exposure to oil, sulphuric acid, and sea water.
- (6) Stability under exposure to sunlight.

(c) The jacket, formerly known as impervious sheath, should have the following properties: (For lead sheath refer to Subsection 18.10.)

Type T—Thermoplastic Jacket.

- (1) Tensile strength, psi, minimum..... 1500
- (2) Elongation at rupture, percent, minimum 100
- (3) After air oven test, 5 days at a temperature of $100 \pm 1\text{C}$
 - a. Tensile strength, percentage of unaged value, minimum 85

- b. Elongation at rupture, percentage of unaged value, minimum 60
- (4) After oil immersion test, 4 hours at a temperature of $70 \pm 1\text{C}$
 - a. Tensile strength, percentage of unaged value, minimum 80
 - b. Elongation at rupture, percentage of unaged value, minimum 60
 - (5) Heat distortion, at a temperature of $121 \pm 1\text{C}$, percent, minimum..... 50
 - (6) Heat shock, at a temperature of $121 \pm 1\text{C}$ No Cracks
(For Test Method See IPCEA Publication E-61-402, latest edition.)

Type N—Thermosetting Jacket.

- (1) Tensile strength, psi, minimum..... 1800
 - (2) Tensile stress at 200 percent elongation, psi, minimum 500
 - (3) Elongation at rupture, percent, minimum. 300
 - (4) Set in 2 inch gauge length, inches, maximum $\frac{3}{8}$
 - (5) After air pressure test, 20 hours at a temperature of $127 \pm 1\text{C}$, 77-83 psi
 - a. Tensile strength, percentage of unaged value, minimum 50
 - b. Elongation at rupture, percentage of unaged value, minimum..... 50
 - (6) After oxygen pressure test, 168 hours at a temperature of $80 \pm 1\text{C}$ 290-310 pounds
 - a. Tensile strength, percentage of unaged value, minimum 50
 - b. Elongation at rupture, percentage of unaged value, minimum..... 50
 - (7) After oil immersion test, 18 hours at a temperature of $121 \pm 1\text{C}$
 - a. Tensile strength, percentage of unaged value, minimum 60
 - b. Elongation at rupture, percentage of unaged value, minimum..... 60
- (For Test Method see IPCEA Publication S-19-81, latest edition.)

Types T and N—Thermoplastic or Thermosetting Jackets.

(1) Cold Bend—Sample of completed cables should not show any cracks after being subjected to a temperature of minus 9C to minus 11C , for one hour and then bent around a mandrel 180 degrees in not more than one minute.

Cable OD	Mandrel Size
0—0.800 inch	$8 \times \text{cable OD}$
0.801—larger	$10 \times \text{cable OD}$

(2) Flame Retardant Properties—Meet requirements of Resistance to Flame, paragraph 18.5 (g)

(3).

18.10 Lead Sheath.—The lead sheath should be formed tightly around the core and should consist of copper-bearing lead or a lead alloy. If copper-bearing lead is used, it should contain not less than 0.04 percent nor more than 0.08 percent copper. If alloy sheath is used the alloying element should be 1.8 to 2.2 percent tin or 0.7 to 0.9 percent antimony.

The average thickness of the lead sheath should conform to the values given in Table 17 (Appendix).

The minimum thickness of the lead sheath at any point should not be less than 90 percent of the average value.

18.11 Bituminous Compound.—Over the lead sheath should be applied a thin coating of bituminous compound. The compound should have no injurious effect upon the lead sheath or the compound filled tape, and should not crack at low temperature or flow at the operating temperature of the cable.

18.12 Armor.—

(a) *General.*—Armor should be of the basket weave type, except for the alternating current propulsion cables where flat metal tape may be used. Armor for single conductor alternating current cables should be of non-magnetic material.

(b) *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 inch in diameter plus or minus 0.0005 inch and should be free from cracks, splints, or other flaws. The wire should be either galvanized steel, commercial bronze, or aluminum.

(1) *Steel Armor.*—Steel armor braid should be of soft annealed wire and should be thoroughly and evenly galvanized. The wire should have a tensile strength of not less than 50,000 pounds per square inch and the elongation in 8 inches should not be less than 12 percent as tested before application to the cable.

(2) *Aluminum Armor.*—Aluminum armor braid should be of an alloy containing not more than 0.2 percent of copper, and not less than 92.5 percent aluminum.

The weave should be of either the "one over-one under" or the "two over-two under" type, at the manufacturer's option. 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 Sheath (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 = $(2F - F^2) \times 100$

$$\text{where } F = \frac{NPd}{\sin \alpha}$$

Where α = angle of braid with axis of cable:

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

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 braid (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

(c) *Metal Tape.*—The armor should consist of one flat metal tape applied helically to the cable. The tape should be of either copper or bronze as specified. The width and thickness of the tape should conform to the values given in Table 18 (Appendix).

18.13 Paint.—The paint over the basket weave armor should be uniformly applied and should adhere firmly to the armor. The paint should be such that it will not discolor a subsequent coating of white paint.

Bronze armor should be painted only when specified.

18.14 Dimensional Tolerances.—The measured maximum overall diameter of the finished cable should be not larger than given in Tables 25 to 33, 38 to 40, and 42 (Appendix). No plus tolerance is allowed. A minus tolerance of not more than 10 percent is permitted on the overall dimension. For cables having an overall diameter of 0.400 inch or less, the minimum tolerance need not be less than 0.040 inch.

18.15 Tests on Finished Cable.—

(a) *High Voltage.*—Each reel (except switch-board wire) of finished cable should be able to successfully withstand for a period of five minutes the high-voltage test potential given in Tables 20, 21, 36 and 42 (Appendix). The test potential should be applied between conductors and between conductors and ground for the time specified. Test should be in accordance with American Standard C68.1.

(b) *Insulation Resistance.*—Each reel of finished cable should have an insulation resistance, measured between each conductor and ground, of not less than that given in Tables 22, 23, 24 and 37 (Appendix). If the test is made at a temperature different from 15.5C (60F) the measured value should be multiplied with the proper correction factor as given in Table 24 (Appendix).

(c) *Bending Test.*—A ten-foot sample of finished cable should be capable of being bent, at room temperature, 180 degrees around a mandrel having a diameter as given in Table 19 (Appendix). 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 4 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 minutes a voltage equal to 150 percent of the test voltage given in Tables 21 and 36 (Appendix).

(d) *Flame Retarding Test*.—All cables should be “flame retarding” when type tested according to the methods in the standards of Underwriters’ Laboratories or American Society for Testing Materials.

(e) *Special Tests on Asbestos-Varnished Cloth Cables*.

(1) Flammability Test:

Specimens.—Specimens should consist of straight sections of completed wire or cable approximately 18 inches in length.

Apparatus.—An enclosure of sufficient size to contain the specimen, supports, heater coil, spark plugs, flame travel gage and their associated accessories should be arranged to eliminate air drafts and permit clear view of the interior through shatter-proof glass windows. Vent holes, distributed around the sides adjacent to the base, should be provided to admit fresh air when an exhaust fan connected to the top of the enclosure, is operated at a minimum suction just sufficient to carry off smoke and gases.

Supports should be suitable for holding the specimens in a vertical position with an unsupported span not less than 14 inches in length. The lower end of the specimen should be wrapped with varnished cloth in such a manner that gases released through this end are diverted toward the spark plug.

Heater coils should consist of 7 turns of 0.102 inch diameter resistance wire conforming to the requirements for Grade E of Navy Department Specification 17W2, space wound to 0.25 inch between centers. The inside diameter of the coil should exceed the overall diameter of the specimen by not less than 0.5 inch nor more than 0.6 inch. The lower end of the heater coil should be located 1.5 inches above the top of the lower specimen support.

Two spark plugs, with extended electrodes spaced $\frac{1}{8}$ inch from the surface of the specimen and the plugs located on diametrically opposite sides of the specimen, should be placed with their longitudinal centerlines in a horizontal plane $\frac{1}{2}$ inch above the top of the heater coil, to ignite the gases emitted from the heated specimen. A suitable electric circuit should be provided to maintain continuous sparking at the electrodes during the specified time. The spark plugs should be mounted in such a manner that they may be moved away from the specimen after ignition takes place so as not to impede the travel of the flame and to prevent their electrodes from becoming fouled by soot.

A suitable flame travel gage should be positioned near the specimen to judge the distance of flame travel without appreciably impeding the progress of the flame.

Procedure.—Flame tests are specified for heat-

and flame-resisting type cables and the required performance is as follows:

<i>Ignition Time Minimum Seconds</i>	<i>Burning Time Maximum Seconds</i>	<i>Flame Travel Maximum Inches</i>
60	60	2

Time of Ignition.—With the enclosure closed and ventilated, the specimen centered in the heater coil, and the spark plugs and flame gage properly located, a stopwatch should be started simultaneously with the energizing of the heater coil and spark plugs. A constant current as specified in table below should be supplied from a suitable transformer source to the heater coil. Ignition should be considered as occurring when the flame transfers from the escaping gases to the surface of the specimen and continues there, disregarding the flashes which may occur in the gasing space prior to the sustained flame. The time required to ignite the specimen should be recorded.

Time of Heating.—For all armored cable, whether tested with or without armor, the heating current should be turned off 30 seconds after ignition occurs. For all unarmored cables, where the ignition time is less than 60 seconds, the heating current should be turned off 60 seconds after being turned on; where the ignition time is greater than 60 seconds, the heating current should be turned off when ignition occurs.

Distance of Flame Travel.—Immediately after ignition occurs, the electric supply to the spark plugs should be cut off and the plugs shifted away from the flame. The maximum distance to which the flame travels along the surface of the specimen, measured from the top of the heater coil, before extinction, should be noted and recorded.

Time Required for Self-Extinction.—The number of seconds that the specimen continues to burn, until the cessation of all flaming, after the current in the heater coil has been cut off, should be recorded as the time required for self-extinction.

Observations.—The amount and color of the smoke and the amount and size of the soot particles should be observed and recorded.

Current in Heating Coil.

<i>Nominal diameter of cable inch</i>	<i>Current Amperes AC rms</i>	<i>Nominal Diameter of cable inches</i>	<i>Current Amperes AC rms</i>
0.050 to 0.099	45	0.80 to 0.89	53
.100 to .19	46	.90 to .99	54
.20 to .29	47	1.00 to 1.09	55
.30 to .39	48	1.10 to 1.39	56
.40 to .49	49	1.40 to 1.79	57
.50 to .59	50	1.80 to 2.29	58
.60 to .69	51	2.30 to 3.00	59
.70 to .79	52		

(2) Drip Test.

One 3 foot section of completed cable should be suspended in a vertical position in an oven maintained for a period of not less than 18 hours at 95C. No material should drip or exude from the end of the cable during the test.

(3) Dielectric After Flame.

Following the flammability test, paragraph 18.15 (e)(1), the specimen should withstand the voltages shown in Table 36 for the particular type by applying the voltage between one conductor and all other conductors and armor for a period of one minute.

(f) Tests for completed Type S insulated cables are to be in accordance with the provisions for acceptance inspection set forth in IPCEA Publication S-19-81, latest edition.

(1) Single conductors of MSIA and MSIB cables (Subsection 18.27) should be subjected to an approved abrasion test. One method of test for abrasion resistance is given below under NOTE.

(g) *Test on Varnished-Cambric-Asbestos and Asbestos-Thermoplastic Insulated Flame Retarding Switchboard Cable.*

(1) Sampling.—Each of the required tests should be made on one sample of each size and type of wire from each lot of 10,000 feet or fraction thereof. If a sample fails to meet any of the prescribed requirements, two additional samples should be taken from the same length. If either sample fails the length may be rejected. If any of the lengths fail to meet any of the requirements, samples should be taken from each length of the lot and tested for this particular requirement to determine the acceptance of each length.

(2) Measurement of Dimensional Requirements.—Four measurements should be made, two to be made near each end of the sample. The measurements should be made with a ratchet micrometer having $\frac{1}{4}$ inch diameter faces and should be the average of two measurements at right angles to each other. The average diameter over each component layer of insulation and braid should not vary more than plus or minus 5 percent from the theoretical diameter over that layer based on the nominal wall thickness shown in Table 35.

(3) Resistance to Flame.—All wires should have such fire-retarding properties that the test specimens will not convey flame, nor continue to burn for more than one minute after five applications of fifteen

seconds each of a standard test flame, the period between applications of flame being fifteen seconds.

Compliance with the requirements of the preceding paragraph should be determined with apparatus and according to the method described in the Underwriter's Laboratories' Standard for rubber-covered wire.

(4) Initial Dielectric Strength. — Dielectric strength tests should be made on five-foot lengths of finished cable wrapped in tin foil. Three thousand volts should be applied for five minutes.

(5) Leakage Resistance Test.—The leakage resistance between metal foil bands placed two inches apart, as measured with a voltage of approximately 200 volts direct current, on a sample immediately after exposure for 16 hours at a temperature of not less than 25C to an atmosphere of moisture in a bell jar in which is placed an open vessel of water, should be not less than one megohm per inch length per inch of circumference.

(6) Bend-Dielectric Test.—On sizes 8 and smaller a 15 inch sample should be bent 90 degrees around a mandrel having the same diameter as the wire. Two bends in the same plane should be made 2 inches apart only sufficient pressure being applied to prevent the sample from slipping.

A sample subjected to this test should show no rupture of the covering, and it should not break down at less than 5000 volts, 60 cycles, applied between the conductor and foil wrapped tightly around the braid of the bent sample at the point of bend. (Fine filings or shot may be used in place of wrapping in metal foil.)

CABLE CONSTRUCTION

Note: All tables are in the Appendix.

18.16 Mineral Insulated Metal Sheathed Cable.—(Type MI)(Table 42)

Mineral insulated-metal sheathed cable is a cable in which one or more electric conductors are insulated with a highly compressed refractory mineral insulation and enclosed in a liquidtight and gas-tight metallic tube sheathing.

Type MI cable for 600 volts should conform to the following:

a. Conductors.—The conductors are solid uncoated copper complying with A.S.T.M. Specifications B4 or B5, and have cross sectional areas corresponding to the standard American Wire Gauge sizes.

b. Insulation.—The insulation is a highly compressed refractory mineral which provides proper spacing for the conductors.

c. Outer Sheath.—The outer sheath should be a round continuous seamless metal tube to provide mechanical protection and a moisture seal, and an adequate path for grounding purposes.

18.17 Single-Conductor, Insulated and Armored.—(Table 25).

First: Stranded conductor (tinned or alloy coated when used with Types R and B insulation).

Second: Insulation—Type R, B or T.

Note: Abrasion Test.—The abrasion resistance of eight specimens from any one cable length (a cable with less than eight conductors should have all conductors tested) should average at least 250 scrapes (2 scrapes per drum revolution).

The abrading machine should consist of an 8" diameter steel wheel approximately 2" wide. The outer surface of the drum should be smooth and two abrading tools should be mounted 180° apart on the circumferential surface of the drum so that the diagonals formed by the abrading edges and opposite edges are coincident with the diameter of the drum. The tools should be mounted in the drum surface so that when clamped in place the diagonals formed by the non-cutting edges are even with the drum surface. The abrading tools should consist of 5/16" square cobalt high-speed steel tool bits (Cleveland Twist Drill Co. #855 or equal) with two side surfaces ground longitudinally at a 90 degree angle with a medium grade wheel (Macklin Co. #48A H8 V6 or equal). The abrading tool should be ground to a minimum amount (0.002" to 0.004" per surface) to produce a 90 degree sharp edge free from visible nicks. The abrading wheel should be mounted on a suitable driving mechanism that rotates the wheel from the fixed end toward the weighted end at approximately 17 rpm. Any convenient potential of 12 to 120 volts should be applied, with suitable protective devices, between the abrading tools and the copper conductor of the specimen. One end of the specimen should be held rigid and a one pound weight should be hung from the opposite end. The electric motor drive should be so arranged that it automatically stops and indicates the number of wheel revolutions when electric contact between the abrading tools and copper conductor occurs.

Third: Compound filled tape or standard braid.
 Fourth: Standard braid.
 Fifth: Basket weave armor.
 Sixth: Paint.

18.18 Single-Conductor, Insulated, Sheathed, and Armored.—(Table 25)

First: Stranded conductor (tinned or alloy coated when used with Types R and B insulation).
 Second: Insulation—Type R, B, T, or V.
 Third: Compound filled tape or standard braid.
 Fourth: Sheath—lead or Type T or N jacket.
 (Note: Type N jacket should not be used with Type T insulation.)
 Fifth: Bituminous compound.
 Sixth: Compound filled tape, } if lead sheathed
 half lapped*.
 Seventh: Basket weave armor, or flat metal tape for propulsion cable.
 Eighth: Paint.

18.19 Single-Conductor, Asbestos-Varnished Cloth Insulated, Sheathed and Armored.—(Table 38).

First: Stranded conductor.
 Second: Wall of felted, impregnated asbestos insulation, Type AV.
 Third: Separator.†
 Fourth: Varnished-cambric insulation, Type V.
 Fifth: Separator.†
 Sixth: Wall of felted, impregnated asbestos insulation, Type AV.
 Seventh: With or without separator, at manufacturer's option.
 Eighth: Sheath—lead or moisture resisting jacket, Type T or N.
 Ninth: Bituminous compound.
 Tenth: Compound filled tape, } if lead sheathed
 half lapped*.
 Eleventh: Basket weave armor, or flat metal tape for propulsion cable.
 Twelfth: Paint.

18.20 Two- or Three-Conductor, Insulated and Armored.—(Tables 26 and 27).

First: Stranded conductor (tinned or alloy coated when used with Types R and B insulation).
 Second: Insulation—Type R, B, or T.
 Third: Compound filled tape or standard braid, color coded.
 Fourth: Two or three conductors cabled with fillers.
 Fifth: Compound filled tape.
 Sixth: Standard braid.
 Seventh: Basket weave armor.
 Eighth: Paint.

18.21 Two- or Three-Conductor, Insulated, Sheathed and Armored.—(Tables 26 and 27).

First: Stranded conductor (tinned or alloy coated when used with Types R and B insulation).
 Second: Insulation—Type R, B, T, or V.
 Third: Compound filled tape or standard braid, color coded.

* If two tapes are used in place of a single tape of one half lap, the minimum lap of the two tapes should not be less than 20 percent of the width of the tape and in no case less than one-quarter inch.

Fourth: Two or three conductors cabled with fillers.

Fifth: Compound filled tape.
 Sixth: Sheath—lead or moisture resistant jacket, Type T or N. (Note: Type N jacket should not be used with Type T insulation.)

Seventh: Bituminous compound
 Eighth: Compound filled tape, } if lead sheathed
 half lapped*.
 Ninth: Basket weave armor.
 Tenth: Paint.

18.22 Two- or Three-Conductor, Asbestos-Varnished Cloth Insulated, Sheathed and Armored.—(Table 38).

First: Stranded conductor.
 Second: Wall of felted impregnated asbestos insulation—Type AV.
 Third: Separator color coded.
 Fourth: Varnish cloth insulation—Type V.
 Fifth: Separator.†
 Sixth: Wall of felted impregnated asbestos insulation—Type AV.
 Seventh: Two or Three conductors cabled with impregnated asbestos filler.
 Eighth: Belt of felted impregnated asbestos.
 Ninth: With or without separator, at manufacturer's option.
 Tenth: Sheath, lead or moisture resistant jacket—Type T or N.
 Eleventh: Bituminous compound.
 Twelfth: Compound filled tape, } if lead sheathed
 half lapped*.
 Thirteenth: Basket weave armor.
 Fourteenth: Paint.

18.23 Four-Conductor, Insulated and Armored, or Sheathed and Armored.

First: No. 14 AWG stranded conductor (tinned or alloy coated when used with Types R and B insulation).
 Second: Insulation—Type R, B, or T.
 Third: Compound filled tape or standard braid, color coded.
 Fourth: Four No. 14 AWG conductors, cabled with fillers.
 Fifth: Compound filled tape.
 Sixth: Standard braid.
 Seventh: Basket weave armor.
 Eighth: Paint.

If sheath is desired modify above as follows:

Sixth: Sheath—lead or moisture resistant jacket, Type T or N. (Note: Type N jacket should not be used with Type T insulation.)
 Seventh: Bituminous compound.
 Eighth: Compound filled tape, } if lead sheathed
 half lapped*.
 Ninth: Basket weave armor.
 Tenth: Paint.

18.24 Single Conductor, Silicone Insulated, Sheathed and Armored.

Sizes: No. 14 AWG to 800 MCM inclusive.

† Where the asbestos insulation is composed of impregnated asbestos tapes, the use of a separator is optional with the manufacturer.

First: Stranded copper conductor.
 Second: Insulation—Type S.
 Third: Glass braid with finishing coat.
 Fourth: Separator Tape.
 Fifth: Special tape.†
 Sixth: Sheath, Moisture Resistant Jacket, Type T.
 Seventh: Basket weave armor.
 Eighth: Paint.

18.25 Two- or Three-Conductor, Silicone Insulated, Sheathed and Armored.

Sizes: No. 14 AWG to 400 MCM inclusive.
 First: Stranded copper conductor.
 Second: Insulation—Type S.
 Third: Glass braid with finishing coat.
 Fourth: Required conductors cabled—with filler, where required.
 Fifth: Separator Tape.
 Sixth: Special tape.‡
 Seventh: Sheath, Moisture Resistant Jacket, Type T.
 Eighth: Basket weave armor.
 Ninth: Paint.

18.26 Four-Conductor, Silicone Insulated, Sheathed and Armored.

First: Size No. 14 AWG stranded copper conductor.
 Second: Insulation—Type S.
 Third: Glass braid with finishing coat.
 Fourth: Conductors cabled—with fillers, where required.
 Fifth: Separator Tape.
 Sixth: Special tape.‡
 Seventh: Sheath, Moisture Resistant Jacket, Type T.
 Eighth: Basket weave armor.
 Ninth: Paint.

18.27 Multi-Conductor Control Cable, Silicone Insulated, Sheathed and Armored; provided

- (a) Cable contains 7 or more conductors.
- (b) The average current per conductor does not exceed 2 amperes.
- (c) The maximum current in any one conductor does not exceed 3 amperes.

First: Size No. 18 AWG stranded.
 Second: Insulation—Type S—0.084" minimum diameter.
 Third: Glass braid with extruded black nylon jacket 0.005 inch to 0.007 inch in thickness.
 Fourth: Required conductor cabled—with fillers, where required.
 Fifth: Separator Tape.
 Sixth: Special Tape.‡
 Seventh: Sheath, Moisture Resistant Jacket, Type T.
 Eighth: Basket weave armor.
 Ninth: Paint.

* If two tapes are used in place of a single tape of one half lap, the minimum lap of the two tapes should not be less than 20 percent of the width of the tape and in no case less than one-quarter inch.

† Where the asbestos insulation is composed of impregnated asbestos tapes, the use of a separator is optional with the manufacturer.

‡ A binder comprised of a tape of asbestos or glass fibers treated with a non-melting saturant and backed with a layer of polyethylene terephthalate film.

18.28 Bell Wire.

First: 7 strands of 0.020 inch copper wire (tinned or alloy coated for Type R insulation).
 Second: Insulation—Type R or T to a diameter of 0.154 inch.
 Third: Standard braid to a diameter of 0.190 inch.

18.29 Communication Cable, Rubber or Thermoplastic Insulated, Sheathed and Armored.—(Table 30).

First: 7 strands of 0.020 inch copper wire (tinned or alloy coated for Types R and B insulation).
 Second: Insulation—Type R, B or T, to a diameter of 0.125 inch.
 Third: Color coded marker braid for Types R and B insulation; colored insulation for Type T insulation.
 Fourth: Required number of single conductors cabled—with fillers, where necessary.
 Fifth: Compound filled tape.
 Sixth: Sheath-lead or Type T or N jacket.
 Seventh: Bituminous compound.
 Eighth: Compound filled tape, half lapped.*
 Ninth: Basket weave armor.
 Tenth: Paint.

18.30 Communication Cable, Asbestos-Thermoplastic Insulation, Sheathed and Armored.—(Table 39).

First: 7 strands of 0.020 inch copper wire.
 Second: Insulation—Type TA.
 Third: Wall of impregnated asbestos as described in Type AV insulation.
 Fourth: Marker braid, color coded, rayon impregnated with a clear moisture and flame retardant compound.
 Fifth: Required number of single conductors cabled with impregnated asbestos fillers where necessary.
 Sixth: Binder tape over the conductors assembly.
 Seventh: Wall of impregnated asbestos insulation.
 Eighth: Separator at manufacturer's option.
 Ninth: Sheath-lead or Type T jacket.
 Tenth: Bituminous compound.
 Eleventh: Compound filled tape, half lapped.*
 Twelfth: Basket weave armor.
 Thirteenth: Paint.

18.31 Two-Conductor, Portable Lamp Cord, Braided, Flat.

This cord should conform to the requirements of the Type PO cord in the latest edition of Underwriters' Laboratories Standard for Flexible Cord and Fixture Wire.

18.32 Two-, Three-, or Four-Conductor, Portable Cord, Jacketed.

This cord should conform to the requirements of types SJ, SJO or SJT cord in the latest edition of Underwriters' Laboratories Standard for Flexible Cord and Fixture Wire.

18.33 Three- or Four-Conductor, Portable Cord, Jacketed.—(Hard Service).

This cord should conform to the requirements of

types S, SO or ST cord in the latest edition of Underwriters' Laboratories Standard for Flexible Cord and Fixture Wire. Cords of greater cross-sectional area than No. 10 should be of construction similar to that of Underwriters' Type S, SO or ST cord.

18.34 Two- or Three-Conductor, Portable Cord, Jacketed and Armored.

First: 41 strands of 0.010 inch copper wire (tinned for Types R and B insulation).

Second: Cotton wraps, or suitable separator.

Third: $\frac{3}{64}$ " wall of Types R, B or S insulation.

Fourth: Marker braid, color coded.

Fifth: 2 or 3 conductors twisted together without fillers.

Sixth: A belt of Type R, B or T insulation not less than $\frac{1}{16}$ " at its thinnest point. (Type R or B belt should not be used with Type T insulation.)

Seventh: Basket weave armor to a diameter.

2-conductor = 0.620"

3-conductor = 0.655"

Eighth: Paint.

18.35 Telephone Cable, Jacketed.—(Table 32).

First: 7 strands of 0.020 inch copper wire.

Second: Type T insulation to a diameter of 0.115 inch. Color code one conductor in each pair.

Third: Two conductors twisted together to form a pair.

Fourth: The required number of pairs cabled with fillers where necessary.

Fifth: Compound filled tape.

Sixth: Type T jacket.

18.36 Telephone Cable, Sheathed and Armored.—(Table 32).

First: 7 strands of 0.020 inch copper wire.

Second: Type T insulation to a diameter of 0.115 inch. Color code one conductor in each pair.

Third: Two conductors twisted together to form a pair.

Fourth: The required number of pairs cabled with fillers where necessary.

Fifth: Compound filled tape.

Sixth: Sheath-lead or moisture resistant jacket Type T.

Seventh: Bituminous compound.

Eighth: Compound filled tape, } if lead sheathed
half lapped.*

Ninth: Basket weave armor.

Tenth: Paint.

18.37 Telephone Cable, Asbestos-Thermoplastic Insulated, Sheathed and Armored.—(Table 40).

First: 7 strands of 0.020 inch copper wire.

Second: Type T insulation.

Third: Marker braid of glass fiber treated with flame resisting lacquer. One conductor of each pair to be color coded.

Fourth: Two conductors twisted together to form a pair.

Fifth: Required number of pairs cabled with asbestos fillers where necessary.

Sixth: Binder tape over the conductor assembly.

Seventh: Wall of impregnated asbestos insulation.

Eighth: With or without separator, at manufacturer's option.

Ninth: Sheath-lead or moisture resistant jacket Type T.

Tenth: Bituminous compound.

Eleventh: Compound filled } if lead sheathed
tape, half lapped.*

Twelfth: Basket weave armor.

Thirteenth: Paint.

18.38 Inter-Cabin Telephone Cable, Jacketed.—(Table 33).†

First: No. 20 AWG, solid copper wire.

Second: $\frac{1}{64}$ inch Type T insulation. Color code one conductor in each pair.

Third: Two conductors twisted together to form a pair.

Fourth: The required number of pairs cabled without fillers.

Fifth: Compound filled tape.

Sixth: Type T jacket.

Seventh: Standard braid.

18.39 Inter-Cabin Telephone Cable, Sheathed and Armored.—(Table 33).†

First: No. 20 AWG solid copper wire.

Second: $\frac{1}{64}$ inch Type T insulation. Color code one conductor in each pair.

Third: Two conductors twisted together to form a pair.

Fourth: The required number of pairs cabled without fillers.

Fifth: Compound filled tape.

Sixth: Sheath-lead or moisture resistant jacket Type T.

Seventh: Bituminous compound.

Eighth: Compound filled tape, } if lead sheathed
half lapped.*

Ninth: Basket weave armor.

Tenth: Paint.

18.40 Single-Conductor, Asbestos-Varnished Cloth Insulated Flame Retarding, Switchboard.

First: Stranded conductor.

Second: Separator at manufacturer's option.

Third: Type V insulation.

Fourth: Separator at manufacturer's option.

Fifth: Wall of felted impregnated asbestos insulation.

Sixth: Standard braid.

Seventh: Gray flameproof paint finish.

* If two tapes are used in place of a single tape of one half lap, the minimum lap of the two tapes should not be less than 20 percent of the width of the tape and in no case less than one-quarter inch.

† American Telephone and Telegraph Specification for bridle wire and double-silk impregnated lead sheath cable are recognized as acceptable construction for applications described in Subsections 18.38 and 18.39.

18.41 Single-Conductor, Asbestos-Thermoplastic Insulated Flame Retarding, Switchboard.

First: Stranded conductor.

Second: Type TA insulation.

Third: Standard braid.

Fourth: Gray flameproof paint finish.

(See Note below)

CABLE DESIGNATIONS

18.42 Cable Designations.—The following cable designations should be used in connection with the cables described in Subsections 18.16 to 18.30 inclusive, and 18.34 to 18.41 inclusive. For Subsections 18.31, 18.32, and 18.33 recognized NEC symbols should be used. The designations are made up of letters and numbers signifying the service (if necessary), number of conductors, type of insulation, type of sheath (if any), protection, and conductor size in circular mils (if necessary). The wire size of lighting and power cable is designated by adding to the cable symbol the circular mil size in thousands, thus

DTL-4 = No. 14 (4110 CM) two conductor, thermoplastic insulated lead and steel armor

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

The number of conductors of communication cable is added to the cable symbol, thus

CTALB-20 = 20 conductor communication cable, asbestos thermoplastic insulated, lead and bronze armor

The number of pairs is similarly added to the telephone cable symbol, thus

TT-TL-10 = 10 pair telephone cable, thermoplastic insulated, lead and steel armor

For example:

(a) SAVIB-6 in which:

S = Single conductor

AV = Asbestos-varnished cloth insulation

I = Moisture resistant jacket

B = Bronze armor

6 = 6530 CM (No. 12)

(b) CRLA-7 in which:

C = Communication cable

R = Rubber insulation (75 C)

L = Lead

A = Aluminum armor

7 = Seven conductors

Note: Switchboard Wire.—Single conductor thermoplastic insulated wire without the wall of felted impregnated asbestos insulation and without the standard braid and gray paint finish may be substituted provided that:

(a) The thermoplastic insulation is suitable for a maximum continuous temperature of at least 105 C, and

(b) The finished wire is capable of meeting the tests prescribed for switchboard wires in Subsection 18.15 (g) (1), (3), (4), (5) and (6).

LEGEND									
Cable Type					Insulation		Outer Covering		Armor
S	Single Conductor	Light & Power			R	Rubber 75 C	A	Braid and Armor	(None) Steel
D	Double	"	"	"	B	Rubber 85 C	L	Lead and Armor	A Aluminum
T	Three	"	"	"	T	Thermoplastic	I	Moisture Resistant	B Bronze
F	Four	"	"	"	V	Varnished cloth		Jacket, Type T or N	
M	Multiple Conductor				AV	Asbestos-Varnished Cloth		as designated, and	
C	Communication				TA	Asbestos Thermoplastic		Armor	
TT	Telephone				M	Mineral	J	Moisture Resistant	
TTC	Inter-Cabin Telephone				S	Silicone		Jacket Unarmored	
P	Portable							(for NEC portable	
W	Switchboard							cords and telephone	
BW	Bell Wire							cable only)	

Subsection Number	Type							Designation
18.16	Single Conductor, Mineral Insulated							SM
"	Two	"	"	"	"	"	"	DM
"	Three	"	"	"	"	"	"	TM
"	Four	"	"	"	"	"	"	FM
"	Seven	"	"	"	"	"	"	MM
18.17	Single Conductor, Rubber Insulated (75 C), Braid & Steel Armor							SRA
"	"	"	"	"	"	"	" Aluminum Armor	SRAA
"	"	"	"	"	"	"	" Bronze Armor	SRAB
"	"	"	"	"	(85 C)	"	" Steel Armor	SBA
"	"	"	"	"	"	"	" Aluminum Armor	SBAA
"	"	"	"	"	"	"	" Bronze Armor	SBAB
"	"	"	Thermoplastic Insulated, Braid &				Steel Armor	STA
"	"	"	"	"	"	"	" Aluminum Armor	STAA
"	"	"	"	"	"	"	" Bronze	STAB
18.18	Single Conductor, Rubber Insulated (75 C), Lead & Steel Armor							SRL
"	"	"	"	"	"	"	" Aluminum Armor	SRLA
"	"	"	"	"	"	"	" Bronze Armor	SRLB
"	"	"	"	"	(85 C)	"	" Steel Armor	SBL
"	"	"	"	"	"	"	" Aluminum Armor	SBLA
"	"	"	"	"	"	"	" Bronze Armor	SBLB
"	"	"	Thermoplastic Insulated, Lead &				Steel Armor	STL
"	"	"	"	"	"	"	" Aluminum Armor	STLA
"	"	"	"	"	"	"	" Bronze Armor	STLB
"	"	"	Varnished Cloth Insulated, Lead &				Steel Armor	SVL
"	"	"	"	"	"	"	" Aluminum Armor	SVLA
"	"	"	"	"	"	"	" Bronze Armor	SVLB
"	"	"	Rubber Insulated (75 C), Jacket &				Steel Armor	SRI
"	"	"	"	"	"	"	" Aluminum Armor	SRIA
"	"	"	"	"	"	"	" Bronze Armor	SRIB
"	"	"	"	"	(85 C)	"	" Steel Armor	SBI
"	"	"	"	"	"	"	" Aluminum Armor	SBIA
"	"	"	"	"	"	"	" Bronze Armor	SBIB
"	"	"	Thermoplastic Insulated, Jacket &				Steel Armor	STI
"	"	"	"	"	"	"	" Aluminum Armor	STIA
"	"	"	"	"	"	"	" Bronze Armor	STIB
"	"	"	Varnished Cloth Insulated, Jacket &				Steel Armor	SVI
"	"	"	"	"	"	"	" Aluminum Armor	SVIA
"	"	"	"	"	"	"	" Bronze Armor	SVIB

Subsection Number	Type	Designation
18.19	Single Conductor, Asbestos-Varnished Cloth Insulated, Lead & Steel Armor	SAVL
"	" " " " " " " " " Aluminum Armor	SAVLA
"	" " " " " " " " " Bronze Armor	SAVLB
"	" " " " " " " " " Jacket & Steel Armor	SAVI
"	" " " " " " " " " Aluminum Armor	SAVIA
"	" " " " " " " " " Bronze Armor	SAVIB
18.20	Two Conductor, Rubber Insulated (75 C), Braid & Steel Armor	DRA
"	" " " " " " " " " Aluminum Armor	DRAA
"	" " " " " " " " " Bronze Armor	DRAB
"	" " " " " " (85 C) " " Steel Armor	DBA
"	" " " " " " " " " Aluminum Armor	DBAA
"	" " " " " " " " " Bronze Armor	DBAB
"	" " " " Thermoplastic Insulated, Braid & Steel Armor	DTA
"	" " " " " " " " " Aluminum Armor	DTAA
"	" " " " " " " " " Bronze Armor	DTAB
"	Three Conductor, Rubber Insulated (75 C), Braid & Steel Armor	TRA
"	" " " " " " " " " Aluminum Armor	TRAA
"	" " " " " " " " " Bronze Armor	TRAB
"	" " " " " " (85 C) " " Steel Armor	TBA
"	" " " " " " " " " Aluminum Armor	TBAA
"	" " " " " " " " " Bronze Armor	TBAB
"	" " " " Thermoplastic Insulated, Braid & Steel Armor	TTA
"	" " " " " " " " " Aluminum Armor	TTAA
"	" " " " " " " " " Bronze Armor	TTAB
18.21	Two Conductor, Rubber Insulated (75 C), Lead & Steel Armor	DRL
"	" " " " " " " " " Aluminum Armor	DRLA
"	" " " " " " " " " Bronze Armor	DRLB
"	" " " " " " (85 C) " " Steel Armor	DBL
"	" " " " " " " " " Aluminum Armor	DBLA
"	" " " " " " " " " Bronze Armor	DBLB
"	" " " " Thermoplastic Insulated, Lead & Steel Armor	DTL
"	" " " " " " " " " Aluminum Armor	DTLA
"	" " " " " " " " " Bronze Armor	DTLB
"	" " " " Varnished Cloth Insulated, Lead & Steel Armor	DVL
"	" " " " " " " " " Aluminum Armor	DVLA
"	" " " " " " " " " Bronze Armor	DVLB
"	Three Conductor, Rubber Insulated (75 C), Lead & Steel Armor	TRL
"	" " " " " " " " " Aluminum Armor	TRLA
"	" " " " " " " " " Bronze Armor	TRLB
"	" " " " " " (85 C) " " Steel Armor	TBL
"	" " " " " " " " " Aluminum Armor	TBLA
"	" " " " " " " " " Bronze Armor	TBLB
"	" " " " Thermoplastic Insulated, Lead & Steel Armor	TTL
"	" " " " " " " " " Aluminum Armor	TTLA
"	" " " " " " " " " Bronze Armor	TTLB
"	" " " " Varnished Cloth Insulated, Lead & Steel Armor	TVL
"	" " " " " " " " " Aluminum Armor	TVLA
"	" " " " " " " " " Bronze Armor	TVLB
"	Two Conductor, Rubber Insulated (75 C), Jacket & Steel Armor	DRI
"	" " " " " " " " " Aluminum Armor	DRIA
"	" " " " " " " " " Bronze Armor	DRIB
"	" " " " " " (85 C) " " Steel Armor	DBI
"	" " " " " " " " " Aluminum Armor	DBIA
"	" " " " " " " " " Bronze Armor	DBIB
"	" " " " Thermoplastic Insulated, Jacket & Steel Armor	DTI
"	" " " " " " " " " Aluminum Armor	DTIA
"	" " " " " " " " " Bronze Armor	DTIB
"	" " " " Varnished Cloth Insulated, Jacket & Steel Armor	DVI
"	" " " " " " " " " Aluminum Armor	DVIA
"	" " " " " " " " " Bronze Armor	DVIB

Subsection Number	Type						Designation
18.21	Three Conductor, Rubber Insulated (75 C) Jacket & Steel Armor						TRI
"	"	"	"	"	"	" Aluminum Armor	TRIA
"	"	"	"	"	"	" Bronze Armor	TRIB
"	"	"	"	"	(85 C)	" Steel Armor	TBI
"	"	"	"	"	"	" Aluminum Armor	TBIA
"	"	"	"	"	"	" Bronze Armor	TBIB
"	"	"	Thermoplastic Insulated, Jacket &			Steel Armor	TTI
"	"	"	"	"	"	" Aluminum Armor	TTIA
"	"	"	"	"	"	" Bronze Armor	TTIB
"	"	"	Varnished-Cambric Insulated, Jacket &			Steel Armor	TVI
"	"	"	"	"	"	" Aluminum Armor	TVIA
"	"	"	"	"	"	" Bronze Armor	TVIB
18.22	Two Conductor, Asbestos-Varnished Cloth Insulated, Lead & Steel Armor						DAVL
"	"	"	"	"	"	" Aluminum Armor	DAVLA
"	"	"	"	"	"	" Bronze Armor	DAVLB
"	"	"	"	"	"	Jacket & Steel Armor	DAVI
"	"	"	"	"	"	" Aluminum Armor	DAVIA
"	"	"	"	"	"	" Bronze Armor	DAVIB
"	Three Conductor, Asbestos-Varnished Cloth Insulated, Lead & Steel Armor						TAVL
"	"	"	"	"	"	" Aluminum Armor	TAVLA
"	"	"	"	"	"	" Bronze Armor	TAVLB
"	"	"	"	"	"	Jacket & Steel Armor	TAVI
"	"	"	"	"	"	" Aluminum Armor	TAVIA
"	"	"	"	"	"	" Bronze Armor	TAVIB
18.23	Four Conductor, Rubber Insulated (75 C), Braid & Steel Armor						FRA
"	"	"	"	"	"	" Aluminum Armor	FRAA
"	"	"	"	"	"	" Bronze Armor	FRAB
"	"	"	"	"	(85 C)	" Steel Armor	FBA
"	"	"	"	"	"	" Aluminum Armor	FBAA
"	"	"	"	"	"	" Bronze Armor	FBAB
"	"	"	Thermoplastic Insulated, Braid &			Steel Armor	FTA
"	"	"	"	"	"	" Aluminum Armor	FTAA
"	"	"	"	"	"	" Bronze Armor	FTAB
18.23	Four Conductor, Rubber Insulated (75 C), Lead & Steel Armor						FRL
"	"	"	"	"	"	" Aluminum Armor	FRLA
"	"	"	"	"	"	" Bronze Armor	FRLB
"	"	"	"	"	(85 C)	" Steel Armor	FBL
"	"	"	"	"	"	" Aluminum Armor	FBLA
"	"	"	"	"	"	" Bronze Armor	FBLB
"	"	"	Thermoplastic Insulated, Lead &			Steel Armor	FTL
"	"	"	"	"	"	" Aluminum Armor	FTLA
"	"	"	"	"	"	" Bronze Armor	FTLB
"	"	"	Rubber Insulated (75 C), Jacket &			Steel Armor	FRI
"	"	"	"	"	"	" Aluminum Armor	FRIA
"	"	"	"	"	"	" Bronze Armor	FRIB
"	"	"	"	"	(85 C)	" Steel Armor	FBI
"	"	"	"	"	"	" Aluminum Armor	FBIA
"	"	"	"	"	"	" Bronze Armor	FBIB
"	"	"	Thermoplastic Insulated, Jacket &			Steel Armor	FTI
"	"	"	"	"	"	" Aluminum Armor	FTIA
"	"	"	"	"	"	" Bronze Armor	FTIB
18.24	Single Conductor, Silicone Insulated, Jacket & Aluminum Armor						SSIA
"	"	"	"	"	"	" Bronze Armor	SSIB
18.25	Two Conductor, Silicone Insulated, Jacket & Aluminum Armor						DSIA
"	"	"	"	"	"	" Bronze Armor	DSIB
"	Three Conductor, Silicone Insulated, Jacket & Aluminum Armor						TSIA
"	"	"	"	"	"	" Bronze Armor	TSIB

Subsection Number	Type	Designation
18.26	Four Conductor, Silicone Insulated, Jacket & Aluminum Armor	FSIA
"	" " " " " " " " Bronze Armor	FSIB
18.27	Multi Conductor, Silicone Insulated, Jacket & Aluminum Armor	MSIA
"	" " " " " " " " Bronze Armor	MSIB
18.28	Bell Wire, Rubber or Thermoplastic Insulated	BW
18.29	Communication, Rubber Insulated (75 C), Lead & Steel Armor	CRL
"	" " " " " " " " Aluminum Armor	CRLA
"	" " " " " " " " Bronze Armor	CRLB
"	" " " " (85 C) " " " Steel Armor	CBL
"	" " " " " " " " Aluminum Armor	CBLA
"	" " " " " " " " Bronze Armor	CBLB
"	" " Thermoplastic Insulated, Lead & Steel Armor	CTL
"	" " " " " " " " Aluminum Armor	CTLA
"	" " " " " " " " Bronze Armor	CTLB
"	" " Rubber Insulated (75 C), Jacket & Steel Armor	CRI
"	" " " " " " " " Aluminum Armor	CRIA
"	" " " " " " " " Bronze Armor	CRIB
"	" " " " (85 C) " " " Steel Armor	CBI
"	" " " " " " " " Aluminum Armor	CBIA
"	" " " " " " " " Bronze Armor	CBIB
"	" " Thermoplastic Insulated, Jacket & Steel Armor	CTI
"	" " " " " " " " Aluminum Armor	CTIA
"	" " " " " " " " Bronze Armor	CTIB
18.30	Communication, Asbestos Thermoplastic Insulated, Lead & Steel Armor	CTAL
"	" " " " " " " " Aluminum Armor	CTALA
"	" " " " " " " " Bronze Armor	CTALB
"	" " " " " " " " Jacket & Steel Armor	CTAI
"	" " " " " " " " Aluminum Armor	CTAIA
"	" " " " " " " " Bronze Armor	CTAIB
18.31	Two Conductor, Portable Lamp Cord, Braided	PO
18.32	Two " " " " " Jacketed	SJO-2
"	Three " " " " " " "	SJO-3
"	Four " " " " " " "	SJO-4
18.33	Two Conductor, Portable Hard Service, Jacketed	SO-2
"	Three " " " " " " "	SO-3
"	Four " " " " " " "	SO-4
18.34	Two Conductor, Portable, Rubber Insulated (75 C), Jacket & Steel Armor	DPRI
"	" " " " " " " " " Aluminum Armor	DPRIA
"	" " " " " " " " " Bronze Armor	DPRI B
"	" " " " " " " " (85 C) " Steel Armor	DPBI
"	" " " " " " " " " Aluminum Armor	DPBIA
"	" " " " " " " " " Bronze Armor	DPBIB
"	" " " " " Thermoplastic Insulated, Jacket & Steel Armor	DPTI
"	" " " " " " " " " Aluminum Armor	DPTIA
"	" " " " " " " " " Bronze Armor	DPTIB
"	Three Conductor, " Rubber Insulated (75 C), Jacket & Steel Armor	TPRI
"	" " " " " " " " " Aluminum Armor	TPRIA
"	" " " " " " " " " Bronze Armor	TPRI B
"	" " " " " " " " (85 C) " Steel Armor	TPBI
"	" " " " " " " " " Aluminum Armor	TPBIA
"	" " " " " " " " " Bronze Armor	TPBIB
"	" " " " " Thermoplastic Insulated, Jacket & Steel Armor	TPTI
"	" " " " " " " " " Aluminum Armor	TPTIA
"	" " " " " " " " " Bronze Armor	TPTIB

NEC Designations

Subsection Number	Type					Designation
18.35	Telephone, Thermoplastic Insulated, Jacketed					TT-TJ
18.36	Telephone, Thermoplastic Insulated, Lead & Steel Armor					TT-TL
"	"	"	"	"	" Aluminum Armor	TT-TLA
"	"	"	"	"	" Bronze Armor	TT-TLB
"	"	"	"	Jacket &	" Steel Armor	TT-TI
"	"	"	"	"	" Aluminum Armor	TT-TIA
"	"	"	"	"	" Bronze Armor	TT-TIB
18.37	" Asbestos-Thermoplastic Insulated, Lead & Steel Armor					TT-TAL
"	"	"	"	"	" Aluminum Armor	TT-TALA
"	"	"	"	"	" Bronze Armor	TT-TALB
"	"	"	"	Jacket &	" Steel Armor	TT-TAI
"	"	"	"	"	" Aluminum Armor	TT-TAIA
"	"	"	"	"	" Bronze Armor	TT-TAIB
18.38	Inter-Cabin Telephone, Thermoplastic Insulated, Jacketed					TTC-TJ
18.39	"	"	"	"	" Lead & Steel Armor	TTC-TL
"	"	"	"	"	" Aluminum Armor	TTC-TLA
"	"	"	"	"	" Bronze Armor	TTC-TLB
"	"	"	"	Jacket &	" Steel Armor	TTC-TI
"	"	"	"	"	" Aluminum Armor	TTC-TIA
"	"	"	"	"	" Bronze Armor	TTC-TIB
18.40	Single Conductor, Switchboard Wire, Asbestos-Varnished-Cloth Insulated					SWAV
18.41	"	"	"	"	" Thermoplastic Insulated	SWTA

SECTION 19

CABLE APPLICATION

- 19.01 General—AC Applications.**—In general, multiple-conductor cable should be used for all alternating-current power and lighting circuits. Except as otherwise recommended herein, all phase wires of any circuit should be contained in a single cable, i.e. within the same armor, to neutralize induction.

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 for 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, as for connections to three single-phase transformers of a three-phase bank, or where 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. Lead sheath should not be used in single conductor cables. Attention is directed to the precautions recommended in Section 20 covering installation.

Further, single conductor cables may be used for instrument and control leads, etc., on switchboards where carrying negligible currents.

- 19.03 Varnished - Cloth and Asbestos-Varnished-Cloth Insulated Cables.**—Cables constructed with varnished-cloth or asbestos-varnished cloth insulation may be used throughout the vessel and should be used in all spaces having an ambient temperature exceeding 50C. Where varnished-cloth insulation is used, the wire size should not be smaller than No. 12 AWG. This necessitates the use of No. 12 wire for lighting branch circuits instead of No. 14. However, asbestos-varnished-cloth No. 14 wire may be used if desired.

Cables constructed with asbestos-varnished-cloth insulation are commonly known as heat- and flame-resisting type cables and are best adapted for installation in high temperature locations or for circuits or spaces where the cable's increased resistance to fire or overheated conductors may reduce the hazard to life and property.

- 19.05 Rubber or Thermoplastic Insulated Cables.**—Rubber or thermoplastic insulated cables may be used in any space where the ambient temperature does not exceed 50C.

- 19.07 Armored Cable.**—All permanently installed light and power cables except as described in Section 19.15 should be armored.

Armoring may be steel, bronze, copper, or aluminum. Bronze, copper, or aluminum armoring should be used for all cables exposed to weather.

- 19.09 Rubber or Thermoplastic Insulated Armored Cables and Varnished-Cloth Insulated Reinforced Jacketed and Armored Cables.**—Single, double, three or four conductor cables of the above

construction may be used for branch circuits, lighting and power in officers', crew's and passengers' living quarters, including mess rooms, dining rooms and public spaces where not exposed to moisture.

Varnished-cloth insulated cables should not have a cross-sectional area less than No. 12 AWG. (See Subsection 19.03.)

Attention is directed to the fact that the life of rubber insulation is very materially reduced if it is exposed to a temperature exceeding 75C. It is therefore important in carrying the cable conductors into lighting fixture and other heat generating devices to vent or design the wiring spaces to prevent conductor insulation from reaching 75C.

- 19.11 Cable with Lead or Moisture Resisting Jacket.**

—Leaded or moisture resisting jacketed cable should be used where exposed to the weather, in public washrooms and toilets which are equipped with bath or showers, and within ten feet of weather deck doors or other access openings to the weather where such openings are not protected by an overhead deck which overhangs the full width of the weather decks to which such doors or access openings lead (unless the cable in the prescribed area is concealed in and protected by fire-resisting joiner work panels), and in general where cable is exposed to moisture. This cable should be used in all other spaces, such as machinery spaces, except as otherwise permitted in Subsections 19.09 and 19.21.

- 19.13 Braided Cable.**—Rubber insulated braided cable may be used in lighting fixtures except as noted in Subsection 19.09. In multiple lamp fixtures 2580 circular mils stranded, rubber and cotton braid insulated wire may be used for the individual lamps and may be spliced in the lighting fixtures.

- 19.15 Communication Wires and Cables.**—For call bell circuits of 25 volts or less within passenger and crew accommodations, single-conductor bell wire as described in Subsection 18.28 may be used, if properly installed in protected raceways.

For communication apparatus, operating on potentials not exceeding 300 volts, such as fire alarms, telegraphs, telemotors, signalling circuits, control circuits, etc., requiring two or more wires, communication cable should be used and should be either leaded and armored or armored, in accordance with the locations described in the preceding paragraphs, except that twin-conductor light and power cable may be substituted for twin-conductor communication cable.

All telephones and telephone systems except those installed for the convenience of passengers, and not essential for the operation of the vessel should be wired with either armored, or leaded and armored telephone cable as described above.

Inter-cabin telephone cable of either the armored, or leaded and armored type as described above, may be used for the passenger non-essential telephone systems.

The American Telephone & Telegraph Specification Double-Silk Impregnated Lead Sheath Cable without armor may be used for telephone circuits

where a large number of ship's service telephones are installed in passengers' and/or crews' quarters. Bridle wire in accordance with American Telephone & Telegraph Specifications may also be used for local wiring for ship's service telephones provided it is rigidly held in place, protected from mechanical injury and not exposed to moisture.

19.17 Portable Conductors.—

(a) *Rubber Sheathed.* Conductors for portable cargo fixtures, tools, waterproof and non-waterproof portables, signalling lights and all portables or semi-portable fixtures outside living quarters should be portable rubber sheathed. Portable conductor for running lights may be portable rubber sheathed. (See Subsection 21.07.)

(b) *Armored.* Armored portable conductor cable may be used for the above applications and should be used where the cable is continuously in contact with oil.

(c) *Braided.* Cables for portable or semi-portable equipment such as desk lights, used in living quarters should be three-conductor, portable, braided.

Cables for hand iron or other appliances for passenger use may be two-conductor, portable, braided.

19.19 Asbestos-Varnished-Cloth and Asbestos Thermoplastic Insulated Switchboard Wire.—This wire should be used in accordance with Subsection 17.03 for switchboard and controller wiring.

19.21 Mineral Insulated Metal Sheathed Cable.—(Type MI).

It may be used for any service up to 600 volts.

It should be used with approved fittings for terminating and connecting to boxes, outlets and other equipment.

Mineral insulated-metal sheathed cable may be used for mains, feeders and branch circuits in both exposed and concealed work, in dry or wet locations.

It may be used where exposed to weather or continuous moisture, where exposed to oil, gasoline, or other conditions not having a deteriorating effect on the metal sheath. The sheath of mineral insulated-metal sheathed cable exposed to destructive corrosive conditions should be made of or protected by materials suitable for those conditions.

Care must be exercised to insure that the total temperature of the terminal fittings will not exceed 85C under any condition of operation.

SECTION 20

CABLE INSTALLATION

20.01 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:

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

(b) Magnetic material between conductors should be avoided.

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

20.03 Cable Continuity and Grounding.—All cables should be continuous between outlet boxes, connection boxes, switchboards, panelboards, switch outlets, receptacle outlets, terminal equipment, etc. 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 sub-circuits the sheath may be grounded at the supply end only. Sheathed or armored cables entering non-watertight boxes or wiring devices should have the sheath or armor secured outside the box by means of a clamp, which is lock-nutted to, or screwed into the box.

20.05 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 oil tanks.

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.

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.

20.07 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 specially protected by removable metal coverings, angle irons or other equivalent means. Horizontal pipes or equivalent used for cable protection should have ¼ inch diameter holes for drainage every five feet.

20.09 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. Cables grouped in a single hanger should be limited preferably to double banking.

Clips or straps used for cable support should each be secured by two screws except that clips for supporting one cable, No. 10 AWG twin or