



BS 173 : 1980

UDC 621.313-13 : [629.113.6 + 629.423]

Method of specifying
**Performance of rotating electrical
machines for rail and road vehicles**

Méthode de spécification des performances des machines électriques tournantes
des véhicules ferroviaires et routiers

Verfahren für die Spezifikation der Leistung von elektrischen umlaufenden
Maschinen für Schienen- und Straßenfahrzeuge

BS 173 : 1980

Foreword

This British Standard method of specifying the performance of rotating electrical machines for rail and road vehicles has been prepared under the direction of the Power Electrical Engineering Standards Committee and is a revision of BS 173 : 1960. The purpose of this revision is to align BS 173 with IEC Publication 349 : 1971 'Rules for rotating electrical machines for rail and road vehicles' and thereby achieving technical equivalence. Additionally this revision implements CENELEC harmonization document HD 225.

For ease of production this standard has been based on the IEC text, the changes being indicated by a marginal mark.



Documents

Document Sharing Hub

CONTENTS

FOREWORD.	Page Inside front cover
CHAPTER I: GENERAL	
SECTION ONE – SCOPE, CLASSIFICATIONS AND OPERATING CONDITIONS	
1. Scope and classifications	3
2. Service conditions	4
SECTION TWO – DEFINITIONS	
3. General	4
4. Field strength of a series excited motor	4
5. Rating of a machine	5
6. Rated quantity	5
7. Classes of ratings	5
8. Continuous rating.	5
9. One-hour rating	6
10. Intermittent rating of an auxiliary machine	6
11. Equivalent rating	6
12. Guaranteed rating.	6
13. Rated voltage.	7
14. Maximum (or minimum) voltage of an auxiliary motor, generator or convertor	8
15. Maximum current	9
16. Rated speed	9
17. Maximum speed	9
18. Output and input of electric motors, heat engines and their electrical transmissions.	10
19. Rated power of electrically propelled vehicles.	10
20. Current ripple factor.	11
21. Pulsation frequency	11
SECTION THREE – MARKING	
22. Rating plate and marking of machines	11
CHAPTER II: TESTS	
SECTION FOUR – TEST CATEGORIES AND SPECIAL RULES	
23. Test categories	12
24. Special rules for traction motors intended for use on single-phase rectifier vehicles	12
25. Special rules for a.c. generators	13
26. Summary of tests	13
SECTION FIVE – TEMPERATURE-RISE TESTS	
27. General	14
28. Type tests	14
29. Routine tests	14
30. Classification of insulating materials.	15
31. Limits of temperature rise	15
32. Measurement of cooling-air temperature during temperature-rise tests	16
33. Methods of measuring temperatures of machine parts	16
34. Initial resistance	17
35. Measuring of resistances and temperatures during the test and correction of measurements	17
SECTION SIX – OVERSPEED TESTS	
36. Overspeed tests	19
SECTION SEVEN – STARTING TESTS	
37. Starting tests	19
SECTION EIGHT – COMMUTATION TESTS	
38. General	21
39. Commutation tests under steady state conditions	21
40. Interruption and restoration tests	23

Clause	SECTION NINE – DIELECTRIC TESTS	Page
41. Dielectric tests		24

SECTION TEN – DETERMINATION OF CHARACTERISTIC CURVES

42. Characteristic curves	25
43. Methods for determining the efficiency.	29
44. Tolerances.	31

SECTION ELEVEN – RUNNING TESTS ON COMPLETE AUXILIARY SETS

45. Tests to check that the set is in good running order.	33
46. Interruption and voltage jump tests	33

SECTION TWELVE – MISCELLANEOUS TESTS ON COMPLETE AUXILIARY SETS

47. Endurance tests.	34
APPENDIX A – Description of recommended methods for determining the efficiency (Clause 43).	35
APPENDIX B – Supply voltage of traction systems	41
APPENDIX C – Terminal markings – d.c. traction motors	42

British Standard Method of specifying

Performance of rotating electrical machines for rail and road vehicles

CHAPTER I : GENERAL

SECTION ONE - SCOPE, CLASSIFICATIONS AND SERVICE CONDITIONS

1. Scope and classifications

1.1 Scope

This standard gives the method for specifying rotating electrical machines 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. This standard also applies to machines installed on trailers hauled by the electrically propelled vehicles. However, this standard is not applicable to rotating electrical machines contained in flameproof enclosures (see BS 4683 : Part 2), or to machines on small road vehicles such as battery-fed delivery vehicles, works trucks, etc. Similarly minor machines, such as windscreen wiper motors, etc. that may be used on traction vehicles, are excluded.

Note. — The titles of the standards publications referred to in this standard are listed on the inside back cover.

Electrical inputs or outputs of machines covered by this standard may be of the following types:

- a) direct current (including rectified multi-phase alternating current);
- b) pulsating current (rectified single-phase alternating current);
- c) single-phase alternating current;
- d) multi-phase alternating current (in general 3-phase).

All the above inputs or outputs may be synthesised and/or varied by phase or pulse control.

1.2 Classifications

For the purpose of this standard the electrical machines concerned are classified as follows:

Note. — The term generator may refer to either an a.c. or d.c. machine.

1.2.1 Traction motors

Motors which are used for propelling rail or road vehicles.

1.2.2 Engine-driven main generators

Generators which are used for supplying power to traction motors on the same vehicle or train.

1.2.3 Main motor-generator sets

Machines which obtain their input power from the line or from a battery, the output supplying power to traction motors on the same vehicle or train.

1.2.4 Auxiliary motors

Motors for driving compressors, fans, auxiliary generators or other auxiliary machines forming part of a vehicle equipment.

1.2.5 *Auxiliary generators*

Generators for supplying power for excitation, control, lighting, battery charging, auxiliary motors, train heating, etc.

1.2.6 *Auxiliary motor-generator sets and convertors*

Machines which obtain their input power from the line or from a battery, the output supplying power for excitation, control, lighting, battery charging, auxiliary motors, etc.

2. **Service conditions**

This standard applies to machines to be used under specified or assumed conditions. Unless otherwise specified by the user, the following operating conditions are assumed:

a) *Altitude*

Height above sea level not exceeding 1 200 m.

b) *Temperature*

Temperature in the shade not exceeding 40 °C.

Whenever the machines are intended to operate where one or both of these limits will be exceeded, special arrangements may be made by agreement between user and manufacturer.

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

SECTION TWO — DEFINITIONS

3. **General**

For the definition of general terms used in this standard, reference should be made to BS 4727 : Part 2 : Group 03 and BS 4727 : Part 2 : Group 04.

The definitions applicable to this standard are contained in Clauses 4 to 21 which follow, however, the different classes of machines concerned have been defined in Sub-clause 1.3.

4. **Field strength of a series excited motor**

4.1 *Field strength*

Ratio of the number of ampere-turns in the excitation windings of the motor operating at a given load to the maximum number of ampere-turns obtainable in the same windings for the same armature current.

4.2 A series excited motor is said to be:

- at *full field* when the current through the field winding is equal to the armature current;
- at *maximum field* when the motor operates with the highest field strength allowed in service;

- at *weak field* when the motor operates with a field strength smaller than the maximum field;
- at *minimum field* when the motor operates with the minimum field strength permitted in service.

Note. — In the case of motors without permanent diverts across excitation windings, maximum field and full field are equivalent.

5. Rating of a machine

The combination of simultaneous values of electrical and mechanical quantities with their duration and sequence, assigned to the machine by the manufacturer. The purpose of the rating is to enable the performance of a machine to be confirmed on the test bed and to serve as a basis both for an assessment of its suitability for a specified duty and for a comparison between different machines.

6. Rated quantity

The numerical value of any quantity included in the rating. For traction machines, certain special quantities are often included in the rating, e.g. current ripple factor for a pulsating current motor, field strength for a variable field motor, and so on.

7. Classes of ratings

There are four classes of ratings:

- a) *continuous rating* (see Clauses 8 and 12);
- b) *one-hour rating* (see Clause 9);
- c) *intermittent rating* (see Clause 10);
- d) *equivalent rating* (see Clause 11) as an alternative to intermittent rating, to be used after agreement between user and manufacturer.

8. Continuous rating

8.1 Continuous rating of a machine

The rating that corresponds to a load that the machine can withstand on the test bed for an unlimited period under the conditions specified in Clause 28, without exceeding the limits of temperature rise given in Clause 31.

All other appropriate requirements in these rules shall also be satisfied.

8.2 Case of engine-driven main generators

These generators shall generally have two continuous ratings, the first determined by the temperature rise of all the windings through which the load current flows (higher value of load current and lower voltage), the second by the temperature rise of the field windings (lower value of load current and higher voltage). In the following sub-clauses, these two continuous ratings are designated by the terms "at lower voltage" and "at higher voltage". These two continuous ratings shall correspond to the regulation curve specified by the manufacturer in accordance with Sub-clause 18.4.

8.3 Special rules for some main motor-generator sets

Rules similar to those specified in Sub-clause 8.2 may, in special cases, be applied to main motor-generator sets.

9. One-hour rating

The rating that corresponds to a load that the machine can withstand on the test bed for one hour without exceeding the limits of temperature rise given in Clause 31, the test being started with the machine cold (see Clause 34) and carried out under the conditions specified in Clause 28.

All other appropriate requirements in this Recommendation shall also be satisfied.

In the case of main generators and the traction motors fed from them, the one-hour rating shall correspond to the regulation curve specified by the manufacturer in accordance with Sub-clause 18.4 as limited by the temperature rise of windings through which the load current flows.

Note. — In very special cases, and after agreement between user and manufacturer, the one-hour rating may be replaced by a shorter time rating.

10. Intermittent rating of an auxiliary machine

The rating that corresponds to a sequence of identical cycles, each including a period of operation at specified values of the load such that, whether separated or not, according to circumstances, by a period of shutdown, after an unlimited number of cycles the temperature rises of the machine do not exceed the limits given in Clause 31.

The duty cycle to be reproduced in tests on auxiliary machines should take into account both the purpose for which these machines are used and the conditions under which they are supplied or driven, and should be specified in a diagram drawn up in advance by agreement between user and manufacturer.

In the case of motor-generator sets, it should be checked that the specified duty cycles of the different machines of the same set correspond to one another.

11. Equivalent rating

The continuous or short time rating with constant values of voltage, current and speed that, as far as temperature rise is concerned, is equivalent to a long series of intermittent duty cycles which the machine has to withstand in actual service. This rating should be agreed between user and manufacturer.

12. Guaranteed rating

Rating guaranteed by the manufacturer.

12.1 *Guaranteed rating of a traction motor*

Normally, the guaranteed rating is the continuous rating. The one-hour rating is not guaranteed; it is given by the manufacturer for information only and is accurately determined during the type tests in order to be used as a basis for the routine tests.

For traction motors of thermo-electric vehicles, the guaranteed continuous rating shall correspond to the guaranteed rating of the main generator at lower voltage, unless otherwise agreed between user and manufacturer.

In very special cases, the one-hour or another short time rating may be used as the guaranteed rating after agreement between user and manufacturer.

12.2 *Guaranteed rating of an engine-driven main generator*

The guaranteed ratings of a main generator are its two continuous ratings, defined in Sub-clause 8.2.

As for traction motors, the one-hour rating is not guaranteed; it is given by the manufacturer for information only and is accurately determined during the type tests in order to be used as a basis for the routine tests.

12.3 *Guaranteed rating of a main motor-generator set*

The guaranteed rating is the continuous rating.

12.4 *Guaranteed rating of an auxiliary machine*

Unless otherwise specified, the guaranteed rating is the continuous rating.

13. **Rated voltage**

The specified value of the voltage at the terminals of the machine.

13.1 *Rated voltage of traction motors*

13.1.1 *General*

Sub-clauses 13.1.2 to 13.1.7 below refer to both single motors and groups of n motors permanently connected in series. In the latter case, the rated voltage of each traction motor is equal to the rated voltage, as defined in Sub-clauses 13.1.2 to 13.1.7, divided by n .

13.1.2 *D.C. motors supplied direct from the contact system*

Unless special arrangements have been agreed between user and manufacturer, the rated voltage shall be the system voltage of the traction system (see Appendix B).

13.1.3 *A.C. motors supplied direct from the contact system*

The rated voltage is not specified herein but in the absence of any specified value, the following conventional value is to be assumed: 90 % of the maximum no-load secondary r.m.s. voltage of the transformer when the principle tap of the corresponding primary winding of the transformer is supplied at the system voltage of the traction system.

13.1.4 *Motors supplied from the contact system through a static convertor located on the vehicle*

The rated voltage, defined as being the arithmetic mean value of the voltage over one cycle, shall be fixed by agreement between user and manufacturer taking into account the characteristics of the converting equipment. (See IEC Publications 310, 411, 411-1 and 411-2.)

13.1.5 *Motors supplied from a source of electrical energy located on the vehicle (e.g. an accumulator battery)*

The rated voltage is equal to the rated voltage of the source.

13.1.6 *Motors on thermo-electric vehicles*

The rated voltage is equal to the lower rated voltage of the associated main generator (see Sub-clause 13.2).

In the case of an a.c. main generator, the rated voltage is the corresponding output voltage of the rectifier inserted between the said generator and the traction motors.

13.1.7 Motors supplied by some main motor-generator sets

The rated voltage is equal to the lower rated voltage of the corresponding main generator (see Sub-clause 8.3).

13.2 Rated voltage of an engine-driven main generator

Two rated voltages shall be specified by the manufacturer and correspond to the two continuous ratings defined in Sub-clause 8.2.

13.3 Rated voltage of a main motor-generator set

The rated voltage of the motor of the set is defined in the same way as in Sub-clause 13.1.2 or 13.1.3 according to the type of machine concerned. The rated voltage of the generator shall be specified by the manufacturer and correspond to the guaranteed rating.

13.4 Rated voltage of an auxiliary motor

Unless special arrangements have been agreed between user and manufacturer, the rated voltage is equal to the system voltage of the traction system (see Appendix B) in all cases where the motor is supplied direct from the contact system. When n motors are permanently connected in series, the rated voltage of each motor is equal to the aforesaid voltage divided by n .

For motors connected permanently in series with protective resistors, these latter devices shall be considered as being component parts of the motors. The rated voltage of such motors is that which is supplied to the assembly comprising the motor and its protective resistor, and the motor shall be tested with a resistor of this value in the circuit.

For a.c. motors and for pulsating current motors supplied from a transformer and/or a convertor located on the vehicle, and for d.c. motors not supplied directly from the contact system, the rated voltage shall be specified by the manufacturer.

13.5 Rated voltage of an auxiliary generator

The rated voltage shall be specified by the manufacturer and correspond to the guaranteed rating.

13.6 Rated voltage of an auxiliary motor-generator set or convertor

The rated voltage of the motor or on the primary side of the convertor is defined in the same way as in Sub-clause 13.4 and according to the type of machine concerned. The rated voltage of the generator or on the secondary side of the convertor shall be specified by the manufacturer and shall correspond to the guaranteed rating.

14. Maximum (or minimum) voltage of an auxiliary motor, generator or convertor**14.1 General**

The maximum (or minimum) voltage of an auxiliary motor, generator or convertor is the highest (or lowest) voltage which the machine will be called upon to withstand in service, transient voltages being excluded.

14.2 Auxiliary motor or convertor supplied directly or indirectly from a contact system

The maximum and minimum voltages shall be based on those specified for the traction system (see Appendix B), account being taken of the regulation of any transformer or regulating equipment interposed between the line and the machine.

If the user anticipates a greater variation in supply voltage, he shall state the expected limits and agree with the manufacturer as to the performance required of the machine when the supply voltage is outside the normal maximum and minimum voltages specified above.

If n motors are permanently connected in series without mechanical coupling, the maximum voltage of each motor shall be taken as equal to 1.2 times the quotient of the total maximum voltage allowed for the group of motors divided by n .

15. Maximum current

The current that must not be exceeded in service. For traction motors and main generators, it shall be clearly shown on the characteristic curves.

16. Rated speed

16.1 *Rated speed of an engine-driven main or auxiliary generator*

The speed equal or corresponding to the rated speed of the driving engine. Due account shall be taken of the ratio of mechanical transmission, if any.

16.2 *Rated speed of a generator with a rotational speed proportional to the speed of the vehicle*

The speed agreed between the user and the manufacturer.

16.3 *Rated speed of machines which are not driven by an engine or by an axle*

The speed corresponding to the guaranteed rating.

17. Maximum speed

17.1 *Maximum speed of a traction motor*

When the characteristics of the vehicle for which the motor is intended are specified, the maximum rotational speed of the motor shall correspond to the maximum service speed of the vehicle, account being taken of the gear ratio and assuming that the wheel diameter corresponds to the half-worn condition defined by the user in the case of metallic wheels or to the mean rolling diameter in the case of rubber tyres.

17.2 *Maximum speed of an engine-driven main or auxiliary generator*

The speed equal or corresponding to the maximum speed at which the driving engine can develop its full power. Due account shall be taken of the ratio of mechanical transmission, if any.

17.3 *Maximum speed of a generator with a rotational speed proportional to the speed of the vehicle*

The speed corresponding to the maximum speed of the vehicle in the conditions defined in Sub-clause 17.1.

17.4 *Maximum speed of a main or auxiliary motor-generator set, an auxiliary convertor or an auxiliary motor*

The speed specified by the manufacturer, account being taken of the most unfavourable conditions of voltage, excitation, frequency, loading, etc., that can occur in service.

18. **Output and input of electric motors, heat engines and their electrical transmissions**

18.1 *Output of a motor*

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

18.2 *Maximum service output of a heat engine*

The specified maximum output at which the user and manufacturer agree that the heat engine shall be adjusted, taking into consideration the atmospheric conditions of the regions where the vehicle fitted with the engine will operate.

18.3 *Maximum shaft input to main generator*

Generally, the maximum service output of the heat engine decreased by the sum of the outputs which it provides to drive directly or indirectly the cooling equipment of the engine and the various auxiliaries of the vehicle (compressors, fans, auxiliary generators, exciters) which are presumed to be operating at the minimum output compatible with the maximum output of the vehicle.

The main generator input, which is transformed into electrical power available at the terminals of the generator for the supply of the traction motors and any other loads, for example train heating, is used to derive the ratings of the main generator.

18.4 *Full power regulation curve of main generator*

The full power output of the main generator is generally maintained substantially constant by variation of the excitation, the external characteristic of the generator (terminal voltage as a function of load current) being substantially hyperbolic over a part of its length. This part of the external characteristic is called the *full power regulation curve* of the generator.

19. **Rated power of electrically propelled vehicles**

19.1 *Rated power of an electric vehicle*

Conventionally, the sum of the outputs, expressed in kilowatts, which are available at the traction motor shafts, the motors operating at their continuous rating.

19.2 *Rated power of a vehicle equipped with heat engines and electric transmission*

Conventionally, the maximum value of the total output, expressed in kilowatts, which is available at the shafts of the traction motors of the vehicle, provided that the loads on the heat engines and main generators do not exceed the maximum values specified in Sub-clauses 18.2 and 18.3, and assuming that the electric train heating is disconnected when the latter is supplied by the main generators.

The statement of this rated output of the vehicle shall be preceded by that of the international rated power of its heat engines, expressed in kilowatts.

Example: A diesel electric locomotive which can develop in service a maximum output of 1 450 kW at its traction motor shafts and which is equipped with a diesel engine having a U.I.C. international rated power of 1 900 kW shall be described as follows:

Diesel electric locomotive of 1 900 kW/1 450 kW.

Note. — The ratio of the two stated outputs cannot represent the efficiency of the vehicle or of its transmission, since, apart from transmission losses, it embodies the various deratings applied to the heat engines as well as the power supplied to certain auxiliaries of the heat engine, the vehicle or the train.

20. Current ripple factor

In compliance with the IEC Publication 411, the ripple factor of the current delivered by a single phase static convertor with or without smoothing reactors is expressed in per cent, and is given conventionally by the formula:

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

in which $I_{\text{max.}}$ and $I_{\text{min.}}$ represent respectively the maximum and the minimum values of the current wave.

This formula is applicable in all cases where the current through the motors is continuous.

21. Pulsation frequency

Frequency of the fundamental alternating component of the pulsating current.

SECTION THREE — MARKING

22. Rating plate and marking of machines

All the machines covered by these rules shall carry a rating plate including the most important characteristics and at least the following information:

1. Manufacturer's name.
2. Manufacturer's type designation.
3. Manufacturer's serial number.
4. Year of manufacture.

Furthermore, a manufacturer's serial number shall be punched both on the frame and on the rotor of each machine. For industrial-type machines of standard production, this number need only be punched on the frame.

In addition, machines which are designed to rotate in only one direction shall carry in an appropriate visible position an arrow to indicate this direction of rotation.

For guidance on appropriate terminal markings see Appendix C.

CHAPTER II : TESTS

SECTION FOUR — TEST CATEGORIES AND SPECIAL RULES

23. Test categories

23.1 General

There are three categories of tests:

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

Descriptions of the tests in each category are given in Clauses 27 to 47.

23.2 Type tests

Type tests are carried out on a single machine of a new design or of a new manufacture, unless otherwise specified.

Machines may be exempted from type tests if the manufacturer produces a duly signed record of type tests already carried out on identical machines constructed on a previous occasion for the same service conditions and the same ratings.

Optional type tests are only to be carried out if they have been expressly specified in the order.

Note. — To obtain reference values for routine testing, certain type tests have to be carried out on several machines (see Clauses 35 and 42).

23.3 Routine tests

Routine tests are carried out on all machines of the same order.

For certain machines, after agreement between user and manufacturer, the routine tests may be replaced by tests carried out on a few machines taken at random out of the order.

Bulk production machines (i.e. industrial type machines of standard constructions) may be exempted from routine tests if they have passed tests in accordance with BS 4999 : Part 60.

23.4 Investigation tests

Investigation tests are special tests of an optional character carried out in order to obtain additional information. They are only to be carried out if they have been expressly specified in the order.

The results of investigation tests are not to be taken as influencing the acceptance of the material.

24. Special rules for traction motors intended for use on single-phase rectifier vehicles

For these motors, certain type tests (temperature-rise, commutation, and characteristic curve tests) shall be made with pulsating current at actual pulsation frequency and d.c. ripple factor.

The equipment used for these tests shall have characteristics which will produce a d.c. ripple factor as close as possible to that which will occur in service over the operating range.

The routine tests on these motors shall be carried out on direct current, provided that the relationships between temperature rises, commutation, and speed characteristics on both direct current and on pulsating current are determined on the type-tested motor.

25. Special rules for a.c. generators

For a.c. generators intended for use with a rectifier for the main current, it is not necessary during the test to use the rectifier to be used on the vehicles, but the test-rectifier should have identical characteristics. The excitation of the a.c. generator can be supplied by any suitable source. However, in the case of self-excited a.c. generators, the tests shall be carried out with the self-excitation equipment or test equipment with similar characteristics.

26. Summary of tests

TABLE I

	Clause	Traction motors		Main generators (engine-driven)		Main motor-generator sets		Auxiliary motors		Auxiliary generators		Auxiliary motor-generator sets and converters	
		With commutator	Without commutator	With commutator	Without commutator	With commutator	Without commutator	With commutator	Without commutator	With commutator	Without commutator	With commutator	Without commutator
Temperature-rise test - Guaranteed rating(s) usually the continuous rating(s) - One-hour rating - Other ratings	27 35	After agreement between user and manufacturer										T S	
Overspeed test	36	S		S		S		S		S		S	
Starting test	37,45	T ¹⁾				T		T				T	
Commutation test - Steady state conditions - Interruption and restoration of the supply	38, 39	S, T		S, T		S, T		S, T		S, T		S, T	
	38, 40	T				T		T				T	
Dielectric test	41	S		S		S		S		S		S	
Characteristic curves	42, 43	S, T		S, T		S, T		S, T		S, T		S, T	
¹⁾ Only for motors intended for vehicles specified in Sub-clause 37.1a). T = type test. S = routine test.													