

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Electric traction – Rotating electrical machines for rail and road vehicles –
Part 1: Machines other than electronic converter-fed alternating current motors**

**Traction électrique – Machines électriques tournantes des véhicules ferroviaires
et routiers –
Partie 1: Machines autres que les moteurs à courant alternatif alimentés par
convertisseur électronique**



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**ELECTRIC TRACTION –
ROTATING ELECTRICAL MACHINES
FOR RAIL AND ROAD VEHICLES –****Part 1: Machines other than electronic converter-fed
alternating current motors**

FOREWORD

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International Standard IEC 60349-1 has been prepared by IEC technical committee 9: Electrical equipment and systems for railways.

This second edition cancels and replaces the first edition, published in 1999, and its amendment 1 (2002) of which it constitutes a technical revision.

The main technical changes with regard to the previous edition are as follows:

- As the limits of vibration velocities have been changed in IEC 60034-14, the limits valid for traction motors are now directly stated in this standard.
- In addition to the existing method for measuring and calculating the sound power level, the methods described in ISO 3741, ISO 3743, ISO 3744, ISO 3745 and ISO 9614 are also allowed. However the maximum sound power levels and the correction for pure tones remain unchanged in Clauses C.7 and C.8.

The text of this standard is based on the following documents:

FDIS	Report on voting
9/1415/FDIS	9/1465/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The list of all parts of IEC 60349 series, published under the general title, *Electric traction – Rotating electrical machines for rail and road vehicles*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

ELECTRIC TRACTION – ROTATING ELECTRICAL MACHINES FOR RAIL AND ROAD VEHICLES –

Part 1: Machines other than electronic converter-fed alternating current motors

1 Scope and object

This part of IEC 60349 is applicable to rotating electrical machines, other than electronic converter-fed alternating current motors, forming part of the equipment of electrically propelled rail and road vehicles. The vehicles may obtain power either from an external supply or from an internal source.

The object of this standard is to enable the performance of a machine to be confirmed by tests and to provide a basis for assessment of its suitability for a specified duty and for comparison with other machines.

Where further testing is to be undertaken in accordance with IEC 61377-2, it may be preferable, to avoid duplication, that some type and investigation tests be carried out on the combined test bed.

NOTE 1 This standard also applies to machines installed on trailers hauled by electrically propelled vehicles.

NOTE 2 The basic requirements of this standard may be applied to rotating electrical machines for special purpose vehicles such as mine locomotives, but it does not cover flameproof or other special features that may be required.

NOTE 3 It is not intended that this standard should apply to machines on small road vehicles such as battery-fed delivery vehicles, works trucks, etc. Neither does it apply to minor machines such as windscreen wiper motors, etc. that may be used on all types of vehicles.

NOTE 4 Industrial type machines complying with the IEC 60034 series may be suitable for certain auxiliary applications.

Electrical inputs or outputs of machines covered by this standard may be as follows:

- a) direct current (including rectified polyphase alternating current);
- b) pulsating current (rectified single-phase alternating current);
- c) unidirectional chopper-controlled current;
- d) single-phase alternating current;
- e) polyphase alternating current (in general three-phase).

In this standard, the electrical machines concerned are classified as follows.

- 1) Traction motors – Motors for propelling rail or road vehicles.
- 2) Engine-driven main generators – Generators for supplying power to traction motors on the same vehicle or train.
- 3) Main motor-generator sets – Machines obtaining power from a line or battery, and supplying power to traction motors on the same vehicle or train.
- 4) Auxiliary motors – Motors for driving compressors, fans, auxiliary generators or other auxiliary machines.
- 5) Auxiliary generators – Generators for supplying power for auxiliary services such as air conditioning, heating, lighting, battery charging, etc.

- 6) Auxiliary motor-generator sets and auxiliary rotary converters – Machines which obtain their power from the line or other source to provide an electrical supply for auxiliary services.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60034-1, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60034-8, *Rotating electrical machines – Part 8: Terminal markings and direction of rotation*

IEC 60085, *Thermal evaluation and designation*

IEC 60638, *Criteria for assessing and coding of the commutation of rotating electrical machines for traction*

IEC 62498-1, *Railway applications – Environmental conditions for equipment – Part 1: Equipment on board rolling stock*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-131, IEC 60050-151, IEC 60050-411 and IEC 60050-811, as well as the following apply.

3.1

rating of a machine

combination of simultaneous values of electrical and mechanical quantities, with their duration and sequence, assigned to a machine by the manufacturer

3.1.1

rated value

numerical value of any quantity included in a rating

NOTE For traction machines, certain special quantities are often included such as current ripple factor for a pulsating current motor, excitation condition for a variable field motor, etc.

3.1.2

continuous rating

electrical load the machine can withstand on the test bed for an unlimited period under the conditions specified in 8.1 without exceeding the limits of temperature rise given in Table 2, all other appropriate requirements in this standard also being satisfied

3.1.2.1

continuous ratings of an engine-driven main generator

an engine-driven main generator normally has two continuous ratings which are defined below:

- a) continuous rating "at lower voltage"

continuous rating determined by the temperature rise of the windings through which the load current flows (higher value of load current and lower voltage)

- b) continuous rating "at higher voltage"

continuous rating determined by the temperature rise of the field windings (lower value of load current and higher voltage)

NOTE 1 These two continuous ratings correspond to points on the full power regulated characteristic as defined in 3.8.2 or on the inherent characteristic as defined in 3.8.3.

NOTE 2 Ratings similar to those specified above may, where appropriate, be applied to a main motor-generator set.

3.1.3

short-time (for example, 1 h) rating

electrical load that a machine can withstand on the test bed for the stated time without exceeding the limits of temperature rise given in Table 2, the test being carried out as specified in 8.1 starting with the machine cold (see Clause A.1), all other appropriate requirements in this standard also being satisfied

3.1.4

short-time overload rating

electrical load that a machine can withstand on the test bed for the stated time without exceeding the limits of temperature rise given in Table 3 (the test being started and carried out as specified in Annex A)

NOTE Short-time overload ratings are of value in determining the suitability of machines for duties which involve relatively long periods of operation below the continuous rating followed by a period above it. These are most likely to occur in locomotive applications. They are not relevant to the repeated short-load cycles of rapid transit and similar duties and should not be specified for such applications.

3.1.5

intermittent duty rating

electrical loads and conditions at which a machine may be operated on a duty cycle without the temperature rises at any point in the cycle exceeding the limits given in Table 2

3.1.6

equivalent rating

continuous rating with constant values of voltage, current and speed that, as far as temperature rise is concerned, is equivalent to a long series of the intermittent duty cycles which the machine has to withstand in service

NOTE This rating should be agreed between user and manufacturer.

3.1.7

guaranteed rating

rating guaranteed by the manufacturer

3.1.7.1

guaranteed rating of a traction motor

the guaranteed rating is normally a continuous rating, but in special cases the manufacturer and user may agree that it is a short-time or intermittent rating

3.1.7.2

guaranteed ratings of an engine-driven main generator

the guaranteed ratings are normally the two continuous ratings defined in 3.1.2, but in special cases, the manufacturer and user may agree that they are short-time or intermittent ratings

3.1.7.3

guaranteed ratings of a main motor-generator set

the guaranteed ratings are normally the continuous rating, but in special cases, the manufacturer and user may agree that they are short-time or intermittent ratings

3.1.7.4

guaranteed rating of an auxiliary machine

unless otherwise specified, the guaranteed rating is the continuous rating

3.2

rated voltage

specified value of the voltage at the terminals of the machine when operating at a rating. If unidirectional, the voltage is the arithmetic mean of the recurring waveform and if alternating it is the root mean square value of the fundamental frequency component of the recurring waveform

NOTE In the case of a machine with a protective resistor permanently in series, the resistor is considered as an integral part of the machine.

3.2.1

rated voltage of a motor fed directly or indirectly from a contact system (including motors of motor-generator sets)

highest value of voltage (excluding transients) which can appear at the motor terminals when it is drawing its rated current with the contact system at its nominal voltage as defined in Annex D

NOTE 1 In some cases, it may be necessary to assign ratings at other than the above voltage in order to fully define the performance of a machine, an example being a motor-generator set giving constant power output over a range of input voltages

NOTE 2 If, in the case of an indirectly fed motor, the regulation characteristic of the transformer or other device is not specified, the rated voltage is taken as 90 % of the open-circuit value

3.2.2

rated voltage of a motor fed from a generator or battery located on the vehicle

3.2.2.1

traction motors

rated voltage corresponding to the maximum voltage of the source when supplying the motor at its rated current

3.2.2.2

auxiliary motors

rated voltage corresponding to the nominal voltage of the auxiliary supply (see note to 3.2.4)

3.2.3

rated voltages of a main generator

two rated voltages corresponding to the two continuous ratings defined in 3.1.2

3.2.4

rated voltage of an auxiliary generator (including generators of auxiliary motor-generator sets or rotary converters)

voltage corresponding to the nominal voltage of the auxiliary supply

NOTE The nominal voltage of the auxiliary supply should normally be agreed between the manufacturer and the user, taking into account factors (such as standardization with other vehicles), which may influence the choice.

3.3

rated speed of a machine

speed at a guaranteed rating of the machine

3.3.1

rated speed of an engine-driven main or auxiliary generator

speed of the generator corresponding to the rated speed of the engine

3.3.2

rated speed of an axle-driven generator

speed agreed between the manufacturer and the user

3.4 maximum (or minimum) voltage

3.4.1 maximum (or minimum) voltage of a machine

highest (or lowest) voltage which the machine will be called upon to withstand in service, transient voltages being excluded. Also excluded is any reduction in the minimum voltage by control means during starting or acceleration

NOTE Unless otherwise agreed the maximum voltage of an auxiliary machine connected in series with other machines without mechanical coupling is taken as 1,2 times the highest voltage of the supply to the machines divided by the number in series.

3.4.2 maximum and minimum voltage of a machine supplied directly or indirectly from a contact system

voltages normally corresponding to the highest and lowest voltages of the traction system (see Annex D), account being taken of the regulation of any transformer or control equipment interposed between the line and the machine

3.5 maximum current

maximum value of current shown on the characteristic curve supplied by the manufacturer

3.6 maximum working speed

3.6.1 maximum working speed of a traction motor

highest rotational speed assigned to the traction motor by the manufacturer

NOTE When the characteristics of the vehicle for which the motor is intended are specified, this speed should be not less than that corresponding to the maximum service speed of the vehicle, assuming fully worn metal wheels or the minimum rolling diameter of rubber types.

3.6.2 maximum working speed of an engine-driven main or auxiliary generator

generator speed corresponding to the maximum governed speed of the engine for the particular application

NOTE This will normally be the maximum governed speed on "no-load". Transient speed variations during load changes should be disregarded.

3.6.3 maximum working speed of a generator with a rotational speed proportional to the speed of the vehicle

highest rotational speed assigned to the generator by the manufacturer. See note in 3.6.1

3.6.4 maximum working speed of a main or auxiliary motor-generator set, an auxiliary converter or an auxiliary motor

highest rotational speed assigned to the machine by the manufacturer

NOTE For specific applications account should be taken, when assigning this maximum speed, of the most unfavourable conditions of voltage, excitation, frequency, loading, etc., that can occur in service.

3.7 output and input power of electrical machines and heat engines

3.7.1 output power of a motor

mechanical output power available at the motor shaft, expressed in kilowatts (kW)

3.7.2

maximum service output power of a heat engine

maximum output power assigned to a heat engine for a particular application

3.7.3

available input power to a main generator

input power converted to electricity to supply the traction motors and other loads, such as train heating, connected to it

NOTE 1 It is used to derive the ratings and characteristics of the generator.

NOTE 2 The maximum available input power to a main generator is the maximum service output power of the heat engine, less the power it provides to drive, either directly or indirectly, the engine cooling equipment and vehicle auxiliaries, assuming these are operating at their minimum input power for the given condition.

NOTE 3 The available input power is not necessarily absorbed by the main generator over its whole working current range.

3.8

main generator characteristics

3.8.1

regulated characteristic

characteristic obtained if the power demand of a main generator is regulated to absorb the available input power, the product of current and voltage remaining substantially constant between the limits of regulation

3.8.2

full power regulated characteristic

regulated characteristic corresponding to the maximum available input power

3.8.3

inherent characteristic

characteristic of a generator designed to operate without load regulating equipment to match its power demand to the available engine output power

3.9

effective field ratio of a series motor

ratio of the actual field ampere-turns to the maximum obtainable at the same armature current

NOTE 1 A series motor is said to be

- in full field when the field current is equal to the armature current;
- in maximum field when the effective field ratio is the maximum used in service;
- in weak field when the effective field ratio is below the maximum;
- in minimum field when the effective field ratio is the minimum used in service.

NOTE 2 For motors without permanent shunts across the field windings, full field and maximum field are the same.

3.10

effective resistance of a series motor

resistance value which, when multiplied by the load current, gives the total resistive voltage drop in the machine windings, i.e. it takes account of any shunt across the field windings

3.11

ripple factor

ripple factor of a continuous pulsating current is defined as:

$$\frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}} \times 100$$

expressed as a percentage in which $I_{\max}$ and $I_{\min}$ are respectively the maximum and the minimum values of the current waveform

NOTE This is in accordance with IEC 61287-1.

3.12

pulsating frequency

frequency of the fundamental alternating component of a pulsating current or voltage

3.13

pulse control

control of the power supply to a machine by varying the starting and terminating points of repeated pulses of voltage or current

NOTE Pulse control devices include, but are not limited to, choppers, inverters and electronically controlled rectifiers.

4 Environmental conditions

Unless otherwise specified by the user, the following environmental conditions are assumed:

a) Altitude

Height above sea level: Class A3 according IEC 62498-1.

b) Temperature

Temperature in the shade: Class T1 according IEC 62498-1.

Whenever the machines are intended to operate where one or both of these limits will be exceeded, special requirements may be agreed between user and manufacturer. For more information refer to IEC 60034-1.

The manufacturer shall be informed by the user of any particularly arduous conditions such as dust, humidity, temperature, snow, dynamic effects, etc. under which the machines are intended to work.

5 Characteristics

5.1 General

Machine specifications shall, as a general rule, include characteristic curves in accordance with the following subclauses. These curves, defined as the "specified characteristics", shall be plotted up to the designed operating limits of each variable.

When the first few machines of a type have been tested, "declared characteristics" shall be produced from the results in accordance with 8.2.

Unless otherwise agreed, the declared characteristics of machines electromagnetically identical with any previously manufactured for the same user or application shall be those of the existing machines, in which case compliance with the characteristics shall be demonstrated by routine tests only.

5.2 Reference temperature

All characteristics, irrespective of the thermal class of insulation system used on the machine to which they apply, shall be drawn for a winding reference temperature of 150 °C which shall be stated on the characteristics.

5.3 Efficiency characteristics

Efficiency characteristics shall take account of losses in external resistances normally included in either the main or excitation circuits. Any power used in providing separate excitation shall be included in the losses unless otherwise accounted for (e.g. as an auxiliary load), in which case the omission shall be stated.

5.4 Commutator type traction motor characteristics

The characteristic curves shall normally show motor speed, torque and efficiency as a function of current. Alternatively the curves may show vehicle speed and tractive effort at the rail as a function of current, in which case the gear ratio, wheel diameter and transmission losses shall be stated. If conventional values are used for the latter, they shall be in accordance with Figure B.10.

Curves shall be drawn for each excitation condition employed on the application except that where continuously variable field control is employed, only the maximum and minimum curves need be drawn. The effective machine resistance for each effective field ratio shall be stated.

The characteristic curves of traction motors supplied directly or indirectly from a contact system, or from a battery located on the vehicle, shall be drawn at the rated voltage, except when the circuit includes equipment (such as a transformer or inductor) which introduces a current-dependent voltage drop at the motor terminals. For these exceptions, the curves shall be drawn for a motor voltage corresponding to the nominal supply voltage and a motor voltage current curve shall be included in the characteristics. If this information is not available, the curves may be drawn for the rated voltage.

The characteristic curves of traction motors used on thermo-electric vehicles shall normally be drawn for a voltage corresponding to the lower voltage of the generator at its continuous rating, but they may, by agreement, be drawn for other voltages.

The characteristic curves of a.c. commutator motors shall be plotted for the rated frequency and shall show the power factor as a function of current.

In the case of motors used for rheostatic or regenerative braking, the characteristics shall show the performance in this mode. Unless otherwise agreed, regenerative braking characteristics shall be drawn for a motor voltage corresponding to 1,1 times the nominal system voltage.

The declared braking characteristics may be derived either by calculation from the results of motoring tests or directly from tests in the braking mode.

5.5 Main generator characteristics

The characteristic curves shall show voltage as a function of load current. In the case of an a.c. generator intended to operate with a rectifier, the characteristics shall also show the output of the rectifier. A brushless alternator and its exciter shall be regarded as a single machine.

Characteristic curves shall be drawn corresponding to the generator input power available for traction at maximum and minimum engine speeds, and if the engine has a number of predetermined intermediate speed notches, additional curves shall be drawn for a sufficient number of these speeds to adequately show the performance of the generator.

Each curve shall be identified with its excitation condition, input power, generator speed and, if applicable, notch number. In addition, the efficiency on the full power characteristic shall be shown for at least two continuous ratings.

NOTE See 5.3 concerning the inclusion of excitation power in the losses when determining the efficiency.

Similar characteristics shall be drawn for the generators of main motor-generator sets, due account being taken of the characteristics of the driving motor and regulating equipment.

5.6 Auxiliary motor characteristics

Characteristic curves of speed, torque (or output power), efficiency and, in the case of a.c. machines, power factor shall be plotted as a function of motor current at the rated voltage and frequency.

Alternatively, and through agreement between the manufacturer and user, the characteristics may be plotted as a function of speed or output power.

Curves shall be drawn for each excitation condition employed in the application.

5.7 Auxiliary generator characteristics

The characteristic curves of output voltage, power and efficiency shall be plotted as a function of output current at the rated speed and, for variable speed machines, at the minimum and maximum speeds for the application. The frequency of a.c. outputs shall be stated.

In the case of generators operating with a voltage regulator the characteristics shall be plotted at the nominal voltage and the range of excitation current stated.

A brushless alternator and its exciter shall be regarded as a single machine.

5.8 Auxiliary motor-generator set and rotary converter characteristics

The characteristic curves of output voltage, output power, machine speed, and input current shall be plotted as a function of output current with the machine supplied at minimum, rated and maximum voltage. The overall efficiency at the continuous rating shall be stated. The characteristics of a.c. machines shall show the power factor.

In the case of machines operating with a voltage or frequency regulator, the characteristics shall be drawn with the voltage or frequency at its nominal value. The range of excitation current shall be stated.

If the machine drives an external load, such as a blower, the power absorbed by this external load shall be shown or stated and the statement of overall efficiency shall be replaced by one of the total input power to the machine at the continuous rating.

6 Marking

6.1 Nameplate

All the machines covered by this part of IEC 60349 shall carry a nameplate visible when the machine is on the workshop floor. It shall include at least the following information:

- a) manufacturer's name;
- b) machine type designation;
- c) machine serial number;
- d) year of manufacture.

The machine serial number and, if applicable, rotation arrow, shall also be easily read when the machine is installed in the vehicle.

A serial number, or unique identification number, shall be punched on both the rotor and the stator of each machine.

6.2 Terminal and lead markings

Terminal and lead markings shall be in accordance with IEC 60034-8, unless otherwise agreed.

7 Test categories and summary of tests

7.1 Test categories

7.1.1 General

There are three categories of tests:

- type tests;
- routine tests;
- investigation tests.

7.1.2 Type tests

Type tests are intended to establish the ratings, characteristics and performance of new types of machine. Where there is a change in place and/or method of manufacture, the user and manufacturer shall agree upon type tests to be repeated. In addition, tests to establish the declared characteristics shall be carried out on further machines in accordance with 8.2.

Unless otherwise agreed, the fully tested machine shall be one of the first ten manufactured.

A machine may be exempted from type tests if the manufacturer produces a record, acceptable to the user, of type tests already carried out on a machine of the same electromagnetic design for the same environmental conditions and at the same ratings.

Before testing commences the manufacturer shall provide the user with a test specification outlining the tests to be undertaken to demonstrate compliance with this standard. Following completion of the type tests the manufacturer shall supply the user with a full type test report.

By agreement between manufacturer and user, more machines may be fully or partially type tested at intervals.

Type tested machines shall also be routine tested.

7.1.3 Routine tests

Routine tests are intended to demonstrate that each machine is sound both electrically and mechanically, and that it is essentially identical with the machine which has been type tested.

Routine tests as specified in Clause 9 shall normally be carried out on all machines but alternative tests may be agreed between user and manufacturer. It may also be agreed that only a proportion of machines chosen at random from those built on the order shall be fully routine tested, subject to overspeed and dielectric tests in accordance with 9.4 and 9.5 being carried out on all machines.

7.1.4 Investigation tests

Investigation tests are optional special tests performed to obtain additional information. They shall be carried out only if agreement between user and manufacturer has been reached

before placing the order. The results of these tests shall not influence the acceptance of a machine unless agreement to the contrary has been similarly reached.

7.2 Summary of tests

Table 1 lists the tests required for compliance with this standard.

Table 1 – Summary of tests

Class of machine machine (subclause 1.3)	Test	Tem- perature rise	Sound- ness	Characteristics		Commutation		Transient	Starting	Noise	Overspeed		Dielectric	Vibration		Commu- tator run-out	
		Type	Routine	Type	Routine	Type	Routine	Type	Type	Type	Type	Type	Type	Imbalance			
	Test category (subclause 7.1)															Optional	Routine
	Clause or subclause																
Traction motors (1.3.1)	Commutator	8.1	9.1	8.2.2	9.2.2	8.3.2	9.3.2	8.4.2*	8.6.2*	Annex C	NA	9.4.2	9.5	8.8	9.6	9.7	
	Wound rotor	8.1	9.1	8.2.3	9.2.3	NA	NA	NA	NA		NA	9.4.2	9.5	8.8	9.6	9.7	
	Cage rotor	8.1	NA	8.2.3	9.2.3	NA	NA	NA	NA		8.7	NA	9.5	9.5	8.8	9.6	9.7
Main Generators (1.3.2)	DC	8.1	9.1	8.2.3	9.2.3	8.3.3	9.3.3	NA	NA	Annex C	NA	9.4.3	9.5	8.8	9.6	9.7	
	AC	8.1	9.1	8.2.3	9.2.3/4	NA	NA	8.5	NA		NA	9.4.3	9.5	8.8	9.6	NA	
Main motor- generator sets (1.3.3)	Motor	8.1	9.1	8.2.2	9.2.2	8.3.2*	9.3.2*	8.4.2*	8.6.3	Annex C	NA	9.4.5	9.5	8.8	9.6	9.7*	
	Generator	8.1	9.1	8.2.3	9.2.3	8.3.3*	9.3.3*	8.5	NA		NA	9.4.5	9.5	8.8	9.6	9.7*	
Auxiliary motors (1.3.4)	Commutator	8.1	9.1	8.2.4	9.2.5	8.3.4	9.3.4	8.4.3/4*	8.6.4	Annex C	NA	9.4.5	9.5	8.8	9.6	9.7	
	Wound rotor	8.1	9.1	8.2.4	9.2.5	NA	NA	NA	8.6.4		NA	9.4.5	9.5	8.8	9.6	NA	
	Cage rotor	8.1	9.1	8.2.4	9.2.5	NA	NA	NA	8.6.4		8.7	NA	9.5	9.5	8.8	9.6	NA
Auxiliary generators (1.3.5)	DC	8.1	9.1	8.2.5	9.2.6	8.3.4	9.3.4	NA	NA	Annex C	NA	9.4.5	9.5	8.8	9.6	9.7	
	AC	8.1	9.1	8.2.5	9.2.6	NA	NA	8.5	NA		NA	9.4.5	9.5	8.8	9.6	NA	
Auxiliary motor- generator sets Rotary converters (1.3.6)	Motor	8.1	9.1	8.2.6	9.2.7	8.3.4*	9.3.4*	8.4.3/4	8.6.4	Annex C	NA	9.4.5	9.5	8.8	9.6	9.7*	
	Generator	8.1	9.1	8.2.6	9.2.7	8.3.4*	9.3.4*	8.5	NA		NA	9.4.5	9.5	8.8	9.6	9.7*	
NA = Not applicable.																	
* Not applicable to all machines in the class; refer to relevant clause.																	
All machines, including those type tested, are to be routine tested.																	

NA = Not applicable.

* Not applicable to all machines in the class; refer to relevant clause.

All machines, including those type tested, are to be routine tested.

8 Type tests

8.1 Temperature-rise tests

8.1.1 General

The tests shall be carried out at the guaranteed ratings except that the user and manufacturer may agree that main alternators be tested as follows:

- a) a test at the rated frequency with the terminals short-circuited and the excitation adjusted to give an output current deemed to produce practically the same stator winding temperature rise as would a load test at the continuous rating at lower voltage;
- b) a test at the rated frequency on open circuit with the excitation adjusted to the value specified for the continuous rating at higher voltage.

When the output of an alternator is rectified, it shall be type tested with its rectifier or with one having similar characteristics.

If one or more of the following conditions apply, the tests shall be carried out with voltage and current waveforms closely resembling those in service:

- 1) if the ripple factor of the load current in service exceeds 10 % of the guaranteed rating;
- 2) if the excitation is pulse controlled.

If it is not practicable to meet this requirement, a method taking into account the effect of the difference between the test and service supplies shall be agreed between user and manufacturer.

NOTE 1 In the case of machines operating on rectified single-phase alternating current at power frequency (50 Hz or 60 Hz) the tests may be carried out using the supply frequency of the place of manufacture whether or not this differs from that of the place of use, provided that the current ripple factor is not less than that in service. The error in the results will be negligible and correction will not be necessary.

NOTE 2 In the case of continuous rating tests, the time to attain steady temperatures may be shortened by commencing the tests at an increased load or reduced ventilation provided that the rated conditions are subsequently maintained for at least 2 h or until it is demonstrated by appropriate means that steady temperatures have been reached.

NOTE 3 Steady temperature is defined as a change in temperature rise of less than 2 K during the final hour of test.

NOTE 4 If the declared excitation current differs from the specified value, the tests have to be carried out with the declared value.

8.1.2 Ventilation during temperature-rise tests

Machines shall be tested with the ventilation arranged as in service with all those parts in place which would affect its temperature rise, including any ducting and filters regarded as part of the vehicle or with an arrangement giving equivalent conditions.

Where cooling is by forced ventilation, the static pressure and the air flow shall be measured at the air inlet of the machine so that a table giving the relationship between these two quantities may be drawn up.

In general, no cooling corresponding to that produced by the motion of the vehicle shall be provided, but in special cases, such as totally enclosed traction motors where this cooling is particularly important, it may be employed if agreed between manufacturer and user.

8.1.3 Judgement of results

The temperature rises of the windings, commutators or slip rings at the "commencement of cooling" shall not exceed the values given in Table 2.

8.1.4 Limits of temperature rise

The different thermal classes of insulating materials are defined in IEC 60085.

Table 2 gives the permissible limits of temperature rise, measured on the test-bed above the temperature of the cooling air, for windings and other parts insulated with materials of the thermal classes at present used in the construction of machines to which this standard applies.

If different parts of the same machine have different classes of insulation, the temperature-rise limit of each part shall be that of its individual class.

Table 2 – Limits of temperature rise for continuous or other ratings

Part of machine	Method of measurement	Thermal class of Insulation system,			
		130(B)	155(F)	180(H)	200
Stationary winding or rotating field windings of alternators or synchronous motors	Resistance	130 K	155 K	180 K	200 K
All other rotating windings	Resistance	120 K	140 K	160 K	180 K
Commutators or slip rings (see note)	Electrical thermometer	120 K	120 K	120 K	120 K
Cage rotors Damping windings	Electrical thermometer	The temperature rise shall not be sufficient to endanger any windings or other parts			

For totally enclosed machines, limits of Table 2 are increased by 10 K.

Where the machines are directly or indirectly exposed to the heat from an engine or from any other source, the adoption of temperature rises lower than those specified in Table 2 may be agreed between user and manufacturer.

NOTE Commutator temperature is only one of many factors affecting commutation and, whilst in general commutation improves with reduction in temperature, this is not invariably the case.

8.1.5 Short-time overload temperature-rise test

If short-time overload ratings are specified, they shall be verified by one or more tests carried out as follows.

At the conclusion of a previous rating test, the starting temperature rise given in Table 3 may be obtained by continuing to plot the cooling curve for the critical winding (see Note 1), until the time at which its temperature rise will reach the "start" value given in Table 3 (see Note 4) can be predicted by extrapolating the curve for a period not exceeding 5 min ahead of the last reading (see Notes 2 and 3). The specified overload shall be applied at this predicted time with normal ventilation conditions and shall be maintained for the specified duration, at which point the test shall be concluded and the temperature rise determined by resistance measurement in accordance with Clause A.5.

If the measured temperature rise is within 20 K of the final value given in Table 3, either the rated current or duration may be amended by calculation to a value estimated to give the Table 3 temperature rise.

If the measured temperature rise differs from the Table 3 value by more than 20 K, the test shall be repeated with amended values of either current or duration.

Table 3 – Temperature rise for short-time overload rating

Part of machine	Thermal class of Insulation			
	130(B)	155(F)	180(H)	200
Stationary windings or rotating field windings of alternators or synchronous motors – at start of test – final	85 K 130 K	100 K 155 K	120 K 180 K	130 K 200 K
All other rotating windings – at start of test – final	75 K 120 K	85 K 140 K	100 K 160 K	110 K 180 K

NOTE 1 The critical winding of commutator type machines is normally the armature. For polyphase machines it is normally the stator.

NOTE 2 If agreed between user and manufacturer, the temperature of other parts (e.g. the rotor cage, commutator, bearings, etc.) may be measured.

NOTE 3 For totally enclosed machines the temperature rises given in Table 3 should be increased by 10 K.

NOTE 4 An alternative method of obtaining the starting temperature rise may be employed if agreed between manufacturer and user.

8.2 Characteristic tests and tolerances

8.2.1 General

Tests to demonstrate compliance with the specified characteristics may be by any suitable method (examples being given in Annex B), load tests being carried out with the machine hot. Direct measurement of input and output shall be used only if measuring equipment of high accuracy is available. Efficiency values calculated from tests shall be corrected to the reference temperature, as shall other results if the correction is significant.

Characteristic tests on pulsating current machines may be carried out on d.c., in which case additional resistance losses due to pulsating current as given in Annex B shall be taken into account when calculating the efficiency.

Efficiency or loss tests are required only on those machines which are to be fully type tested as defined in 7.1.2.

Reversible machines shall be tested in both directions of rotation.

8.2.2 Commutator type traction motors

8.2.2.1 Sufficient test readings (for example four or five for each curve) shall be taken to enable declared characteristic curves corresponding to the specified characteristics to be plotted.

Declared speed/current curves shall be produced by plotting the average of the speeds of the first four machines tested. These averages shall not vary from the corresponding specified values by more than the design tolerances given in Table 4 and the speed of any individual machine shall not differ from the corresponding declared speed by more than the manufacturing tolerances listed in the same Table.

The declared torque/current curves shall be calculated from the speed/current curves using efficiency values derived from the type test.

NOTE 1 As stated in 5.4, declared braking characteristics may either be calculated from the declared motoring characteristics or be derived from tests in the braking mode. Braking characteristics are not tolerated, compliance of the machine with the specified basic electro-magnetic characteristics having been demonstrated in the motoring mode.

Table 4 – Tolerances on the speed of commutator type traction motors

Excitation condition or effective field ratio	Design tolerance %		Manufacturing tolerance %	
	Point Ch1	Point Ch2	Point Ch1	Point Ch2
Maximum	± 5	± 3	± 3,5	± 3
Between maximum and 50 %	± 6	± 4	± 5	± 3
Less than 50 %	± 7	± 5	± 7	± 5

Point Ch1 is the current shown on the relevant specified or declared curve at 80 % of the maximum working speed, or the minimum current shown if the speed at that point is less than 80 % of the maximum working speed (see Figure 1).

Point Ch2 is at 90 % of the maximum current shown on the relevant curve (see Figure 1).

Between these points the tolerances shall be linearly graded with respect to current.

Where the characteristics of a separately excited machine differ from Figure 1 such that Table 4 cannot be applied (for example a rising characteristic) the tolerance shall be agreed between manufacturer and user.

NOTE 2 Such a machine could be treated similarly to a main generator (see 8.2.3) in that the speed/current characteristic may be modified following the type test with the tolerance on speed for the routine test at the modified values. Any adjustment to the specified excitation should be within the capability of the control system and of the field winding guaranteed rating(s).

The tolerances shall be increased by 1 % in the case of motors with a guaranteed rated output below 75 kW.

The declared excitation currents of a separately excited motor and the effective field ratios of a series excited one may differ from the specified values provided they remain within the capacity of the excitation control equipment.

8.2.2.3 The losses at the guaranteed rating shall not exceed the value derived from the specified characteristic by more than 15 %.

NOTE When a conventional rather than a measured value is used for the transmission losses, the comparison between specified and declared losses should be based on the machine losses only.

8.2.3 Main generators (refer to Figure 2)

8.2.3.1 Alternators designed to operate with rectified output shall normally be tested with a suitable rectifier. A brushless alternator and its exciter shall be regarded as a single machine.

If it is not practicable to test main alternators at full power, suitable open-circuit and short-circuit tests shall be carried out to prove the characteristics and determine the efficiency by summation of losses method, in accordance with Annex B. The details of the tests shall be agreed between user and manufacturer.

8.2.3.2 In the case of a regulated generator, sufficient readings shall be taken to enable declared characteristic curves corresponding to the specified characteristics to be plotted directly from the readings or by calculation from the results of open-circuit and short-circuit tests. The curves shall be based on the average of tests on the first four machines.

At this stage the manufacturer shall be free to modify the excitation values, the new values being maintained for all subsequent tests. It shall also be demonstrated that the excitation

required to produce the declared characteristics is within the capacity of the regulating equipment.

The maximum current and the maximum voltage shown on the regulated portion of the full power declared characteristic (points Ch1 and Ch2) shall not vary from the corresponding values on the specified curves by more than $\pm 5\%$.

8.2.3.3 In the case of an inherent characteristic generator, sufficient readings shall be taken on the first four machines tested to enable the declared characteristics to be plotted as the average of the four results. The excitation values may be modified from those of the specified curves, but the revised values shall then be retained for all subsequent tests.

The declared maximum current, the voltage at the rated current and the open-circuit voltage (points Ch1, Ch2 and Ch3) shall not vary from the corresponding values on the specified curve by more than $\pm 5\%$.

8.2.3.4 For both regulated and inherent characteristic generators the losses at the two continuous ratings (defined in 3.1.2) shall not exceed the specified value by more than 15 %.

8.2.4 Auxiliary motors

Sufficient readings shall be taken on the first four machines tested to enable declared characteristic curves corresponding to the specified characteristics to be derived from the average of the readings.

In addition, declared speed and torque (or output) curves shall be determined at the maximum and minimum machine voltages if these differ by more than $\pm 5\%$ from the rated value.

The declared characteristic curves for current values between 0,8 and 1,2 times the guaranteed rating shall not differ from the specified characteristics by more than $\pm 5\%$.

The losses at the guaranteed rating shall not exceed the specified value by more than 15 %.

8.2.5 Auxiliary generators

Sufficient readings shall be taken on the first four machines tested to enable declared characteristic curves corresponding to the specified characteristics to be derived from the average of the readings. For machines operating with a voltage regulator, at least one of these tests shall be carried out with the regulator in circuit.

The declared output voltage of an unregulated generator shall not differ by more than $\pm 5\%$ from the specified characteristic at any point between open circuit and the guaranteed rating. The tolerance on the voltage of a regulated generator is a function of the regulator characteristics and not that of the machine. The excitation currents may differ from the specified values provided they remain within the capacity of the regulator.

The losses at the guaranteed rating shall not exceed the specified value by more than 15 %.

In addition, the open-circuit and short-circuit characteristics of alternators shall be measured at the rated speed and the average characteristics drawn to form the basis for routine test evaluation.

8.2.6 Auxiliary motor-generator sets and rotary converters

Sufficient readings shall be taken on the first four machines tested to enable declared characteristic curves corresponding to the specified characteristics to be derived from the average of the readings. In the case of regulated machines, at least one test shall be carried out with the regulators in circuit.

For unregulated machines, the declared output voltage characteristic shall not differ from the specified characteristic by more than $\pm 5\%$ at any point between open circuit and the rated current. Unless specified otherwise, the speed-current characteristic is not toleranced.

The tolerances on the voltage and frequency of a regulated machine are functions of the characteristics of the regulators and not those of the machine.

The exciting current of a regulated machine operating at any point on the declared characteristic shall be within the declared range. This may differ from the specified range provided the revised values are within the capacity of the regulator.

The losses of the machine at the guaranteed rating shall not exceed the specified value by more than 15 % except for machines driving an external load, in which case the input at the guaranteed rating shall not exceed the specified value by more than 5 %.

8.3 Commutation tests

8.3.1 General

Commutation test results shall be recorded in accordance with IEC 60638. The tests shall be withstood by the machines without mechanical deterioration, flashover or permanent damage, permanent damage being that which would affect the satisfactory operation of the machine after completion of the test.

The tests shall be carried out with the machine hot, each test point being held for not more than 30 s. If a machine shows signs of excessive heating following the test points at high current, it may be run for a period at low current to cool it to a more normal operating temperature.

Machines which operate with separate or compound excitation shall be tested with the appropriate excitation conditions for each point.

Machines shall be tested in each direction of rotation which occurs in service for the particular application. The brushes shall not be disturbed between tests in different directions of rotation.

The tests may be carried out in any desired sequence of currents and rotations. Whenever rotation is reversed, the machine may be run in the new direction for not more than 15 min at a current and speed chosen to achieve acceptable contact conditions between the brushes and the commutator.

Machines tested in one direction only shall have run for a sufficient time to ensure that the brushes are fully bedded in before each test point.

Alternating and pulsating current motors shall normally be tested at the rated frequency for a.c. motors, and at the service pulsation frequency and current ripple factor for pulsating current motors. In certain cases, the frequency may be altered in accordance with Note 1 to 8.1.1.

8.3.2 Traction motors (refer to Figure 1)

Commutation tests shall be made at the following points.

- Commutation point number 1 (Com1): at the maximum speed shown on the characteristic with the motor taking the highest current which can normally be drawn at this speed in service.
- Commutation point number 2 (Com2): at the guaranteed rating current.

- Commutation point number 3 (Com3): at the maximum current shown on the relevant curve.

Tests Com2 and Com3 shall be carried out at the maximum and minimum excitation used at these points in service.

The test voltage shall be chosen as follows:

- for motors supplied either directly or indirectly from a contact system:
 - the voltage corresponding to the highest voltage of the system;
- for motors for thermo-electric vehicles:
 - the voltage at the motor terminals when operating on the full power characteristic of the main generator;
- for motors supplied from a battery:
 - the voltage corresponding to the no-load voltage of a fully charged battery.

If, in carrying out tests Com2 and Com3 at the voltage specified above, the motor speed is higher than that for Com1, the voltage shall be reduced to give the latter speed.

If, in any of the above cases, the maximum voltage which can be applied to the motor is limited by control means, the tests shall be carried out at the limited voltage.

In addition, for series excited motors permanently connected in series without either mechanical coupling or automatic anti-slip protection, a commutation test shall be made at maximum field with the load current adjusted so that the motor runs at its maximum working speed when supplied at 1,5 times its rated voltage for a line or battery supplied motor, or at 1,5 times its maximum voltage for a thermo-electric vehicle motor.

NOTE Equipment which only indicates the presence of wheelslip and leaves corrective action to the driver is not sufficient to give exemption from the test.

Motors used for regenerative or rheostatic braking shall be tested at a reasonable number of values (for example four or five) of speed and current within the envelope of the braking characteristic curves.

If the regenerative or rheostatic braking circuit used in service is such that the unidirectional current ripple is greater than 10 %, commutation tests in the braking mode shall be carried out under conditions closely resembling those in service.

8.3.3 Main generators (refer to Figure 2)

Commutation tests shall be made at the following points on the full power characteristic as shown in Figure 2.

- Com1: the maximum current;
- Com2: the current at the continuous rating at lower voltage;
- Com3: the current at the unloading point or, for an unregulated generator, 50 % of the current for test Com2.

8.3.4 Auxiliary motors and generators and motor-generator sets

Commutation tests shall be carried out at not more than four points chosen to cover the whole extent of the machine characteristic at the maximum and minimum voltages as defined in 3.5.

8.4 Transient tests

8.4.1 General

Transient tests shall be carried out on d.c. and pulsating current motors supplied directly or indirectly from a contact system. They are not required if the supply to the machine includes electronic equipment which limits the current on re-connection after an interruption or following a voltage jump to a value not exceeding the maximum shown on the characteristic.

The machine shall withstand each test without mechanical deterioration, flashover or permanent damage, permanent damage being that which would prevent successful operation of the machine after the test.

It is recognized that for motors of high power, limitations of the test plant may prevent full compliance with the specified test procedure. In such cases, the manufacturer and the user shall agree on a modified procedure.

8.4.2 Traction motors and motors of main motor-generator sets

The test shall be made using a manual or automatic switch to interrupt the supply from the contact system when the motor is taking its guaranteed rated current followed by reconnection about 1 s after switching off.

If the normal circuit includes an automatic device to insert resistance or otherwise protect against excessive current on reconnection, the test shall be carried out with this device in circuit, or with a time interval equal to the operating time of the device.

The speed of rotation of the motor shall be maintained as constant as possible during the period of interruption.

If field weakening is effected by a single method (field diversion, tap changing or, in the case of separate excitation, regulation of current), the test shall be carried out three times at maximum field and three times at minimum field, at intervals of a few minutes, using field weakening devices identical or equivalent to those employed in service.

If, however, field weakening is obtained on some notches by one method and on other notches by a different one, the test shall be carried out three times at the maximum excitation and three times at the minimum excitation of each of the field weakening methods.

It shall be confirmed by a suitable transient recorder that at the instant of re-connection the motor terminal voltage (or, if an inductor is permanently connected in series with the motor, the voltage across the motor and inductor) is at least that corresponding to the highest system voltage, and that the voltage does not subsequently fall below 0,9 times the value corresponding to the nominal system voltage.

8.4.3 Auxiliary motors, auxiliary motor-generator sets and auxiliary rotary converters

The tests shall be carried out with the motor equipped with control and protective gear simulating the normal service conditions. In the case of a motor-generator set the circuit shall include the voltage and frequency regulators.

The supply shall be interrupted and restored four times in succession, allowing the normal load conditions to be re-established between successive interruptions, the motor operating at its guaranteed rating with the weakest field that can be obtained at this point in service. Two tests shall be made with an interval of approximately 1 s between interruption and restoration and two with an interval marginally less than the operating time of the protective equipment. The supply voltage conditions shall be as defined in 8.4.2.

In the case of machines which can feed back into the main circuits of the vehicle during interruptions of supply, this condition shall be simulated by short-circuiting the machine during the interruption, or by other suitable means. This is not required if the normal circuit includes means (such as a diode), to positively prevent feedback.

8.4.4 Voltage jump test on auxiliary motors, auxiliary motor-generator sets and auxiliary rotary converters

The machine shall be supplied at its minimum voltage through a series resistance which, when short-circuited, will cause the voltage to rise to the maximum value. The machine's normal control and protective gear, including the generator voltage regulator, shall also be in the circuit.

The test shall be carried out five times in succession, the minimum voltage conditions being restored between each voltage jump. It shall be confirmed by a transient recorder that the supply voltage, after the resistance is short-circuited, does not fall below that corresponding to the nominal system voltage.

Auxiliary motors driving mechanical loads shall be tested at the load normally imposed on the motor when operating at minimum voltage and field.

Motor-generator sets shall be tested with the generator delivering its guaranteed rated power or the maximum power it is capable of supplying at the minimum input voltage if this is less than the guaranteed rating.

8.5 Short-circuit tests on main and auxiliary alternators

Main and auxiliary alternators shall be subjected to tests which simulate fault conditions, using a test circuit which includes the protection and means of excitation provided in service or their equivalents.

Each test shall consist of a short circuit applied for 5 s with the machine operating at its rated speed on open circuit with the guaranteed rated value of excitation current.

At the conclusion of each test, it shall be shown that the protection has operated and that the machine has suffered no electrical or mechanical damage.

The short circuit shall be applied as follows:

- alternators supplying a mainly rectified output:
one test shall be made with the full rectifier bridge short-circuited and another with one bridge arm short-circuited;
- alternators supplying mainly a.c. loads:
one test shall be made with all phases short-circuited together and another with a single line-to-line short circuit or, in the case of a system with solidly earthed neutral, a single line-to-neutral short circuit.

8.6 Starting tests

8.6.1 General

The following types of machine shall be subjected to starting tests:

- a) single-phase a.c. commutator motors intended for driving locomotives and other vehicles intended for similar haulage duties;
- b) main motor-generator sets;
- c) auxiliary motors, auxiliary motor-generator sets and auxiliary rotary converters.

8.6.2 Single-phase a.c. locomotive motors

Unless otherwise agreed when placing the order, the motor shall be run at its maximum current for 1 min when hot. The power supply shall be at the rated frequency with the voltage adjusted so that the motor rotates at about 5 % of its maximum working speed. The ventilation shall be equivalent to that when in service.

The test shall be carried out in both directions of rotation and shall not cause any permanent damage to the commutator, permanent damage being defined as that which would affect the subsequent satisfactory operation of the machine.

8.6.3 Main motor-generator sets

The tests shall be carried out with the normal starting and protective gear and, in the case of a.c. motors, at the rated frequency.

Machines intended to operate on pulsating current or with pulse control shall be tested with supply conditions closely resembling those in service.

The motor shall be subjected to two successive starts at minimum voltage followed by two at maximum voltage with a 5 min interval between each start. It shall be loaded so that the torque developed is approximately the same as when starting under service conditions.

The starting performance shall be satisfactory with no excessive temperature rise of any part of the machine, flashover or permanent damage to the commutator. During the tests at maximum voltage the machine voltage shall not fall below 0,9 times the maximum value as defined in 3.4. If test plant limitations prevent this being attained the manufacturer and the user may agree on an alternative procedure.

8.6.4 Auxiliary motors, auxiliary motor-generator sets and auxiliary rotary converters

The tests shall be carried out with the normal starting and protective gear and, in the case of a.c. motors, at the rated frequency.

Machines intended to operate on pulsating current or with pulse control shall be tested with supply conditions closely resembling those in service.

The motor shall be subjected to five successive starts at minimum voltage followed by five at maximum voltage with an interval of 2 min between starts. It shall be loaded so that the torque developed is approximately the same as when starting under service conditions.

The performance and supply capacities shall be as specified in 8.6.3.

8.7 Overspeed tests

Unless agreed otherwise, overspeed tests are type tests only on machines other than commutator and wound rotor machines. Details of the tests are given in 9.4.

8.8 Vibration tests

8.8.1 Internally generated vibration characteristics

A quantitative vibration measurement is to be taken as a type test.

For vibration measurement during type test the machine can simply be placed on the test board without any mounting equipment. The velocity of vibration at machine speeds up to 3 600 rev/min shall be within the limit of 3,5 mm/s. For speed above 3 600 rev/min the velocity shall be less than 5,25 mm/s.

If the machine design has no fixed bearing the longitudinal velocity of vibration could be excluded.

For additional information see IEC 60034-14.

Measurements on variable speed machines shall be taken at a number of speeds covering the whole working range.

Vibration velocities in excess of the limiting values may arise from the resonances in the test mountings, in which case they shall be disregarded provided that they do not coincide with a discrete working speed and that the general level of velocity over the speed range is within limits.

Should such a resonance occur at a discrete working speed the test shall be repeated with an alternative mounting arrangement.

NOTE The effect of externally generated vibrations on the machine is outside the scope of this standard. Reference should be made to IEC 61373.

9 Routine tests

9.1 Short-time soundness test

9.1.1 General

A short-time soundness test shall be carried out on all machines except those with cage-type rotors.

9.1.2 Test conditions

The machine shall be run on load, normally for 1 h starting cold, the test conditions (voltage, current, excitation and ventilation) being chosen to give final winding temperature rises reasonably close to those obtained at the end of the guaranteed rating type test.

Motors which operate in service on pulsating current shall be tested on direct current.

AC generators may be tested on short circuit. If the output of an a.c. generator is to be rectified, the test may be carried out without the rectifier.

Machines may be tested in pairs, one acting as a motor and the other as a generator.

The method of measuring temperature and resistance shall be in accordance with Annex A, except that the plotting of heating and cooling curves shall be as detailed in 9.1.3.

9.1.3 Plotting of heating and cooling curves

Heating or cooling curves shall be plotted as for the type test on the first ten machines of an order. The curves for each winding of the first four machines tested shall be averaged to provide a temporary basis for acceptance or rejection of further machines until ten have been tested. The "declared heating or cooling curve" for each winding shall then be the average of the ten tests.

If machines are tested in pairs, separate averages shall be established for generators and motors.

On subsequent tests, a single resistance value or temperature measurement normally taken within 1 min of the commencement of cooling is sufficient. The time at which this reading is

taken shall be recorded to enable the result to be compared with the corresponding declared curve and may be extended beyond 1 min in accordance with Clause A.4.

9.1.4 Judgement of results

A machine will be deemed to have passed the routine soundness test if the temperature rises, at the recorded time from the commencement of cooling, do not vary from the declared curve values as defined in 9.1.3 by more than $\pm 8\%$ or $\pm 10\text{ K}$, whichever is the greater.

NOTE If the declared curve temperature rises have been established close to the limits given in Table 2, it is possible, and acceptable, for the results of individual routine tests to exceed these limiting values.

If a machine exceeds the declared curve temperature rise by more than the permitted amount, it may be given a type test at its guaranteed rating and shall be accepted if it passes that test.

Within an order, variation in material quality within permitted limits may cause a noticeable drift in average temperature rises. Should this result in frequent failure to pass the routine tests despite successful performance on subsequent type tests, a new declared curve may be established which shall not be more than 5 % higher than the previous one.

9.2 Characteristic tests and tolerances

9.2.1 General

The tests may be carried out by any suitable method with the machine hot. The readings need not be corrected to the temperature of reference unless not so doing would result in the machine being rejected.

Efficiency tests are not required, nor are tests in the braking mode.

Machines which operate, in service, on pulsating current shall be tested on direct current and machines intended for a synthesized polyphase supply shall be tested on sinusoidal alternating current.

Reversible machines shall be tested in both directions of rotation.

9.2.2 Commutator type traction motors (see Figure 1)

Speed readings shall be taken at points Ch1 and Ch2 for the maximum and minimum excitation conditions. In the case of separately excited motors, curves shall be drawn for constant excitation and a reading at point Ch2 only is sufficient.

The speeds shall not vary from the declared values by more than the manufacturing tolerances given in Table 4.

9.2.3 Main generators (refer to Figure 2)

In the case of a regulated generator, readings shall be taken at the following points on the full power regulated curve with the separate excitation currents at the corresponding values established by the type test:

- Ch1: at the maximum current on the regulated portion of the declared characteristic;
- Ch2: at the maximum voltage on the regulated portion of the declared characteristic.

The maximum current and maximum voltage shall not vary from the corresponding values on the declared curve by more than $\pm 5\%$.

NOTE If the maximum current shown on the declared characteristic is on the regulated portion of the characteristic, the tolerance on current does not apply, it being sufficient to demonstrate that the excitation current is within the declared limits at the maximum load current.

In the case of an inherent characteristic generator, readings shall be taken at the following three points on the highest power curve:

- Ch1: the voltage corresponding to maximum current;
- Ch2: the rated current at lower voltage;
- Ch3: open circuit.

The maximum current at point Ch1 and the voltages at points Ch2 and Ch3 shall not vary from the declared values by more than $\pm 5\%$.

9.2.4 Alternative tests for alternators

These shall consist of open-circuit and short-circuit tests.

The open-circuit voltage and short-circuit current shall not vary from the values established during type testing by more than $\pm 5\%$.

9.2.5 Auxiliary motors

The speed of commutator type machines shall be measured at the guaranteed rating with maximum field and shall not differ from the declared value by more than $\pm 5\%$.

The slip of asynchronous machines shall be measured at the guaranteed rating and shall not vary from the declared value by more than $\pm 20\%$.

9.2.6 Auxiliary generators

For unregulated d.c. generators the voltage at open circuit and at the rated current shall be measured with the machine operating at the rated speed. These voltages shall not vary from the declared values by more than $\pm 5\%$.

For regulated d.c. generators, the excitation currents required to generate the rated voltage at open circuit at maximum speed and at maximum load and minimum speed shall be measured. They shall not vary from the declared values by more than $\pm 5\%$.

For a.c. generators, the open-circuit voltage and short-circuit current at rated speed shall be measured at two specified values of excitation which, unless otherwise agreed, shall be 100 % and 50 % of the maximum excitation current. The voltages and currents shall not vary from the values established during type tests by more than $\pm 5\%$.

The tolerance specified for machines operating with a regulator may be widened provided that the declared output voltage characteristic can be obtained within the capacity of the regulator and that the field winding temperature rise meets the requirements of the soundness test.

9.2.7 Auxiliary motor-generator sets and converters

For unregulated sets, the output voltage and machine speed shall be measured with the set supplied at the maximum and minimum voltage with the generator open circuit and also when delivering its rated output current. In the case of an a.c. generator, the output shall be at the specified power factor. The output voltage and, if applicable, frequency shall not vary from the corresponding declared curve values by more than $\pm 5\%$.

For regulated sets, a maximum of four sets of readings shall be taken at points chosen to confirm that any point on the declared characteristic can be met within the capacity of the regulating equipment. Normally measurements at maximum supply voltage and no load on the one hand, and at minimum supply voltage and maximum load on the other hand are sufficient, but in some cases additional measurements may be desirable. The tolerances on voltage and

frequency depend on the regulators and not the machine. The input current at the load test points shall not vary from the corresponding declared value by more than $\pm 5\%$.

9.3 Commutation routine tests

9.3.1 General

The general requirements for commutation routine tests are the same as those given in 8.3 for type tests except that pulsating current motors may be tested on direct current.

9.3.2 Traction motors (refer to Figure 1)

Traction motors shall be tested at points Com1, Com2 and Com3 at the minimum excitation used at these points in service.

An additional test for motors connected permanently in series is not required nor are braking tests.

9.3.3 Main generators (refer to Figure 2)

Main generators shall be tested at points Com1 and Com2.

9.3.4 Auxiliary motors and generators and motor-generator sets

Motors shall be tested at their maximum voltage at a current 1,5 times the guaranteed rating or at the maximum current for the particular application if this is the lesser. The speed shall be the maximum attainable in normal service for the test conditions.

Generators (including those forming part of a motor-generator set) shall be similarly tested but at the nominal output voltage for the test conditions.

Motors of motor-generator sets shall be tested at their minimum voltage with the generator supplying the maximum output attainable in normal service for the test conditions.

9.4 Overspeed tests

9.4.1 General

Overspeed tests are routine tests for all commutator and wound-rotor machines and unless agreed otherwise, are type tests for other types of machine. Machines shall be run for 2 min when hot at the speeds specified in 9.4.2 to 9.4.5, after which they shall show no permanent deformation and shall pass the dielectric tests specified in 9.5.

9.4.2 Traction motors

Traction motors shall be tested at 1,2 times the maximum working speed as defined in 3.7.1.

Where two or more series excited motors are permanently connected in series with no mechanical coupling, the overspeed shall be increased to 1,3. Where wheelslip protection is provided the factor may remain at 1,2 if agreed between user and manufacturer.

NOTE Equipment which only indicates the presence of wheelslip and leaves corrective action to the driver is not sufficient to give exemption from the increased overspeed factor.

9.4.3 Main or auxiliary engine-driven generators

Main or auxiliary engine-driven generators shall be tested at 1,2 times the maximum working speed as defined in 3.6.2.

9.4.4 Generators driven by a vehicle axle

Generators driven by an axle shall be tested at 1,2 times the maximum working speed defined in 3.6.3.

9.4.5 Main or auxiliary motor-generator sets, auxiliary converters and auxiliary motors

Main or auxiliary motor-generator sets, auxiliary converters and auxiliary motors shall be tested at 1,2 times the maximum working speed defined in 3.6.4.

9.5 Dielectric tests

The test voltage shall normally be carried out using a.c. of near sinusoidal waveform and between 25 Hz and 100 Hz frequency, but d.c. testing may be employed if agreed between user and manufacturer before placing an order.

The test voltage shall be applied between the windings of each circuit and the frame with the windings of all other circuits connected to the frame. It shall be applied only to new machines with all their parts in place as under normal working conditions.

The test shall be carried out immediately after the routine tests specified in the preceding clauses.

The test voltage shall be applied gradually, commencing at not more than one-third of the final value given in Table 5. The final value, when reached, shall be maintained for 60 s.

Table 5 – Dielectric test voltages

Group	Winding	Test voltage
1	a) Windings directly connected to the contact system. b) Windings connected to the contact system through a transformer rectifier or chopper without an intermediate circuit	AC test: $2,25 U_1 + 2\,000\text{ V}$ DC test: $3,825 U_1 + 3\,400\text{ V}$
2	Windings not connected to the contact system (except group 3)	AC test: $2 U_2 + 1\,000\text{ V}$ with a minimum of $1\,500\text{ V}$ DC test: $3,4 U_2 + 1\,700\text{ V}$ with a minimum of $2\,550\text{ V}$
3	Field windings of a.c. generators	AC test: $10 U_3$ with a minimum of $1\,500\text{ V}$ and a maximum of $3\,500\text{ V}$ DC test: $17 U_3$ with a minimum of $2\,550\text{ V}$ and a maximum of $5\,950\text{ V}$
U_1 is the highest voltage to earth which can be applied to the winding when the contact system is at nominal voltage. U_2 is the highest voltage to earth which can be applied to the winding in normal service. U_3 is the highest excitation voltage.		
NOTE 1 Motors supplied by a transformer/rectifier from an a.c. supply or by a chopper from a d.c. system are within group 1. NOTE 2 The test voltages are r.m.s. values, as are U_1 , U_2 and U_3 for alternating voltages. For unidirectional voltages, including the output of pulse control systems, U_1 , U_2 and U_3 are the arithmetic means of the waveforms. NOTE 3 If the winding voltage is not normally earth referenced then U_1 , U_2 and U_3 should be taken as the highest voltage that can appear on the winding, should any point in its circuit become connected to earth. NOTE 4 In determining U_1 and U_2 , consideration should also be given to the voltage which may appear within the circuit due to the control system and the characteristics of the protection devices.		

9.6 Vibration tests (imbalance)

Each machine shall be checked for vibrations associated with machine imbalance. It shall normally be adequate to demonstrate that a machine runs smoothly throughout its operating speed range when mounted on the test bed, and the standard of balancing should be that it is achieved.

In applications where machine vibration is considered critical, if agreed between user and manufacturer, the test detailed in 8.8 can be carried out on each machine.

9.7 Commutator radial run-out measurement

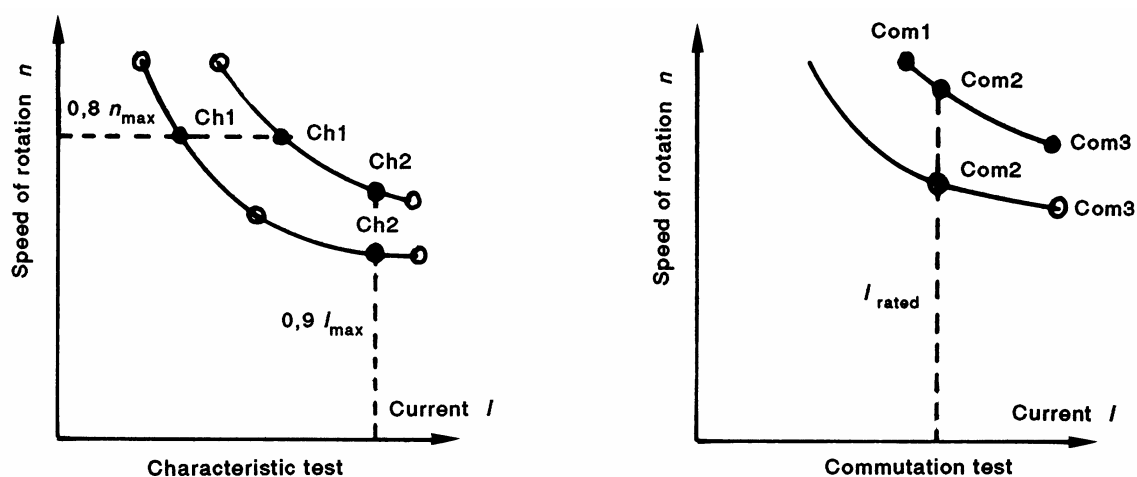
If specified by the user a commutator radial run-out measurement shall be taken immediately after completion of the routine test. Where practicable, it shall be carried out using an instrument that gives a permanent record.

The radial run-out is the difference between maximum and minimum bar heights following measurement of each bar on the commutator. The values shall not exceed the values given in Table 6 and there shall be no abrupt changes in profile.

In certain cases, it may be necessary to specify lower limits than those given in Table 6 and in others (such as low speed auxiliary machines), acceptable commutation can be obtained with higher run-outs. In such cases, modified limits shall be agreed between manufacturer and user.

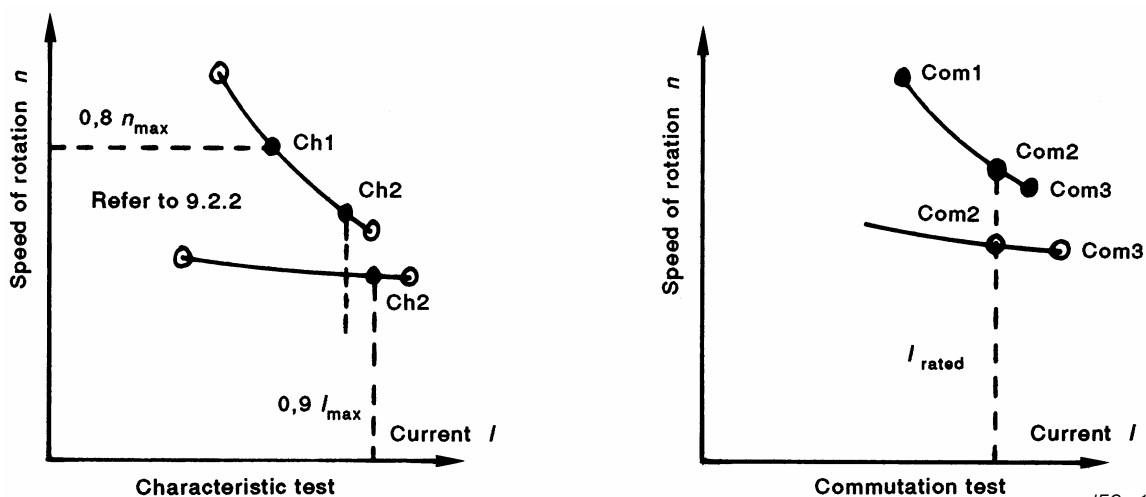
Table 6 – Limits of commutator radial run-out

Commutator diameter	Maximum radial run-out mm
Up to 400 mm	0,03
400 mm to 800 mm	0,04
Over 800 mm and all single-bearing or overhung machines	0,06



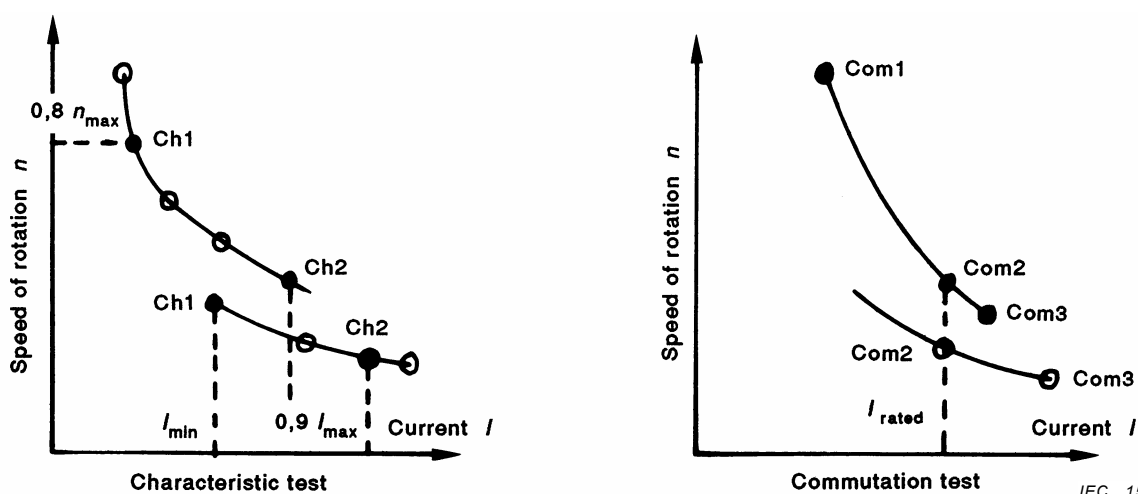
IEC 1556/99

Figure 1a) – Series motor supplied from a contact system



IEC 1557/99

Figure 1b) – Separately excited or compound motor supplied from a contact system



IEC 1558/99

Figure 1c) – Thermoelectric vehicle motor

- KEY
- Type test point
 - Type and routine test point

Figure 1 – Commutator type traction motor test points

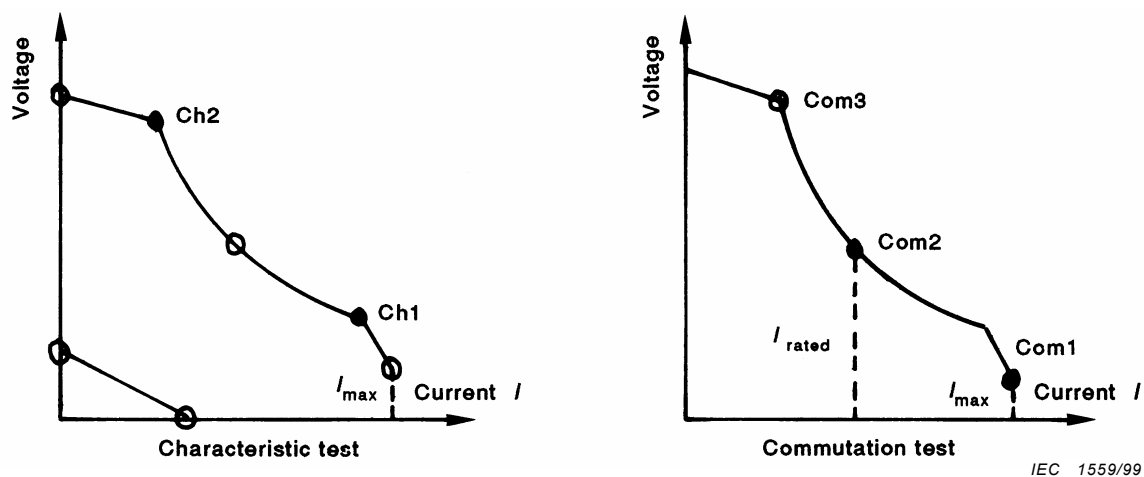


Figure 2a) – Regulated generator

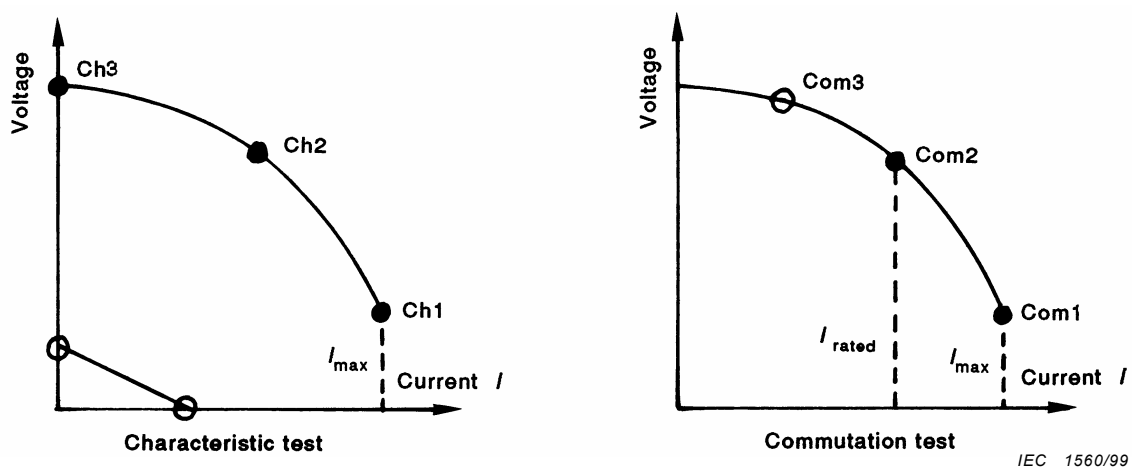


Figure 2b) – Inherent characteristic generator

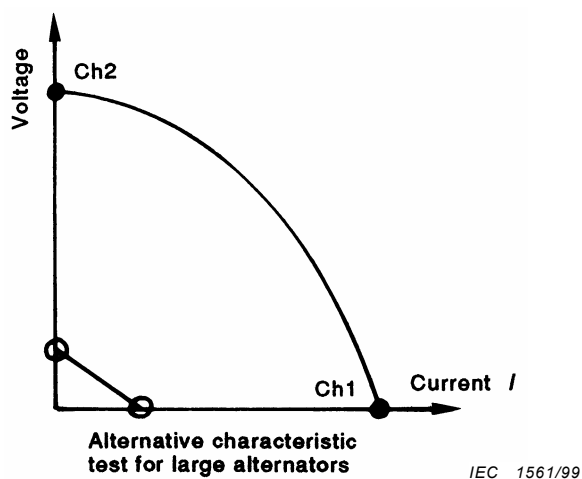


Figure 2c) – Alternative characteristic test for large alternators

- KEY
- Type test point
 - Type and routine test point

Figure 2 – Main generator test points

Annex A (normative)

Measurement of temperature

A.1 Temperature of the machine parts

Two methods of measuring the temperature of machine parts shall be used:

- a) the resistance method for insulated windings;
- b) the electrical thermometer method for commutators, slip-rings and permanently short-circuited uninsulated windings.

No correction shall be made to the measured temperature rises if the temperature of the cooling air is between 10 °C and 40 °C during the test. If, for a type test, the temperature of the cooling air is outside these limits, a correction to the measured temperature rises may be agreed between user and manufacturer.

Before starting a short time test, it shall be confirmed by either thermometer or resistance measurements that the windings are within 4 K of the temperature of the cooling air. When calculating the winding temperature rises, any difference in initial temperature up to 4 K shall be subtracted from the results if the winding is the hotter or added to it if it is the cooler.

Resistance method

In this method, the temperature rise of the windings is determined by their increase in resistance.

For copper windings, the temperature rise at the end of a test is determined by the following formula:

$$\text{Temperature rise} = t_2 - t_a = \frac{R_2}{R_1} (235 + t_1) - (235 + t_a)$$

where

- t_1 is the initial temperature of the winding in degrees Celsius;
- R_1 is the initial resistance of the winding at temperature t_1 ;
- t_2 is the temperature of the winding at the end of the test in degrees Celsius;
- R_2 is the resistance of the winding at the end of the test;
- t_a is the temperature of the cooling air at the end of the test in degrees Celsius.

NOTE For materials other than copper, the value 235 in the above formula should be replaced with the reciprocal of the temperature coefficient of resistance at 0 °C for the material considered.

Electrical thermometer method

In this method, the temperature is determined by means of electrical thermometers applied to the hottest accessible spots of the relevant parts immediately after the machine is stopped.

A.2 Temperature of the cooling air

For totally enclosed machines, without external fan ventilation, the cooling air temperature shall be measured by not less than four thermometers distributed around the machine and spaced between 1 m and 2 m from it.

In all other cases, the temperature of the cooling air shall be measured at its entry to the machine and, in the case of more than one entry point, shall be the average of the measurements.

In both cases, the thermometers shall be protected from radiated heat and draughts so that they record the true temperature of the air entering or around the machine. In order to avoid errors due to variations in the temperature of the cooling air, all reasonable precautions shall be taken to keep such variations to a minimum.

The temperature of the cooling air at the end of a test shall be the average of measurements taken at intervals of approximately 15 min during the last hour of a continuous rating test or throughout the duration of a short time test.

A.3 Measurement of resistance

A.3.1 Initial cold resistance

The initial cold resistance measurement shall be carried out using the same instruments as for subsequent hot measurements but the measurement need not be repeated at the beginning of each test. The temperatures of the windings shall be taken as their surface temperature as recorded by the thermometer at the time of the resistance measurement, and shall not differ from the temperature of the ambient air at that time by more than 4 K.

A.3.2 Hot resistance

If it is practicable to measure the voltage drop in a winding carrying direct current whilst the machine is operating, the resistance shall be calculated from such measurements taken at intervals during the test with the winding carrying the test current.

In other cases, the resistance shall be measured as soon as possible after stopping the machine at the end of the test. Measurement may be by the voltmeter and ammeter method (volt-amp method), by using a bridge or by other suitable methods, but the same method shall be employed for all readings, including the initial cold one, on a given winding.

If the voltmeter and ammeter method is used the current shall be high enough to give the necessary accuracy without itself influencing the temperature rise. (In general, a value not exceeding 10 % of the rated current will meet the latter requirement.) When measuring armature resistance the current shall be fed to the commutator through the brushes, and the voltage shall be measured between a pair of marked bars lying between two brush arms and covering a span of at least half the number of commutator bars per pole.

When a bridge is used, the voltage probes shall be placed as for the volt-amp method. For windings with equalizing connections, the current probes shall be applied at the brush positions adjacent to the voltage probes.

For type tests, the same pair of marked bars shall be used for cold and hot readings, unless it is demonstrated that the difference in resistance between pairs of equally spaced bars distributed around the commutator is negligible.

A.4 Stopping of machines and time of "commencement of cooling"

At the end of a test, machines shall be stopped in as short a time as possible.

A method of braking in which the machine under test does not carry current is preferred, in which case the "commencement of cooling" shall be the instant when the main circuits are opened immediately before braking, any separate ventilation being cut off at this instant.

If such a method is impracticable, methods in which the test machine carries current may be used provided that they stop the machine quickly and that the load current remains reasonably constant during the braking period. The "commencement of cooling" shall be when the load current has fallen to 80 % of the test value, at which instant the ventilation shall be cut off.

For large machines which it is not practicable to stop in time to permit resistance measurements to commence within 45 s of the "commencement of cooling", special braking arrangements and an extension of time to not more than 2 min shall be agreed between user and manufacturer. It may also be agreed that this maximum time limit shall apply if special brushes are installed when taking cooling curves.

A.5 Time of the hot resistance measurements and extrapolation of the cooling and heating curves

- a) For resistances measurable while the machine is operating, the last measurements shall be made just before the end of the temperature-rise test. In the case of a short-time test, they shall be taken not more than 10 s before braking commences.
- b) Resistance measurements of each winding not measurable while the machine is operating shall commence not later than 45 s after the "commencement of cooling" (see 8.1.5 for exceptions) and shall be continued for at least 5 min.

The time between successive measurements shall not exceed 20 s during the first 3 min and 30 s thereafter.

The temperature rises calculated from these readings shall be plotted as a function of time using a logarithmic scale for temperature and a linear scale for time, the resulting curve being extrapolated to the time of "commencement of cooling" to give the temperature rise at the end of the test.