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Road vehicles — Electrical performance of starter motors — Test methods and general requirements

Véhicules routiers — Caractéristiques électriques des démarreurs — Méthodes d'essai et conditions générales

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 8856 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 3, *Electrical and electronic equipment*.

This second edition cancels and replaces the first edition (ISO 8856:1988), of which it constitutes a technical revision.

Annex A forms an integral part of this International Standard.

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Road vehicles — Electrical performance of starter motors — Test methods and general requirements

1 Scope

This International Standard lays down test methods and general requirements for the determination of the electrical characteristics of d.c. starter motors intended to start internal combustion engines of road vehicles.

2 Definitions

For the purposes of this International Standard, the following definitions apply.

2.1 nominal power, P_{nom}**:** Power declared by the starter motor manufacturer corresponding to the maximum power output at the reference temperature of 20 °C when determined in accordance with this International Standard.

2.2 power output, P**:** Power derived from measurements of torque and rotational frequency of the starter motor pinion shaft.

2.3 power supply: Battery or simulator which delivers a voltage/current characteristic as defined in this International Standard.

2.4 internal resistance of starter motor: Value of the terminal voltage divided by the starter motor current (steady state solenoid current included) with the armature shaft locked (no rotation).

3 Test conditions

3.1 Temperature and time

Tests shall be carried out at an ambient temperature of (23 ± 5) °C unless otherwise specified.

3.1.1 Test method A

Ensure that all parts of the starter motor are at the temperature of (23 ± 5) °C, or to avoid a need for temperature correction, the starter motor may be preconditioned at (20 ± 2) °C.

The time for each discrete point measurement shall be 3 s.

3.1.2 Test method B

Ensure that all parts of the starter motor are at the temperature of (23 ± 5) °C, or to avoid a need for temperature correction, the starter motor may be preconditioned at (20 ± 2) °C.

The total test time shall be 10 s.

3.1.3 Test method C

The starter motor shall be preconditioned at a temperature of (– 20 ± 2) °C. If required, other temperatures may be used as agreed between starter motor manufacturer and the engine manufacturer.

The total test time shall be 10 s.

3.2 Measurement accuracy

The overall capability of the test equipment shall enable the parameters to be measured within the accuracy shown in table 1. This requirement shall be respected throughout the test procedure.

Table 1 — Measurement accuracy

Parameter	Accuracy %
Current	± 1
Voltage	± 1
Rotational frequency	± 2
Torque	± 2

3.3 Voltage/current characteristic of starter motor power supply

The voltage/current characteristic of the power supply is a straight line pointing downwards (see figure 1). It is determined at + 20 °C or – 20 °C either by two pairs of values [(U_1, I_1) and (U_2, I_2) or (U'_1, I_1) and (U_2, I'_2)], or by one pair of values [(U, I)] and the internal resistance of the starter motor power supply.

The voltage/current characteristic shall be selected from table 2 without exceeding the values stated by the starter motor manufacturer, and the battery discharge capability as agreed between the starter motor manufacturer and the vehicle manufacturer.

The voltage/current characteristic for a starter motor may also be selected in relation to the nominal power (see table A.1).

If required, other voltage/current characteristics may be used as agreed between the starter motor manufacturer and the engine manufacturer.

The voltage values shall be taken at the starter motor terminals.

3.4 Preparation of test samples

In order to ensure uniform functioning, the new starter motor to be tested shall be preconditioned as follows:

a) 15 s running at a torque equal to 25 % of the lock torque value;

b) 60 s rest;

c) 15 s running at a torque equal to 25 % of the lock torque value.

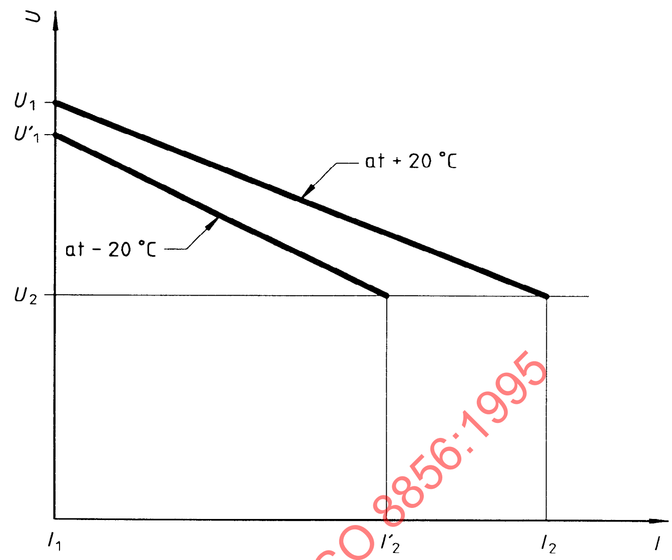

Figure 1 — Voltage/current characteristic of starter motor power supply

4 Test benches

The following two types of test bench may be used.

NOTE 1 Geared and non-geared test benches produce different apparent power and this should be taken into consideration, particularly when testing small power starter motors.

4.1 Type 1 test bench

The test bench in figure 2 (type 1) allows performance measurements to be taken by engaging the pinion with a ring-gear. The backlash between the pinion and the ring-gear teeth shall be in accordance with the starter motor manufacturer's recommendations.

4.2 Type 2 test bench

The test bench in figure 3 (type 2) permits direct starter motor measurement at the armature shaft. The starter motor shall be coupled to the test device coaxially through a suitable coupling. The drive end bracket of outboard bearing starter motors may be replaced by a special bearing bracket to permit coupling to the starter motor shaft.

Table 2 — Voltage/current characteristic of starter motor power supply for starter motor testing

Voltage/current characteristic No.	Nominal voltage V	Voltage/current characteristic at + 20 °C				Voltage/current characteristic at – 20 °C			
		U_1 V	I_1 A	U_2 V	I_2 A	U'_1 V	I_1 A	U_2 V	I'_2 A
1	12	12	0	6	400	11,5	0	6	220
2					600				360
3					800				480
4					1 000				700
5					1 200				840
6					1 500				1 050
7					2 000				1 400
8					3 000				2 100
9	24	24	0	12	600	23	0	12	330
10					800				440
11					1 000				550
12					1 200				720
13					1 500				900
14					1 700				1 020
15					2 000				1 400
16					2 400				1 680

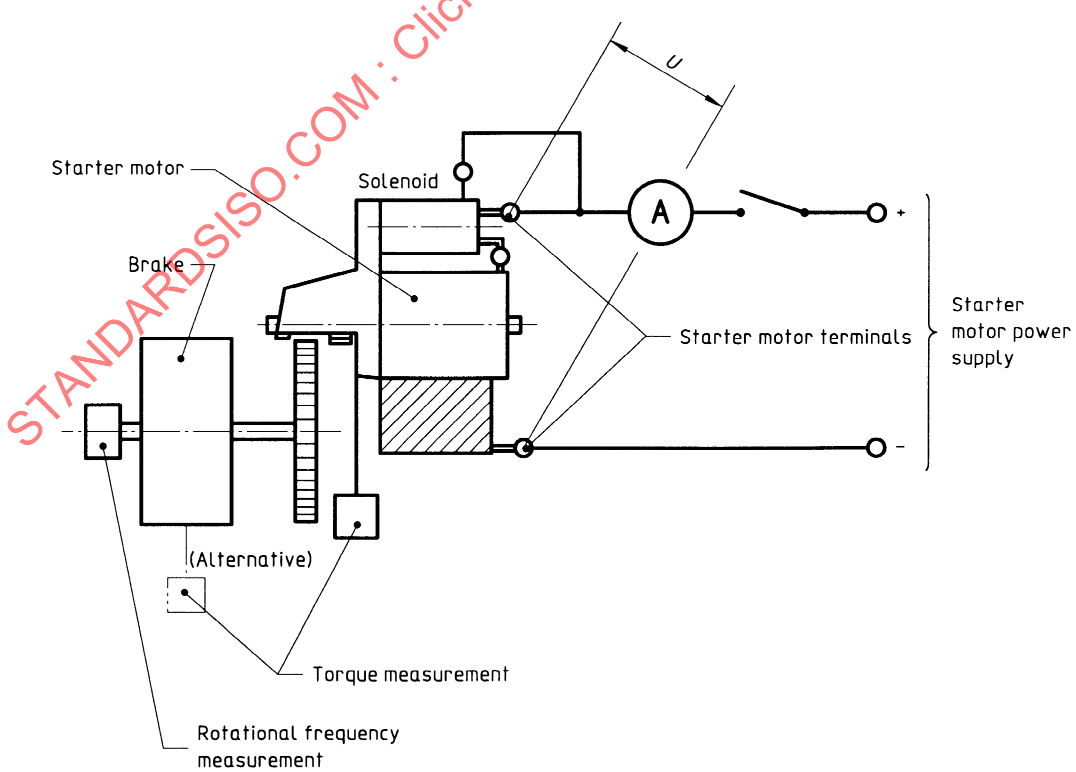

Figure 2 — Type 1 test bench

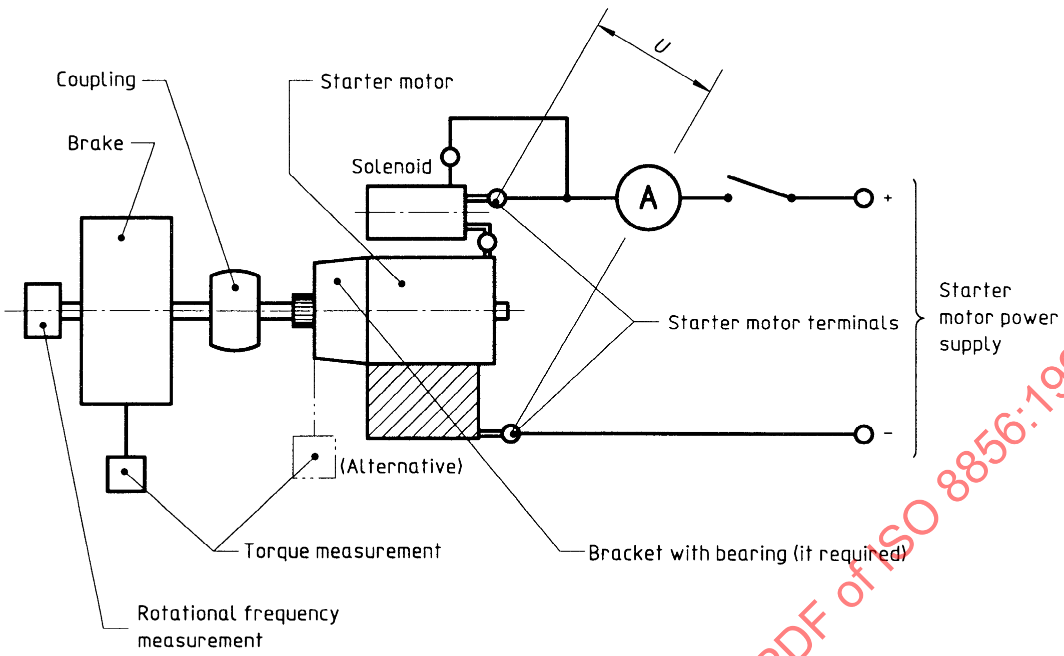

Figure 3 — Type 2 test bench

5 Test methods

Test method A or B shall be used and if required by the user, also method C.

5.1 General

The test reference temperature is + 20 °C.

If it is important to know the starter motor performance at a temperature of – 20 °C, this can be measured according to 5.2.3 or calculated by using the values measured in accordance with 5.2.1 or 5.2.2 and the calculation methods described in clause 6.

If required, temperatures different from – 20 °C may be considered as agreed between the starter motor manufacturer and the vehicle manufacturer.

5.2 Test procedures

5.2.1 Method A — Discrete point method

Run the starter motor at various discrete torque loads and record the torque, current, voltage and rotational frequency at each of these discrete points. Record enough points to develop curves (see figure 4).

After each measurement point, cool all parts of the starter motor to test temperature (see 3.1.1).

5.2.2 Method B — Continuous mode method

Operate the starter motor in a continuous mode, increase the torque load (until the starter motor stalls, if required) while torque, current, voltage and rotational frequency are automatically recorded.

5.2.3 Method C — Continuous mode method at – 20 °C

Take the starter motor from the cooling device and test it according to 5.2.2. The test shall be completed within 3 min after the starter motor has been removed from the cooling device.

6 Measurement correction

The measured values of torque and rotational frequency shall be corrected taking into account the influence of test bench, inertia and temperature.

The calculations described below are applicable for permanent field starter motors and series wound field starter motors.

Starter motors with compound wound field are not considered because these types of starter motors are not as often used as the types above and the calculation is much more difficult. However, the values of torque and rotational frequency of these starter motors shall also be corrected for the change in resistance of the shunt winding with temperature.

6.1 Correction of torque

Torque measurement is recorded as either a frame reaction or as taken at the torque loading point. In the second case the corrections given in 6.1.1 to 6.1.3 apply.

6.1.1 Correction of torque with ring-gear efficiency

This is only required for measured values taken with the type 1 test bench. The correction shall be made using the following formula:

$$M_1 = M_{\text{mes}} \times \frac{z_1}{z_2 \eta} \qquad \ldots (1)$$

where

- M_1 is the torque corrected with ring-gear efficiency;
- M_{mes} is the torque measured;
- z_1 is the number of teeth on the starter motor pinion;
- z_2 is the number of teeth on the ring-gear of the test bench;
- η is the ring gear efficiency.

6.1.2 Correction of torque with inertia

Use the following correction for torque for armature deceleration:

$$M_2 = M_{\text{mes}} - \frac{\pi \times \Delta n}{30 \times \Delta t} \times (J_{\text{br}} + J_{\text{a}}) \qquad \ldots (2)$$

where

- M_2 is the torque corrected with inertia;
- M_{mes} is the torque measured;
- Δn is the rotational frequency difference between two braking points expressed in revolutions per minute (r/min);
- Δt is the time difference between two braking points expressed in seconds;
- J_{br} is the moment of inertia of the measuring device expressed in kilogram square metres;
- J_{a} is the moment of inertia of armature and other revolving parts expressed in kilogram square metres. For starter motors with built-in reduction gear, the moment of inertia of the armature shall be referred to the pinion shaft.

6.1.3 Correction of torque with temperature

In the case of permanent magnet field starter motors the magnetic flux changes with the temperature. The torque corrected as in 6.1.1 or 6.1.2 shall be further corrected in accordance with the following formula:

$$M_3 = M_1[1 - \beta(t_1 - t_2)] \qquad \ldots (3)$$

or

$$M_3 = M_2[1 - \beta(t_1 - t_2)] \qquad \ldots (4)$$

where

- M_3 is the torque corrected with temperature;
- M_1 and M_2 are as defined in equations (1) and (2);
- t_1 is the initial temperature, in degrees Celsius;
- t_2 is the final temperature, in degrees Celsius;
- β is the magnetic induction coefficient of the permanent magnet field. The value of β may vary between -2×10^{-3} °C^{-1} and $-2{,}3 \times 10^{-3}$ °C^{-1}. In the case of a wound field starter motor $\beta = 0$.

6.2 Correction of rotational frequency with temperature

The rotational frequency, n, is given by the formula:

$$n = k \frac{E}{\Phi} \qquad \ldots (5)$$

where

- k is a constant depending on the starter motor size;
- E is the back-electromotive force, in volts;
- Φ is the magnetic flux available in the starter motor field, in webers.

The rotational frequency change is generally calculated by comparing the back-electromotive forces using the equation:

$$E = U - RI \qquad \ldots (6)$$

where

E is the back-electromotive force, in volts;

U is the applied voltage, in volts;

R is the internal resistance of the starter motor, in ohms;

I is the starter motor current, in amperes.

For a temperature change from t_1 to t_2, the starter motor internal resistance changes from R_1 to R_2 given by the formula:

$$R_2 = [1 + \alpha(t_2 - t_1)] \times R_1 \qquad \ldots (7)$$

where

t_1 and t_2 are expressed in degrees Celsius;

α is the temperature coefficient of the resistance at temperature t_2 for the starter motor winding material. The value for α for copper (100 %) as in the International Annealed Copper Standard (IACS), is $3{,}93 \times 10^{-3}$ °C^{-1} at 20 °C. For starter motors constructed with composite copper/aluminium windings, it will be necessary to calculate the value of α.

In the case of a permanent magnetic field starter motor, the magnetic flux changes with the temperature.

The rotational frequency change from n_1 to n_2 is calculated using the formula

$$n_2 = \frac{E_2}{E_1} \times \frac{1}{1 - \beta(t_1 - t_2)} \times n_1 \qquad \ldots (8)$$

where E_1 and E_2 are calculated using formula (6), and t_1, t_2 and β are as specified in 6.1.3.

7 Presentation of results

7.1 Power output calculation

Starter motor power output P, in kilowatts, may be determined by the following formula:

$$P = \frac{M \times n}{9549{,}3} \qquad \ldots (9)$$

where

M is the torque, in newton metres;

n is the rotational frequency in minutes to the power minus one.

7.2 Graphic presentation of starter motor characteristic curves

Performance characteristics shall be presented in accordance with figure 4. When necessary, the measured parameters shall be corrected to the reference temperature of + 20 °C (see clause 6) and the test bench employed shall be specified.

If a calculated value of α is used, the value shall be recorded.

If so required, the starter motor performance may be reproduced as a rotational frequency/torque characteristic.

If the test is made at or related mathematically to a low temperature, this shall be noted in the test report and no correction to + 20 °C is required.

7.3 Change of rotational frequency characteristic

To change the rotational frequency characteristic of a performance curve as in figure 4, the following data shall be taken at suitable steps of current:

a) starter motor rotational frequency, n;

b) terminal voltage, U;

c) starter motor resistance, R.

The rotational frequency is calculated using equation (8) at each selected value of current and thus a new rotational frequency characteristic curve is established.

For changes in applied voltage, the value U in the equation (6) is affected, and the rotational frequency calculated using equation (8). The power output characteristic is calculated as in 7.1.

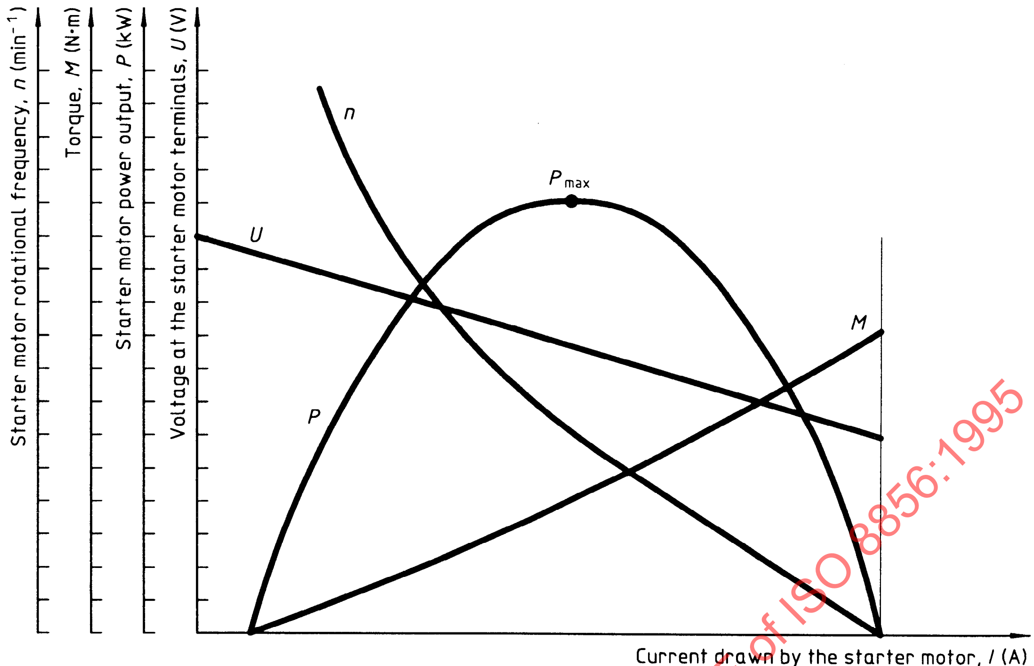

Figure 4 — Presentation of results