

IEEE Standard for Rotating Electric Machinery for Rail and Road Vehicles

Sponsor

**Electric Machinery Committee
of the
IEEE Power Engineering Society**

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Abstract: This standard applies to rotating electric machinery which forms part of the propulsion and major auxillary equipment on internally and externally powered electrically propelled rail and road vehicles and similar large transport and haulage vehicles and their trailers where specified in the contract.

Keywords: amature, electric input, electric output, impedance, load, phase control, propulsion re-generation, shutdown, ventilation waveforms, windage

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Introduction

(This introduction is not part of IEEE Std 11-2000, IEEE Standard for Rotating Electric Machinery for Rail and Road Vehicles.)

This standard provides for usual conditions. In addition, it provides for special conditions that have been found convenient or necessary at times in the industry, which may be invoked by agreement between the manufacturer and purchaser. The conditions chosen may affect the economics or performance, or both, of machines in a given situation.

Provisions where special agreement between manufacturer and purchaser may be invoked are as follows:

<u>Subclause</u>	<u>Provision</u>
1.3.2	High ambient temperature
1.3.3	Special conditions of environment
1.4.1	Type test quantities
1.4.2	Routine overspeed and single phase or locked rotor test
1.4.2.3	Routine commutation and characteristic test quantities, quality control, and sampling plan
1.5.6	Special conditions of electric input or output
4.2.3	Greatest continuous rating
5.2	Waiver of temperature-rise limits
7.1	Dielectric test
8.2.1	Commutation routine tests
8.2.3	Level of visible sparking
8.3.1	Interruption type tests
9.3.1	Maximum design speed
10.1.1	Routine test tolerances
10.6.4.2	Assumed stray load loss
10.6.5	Assumed harmonic losses
10.7.4	Tolerance from contract curve
10.8.1, 10.8.2, 10.8.3	Routine test tolerances
11.2	Variation of performance with voltage
11.3	Load reduction under condition of low supply voltage
13.1	Commutator trueness measurement
13.2	Vibration measurement
13.3	Sound measurement
13.4	Shaft voltage

This standard parallels the major technical contents of International Electrotechnical Commission (IEC) Recommendation Publication 349, Rules for Rotating Electrical Machines for Rail and Road Vehicles. However, it differs from IEC recommendation 349 in important respects.

These differences have been called to the attention of the U.S. Committee of Experts for IEC Technical Committee 9, the International Mixed Committee on Electric Traction Equipment.

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IEEE Standard for Rotating Electric Machinery for Rail and Road Vehicles

1. Overview

1.1 Scope

This standard applies to rotating electric machinery which forms part of the propulsion and major auxiliary equipment on internally and externally powered electrically propelled rail and road vehicles and similar large transport and haulage vehicles and their trailers where specified in the contract.

Major auxiliary equipment includes equipment such as blower and compressor motors, motor-generator and motor-alternator sets, auxiliary generators, and exciters, usually larger than 3 kW.

1.2 Purpose

The purpose of this standard is to define ratings, tests, and calculation procedures to permit comparison among machines for similar use, and to enable evaluation of the suitability of machines for a given use.

1.3 Service conditions

This standard applies under the following conditions:

1.3.1 Altitude

All temperature tests at the manufacturer's plant shall be made at the sea-level rating. No correction in rating is necessary when normal service altitude does not exceed 1200 m (4000 ft). A reduction in current rating of 1% shall be made for each 300 m (1000 ft) additional elevation or fraction thereof.

1.3.2 Temperature

Whenever the temperature in the shade exceeds 40 °C, special stipulations may be agreed upon by the manufacturer and the purchaser.

1.3.3 Special conditions

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

1.4 Test categories

1.4.1 Type tests

Type tests to establish ratings and characteristics shall be carried out on all new products. The number of type tests shall be one for every order for a new type, up to 100 machines on the order, and one for every additional 300 machines (or part thereof) for larger orders, unless otherwise agreed to between manufacturer and purchaser. Machines given type tests shall also be given routine tests.

1.4.2 Routine tests

Routine tests show that each machine is ready for service and like the type tested machines. Resistance, rotation, vibration, heating-up run, bearing temperature, and dielectric tests shall be carried out on all machines. In no case do routine tests require precise temperature measurement.

For inverter-driven induction motors, no-load phase balance and magnetizing current and kilowatt input tests shall be run, and overspeed and single phase tests may be run by agreement.

For synchronous machines, overspeed test shall be run on each machine.

For dc machines, overspeed test shall be run on each machine, and requirements for commutation and characteristic tests shall be met by one of the methods given below.

1.4.2.1

Load test may be used to demonstrate commutation and characteristics directly.

1.4.2.2

Simulated load test may be used to demonstrate that the factors that affect commutation and characteristics agree with identical tests on machines that have had type test.

1.4.2.3

On machines produced in large quantity and assembled by precision methods, statistical methods may be used to determine the number of machines subject to commutation and characteristic tests. The quality control and sampling plan may be subject to agreement between manufacturer and purchaser.

1.5 Electric inputs or outputs

1.5.1

DC motors supplied from rectified polyphase alternating current with not less than six-pulse rectification without phase control are considered to be operating on smooth current. No correction is needed from tests run on smooth current.

1.5.2

DC motors supplied from rectified single-phase alternating current or from pulse-control devices are considered to be operating on undulating current. Type tests for temperature rise, commutation, characteristics, and efficiency shall be made with undulating current with pulsation frequency and ripple as in service. Tests with smooth current may also be run.

1.5.3

AC machines that operate with essentially sinusoidal waveform should be tested under those conditions.

1.5.4

AC machines producing or fed with nonsinusoidal waveform should have type tests with waveforms as in service. Tests with sinusoidal waveform may also be run.

1.5.5

The effects of load characteristics and supply characteristics (11.3 and 11.4) shall be taken into account in specifying electric inputs or outputs of machines, particularly ac auxiliaries.

1.5.6

Special conditions of electric input or output are subject to agreement between manufacturer and purchaser.

2. References

This standard shall be used in conjunction with the following publications. When a standard is superseded by an approved revision, the revision shall apply.

ANSI/NEMA CB 1–1995, Brushes for Electrical Machines.¹

IEEE Std 1–1986 (Reaff 1992), IEEE Standard General Principles for Temperature Limits in the Rating of Electric Equipment and for the Evaluation of Electrical Insulation.²

IEEE Std 112–1996, IEEE Standard Test Procedure for Polyphase Induction Motors and Generators.

3. Definitions

3.1 alternator: An ac generator.

3.2 as built curve: A curve that is found on an individual machine during testing. *Syn:* **manufactured curve.**

3.3 average voltage: The value declared by the user to be the average of the system described, where externally powered.

¹NEMA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (<http://global.ihs.com/>).

²IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).

3.4 continuous rating: The output that the machine can sustain for an unlimited period under the conditions of Clause 4 without exceeding the limits of temperature rise of Clause 5.

3.5 contract curve: A specified machine characteristic curve that becomes part of the contract.

3.6 current ripple: Current ripple, for the purpose of this standard, is defined as $[(I_{\max} + I_{\min}) / (I_{\max} - I_{\min})] \times 100$ expressed in percent, where $I_{\max}$ and $I_{\min}$ are the maximum and minimum values of the current waveform, provided that the current is continuous.

3.7 declared curve: A characteristic curve of the machine type, as obtained by averaging the results of testing four to ten machines, of which at least two shall have had a type test.

3.8 electric thermometer: An instrument that utilizes electric means to measure temperature (IEEE Std 100-1996). Electric thermometers include thermocouples and resistance temperature detectors.

3.9 heating-up run: A period of operation with current and ventilation designed to bring the machine to approximately its temperature-rise limit.

3.10 manufacturer: The organization supplying the electric machinery to the purchaser. For the purpose of this standard it may include a repair contractor.

3.11 nominal system voltage: A number used to denote the general level of voltage of the system described and, in the case of an externally powered system, selected from the list of preferred values in Clause 11.

3.12 one hour rating: The output that the machine can sustain for 1 h starting cold under the conditions of Clause 4 without exceeding the limits of temperature rise of Clause 5.

3.13 purchaser: The organization placing the contract for the machinery or its repair; often called the “user.”

3.14 pulse control: Means by which the voltage applied to a machine circuit departs from being essentially constant if unidirectional, or from being essentially sinusoidal if alternating. Pulse control devices include, but are not limited to, choppers, inverters, and rectifiers.

3.15 rated voltage: The voltage specified at the terminals of a machine.

3.16 rating: The output at the shaft if a motor, or at the terminals if a generator, assigned to a machine under specified conditions of speed, voltage, temperature rise, etc.

3.17 routine test: A test showing that each machine has been run and found to be sound electrically and mechanically, and is essentially identical with those that have been type tested.

3.18 short-time overload rating: The output that the machine can sustain for a specified time starting hot under the conditions of Clause 4, without exceeding the limits of temperature rise of Clause 5.

3.19 smooth current: Current that remains unidirectional and the ripple of which does not exceed 3%.

3.20 type test: A test made by the manufacturer on a machine that is identical in all essential respects with those supplied on an order, to demonstrate that it complies with this standard.

3.21 undulating current: Current that remains unidirectional, but the ripple of which exceeds that defined for smooth current.

4. Ratings and temperature-rise tests

4.1 Classes of ratings

This standard recognizes three classes of ratings: continuous rating, 1 h rating, and short time overload rating.

4.2 Continuous ratings and temperature-rise tests

4.2.1

The continuous rating of a machine applied in duty that is long compared to the thermal time constant of the machine generally will be the point of greatest continuous tractive effort with the highest continuous flux level. The test shall be performed with inputs as in service unless 4.6.1 applies. It shall be ascertained that no other point is limiting.

4.2.2

The continuous rating of a machine applied in duty that has short cycles compared to the thermal time constant of the machine will be the steady rating that produces the same heating with the same ventilation in the same time as the duty cycle. This continuous rating is calculated from speed, time, distance, rms current, etc., over the duty cycle. Ripple in dc or harmonics in ac change during the duty cycle so it may not be possible to provide the continuous rating point with waveforms as in service. Subclause 4.6.1 may apply.

A duty cycle test shall be performed with the pulse control to be used in service to demonstrate that the temperature rises are comparable to those at the calculated continuous rating. The machine shall be operated in simulation of the actual duty cycle, including dwell time, as realistically as possible. The cycle shall be repeated until temperature rises have leveled. The test shall end at a temperature rise peak, if appreciable.

4.2.3

Where agreed, a machine may be tested to find the greatest continuous rating that will meet temperature rise limits with assurance. Such a rating must be used with care that other conditions have not changed to render the rating inapplicable.

4.2.4

A continuous temperature test shall be continued until the temperature rises that can be observed during the test have attained steady final values. See Table 1 in 5.1. In order to abridge the long time required to attain steady temperatures, reasonable overload or reduction of ventilation during the preliminary heating period is permissible.

4.3 Initial temperature of machine for temperature-rise test to determine 1 h rating

The temperature-rise test to determine the 1 h rating shall commence only when the windings and other parts of the machine are within 4 °C of the cooling-air temperature at the time of starting the test.

4.4 Making of short-time overload test

The short-time overload capacity of the machine shall be determined by one or more temperature-rise tests following the continuous rating test at the highest continuous current. The cooling curve of the earlier rating

test shall be plotted as taken, and the overload shall be applied when the extrapolation of this curve indicates that the proper initial armature temperature rise has been reached. The overload shall then be applied under normal ventilation conditions and at the voltage that corresponds to the test current on the machine characteristic and shall be maintained constant for a period estimated to reach the final temperature rise given in Table 2 in 5.1. The short-time overload rating of the machine may be calculated from a test that does not differ in final temperature rise from that in Table 2 by more than $\pm 10^\circ\text{C}$.

4.5 Ventilation during temperature-rise test

The test shall be carried out with the machine arranged as in service, with all those parts that would affect the temperature rise of the machine in place, but without any ventilation corresponding to that produced by the motion of the vehicle itself.

4.6 Waveforms during temperature-rise tests

4.6.1

Smooth current or sine wave power may be used rather than pulse-controlled if the ripple or harmonic content would be so low that the added losses may be neglected or accounted for.

4.6.2

Rating test(s) shall be repeated with smooth current or sine wave supply to establish reference for further type tests. If type test equipment can not reach the rating point, another point at the same flux level may have to be used.

4.6.3

Heat run(s) on waveforms as in service are required on one machine deemed typical. Other type tests are compared to the reference test(s).

4.7 Voltage during temperature-rise test

The voltage applied to a machine during the temperature-rise test shall be the rated voltage as defined in 4.8.

4.8 Rated voltage

4.8.1 Motors on externally powered vehicles

The rated voltage of a motor is the same as the nominal supply voltage of the traction network (see Table 4, Clause 11) in all cases where the motor is fed directly from the line.

4.8.2 Motors in series

For motors connected permanently in series the rated voltage of the motor is designated by the ratio E/n , E being the nominal supply voltage and n the number of motors in series.

4.8.3 Motors on internally powered vehicles

The rated voltage of a traction motor fed from a generator carried on the vehicle shall be at least equal to its share of the generator output voltage at the continuous rating of the motor.