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Recommended Practice
for
**ELECTRIC INSTALLATIONS
ON SHIPBOARD**

(1951 Revision)

(Effective December 20, 1951)



Published by
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 West Thirty-ninth Street, New York 18, N. Y.

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for
**ELECTRIC INSTALLATIONS
ON SHIPBOARD**

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**Prepared by the Committee
on
Marine Transportation**



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Development of the Standards of the American Institute of Electrical Engineers

Recognizing the importance in the development of electrical engineering, of standardization in the electrical field, the AIEE in 1898 appointed a Committee on Standardization, consisting of seven members having qualifications and experience from designing, manufacturing and operating standpoints. The report of this Committee was accepted at a meeting of the Institute in June 1899.

Experience gained in applications of the Standards and further developments in electric apparatus and methods showed the necessity of revision, and a committee was appointed which after consultation with manufacturing and operating engineers presented the first revised report on Standardization Rules of the AIEE in June 1902.

The next revision was undertaken by a committee of ten, which presented its report in May 1906.

In September 1906, a Standards Committee of eleven members was appointed for further revision and its report was presented in June 1907.

The appreciation of the importance and value of standardization resulted in the formation of a Standing Committee, with the title of Standards Committee of the AIEE. This became effective in the Constitution of June 1907. The scope and amount of work necessitated increasing the number of members from time to time until in 1922 there were 37 members divided into a number of subcommittees specializing on various subjects.

AIEE Standards published in a single volume as each revision was adopted have been generally accepted as Standards of the electrical industry of the United States since the adoption of the first report in 1899. Subsequent reports on Standards were made and published, in some cases in several editions. The dates of adoption by the Board of Directors of such reports are as follows: June 20, 1902; June 21, 1907; June 27, 1912; July 10, 1914; June 30, 1915; June 28, 1916; November 8, 1918; October 8, 1920, and June 29, 1922.

On June 29, 1922, in view of the increasing complexity of the work, a reorganization of the Standards Committee was effected, and a working organization established which provided for an increase in standardization work and for the appointment on Working Committees of the Standards Committee of non-Institute members.

The present plan under which the Institute Standards are being issued involves the separation of the complete body of Standards into more than forty sections, each published as a separate pamphlet and dealing with a specific subject. Each section of the Standards has been formulated either by a Working Committee of the Standards Committee which has been made as representative as possible for the work in hand, by an AIEE technical committee or subcommittee, or by a Sectional Committee organized according to the procedure of the American Standards Association. The division of the Standards into a number of separate publications simplifies the process of keeping the Standards revised to conform with the latest developments and enables those interested in a particular field to obtain in concise form the material relating to that field. In framing the Institute Standards the chief purpose has been to define terms and conditions which characterize the rating and behavior of electric machinery and apparatus, with special reference to the conditions of acceptance tests.

The AIEE Standards Committee takes this occasion to draw attention to the value of suggestions based upon experience gained in the application of the Standards to general practice. Any suggestions looking toward improvement in the Standards will be welcomed for the guidance of the Committee in preparation of future editions, and should be communicated to the Secretary of the AIEE Standards Committee, 33 West 39th Street, New York 18.

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Foreword

"Recommended Practice for Electric Installations on Shipboard", AIEE Standard No. 45, constitutes the chief undertaking of the Committee on Marine Transportation of the American Institute of Electrical 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 and 1945. In April 1943 a supplement to No. 45, identified as No. 45A (revised as of January 1, 1944), was issued to apply during the national emergency only. This was drawn up at the request of and in cooperation with the War Production Board. Its sole purpose was the conservation of critical materials. As the use of the provisions of 45A resulted in a shipboard electric installation of a lower standard than is contemplated in the regular standard, No. 45, it was withdrawn as obsolete by direction of the Committee on Marine Transportation in September 1945. This present edition of "Recommended Practice for Electric Installations on Shipboard" includes all items covered in 45A which it has been agreed should be recommended as standard construction and represents a further development. The major revisions from the 1948 edition and new material are indicated by the symbol ♦ under the Subsection number or in front of a paragraph as in Subsections 11.53 and 11.55, for example. Minor typographical changes are not so indicated. This edition was approved by the AIEE, December 3, 1951.

The 1951-1952 Committee on Marine Transportation personnel follows:

J. B. FEDER, <i>Chairman</i> U. S. Coast Guard	J. E. JONES Cutler-Hammer, Inc.
W. E. JACOBSEN, <i>Vice-Chairman</i> General Electric Co.	C. KROMMENHOCK Todd Shipyards Corp.
W. N. ZIPPLER, <i>Secretary</i> Gibbs & Cox, Inc.	V. W. MAYER U. S. Maritime Administration
W. B. ARMSTRONG U. S. Department of the Navy	S. N. MEAD Sig-Trans, Inc.
H. C. COLEMAN Westinghouse Electric Corp.	W. H. REED Bruce Electric Co.
P. J. DU MONT Grace Lines	E. M. ROTHEN Russell & Stoll Co.
R. W. FROST Henschel Corp.	J. D. SHUSTER Bethlehem Steel Co.
A. R. GATEWOOD American Bureau of Shipping	C. W. SOUDER Sperry Gyroscope Co., Inc.
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L. M. GOLDSMITH The Atlantic Refining Co.	G. O. WATSON Lloyd's Register of Shipping
P. A. GUISE United Fruit Co.	O. A. WILDE Sun Shipbuilding & Dry Dock Co.
H. F. HARVEY, JR. Newport News Shipbuilding & Dry Dock Co.	

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 AIEE, 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 are frequently modifying 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 encountered at sea.

(b) Roll, pitch and vibration of a vessel under way.

(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 living spaces, 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, explosive mixtures of dust or gases*, steam, salt spray, excessive moisture or dripping water, 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.

*Explosionproof equipment only 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 regulations, 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 regulations, 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. (ASA C42 05.20.057) (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. (ASA C42 05.20.070) (Unless distinctly specified otherwise, the term "alternating current" refers to a circuit which reverses at regularly recurring intervals 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. (ASA C42 05.05.190) (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. (ASA C42 05.05.180) (The frequency of an alternating current is the number of cycles per second.)
- 2.15 Single-Phase Circuit.**—A single-phase circuit is a circuit energized by a single alternating electromotive force.
(ASA C42 35.40.050)
- 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.
- 2.17 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.
(ASA C42 35.40.060)
- Note:* In practice, the phases may vary several degrees from the specified angle.
- 2.19 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 10.95.250)

- 2.21 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 10.15.350)
- 2.23 Electronics.**—Electronics is that branch of science and technology which relates to the conduction of electricity through gases or in vacuo.
(ASA C42 70.05.005)
- 2.25 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.
- 2.27 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.
- 2.29 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. (ASA C42 05.45.040)
- 2.31 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. (ASA C42 05.15.050)
- 2.33 Reactor.**—A reactor is a device, the primary purpose of which is to introduce reactance into a circuit. (ASA C42 05.45.085)
A reactor is a device used for introducing reactance into a circuit for purposes such as motor starting, paralleling transformers and control of current. (ASA C42 15.40.005)
- 2.35 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 reac-

*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 American Standard C42 dated 1941. That portion in parentheses is added by the Marine Transportation Committee and by AIEE nomenclature is identified as "discussion".

tance 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.

(ASA C42 05.20.205)

- 2.37 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 10.10.010)

- 2.39 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.

(ASA C42 10.10.020)

- 2.41 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 10.10.030)

- 2.43 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 10.10.035)

- 2.45 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.

- 2.47 Corrosion-Resistant Parts.**—

(a) General—Where essential to minimize deterioration due to marine atmospheric 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.

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.

- 2.49 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 10.10.050) (A generator producing direct current is usually called a direct-current generator, and a generator producing alternating current is called an alternating-current generator or by the deprecated term alternator.)

- 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 con-

nected 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, the field poles of which are permanent magnets.
(ASA C42 10.10.060)
- 3.11 Exciter.**—An exciter is an auxiliary generator which supplies energy for the field excitation of another electric machine. (ASA C42 10.10.070)
- 3.13 Pilot Exciter.**—A pilot exciter is an exciter which supplies energy for the field excitation of another exciter. (ASA C42 10.10.080)
- 3.15 Synchronous Generator.**—A synchronous generator is a synchronous alternating-current machine which transforms mechanical power into electric power. (ASA C42 10.10.100) (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 10.10.110)
- 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 10.10.120) (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 10.10.140)

- 3.23 Induction Generator.**—An induction generator is an induction machine, driven above synchronous speed by an external source of mechanical power. (ASA C42 10.10.150)

SECTION 4

MOTOR CLASSIFICATION

- 4.01 Electric Motor.**—An electric motor is a machine which transforms electric energy into mechanical energy. (ASA C42 10.10.200)
- 4.03 Universal Motor.**—A universal motor is a series-wound or a compensated series-wound motor which may be operated either on direct current or single-phase alternating current at approximately the same speed and output. These conditions must be met when the direct-current and alternating-current voltages are approximately the same and the frequency of the alternating current is not greater than 60 cycles per second. (ASA C42 10.10.210)
- 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 10.10.330)
- 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 10.10.335)
- 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 10.10.340) (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 10.10.350) (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 induction machine which converts electric power delivered to the primary circuit into mechanical power. The secondary circuit is short-circuited or closed through a suitable circuit.
(ASA C42 10.10.260)
- 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 10.10.280)

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 10.10.270) (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 from an alternating-current system into mechanical power. Synchronous motors usually have direct-current field excitation. (ASA C42 10.10.300) (A synchronous motor operates at synchronous speed and therefore operates with zero slip. The synchronous speeds depend upon the frequency of the supply system and the number of poles.)

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 10.10.440)

4.23 Amortisseur Winding.—An amortisseur winding is a permanently short-circuited winding, usually uninsulated, so arranged as to oppose rotation or pulsation of the magnetic field with respect to the pole shoes. (ASA C42 10.15.360)

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 10.15.370)

SECTION 5

CONVERTERS—ROTARY

5.01 Dynamotor.—A dynamotor is a machine which combines both motor and generator action in one magnetic field, either with two armatures, or with one armature having two separate windings. (ASA C42 10.10.450) (The two windings may be in the same slots.)

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 10.10.460)

5.05 Synchronous Converter (Rotary Converter).—A synchronous converter is a synchronous machine which converts alternating current to direct current or vice-versa. The armature winding is connected to the collector rings and commutator. (ASA C42 10.10.470)

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 10.10.560)

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 10.10.570)

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 10.10.540)

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 10.20.010)

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 10.20.020)

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 shunt motor with field resistance control designed for a considerable range of speed adjustment. (ASA C42 10.20.040)

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 10.20.050)

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 motor, or an induction motor with large slip. (ASA C42 10.20.060)

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 compound-wound direct-current motor adjusted by field control, or a slip-ring induction motor with rheostatic speed control. (ASA C42 10.20.070)

SECTION 7

VENTILATION OF MACHINES

- 7.01 Open Machine.**—An open machine is a self-ventilated machine having no restriction to ventilation other than that necessitated by mechanical construction. (ASA C42 10.25.050)
- 7.03 Self-Ventilated Machine.**—A self-ventilated machine is one which has its ventilating air circulated by means integral with the machine. (ASA C42 10.25.010)
- 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. (ASA C42 10.25.020)
- 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. (ASA C42 10.25.030)
- 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. (ASA C42 10.25.040)
- 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 10.25.060)
- 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 10.25.070)

SECTION 8

ENCLOSURE OF MACHINES

- 8.01 Protected Machine.**—A protected machine is one in which all ventilating openings in the frame are protected with wire screen, expanded metal, or perforated covers.
- Note:* A common form of specification for "protected machine" 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." (ASA C42 10.30.010)

8.03 Semi-Protected Machine.—A semi-protected machine is one in which part of the ventilating openings in the frame, usually in the top half are protected as in the case of a "protected machine," but the others are left open. (ASA C42 10.30.020)

8.05 Drip-Proof Machine.—A drip-proof machine is one in which the ventilating openings are so constructed that drops of liquid or solid particles falling on the machine at any angle not greater than 15 degrees from the vertical, cannot enter the machine either directly, or by striking and running along a horizontal or inwardly inclined surface. (ASA C42 10.30.030)

8.07 Splashproof Machine.—A splashproof machine is one in which the ventilating openings are so constructed that drops of liquid or solid particles falling on the machine or coming towards it in a straight line at any angle not greater than 100 degrees from the vertical cannot enter the machine either directly or by striking and running along a surface. (ASA C42 10.30.040)

8.09 Waterproof Machine.—A waterproof machine is a totally enclosed machine so constructed that a stream of water from a hose (not less than 1 inch in diameter) under a head of 35 feet and from a distance of about 10 feet can be played on the machine from any direction for a period of 15 minutes without leakage, except that 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 machine. The hose nozzle should be adjusted to give a solid stream at the enclosure. The machine should be provided with a check valve for drainage or a tapped hole at the lowest part of the frame which will serve for application of drain pipe or drain plug.

8.11 Submersible Machine.—A submersible machine is one so constructed that it will operate successfully when submerged in water under specified conditions of pressure and time (ASA C42 95.90.195)

8.13 Explosionproof Machine.—An explosionproof machine is one in an enclosing case which is so designed and constructed to withstand an explosion of a specified gas or dust which may occur within it, and to prevent the ignition of the specified gas or dust surrounding the machine by sparks, flashes or explosions of the specified gas or dust which may occur within the machine casing. (ASA C42 10.30.050)

Note: Explosionproof 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.

8.15 Flameproof Enclosure.—A flameproof enclosure is an enclosure that will not permit a flame to be maintained within it or will not be injured readily when subjected to flame.

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 10.40.020)
- 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 for one minute, with rated voltage applied at rated frequency and with normal excitation. (ASA C42 10.40.060)
- 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 10.40.070)
- 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. (ASA C42 05.50.015)
- 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. (ASA C42 05.50.025)

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 25.05.005)
- 11.03 Basic Functions.**—The basic functions of a controller are acceleration, retardation, line closing, reversing, etc. (ASA C42 25.05.010)
- 11.05 Full Magnetic Controller.**—A full magnetic controller is an electric controller having all of its basic functions performed by electromagnets. (ASA C42 25.05.030)
- 11.07 Semi-Magnetic Controller.**—A semi-magnetic controller is an electric controller having only part of its basic functions performed by electromagnets. (ASA C42 25.05.035)
- 11.09 Manual Controller.**—A manual controller is an electric controller having all of its basic functions performed by hand. (ASA C42 25.05.025)

- 11.11 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 25.05.015)

- 11.13 Starter.**—A starter is an electric controller for accelerating a motor from rest to normal speed. (ASA C42 25.05.075) (A device designed for starting a motor in either direction of rotation includes the additional function of reversing and should be designated a controller.)
- 11.15 Automatic Starter.**—An automatic starter is a starter which controls automatically the acceleration of a motor. (ASA C42 25.05.080)
- 11.17 Autotransformer Starter.**—An autotransformer starter is a starter having an autotransformer to furnish a reduced voltage for starting. It includes the necessary switching mechanism and is frequently called a compensator or autostarter. (ASA C42 25.05.085)
- 11.19 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.
- 11.21 Master Switch.**—A master switch is a switch which dominates the operation of contactors, relays, or other magnetically operated devices. (ASA C42 25.05.115)
- 11.23 Resistor.**—A resistor is a device the primary purpose of which is to introduce resistance into an electric circuit. (ASA C42 05.45.015) (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.)
- 11.25 Drip-Proof Control Apparatus.**—Drip-proof control apparatus is apparatus so constructed or protected that its successful operation is not interfered with when subjected to falling moisture or dirt when tilted to any angle up to 15 degrees from the vertical.
- 11.27 Waterproof Control Apparatus.**—Waterproof control apparatus is apparatus so constructed that a stream of water from a hose (not less than 1 inch in diameter) under a head of about 35 feet and from a distance of about 10 feet can be played on the apparatus without leakage. The hose nozzle should be adjusted to give a solid stream at the enclosure.

- 11.29 Submersible Control Apparatus.**—Submersible control apparatus is apparatus so constructed that it will operate successfully when submerged in water under specified conditions of pressure and time.
- 11.31 Explosionproof Control Apparatus.**—For explosionproof control apparatus see Subsection 8.13.
- 11.33 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 equipment governed. (ASA C42 20.25.465)
- 11.35 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 20.25.505)
- 11.37 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 in the main circuit but not to prevent the re-establishment of the main circuit on return of voltage. (ASA C42 20.25.510)
- 11.39 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. (ASA C42 25.05.060)
- 11.41 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. (ASA C42 25.05.065)
- 11.43 Overload Relay.**—An overload relay is an overcurrent relay in the circuit of a motor which functions at a predetermined value of overcurrent to cause the disconnection of the motor from the line.
Note: An overload relay is intended to protect the motor or controller and does not necessarily protect itself.
(ASA C42 25.15.005)
- 11.45 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. (ASA C42 20.25.320)
- 11.47 Molded-Case Circuit Breaker.**—A molded-case circuit breaker is a breaker assembled as an integral unit in a supporting and enclosing housing of insulating material; the overcurrent and tripping means being of the thermal type, the magnetic type, or a combination of both.
- 11.49 Rated Continuous Current.**—The rated continuous current of a switch or circuit breaker is the designated limit in rms amperes or direct-current

*(but not necessarily on short circuit)

amperes which it will carry continuously without exceeding the limit of observable temperature rise. (ASA C42 20.10.100)

- 11.51 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.)

- 11.53 Control Circuit.**—The control circuit of a control apparatus or system is the circuit which does not carry the main load current, and by means of which the electric signals directing the performance of the controller are transmitted.

- 11.55 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

CLASSES OF INSULATING MATERIAL*

- 12.01 Class O Insulation.**—Class O insulation consists of cotton, silk, paper and similar organic materials when neither impregnated** nor immersed in a liquid dielectric. (ASA C42 95.25.025)
- 12.03 Class A Insulation.**—Class A insulation consists of: (1) cotton, silk, paper, and similar organic materials when either impregnated** or immersed in a liquid dielectric; (2) molded and laminated materials with cellulose filler, phenolic resins and other resins of similar properties; (3) films and sheets of cellulose acetate and other cellulose derivatives of similar properties; and (4) varnishes (enamel) as applied to conductors. (ASA C42 95.20.010)
- 12.05 Class B Insulation.**—Class B insulation consists of mica, asbestos, fiberglass and similar inorganic materials in built-up form with organic binding substances. A small proportion of Class A

*From Introduction to AIEE Standards (AIEE No. 1).

**An insulation is considered to be "impregnated" when a suitable substance replaces the air between its fibers, even if this substance does not completely fill the spaces between the insulated conductors. The impregnating substances in order to be considered suitable, must have good insulating properties; must entirely cover the fibers and render them adherent to each other and to the conductor; must not produce interstices within itself as a consequence of evaporation of the solvent or through any other cause; must not flow during the operation of the machine at full working load or at the temperature limit specified; and must not unduly deteriorate under prolonged action of heat.

materials may be used for structural purposes only.*** (ASA C42 95.25.015)

12.07 Class C Insulation.—Class C insulation consists entirely of mica, porcelain, glass, quartz and similar inorganic materials. (ASA C42 95.25.020)†

12.09 Class H Insulation.—Class H insulation consists of (1) mica, asbestos, fiberglass and similar inorganic materials in built-up form with binding substances composed of silicone compounds, or materials with equivalent properties; (2) silicone compounds in rubbery or resinous forms, or materials with equivalent properties. A minute proportion of Class A materials may be had only where essential for structural purposes during manufacture.††

SECTION 13

TYPES OF CIRCUITS

13.01 Lighting Branch Circuits.—Lighting branch circuits are circuits supplying energy to lighting outlets only. (ASA C42 95.10.050) (Lighting branch circuits also may supply portable desk or bracket fans, small heating appliances, motors of ¼ hp and less and other portable apparatus of not over 660 watts each.)

13.03 Appliance Branch Circuits.—Appliance branch circuits are circuits supplying energy either to permanently wired appliances or to attachment-plug receptacles; that is, appliance or convenience outlets or to a combination of permanently wired appliances and additional attachment-plug outlets on the same circuit, such circuits to have no permanently connected lighting fixtures. (ASA C42 95.10.055)

13.05 Motor Branch Circuits.—A motor branch circuit is a branch circuit supplying energy only to motors. (ASA C42 95.10.065)

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

***The electrical and mechanical properties of the insulated winding must not be impaired by application of the temperature permitted for Class B material. (The word "impair" is here used in the sense of causing any change which could disqualify the insulating material for continuous service.) The temperature endurance of different Class B insulation assemblies varies over a considerable range, in accordance with the percentage of Class A materials employed, and the degree of dependence placed on the organic binder for maintaining the structural integrity of the insulation.

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

††The electrical and mechanical properties of the insulated winding must not be impaired by the application of the temperature permitted for Class H material. (The word "impaired" is here used in the sense of causing any change which could disqualify the insulating material for continuous service.)

one or more secondary distribution centers, one or more branch-circuit distribution centers, or any combination of these two types of equipment. (ASA C42 95.10.025) (Bus tie circuits between 3-wire direct-current main and emergency switchboards are not considered as feeders.)

13.11 Branch Circuit.—A branch circuit is that portion of the wiring system terminating in an energy-consuming appliance or device.

13.13 Outlet.—An outlet is a point on the wiring system at which current is taken to supply fixtures, lamps, heaters, motors, or current-consuming equipment generally. (ASA C42 95.10.090)

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 95.10.095)

13.17 Receptacle Outlet.—A receptacle outlet is an outlet intended to be equipped with one or more receptacles, not of the screw-shell type, or provided with one or more points of attachment within one foot, intended to receive attachment plugs. (ASA C42 95.10.100)

13.19 Plug.—A 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 95.15.005)

13.21 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. (ASA C42 95.10.070)

13.23 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.

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

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

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

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

14.07 Selection of Voltage and Distribution System —DC.—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 panelboards should be 115 volts two-wire.

14.09 Selection of Voltage and Distribution System —AC.—For small vessels having little power,

three-phase, 120 volt generators may be used with the 115 volt lighting and power distribution system. For vessels requiring considerable power apparatus, three-phase, 230 volt generators may be considered with three-phase, 220 volt distribution for the power system and 115 volt single-phase two-wire or 115/230 volt single-phase three-wire or 115 volt three-phase three-wire as obtained through transformers for distribution to the lighting system. Each of the three single-phases should have about the same load so the currents will be about equal in each phase wire at the point where the three single-phase systems are joined into one three-phase system. For large vessels with a large amount of power, the use of 450 volt three-phase generators with 440 volts or 220 volts for power distribution and 115 volts for the lighting system as described for the 230 volt generator system above may be preferable.

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

DIRECT-CURRENT EQUIPMENT AND INSTALLATION

SECTION 15

D-C GENERATING SETS

15.01 Installation and Location. — Generating sets should be located in a well ventilated place as dry as possible. 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 armature.

When diesel engine 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.

15.05 Generating Sets—Emergency.—In addition to the foregoing, Government Regulatory Agencies require the installation of a diesel engine driven generating set and/or storage batteries located above the bulkhead deck for operating the emergency lighting and power systems. The capacity of the diesel driven 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. Fuel oil with a flash point less than 150F, as determined by Pensky-Martens closed cup testers, should not be used.

15.07 Generator Windings.—In the case of 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 generators, it is recommended that the series field terminal be negative.

15.09 Voltage Regulation and Compounding.—The inherent voltage regulation of each type of generator should be as follows:

(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 3.5 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 of a type capable of withstanding ship-board conditions 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 Subsection 15.09(b).

(b) Compound-wound generators should be designed as to governing of prime mover, compounding and regulation of the generator, so that with the generator at full-load operating temperature, and starting at 20 percent load with voltage within 1 percent of rated voltage, it should give at full load a voltage within 1½ percent of rated voltage. The average of the ascending and descending voltage regulation curves between 20 percent load and full load should not vary more than 3 percent from rated voltage.

(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 3.5 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.

15.11 Parallel Operation.—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.

When tests are made to determine if successful parallel operation 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) The starting point for the test should be at 75 percent load with each generator carrying its proportionate share.

(d) 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 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.

15.13 Prime Movers.—Generating sets may be driven by steam engines either of the turbine or reciprocating type, 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 armature shaft.

For turbine driven 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. The overspeed device should be contact opening.

15.15 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.

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

15.19 Insulation of Windings.—All assembled armatures and also the armature coils for open-slot 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.

15.21 Lubrication.—All 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. In cases where the shaft will be located athwartship, the manufacturer should be so advised. Turbine driven generating sets depending on forced lubrication should be arranged to shut down automatically on loss of oil pressure, by shutting off the steam supply to the turbine and tripping the generator circuit breaker.

15.23 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.

15.25 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 an insulating terminal board having secured terminals to which the lugs of the incoming cables can be readily fastened. The terminal board 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 an insulating terminal board 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 board 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.

15.27 Nameplates.—Nameplates of corrosion-resistant material containing the following minimum amount of information should be supplied and mounted in a conspicuous place:

(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 kw for generator.

(f) Voltage, no-load and full-load.

(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 2 hour, 25 percent overload the temperature rise at the end of the 2 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) Shunt, stabilized shunt, series or compound generator.

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

15.29 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 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.

15.31 Limits of Temperature Rises for Direct-Current Generators.—Temperature rise of each of the various parts 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.

15.33 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 specified in Tables 1 and 2 (Appendix).

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

15.35 Sparking.—The generators should operate with brushes in a fixed position, and without objectionable sparking from no load to full load. There should be no injurious sparking or spitting at the brushes when $1\frac{1}{4}$ load is thrown on or off in one step.

15.37 Insulation—Voltage Test. — The dielectric strength of the insulation of the sets 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 C68.1.

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

15.41 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 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.

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

15.45 Space Heaters.—Space heaters may 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/1000 lbs.

15.47 Motor-Generator Sets — Overspeed Protection.—Motor-generator sets having d-c motors or 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.

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, 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.

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

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 $\frac{1}{16}$ inch minimum thickness, not less than three inches deep. For alkaline batteries the shelves should be similarly lined with steel, not less than $\frac{1}{32}$ 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 $\frac{3}{4}$ inch high on the bottom, and with similar spacer blocks at the sides,

or with equivalent provision to assure $\frac{3}{4}$ 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 $1\frac{1}{2}$ 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

D-C 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 louvres 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 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 louvres 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 attached to the front of the switchboard should be provided for all panels; a horizontal rail arrangement 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 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 by their mounting screws or by case ground wire. 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 wires should be marked at each connection with the wiring diagram designation.

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.

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 AIEE 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.

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.

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, 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 dual 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 thermal type, 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.

Corrosion-resistant parts should be in accordance with Subsection 27.21.

◆ 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 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 AIEE 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 Interrupting Requirements for Air Circuit Breakers and Fuses.—The increased use of electric power on vessels has resulted in a considerable increase in the size of the electric generating plant. With these larger generating plants, it is essential to give careful consideration to short-circuit protection.

As a minimum requirement any circuit breaker or fuse installed at a point in the circuit where the maximum possible short-circuit current exceeds its interrupting rating should be backed up by a circuit breaker with an instantaneous trip setting not more than 90 percent of the interrupting rating of the device protected. The initial circuit breaker in the series, that is, nearest the source of power, should have an interrupting rating not less than the maximum short-circuit current available at the point where it is installed.

If a feeder overcurrent protective device is backed up by the circuit breakers of two or more generators operating in parallel, the instantaneous trip setting of each generator circuit breaker should be not more than 90 percent of the interrupting rating of the device protected, divided by the number of generators operating in parallel. Consideration may be given to providing additional back-up circuit breakers, and time delay on generator circuit breakers to provide greater continuity of service.

In the absence of precise data, when calculating the maximum short-circuit current of a direct-current system, it should be assumed that each generator (excluding spare) will, if limited only by internal resistance, contribute ten times its normal rated current and that all motors which may be in operation simultaneously will, limited by internal resistance, contribute six times their combined normal ratings.

17.11 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.

Buses and connections should be arranged positive, neutral, and negative from right to left, as viewed from the front of the switchboard; and positive, neutral, and negative from top to bottom and from front to rear. Equalizer buses where required may be located in the most convenient arrangement.

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.

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

(a) *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. 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 17.09.)

- ◆ Fused switches may be used in place of circuit breakers for generators rated less than 25 kw, and not arranged for parallel operation.

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.

(c) *Generator Reverse-Current.*

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

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

(d) *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 15.13 and 15.47.)

(e) *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 should not be, and circuit breaker overload trips need not be, provided for the neutral conductor of a 3-wire grounded system. For thermal overcurrent trips, the type compensated for varying ambient temperature is preferred, if obtainable. Fuses of more than 200 ampere rating should not be used except in bus feeders from emergency lighting batteries.

The trip attachment for circuit breakers on systems having a total generating capacity of more than 100 kw should have time overcurrent and instantaneous trip features. (See Subsection 17.09.)

For systems having a total generating capacity of 100 kw or less, feeder circuit breakers may have the time overcurrent trip feature only.

(f) *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.

(g) *Potential Circuit Overcurrent Protection.*

Each conductor for potential circuits to instruments, pilot lamps and ground detector lamps should be protected by enclosed fuses.

(h) *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.

(i) *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. Duplicate indicating lights, with a suitable label plate on the front of the switchboard should indicate when power is available from shore.

17.15 Grounding Three-Wire Dual Voltage 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. To effect this arrangement, no interrupting device should be provided in the neutral conductor of the bus tie feeder connecting the two switchboards.

17.17 Bus Bars and Copper Connections.—All copper bus bars and copper 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 starting and short-circuit currents.

Copper 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 0.0005 inch thick and should not show a tendency to peel off under normal operating conditions.

The contact surfaces and studs of all 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.

Buses should be designed on the basis of generator capacity and feeder loads. For a single generator, the generator or 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 should not be greater than the generator buses which supply them. Buses or 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 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.

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 All Generators (Two-Wire or Three-Wire).*

1—Watt-hour meter per generator, if specified

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
- 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—Bus, calibrating and shore connection voltmeter
- 1—Voltmeter switch for connecting above voltmeter to bus, shore connection and to check generator voltmeters
- 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
- 1—Voltmeter switch for positive to negative and positive or negative to neutral 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
- 1—Bus calibrating and shore connection voltmeter
- 1—Voltmeter switch for connecting above voltmeter to bus, shore connections, and to check generator voltmeters

(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 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 direct-current 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 direct-current 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.

17.27 Emergency and Interior 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 require-

ments of preceding Subsections 17.01 to 17.25 inclusive, 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) *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).

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

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

(d) *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.

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

- (1) 120/240 volt bus connected directly to the final emergency bus.
- (2) 120 volt or 120/240 volt bus connected directly to the temporary emergency bus.
- (3) 24 volt bus supplied from duplicate storage batteries (see Figure 15, Appendix).
- (4) 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.

(e) *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 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.

17.29 Spare Parts.—Spare parts should be provided as required by the applicable Classification Societies. Spare parts should be stowed as provided in Subsection 15.41.

SECTION 18

D-C WIRES AND CABLES—CONSTRUCTION

18.01 Copper Conductors.

(a) *General.*—The conductors should be of soft annealed copper wires and should be tinned or alloy coated unless otherwise specified.

(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 benzene, 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 15.6. 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 $\frac{1}{2}$ inch from the end of the sample, the sample has failed.

(d) *Alloyed Coating*

Continuity of Coating

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

(2) The continuity of coating on the wire shall be determined on representative samples taken before stranding or insulating. The continuity of coating shall 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 shall be not darker than that of the reference color standard solution. In the sodium polysulfide-hydrochloric acid test the specimens, following the specified immersions, shall 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 persulfate test shall 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 shall 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 shall 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 shall be completely coated with wax to protect the exposed copper. The wax-coated length shall 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 shall be freshly prepared each day tests are to be conducted and shall 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)) shall be immersed in the quantity of test solution prescribed in Table A, using as the container a test tube of appropriate dimensions. The specimen shall be immersed in the test solution at a temperature between 83F and 87F for a period of 15 minutes. The specimen shall 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 shall be made by viewing the solutions lengthwise of the test tubes. The color of the test solution after immersion of the test specimen shall 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 shall each have a length of about 6 inches. They shall be tagged or marked to correspond with the coil, spool, or reel from which they were cut.

(2) Treatment of Specimens.—The test specimens shall 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 shall be kept wrapped in a clean, dry cloth until required for test. That part of the specimen to be immersed in the test solution shall not be handled. Care shall be taken to avoid abrasion by the cut ends.

(3) Special Solutions:

Sodium Polysulfide Solution (specific gravity 1.142).—A concentrated solution shall 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 shall 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 shall 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) shall 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 shall 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 shall 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 shall be immersed for 30 seconds in the sodium polysulfide solution, washed, and then shaken lightly to remove excess water.

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

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

d. The specimen shall be immersed for 1 minute in the HCl solution, washed, and then shaken lightly to remove excess water. After the operations described, the specimens shall 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 shall 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 laid in opposite direction.

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.

18.03 Insulation.

(a) *General*.—The insulation should be either rubber (natural or synthetic) varnished cambric asbestos-varnished-cambric thermoplastic or thermo-

plastic-asbestos as recommended herein, except for switchboard wires which should be either varnished-cambric-asbestos, or thermoplastic-asbestos insulated.

(b) *Rubber Insulation*.—The rubber insulation should be of the heat-resisting type, homogeneous in character, tough, elastic and applied concentrically about the conductor and should fit tightly thereto.

The physical and electrical properties of the insulation should meet the following requirements:

A. Natural Rubber

- (1) Tensile strength, psi, minimum 1500
- (2) Tensile stress at 200 percent elongation, psi, minimum 400
- (3) Elongation at rupture in 2 inch gauge length, percent, minimum 400
- (4) Set in 2 inch gauge length, inches, maximum ¾
- (5) After 20 hours exposure in air at 80 psi pressure and 127C (260F)
 - Tensile strength, psi, minimum..... 1000
 - Depreciation in tensile strength, percent, maximum 50
 - Elongation, percent, minimum..... 300
 - Depreciation in elongation, percent, maximum 35
- (6) After 168 hours exposure in oxygen atmosphere at 300 psi pressure and 80C (176F)
 - Depreciation in tensile strength and elongation, percent, maximum..... 25
- (7) Specific inductive capacity after 24 hours immersion in distilled water, maximum.... 5
- (8) Increase in specific inductive capacity between the ends of first and fourteenth days immersion in distilled water, percent, maximum 20
- (9) Increase in specific inductive capacity between the ends of seventh and fourteenth days immersion in distilled water, percent, maximum 5

B. Synthetic Rubber

- (1) Tensile strength, psi, minimum.... 700
- (2) Elongation at rupture, percent, minimum 300 (2"-8")
- (3) Tensile strength after 20 hours exposure in air at 80 psi pressure and 127C, minimum 50 percent of original
- (4) Elongation at rupture after 20 hours exposure in air at 80 psi pressure and 127C, minimum 50 percent of original
- (5) Tensile strength after 168 hours in oxygen atmosphere at 300 psi pressure and 80C, minimum..... 50 percent of original
- (6) Elongation at rupture after 168 hours in oxygen atmosphere at 300 psi pressure and 80C, minimum..... 50 percent of original

- (7) Note: When the insulation has been subjected to a second vulcanization, such as is required for the application of a thermosetting jacket, the physical properties shall be not less than 75 percent of the above requirements.

C. Thermoplastic

- | | |
|--|------------------------|
| (1) Tensile strength, psi minimum.... | 1500 |
| (2) Elongation at rupture, percent, minimum | 100(2"-4") |
| (3) Tensile strength after 5 days in air oven at 99C-101C | 85 percent of original |
| ◆ (4) Elongation at rupture after 5 days in air oven at 99C-101C minimum | 60 percent of original |
| (5) Tensile strength after 4 hours in SAE 20 oil at a temperature of 69C-71C (dry and allow to rest for a period of from 16 - 48 hours) | 85 percent of original |
| (6) Elongation at rupture after 4 hours in SAE 20 oil at a temperature of 69C-71C (dry and allow to rest for a period of from 16 - 48 hours), minimum | 85 percent of original |
| (7) Heat shock—The thermoplastic insulation shall not show any cracks after the wire or cable has been wound 6 adjacent turns around a mandrel equal to its own diameter and subjected to a temperature of 120C-122C for one hour. The sample shall be tight against the mandrel and held firmly in place. | |
| (8) Flame Retardant Properties — Meet requirement of resistance to flame, paragraph 18.27e(3). | |
| (9) Cold Bend—Sample shall not show any cracks after being subjected to a temperature of minus 9C to minus 11C for one hour and then bend around a $\frac{5}{16}$ inch mandrel 180 degrees in not more than one minute. | |

D. All Rubberlike Insulations.

For test procedures refer to ASTM Specification D-470, latest issue.

The above tests should not be made on insulation walls less than 3/64 inch, due to the difficulty in obtaining uninjured samples, therefore the tests should be applied to a slab of the compound instead of the thin wall.

(c) *Varnished-Cambric Insulation.*—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-cambric 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 2½C) 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.

(d) *Asbestos Insulation.*—The asbestos insulation should consist of best quality, long fibre chrysotile 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.

Where asbestos is used in combination with varnished-cambric or thermoplastic insulation, the thickness of the insulation of component layers should be in accordance with Table 33 (Appendix).

- ◆ Where felted asbestos is specified, glass roving or impregnated asbestos tapes may be used as a substitute or alternate.

(e) *Thickness of Insulation*.—The average thickness of rubber, varnished-cambric, and combinations of asbestos with varnished cambric or thermoplastic insulation, should conform to the values given in Tables 14 and 33 (Appendix). The minimum thickness at any point should not be less than 90 percent of the average recommended value.

18.05 Compound Filled Tape.—Compound filled 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.

18.07 Braid.

(a) *General*.—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.

18.09 Color Code.—Color coding of rubber filled tapes and marker braids should conform to Table 16 (Appendix). 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

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

18.13 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.

18.14 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

18.15 Reinforced Rubber Sheath.—The reinforced rubber sheath should consist of a rubber filled, rubber coated tape or of a rubber filled tape in combination with rubber tape, wound helically to a thickness at any point of not less than 3/32 inch nor more than 4/32 inch. In this application, rubber should be construed to include Neoprene and Buna N.

After vulcanization, the sheath should be a firmly bound, strong, elastic, homogeneous mass, which should not be sticky or tacky and should not be separated readily into layers. It should remain soft and flexible under continuous vibration or frequent bending when used under intermittent or continuous high temperature (75°C). The sheath should be watertight.

18.17 Impervious Sheath.—The sheath shall be constructed of a thermoplastic or thermosetting synthetic sheath compound to a thickness as given in Table 17 for lead sheath.

(a) The composition and construction of the impervious sheath shall 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.

(b) The impervious sheath shall have the following physical properties:

- (1) Thermoplastic synthetic sheath compound.
Tensile strength, psi, min..... 1500

Elongation at rupture min percent	100 (2"-4")
Tensile strength after 5 days in air oven at 99C-101C.....	85 percent of original
Elongation at rupture after 5 days in air oven at 99C-101C	60 percent of original
Tensile strength after 4 hours in SAE 20 oil at a temperature of 69C-71C (dry and allow to rest for a period of from 16 to 48 hours)	85 percent of original
Elongation at rupture after 4 hours in SAE 20 oil at a temperature of 69C-71C (dry and allow to rest for a period of from 16 to 48 hours).....	85 percent of original
(2) Thermosetting synthetic sheath compound.	
Tensile strength, psi, min.....	1800
Elongation at rupture, min percent	300 (2"-8")
Tensile stress at 200 percent elongation, psi, min.....	500
Set in 2 inch gage length, inches max	3/8"
Tensile strength after 7 days in air oven at 70C psi, min.....	1600
Elongation at rupture after 7 days in air oven at 70C min percent	250 (2"-7")
Tensile strength after 96 hours in oxygen bomb, 300 lbs pressure 70C, psi, min.....	1600
Elongation at rupture after 96 hours in oxygen bomb, 300 lbs pressure 70C, percent min.....	250 (2"-7")
Tensile strength after 18 hours in oil at a temperature of 120C-122C, psi, min.....	60 percent of original
Elongation at rupture after 18 hours in oil at a temperature of 120C-122C, percent min.....	60 percent of original

(3) Thermoplastic or Thermosetting Sheath.

Cold bend—Sample of completed thermoplastic sheathed cable shall not show any cracks after being subjected to a temperature of minus 9C to minus 11C, for one hour and then bend around a mandrel 180 degrees in not more than one minute.

Cable OD	Mandrel Size
0—0.800 inch	8 × cable OD
0.801—larger	10 × cable OD

Flame Retardant Properties—Meet requirements of Resistance to Flame, paragraph 18.29 e (3).

- 18.19 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 shall contain not less than 0.04 percent nor more than 0.08 percent copper. If alloy

sheath is used the alloying element shall 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.

- 18.21. 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.

18.23 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.

(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, 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	91	96	45	70
2.001 and over	91	96	50	80

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

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

Where a = angle of braid with axis of cable:

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

d = diameter of individual braid wires in inches
 C = number of carriers

D = diameter of cable under armor in inches

N = number of wires per carrier

P = picks per inch of cable length

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

Cable diameter under 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).

18.25 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.

18.27 Dimensional Tolerances.—The measured maximum overall diameter of the finished cable should be not larger than given in Tables 25 to 31 and 36 to 39 (Appendix). No plus tolerance is allowed. A minus tolerance of not more than 7.5 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 0.030 inch.

18.29 Tests on Finished Cable.—

(a) *High Voltage*.—Each reel (except switchboard 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 and 34 (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 and 35 (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 34 (Appendix).

(d) *Special Tests on Asbestos-Varnished-Cambric Heat and Flame-Resisting Cables.*

(1) Flammability Test:

Specimens.—Specimens shall 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 shall 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, shall 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 shall 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 shall be wrapped with varnished cambric in such a manner that gases released through this end are diverted toward the spark plug.

Heater coils shall 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 shall 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 shall 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, shall 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 shall be provided to maintain continuous sparking at the electrodes during the specified time. The spark plugs shall 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 shall 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:

Ignition Time Minimum Seconds	Burning Time Maximum Seconds	Flame Travel Maximum Inches
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 shall be started simultaneously with the energizing of the heater coil and spark plugs. A constant current as specified in table below shall be supplied from a suitable transformer source to the heater coil. Ignition shall 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 shall be recorded.

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

Distance of Flame Travel.—Immediately after ignition occurs, the electric supply to the spark plugs shall 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, shall 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, shall 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 shall be observed and recorded.

Current in Heating Coil.

Nominal diameter of cable inch	Current Amperes AC rms	Nominal Diameter of cable inches	Current Amperes AC rms
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 shall be suspended in a vertical position in an oven maintained for a period of not less than 18 hours at 95C. No material shall drip or exude from the end of the cable during the test.

(3) Dielectric After Flame.

Following the flammability test, paragraph 18.27 d(1), the specimen shall withstand the voltages shown in Table 34 for the particular type by apply-

ing the voltage between one conductor and all other conductors and armor for a period of one minute.

(e) *Test on Varnished-Cambric-Asbestos and Thermoplastic Asbestos 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 the tables.

(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.

18.31 Single-Conductor, Rubber Insulated and Braided.—(Table 25).

First: Tinned, stranded conductor.
Second: Rubber insulation.
Third: Compound filled tape or standard braid.
Fourth: Standard braid.

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

First: Tinned, stranded conductor.
Second: Rubber insulation.
Third: Compound filled tape or standard braid.
Fourth: Standard braid.
Fifth: Basket weave armor.
Sixth: Paint.

18.33 Single-Conductor, Rubber Insulated, Leaded and Armored.—(Table 25).

First: Tinned, stranded conductor.
Second: Rubber insulation.
Third: Compound filled tape or standard braid.
Fourth: Lead sheath.
Fifth: Bituminous compound.
Sixth: Compound filled tape, half lapped*.
Seventh: Basket weave armor.
Eighth: Paint.

18.34 Single-Conductor, Varnished-Cambric Insulated, Leaded and Armored.—(Table 25).

First: Tinned, stranded conductor.
Second: Varnished-cambric insulation.
Third: Compound filled tape or standard braid.
Fourth: Lead sheath.
Fifth: Bituminous compound.
Sixth: Compound filled tape, half lapped*.
Seventh: Basket weave armor.
Eighth: Paint.

18.35 Single-Conductor, Asbestos-Varnished-Cambric Insulated Leaded and Armored. — (Table 36).

First: Tinned, stranded conductor.
Second: Wall of felted, impregnated asbestos insulation.
Third: Separator.
Fourth: Varnished-cambric insulation.
Fifth: Separator.
Sixth: Wall of felted, impregnated asbestos insulation.
Seventh: With or without separator, at manufacturers' option.
Eighth: Lead sheath.
Ninth: Bituminous compound.
Tenth: Compound filled tape half lapped*.
Eleventh: Basket weave armor.
Twelfth: 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.

18.36 Single-Conductor, Varnished-Cambric Insulated, Reinforced Sheathed and Armored.†—(Table 25).

First: Tinned, stranded conductor.
Second: Varnished-cambric insulation.
Third: Compound filled tape.
Fourth: Reinforced rubber sheath.
Fifth: Compound filled tape.
Sixth: Basket weave armor or for propulsion cables flat metal tape.
Seventh: Paint.

18.37 Single-Conductor, Asbestos-Varnished-Cambric Insulated Impervious Sheathed and Armored.†—(Tables 36 and 37).

First: Tinned, stranded conductor.
Second: Wall of felted impregnated asbestos insulation.
Third: Separator.
Fourth: Varnished-cambric insulation.
Fifth: Separator.
Sixth: Wall of felted impregnated asbestos insulation.
Seventh: With or without separator, at manufacturer's option.
Eighth: Impervious sheath.
Ninth: Basket weave armor or for propulsion cables, flat metal tape.
Tenth: Paint.

18.38 Two-Conductor, Rubber Insulated and Braided.—(Table 26).

First: Tinned, stranded conductor.
Second: Rubber insulated.
Third: Compound filled tape or standard braid, color coded.
Fourth: Two conductors cabled with fillers.
Fifth: Compound filled tape.
Sixth: Standard braid.

18.39 Two-Conductor, Rubber Insulated and Armored.—(Table 26).

First: Tinned, stranded conductor.
Second: Rubber insulation.
Third: Compound filled tape or standard braid, color coded.
Fourth: Two conductors cabled with fillers.
Fifth: Compound filled tape.
Sixth: Standard braid.
Seventh: Basket weave armor.
Eighth: Paint.

18.40 Two-Conductor, Rubber Insulated, Leaded and Armored.—(Table 26).

First: Tinned, stranded conductor.
Second: Rubber insulation.
Third: Compound filled tape or standard braid, color coded.
Fourth: Two conductors cabled with fillers.
Fifth: Compound filled tape.
Sixth: Lead sheath.

† For conductor sizes 750,000 circular mils and larger, annular conductors may be used if cables are to be operated in a-c circuits. For dimensions and weights of annular conductor cables, refer to Table 28. For propulsion cables see Subsection 101.33.

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

18.41 Two-Conductor, Varnished-Cambric Insulated, Leaded and Armored.—(Table 26).

First: Tinned, stranded conductor.
 Second: Varnished-cambric insulation.
 Third: Compound filled tape, color coded.
 Fourth: Two conductors cabled with fillers.
 Fifth: Rubber filled tape.
 Sixth: Lead sheath.
 Seventh: Bituminous compound.
 Eighth: Compound filled tape, half lapped*.
 Ninth: Basket weave armor.
 Tenth: Paint.

18.42 Two-Conductor, Asbestos-Varnished-Cambric Insulated Leaded and Armored.—(Table 36).

First: Tinned, stranded conductor.
 Second: Wall of felted impregnated asbestos insulation.
 Third: Separator color coded.
 Fourth: Varnished-cambric insulation.
 Fifth: Separator.
 Sixth: Wall of felted impregnated asbestos insulation.
 Seventh: Two conductors cabled with impregnated asbestos fillers.
 Eighth: Belt of felted impregnated asbestos insulation.
 Ninth: With or without separator, at manufacturer's option.
 Tenth: Lead sheath.
 Eleventh: Bituminous compound.
 Twelfth: Compound filled tape, half lapped*.
 Thirteenth: Basket weave armor.
 Fourteenth: Paint.

18.43 Two-Conductor, Varnished-Cambric Insulated, Reinforced Sheathed and Armored.—(Table 26).

First: Tinned, stranded conductor.
 Second: Varnished-cambric insulation.
 Third: Compound filled tape, color coded.
 Fourth: Two conductors cabled with fillers.
 Fifth: Compound filled tape.
 Sixth: Reinforced rubber sheath.
 Seventh: Compound filled tape.
 Eighth: Basket weave armor.
 Ninth: Paint.

18.44 Two-Conductor, Asbestos-Varnished-Cambric Insulated Impervious Sheath and Armored.—(Table 36).

First: Tinned, stranded conductor.
 Second: Wall of felted impregnated asbestos insulation.
 Third: Separator color coded.
 Fourth: Varnished-cambric insulation.
 Fifth: Separator.
 Sixth: Wall of felted impregnated asbestos insulation.

* See footnote page 36.

Seventh: Two conductors cabled with impregnated asbestos fillers.

Eighth: Belt of felted impregnated asbestos insulation.

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

Tenth: Impervious sheath.

Eleventh: Basket weave armor.

Twelfth: Paint.

18.45 Three-Conductor, Rubber Insulated and Braided.—(Table 27).

First: Tinned, stranded conductor.
 Second: Rubber insulation.
 Third: Compound filled tape or standard braid, color coded.
 Fourth: Three conductors cabled with fillers.
 Fifth: Compound filled tape.
 Sixth: Standard braid.

18.46 Three-Conductor, Rubber Insulated and Armored.—(Table 27).

First: Tinned, stranded conductor.
 Second: Rubber insulation.
 Third: Compound filled tape or standard braid, color coded.
 Fourth: Three conductors cabled with fillers.
 Fifth: Compound filled tape.
 Sixth: Standard braid.
 Seventh: Basket weave armor.
 Eighth: Paint.

18.47 Three-Conductor, Rubber Insulated, Leaded and Armored.—(Table 27).

First: Tinned, stranded conductor.
 Second: Rubber insulation.
 Third: Compound filled tape or standard braid, color coded.
 Fourth: Three conductors cabled with fillers.
 Fifth: Compound filled tape.
 Sixth: Lead sheath.
 Seventh: Bituminous compound.
 Eighth: Compound filled tape, half lapped*.
 Ninth: Basket weave armor.
 Tenth: Paint.

18.48 Three-Conductor, Varnished-Cambric Insulated, Leaded and Armored.—(Table 27).

First: Tinned, stranded conductor.
 Second: Varnished-cambric insulation.
 Third: Compound filled tape, color coded.
 Fourth: Three conductors cabled with fillers.
 Fifth: Compound filled tape.
 Sixth: Lead sheath.
 Seventh: Bituminous compound.
 Eighth: Compound filled tape, half lapped*.
 Ninth: Basket weave armor.
 Tenth: Paint.

18.49 Three-Conductor, Asbestos-Varnished-Cambric Insulated Leaded and Armored.—(Table 36).

First: Tinned, stranded conductor.
 Second: Wall of felted impregnated asbestos insulation.
 Third: Separator color coded.

- Fourth: Varnished-cambric insulation.
- Fifth: Separator.
- Sixth: Wall of felted impregnated asbestos insulation.
- Seventh: Three conductors cabled with impregnated asbestos fillers.
- Eighth: Belt of felted impregnated asbestos insulation.
- Ninth: With or without separator, at manufacturer's option.
- Tenth: Lead sheath.
- Eleventh: Bituminous compound.
- Twelfth: Compound filled tape, half lapped*.
- Thirteenth: Basket weave armor.
- Fourteenth: Paint.

18.50 Three-Conductor, Varnished-Cambric Insulated, Reinforced Sheathed and Armored.—(Table 27).

- First: Tinned, stranded conductor.
- Second: Varnished-cambric insulation.
- Third: Compound filled tape, color coded.
- Fourth: Three conductors cabled with fillers.
- Fifth: Compound filled tape.
- Sixth: Reinforced rubber sheath.
- Seventh: Compound filled tape.
- Eighth: Basket weave armor.
- Ninth: Paint.

18.51 Three-Conductor, Asbestos-Varnished-Cambric Insulated Impervious Sheath and Armored.—(Table 36).

- First: Tinned, stranded conductor.
- Second: Wall of felted impregnated asbestos insulation.
- Third: Separator color coded.
- Fourth: Varnished-cambric insulation.
- Fifth: Separator.
- Sixth: Wall of felted impregnated asbestos insulation.
- Seventh: Three conductors cabled with impregnated asbestos fillers.
- Eighth: Belt of felted impregnated asbestos insulation.
- Ninth: With or without separator, at manufacturer's option.
- Tenth: Impervious sheath.
- Eleventh: Basket weave armor.
- Twelfth: Paint.

18.52 Four-Conductor, Rubber Insulated and Armored.—

- First: No. 14 AWG tinned, stranded conductor.
- Second: Rubber insulation.
- Third: Compound filled tape or standard braid, color coded.
- Fourth: Four conductors cabled with fillers.
- Fifth: Compound filled tape.
- Sixth: Standard braid.
- Seventh: Basket weave armor.
- Eighth: Paint.

18.53 Four-Conductor, Rubber Insulated, Leaded and Armored.—

- First: No. 14 AWG tinned, stranded conductor.

- Second: Rubber insulation.
- Third: Compound filled tape or standard braid, color coded.
- Fourth: Four conductors cabled with fillers.
- Fifth: Compound filled tape.
- Sixth: Lead sheath.
- Seventh: Bituminous compound.
- Eighth: Compound filled tape, half lapped*.
- Ninth: Basket weave armor.
- Tenth: Paint.

18.54 Bell Wire.—

- First: 7 strands of 0.020 inch tinned, copper wire.
- Second: Rubber insulation to a diameter of 0.154 inch.
- Third: Standard braid to a diameter of 0.190 inch.

18.55 Interior Communication Cable, Reinforced Rubber Sheathed, Braided.—(Table 29).

- First: 7 strands of 0.020 inch tinned, copper wire.
- Second: Rubber or thermoplastic insulation to a diameter of 0.115 inch.
- Third: Marker braid, color coded.
- Fourth: The required number of single conductors cabled with fillers where necessary.
- Fifth: Compound filled tape.
- Sixth: Reinforced rubber sheath.
- Seventh: Compound filled tape.
- Eighth: Standard braid.

18.56 Interior Communication Cable, Thermoplastic-Asbestos Insulation Leaded and Armored.—(Table 38).

- First: 7 strands of 0.020 inch tinned copper wire.
- Second: Thermoplastic insulation.
- Third: Wall of impregnated asbestos insulation.
- Fourth: Marker braided—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 conductor assembly.
- Seventh: Wall of impregnated asbestos insulation.
- Eighth: With or without separator, at manufacturer's option.
- Ninth: Lead sheath.
- Tenth: Bituminous compound.
- Eleventh: Compound filled tape, half lapped*.
- Twelfth: Basket weave armor.
- Thirteenth: Paint.

18.57 Interior Communication Cable, Reinforced Rubber Sheathed, Armored.—(Table 29).

- First: 7 strands of 0.020 inch tinned, copper wire.
- Second: Rubber or thermoplastic insulation to a diameter of 0.115 inch.
- Third: Marker braid, color coded.
- Fourth: The required number of single conductors cabled with fillers where necessary.
- Fifth: Compound filled tape.
- Sixth: Reinforced rubber sheath.
- Seventh: Compound filled tape.
- Eighth: Basket weave armor.
- Ninth: Paint.

* See footnote page 36.

18.58 Interior Communication Cable, Thermoplastic-Asbestos Insulation, Impervious Sheathed and Armored.—(Table 38).

- First: 7 strands of 0.020 inch tinned copper wire.
- Second: Thermoplastic insulation.
- Third: Wall of impregnated asbestos insulation.
- Fourth: Marker braided—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: With or without separator, at manufacturer's option.
- Ninth: Impervious sheath.
- Tenth: Basket weave armor.
- Eleventh: Paint.

18.59 Interior Communication Cable, Leaded and Armored.—(Table 29).

- First: 7 strands of 0.020 inch tinned, copper wire.
- Second: Rubber or thermoplastic insulation to a diameter of 0.115 inch.
- Third: Marker braid, color coded.
- Fourth: The required number of single conductors cabled with fillers where necessary.
- Fifth: Compound filled tape.
- Sixth: Lead sheath.
- Seventh: Bituminous compound.
- Eighth: Compound filled tape, half lapped*.
- Ninth: Basket weave armor.
- Tenth: Paint.

18.60 Two-Conductor, Portable Lamp Cord, Rubber Sheathed, Flat.—

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

18.61 Two-Conductor Portable Cord, Rubber Sheathed.—

- First: This cord should conform to the requirements of the Type S Cord in the latest edition of Underwriters' Laboratories Standard for Flexible Cord and Fixture Wire. Portable cords of greater cross-sectional area than No. 10 should be of construction similar to that of Underwriters' Type S Cord.

18.62 Two-Conductor Portable Cord, Armored.—

- First: 41 strands of 0.010 inch untinned copper wire.
- Second: Cotton wrap.
- Third: 3/64 inch wall of rubber insulation.
- Fourth: Marker braid, color coded.
- Fifth: Two conductors twisted together without fillers.
- Sixth: A belt of rubber insulation not less than 4/64 inch at its thinnest point.
- Seventh: Standard braid or compound filled tape.

- Eighth: Basket weave armor, steel to a diameter of 0.620 inch.

Ninth: Paint.

18.63 Three-Conductor or Four-Conductor, Portable Cord, Rubber Sheathed.—

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

18.64 Three-Conductor, Portable Cord, Armored.—

- First: 41 strands of 0.010 inch untinned copper wire.
- Second: Cotton wrap.
- Third: 3/64 inch wall of rubber insulation.
- Fourth: Marker braid, color coded.
- Fifth: Three conductors twisted together without fillers.
- Sixth: A belt of rubber insulation not less than 4/64 inch at its thinnest point.
- Seventh: Standard braid or compound filled tape.
- Eighth: Basket weave armor, steel to a diameter of 0.655 inch.
- Ninth: Paint.

18.65 Telephone Cable, Reinforced Rubber Sheathed, Braided.—(Table 30).

- First: 7 strands of 0.020 inch tinned, copper wire.
- Second: Rubber or thermoplastic insulation to a diameter of 0.115 inch.
- Third: Marker braid. Color code one conductor in each pair.
- Fourth: Two conductors twisted together to form a pair.
- Fifth: The required number of pairs cabled with fillers where necessary.
- Sixth: Compound filled tape.
- Seventh: Reinforced rubber sheath.
- Eighth: Compound filled tape.
- Ninth: Standard braid.

18.66 Telephone Cable, Reinforced Rubber Sheathed, Armored.—(Table 30).

- First: 7 strands of 0.020 inch tinned, copper wire.
- Second: Rubber or thermoplastic insulation to a diameter of 0.115 inch.
- Third: Marker braid. Color code one conductor in each pair.
- Fourth: Two conductors twisted together to form a pair.
- Fifth: The required number of pairs cabled with fillers where necessary.
- Sixth: Compound filled tape.
- Seventh: Reinforced rubber sheath.
- Eighth: Compound filled tape, half lapped*.
- Ninth: Basket weave armor.
- Tenth: Paint.

18.67 Telephone Cable, Thermoplastic-Glass-Asbestos Insulated, Leaded and Armored.—(Table 39).

- First: 7 strands of 0.020 inch tinned copper wire.
- Second: Thermoplastic insulation.
- Third: Marker braid—of glass fiber treated with flame-resisting lacquer. One conductor of each pair to be color coded.

* See footnote page 36.

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: Lead sheath.

Tenth: Bituminous compound.

Eleventh: Compound filled tape, half lapped*.

Twelfth: Basket weave armor.

Thirteenth: Paint.

18.68 Telephone Cable, Leaded and Armored.—(Table 30).

First: 7 strands of 0.020 inch tinned copper wire.

Second: Rubber or thermoplastic insulation to a diameter of 0.115 inch.

Third: Marker braid. Color code one conductor in each pair.

Fourth: Two conductors twisted together to form a pair.

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

Sixth: Compound filled tape.

Seventh: Lead sheath.

Eighth: Bituminous compounds.

Ninth: Compound filled tape, half lapped*.

Tenth: Basket weave armor.

Eleventh: Paint.

18.69 Telephone Cable, Thermoplastic-Glass-Asbestos Insulated, Impervious Sheath and Armored.—(Table 39).

First: 7 strands of 0.020 inch tinned copper wire.

Second: Thermoplastic 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: Impervious sheath.

Tenth: Basket weave armor.

Eleventh: Paint.

18.70 Inter-Cabin Telephone Cable, Reinforced Rubber Sheathed, Braided.—(Table 31).

First: No. 20 AWG, solid tinned copper wire.

Second: $\frac{1}{64}$ inch rubber or thermoplastic insulation.

Third: Marker braid. Color code one conductor in each pair.

Fourth: Two conductors twisted together to form a pair.

Fifth: The required number of pairs cabled without fillers.

Sixth: Compound filled tape.

Seventh: Reinforced rubber sheath.

Eighth: Compound filled tape.

Ninth: Standard braid.

18.71 Inter-Cabin Telephone Cable, Reinforced Rubber Sheathed, Armored.—(Table 31).

First: No. 20 AWG, solid tinned copper wire.

Second: $\frac{1}{64}$ inch rubber or thermoplastic insulation.

Third: Marker braid. Color code one conductor in each pair.

Fourth: Two conductors twisted together to form a pair.

Fifth: The required number of pairs cabled without fillers.

Sixth: Rubber filled tape.

Seventh: Reinforced rubber sheath.

Eighth: Compound filled tape.

Ninth: Basket weave armor.

Tenth: Paint.

18.72 Inter-Cabin Telephone Cable, Leaded and Armored.—(Table 31).

First: No. 20 AWG, solid tinned copper wire.

Second: $\frac{1}{64}$ inch rubber insulation.

Third: Marker braid. Color code one conductor in each pair.

Fourth: Two conductors twisted together to form a pair.

Fifth: The required number of pairs cabled without fillers.

Sixth: Compound filled tape.

Seventh: Lead sheath.

Eighth: Bituminous compound.

Ninth: Compound filled tape, half lapped*.

Tenth: Basket weave armor.

Eleventh: Paint.

18.73 Single-Conductor, Varnished-Cambric-Asbestos Insulated Flame Retarding, Switchboard.—

First: Tinned, stranded conductor.

Second: Separator at manufacturer's option.

Third: Varnished-cambric insulation.

Fourth: Separator at manufacturer's option.

Fifth: Wall of felted, impregnated asbestos insulation.

Sixth: Standard braid.

Seventh: Gray flameproof paint finish.

18.74 Single Conductor, Thermoplastic-Asbestos Insulated Flame Retarding, Switchboard.—

First: Tinned stranded conductor.

Second: Thermoplastic insulation.

Third: Wall of felted impregnated asbestos insulation.

Fourth: Standard braid.

Fifth: Gray flameproof paint finish.

CABLE DESIGNATIONS

18.75 Cable Designations.—The following cable designations should be used in connection with the cables described in Subsections 18.31 to 18.74, inclusive. 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

DRL-4 = No. 14 (4110 CM) TCRIL & SA

SVLB-250 = 250,000 CM SCVCL & BA

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

ICL-20 = 20 conductor ICL & SA

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

TTL-10 = 10 pair telephone cable L & SA

For example:

(a) SAVIB-6 in which:

S = Single conductor

AV = Asbestos-Varnished-cambric insulated

I = Impervious sheathed and armored

B = Bronze armor

6 = 6530 CM (No. 12)

(b) ICTIA-12 in which:

IC = Interior Communication

T = Thermoplastic-asbestos insulation

I = Impervious sheathed and armored

A = Aluminum armor

12 = Twelve conductors

LEGEND

Cable Type	Insulation	Outer Covering	Armor
S Single Conductor Light & Power	R Rubber	D Braided	(None) Steel
D Double “ “ “ “	V Varnished Cambric	A Armored Only	A Aluminum
T Triple “ “ “ “	AV Asbestos-Varnished-Cambric	(No lead or sheath)	B Bronze
F Four “ “ “ “	T Thermoplastic	L Leaded & Armored	
IC Interior Communication		S Reinforced Sheathed & Armored	
TT Telephone		I Impervious Sheathed & Armored	
TTC Inter-Cabin Telephone			
P Portable			
W Switchboard			

Note—Armor to be steel unless otherwise designated

Paragraph Number	Type	Designation
18.31	Single Conductor, Rubber Insulated & Braided	SRD
18.32	“ “ “ “ “ Steel Armored	SRA
“	“ “ “ “ “ Aluminum Armored	SRAA
“	“ “ “ “ “ Bronze Armored	SRAB
18.33	“ “ “ “ “ Leaded & Steel Armored	SRL
“	“ “ “ “ “ “ Aluminum Armored	SRLA
“	“ “ “ “ “ “ Bronze Armored	SRLB
“	“ “ “ “ “ Impervious Sheathed & Steel Armored	SRI
“	“ “ “ “ “ “ Aluminum Armored	SRIA
“	“ “ “ “ “ “ Bronze Armored	SRIB
18.34	“ “ VC “ Leaded & Steel Armored	SVL
“	“ “ “ “ “ “ Aluminum Armored	SVLA
“	“ “ “ “ “ “ Bronze Armored	SVLB
“	“ “ “ “ “ Impervious Sheathed & Steel Armored	SVI
“	“ “ “ “ “ “ Aluminum Armored	SVIA
“	“ “ “ “ “ “ Bronze Armored	SVIB
18.35	Single Conductor Asbestos-VC Insulated Leaded & Steel Armored	SAVL
“	“ “ “ “ “ “ “ Aluminum Armored	SAVLA
“	“ “ “ “ “ “ “ Bronze Armored	SAVLB
18.36	“ “ VC Insulated Reinforced Sheathed & Steel Armored	SVS
“	“ “ “ “ “ “ “ Aluminum Armored	SVSA
“	“ “ “ “ “ “ “ Bronze Armored	SVSB
18.37	“ “ Asbestos-VC Insulated Impervious Sheathed & Steel Armored	SAVI
“	“ “ “ “ “ “ “ Aluminum Armored	SAVIA
“	“ “ “ “ “ “ “ Bronze Armored	SAVIB
18.38	Double Conductor, Rubber Insulated & Braided	DRD
18.39	“ “ “ “ “ “ Steel Armored	DRA
“	“ “ “ “ “ “ Aluminum Armored	DRAA
“	“ “ “ “ “ “ Bronze Armored	DRAB



Documents

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Paragraph Number	Type	Designation
18.40	Double Conductor, Rubber Insulated Lead & Steel Armored	DRL
"	" " " " " " Aluminum Armored	DRLA
"	" " " " " " Bronze Armored	DRLB
"	" " " " " " Impervious Sheathed & Steel Armored	DRI
"	" " " " " " " Aluminum Armored	DRIA
"	" " " " " " " Bronze Armored	DRIB
18.41	" " VC Insulated Lead & Steel Armored	DVL
"	" " " " " " Aluminum Armored	DVLA
"	" " " " " " Bronze Armored	DVLB
"	" " " " " " Impervious Sheathed & Steel Armored	DVI
"	" " " " " " " Aluminum Armored	DVIA
"	" " " " " " " Bronze Armored	DVIB
18.42	" " Asbestos-VC Insulated Lead & Steel Armored	DAVL
"	" " " " " " Aluminum Armored	DAVLA
"	" " " " " " Bronze Armored	DAVLB
18.43	" " VC Insulated Reinforced Sheathed & Steel Armored	DVS
"	" " " " " " Aluminum Armored	DVSA
"	" " " " " " Bronze Armored	DVSB
18.44	" " Asbestos-VC Insulated Impervious Sheathed & Steel Armored	DAVI
"	" " " " " " " Aluminum Armored	DAVIA
"	" " " " " " " Bronze Armored	DAVIB
18.45	Triple Conductor, Rubber Insulated & Braided	TRD
18.46	" " " " " " Steel Armored	TRA
"	" " " " " " Aluminum Armored	TRAA
"	" " " " " " Bronze Armored	TRAB
18.47	" " " " " " Lead & Steel Armored	TRL
"	" " " " " " " Aluminum Armored	TRLA
"	" " " " " " " Bronze Armored	TRLB
"	" " " " " " Impervious Sheathed & Steel Armored	TRI
"	" " " " " " " Aluminum Armored	TRIA
"	" " " " " " " Bronze Armored	TRIB
18.48	" " VC Insulated Lead & Steel Armored	TVL
"	" " " " " " Aluminum Armored	TVLA
"	" " " " " " Bronze Armored	TVLB
"	" " " " " " Impervious Sheathed & Steel Armored	TVI
"	" " " " " " " Aluminum Armored	TVIA
"	" " " " " " " Bronze Armored	TVIB
18.49	" " Asbestos-VC Insulated Lead & Steel Armored	TAVL
"	" " " " " " Aluminum Armored	TAVLA
"	" " " " " " Bronze Armored	TAVLB
18.50	" " VC Insulated Reinforced Sheathed & Steel Armored	TVS
"	" " " " " " Aluminum Armored	TVSA
"	" " " " " " Bronze Armored	TVSB
18.51	" " Asbestos-VC Insulated Impervious Sheathed & Steel Armored	TAVI
"	" " " " " " " Aluminum Armored	TAVIA
"	" " " " " " " Bronze Armored	TAVIB
18.52	Four Conductor, Rubber Insulated & Steel Armored	FRA
"	" " " " " " Aluminum Armored	FRAA
"	" " " " " " Bronze Armored	FRA B
18.53	" " " " " " Lead & Steel Armored	FRL
"	" " " " " " " Aluminum Armored	FRLA
"	" " " " " " " Bronze Armored	FRLB
"	" " " " " " Impervious Sheathed & Steel Armored	FRI
"	" " " " " " " Aluminum Armored	FRIA
"	" " " " " " " Bronze Armored	FRIB
18.54	Bell Wire	BW
18.55	Interior Communication Cable, Reinforced Rubber Insulated, Braided	ICD
18.56	" " " " " " Thermoplastic-Asbestos Insulated Lead & Steel Armored	ICTL
18.56	" " " " " " " Aluminum Armored	ICTLA
18.56	" " " " " " " Bronze Armored	ICTLB

Paragraph Number	Type							Designation
18.57	Interior Communication Cable, Reinforced Rubber Sheathed, Steel Armored							ICS
"	"	"	"	"	"	"	Aluminum Armored	ICSA
"	"	"	"	"	"	"	Bronze Armored	ICSB
18.58	"	"	"	Thermoplastic-Asbestos Insulated, Impervious Sheathed & Steel Armored				ICTI
"	"	"	"	"	"	"	Impervious Sheathed & Aluminum Armored	ICTIA
"	"	"	"	"	"	"	Impervious Sheathed & Bronze Armored	ICTIB
18.59	"	"	"	Leaded & Steel Armored				ICL
"	"	"	"	"	"	"	Aluminum Armored	ICLA
"	"	"	"	"	"	"	Bronze Armored	ICLB
"	"	"	"	Impervious Sheathed & Steel Armored				ICI
"	"	"	"	"	"	"	Aluminum Armored	ICIA
"	"	"	"	"	"	"	Bronze Armored	ICIB
18.60	Two-Conductor, Portable Lamp Cord, Rubber Sheathed, Flat							DPF
18.61	"	"	"	Cord, Rubber Sheathed				DP
18.62	"	"	"	Armored				DPA
18.63	Three	"	"	"	Rubber Sheathed			TP
"	Four	"	"	"	"	"		FP
18.64	Three	"	"	"	Armored			TPA
18.65	Telephone Cable, Reinforced Rubber Sheathed, Braided							TTD
18.66	"	"	"	"	"	"	Steel Armored	TTA
"	"	"	"	"	"	"	Aluminum Armored	TTAA
"	"	"	"	"	"	"	Bronze Armored	TTAB
18.67	"	"	Thermoplastic-Glass-Asbestos Insulated, Leaded & Steel Armored					TTTL
"	"	"	"	"	"	"	Aluminum Armored	TTTLA
"	"	"	"	"	"	"	Bronze Armored	TTTLB
18.68	"	"	Leaded & Steel Armored					TTL
"	"	"	"	"	"	"	Aluminum Armored	TTLA
"	"	"	"	"	"	"	Bronze Armored	TTLB
18.69	"	"	Thermoplastic-Glass-Asbestos Insulated, Impervious Sheath & Steel Armored					TTTI
"	"	"	"	"	"	"	Aluminum Armored	TTTIA
"	"	"	"	"	"	"	Bronze Armored	TTTIB
18.70	Inter-Cabin Telephone Cable, Reinforced Rubber Sheathed, Braided							TTCD
18.71	"	"	"	"	"	"	Steel Armored	TTCA
"	"	"	"	"	"	"	Aluminum Armored	TTCAA
"	"	"	"	"	"	"	Bronze Armored	TTCAB
18.72	"	"	"	"	Leaded & Steel Armored			TTCL
"	"	"	"	"	"	"	Aluminum Armored	TTCLA
"	"	"	"	"	"	"	Bronze Armored	TTCLB
"	"	"	"	Impervious Sheathed & Steel Armored				TTCI
"	"	"	"	"	"	"	Aluminum Armored	TTCIA
"	"	"	"	"	"	"	Bronze Armored	TTCIB
18.73	Single-Conductor VC-Asbestos Insulated Flame Retarding, Switchboard							SAVW
18.74	"	"	Thermoplastic Asbestos Insulated Flame Retarding Switchboard					STW

SECTION 19

D-C CABLES—APPLICATIONS

19.01 Varnished-Cambric and Asbestos-Varnished-Cambric Insulated Cables.—Cables constructed with varnished-cambric or asbestos-varnished cambric insulation may be used throughout the vessel and should be used in all spaces having an ambient temperature exceeding 50C. Where varnished-cambric 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-cambric No. 14 wire may be used if desired.

Cables constructed with asbestos-varnished-cambric 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.

19.03 Rubber Insulated Cables.—Rubber insulated cables may be used in any space where the ambient temperature does not exceed 50C.

- 19.05 Armored Cable.**—All permanently installed light and power cables except as described in Section 19.13 should be armored.

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

- 19.07 Rubber Insulated Armored Cables and Varnished-Cambric Insulated Reinforced Sheathed 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-cambric insulated cables should not have a cross-sectional area less than No. 12 AWG. (See Subsection 19.01.)

Attention is directed to the fact that the life of rubber insulation is very materially reduced if it is exposed to a temperature exceeding 75°C. 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 75°C.

- 19.09 Cable with Lead or Impervious Sheath.**—

Leaded or impervious sheathed 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 Subsection 19.07.

- 19.11 Substitution of Reinforced Rubber Sheath or**

◆ **Impervious Sheath for Lead Sheath.**—If desired the detailed specification for cable construction as given in Section 18.31 to 18.74 may be modified by the substitution of the reinforced rubber sheath or impervious sheath as defined in Sections 18.15 and 18.17, in place of the specified lead sheath. The bituminous compound and compound filled tape should be omitted.

- 19.13 Braided Cable.**—Rubber insulated braided cable may be used in lighting fixtures except as noted in Subsection 19.07. 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 Interior 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 18.54 may be used, if properly installed in protected raceways.

For interior 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, interior 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 interior 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-Cambric and Asbestos Thermoplastic Insulated Switchboard Wire.**—This wire should be used in accordance with Subsection 17.03 for switchboard and controller wiring.

SECTION 20

D-C CABLE INSTALLATION

- 20.01 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.

- 20.03 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.

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.

- 20.05 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 $\frac{1}{4}$ inch diameter holes for drainage every five feet.

- 20.07 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 smaller, may be of the one-screw type. Cables supported by clips or straps on under side of beams should be run on backing plates or the equivalent. Cable supports should be spaced not more than 18 inches where vertical and 14 inches where horizontal.

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

- 20.09 Cables—Radius of Bends.**—Leaded and armored cables should not be bent to a radius of less than 8 cable diameters. Other cables may be bent to a radius of 6 diameters.

- 20.11 Cables Through Bulkheads, Decks, Beams, Etc.**—Where cables pass through watertight decks or bulkheads, a watertight stuffing tube capable of taking packing should be employed. Where cables

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

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

- 20.15 Cables—Ratproofing.**—During the installation of cables due consideration should be given to the feasibility of ratproofing as required by the Public Health Service.

- 20.17 Installation of Lowvoltage Bell Wiring.**—

◆ Wires serving low voltage circuits such as call bells for staterooms, public spaces, etc., should be neatly grouped and run together and distributed as required. These wires should be protected by molding, split fibre tubing or equivalent wrapping. The battery and branch leads may be tapped off by splicing. It is recommended that protected accessible connection blocks be used wherever possible instead of splicing within wireway enclosures. Lowvoltage (25 volts or less) circuits should be run in separate raceways from other systems except when contained in interior communication cable.

Where bell wire branch leads and other circuits are contained in a door frame, an H-section or a similar runway, a loom or equivalent casing over the bell wire should be considered adequate separation.

Where the public spaces, passages, staterooms, etc., are ceiled, the call bell wiring should be run and secured above or behind the ceiling. Molding may be used in similar locations where there is no ceiling. Call bell wiring leading through crew's quarters and other living spaces where they may be subject to mechanical injury should be protected.

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

SECTION 21

D-C DISTRIBUTION

- 21.01 Distribution—General.**—In general, the methods of distribution are as follows:

From the distribution section of the ship's service or emergency generator switchboards to:

(a) A branch circuit for an individual controller and motor.

(b) A distribution panel.

(c) A power distribution panel or panelboard then to a branch circuit for an individual controller and motor.

(d) A lighting branch circuit.

(e) A panelboard then to a lighting branch circuit.

(f) More than one distribution panel or panelboard, each serving to subdivide the feeders to sub-feeders supplying other panels and/or branch circuits.

(g) Another switchboard, then by any individual or combinations of (a) to (f) above, as desired.

The number and size of the subdivisions depends on the size of the vessel and electric plant.

Except in the case of small vessels and small electric plants, it is recommended that the lighting distribution system and the power distribution system be maintained as separate distribution systems from the ship's service generator and emergency generator switchboards.

- 21.03 Location and Type of Distribution Panels and Panelboards.**—All distribution panels and panelboards should be located so that they are readily accessible at all times to qualified personnel. They should not be located in bunkers, cargo holds and similar spaces. If the method of operation demands the operation of the switches by unqualified persons, the distribution panels or the panelboard should be of the safety type. This type of distribution panel or panelboard should be used for the distribution to all lighting branch circuits.

Distribution panels and panelboards located on weather decks or other spaces exposed to the weather or other severe moisture conditions should be waterproof, elsewhere they may be of drip-proof construction.

Distribution panels of the switchboard type, unless installed in machinery spaces or in compartments assigned exclusively to electric equipment and accessible only to authorized personnel, should be completely enclosed or otherwise protected against accidental contact and unauthorized operation.

- 21.05 Metallic Circuits.**—All circuits should be completely metallic, and no ground return circuits should be employed except for aerial or submarine transmission.
- 21.07 Grounding of Permanent Equipment.**—The frames or cases of all permanently installed generators, motors, controllers, instruments and similar equipment, for which the arrangement and method of installation does not assure positive grounding, should be permanently grounded through separate conductors, securely attached and protected against damage.
- 21.09 Grounding of Portable Equipment.**—Portable equipment such as portable motor units for lifeboat hoisting or any other portable equipment fitted with portable cables and attaching devices and which operate on either two or three-wire circuits of 115 volts or more should have their frames grounded. This should be accomplished by an additional conductor in the portable cable and grounding device in the attachment plug and receptacle.
- 21.11 Demand Factor and Voltage Drop for Lighting Circuits.**—Conductors for all lighting circuits

should be calculated for the total connected load including not less than 50 watts for each receptacle and including 50 percent of rating of spare switches on the switchboard and the average active circuit load for the spare switches on the panelboards. The drop in voltage from the generator switchboard to the farthest fixed outlet on the branch circuit should not exceed 3 percent. Feeders for circuits including cargo receptacles should be figured on the basis of expected load, but including not less than 300 watts per receptacle.

- 21.13 Demand Factor and Voltage Drop for Searchlight Circuits.**—Conductors for searchlight circuits should be calculated for the rated current of the lamp. For arc searchlights, where a resistance is permanently connected in the circuit, the voltage drop need not be limited except that where motor control is employed, the drop should be limited to a value which will permit satisfactory operation of the motor and lamp at all times.

- 21.15 Demand Factor and Voltage Drop for Appliance Circuits.**—Conductors for appliance circuits should be calculated for carrying capacities for rated current of the appliance; the drop in voltage should not exceed 5 percent from generator switchboard to the most remote appliance.

- 21.17 Conductor Rating and Voltage Drop for Galley Circuits.**—Conductors for galley equipment should be calculated on the basis of 100 percent demand factor for the first 50 kw of connected load. Connected load in excess of 50 kw should be calculated on the basis of 65 percent demand. Based on rated load as calculated above, the voltage drop should not exceed 5 percent from the generator switchboard to the most remote piece of equipment.

- 21.19 Conductor Rating and Voltage Drop for Motor Circuits.**—Except as recommended below and in Subsection 21.43, conductors supplying one or more motors should have a continuous current-carrying capacity equal to 125 percent of the nameplate rating of the largest motor plus the sum of the nameplate ratings of all other motors supplied, and including 50 percent of the rating of spare switches on the distribution panel.

Conductors supplying a group of three or more workshop tool motors should have a continuous current-carrying capacity equal to 125 percent of the nameplate rating of the largest motor plus 50 percent of the sum of the nameplate ratings of all other motors of this group.

Conductors supplying two or more motors driving cargo winches arranged for the "Burtoning" method of cargo handling should have a continuous current-carrying capacity equal to 125 percent of the largest motor plus 50 percent of the sum of the nameplate ratings of all other motors.

Conductors supplying two or more motors driving 'tween deck cargo winches or cargo elevators should have a continuous current-carrying capacity equal to 125 percent of the largest motor plus 75 percent of the sum of the nameplate ratings of all other motors.

If any circuit which supplies cargo winch or cargo

elevator motors supplies also motors driving windlasses or capstans which will not operate at the same time as the cargo handling motors, the current carrying capacity should be based on the cargo handling load, calculated as recommended above, or on the windlass and capstan load, whichever is the greater, but not on the combined motor ratings.

The voltage drop to any motor, based on rated load calculated as recommended above, should not exceed 5 percent from the generator switchboard to the most remote motor.

- 21.21 Demand Factor and Voltage Drop for Generator and Bus-Tie Circuits.**—Conductors from each generator to the generator switchboard should be calculated for 125 percent of the continuous rating of each generator.

Conductors between generator switchboards of different generating stations should be calculated on the basis of 75 percent of the station having the greatest generating capacity. The drop in voltage from each generator to its adjacent generator switchboard should not exceed one percent, and the drop in voltage between generator switchboards should not exceed two percent.

Conductors from storage batteries to the point of distribution should be calculated for a maximum charge, or discharge rate of the storage batteries, and the drop in voltage from the storage batteries to the point of distribution should not exceed one percent.

Conductors from generator switchboard to outlet for receiving shore power should be calculated on the basis of the load required for this condition, or as recommended, and the drop in voltage from the outlet to the generator switchboard should not exceed two percent.

- 21.23 Balance of Circuits for Three-Wire Systems.**

- ◆ —Since branch lighting circuits are to be of the two-wire type, the three-wire system should not extend beyond the final distribution panel or panelboard. The 115 volt two-wire lighting branch circuits should be so disposed that the load will be balanced within 15 percent at the individual distribution panels or panelboards as well as for the complete lighting system. Portable equipment loads, such as vacuum cleaners, portable tools, etc. need not be considered in computing the unbalance.

- 21.25 Conductor Identification.**—The individual conductors of branch circuit cables should have or be marked with distinguishing colors, and in grounded systems, the grounded conductor should be connected to the shell of all sockets and all single-pole switches should be in the ungrounded conductor. In two-wire ungrounded systems, the color of conductors connected to single-pole switches should be uniform throughout.

- 21.27 Overcurrent Protection of Conductors.**—Except as otherwise recommended in Subsections 17.13, 27.01 and 28.09, overcurrent protection by fuses or circuit breakers should be provided for all ungrounded conductors. Fuses should not, and circuit breaker overcurrent trips need not be provided for the neutral conductor of a three-wire

grounded system but provision should be made for feeder disconnect including the neutral.

Except for protection of emergency lighting battery cables as recommended in Subsection 16.13, fuses of a rating greater than 200 amperes should not be used. Circuit breakers of the molded case or of the open type should be used when a greater rating is required, and are preferred for all circuits.

- 21.29 Overcurrent Protection of Fixture Wires**

- ◆ **and Cords.**—Fixture wire or flexible cords, sizes No. 16 or No. 18 are considered properly protected when preceded by a branch circuit overcurrent device.

- 21.31 Feeder and Branch Continuity.**—Except as otherwise permitted below and in Subsections 21.33 and 23.07, each feeder and each branch circuit supplying a single energy consuming appliance should be continuous throughout its length. In instances of feeders of large size and exceptional length, feeder boxes may be used to effect ease of installation with least possible damage to insulation. Under direction of Regulatory Agencies, the use of feeder boxes may be permitted in instances where renewal of feeders is necessary due to vessel's structural damage.

- 21.33 Feeder Connections.**—Where a feeder supplies more than one distribution panel or panelboard, it may be continuous from the switchboard to the farthest panel or it may be severed at any intermediate panel, in which case the incoming and outgoing conductors should be connected to the panel buses by suitable lugs. If the bus bars of any distribution panel or panelboard carry "through" load, the size of the buses should be suitable for the total current. The size of feeder conductors will ordinarily be uniform for the total length but may be reduced at any intermediate distribution panel or panelboard provided that the smallest section of the feeder is protected by the overload device at the distribution switchboard.

- 21.35 Distribution for Navigating Lights.**—A separate feeder from the emergency switchboard should be provided for all lights supplied from the temporary bus and located in, or controlled from the wheelhouse. A panel or panels with a fused switch or circuit breaker for each branch circuit should be provided for any navigating or signal lights not controlled by the running light panel, for emergency lights in the wheelhouse and chartroom and any other temporary emergency lighting except the running light indicator panel. Through feed, without switch or overload protection, should be provided for the running light indicator panel. The rating of the cable and the fuse or circuit breaker on the emergency switchboard for this feeder should be not less than 30 amperes or not less than 125 percent of the connected load whichever is greater, including allowance for spare branch circuits. (This feeder should not supply floodlights for lifeboat launching).

One four-conductor, or two two-conductor branch circuit cables should be provided from the telltale panel for each two-light navigation light. Each four-conductor branch circuit cable from the tell-

tale panel should terminate in a waterproof, two-gang, two circuit receptacle located adjacent to the running light. If two two-conductor branch circuit cables are provided, each cable should terminate in a single gang, waterproof receptacle. The receptacles should be of the grounding type described in Subsection 23.13. Two three-conductor portable connections should be provided for each two-light running light, and each should be fitted with a three-pole plug, arranged to ground the case of the light when the plug is inserted in the receptacle.

21.37 Distribution for Machinery Space Lighting.—

Separate feeders should be installed for the engine-room spaces, fireroom spaces and auxiliary spaces opening thereon, including bunkers and store-rooms, and no lights outside these spaces should be supplied therefrom. The number and sizes of the feeders should depend on the number of lights and extent of spaces covered. It is recommended that alternate groups of lights within these spaces be so arranged that the failure of any one circuit will not leave these spaces in darkness.

21.39 Distribution for Cargo Space Lighting.—

Separate feeders should be installed for all cargo lighting. The distribution panels or panelboards should be located outside cargo spaces. Outlets in cargo spaces should not be connected to feeders which are required for lighting or handling the vessel while under way.

When a feeder supplies cargo spaces used alternately for passengers or cargo, the distribution panels or panelboards should contain all switches and fuses for these spaces, and the cabinet enclosing the panelboard should be provided with a lock.

21.41 Distribution for Lighting Passenger and Ship's Personnel Accommodations.—

For vessels provided with fire screen bulkheads forming fire zones, it is recommended that at least two separate feeders be provided exclusively for each vertical zone between two screen bulkheads which may serve all decks within the zone. One of these may be the emergency lighting feeder. The supply of lights in all passageways and public spaces and in any berthing compartment accommodating more than 25 persons should be divided between two feeders so that if either fails there will be sufficient light to prevent panic and to permit passengers and personnel readily to find their way to the open deck. The two feeders serving one compartment should be separated as widely as practicable to minimize the possibility of damage to both from fire or other casualty.

Electric service to each passenger stateroom should be supplied by at least two separate branch circuits connected to the general lighting system, and the lighting should be so divided that, in the event of failure of one branch circuit, there will be sufficient light to permit use of the space.

21.43 Distribution for Power Equipment.—In general, power feeders for cargo elevators, cargo hoists and cargo winches which should be disconnected when the vessel is under way should not be

used to supply ventilation sets, drainage pump motors, or any apparatus required for the ship's operation.

Separate feeders from generator or subdistribution switchboards should be run for engine and fire room auxiliaries; for motors for cargo handling gear, for steering gear, for radio transmitters, for arc searchlights, and for ventilation sets. Cargo ventilation fans and fans for ventilation of passenger accommodations should not be supplied from the same feeder.

Except as otherwise provided herein, two circuits should be provided from the ship's service switchboard to the steering gear room. These circuits should be widely separated so as to minimize failure of both feeders by collision, fire or other casualty. Both feeders may connect to the ship's service switchboard, or, if the capacity of the emergency supply and the bus feeder from the main to the emergency switchboard, and its over-current device, are adequate, one feeder may connect to the main switchboard and one to the emergency switchboard. The feeder circuit breaker on the emergency switchboard may be set at not less than 200 percent of the steering motor rating. Each circuit should have a continuous current-carrying capacity of not less than 125 percent of the rating of the motor or motors simultaneously operated therefrom. When the cable run from the ship's service switchboard to the steering gear is relatively short, as with the usual tank vessel arrangement, and when there is no watertight bulkhead between (assuring ready access), only one feeder may be provided.

In order to prevent the spread of fire, arrangements should be made to permit stopping all vent fans from a central point. For further details see Subsection 25.09.

21.45 Distribution for Heating Equipment.—

Separate feeders and distribution panels should be provided for air heaters when they are used extensively to supplement or supplant other systems of heating.

Provided that the respective minimum wire size and maximum fuse rating is as described for fixed appliances in the first paragraphs of Subsection 21.49, isolated heaters or groups of heaters of aggregate rating not exceeding 6, 15, or 20 amperes may be supplied by branch circuits from lighting panels.

An individual heating appliance of any rating may be supplied by a branch circuit from a power distribution panel.

21.47 Motor Branch Circuits.—

A separate branch circuit should be provided for each fixed motor having a full-load current rating of 6 amperes or more and the conductors should have a carrying capacity of not less than 125 percent of the motor full-load current rating, and not less than the recommendations which are given in Table 8 (Appendix) for the more usual motor ratings. No branch circuit should have conductors less than No. 14 AWG wire.

21.49 Appliance Branch Circuits (Other Than Motor Operated).—Fixed appliances having an aggregate rating of not more than 6 amperes may be grouped on a branch circuit wired with not less than No. 14 AWG wire and fused not in excess of 10 amperes. Fixed appliances having an aggregate rating of not more than 15 amperes may be grouped on a branch circuit wired with not less than No. 12 AWG wire and fused not in excess of 15 amperes. Fixed appliances having an aggregate rating of not more than 20 amperes may be grouped on a branch circuit wired with not less than No. 10 AWG wire and fused not in excess of 20 amperes.

In the above cases no other outlets or appliances should be connected to the branch circuit except that current-on indicating lights may be considered a part of the appliance. Individual appliances with a rating of 15 amperes or more should be wired with a separate branch circuit having a current-carrying capacity of not less than the full-load rating of the appliance and protected by a fuse of not greater rating or nearest larger size than the appliance. Indicating lights within the appliance may be considered to be protected by the branch circuit fuse. For range units, bake ovens, griddles, broilers, in which self-contained fuses are provided for each individually controlled heating element only one branch circuit need be provided for each assembled unit.

21.51 Motors Larger than One-Quarter Horsepower.—In general, motors larger than $\frac{1}{4}$ hp should not be connected to lighting circuits.

21.53 Receptacles for 230 Volt Portable Equipment.—In cases where it is necessary to use 230 volt portable motors the receptacles for their attachment should be permanently marked indicating the voltage and of a type which will not permit attaching 115 volt equipment.

21.55 Lighting Branch Circuits—Maximum Connected Load.—Except as otherwise provided hereinafter and in Subsection 21.45, the connected load on branch circuits should not exceed 880 watts for No. 14 AWG conductor or 1380 watts for No. 12 AWG or larger conductors.

The connected load on branch circuits, with conductors not smaller than No. 12 AWG, supplying;

- (1) sockets of the heavy duty type such as mogul or bipost base;
- (2) receptacles rated more than 15 amperes; or
- (3) keyless sockets (including those used for electric discharge lamps) grouped in a single compartment, such as one of the public spaces, and located at a height to prevent ready attachment of appliances or installation of larger lamps; should not exceed 1760 watts.

21.57 Lighting Branch Circuits—Wire Size.—All branch circuits should be wired with not less than No. 14 AWG conductors.

21.59 Lighting Branch Circuits—Overcurrent Protection.—Each lighting branch circuit should be protected by an overcurrent device in each wire. Except as otherwise provided hereinafter, circuit

breakers should have a maximum rating of 15 amperes for No. 14 AWG or larger conductors, and fuses should have a maximum rating of 10 amperes for No. 14 AWG conductors or 15 amperes for No. 12 AWG or larger conductors.

For branch circuits with a maximum connected load of 1760 watts, as described in the second paragraph of Subsection 21.55, the overcurrent devices should be rated 20 amperes.

21.61 Motor Branch Circuits—Overcurrent Protection.—For dc motor branch circuits, overcurrent protection by fuses (limited to 200 ampere rating) should conform to Table 8 (Appendix).

For any circuit breaker protecting a dc motor branch circuit the maximum rating or setting of the trip element should be the standard rating or setting equal to or (if not in exact agreement) next above 1.5 times the full load rating of the motor served.

21.63 Rating of Setting of Protection Devices.—Except as otherwise recommended for motor branch circuits Subsection 21.61 and, in Subsection 28.09 for steering gear circuits, the rating of fuses or of trip elements of thermal trip, time delay circuit breakers with fixed setting, should not exceed the rated capacity of the conductors protected, as listed in Table 9 (Appendix).

Except as otherwise recommended in Subsection 21.61 and 28.09, the trip setting of a magnetic trip circuit breaker of the time delay or instantaneous type should not exceed 125 percent of the rated capacity of the conductors protected as listed in Table 9 (Appendix).

21.65 Control and Indicating Circuits for Power and Lighting Equipment.—Individual conductors for control circuits when installed on switchboards, distribution panels, panelboards, motor control panels, heater control panels, etc. should be as required by the sections herein covering construction of the several types of equipment. If the control circuit extends to a device external to the originating device, interior communication cable and connection boxes of the type described herein may be used, provided the insulation and current-carrying capacity are adequate for the purpose intended. Increased current-carrying capacity may be obtained by paralleling individual conductors within the cable. Individual conductors will be considered adequately protected against short circuits by 15 ampere fuses for interior communication cable and 30 amperes for No. 14 AWG, of other than the so-called time delay type.

21.67 Wire Connections.—Wire joints or connections should be made in flame-retarding outlet boxes which should be completely metallic, or in wiring appliances. Except for portable cords, bell wires and lighting branch circuits, all wire ends should be provided with lugs, and connections should be made by binding screws, studs or equivalent on insulating material bases. In lieu of lugs the ends of lighting branch circuit wires may be formed into eyes and soldered for securing on the terminals. The lug