



- Samuel Davis Greene

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THE INSTITUTE is not, as a body, responsible for the statements of fact or opinions advanced in papers or discussions at its meetings, and it is understood that papers and discussions should not include matters relating to politics or purely to trade.

Constitution, Article VII, Sec. 2.

TRANSACTIONS
OF THE
AMERICAN INSTITUTE OF
ELECTRICAL ENGINEERS,

Vol. XVI. JANUARY TO DECEMBER. 1899.

New York, January 25th, 1899.

The 131st meeting of the INSTITUTE was held this date at 12 West 31st Street, and was called to order by President Kennelly at 8 o'clock p. m.

The Secretary announced that at the meeting of the Executive Committee in the afternoon, the following associate members were elected :

Name.	Address.	Endorsed by
DAGGETT, ROYAL BRADFORD	Electrical Engineer, Electric Storage Battery Co., Marquette Building, Chicago, Ill.	Herbert Lloyd. J. B. Entz. H. H. Wait.
DYER, ERNEST I.	Engineer and Manager of the Engineering Department of the American Trading Co., Box 28 Yokohama, Japan.	C. L. Cory. J. N. LeConte. J. A. Lighthipe.
HILL, GEO. HENRY	Chief Engineer, Elevator Department, Sprague Electric Co., Bloomfield, N. J.; residence, New York City.	F. J. Sprague. E. R. Carichoff. Louis Duncan.
HILL, ERNEST ROWLAND	Electrical Engineer, Westinghouse E. & M. Co., Pittsburg, Pa.	C. F. Scott. L. B. Stillwell. Harris J. Ryan.
LYNN, WM. A.	Assistant in Electrical Engineering, University of California, Berkeley, Cal.	C. L. Cory. J. N. LeConte. F. V. T. Lee.
SIMPSON, J. MANLEY	Assistant Superintendent, North-Western Grass Twine Co., P. O. Box 2513, St. Paul, Minn.	F. A. C. Perrine. C. A. Carus-Wilson Ralph W. Pope.
THOMPSON, THOS. PERRIN	Electrical Laboratorian, Brooklyn Navy Yard; residence, 217 Cumberland St., Brooklyn, N. Y.	Townsend Wolcott Frederick Bedell. Harris J. Ryan.
THOMPSON, ALFRED J.	Electrical Engineer and Contractor, San Ignacio 50, Havana, Cuba.	Thos. A. Edison. A. E. Kennelly. Gano S. Dunn.
WILSON, ROBERT M.	Faculty of Applied Science, McGill University; residence, 113 Shuter Street, Montreal, Que.	R. B. Owens. R. A. Ross. Ralph W. Pope.
Total, 9.		

The following Associate Members were transferred to membership.

Approved by Board of Examiners, December 9th, 1898.

PHILANDER BETTS, Electrician U. S. Navy Yard, Washington, D. C.
WINDEN ELWELL GOLDSBOROUGH, Professor of Electrical Engineering, Purdue
University, Lafayette, Ind.

THE PRESIDENT:—In introducing the paper of the evening, I have the pleasure to announce that Mr. Greene himself is present and he has, as you know, been spending some months professionally in the navy. We shall look for an interesting paper at his hands upon "Electricity on Board Ship."

pany, one from Professor Elihu Thomson, extending an invitation to his house on Wednesday evening; one from the Vice-President's office of the Boston Elevated Railway; one from the Mayor of Cambridge; a letter of regret from Mr. Dunn saying he had been obliged to change his plans on account of his health, which necessitated his going to Haines Falls in the Catskills; a letter from the New England Gas and Coke Company, inviting the members to visit its new works at Everett.

THE PRESIDENT:—There is one report to be laid before the INSTITUTE this morning, and that is the report of the Committee on Standardization. The Chairman of that committee is Prof. Crocker, and I am sorry that Professor Crocker is abroad and not here to-day to present it. But this committee was appointed nearly two years ago and its provisional report was laid before the INSTITUTE at the last General Meeting a year ago at Omaha. The report has been before the INSTITUTE therefore for a year, and criticisms have been invited and a number have been received, and it is in printed form before you this morning. The matter is now before the INSTITUTE for action.

MR. A. V. GARRATT:—Mr. President, I believe that this report representing as it does a vast amount of careful, conscientious and well digested labor on the part of our very able Committee, should be either rejected or accepted as a whole as it is here printed before us. I therefore move you the acceptance of the report as presented to us in printed form and that it be published in the TRANSACTIONS.

[Motion seconded and adopted.]

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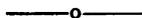
NEW YORK, N. Y.

JUNE, 1899.

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REPORT OF THE COMMITTEE ON
STANDARDIZATION.

[Accepted by the INSTITUTE, June 26th, 1899.]



To The Council of The AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

Gentlemen :

Your committee on Standardization begs to submit the following report, covering such subjects as have been deemed of pressing and immediate importance, and which are of such a nature that general agreement may be expected upon them.

While it is the opinion of the committee that many other matters might advantageously have been considered, as, for example, standard methods of testing ; yet it has been deemed inexpedient to attempt to cover in a single report more than is here submitted.

Yours respectfully,

FRANCIS B. CROCKER, *Chairman.*

CARY T. HUTCHINSON,

A. E. KENNELLY.

J. W. LIEB, Jr.

CHARLES P. STEINMETZ.

LEWIS B. STILLWELL.

ELIHU THOMSON.

GENERAL PLAN.

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	(V) Table of Sparking Distances.	

Electrical Apparatus will be treated under the following heads:—

I. Commutating Machines, which comprise a constant magnetic field, a closed-coil armature, and a multi-segmental commutator connected thereto.

Under this head may be classed the following: Direct-current generators; direct-current motors; direct-current boosters; motor-generators; dynamotors; converters and closed-coil arc machines

A booster is a machine inserted in series in a circuit to change its voltage, and may be driven either by an electric motor, or otherwise. In the former case it is a motor-booster.

A motor-generator is a transforming device consisting of two machines; a motor and a generator, mechanically connected together.

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.

For Converters, see III.

II. 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.

III. Synchronous Commutating Machines:—These include: 1. Synchronous converters; *i. e.*, converters from alternating to direct, or from direct to alternating current, and 2. Double-current generators; *i. e.*, generators producing both direct and alternating currents.

A converter is a rotary device transforming electric energy from one form into another without passing it through the intermediary form of mechanical energy.

A converter may be either:

a. A direct current converter, converting from a direct current to a direct current or.

b. A synchronous converter, formerly called a rotary converter, converting from an alternating to a direct current, or vice versa.

Phase converters, are converters from an alternating-current system to an alternating-current system of the same frequency but different phase.

Frequency converters are converters from an alternating-current system of one frequency to an alternating-current system of another frequency, with or without changes of phase.

IV. Rectifying Machines, or Pulsating-Current Generators, which produce a unidirectional current of periodically varying strength.

V. Stationary Induction Apparatus, *i. e.*, stationary apparatus changing electric energy from one form into another, without passing it through an intermediary form of energy. These comprise

a. Transformers, or stationary induction apparatus in which the primary and secondary windings are electrically insulated from each other.

b. Auto-transformers, formerly called compensators; *i. e.*, stationary induction apparatus in which part of the primary winding is used as a secondary winding; or conversely.

c. Potential regulators, or stationary induction apparatus having a coil in shunt, and a coil in series with the circuit, so arranged that the ratio of transformation between them is variable at will.

These may be divided into:—

1. Compensator potential regulators, in which the number of turns of one of the coils is changed.

2. Induction potential-regulators, in which the relative positions of primary and secondary coils is changed.

3. Magneto potential-regulators, in which the direction of the magnetic flux with respect to the coils is changed.

d. Reactive coils, or Reactance coils, formerly called choking coils; *i. e.*, stationary induction apparatus used to produce impedance or phase displacement.

VI. Rotary Induction Apparatus, which consist of primary and secondary windings rotating with respect to each other. They comprise

a. Induction motors.

b. Induction generators.

c. Frequency changers.

d. Rotary phase converters.

EFFICIENCY.

1. The "efficiency" of an apparatus is the ratio of its net power output to its gross power input.¹

2. Electric power should be measured at the terminals of the apparatus.

3. In determining the efficiency of alternating-current apparatus, the electric power should be measured when the current is in phase with the *e. m. f.*, unless otherwise specified, except when a definite phase difference is inherent in the apparatus, as in induction motors, etc.

4. 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 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. The brush friction, however, should be included.

a. Where a machine has auxiliary apparatus, such as an exciter, the power lost in the auxiliary apparatus should not be charged to the machine but to the plant consisting of machine and auxiliary apparatus taken together. The plant efficiency in such cases should be distinguished from the machine efficiency.

5. The efficiency may be determined by measuring all the losses individually and adding their sum to the output to derive the input, or subtract-

¹ 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.

ing their sum from the input to derive the output. All losses should be measured at, or reduced to, the temperature assumed in continuous operation, or in operation under conditions specified. (See Sections 25 to 31.)

In order to consider the application of the foregoing rules to various machines in general use, the latter may be conveniently divided into classes as follows:

I. Commutating Machines.

6. In commutating machines the losses are:—

- a.* Bearing friction and windage. (See Section 4.)
 - b.* Molecular magnetic friction, and eddy currents in iron and copper. These losses should be determined with the machine 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 proportion to the speed or to any definite power of the voltage.
 - c.* Armature resistance losses, I^2r' , where I is the current strength in the armature, and r' is the resistance between armature brushes, excluding the resistance of brushes and brush contacts.
 - d.* Comutator brush friction.
 - e.* Commutator brush-contact resistance. It is desirable to point out that with carbon brushes the losses (*d*) and (*e*) are usually considerable in low-voltage machines.
 - f.* Field excitation. With separately excited fields, the loss of power in the resistance of the field coils alone should be considered. With shunt fields or series fields, 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.
- (*b*) and (*c*) are losses in the armature or "armature losses;" (*d*) and (*e*) "commutator losses;" (*f*) "field losses."

7. The difference between the total losses under load and the sum of the losses above specified, should be considered as "load losses," and are usually trivial in commutating machines of small field distortion. When the field distortion is large, as is shown 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 Section II.

8. Boosters should be considered and treated like other direct-current machines in regard to losses.

9. In motor-generators, dynamotors or converters, the efficiency is the $\frac{\text{electric output}}{\text{electric input}}$.

II. Synchronous Machines.—

10. In synchronous machines the output or input should be measured with the current in phase with the terminal E. M. F., except when otherwise expressly specified.

Owing to the uncertainty necessarily involved in the approximation of load losses, it is preferable, whenever possible, to determine the efficiency of synchronous machines by input and output tests.

11. The losses in synchronous machines are:

- a.* Bearing friction and windage; see Sec. 4.
- b.* Molecular magnetic friction and eddy currents in iron, copper and other metallic parts. These losses should be determined at open circuit of the machine at the rated speed and at the rated voltage, $+Ir$ in a synchronous generator, $-Ir$ in a synchronous motor, where I = current in armature, r = armature resistance. It is undesirable to compute these losses from observations made at other speeds or voltages.

These losses may be determined either by driving the machine by a motor, or by running it as a synchronous motor, and adjusting its fields so as to get minimum current input and measuring the input by wattmeter. The

former is the preferable method, and in polyphase machines the latter method is liable to give erroneous results in consequence of unequal distribution of currents in the different circuits caused by inequalities of the impedance of connecting leads, etc.

c. Armature-resistance loss, which may be expressed by $p I^2 r$; 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.

d. Load losses as defined in section 7. While these 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.

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.

e. Collector-ring friction and contact resistance. These are generally negligible, except in machines of extremely low voltage.

f. Field excitation. In separately-excited machines, the $I^2 r$ of the field coils proper should be used. In self-exciting machines, however, the loss in the field rheostat should be included. (See Section 6 *f.*)

III. Synchronous Commutating Machines.

12. In synchronous converters, the power on the alternating-current side is to be measured with the current in phase with the terminal e. m. f., unless otherwise specified.

13. In double-current generators, the efficiency of the machine should be determined as a direct-current generator in accordance with section 6., and as an alternating-current generator in accordance with section 11. The two values of efficiency may be different, and should be clearly distinguished.

14. In synchronous converters the losses should be determined when driving the machine by a motor. These losses are:—

a. Bearing friction and windage, see section 4.

b. Molecular magnetic friction and eddy currents in iron, copper and metallic parts. These losses should be determined at open circuit and at the rated terminal voltage, no allowance being made for the armature resistance, since the alternating and the direct currents flow in opposite directions.

c. Armature resistance. The 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 1.37 in single-phasers, 0.56 in three-phasers, 0.37 in quarter-phasers and 0.26 in six-phasers

d. Load losses. The load losses should be determined in the same manner as described in section 11 *d.*, with reference to the direct-current side.

e and *f.* Losses in commutator and collector friction and brush-contact resistance. See sections 6 and 11.

g. Field excitation. In separately-excited fields, the $I^2 r$ loss in the field coils proper should be taken, while in shunt and series fields the rheostat loss should be included, except where fields and rheostats are intentionally modified to produce effects outside of the conversion of electric power, as for producing phase displacement for voltage control. In this case 25 per cent. of the $I^2 r$ loss in the field proper at non-inductive alternating circuit should be added as proper estimated allowance for normal rheostat losses. (See Section 6 *f.*)

15. Where two similar synchronous machines are available, their efficiency can 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 might be to supply the losses by an alternator between the two machines, using potential regulators.

IV. Rectifying Machines or Pulsating-Current Generators.—

16. These include: Open-coil arc machines, constant-current rectifiers, constant-potential rectifiers.

The losses in open-coil arc machines are essentially the same as in sections 6 to 9 (closed-coil commutating machines.) In alternating-current rectifiers, however, the output must be measured by wattmeter and not by voltmeter and ammeter, since owing to the pulsation of current and *E. M. F.*, a considerable discrepancy may exist between watts and volt-amperes, amounting to as much as 10 or 15 per cent.

17. In constant-current rectifiers, transforming from constant-potential alternating to constant direct current by means of constant-current transformers and rectifying commutators, the losses in the transformers are to be included in the efficiency and have to be measured when operating the rectifier, since in this case the losses are generally greater than when feeding an alternating secondary circuit. In constant-current transformers the load losses are usually larger than in constant-potential transformers and thus should not be neglected.

The most satisfactory method of determining the efficiency in rectifiers is to measure electric input and electric output by wattmeter. The input is usually not non-inductive, owing to a considerable phase displacement and to wave distortion. For this reason the apparent efficiency should also be considered, since it is usually much lower than the true efficiency. The power consumed by the synchronous motor or other source driving the rectifier should be included in the electric input.

V. Stationary Induction Apparatus.—

18. Since the efficiency of induction apparatus depends upon the wave shape of *E. M. F.*, it should be referred to a sine wave of *E. M. F.*, except where expressly specified otherwise. The efficiency should be measured with non-inductive load, and at rated frequency, except where expressly specified otherwise. The losses are:

a. Molecular magnetic friction and eddy currents measured at open circuit and at rated voltage — $I^2 r$, where I = rated current, r = resistance of primary circuit.

b. Resistance losses, the sum of the $I^2 r$ of primary and of secondary in a transformer, or of the two sections of the coil in the compensator or auto-transformer, where I = current in the coil or section of coil, r = resistance.

c. Load losses: *i. e.*, eddy currents in the iron and especially in the copper conductors, caused by the current. They should be measured by short-circuiting the secondary of the transformer and impressing upon the primary an *E. M. F.* sufficient to send full-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.

d. Losses due to the methods of cooling, as power consumed by the blower in air-blast transformers, and power consumed by the motor driving pumps in oil or water-cooled transformers. Where the same cooling apparatus supplies a number of transformers or is installed to supply future additions, allowance should be made therefor.

19. 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.

VI. Rotary Induction Apparatus.

20. Owing to the existence of load losses and since the magnetic density in the induction motor under load changes in a complex manner, the efficiency should be determined by measuring the electric input by wattmeter and the mechanical output at the pulley, gear, coupling, etc.

21. The efficiency should be determined at the rated frequency and the input measured with sine waves of impressed E. M. F.

22. The efficiency may be calculated from the apparent input, the power factor, and the power output. The same applies to induction generators. Since phase displacement is inherent in induction machines, their apparent efficiency is also important.

23. In frequency changers; *i. e.*, apparatus transforming from a polyphase system to an alternating system of different frequency, with or without a change in the number of phases, and phase converters; *i. e.*, apparatus converting from an alternating system, usually single phase, to another alternating system, usually polyphase, of the same frequency, the efficiency should also be determined by measuring both output and input.

VII. Transmission Lines.

24. The efficiency of transmission lines should be measured with non-inductive load at the receiving end, with the rated receiving pressure and frequency, also with sinusoidal impressed E. M. F.'s., except where expressly specified otherwise, and with the exclusion of transformers or other apparatus at the ends of the line.

RISE OF TEMPERATURE.

General Principles.—

25. Under regular service conditions, the temperature of electrical machinery should never be allowed to remain at a point at which permanent deterioration of its insulating material takes place.

26. The rise of temperature should be referred to the standard conditions of a room-temperature of 25° C., a barometric pressure of 760 mm. and normal conditions of ventilation; that is, the apparatus under test should neither be exposed to draught, nor enclosed, except where expressly specified.

27. If the room temperature during the test differs from 25° C., the observed rise of temperature should be corrected by 1/2 per cent for each degree C.² 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. The thermometer indicating the room temperature should be screened from thermal radiation emitted by heated bodies, or from draughts of air. When it is impracticable to secure normal conditions of ventilation on account of an adjacent engine, or other sources of heat, the thermometer for measuring the air temperature should be placed so as fairly to indicate the temperature which the machine would have if it were idle, in order that the rise of temperature determined shall be that caused by the operation of the machine.

28. The temperature should be measured after a run of sufficient duration to reach practical constancy. 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.

In apparatus intended for intermittent service, as railway motors, starting rheostats, etc., the rise of temperature should be measured after a shorter time, depending upon the nature of the service, and should be specified.

In apparatus which by the nature of their service may be exposed to overload, as railway converters, and in very high voltage circuits, a smaller rise of temperature should be specified 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.

2. This correction is also intended to compensate, as nearly as is at present practicable, for the error involved in the assumption of a constant temperature coefficient of resistivity; *i. e.* 0.4 per cent. per deg. C. taken with varying initial temperatures.

29. In electrical conductors, the rise of temperature should be determined by their increase of resistance. For this purpose the resistance may be measured either by galvanometer test, or by drop-of-potential method. A temperature coefficient of 0.4 per cent per degree C., may be assumed for copper.³ Temperature elevations measured in this way are usually in excess of temperature elevations measured by thermometers.

30. It is recommended that the following maximum values of temperature elevation should not be exceeded :

Commutating machines, rectifying machines, and synchronous machines.

Field and armature, by resistance, 50° C.

Commutator and collector rings and brushes, by thermometer, 55° C.

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

Rotary induction apparatus:

Electric circuits, 50° C., by resistance.

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

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

Transformers for continuous service—electric circuits by resistance 50° C., other parts by thermometer, 40° C., under conditions of normal ventilation.

Reactive coils, induction and magneto regulators—electric circuits by resistance 55° C., other parts by thermometer 45° C.

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. In using the thermometer, 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.

31. In the case of apparatus intended for intermittent service, the temperature elevation which is attained at the end of the period corresponding to the term of full load, should not exceed 50° C by resistance in electric circuits. In the case of transformers intended for intermittent service, or not operating continuously at full 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 40° C by thermometer in other parts, after the period corresponding to the term of full 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 full-load test may be taken as three hours, unless otherwise specified. In the case of railway, crane, and elevator motors, the conditions of service are necessarily so varied that no specific period corresponding to the full-load term can be stated.

INSULATION.

32. 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.

Insulation Resistance.

33. Insulation resistance tests should, if possible, be made at the pressure for which the apparatus is designed.

The insulation resistance of the complete apparatus must be such that the rated voltage of the apparatus will not send more than $\frac{I}{1,000,000}$ of the full load current, at the rated terminal voltage, through the insulation. Where the value found in this way exceeds 1 megohm, 1 megohm is sufficient.

3. By the formula $R_T = R_t (1 + 0.004 \theta)$. Where R_t is the resistance at room temperature, R_T the resistance when heated, and θ the temperature elevation ($T-t$) in degrees centigrade.

REGULATION.

42 The term regulation should have the same meaning as the term "inherent regulation," at present frequently used.

43 The regulation of an apparatus intended for the generation of constant potential, constant current, constant speed, etc., is to be measured by the maximum variation of potential, current, speed, etc., occurring within the range from full load to no load, under such constant conditions of operation as give the required full-load values, the condition of full load being considered in all cases as the normal condition of operation.

44 The regulation of an apparatus intended for the generation of a potential, current, speed etc., varying in a definite manner between full load and no load, is to be measured by the maximum variation of potential, current, speed, etc., from the satisfied condition, under such constant conditions of operation as give the required full-load values.

If the manner in which the variation in potential, current, speed, etc., between full load and no load is not specified, it should be assumed to be a simple linear relation; *i. e.* undergoing uniform variation between full load and no load.

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 it possesses when specified as an over-compounded generator.

45. The regulation is given in percentage of the full-load value of potential, current, speed, etc., and the apparatus should be steadily operated during the test under the same conditions as at full load.

46. The regulation of generators is to be determined at constant speed; of alternating apparatus at constant impressed frequency.

47. The regulation of a generator-unit, consisting of a generator united with a prime-mover, should be determined at constant conditions of the prime mover; *i. e.* constant steam pressure, head, etc. It would include 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.

48. In apparatus generating, transforming or transmitting 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.

49. In alternating apparatus receiving electric power, regulation should refer to a sine wave of *E. M. F.*, except where expressly specified otherwise.

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

- a. At constant excitation in separately excited fields
- b. With constant resistance in shunt field circuits and
- c. With constant resistance shunting series fields; *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.

51. In constant-potential machines, the regulation is the ratio of the maximum difference of terminal voltage from the rated full-load value (occurring within the range from full load to open circuit) to the full-load terminal voltage.

52. In constant-current machines, the regulation is the ratio of the maximum difference of current from the rated full-load value (occurring within the range from full load to short circuit), to the full-load current.

53. In constant-power machines, the regulation is the ratio of maximum difference of power from the rated full load value (occurring within the range of operation specified) to the rated power.

54. In over-compounded machines, the regulation is the ratio of the maximum difference in voltage from a straight line connecting the no-load

and full-load values of terminal voltage as function of the current, to the full-load terminal voltage.

55. In constant-speed continuous-current motors, the regulation is the ratio of the maximum variation of speed from its full-load value (occurring within the range from full-load to no-load) to the full-load speed.

56. In transformers, the regulation is the ratio of the rise of secondary terminal voltage from full-load to no-load, (at constant primary impressed terminal voltage) to the secondary terminal voltage.

57. In induction motors, the regulation is the ratio of the rise of speed from full-load to no-load, (at constant impressed voltage), to the full-load speed.

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.

58. In converters, dynamotors, motor-generators, and frequency changers, the regulation is the ratio of the maximum difference of terminal voltage at the output side from the rated full-load voltage, (at constant impressed voltage and at constant frequency), to the full-load voltage on the output side.

59. In transmission lines, feeders, etc., the regulation is the ratio of maximum voltage difference at the receiving end, between no-load and full non-inductive load, to the full-load voltage at the receiving end, with constant voltage impressed upon the sending end.

60. In steam engines, the regulation is the ratio of the maximum variation of speed in passing from full-load to no load (at constant steam pressure at the throttle), to the full-load speed.

61. In a turbine or other water-motor, the regulation is the ratio of the maximum variation of speed from full-load to no-load (at constant head of water; *i. e.*, at constant difference of level between tail race and head race), to the full-load speed.

Variation and Pulsation.—

62. In prime movers which do not give an absolutely uniform rate of rotation or speed, as in steam engines, the "variation" 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 as 360°; and the pulsation is the ratio of the maximum change of speed in an engine cycle to the average speed.

63. In alternators or alternating-current circuits in general, the variation is the maximum difference in phase of the generated wave of *E. M. F.* from a wave of absolutely constant frequency, expressed in degrees, and is due to the variation of the prime mover. The pulsation is the ratio of the maximum change of frequency during an engine cycle to the average frequency.

64. If n = number of poles, the variation of an alternator is $\frac{n}{2}$ times the variation of its prime mover if direct connected, and $\frac{n}{2}\phi$ times the variation of the prime mover if rigidly connected thereto in the velocity ratio ϕ .

65. The pulsation of an alternating-current circuit is the same as the pulsation of the prime mover of its alternator.

RATING.

66. Both electrical and mechanical power should be expressed in kilowatts, except when otherwise specified. Alternating-current apparatus should be rated in kilowatts on the basis of non-inductive condition; *i. e.*, with the current in phase with the terminal voltage.

67. Thus the electric power generated by an alternating-current apparatus equals its rating only at non-inductive load, that is when the current is in phase with the terminal voltage.

68. Apparent power should be expressed in kilovolt-amperes as distinguished from real power in kilowatts.

69. If a power-factor other than 100% is specified, the rating should be expressed in kilovolt-amperes and power-factor, at full load.

70. The full-load current of an electric generator is that current which with the rated full-load terminal voltage gives the rated kilowatts, but in alternating-current apparatus only at non-inductive load.

71. Thus in machines in which the full load voltage differs from the no-load voltage, the full-load current should refer to the former.

If P = rating of an electric generator and E = full-load terminal voltage, the full-load current is :

$$I = \frac{P}{E} \text{ in a continuous-current machine or single phase-alternator.}$$

$$I = \frac{P}{E \sqrt{3}} \text{ in a three-phase alternator.}$$

$$I = \frac{P}{2E} \text{ in a quarter-phase alternator.}$$

72. Constant-current machines such as series arc-light generators, should be rated in kilowatts based on terminal volts and amperes at full load.

73. The rating of a fuse or circuit breaker should be the current-strength at which it will open the circuit, and not the working-current strength.

Classification of Voltages and Frequencies.

74. In direct-current, low-tension generators, the following average terminal voltages are in general use and are recommended :

125 volts. 250 volts. 550 volts.

75. In direct-current, and alternating-current, low-pressure circuits, the following average terminal voltages are in general use and are recommended :

110 volts, 220 volts.

In direct-current power circuits, for railway and other service, 500 volts may be considered as standard.

76. In alternating-current, high-pressure circuits at the receiving end, the following pressures are in general use, and are recommended :

1000 volts. 2000 volts. 3000 volts. 6000 volts
10000 volts. 15000 volts. 20000 volts.

77. In alternating-current high-pressure generators, or generating systems the following terminal voltages are in general use and are recommended :

1150 volts 2300 volts 3450 volts

These pressures allow of a maximum drop in transmission of 15% of the pressure at the receiving end. If the drop required is greater than 15%, the generator should be considered as special.

78. In alternating-current circuits, the following approximate frequencies are recommended as desirable :

25 ~ or 30 ~ 40 ~ 60 ~ 120 ~⁽⁴⁾

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

Overload Capacities.

79. All guarantees on heating, regulation, sparking, etc., should apply to the rated load, except where expressly specified otherwise, and in alternating-current apparatus to the current in phase with the terminal E. M. F., except where a phase displacement is inherent in the apparatus.

80. All apparatus should be able to carry a reasonable overload without self destruction by heating, sparking, mechanical weakness, etc. and with an increase of temperature elevation not exceeding 15° C, above those specified for full loads. See Secs. 25 to 31.

81. Overload guarantees should refer to normal conditions of operation regarding speed, frequency, voltage, etc., and to non-inductive conditions in the alternating apparatus, except where a phase displacement is inherent in the apparatus.

82. The following overload capacities are recommended :

4. The frequency of 120~ may be considered as covering the already existing commercial frequencies between 120~ and 140~, and the frequency of 60 ~ as covering the already existing commercial frequencies between 60 ~ and 70 ~.

1st. In direct-current generators and alternating-current generators; 25% for one-half hour.

2d. In direct-current motors and synchronous motors, 25% for one-half hour, 50% for one minute; except in railway motors and other apparatus intended for intermittent service.

3d. Induction motors. 25% for one-half hour, 50% for one minute.

4th. Synchronous converters. 50% for one half hour.

5th. Transformers. 25% for one-half hour. 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.

6th. Exciters of alternators and other synchronous machines, 10% more overload than is required for the excitation of the synchronous machine at its guaranteed overload, and for the same period of time.

APPENDIX I.

EFFICIENCY.

Efficiency of Phase-Displacing Apparatus.

In apparatus producing phase displacement as, for example, synchronous compensators, exciters of induction generators, reactive coils, condensers, polarization cells, etc., the efficiency should be understood to be the ratio of the volt-ampere activity to the volt-ampere activity plus power loss.

The efficiency may be calculated by determining the losses individually, adding to them the volt-ampere activity, and then dividing the volt-ampere activity by the sum.

1st. In synchronous compensators and exciters of induction generators, the determination of losses is the same as in other synchronous machines under Sections 10 and 11.

2nd. In reactive coils the losses are molecular friction, eddy losses, and I^2r loss. They should be measured by wattmeter. The efficiency of reactive coils should be determined with a sine wave of impressed E. M. F., except where expressly specified otherwise.

3rd. In condensers, the losses are due to dielectric hysteresis and leakage and should be determined by wattmeter with a sine wave of E. M. F.

4th. In polarization cells, the losses are those due to electric resistivity and a loss in the electrolyte of the nature of chemical hysteresis and are usually very considerable. They depend upon the frequency, voltage and temperature, and should be determined with a sine wave of impressed E. M. F., except where expressly specified otherwise.

APPENDIX II.

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.

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.

Since the apparent efficiency of apparatus generating 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.

APPENDIX III.

Power Factor and Inductance Factor.

The power factor in alternating circuits or apparatus may be defined as the ratio of the electric power, in watts, to volt-amperes.

The inductance factor is to be considered as the ratio of wattless volt-amperes to total volt-amperes.

Thus, if p = power factor, q = inductance factor,
then

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

The power factor is the $\frac{\text{(energy component of current or E. M. F.)}}{\text{(total current or E. M. F.)}}$

and the inductance factor is the $\frac{\text{(wattless component of current or E. M. F.)}}{\text{(total current or E. M. F.)}} = \frac{\text{true power}}{\text{volt-amperes.}}$

Since the power-factor of apparatus supplying electric power depends upon the power-factor of the load, the power-factor of the load should be considered as unity, unless otherwise specified.

APPENDIX IV.

The following notation is recommended:—

E, e , voltage, E. M. F., potential difference

J, i , current

P , power

Φ , magnetic flux

\mathcal{B} , magnetic density

R, r , resistance

X, x , reactance

Z, z , impedance

L, l , inductance

C, c , capacity.

Vector quantities when used should be denoted by capital italics.

APPENDIX V.

Table of Sparking Distances in Air between Opposed Sharp Needle-Points, for Various Effective Sinusoidal Voltages, in inches and in centimetres.

Kilovolts Sq. Root of Mean Square.	Distance.		Kilovolts Sq. Root of Mean Square.	Distance.	
	Inches	Cms.		Inches	Cms.
5	0.225	0.57	60	4.65	11.8
10	0.47	1.19	70	5.85	14.9
15	0.725	1.84	80	7.1	18.0
20	1.0	2.54	90	8.35	21.2
25	1.3	3.3	100	9.6	24.4
30	1.625	4.1	110	10.75	27.3
35	2.0	5.1	120	11.85	30.1
40	2.45	6.2	130	12.95	32.9
45	2.95	7.5	140	13.95	35.4
50	3.55	9.0	150	15.0	38.1

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