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RULES FOR OHMIC RESISTORS
USED IN THE POWER CIRCUITS
OF ELECTRICALLY POWERED VEHICLES

NOTE - This leaflet reproduces the whole text of Publication No.322 of the International Electrotechnical Commission (IEC).

The following regulations are obligatory for UIC Member Railways.

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FOREWORD

- 1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.
- 2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.
- 3) In order to promote this international unification, the IEC express the wish that all National Committees having as yet no national rules, when preparing such rules, should use the IEC recommendations as the fundamental basis for these rules in so far as national conditions will permit.
- 4) The desirability is recognized of extending international agreement on these matters through an endeavour to harmonize national standardization rules with these recommendations in so far as national conditions will permit. The national Committees pledge their influence towards that end.

PREFACE

This Recommendation is based on draft rules prepared by the International Union of Railways and submitted in 1963 to the International Mixed Committee on Electric Traction Equipment.

Various amendments were discussed at the meetings held in Tokyo in 1965 and in Prague in 1967. As a result of this latter meeting, a new draft was submitted in November 1967 to the IEC National Committees for approval under the Six Months' Rule, and to the International Union of Railways. Some amendments were submitted to the IEC National Committees for approval under the Two Months' Procedure in January 1969.

The text thus amended was explicitly approved by the following IEC National Committees:

Australia	Netherlands
Belgium	Norway
Denmark	Poland
France	South Africa
Germany	Sweden
Hungary	Switzerland
Israel	Turkey
Italy	Union of Soviet Socialist Republics
Japan	United Kingdom

and by the International Union of Railways.

CHAPTER I

GENERAL

1. Scope

The rules contained in this Recommendation apply to ohmic resistors (resistors for starting, transition, circuit interruption, braking, shunting, stabilizing, etc.) used in the power circuits of electrically powered vehicles in the following categories :

- vehicles supplied with so-called high-voltage d.c., i.e. with a voltage between 600 V and 3 000 V ;
- vehicles supplied with high-voltage a.c. at industrial frequency or at special frequencies ;
- multi-system vehicles capable of being supplied from a number of the systems described above ;
- vehicles with independent power source (i.e. accumulators, or heat engines with electrical or other transmission) but excluding road vehicles.

They are also applicable to resistors permanently or temporarily inserted in the main auxiliary circuits of the above vehicles, and any trailers and driving trailers in motor coach trains.

NOTE. - Certain of these rules may, after agreement between user and manufacturer, be used for resistors installed on other vehicles such as d.c. electric rolling stock supplied at voltages below 600 V, mine locomotives, trolley buses, etc.

2. Object

The present rules are intended to define :

- the conditions which resistors should satisfy ;
- the tests to check that the conditions are in fact satisfied ;
- the descriptive markings to be applied.

3. Definitions

For the definitions of general terms used in this Recommendation, reference should be made to IEC Publications 50 (05) and 50 (30), International Electrotechnical Vocabulary, Group 05 : Fundamental Definitions, and Group 30 : Electric traction. For the purposes of this Recommendation, the following definitions shall apply:

3.1 Resistor element

Resistive conductor, designed without break of continuity, forming part of a resistance box or frame.

The elements are usually in the form of grids, plates, strips, ribbons or wires. They may have intermediate tapings.

3.2 Resistor box or frame

A set of resistor elements assembled into a single structure.

3.3 Resistor block

A frame or compartment in which a number of resistor boxes or frames are mounted.

3.4 Resistor section

Part of a resistant circuit contained between two consecutive terminals connected to apparatus such as contactors or controllers.

3.5 Complete starting or braking resistor

Set of starting or braking resistors on a vehicle.

3.6 Primary insulation

The insulation next to live metal.

3.7 Maximum temperature (t_m)

The maximum conductor temperature which a resistor box, frame or block can withstand permanently without any resulting damage to their constituent materials, including insulants.

3.8 Continuous current (I_c)

Current value specified by the manufacturer that a resistor, or resistor section, can withstand on the test bed for an indefinite period in specified ventilation or cooling conditions, without the temperature t_m being exceeded.

3.9 Rated values of resistances

Rated values of resistances are specified values.

These values do not include the resistance of connections between boxes connected in series or in parallel to form a set, nor the resistance of connections to apparatus (contactors, controllers).

Except when stated otherwise, the rated values of resistance are shown at a temperature of 20° C.

4. Categories of tests

4.1 General

There are three categories of tests :

- type tests
- routine tests ;
- investigation tests.

The differentiation between these three categories of tests is brought out in the text.

4.2 Type tests

Type tests are those made on a single piece of apparatus of a given design.

Equipment in current manufacture is considered to have satisfied the type tests and is exempted from them, if the manufacturer presents duly signed reports of type tests already made on identical apparatus constructed on a previous occasion.

Optional type tests may only be required if they have been expressly specified in the order.

4.3 Routine tests

Routine tests are those made on the whole of the equipment of the same order. For certain apparatus, after agreement between user and manufacturer, routine tests may be replaced by spot checks on part of the order.

4.4 Investigation tests

Investigation tests are special tests, which are optional, and made on a single item in order to obtain additional information on its per-

formance ; their execution may only be required if they are expressly specified in the order.

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

CHAPTER II

CONDITIONS TO BE SATISFIED BY RESISTORS

5. Resistance values

Unless otherwise agreed between user and manufacturer, the values of resistance, measured when cold and corrected if necessary to the reference temperature of 20° C, shall not vary from the rated value by more than the amounts shown in the following Tables I and II.

TABLE I

Tolerances on the resistance of boxes, frames, blocks or sections of resistors and complete resistors.

Resistor type	Tolerances
Starting resistor Braking resistor Permanent shunting resistor	$\left. \begin{array}{l} + 7\% \\ - 5\% \end{array} \right\}$
Shunting resistor for field weakening of direct or pulsating current motors a) weak field between 100% and 50% of full field b) weak field less than 50% of full field	$\pm 5\%$ (1) $\pm 3\%$ (1)
Shunting resistor for interpoles of single-phase commutator motors	$\pm 3\%$
Circuit interrupting resistor	$\pm 10\%$
(1) In the case of adjustable resistor this tolerance can be raised to $+ 7\%$ $- 5\%$	

TABLE II

Tolerances on resistor elements

Nature of resistor element	Tolerances
Cast grids	$\pm 10\%$
Ribbons, wires, etc.	$\pm 5\%$

6. Permissible temperatures and temperature rises

The permissible maximum temperature (t_m) of resistors and the permissible temperature-rise limits will be determined by agreement between user and manufacturer, in relation to the nature of the materials used, to the general design of the apparatus, and to the temperatures which partitions and adjacent accessories (cables, cable sockets, etc.) are able to withstand.

At the request of the user, the manufacturer should submit diagrams showing loading cycles for each resistance section, based on the most severe conditions of service (taking into consideration exceptional cases such as motor damage, slipping, signal at danger, decrease of resistor cooling etc.) fixed by the user.

7. Short-circuit withstand

The resistors shall be able to withstand without deterioration or permanent distortion, short-circuit currents, the value and duration of which will be determined by agreement between user and manufacturer, having regard to the characteristics of the circuits in which they will be inserted in the vehicle.

8. Vibration and shock withstand

The resistor boxes or frames mounted complete shall be designed to be able to withstand in service without deterioration :

- in each of the three directions : vertical, longitudinal and transverse, sustained sinusoidal vibrations in the frequency range 1 Hz to 50 Hz the amplitude *a* of which, expressed in millimetres, is given in relation to frequency *f* by the formulae :

$$a = \frac{25}{f} \text{ for } f \text{ between 1 Hz and 10 Hz}$$

$$a = \frac{250}{f^2} \text{ for } f \text{ between 10 Hz and 50 Hz}$$

- in the direction corresponding to the longitudinal movement of the vehicle, shocks producing maximum acceleration of 3 *g* (*g* being the value of acceleration due to gravity).

In addition, the elements and accessories of the resistors shall not exhibit harmful resonance for the frequencies in the above range.

9. Protection against corrosion

All precautions shall be taken to give adequate protection against corrosion for all the components of the resistor, especially contact surfaces.

10. Performance in rain and snow

If the resistors are to be installed on a vehicle in such a way that they are exposed to rain and snow, they shall be able to withstand the effects of these elements without mechanical or electrical damage.

CHAPTER III

TESTS

11. List of tests

The type and routine tests to be made on resistors are indicated in Table III below, which also specifies the clause or sub-clause number to which reference should be made.

TABLE III

List of tests

Nature of test	Clause or sub-clause	
	Type test	Routine test
Check on characteristic of resistor elements material	12	
Check on rated resistance	13.2 and 13.3	13.1
Temperature-rise tests	14	
Tests for withstanding vibration and shock	15	
Dielectric tests		16
Hygroscopic test (1)	17	
Short-circuit test (1)	18	
Test for performance in rain (2)	19	

(1) Optional type test.
 (2) This test must be applied only if the resistors on the vehicle are exposed to rain and snow.

12. Check on characteristics of resistor elements material (type test)

The resistivity and the average value of the temperature coefficient over the range between the ambient and maximum temperatures (t_m) will be determined from test pieces taken from the alloy forming the resistor elements material.

13. Check on rated resistance (type and routine tests)

13.1 Checks on the rated value of resistance for resistor boxes, frames, blocks, resistor sections or complete resistors are carried out by using a voltmeter and ammeter, or a Kelvin double bridge, the current through the resistors being sufficient to eliminate the errors due to contact resistances.

Readings are taken at the ambient temperature of the workshop.

If necessary, the values measured are to be corrected to the reference temperature of 20° C. The tolerances allowed in relation to the rated values are shown in Clause 5.

13.2 Resistance measurements are repeated at the end of the temperature-rise test described in Sub-clause 14.2. The resistance increase noted should approximate to the value calculated on the basis of the temperature coefficient determined during the tests described in Clause 12.

13.3 After the temperature-rise test, the resistance is measured again at the ambient temperature of the workshop. The reading obtained, corrected if necessary to the reference temperature of 20° C, shall not exceed by more than 3% the value measured before the temperature-rise test, and shall, in any case, remain within the limits of tolerance given in Table 1, page 9.

14. Temperature-rise tests (type test)

14.1 General

The temperature-rise tests are made on a finished and mounted resistor installed in conditions as identical as possible to those on the

vehicles, especially in regard to the cross-section of the connecting leads, the resistor position, etc. The cooling conditions shall be mutually agreed between user and manufacturer so as to reproduce the normal service conditions as closely as possible.

The temperature-rise of the resistor elements and, if necessary, of the connection terminals is recorded by electrical thermometers placed at the points assumed to be the hottest. For the measurement of the temperature-rises of the resistor elements, paints or colours, sensitive to heat, may also be used.

14.2 Test of resistor boxes or frames

In each case there shall be applied to the resistor box or frame of resistors :

- either the continuous current I_C (see Sub-clause 3.8), the test being continued until steady values of temperature are reached ;
- or the specified duty cycle (see Clause 6).

In the latter case, the cycle is repeated several times, the number of successive cycles and the no-load interval between two consecutive cycles being fixed by agreement between user and manufacturer.

During the test, the temperature rises observed must not exceed the specified limits.

In the case of resistors, such as limiting or transition resistors, which are only in use for very short periods, the test using the duty cycle may be replaced by the experimental determination of the thermal capacity using methods to be agreed between user and manufacturer.

On completion of the temperature-rise test, the resistors must be in perfect working order. In particular, they must be capable of withstanding the dielectric tests prescribed in Clause 16.

14.3. Test on resistor blocks and complete resistors

Temperature-rise tests on resistor blocks and on complete resistors are usually carried out when the vehicle is completed. See IEC Publication 165: Rules for the Testing of Electric Rolling Stock on Completion of Construction and before Entry into Service.

If the resistor blocks or complete resistors are supplied separately, user and manufacturer should agree on the method of execution of the tests.

15. Tests for withstanding vibration and shock (optional type test)

The resistor box or frame is fixed, in a suitable position, on to a machine producing sinusoidal vibrations of adjustable amplitude and frequency, then subjected to the tests of Sub-clauses 15.1 and 15.2.

The box or frame is then fixed on a suitable device and subjected to the test of Sub-clause 15.3.

After these tests, the resistor box or frame must be able to withstand successfully the electrical tests, and particularly the dielectric strength tests described in Clause 16.

15.1 Investigation of resonant frequencies

With a view to investigating the possible presence of critical frequencies causing resonances in the parts of the box or frame, the frequency must be gradually varied from 1 Hz to 50 Hz in a time at least equal to 4 min, the amplitude of the oscillations being that shown in Clause 8.

The test is carried out successively in each of the three directions shown in Clause 8.

15.2 Sustained vibration tests

In each of the three directions given in Clause 8, the resistor box

or frame is, when cold, subjected, for a time not less than 15 min to be agreed between user and manufacturer, to a sustained vibration test :

- either at the critical frequency if such a frequency, well defined, has been detected during the test described in Sub-clause 15.1 ;
- or, otherwise, at 10 Hz.

In both cases, the amplitude of the vibrating table is adjusted to the value corresponding to the frequency considered (see Clause 8).

15.3 Test simulating buffing shocks

In the direction corresponding to the longitudinal movement of the vehicle on which it will be mounted, the resistor box or frame is subjected to a series of three successive impacts each corresponding to a maximum acceleration of 3 g.

16. Dielectric tests (routine test)

16.1 These tests are carried out at the normal temperature of the test site on each resistor box, frame or block.

The test voltage at the nominal frequency of 50 Hz or 60 Hz shall be as nearly as possible sinusoidal.

The r.m.s. values of this voltage, the time of application of which is fixed uniformly at 1 min in all cases, are given below :

- resistors with single insulation 2.5 U + 2 000 V
- resistors with double insulation :
 - a) primary insulation 3 000 V
 - b) secondary insulation 2.5 U + 2 000 V
- resistors with triple insulation :
 - a) primary insulation 3 000 V

- b) secondary insulation 2 $U + 1\ 000\ V$
- c) tertiary insulation 2,5 $U + 2\ 000\ V$

NOTE. - In the above, U is the rated voltage of the circuit in which the resistor box, frame or block is inserted.

16.2 The test voltage to be applied to the transition resistors of high-voltage tap-changers on single-phase powered vehicles will form the subject of an agreement between user and manufacturer.

17. Hygroscopic test (optional type test)

The resistor box or frame is placed, for 24 h, in a humid enclosure at a temperature of 20° C to 25° C and showing a relative humidity of at least 95%.

As soon as possible, and in any case less than 5 min after removal from the humid enclosure and after wiping off extraneous surface moisture with a clean cloth, a dielectric test is carried out, using test voltages of values 1 000 V less than the values shown in Clause 16.

No flashover shall occur.

18. Short-circuit test (optional type test)

With the elements at a temperature of about 20° C, the resistor box or frame is subjected to a current, the value and duration of which are specified in Clause 7. This current shall be established in less than 0,05 s.

This test is carried out three times at intervals of 3 s.

No permanent distortion or burning shall occur.

19. Test for performance in rain (type test)

If applicable (see Clause 10), the resistor box or frame on test is brought to temperature t_m by the application of an appropriate current, and is then sprayed with cold water at a temperature of 10° C to 20° C.

Unless otherwise agreed, the spray shall be made in a direction which in the vertical plane forms an angle of 45° with the direction of motion and with an output of 3 mm/min for 5 min.

The test should be carried out three times without producing any ill effects. The insulators especially shall not be cracked.

At the end of the third test, a dielectric test shall be carried out, using test voltages of values 1 000 V less than the values shown in Clause 16.

No flashover shall occur.

20. Condition of resistor after tests

After the tests specified in the preceding clauses, a check shall be made that :

- no screw or nut is loose ;
- the elastic inserts have correctly fulfilled their purpose ;
- there is no distortion or corrosion or scaling of any components ;
- the resistor elements are not cracked or broken ;
- the insulators have suffered no damage.

CHAPTER IV

RATING PLATE

21. Rating plate

Each resistor box or frame shall be provided with a plate displaying, in principle, the following information :

- manufacturer's name ;
 - indication of type and series ;
 - value at 20° C of the rated total resistance and, if required, of the partial resistance between connection terminals ;
 - year of manufacture.
-

APPLICATION

With effect from 1st November, 1971.

All Railways in the Union.

RECORD REFERENCES

Heading under which the question has been dealt with :

- Study of questions of common interest relating to electrical equipment on powered stock, and participation in the work of the International Joint Committee for Electric Traction Equipment (CMT), insofar as this concerns the UIC.

(Sub-Committee for Electric Traction : Paris, January, 1971).
