STANDARDIZATION RULES OF THE A. I. E. E.

NEW YORK, JUNE 17, 1907.

DR. SAMUEL SHELDON,

PRESIDENT, AMERICAN INSTITUTE ELECTRICAL ENGINEERS,
33 West 39th Street,
New York City.

DEAR SIR:—

In accordance with a motion made by Dr. Steinmetz, and duly carried at the last Annual Convention of the Institute, at Milwaukee, the Standardization Rules have been revised in form and wording and in accordance with various suggestions received from members of the Institute. This work has been accomplished by the Standards Committee which has held monthly meetings beginning in September last.

Dr. Steinmetz' motion provided that the Standardization Rules when completed by the Committee should be submitted to the Board of Directors for final adoption and promulgation. I therefore submit the revised Standardization Rules through you to the Board of Directors, and request that they be formally approved and adopted.

Respectfully yours,

(Signed) FRANCIS B. CROCKER,
Chairman, Standards Committee.

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Approved by vote of the Board of Directors, June 21, 1907.

RALPH W. POPE,
Secretary.

New York, June 21, 1907.

STANDARDIZATION RULES

of the

American Institute of Electrical Engineers.

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I. DEFINITIONS AND TECHNICAL DATA.

- 1 *Note:* The following definitions and classifications are intended to be practically descriptive and not scientifically rigid.

A. DEFINITIONS. CURRENTS.

- 2 A DIRECT CURRENT is a unidirectional current.
- 3 A CONTINUOUS CURRENT is a steady, or non-pulsating, direct current.
- 4 A PULSATING CURRENT is a current equivalent to the superposition of an alternating current upon a continuous current.
- 5 An ALTERNATING CURRENT is a current which, when plotted, consists of half-waves of equal area in successively opposite directions from the zero line.
- 6 An OSCILLATING CURRENT is a current alternating in direction, and of decreasing amplitude.

B. DEFINITIONS. ROTATING MACHINES.

- 7 A GENERATOR transforms mechanical power into electrical power.
- 8 A DIRECT-CURRENT GENERATOR produces a direct current that may or may not be continuous.
- 9 An ALTERNATOR or ALTERNATING-CURRENT GENERATOR produces alternating current, either single-phase or polyphase.
- 10 A POLYPHASE GENERATOR produces currents differing symmetrically in phase: such as two-phase currents, in which the terminal voltages on the two circuits differ in phase by 90 degrees; or three-phase currents, in which the terminal voltages on the three circuits differ in phase by 120 degrees.
- 11 A DOUBLE-CURRENT GENERATOR produces both direct and alternating currents.
- 12 A MOTOR transforms electrical into mechanical power.
- 13 A BOOSTER is a machine inserted in series in a circuit to change its voltage. It may be driven by an electric motor (in which case it is termed a motor-booster) or otherwise.
- 14 A MOTOR-GENERATOR is a transforming device consisting of a motor mechanically connected to one or more generators.
- 15 A DYNAMOTOR is a transforming device combining both motor and generator action in one magnetic field, with two armatures; or with an armature having two separate windings and independent commutators.
- 16 A CONVERTER is a machine employing mechanical rotation in changing electrical energy from one form into another. A converter may belong to either of several types, as follows:
 - 17 a. A DIRECT-CURRENT CONVERTER converts from a direct current to a direct current.
 - 18 b. A SYNCHRONOUS CONVERTER (commonly called a rotary converter) converts from an alternating to a direct current, or *vice versa*.
 - 19 c. A MOTOR-CONVERTER is a combination of an induction motor with a synchronous converter, the secondary of the former feeding the armature of the latter with current at some frequency other than the impressed frequency; *i.e.*, it is a synchronous converter concatenated with an induction motor.
 - 20 d. A FREQUENCY-CONVERTER converts from an alternating-current system of one frequency to an alternating-current system of another frequency, with or without a change in the number of phases or in voltages.
 - 21 e. A ROTARY PHASE CONVERTER converts from an alternating-current system of one or more phases to an alternating-current system of a different number of phases, but of the same frequency.

C. DEFINITIONS. STATIONARY INDUCTION APPARATUS.

- 22 STATIONARY INDUCTION APPARATUS change electric energy to electric energy through the medium of magnetic energy. They comprise several forms, distinguished as follows:
- 23 *a.* In TRANSFORMERS the primary and secondary windings are insulated from one another.
- 24 *b.* In AUTO-TRANSFORMERS, also called compensators, a part of the primary winding is used as a secondary winding, or conversely.
- 25 *c.* In POTENTIAL REGULATORS a coil is in shunt and a coil is in series with the circuit, so arranged that the ratio of transformation between them is variable at will. They are of the following three classes:
- 26 (*a*) COMPENSATOR POTENTIAL REGULATORS in which a number of turns of one of the coils are adjustable.
- 27 (*b*) INDUCTION POTENTIAL REGULATORS in which the relative positions of the primary and secondary coils are adjustable.
- 28 (*c*) MAGNETO POTENTIAL REGULATORS in which the direction of the magnetic flux with respect to the coils is adjustable.
- 29 *d.* REACTORS, or REACTANCE COILS, formerly called choking coils, are a form of stationary induction apparatus used to produce reactance or phase displacement.

D. GENERAL CLASSIFICATION OF APPARATUS.

- 30 COMMUTATING MACHINES. Under this head may be classed the following: Direct-current generators; direct-current motors; direct-current boosters; motor-generators; dynamotors; converters, compensators or balancers; closed-coil arc machines, and alternating-current commutating motors.
- 31 Commutating machines may be further classified as follows:
- 32 *a.* DIRECT-CURRENT COMMUTATING MACHINES, which comprise a magnetic field of constant polarity, a closed-coil armature, and a multisegmental commutator connected therewith.
- 33 *b.* ALTERNATING-CURRENT COMMUTATING MACHINES, which comprise a magnetic field of alternating polarity, a closed-coil armature, and a multisegmental commutator connected therewith.
- 34 *c.* SYNCHRONOUS COMMUTATING MACHINES, which comprise synchronous converters, motor converters and double-current generators.
- 35 SYNCHRONOUS MACHINES, which comprise a constant magnetic field, and an armature receiving or delivering alternating-currents in synchronism with the motion of the machine; *i.e.*, having a frequency equal to the product of the number of pairs of poles and the speed of the machine in revolutions per second.
- 36 STATIONARY INDUCTION APPARATUS, which include transformers, auto-transformers, potential regulators, and reactors or reactance coils.
- 37 ROTARY INDUCTION APPARATUS, or INDUCTION MACHINES, which include apparatus wherein the primary and secondary windings rotate with respect to each other; *i.e.*, induction motors, induction generators, frequency converters, and rotary phase converters.
- 38 UNIPOLAR or ACYCLIC MACHINES, in which the voltage generated in the active conductors maintains the same direction with respect to those conductors.
- 39 RECTIFYING APPARATUS, PULSATING-CURRENT GENERATORS.
- 40 ELECTROSTATIC APPARATUS, such as condensers, etc.
- 41 ELECTROCHEMICAL APPARATUS, such as batteries, etc.
- 42 ELECTROTHERMAL APPARATUS, such as rheostats, heaters, etc.
- 43 PROTECTIVE APPARATUS, such as fuses, lightning arresters, etc.
- 44 LUMINOUS SOURCES.

E. MOTORS. SPEED CLASSIFICATION.

- 45 MOTORS may, for convenience, be classified with reference to their speed characteristics as follows:
- 46 *a.* CONSTANT-SPEED MOTORS, in which the speed is either constant or does not materially vary; such as synchronous motors, induction motors with small slip, and ordinary direct-current shunt motors.

- 47 *b. MULTISPEED MOTORS* (two-speed, three-speed, etc.), which can be operated at any one of several distinct speeds, these speeds being practically independent of the load, such as motors with two armature windings.
- 48 *c. ADJUSTABLE-SPEED MOTORS*, in which the speed can be varied gradually over a considerable range; but when once adjusted remains practically unaffected by the load, such as shunt motors designed for a considerable range of field variation.
- 49 *d. VARYING-SPEED MOTORS*, or motors in which the speed varies with the load, decreasing when the load increases; such as series motors.

F. DEFINITION AND EXPLANATION OF TERMS.

(I) *LOAD FACTOR.*

- 50 The **LOAD FACTOR** of a machine, plant or system is the ratio of the average power to the maximum power during a certain period of time. The average power is taken over a certain interval of time, such as a day or a year, and the maximum is taken over a short interval of the maximum load within that interval.
- 51 In each case the interval of maximum load should be definitely specified. The proper interval is usually dependent upon local conditions and upon the purpose for which load factor is to be determined.

(II) *NON-INDUCTIVE LOAD AND INDUCTIVE LOAD.*

- 52 A non-inductive load is a load in which the current is in phase with the voltage across the load.
- 53 An inductive load is a load in which the current lags behind the voltage across the load. A load in which the current leads the voltage across the load is sometimes called an anti-inductive load.

(III) *POWER-FACTOR AND REACTIVE FACTOR.*

- 54 The **POWER-FACTOR** in alternating-current circuits or apparatus is the ratio of the electric power in watts to the apparent power in volt-amperes. It may be expressed as follows:

$$\frac{\text{true power}}{\text{apparent power}} = \frac{\text{watts}}{\text{volt-amperes}} = \frac{\text{energy current}}{\text{total current}} = \frac{\text{energy voltage}}{\text{total voltage}}$$

- 55 The **REACTIVE FACTOR** is the ratio of the wattless volt-amperes (*i.e.*, the product of the wattless component of current by voltage, or wattless component of voltage by current) to the total amperes. It may be expressed as follows:

$$\frac{\text{wattless volt-amperes}}{\text{total volt-amperes}} = \frac{\text{wattless current}}{\text{total current}} = \frac{\text{wattless voltage}}{\text{total voltage}}$$

- 56 **POWER-FACTOR** and **REACTIVE FACTOR** are related as follows:

If p = power-factor, q = reactive-factor, then with sine waves of voltage and current,

$$p^2 + q^2 = 1$$

With distorted waves of voltage and current,

$$p^2 + q^2 = \text{or} < 1$$

(IV) *SATURATION-FACTOR.*

- 57 The **SATURATION-FACTOR** of a machine is the ratio of a small percentage increase in field excitation to the corresponding percentage increase in voltage thereby produced. The saturation factor is, therefore, a criterion of the degree of saturation attained in the magnetic circuits at any excitation selected. Unless otherwise specified, however, the saturation factor of a machine refers to the excitation existing at normal rated speed and voltage. It is determined from measurements of saturation made on open circuit at rated speed.
- 58 The **PERCENTAGE OF SATURATION** of a machine at any excitation may be found from its saturation curve of generated voltage as ordinates, against

excitation as abscissas, by drawing a tangent to the curve at the ordinate corresponding to the assigned excitation, and extending the tangent to intercept the axis of ordinates drawn through the origin. The ratio of the intercept on this axis to the ordinate at the assigned excitation, when expressed in percentage, is the percentage of saturation and is independent of the scale selected for excitation and voltage. This ratio is equal to the reciprocal of the saturation-factor at the same excitation, deducted from unity. Thus, if f be the saturation factor and p the percentage of saturation ratio,

$$p = 1 - \frac{1}{f}$$

(V) *VARIATION AND PULSATION.*

- 59 The **VARIATION IN PRIME MOVERS** which do not give an absolutely uniform rate of rotation or speed, as in reciprocating steam engines, is the maximum angular displacement in position of the revolving member expressed in degrees, from the position it would occupy with uniform rotation, and with one revolution taken as 360°.
- 60 The **PULSATION IN PRIME MOVERS** is the ratio of the difference between the maximum and minimum velocities in an engine-cycle to the average velocity.
- 61 The **VARIATION IN ALTERNATORS** or alternating-current circuits in general is the maximum difference in phase of the generated voltage wave from a wave of absolutely constant frequency, expressed in electrical degrees (one cycle equals 360 degrees) and may be due to the variation of the prime mover.
- 62 The **PULSATION IN ALTERNATORS** or alternating-current circuits, in general, is the ratio of the difference between maximum and minimum frequency during an engine cycle to the average frequency.
- 63 **RELATION OF VARIATION** in prime mover and alternator.
- 64 If n = number of pairs of poles, the variation of an alternator is n times the variation of its prime mover, if direct-connected, and n/p times the variation of the prime mover if rigidly connected thereto in the velocity ratio p .

II. PERFORMANCE SPECIFICATIONS AND TESTS.

A. RATING.

- 65 **RATING BY OUTPUT.** All electrical apparatus should be rated by output and not by input. Generators, transformers, etc., should be rated by electrical output: motors by mechanical output.
- 66 **RATING IN KILOWATTS.** Electrical power should be expressed in kilowatts, except when otherwise specified.
- 67 **APPARENT POWER, KILOVOLT-AMPERES.** Apparent power in alternating-current circuits should be expressed in kilovolt-amperes as distinguished from real power in kilowatts. When the power factor is 100 per cent., the apparent power in kilovolt-amperes is equal to the kilowatts.
- 68 The **RATED (FULL-LOAD) CURRENT** is that current which, with the rated terminal voltage, gives the rated kilowatts, or the rated kilovolt-amperes. In machines in which the rated voltage differs from the no-load voltage, the rated current should refer to the former.
- 69 **DETERMINATION OF RATED CURRENT.** The rated current may be determined as follows: If P = rating in watts, or apparent watts if the power factor be other than 100 per cent., and E = full-load terminal voltage, the rated current per terminal is:
- 70 $I = \frac{P}{E}$ in a direct-current machine or single-phase alternator.
- 71 $I = \frac{1}{\sqrt{3}} \frac{P}{E}$ in a three-phase alternator.
- 72 $I = \frac{1}{2} \frac{P}{E}$ in a two-phase alternator.

- 73** **NORMAL CONDITIONS.** The rating of machines or apparatus should be based upon certain normal conditions to be assumed as standard, or to be specified. These conditions include voltage, current, power-factor, frequency, wave shape and speed; or such of them as may apply in each particular case. Performance tests should be made under these standard conditions unless otherwise specified.
- 74** **a. POWER FACTOR.** Alternating-current apparatus should be rated in kilowatts, at 100 per cent. power factor; *i.e.*, with current in phase with terminal voltage, unless a phase displacement is inherent in the apparatus or is specified. If a power factor other than 100 per cent. is specified, the rating should be expressed in kilovolt-amperes and power factor, at rated load.
- 75** **b. WAVE SHAPE.** In determining the rating of alternating-current machines or apparatus, a sine wave shape of alternating current and voltage is assumed, except where a distorted wave shape is inherent to the apparatus. See Secs. 79-83.
- 76** **FUSES.** The rating of a fuse should be the maximum current which it will continuously carry.
- 77** **CIRCUIT-BREAKERS.** The rating of a circuit-breaker should be the maximum current which it is designed to carry continuously.
- 78** **a. NOTE.** In addition thereto, the maximum current and voltage at which a fuse or a circuit-breaker will open the circuit should be specified. It is to be noted that the behavior of fuses and of circuit-breakers is much influenced by the amount of electric power available on the circuit.

B. WAVE SHAPE.

- 79** The **SINE WAVE** should be considered as standard, except where a difference in the wave form from the sinusoidal is inherent in the operation of the apparatus.
- 80** A **MAXIMUM DEVIATION** of the wave from sinusoidal shape not exceeding 10 per cent. is permissible, except when otherwise specified.
- 81** The **DEVIATION** of wave form from the sinusoidal is measured by determining the form by oscillograph or wave meter, computing therefrom the equivalent sine wave of equal length, superposing the latter upon the observed wave in such a manner as to give least difference, and then dividing the maximum difference at any ordinate by the maximum value of the equivalent sine wave.
- 82** The **EQUIVALENT SINE WAVE** is a sine wave having the same frequency and the same effective or r.m.s. (root of mean square) value as the actual wave.
- 83** **NON-SINE WAVES.** The phase displacement between two waves which are not sine waves, is that phase displacement between their equivalent sine waves which would give the same average product of instantaneous values as the actual waves; *i.e.*, the same electro-dynamometer reading.

C. EFFICIENCY.

(I) DEFINITIONS.

- 84** The **EFFICIENCY** of an apparatus is the ratio of its net power output to its gross power input.
- 85** **a. NOTE.** An exception should be noted in the case of storage batteries or apparatus for storing energy in which the efficiency, unless otherwise qualified, should be understood as the ratio of the energy output to the energy intake in a normal cycle. An exception should also be noted in the case of luminous sources.
- 86** **APPARENT EFFICIENCY.** In apparatus in which a phase displacement is inherent to their operation, apparent efficiency should be understood as the ratio of net power output to volt-ampere input.
- 87** **a. NOTE.** Such apparatus comprise induction motors, reactive synchronous converters, synchronous converters controlling the voltage of an alternating-current system, self-exciting synchronous motors, potential regulators and open magnetic circuit transformers, etc.
- 88** **b. NOTE.** Since the apparent efficiency of apparatus delivering electric power depends upon the power-factor of the load, the apparent efficiency, unless otherwise specified, should be referred to a load power-factor of unity.

(II) DETERMINATION OF EFFICIENCY.

- 89** **METHODS.** Efficiency may be determined by either of two methods, viz.: by measurement of input and output; or, by measurement of losses.
- 90** *a. METHOD OF INPUT AND OUTPUT.* The input and output may both be measured directly. The ratio of the latter to the former is the efficiency.
- 91** *b. METHOD BY LOSSES.* The losses may be measured either collectively or individually. The total losses may be added to the output to derive the input, or subtracted from the input to derive the output.
- 92** **COMPARISON OF METHODS.** The output and input method is preferable with small machines. When, however, as in the case of large machines, it is impracticable to measure the output and input; or when the percentage of power loss is small and the efficiency is nearly unity, the method of determining efficiency by measuring the losses should be followed.
- 93** **ELECTRIC POWER** should be measured at the terminals of the apparatus. In tests of polyphase machines, the measurement of power should not be confined to a single circuit but should be extended to all the circuits in order to avoid errors of unbalanced loading.
- 94** **MECHANICAL POWER** in machines should be measured at the pulley, gearing, coupling, etc., thus excluding the loss of power in said pulley, gearing or coupling, but including the bearing friction and windage. The magnitude of bearing friction and windage may be considered, with constant speed, as independent of the load. The loss of power in the belt and the increase of bearing friction due to belt tension should be excluded. Where, however, a machine is mounted upon the shaft of a prime mover, in such a manner that it cannot be separated therefrom, the frictional losses in bearings and in windage, which ought, by definition, to be included in determining the efficiency, should be excluded, owing to the practical impossibility of determining them satisfactorily.
- 95** In **AUXILIARY APPARATUS**, such as an exciter, the power lost in the auxiliary apparatus should not be charged to the principal machine, but to the plant consisting of principal machine and auxiliary apparatus taken together. The plant efficiency in such cases should be distinguished from the machine efficiency.
- 96** **NORMAL CONDITIONS.** Efficiency tests should be made under normal conditions herein set forth and which are to be assumed as standard. These conditions include voltage, current, power-factor, frequency, wave shape, speed and barometric pressure, temperature, or such of them as may apply in each particular case. Performance tests should be made under these standard conditions unless otherwise specified. See Secs. 73-75.
- 97** *a. TEMPERATURE.* The efficiency of all apparatus, except such as may be intended for intermittent service, should be either measured at, or reduced to, the temperature which the apparatus assumes under continuous operation at rated load, referred to a room temperature of 25° C. See Secs. 267-292.
- 98** With apparatus intended for intermittent service, the efficiency should be determined at the temperature assumed under specified conditions.
- 99** *b. POWER FACTOR.* In determining the efficiency of alternating-current apparatus, the electric power should be measured when the current is in phase with the voltage, unless otherwise specified, except when a definite phase difference is inherent in the apparatus, as in induction motors, induction generators, frequency converters, etc.
- 100** *c. WAVE SHAPE.* In electrical apparatus, the sine wave should be considered as standard, except where a difference in the wave form from the sinusoidal is inherent in the operation of the apparatus. See Secs. 79-83.

(III) MEASUREMENT OF LOSSES.

- 101** **LOSSES.** The usual sources of losses in electrical apparatus and the methods of determining these losses are as follows:
- 102** *(A) BEARING FRICTION AND WINDAGE.*
The magnitude of bearing friction and windage (which may be considered as independent of the load) is conveniently measured by driving

the machine from an independent motor, the output of which may be suitably determined. See Sec. 94.

(B) COMMUTATOR BRUSH FRICTION.

- 103 The magnitude of the commutator brush friction (which may be considered as independent of the load) is determined by measuring the difference in power required for driving the machine with brushes on and with brushes off (the field being unexcited).

(C) COLLECTOR-RING BRUSH FRICTION.

- 104 Collector-ring brush friction may be determined in the same manner as commutator brush friction. It is usually negligible.

(D) MOLECULAR MAGNETIC FRICTION AND EDDY CURRENTS.

- 105 These losses include those due to molecular magnetic friction and eddy currents in iron and copper and other metallic parts, also the losses due to currents in the cross-connections of cross-connected armatures.

- 106 In MACHINES these losses should be determined on open circuit and at a voltage equal to the rated voltage $+Ir$ in a generator, and $-Ir$ in a motor, where I denotes the current strength and r denotes the internal resistance of the machine. They should be measured at the correct speed and voltage, since they do not usually vary in any definite proportion to the speed or to the voltage.

- 107 NOTE. The TOTAL LOSSES in bearing friction and windage, brush friction, magnetic friction and eddy currents can, in general, be determined by a single measurement by driving the machine with the field excited, either as a motor, or by means of an independent motor.

- 108 RETARDATION METHOD. The no-load iron, friction, and windage losses may be segregated by the Retardation Method, in which the generator should be brought up to full speed (or, if possible, to about 10 per cent. above full speed) as a motor, and, after cutting off the driving power and excitation, frequent readings should be taken of speed and time, as the machine slows down, from which a speed-time curve can be plotted. A second curve should be taken in the same manner, but with full field excitation; from the second curve the iron losses may be found by subtracting the losses found in the first curve.

- 109 The speed-time curves can be plotted automatically by belting a small separately excited generator (say 1/10 kw.) to the generator shaft and connecting it to a recording voltmeter. When the retardation method is not feasible, the frictional losses in bearings and in windage, which ought, by definition, to be included in determining the efficiency, may be excluded; but this should be expressly stated.

(E) ARMATURE-RESISTANCE LOSS.

- 110 This loss may be expressed by pI^2r , where r = resistance of one armature circuit or branch, I = the current in such armature circuit or branch, and p = the number of armature circuits or branches.

(F) COMMUTATOR BRUSH AND BRUSH-CONTACT RESISTANCE LOSS.

- 111 It is desirable to point out that with carbon brushes these losses may be considerable in low-voltage machines.

(G) COLLECTOR-RING AND BRUSH-CONTACT RESISTANCE LOSS.

- 112 This loss is usually negligible, except in machines of extremely low voltage or in unipolar machines.

(H) FIELD EXCITATION LOSS.

- 113 With separately excited fields, the loss of power in the resistance of the field coils alone should be considered. With either shunt- or series-field windings, however, the loss of power in the accompanying rheostat should also be included, the said rheostat being considered as an essential part of the machine, and not as separate auxiliary apparatus.

- 114 (I) LOAD LOSSES.

The load losses may be considered as the difference between the total losses under load and the sum of the losses above specified.

- 115** *a.* In COMMUTATING MACHINES of small field distortion, the load losses are usually trivial and may, therefore, be neglected. When, however, the field distortion is large, as is shown, for instance, by the necessity for shifting the brushes between no load and full load, or with variations of load, these load losses may be considerable, and should be taken into account. In this case the efficiency may be determined either by input and output measurements, or the load losses may be estimated by the method of Sec. 116.
- 116** *b.* ESTIMATION OF LOAD LOSSES. While the load losses cannot well be determined individually, they may be considerable and, therefore, their joint influence should be determined by observation. This can be done by operating the machine on short-circuit and at full-load current, that is, by determining what may be called the "short-circuit core loss." With the low field intensity and great lag of current existing in this case, the load losses are usually greatly exaggerated.
- 117** One-third of the short-circuit core loss may, as an approximation, and in the absence of more accurate information, be assumed as the load loss.

(IV) EFFICIENCY OF DIFFERENT TYPES OF APPARATUS.

(A) DIRECT-CURRENT COMMUTATING MACHINES.

- 118** In DIRECT-CURRENT COMMUTATING MACHINES the losses are:
- 119** *a.* BEARING FRICTION AND WINDAGE. See Measurement of Losses (A), Sec. 102.
- 120** *b.* MOLECULAR MAGNETIC FRICTION AND EDDY CURRENTS. See Measurement of Losses (D), Sec. 105.
- 121** *c.* ARMATURE RESISTANCE LOSSES. See Measurement of Losses (E), Sec. 110.
- 122** *d.* COMMUTATOR BRUSH FRICTION. See Measurement of Losses (B), Sec. 103.
- 123** *e.* COMMUTATOR BRUSH AND BRUSH CONTACT RESISTANCE. See Measurement of Losses (F), Sec. 111.
- 124** *f.* FIELD EXCITATION LOSS. See Measurement of Losses (H), Sec. 113.
- 125** *g.* LOAD LOSSES. See Measurement of Losses (I), Sec. 114.
- 126** NOTE. *b* and *c* are losses in the armature or "armature losses"; *d* and *e* "commutator losses"; *f* "field losses."

(B) ALTERNATING-CURRENT COMMUTATING MACHINES.

- 127** In ALTERNATING-CURRENT COMMUTATING MACHINES, the losses are:
- 128** *a.* BEARING FRICTION AND WINDAGE. See Measurement of Losses (A), Sec. 102.
- 129** *b.* ROTATION LOSS, measured with the machine at open circuit, the brushes on the commutator, and the field excited by alternating current when driving the machine by a motor.
- 130** This loss includes molecular magnetic friction, and eddy currents, caused by rotation through the magnetic field, I^2r losses in cross-connections of cross-connected armatures, I^2r and other losses in armature-coils and armature-leads which are short-circuited by the brushes as far as these losses are due to rotation.
- 131** *c.* ALTERNATING or TRANSFORMER LOSS. These losses are measured by wattmeter in the field circuit, under the conditions of test *b*. They include molecular magnetic friction and eddy-currents due to the alternation of the magnetic field, I^2r losses in cross-connections of cross-connected armatures, I^2r and other losses in armature coil and commutator leads which are short-circuited by the brushes, as far as these losses are due to the alternation of the magnetic flux.
- 132** The losses in armature-coils and commutator leads short-circuited by the brushes, can be separated in *b*, and *c*, from the other losses, by running the machine with and without brushes on the commutator.
- 133** *d.* I^2r LOSS, OTHER LOAD LOSSES in armature and compensating winding and I^2r loss of brushes, measured by wattmeter connected across the armature and compensating winding.
- 134** *e.* FIELD EXCITATION LOSS. See Measurement of Losses (H), Sec. 113.
- 135** *f.* COMMUTATOR BRUSH-FRICTION. See Measurement of Losses (B), Sec. 103.

(C) SYNCHRONOUS COMMUTATING MACHINES.

- 136** 1. In DOUBLE-CURRENT GENERATORS, the efficiency of the machine should be determined as a direct-current generator, and also as an alternating-current generator. The two values of efficiency may be different, and should be clearly distinguished.
- 137** 2. In CONVERTERS the losses should be determined when driving the machine by a motor. These losses are:
- 138** a. BEARING FRICTION AND WINDAGE. See Measurement of Losses (A), Sec. 102.
- 139** b. MOLECULAR MAGNETIC FRICTION AND EDDY CURRENTS. See Measurement of losses (D) Sec. 105.
- 140** c. ARMATURE RESISTANCE LOSS. This loss in the armature is $q I^2 r$, where I = direct current in armature, r = armature resistance and q , a factor which is equal to 1.47 in single-circuit single-phase, 1.15 in double-circuit single-phase, 0.59 in three-phase, 0.39 in two-phase, and 0.27 in six-phase converters.
- 141** d. COMMUTATOR-BRUSH FRICTION. See Measurement of Losses (B), Sec. 103.
- 142** e. COLLECTOR-RING BRUSH FRICTION. See Measurement of Losses (C), Sec. 104.
- 143** f. COMMUTATOR-BRUSH AND BRUSH-CONTACT RESISTANCE LOSS. See Measurement of Losses (F), Sec. 111.
- 144** g. COLLECTOR-RING BRUSH-CONTACT RESISTANCE LOSS. See Measurement of Losses (G), Sec. 112.
- 145** h. FIELD EXCITATION LOSS. See Measurement of Losses (H), Sec. 109.
- 146** i. LOAD LOSSES. These can generally be neglected, owing to the absence of field distortion.
- 147** 3. THE EFFICIENCY OF TWO SIMILAR CONVERTERS may be determined by operating one machine as a converter from direct to alternating, and the other as a converter from alternating to direct, connecting the alternating sides together, and measuring the difference between the direct-current input, and the direct-current output. This process may be modified by returning the output of the second machine through two boosters into the first machine and measuring the losses. Another modification is to supply the losses by an alternator between the two machines, using potential regulators.

(D) SYNCHRONOUS MACHINES.

- 148** In SYNCHRONOUS MACHINES the losses are:
- 149** a. BEARING FRICTION AND WINDAGE. See Measurement of Losses (A), Sec. 102.
- 150** b. MOLECULAR MAGNETIC FRICTION AND EDDY CURRENTS. See Measurement of Losses (D), Sec. 105.
- 151** c. ARMATURE RESISTANCE LOSS. See Measurement of Losses (E) Sec. 110.
- 152** d. COLLECTOR-RING BRUSH FRICTION. See Measurement of Losses (C), Sec. 104.
- 153** e. COLLECTOR-RING BRUSH CONTACT RESISTANCE LOSS. See Measurement of Losses (G), Sec. 112.
- 154** f. FIELD EXCITATION LOSS. See Measurement of Losses (H), Sec. 113.
- 155** g. LOAD LOSSES. See Measurement of Losses (I), Sec. 114.

(E) STATIONARY INDUCTION APPARATUS.

- 156** In STATIONARY INDUCTION APPARATUS, the losses are:
- 157** a. MOLECULAR MAGNETIC FRICTION AND EDDY CURRENTS measured at open secondary circuit, rated frequency, and at rated voltage — $I r$, where I = rated current, r = resistance of primary circuit.
- 158** b. RESISTANCE LOSSES, the sum of the $I^2 r$ losses in the primary and in the secondary windings of a transformer, or in the two sections of the coil in a compensator or auto-transformer, where I = rated current in the coil or section of coil, and r = resistance.
- 159** c. LOAD LOSSES, *i.e.*, eddy currents in the iron and especially in the copper conductors, caused by the current at rated load. For practical

purposes they may be determined by short-circuiting the secondary of the transformer and impressing upon the primary a voltage sufficient to send rated load current through the transformer. The loss in the transformer under these conditions measured by wattmeter gives the load losses + $I^2 r$ losses in both primary and secondary coils.

- 160 In CLOSED MAGNETIC CIRCUIT TRANSFORMERS, either of the two circuits may be used as primary when determining the efficiency.

- 161 In POTENTIAL REGULATORS, the efficiency should be taken at the maximum voltage for which the apparatus is designed, and with non-inductive load, unless otherwise specified.

(F) ROTARY INDUCTION APPARATUS, OR INDUCTION MACHINES.

- 162 In ROTARY INDUCTION APPARATUS, the losses are:

- 163 a. BEARING FRICTION AND WINDAGE. See Measurement of Losses (A), Sec. 102.

- 164 b. MOLECULAR MAGNETIC FRICTION AND EDDY CURRENTS in iron, copper and other metallic parts; also $I^2 r$ losses which may exist in multiple-circuit windings. *a* and *b* together are determined by running the motor without load at rated voltage, and measuring the power input.

- 165 c. PRIMARY $I^2 R$ LOSS, which may be determined by measurement of the current and the resistance.

- 166 d. SECONDARY $I^2 R$ LOSS, which may be determined as in the primary, when feasible; otherwise, as in squirrel-cage secondaries, this loss is measured as part of *e*.

- 167 e. LOAD LOSSES; *i.e.*, molecular magnetic friction, and eddy currents in iron, copper, etc., caused by the stray field of primary and secondary currents, and secondary $I^2 R$ loss when undeterminable under (*d*). These losses may for practical purposes be determined by measuring the total power, with the rotor short-circuited at standstill and a current in the primary circuit equal to the primary energy current at full load. The loss in the motor under these conditions may be assumed to be equal to the load losses + $I^2 r$ losses in both primary and secondary coils.

(G) UNIPOLAR OR ACYCLIC MACHINES.

- 168 In UNIPOLAR MACHINES, the losses are:

- 169 (a) BEARING FRICTION AND WINDAGE. See Measurement of Losses (A), Sec. 102.

- 170 (b) MOLECULAR MAGNETIC FRICTION AND EDDY CURRENTS. See Measurement of Losses (E), Sec. 106.

- 171 (c) ARMATURE RESISTANCE LOSSES. See Measurement of Losses (E), Sec. 110.

- 172 (d) COLLECTOR BRUSH FRICTION. See Measurement of Losses (C), Sec. 104.

- 173 (e) COLLECTOR BRUSH CONTACT RESISTANCE. See Measurement of Losses (G), Sec. 112.

- 174 (f) FIELD-EXCITATION as in Sec. 113. See Measurement of Losses (H), Sec. 113.

- 175 (g) LOAD LOSSES. See Measurement of Losses (I), Sec. 114.

(H) RECTIFYING APPARATUS, PULSATING-CURRENT GENERATORS.

- 176 THIS DIVISION INCLUDES: open-coil arc machines and mechanical and other rectifiers.

- 177 In RECTIFIERS the most satisfactory method of determining the efficiency is to measure both electric input and electric output by wattmeter. The input is usually inductive, owing to phase displacement and to wave distortion. For this reason the power factor and the apparent efficiency should also be considered, since the latter may be much lower than the true efficiency. The power consumed by auxiliary devices, such as the synchronous motor or cooling devices, should be included in the electric input.

- 178 In CONSTANT-CURRENT RECTIFIERS, transforming from constant potential alternating to constant direct current, by means of constant-current transforming devices and rectifying devices, the losses in the transforming devices are to be included in determining the efficiency and have to be

measured when operating the rectifier, since in this case the losses may be greater than when feeding an alternating secondary circuit. In constant-current transforming devices, the load losses may be considerable, and, therefore, should not be neglected.

- 179** In OPEN COIL ARC MACHINES, the losses are essentially the same as in direct-current (closed coil) commutating machines. In this case, however, the load losses are usually greater, and the efficiency should preferably be measured by input- and output-test, using wattmeters for measuring the output. In alternating-current rectifiers, the output should, in general, be measured by wattmeter and not by voltmeter and ammeter, since owing to pulsation of current and voltage, a considerable discrepancy may exist between watts and volt-amperes. If, however, a direct-current and an alternating-current meter in the rectified circuit (either a voltmeter or an ammeter) give the same reading, the output may be measured by direct-current voltmeter and ammeter. The type of alternating-current instrument here referred to should indicate the effective or root-of-mean-square value and the type of direct-current instrument the arithmetical mean value, which would be zero on an alternating-current circuit.

(I) TRANSMISSION LINES.

- 180** The EFFICIENCY of transmission lines should be measured with non-inductive load at the receiving end, with the rated receiving voltage and frequency, also with sinusoidal impressed wave form, except where expressly specified otherwise, and with the exclusion of transformers or other apparatus at the ends of the line.

(J) PHASE-DISPLACING APPARATUS.

- 181** In APPARATUS PRODUCING PHASE DISPLACEMENT as, for example, synchronous compensators, exciters of induction generators, reactors, condensers, polarization cells, etc., the efficiency should be understood to be the ratio of the volt-amperes minus power loss to the volt-amperes.
- 182** The EFFICIENCY may be calculated by determining the losses, subtracting them from the volt-amperes, and then dividing the difference by the volt-amperes.
- 183** In SYNCHRONOUS COMPENSATORS and exciters of induction generators, the determination of losses is the same as in other synchronous machines.
- 184** In REACTORS the losses are molecular magnetic friction, eddy losses and $I^2 r$ loss. They should be measured by wattmeter. The efficiency of reactors should be determined with a sine wave of impressed voltage except where expressly specified otherwise.
- 185** In CONDENSERS, the losses are due to dielectric hysteresis and leakage, and should be determined by wattmeter with a sine wave of voltage.
- 186** In POLARIZATION CELLS, the losses are those due to electric resistivity and a loss in the electrolyte of the nature of chemical hysteresis. These losses may be considerable. They depend upon the frequency, voltage and temperature, and should be determined with a sine wave of impressed voltage, except where expressly specified otherwise.

D. REGULATION.

(I) DEFINITIONS.

- 187** DEFINITION. The regulation of a machine or apparatus in regard to some characteristic quantity (such as terminal voltage, current or speed) is the ratio of the deviation of that quantity from its normal value at rated load to the normal rated load value. The term "regulation," therefore, has the same meaning as the term "inherent regulation," occasionally used.
- 188** CONSTANT STANDARD. If the characteristic quantity is intended to remain constant (e.g., constant voltage, constant speed, etc.) between rated load and no load, the regulation is the ratio of the maximum variation from the rated load value to the no-load value.
- 189** VARYING STANDARD. If the characteristic quantity is intended to vary in a definite manner between rated load and no load, the regulation is the ratio of the maximum variation from the specified condition to the normal rated-load value.

- 190** (a) NOTE. If the law of the variation (in voltage, current, speed, etc.) between rated load and no load is not specified, it should be assumed to be a simple linear relation; *i.e.*, one undergoing uniform variation between rated load and no load.
- 191** (b) NOTE. The regulation of an apparatus may, therefore, differ according to its qualification for use. Thus, the regulation of a compound-wound generator specified as a constant-potential generator, will be different from that which it possesses when specified as an over-compounded generator.
- 192** In CONSTANT-POTENTIAL MACHINES, the regulation is the ratio of the maximum difference of terminal voltage from the rated-load value (occurring within the range from rated load to open circuit) to the rated load terminal voltage.
- 193** In CONSTANT-CURRENT MACHINES, the regulation is the ratio of the maximum difference of current from the rated load value (occurring within the range from rated-load to short-circuit, or minimum limit of operation), to the rated-load current.
- 194** In CONSTANT-POWER APPARATUS, the regulation is the ratio of maximum difference of power from the rated load value (occurring within the range of operation specified) to the rated power.
- 195** In CONSTANT-SPEED DIRECT-CURRENT MOTORS and INDUCTION MOTORS the regulation is the ratio of the maximum variation of speed from its rated load value (occurring within the range from rated load to no-load) to the rated load speed.
- 196** The regulation of an induction motor is, therefore, not identical with the slip of the motor, which is the ratio of the drop in speed from synchronism, to the synchronous speed.
- 197** In CONSTANT-POTENTIAL TRANSFORMERS, the regulation is the ratio of the rise of secondary terminal voltage from rated non-inductive load to no-load (at constant primary impressed terminal voltage) to the secondary terminal voltage at rated load.
- 198** In OVER-COMPOUNDED MACHINES, the regulation is the ratio of the maximum difference in voltage from a straight line connecting the no-load and rated-load values of terminal voltage as function of the load current, to the rated-load terminal voltage.
- 199** In CONVERTERS, DYNAMOTORS, MOTOR-GENERATORS AND FREQUENCY CONVERTERS, the regulation is the ratio of the maximum difference of terminal voltage at the output side from the rated-load voltage, to the rated-load voltage on the output side.
- 200** In TRANSMISSION LINES, FEEDERS, ETC., the regulation is the ratio of the maximum voltage difference at the receiving end, between rated non-inductive load and no load to the rated-load voltage at the receiving end (with constant voltage impressed upon the sending end).
- 201** In STEAM ENGINES, the regulation is the ratio of the maximum variation of speed in passing slowly from rated-load to no-load (with constant steam pressure at the throttle) to the rated-load speed. For variation and pulsation see Secs. 59-64.
- 202** In a HYDRAULIC TURBINE or OTHER WATER-MOTOR, the regulation is the ratio of the maximum variation of speed in passing slowly from rated-load to no-load (at constant head of water; *i.e.*, at constant difference of level between tail race and head race), to the rated-load speed. For variation and pulsation see Secs. 59-64.
- 203** In a GENERATOR-UNIT, consisting of a generator united with a prime-mover, the regulation should be determined at constant conditions of the prime-mover; *i.e.*, constant steam pressure, head, etc. It includes the inherent speed variations of the prime-mover. For this reason the regulation of a generator-unit is to be distinguished from the regulation of either the prime-mover, or of the generator contained in it, when taken separately.

(II) CONDITIONS FOR AND TESTS OF REGULATION.

- 204** SPEED. The REGULATION OF GENERATORS is to be determined at constant speed, and of alternating apparatus at constant impressed frequency.
- 205** NON-INDUCTIVE LOAD. In apparatus generating, transforming or trans-

mitting alternating currents, regulation should be understood to refer to non-inductive load, that is, to a load in which the current is in phase with the e.m.f. at the output side of the apparatus, except where expressly specified otherwise.

206 **WAVE FORM.** In alternating apparatus receiving electric power, regulation should refer to a sine wave of e.m.f., except where expressly specified otherwise.

207 **EXCITATION.** In commutating machines, rectifying machines, and synchronous machines, such as direct-current generators and motors, alternating-current and polyphase generators, the regulation is to be determined under the following conditions:

(1) At constant excitation in separately excited fields.

(2) With constant resistance in shunt-field circuits, and

(3) With constant resistance shunting series-field circuits; *i.e.*, the field adjustment should remain constant, and should be so chosen as to give the required full-load voltage at full-load current.

208 **IMPEDANCE RATIO.** In alternating-current apparatus, in addition to the non-inductive regulation, the impedance ratio of the apparatus should be specified; *i.e.*, the ratio of the voltage consumed by the total internal impedance of the apparatus at full-load current, to its rated full-load voltage. As far as possible, a sinusoidal current should be used.

209 **COMPUTATION OF REGULATION.** When in synchronous machines the regulation is computed from the terminal voltage and impedance voltage, the exciting ampere-turns corresponding to terminal voltage plus armature-resistance-drop, and the ampere-turns at short-circuit corresponding to the armature-impedance-drop, should be combined vectorially to obtain the resultant ampere-turns, and the corresponding internal e.m.f. should be taken from the saturation curve.

E. INSULATION.

(I) *INSULATION RESISTANCE.*

210 **INSULATION RESISTANCE** is the ohmic resistance offered by an insulating coating, cover, material or support to an impressed voltage, tending to produce a leakage of current through the same.

211 **OHMIC RESISTANCE AND DIELECTRIC STRENGTH.** The ohmic resistance of the insulation is of secondary importance only, as compared with the dielectric strength, or resistance to rupture by high voltage. Since the ohmic resistance of the insulation can be very greatly increased by baking, but the dielectric strength is liable to be weakened thereby, it is preferable to specify a high dielectric strength rather than a high insulation resistance. The high-voltage test for dielectric strength should always be applied.

212 **RECOMMENDED VALUE OF RESISTANCE.** The insulation resistance of complete apparatus should be such that the rated voltage of the apparatus

will not send more than $\frac{1}{1,000,000}$ of the rated-load current, at the rated

terminal voltage, through the insulation. Where the value found in this way exceeds 1 megohm, it is usually sufficient.

213 **INSULATION RESISTANCE TESTS** should, if possible, be made at the pressure for which the apparatus is designed.

(II) *DIELECTRIC STRENGTH.*

(A) *TEST VOLTAGES.*

214 **DEFINITION.** The dielectric strength of an insulating wall, coating, cover or path is measured by the voltage which must be applied to it in order to effect a disruptive discharge through the same.

215 **BASIS FOR DETERMINING TEST VOLTAGES.** The test voltage which should be applied to determine the suitability of insulation for commercial operation is dependent upon the kind and size of the apparatus and its normal operating voltage, upon the nature of the service in which it is to be used, and the severity of the mechanical and electrical stresses to

- 225** (b) **CONSTANT-CURRENT APPARATUS.** The testing voltage is to be based upon a rated terminal voltage equal to the maximum voltage which may exist at open or closed circuit.
- 226** (c) **APPARATUS IN SERIES.** For tests of machines or apparatus to be operated in series, so as to employ the sum of their separate voltages the testing voltage is to be based upon a rated terminal voltage equal to the sum of the separate voltages except where the frames of the machines are separately insulated, both from the ground and from each other, in which case the test for insulation between machines should be based upon the voltage of one machine, and the test between each machine and ground to be based upon the total voltage of the series.
- (B) **METHODS OF TESTING.**
- 227** **CLASSES OF TESTS.** Tests for dielectric strength cover such a wide range in voltage that the apparatus, methods and precautions which are essential in certain cases do not apply to others. For convenience, the tests will be separated into two classes:
- 228** **CLASS 1.** This class includes all apparatus for which the test voltage does not exceed 10 kilovolts, unless the apparatus is of very large static capacity, *e.g.*, a large cable system. This class also includes all apparatus of small static capacity, such as line insulators, switches and the like, for all test voltages.
- 229** **METHOD OF TEST FOR CLASS 1.** The test voltage is to be continuously applied for the prescribed interval,—(one minute unless otherwise specified). The test voltage may be taken from a constant-potential source and applied directly to the apparatus to be tested, or it may be raised gradually as specified for tests under Class 2.
- 230** **CLASS 2.** This class includes all apparatus not included in Class 1.
- 231** **METHOD OF TEST FOR CLASS 2.** The test voltage is to be raised to the required value smoothly and without sudden large increments and is then to be continuously applied for the prescribed interval,—(one minute, unless otherwise specified), and then gradually decreased.
- 232** **CONDITIONS AND PRECAUTIONS FOR CLASS 1 and CLASS 2.** The following apply to all tests:
- 233** The **WAVE SHAPE** should be approximately sinusoidal and the apparatus in the testing circuits should not materially distort this wave.
- 234** The **SUPPLY CIRCUIT** should have ample current-supply capacity so that the charging current which may be taken by the apparatus under test will not materially alter the wave form nor materially affect the test voltage. The circuit should be free from accidental interruptions.
- 235** **RESISTANCE OR INDUCTANCE** in series with the primary of a raising transformer for the purpose of controlling its voltage is liable seriously to affect the wave form, thereby causing the maximum value of the voltage to bear a different and unknown ratio to the root mean square value. This method of voltage adjustment is, therefore, in general, undesirable. It may be noted that if a resistance or inductance is employed to limit the current when burning out a fault, such resistance or inductance should be short circuited during the regular voltage test.
- 236** The **INSULATION** under test should be in normal condition as to dryness and the temperature should when possible be that reached in normal service.
- 237** **ADDITIONAL CONDITIONS AND PRECAUTIONS FOR CLASS 2.** The following conditions and precautions, in addition to the foregoing, apply to tests of apparatus included in Class 2.
- 238** **SUDDEN INCREMENT OF TESTING VOLTAGE** on the apparatus under test should be avoided, particularly at high voltages and with apparatus having considerable capacity, as a momentarily excessive rise in testing voltage will result.
- 239** **SUDDEN VARIATIONS IN TESTING VOLTAGE** of the circuit supplying the voltage during the test should be avoided as they are likely to set up injurious oscillation.
- 240** **GOOD CONNECTIONS** in the circuits supplying the test voltage are essential in order to prevent injurious high frequency disturbances from being set up. When a heavy current is carried by a small water rheostat,

arcing may occur, causing high-frequency disturbances which should be carefully avoided.

- 241** **TRANSFORMER COILS.** In high-tension transformers, the low-tension coil should preferably be connected to the core and to the ground when the high-tension test is being made, in order to avoid the stress from low-tension to core, which would otherwise result through condenser action. The various terminals of each winding of the high-tension transformer under test should be connected together during the test in order to prevent undue stress on the insulation between turns or sections of the winding in case the high-voltage test causes a break-down.

(C) **METHODS FOR MEASURING THE TEST VOLTAGE.**

- 242** **FOR MEASURING THE TEST VOLTAGE**, two instruments are in common use, (1) the spark gap and (2) the voltmeter.

- 243** 1. **THE SPARK GAP** is ordinarily adjusted so that it will break down with a certain predetermined voltage, and is connected in parallel with the insulation under test. It ensures that the voltage applied to the insulation is not greater than the break-down voltage of the spark gap. A given setting of the spark gap is a measure of one definite voltage, and, as its operation depends upon the maximum value of the voltage wave, it is independent of wave form and is a limit on the maximum stress to which the insulation is subjected. The spark gap is not conveniently adapted for comparatively low voltages.

- 244** In **SPARK-GAP MEASUREMENTS**, the spark gap may be set for the required voltage and the auxiliary apparatus adjusted to give a voltage at which this spark gap just breaks down. The spark gap should then be adjusted for, say, 10 per cent. higher voltage, and the auxiliary apparatus again adjusted to give the voltage of the former breakdown, which is to be the assumed voltage for the test. This voltage is to be maintained for the required interval.

- 245** **THE SPARK POINTS** should consist of new sewing needles, supported axially at the ends of linear conductors which are each at least twice the length of the gap. There should be no extraneous body near the gap within a radius of twice its length. A table of approximate striking distances is given in Appendix D. This table should be used in connection with tests made by the spark-gap methods.

- 246** A **NON-INDUCTIVE RESISTANCE** of about one-half ohm per volt should be inserted in series with each terminal of the gap so as to keep the discharge current between the limits of one-quarter ampere and 2 amperes. The purpose of the resistance is to limit the current in order to prevent the surges which might otherwise occur at the time of break-down.

- 247** 2. **THE VOLTMETER** gives a direct reading, and the different values of the voltage can be read during the application and duration of the test. It is suitable for all voltages, and does not introduce disturbances into the test circuit.

- 248** In **VOLTMETER MEASUREMENTS**, the voltmeter should, in general, derive its voltage from the high-tension testing circuit either directly or through an auxiliary ratio transformer. It is permissible, however, to measure the voltage at other places,—for example, on the primary of the transformer, provided the ratio of transformation does not materially vary during the test; or that proper account is taken thereof.

- 249** **SPARK GAP AND VOLTMETER.** The spark gap may be employed as a check upon the voltmeter used in high-tension tests in order to determine the transformation ratio of the transformer, the variation from the sine wave form and the like. It is also useful in conjunction with voltmeter measurements to limit the stress applied to the insulating material.

(D) **APPARATUS FOR SUPPLYING TEST VOLTAGE.**

- 250** **THE GENERATOR OR CIRCUIT** supplying voltage for the test should have ample current carrying capacity, so that the current which may be taken for charging the apparatus to be tested will not materially alter the wave form nor otherwise materially change the voltage.

THE TESTING TRANSFORMER should be such that its ratio of transformation does not vary more than 10 per cent. when delivering the charg-

ing current required by the apparatus under test. (This may be determined by short-circuiting the secondary or high voltage winding testing transformer and supplying 1/10 of the primary voltage to the primary under this condition. The primary current that flows under this condition is the maximum which should be permitted in regular dielectric tests.)

251 The VOLTAGE CONTROL may be secured in either of several ways, which, in order of preference, are as follows:

252 1. By generator field circuit.

253 2. By magnetic commutation.

254 3. By change in transformer ratio.

255 4. By resistance or choke coils.

256 In GENERATOR VOLTAGE CONTROL, the voltage of the generator should preferably be about its approximate normal rated-load value when the full testing voltage is attained, which requires that the ratio of the raising transformer be such that the full testing voltage is reached when the generator voltage is normal. This avoids the instability in the generator which may occur if a considerable leading current is taken from it when it has low voltage and low field current.

257 In MAGNETIC COMMUTATION, the control is effected by shunting the magnetic flux through a secondary coil so as to vary the induction through the coil and the voltage induced in it. The shunting should be effected smoothly, thus avoiding sudden changes in the induced voltage.

258 In TRANSFORMER VOLTAGE CONTROL, by change of ratio, it is necessary that the transition from one step to another be made without interruption of the test voltage, and by steps sufficiently small to prevent surges in the testing circuit. The necessity of this precaution is greater as the inductance or the static capacity of the apparatus in the testing circuit under test is greater.

259 When RESISTANCE COILS OR REACTORS are used for voltage control, it is desirable that the testing voltage should be secured when the controlling resistance or reactance is very nearly or entirely out of circuit in order that the disturbing effect upon the wave form which results may be negligible at the highest voltage.

F. CONDUCTIVITY.

260 COPPER. The conductivity of copper in electric wires and cables should not be less than 98% of Matthiessen's standard of conductivity, as defined in the Copper Wire Table of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

G. RISE OF TEMPERATURE.

(I) MEASUREMENT OF TEMPERATURE.

(A) METHODS.

261 There are two methods in common use for determining the rise in temperature, viz.: (1) by thermometer, and (2) by increase in resistance of an electric circuit.

262 1. By THERMOMETER. The following precautions should be observed in the use of thermometers:

263 a. PROTECTION. The thermometers indicating the room temperature should be protected from thermal radiation emitted by heated bodies, or from draughts of air or from temporary fluctuations of temperature. Several room thermometers should be used. In using the thermometer by applying it to a heated part, care should be taken so to protect its bulb as to prevent radiation from it, and, at the same time, not to interfere seriously with the normal radiation from the part to which it is applied.

264 b. BULB. When a thermometer is applied to the free surface of a machine, it is desirable that the bulb of the thermometer should be covered by a pad of definite area. A convenient pad may be formed of cotton waste in a shallow circular box about one and a half inches in diameter, through a slot in the side in which the thermometer bulb is inserted. An unduly large pad over the thermometer tends to interfere with the natural liberation of heat from the surface to which the thermometer is applied.

- 265** 2. By INCREASE IN RESISTANCE. The resistance may be measured either by Wheatstone bridge, or by drop-of potential method. A temperature coefficient of 0.42 per cent. per degree C., from and at 0° C., may be assumed for copper.

The temperature-coefficients from and at each degree cent. between 0° C. and 50° C. are given in Appendix E. The temperature rise may be determined either (1) by dividing the percentage increase of initial resistance by the temperature-coefficient for the initial temperature expressed in per cent.; or (2) by multiplying the increase in per cent. of the initial resistance by 238.1 plus the initial temperature in degrees C., and then dividing the product by 100.

- 266** 3. COMPARISON OF METHODS. In electrical conductors, the rise of temperature should be determined by their increase of resistance where practicable. Temperature elevations measured in this way are usually in excess of temperature elevations measured by thermometers. In very low resistance circuits, thermometer measurements are frequently more reliable than measurements by the resistance method. Where a thermometer applied to a coil or winding, indicates a higher temperature elevation than that shown by resistance measurement, the thermometer indication should be accepted.

(B) NORMAL CONDITIONS FOR TESTS.

- 267** 1. DURATION OF TESTS. The temperature should be measured after a run of sufficient duration for the apparatus to reach a practically constant temperature. This is usually from 6 to 18 hours, according to the size and construction of the apparatus. It is permissible, however, to shorten the time of the test by running a lesser time on an overload in current and voltage, then reducing the load to normal, and maintaining it thus until the temperature has become constant.

- 268** 2. ROOM TEMPERATURE. The rise of temperature should be referred to the standard condition of a room temperature of 25° C.

- 269** TEMPERATURE CORRECTION. If the room temperature during the test differs from 25° C., correction on account of difference in resistance should be made by changing the observed rise of temperature by one-half per cent. for each degree C. Thus with a room temperature of 35° C., the observed rise of temperature has to be decreased by 5 per cent., and with a room temperature of 15° C., the observed rise of temperature has to be increased by 5 per cent. In certain cases, such as shunt-field circuits without rheostat, the current strength will be changed by a change of room temperature. The heat-production and dissipation may be thereby affected. Correction for this should be made by changing the observed rise in temperature in proportion as the $I^2 R$ loss in the resistance of the apparatus is altered owing to the difference in room temperature.

- 270** 3. BAROMETRIC PRESSURE. VENTILATION. A barometric pressure of 760 mm. and normal conditions of ventilation should be considered as standard, and the apparatus under test should neither be exposed to draught nor enclosed, except where expressly specified. The barometric pressure needs to be considered only when differing greatly from 760 mm.

- 271** BAROMETRIC PRESSURE CORRECTION. When the barometric pressure differs greatly from the standard pressure of 760 mm. of mercury, as at high altitudes, a correction should be applied. In the absence of more accurate data, a correction of 1% of the observed rise in temperature for each 10 mm. deviation from the 760 m.m. standard is recommended. For example at a barometric pressure of 680 mm. the observed rise of temperature is to be reduced by

$$\frac{760-680}{10} = 8\%.$$

(II) LIMITING TEMPERATURE RISE.

- 272** GENERAL. The temperature of electrical machinery under regular service conditions, should never be allowed to remain at a point at which permanent deterioration of its insulating material takes place.

- 273** LIMITS RECOMMENDED. It is recommended that the following maximum

values of temperature elevation, referred to a standard room temperature of 25 degrees centigrade, at rated load under normal conditions of ventilation or cooling, should not be exceeded.

(A) MACHINES IN GENERAL.

- 274 In commutating machines, rectifying machines, pulsating-current generators, synchronous machines, synchronous commutating machines and unipolar machines, the temperature rise in the parts specified should not exceed the following:

275 Field and armature, 50° C.

276 Commutator and brushes, by thermometer, 55° C.

277 Collector rings, 65° C.

278 Bearings and other parts of machine, by thermometer, 40° C.

- 279 (B) ROTARY INDUCTION APPARATUS. The temperature rise should not exceed the following:

280 Electric circuits, 50° C., by resistance.

281 Bearings and other parts of the machine 40° C., by thermometer.

282 In squirrel-cage or short-circuited armatures, 55° C., by thermometer, may be allowed.

(C) STATIONARY INDUCTION APPARATUS.

- 283 a. TRANSFORMERS FOR CONTINUOUS SERVICE. The temperature rise should not exceed 50 degrees centigrade in electric circuits, by resistance; and in other parts, by thermometer.

284 b. TRANSFORMERS FOR INTERMITTENT SERVICE. In the case of transformers intended for intermittent service, or not operating continuously at rated load, but continuously in circuit, as in the ordinary case of lighting transformers, the temperature elevation above the surrounding air-temperature should not exceed 50° C., by resistance in electric circuits and by thermometer in other parts, after the period corresponding to the term of rated load. In this instance, the test load should not be applied until the transformer has been in circuit for a sufficient time to attain the temperature elevation due to core loss. With transformers for commercial lighting, the duration of the rated-load test may be taken as three hours, unless otherwise specified.

- 285 c. REACTORS, induction- and magneto-regulators—electric circuits by resistance and other parts by thermometer, 50° C.

286 a. LARGE APPARATUS. Large generators, motors, transformers, or other apparatus in which reliability and reserve overload capacity are important, are frequently specified not to rise in temperature more than 40 degrees centigrade under rated load and 55 degrees centigrade at rated overload. It is, however, ordinarily undesirable to specify lower temperature elevations than 40 degrees centigrade at rated load, measured as above.

(D) RHEOSTATS.

- 287 In RHEOSTATS, HEATERS and other electrothermal apparatus, no combustible or inflammable part or material, or portion liable to come in contact with such material, should rise more than 50° C. above the surrounding air under the service conditions for which it is designed.

288 a. PARTS OF RHEOSTATS. Parts of rheostats and similar apparatus rising in temperature, under the specified service conditions, more than 50° C., should not contain any combustible material, and should be arranged or installed in such a manner that neither they, nor the hot air issuing from them, can come in contact with combustible material.

(E) LIMITS RECOMMENDED IN SPECIAL CASES.

- 289 a. HEAT RESISTING INSULATION. With apparatus in which the insulating materials have special heat-resisting qualities, a higher temperature elevation is permissible.

290 b. HIGH AIR TEMPERATURE. In apparatus intended for service in places of abnormally high temperature, a lower temperature elevation should be specified.

291 c. APPARATUS SUBJECT TO OVERLOAD. In apparatus which by the nature of its service may be exposed to overload, or is to be used in very high voltage circuits, a smaller rise of temperature is desirable than in apparatus not liable to overloads or in low-voltage apparatus. In apparatus built for conditions of limited space, as railway motors, a higher rise of temperature must be allowed.

- 292** *d. APPARATUS FOR INTERMITTENT SERVICE.* In the case of apparatus intended for intermittent service, except railway motors, the temperature elevation which is attained at the end of the period corresponding to the term of rated load, should not exceed the values specified for machines in general. In such apparatus the temperature elevation, including railway motors, should be measured after operation, under as nearly as possible the conditions of service for which the apparatus is intended, and the conditions of the test should be specified.

H. OVERLOAD CAPACITIES.

- 293** *PERFORMANCE WITH OVERLOAD.* All apparatus should be able to carry the overload hereinafter specified without serious injury by heating, sparking, mechanical weakness, etc., and with an additional temperature rise not exceeding 15° C., above those specified for rated loads, the overload being applied after the apparatus has acquired the temperature corresponding to rated load continuous operation. Rheostats to which no temperature rise limits are attached are naturally exempt from this additional temperature rise of 15° C. under overload specified in these rules.
- 294** *NORMAL CONDITIONS.* Overload guarantees should refer to normal conditions of operation regarding speed, frequency, voltage, etc., and to non-inductive conditions in alternating apparatus, except where a phase displacement is inherent in the apparatus.
- 295** *OVERLOAD CAPACITIES RECOMMENDED.* The following overload capacities are recommended:
- 296** *a. GENERATORS.* Direct-current generators and alternating-current generators, 25 per cent. for two hours.
- 297** *b. MOTORS.* Direct-current motors, induction motors and synchronous motors, not including railway and other motors intended for intermittent service, 25 per cent. for two hours, and 50 per cent. for one minute.
- 298** *c. CONVERTERS.* Synchronous converters, 25 per cent. for two hours, 50 per cent. for one-half hour.
- 299** *d. TRANSFORMERS AND RECTIFIERS.* Constant-potential transformers and rectifiers, 25 per cent. for two hours; except in transformers connected to apparatus for which a different overload is guaranteed, in which case the same guarantees shall apply for the transformers as for the apparatus connected thereto.
- 300** *e. EXCITERS.* Exciters of alternators and other synchronous machines, 10 per cent. more overload than is required for the excitation of the synchronous machine at its guaranteed overload, and for the same period of time. All exciters of alternating-current, single-phase or polyphase generators should be able to give at its rated speed, sufficient voltage and current to excite the alternator, at the rated speed, to the full-load terminal voltage, at the rated output in kilovolt-amperes and with 50 per cent. power factor.
- 301** *f. A CONTINUOUS-SERVICE RHEOSTAT,* such as an armature- or field-regulating rheostat, should be capable of carrying without injury for two hours, a current 25 per cent. greater than that at which it is rated. It should also be capable of carrying for one minute a current 50 per cent. greater than its rated load current, without injury. This excess of capacity is intended for testing purposes only, and this margin of capacity should not be relied upon in the selection of the rheostat.
- 302** *g. An INTERMITTENT SERVICE OR MOTOR-STARTING RHEOSTAT* is used for starting a motor from rest and accelerating it to rated speed. Under ordinary conditions of service, and unless expressly stated otherwise, a motor is assumed to start in fifteen seconds and with 150% of rated current strength. A motor-starter should be capable of starting the motor under these conditions once every four minutes for one hour.
- 303** *(a) This TEST* may be carried out either by starting the motor at four-minute intervals, or by placing the starter at normal temperature across the maximum voltage for which it is marked, and moving the lever uniformly and gradually from the first to the last position during a period of fifteen seconds, the current being maintained substantially constant at said 50% excess by introducing resistance in series or by other suitable means.

- 304** (b) OTHER RHEOSTATS FOR INTERMITTENT-SERVICE are employed under such special and varied conditions, that no general rules are applicable to them.

III. VOLTAGES AND FREQUENCIES.

A. VOLTAGES.

- 305** DIRECT-CURRENT GENERATORS. In direct-current, low-voltage generators, the following average terminal voltages are in general use and are recommended:

125 volts. 250 volts. 550 to 600 volts.

- 306** LOW-VOLTAGE CIRCUITS. In direct-current and alternating-current low-voltage circuits, the following average terminal voltages are in general use and are recommended:

110 volts. 220 volts.

- 307** PRIMARY DISTRIBUTION CIRCUITS. In alternating-current, constant-potential, primary-distribution circuits, an average voltage of 2,200 volts, with step-down transformer ratios 1/10 and 1/20, is in general use, and is recommended.

- 308** TRANSMISSION CIRCUITS. In alternating-current constant-potential transmission circuits, the following average voltages are recommended.

6,600 11,000 22,000 33,000 44,000 66,000 88,000

- 309** TRANSFORMER RATIO. It is recommended that the standard transformer ratios should be such as to transform between the standard voltages above named. The ratio will, therefore, usually be an exact multiple of 5 or 10, *e. g.*, 2,200 to 11,000; 2,200 to 44,000.

- 310** RANGE IN VOLTAGE. In alternating-current generators, or generating systems, a range of terminal voltage should be provided from rated voltage at no load to 10 per cent. in excess thereof, to cover drop in transmission. If a greater range than ten per cent. is specified, the generator should be considered as special.

B. FREQUENCIES.

- 311** In ALTERNATING-CURRENT CIRCUITS, the following frequencies are, standard:

25~ 60~

- 312** These frequencies are already in extensive use and it is deemed advisable to adhere to them as closely as possible.

IV. GENERAL RECOMMENDATIONS.

- 313** NAME PLATES. All electrical apparatus should be provided with a name plate giving the manufacturer's name, the voltage and the current in amperes for which it is designed. Where practicable, the kilowatt capacity, character of current, speed, frequency, type, designation and serial number should be added.

- 314** DIAGRAMS OF CONNECTIONS. All electrical apparatus when leaving the factory should be accompanied by a diagram showing the electrical connections and the relation of the different parts in sufficient detail to give the necessary information for proper installation.

- 315** RHEOSTAT DATA. Every rheostat should be clearly and permanently marked with the voltage and amperes, or range of amperes, for which it is designed.

- 316** COLORED INDICATING LIGHTS. When using colored indicating lights on switch-boards, red should denote danger such as "switch closed," or "circuit alive"; green should denote safety, such as "switch open," or "circuit dead."

- 317** When white lights are used a light turned on should denote danger, such as "switch closed" or "circuit alive"; while the light out should denote safety, such as "switch open," or "circuit dead." Low-efficiency lamps should be used.
- 318** The use of colored lights is recommended, as safer than white lights.
- 319** GROUNDING METAL WORK. It is desirable that all metal work near high potential circuits be grounded.
- 320** CIRCUIT OPENING DEVICES. The following definitions are recommended.
- 321** *a.* A CIRCUIT-BREAKER is an apparatus for breaking a circuit at the highest current which it may be called upon to carry.
- 322** *b.* A DISCONNECTING SWITCH is an apparatus designed to open a circuit only when carrying little or no current.
- 323** *c.* An AUTOMATIC CIRCUIT-BREAKER is an apparatus for breaking a circuit automatically under an excessive strength of current. It should be capable of breaking the circuit repeatedly at rated voltage and at the maximum current which it may be called upon to carry.
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V. APPENDICES AND TABULAR DATA.

APPENDIX A. NOTATION.

- The following notation is recommended:
- 324** *E, e*, voltage, e.m.f., potential difference
I, i, current
P, power
 Φ , magnetic flux
 $\mathfrak{B}, B$, magnetic density
R, r, resistance
x, reactance
Z, z, impedance
L, l, inductance
C, c, capacity
Y, y, admittance
b, s, susceptance
G, g, conductance
 Vector quantities when used should be denoted by capital italics.

APPENDIX B.—RAILWAY MOTORS.

(I) RATING.

- 325** INTRODUCTORY NOTE ON RATING. Railway motors usually operate in a service in which both the speed and the torque developed by the motor are varying almost continually. The average requirements, however, during successive hours in a given class of service are fairly uniform. On account of the wide variation of the instantaneous loads, it is impracticable to assign any simple and definite rating to a motor which will indicate accurately the absolute capacity of a given motor or the relative capacity of different motors under service conditions. It is also impracticable to select a motor for a particular service without much fuller data with regard both to the motor and to the service than is required, for example, in the case of stationary motors which run at constant speeds.
- 326** SCOPE OF NOMINAL RATING. It is common usage to give railway motors a nominal rating in horse power on the basis of a one-hour test. As above explained, a simple rating of this kind is not a proper measure of service capacity. This nominal rating, however, indicates approximately the maximum output which the motor should ordinarily be called upon to develop during acceleration. Methods of determining the continuous capacity of a railway motor for service requirements are given under a subsequent heading.
- 327** The NOMINAL RATING of a railway motor is the horse-power output at the car-axle, that is, including gear and other transmission losses, which gives a rise of temperature above the surrounding air (referred to a room

temperature of 25 degrees cent.) not exceeding 90 degrees cent. at the commutator and 75 degrees Cent. at any other part after one hour's continuous run at its rated voltage (and frequency, in the case of an alternating-current motor) on a stand, with the motor-covers removed, and with natural ventilation. The rise in temperature is to be determined by thermometer, but the resistance of no electrical circuit in the motor shall increase more than 40% during the test.

(II) *SELECTION OF MOTOR FOR SPECIFIED SERVICE.*

- 328** GENERAL REQUIREMENTS. The suitability of a railway motor for a specified service depends upon the following considerations:
- 329** a. Mechanical ability to develop the requisite torque and speeds as given by its speed-torque curve.
- 330** b. Ability to commutate successfully the current demanded.
- 331** c. Ability to operate in service without occasioning a temperature rise in any part which will endanger the life of the insulation.
- 332** OPERATING CONDITIONS, TYPICAL RUN. The operating conditions which are important in the selection of a motor include the weight of load, the schedule speed, the distance between stops, the duration of stops, the rate of acceleration and of braking retardation, the grades and the curves. With these data at hand, the outputs which are required of the motor may be determined, provided the service requirements are within the limits of the speed-torque curve of the motor. These outputs may be expressed in the form of curves giving the instantaneous values of current and of voltage which must be applied to the motor. Such curves may be laid out for the entire line, but they are usually constructed only for a certain average or typical run, which is fairly representative of the conditions of service. To determine whether the motor has sufficient capacity to perform the service safely, further tests or investigations must be made.
- 333** CAPACITY TEST OF RAILWAY MOTOR IN SERVICE. The capacity of a railway motor to deliver the necessary output may be determined by measurement of its temperature after it has reached a maximum in service. If a running test cannot be made under the actual conditions of service, an equivalent test may be made in a typical run back and forth, under such conditions of schedule speed, length of run, rate of acceleration, etc., that the test cycle of motor losses and conditions of ventilation are essentially the same as would be obtained in the specified service.
- 334** METHODS OF COMPARING MOTOR CAPACITY WITH SERVICE REQUIREMENTS. Where it is not convenient to test motors under actual service conditions or in an equivalent typical run, recourse may be had to one of the two following methods of determining temperature rise now in general use:
- 335** 1. METHOD BY LOSSES AND THERMAL CAPACITY CURVES. The heat developed in a railway motor is carried partly by conduction through the several parts and partly by convection through the air to the motor-frame whence it is distributed to the outside air. As the temperature of the several parts is thus dependent not only upon their own internal losses but also upon the temperature of neighboring parts, it becomes necessary to determine accurately the actual value and distribution of losses in a railway motor for a given service and reproduce them in an equivalent test-run. The results of a series of typical runs expressed in the form of thermal capacity curves will give the relation between degrees rise per watt loss in the armature and in the field for all ratios of losses between them met with in the commercial application of a given motor.
- 336** This method consists, therefore, in calculating the several internal motor losses in a specified service and determining the temperature rise with these losses from thermal capacity curves giving the degrees rise per watt loss as obtained in experimental track tests made under the same conditions of ventilation.
- 337** The following motor losses cause its heating and should be carefully determined for a given service: $I^2 R$ in the field; $I^2 R$ in the armature; $I^2 R$ in the brush contacts, core loss and brush friction.
- 338** The loss in the bearings (in the case of geared motors) also adds somewhat to the motor-heating, but owing to the variable nature of such losses they are generally neglected in making calculations.

- 339** 2. METHOD BY CONTINUOUS CAPACITY OF MOTOR. The essential losses in the motor, as found in the typical run, are in most cases those in the motor windings and in the core. The mean service conditions may be expressed in terms of the current which would produce the same losses in the motor windings and the voltage which, with that current, would produce the same core losses as the average in service. The continuous capacity of the motor is given in terms of the amperes which it will carry when run on a testing stand—with covers on or off, as specified—at different voltages, say, 40, 60, 80 and 100 per cent. of the rated voltage—with a temperature rise not exceeding 90 degrees at the commutator and 75 degrees at any other part, provided the resistance of no electric circuit in the motor increases more than 40 per cent. A comparison of the equivalent service conditions with the continuous capacity of the motor will determine whether the service requirements are within the safe capacity of the motor.
- 340** This method affords a ready means of determining whether a specified service is within the capacity of a given motor and it is also a convenient approximate method for comparing the service capacities of different motors.

APPENDIX C. PHOTOMETRY AND LAMPS.

- 341** CANDLE-POWER. The luminous intensity of sources of light is expressed in candle-power. The unit of candle-power should be derived from the standards maintained by the National Bureau of Standards at Washington, D. C., which standard unit of candle-power equals 100/88 of the Hefner unit under Reichsanstalt standard conditions for the Hefner. In practical measurements seasoned and carefully standardized incandescent lamps are more reliable and accurate than the primary standard.
- 342** CANDLE-LUMEN. The total flux of light from a source is equal to its mean spherical intensity multiplied by 4π . The unit of flux is called the candle-lumen. A candle lumen is the $\frac{1}{4\pi}$ -th part of the total flux of light emitted by a source having a mean spherical intensity of one candle-power.
- 343** CANDLE-METER. The unit of illumination is the candle-meter. This is the normal illumination produced by one unit of candle-power at a distance of one metre.
- 344** a. CANDLE-FOOT. Illumination is occasionally expressed in candle-feet. A candle-foot is the normal illumination produced by one unit of candle-power at a distance of one foot.
- 345** 1 candle-foot = 10.764 candle-metres.
The use of the candle-metre unit is preferable and is recommended.
- 346** THE EFFICIENCY OF ELECTRIC LAMPS is properly stated in terms of mean spherical candle-power per watt at lamp terminals. This use of the term efficiency is to be considered as 'special, and not to be confused with the generally accepted definition of efficiency in Sec. 85.
- 347** a. EFFICIENCY, AUXILIARY DEVICES. In illuminants requiring auxiliary power-consuming devices outside of the luminous body, such as steadying resistances in constant potential arc lamps, a distinction should be made between the net efficiency of the luminous source and the gross efficiency of the lamp. This distinction should always be stated. The gross efficiency should include the power consumed in the auxiliary resistance, etc. The net efficiency should, however, include the power consumed in the controlling mechanism of the lamp itself. Comparison between such sources of light should be made on the basis of gross efficiency, since the power consumed in the auxiliary device is essential to the operation.
- 348** b. A STANDARD CIRCUIT VOLTAGE of 110 volts, or a multiple thereof may be assumed, except where expressly stated otherwise.
- 349** WATTS PER CANDLE. The specific consumption of an electric lamp is its watt consumption per mean spherical candle-power. "Watts per candle" is the term used commercially in connection with incandescent lamps, and denotes, watts per mean horizontal candle-power.
- 350** PHOTOMETRIC TESTS in which the results are stated in candle-power should always be made at such a distance from the source of light that

APPENDIX E. TEMPERATURE COEFFICIENTS.

360 Table of Temperature Coefficients of Resistivity in Copper at Different Initial Temperatures Centigrade.

Initial temperature cent. i	Temp. coefficient in percent. per degree cent.	Initial temperature cent. i	Temp. coefficient in percent. per degree cent.
0.....	0.4200	26.....	0.3786
1.....	0.4182	27.....	0.3772
2.....	0.4165	28.....	0.3758
3.....	0.4148	29.....	0.3744
4.....	0.4131	30.....	0.3730
5.....	0.4114	31.....	0.3716
6.....	0.4097	32.....	0.3702
7.....	0.4080	33.....	0.3689
8.....	0.4063	34.....	0.3675
9.....	0.4047	35.....	0.3662
10.....	0.4031	36.....	0.3648
11.....	0.4015	37.....	0.3635
12.....	0.3999	38.....	0.3622
13.....	0.3983	39.....	0.3609
14.....	0.3967	40.....	0.3596
15.....	0.3951	41.....	0.3583
16.....	0.3936	42.....	0.3570
17.....	0.3920	43.....	0.3557
18.....	0.3905	44.....	0.3545
19.....	0.3890	45.....	0.3532
20.....	0.3875	46.....	0.3520
21.....	0.3860	47.....	0.3508
22.....	0.3845	48.....	0.3495
23.....	0.3830	49.....	0.3483
24.....	0.3815	50.....	0.3471
25.....	0.3801		

The fundamental relation between the increase of resistance in copper and the rise of temperature may be taken as

$$R_t = R_0 (1 + 0.0042 t)$$

where R_0 is the resistance of the copper conductor at 0° C. and R_t is the corresponding resistance at t° C. This is equivalent to taking a temperature coefficient of 0.42% per deg. C. temperature rise above 0° C. For initial temperatures other than 0° C., a similar formula may be used substituting the coefficients in the above table corresponding to the actual initial temperature. The formula thus becomes at 25° C.

$$R_{i+r} = R_i (1 + \frac{0.3801 r}{100})$$

where R_i is the initial resistance at 25° C. R_{i+r} the final resistance and r the temperature rise above 25° C.

In order to find the temperature rise in degrees cent. from the initial resistance R_i at the initial temperature t° C. and the final resistance $R_i + r$, we may use the formula

$$r = (238.1 + i) \left(\frac{R_i + r}{R_i} - 1 \right) \text{ degrees C.}$$

See Sec. 265.

HISTORY OF THE STANDARDIZATION RULES A.I.E.E.

IN CONNECTION WITH THE PRESENTATION OF THE STANDARDIZATION RULES
TO THE AMERICAN INSTITUTE ELECTRICAL ENGINEERS AT THE 23D
ANNUAL CONVENTION HELD AT NIAGARA FALLS, JUNE 27, 1907.

The first step taken by the Institute toward the standardization of electrical apparatus and methods was a topical discussion on "The Standardization of Generators, Motors and Transformers," which took place simultaneously in New York and Chicago on the evening of January 26, 1898. This discussion appears in the Institute TRANSACTIONS, Vol. XV, pages 3 to 32. The opinions expressed were generally favorable to the scheme of standardization of electrical apparatus, although some members feared that difficulties might arise. As a result of this discussion, a Committee on Standardization was appointed by the Council of the Institute, consisting of the following members:

FRANCIS B. CROCKER, *Chairman*.

CARY T. HUTCHINSON
ARTHUR E. KENNELLY
JOHN W. LIEB, JR.

CHARLES P. STEINMETZ
LEWIS B. STILLWELL
ELIHU THOMSON

After a careful consideration of the matter and consultation with the members of the Institute and interested parties generally, a "Report of the Committee on Standardization" was presented and accepted by the Institute, June 26, 1899. These original rules appeared in the Institute TRANSACTIONS, Vol. XVI, pages 255 to 268.

As a result of changes and developments in the electric art, it was subsequently found necessary to revise the original report, this work being carried out by the following Committee on Standardization:

FRANCIS B. CROCKER, *Chairman*.

ARTHUR E. KENNELLY
JOHN W. LIEB, JR.
C. O. MAILLOUX

CHARLES P. STEINMETZ
LEWIS B. STILLWELL
ELIHU THOMSON

This revised report was adopted at the 19th Annual Convention at Great Barrington, Mass., on June 20, 1902, and appears in the Institute TRANSACTIONS, Vol. XIX, pages 1075 to 1092.

In consequence of still further change and development in electrical apparatus and methods, it was decided in September, 1905, that a second

revision was needed, and the following Committee was appointed to do this work:

FRANCIS B. CROCKER, *Chairman*.

ARTHUR E. KENNELLY, *Secretary*.

HENRY S. CARHART

JOHN W. LIEB, JR.

C. O. MAILLOUX

ROBERT B. OWENS

CHARLES F. SCOTT

CHARLES P. STEINMETZ

HENRY G. STOTT

S. W. STRATTON

This Committee held monthly meetings and carried on extensive correspondence with manufacturers, consulting and operating engineers and other interested parties, and as a result, presented its report at the 23d Annual Convention, held at Milwaukee, May 28-30, 1906. After considerable discussion the report was accepted and referred back to the Committee for amendment and rearrangement in form. It was then to be submitted to the Board of Directors for final adoption. In September, 1906, the following Standardization Committee was appointed:

FRANCIS B. CROCKER, *Chairman*.

ARTHUR E. KENNELLY, *Secretary*.

A. W. BERRESFORD

C. O. MAILLOUX

R. B. OWENS

CHARLES F. SCOTT

CHARLES P. STEINMETZ

HENRY G. STOTT

S. W. STRATTON

ELIHU THOMSON

This Committee held monthly meetings, also sub-committee meetings, and carefully referred the rules as a whole, and each part of them, to the members of the Institute. The rules were also entirely rearranged as to form, and put in shape to facilitate ready reference to them and enable future revisions to be made without breaking up the logical arrangement. Thus amended the rules were submitted to the Board of Directors and approved by it on June 21, 1907. The Board also directed that the rules should be presented, as accepted by the Board, at the Annual Convention held at Niagara Falls, June 24 to 27, 1907, which action was taken by President Sheldon on June 26, 1905. By the Constitution which went into effect June 10, 1907, this Committee has been made a standing committee with the title "Standards Committee," consisting of nine members.