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Electrically propelled road vehicles — Test specification for electric propulsion components —

Part 5: Operating load testing of the motor system

Véhicules à propulsion électrique — Spécification d'essai pour les composants de propulsion électrique —

Partie 5: Essai de charge de fonctionnement d'un système de moteur

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Foreword

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This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 37, *Electrically propelled vehicles*.

A list of all parts in the ISO 21782 series can be found on the ISO website.

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Electrically propelled road vehicles — Test specification for electric propulsion components —

Part 5: Operating load testing of the motor system

1 Scope

This document specifies operating load tests and test criteria for the motor system designed as a voltage class B electric propulsion system for electrically propelled road vehicles.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO 21782-1:2019, *Electrically propelled road vehicles — Test specification for electric propulsion components — Part 1: General test conditions and definitions*

ISO 21498-1, *Electrically propelled road vehicles — Specification of voltage sub-classes for voltage class B*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 21782-1 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Symbols and abbreviated terms

For the purposes of this document, symbols and abbreviated terms given in ISO 21782-1 apply.

5 Tests and requirements

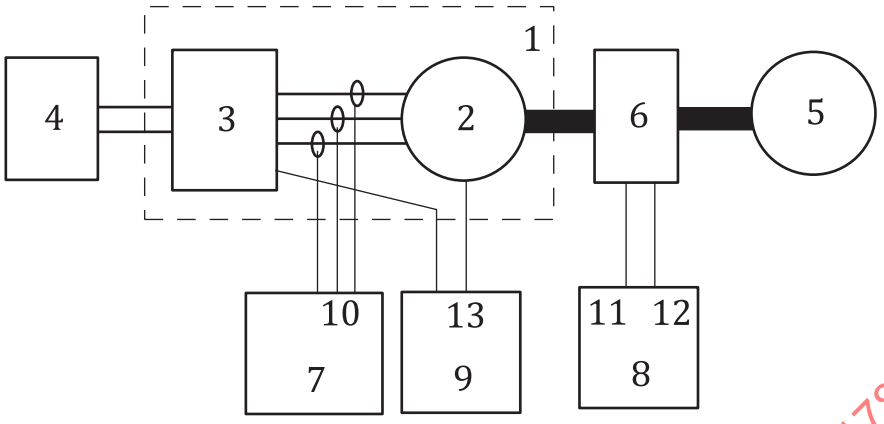
5.1 Endurance test

5.1.1 General

The purpose of this test is to evaluate and rank the strength for the components – motor shaft key, rotor fixture, shaft tightening part, stator fixtures, power semiconductor chip, and DC bus capacitor – which are affected by mechanical or electrical fatigue. The test is set considering repeated operations at the upper specification limits of the motor system, which operate under the conditions of the paired inverter and motor combination. Unless otherwise specified, the test method can be decided by the supplier and customer.

5.1.2 Test diagram

The test diagram is shown in Figure 1.



Key

1 DUT
2 motor
3 inverter
4 DC power supply
5 load
6 torque / speed detector
7 power meter
8 torque / speed meter
9 thermo meter
10 inverter output current (in A)
11 motor torque (in Nm)
12 motor speed (in min^{-1})
13 measurement points temperatures (in °C)

Figure 1 — Diagram for the endurance test of the motor system

5.1.3 Test conditions

Test conditions are shown in Table 1.

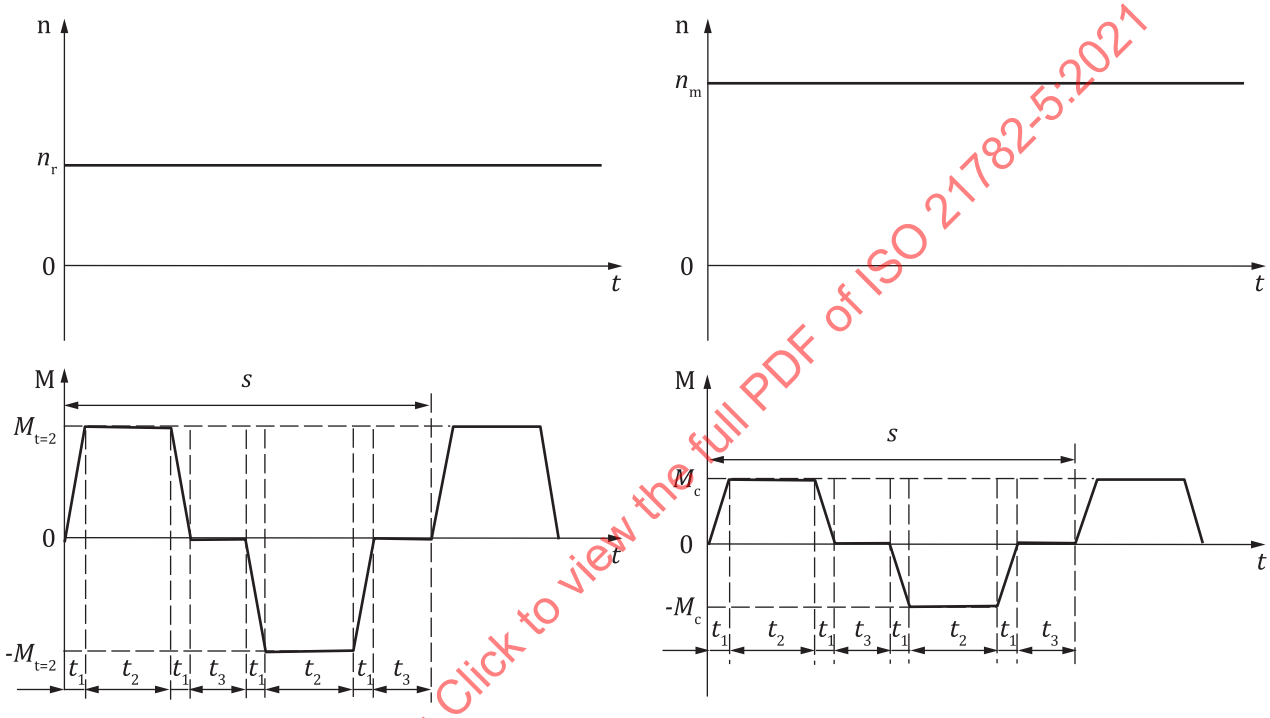
Table 1 — Conditions for endurance test of the motor system

Items		Value	Remark
Inverter input voltage		Rated voltage as defined in ISO 21782-1:2019, 3.22	— DC voltage tolerance, see ISO 21782-1:2019, 5.3
Ambient conditions		Room temperature (RT) and humidity as defined in ISO 21782-1:2019, 5.4	
Coolant temperature	Liquid	Maximum temperature for unlimited operating capability	— Ethylene glycol and propylene glycol as example of coolant
	Air	Maximum temperature for unlimited operating capability	
Coolant flow rate	Liquid	Minimum flow rate for unlimited operating capability	
	Air	Minimum flow rate for unlimited operating capability	

5.1.4 Test procedure

The test pattern consisting of maximum torque mode and maximum speed mode is shown in Figure 2. Time parameter t_1, t_2 and t_3 in Figure 2 shall be as shown in Table 2. The tests shall be conducted by alternating the maximum torque mode and maximum speed mode as shown in Figure 3 and Table 3. The tests shall be conducted by repeating the number of cycles according to the corresponding rank listed in Table 4. The temperature of each part of the motor system shall be controlled so that they are substantially equal to the saturation temperature.

NOTE To protect torque meter, test can be performed without it, after setting up the maximum torque. In that case, torque meter can be replaced by power meter to measure motor input currents.



a) maximum torque mode **b) maximum speed mode**

Key

t	time (in s)
n	speed (in min^{-1})
n_r	rated speed (in min^{-1})
n_m	maximum speed (in min^{-1})
M	torque (in Nm)
$M_{t=2}$	maximum torque of the motor system for duration of t_0=2 (in Nm)
M_c	calculated torque of the motor system at operating point "c" (in Nm)
s	1 cycle
t_1, t_2, t_3	time parameter

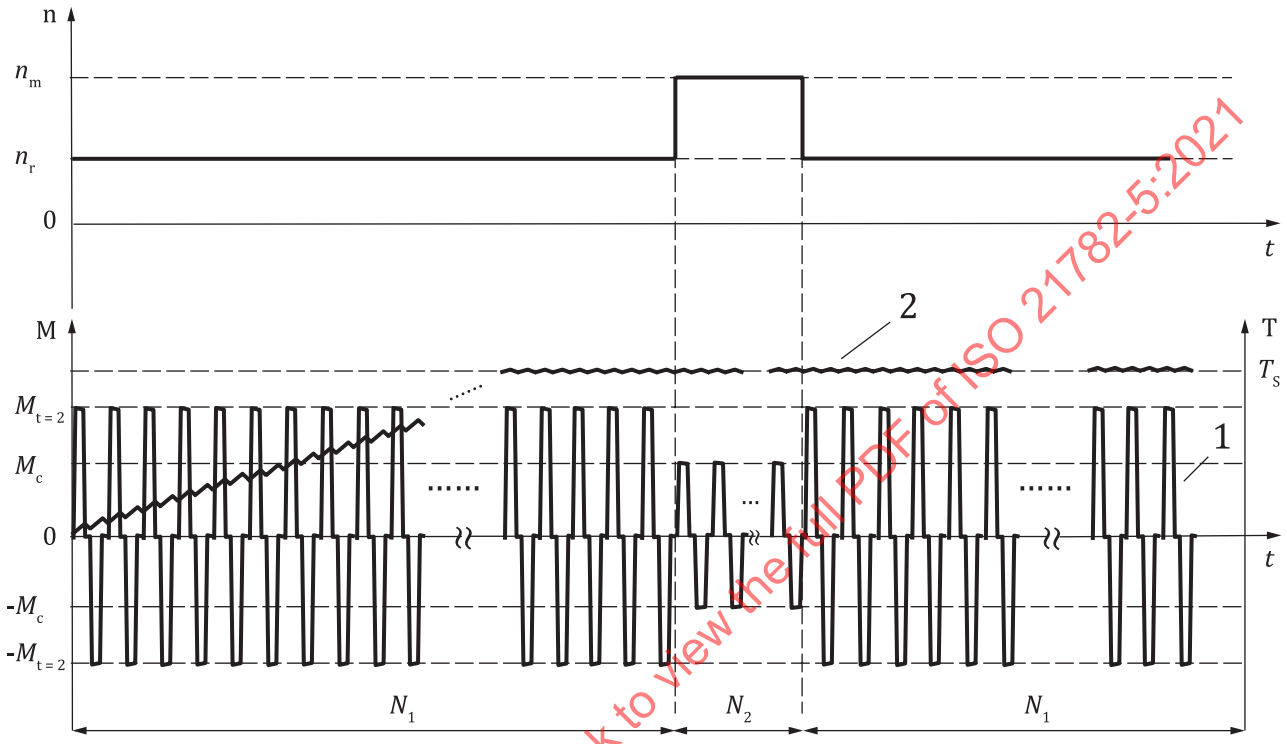
Figure 2 — Endurance test pattern for the motor system

Table 2 — Description of time parameter in Figure 2

Time parameters	Requirements and recommendations
t_1	This shall be reduced to the technically possible minimum.
t_2	This should be shorter than 1 s.

Table 2 *(continued)*

Time parameters	Requirements and recommendations
t_3	This shall be controlled so that the temperature of the motor system does not exceed the maximum temperature for unlimited operating capability (T_S).



Key

t time (in s)
n speed (in min^{-1})
n_r rated speed (in min^{-1})
n_m maximum speed (in min^{-1})
M torque (in Nm)
$M_{t=2}$ maximum torque of the motor system for duration of t_0=2 (in Nm)
M_c calculated torque of the motor system at operating point "c" (in Nm)
T temperature (in °C)
T_S maximum temperature for unlimited operating capability (in °C)
N_1 number of cycles of maximum torque mode
N_2 number of cycles of maximum speed mode
1 motor torque
2 measurement points temperatures

Figure 3 — Long time span view of Figure 2

Table 3 — Values of parameter in Figure 3

Parameters	Value[a]
N_1	850
N_2	150

[a] The value of parameters N_1 and N_2 can be decided by agreement between the supplier and customer. But the ratio of N_1 and N_2 shall be 850:150(17:3).

Table 4 — Number of cycles of endurance test for the motor system

Ranks	Number of cycles
S	2 000 000
A	1 000 000
B	500 000
C	300 000

5.1.5 Test requirements

5.1.5.1 General

The cyclic test shall be started from C rank, which is listed in Table 4. Confirmation by energizing and disassembling shall be conducted after the endurance test. Before starting the test, target rank shall be decided by the supplier and customer. After each rank, energizing should be done to confirm that difference before and after the test are within the respective criteria shown in Table 5, but the supplier and customer can agree to only do energizing after the target rank. After the target rank has been achieved, disassembling shall be done to confirm the respective criteria shown in Table 6 are fulfilled.

5.1.5.2 Energizing

Before conducting this test, the data of the tests shown in Table 5 shall be obtained in order to compare the data before and after this test.

— Back electromotive force (back-EMF) measurement

The back-EMF of the motor is measured at the 10 % of maximum speed driven externally. They shall be within 5 % difference before and after the test.

NOTE If the type of motor is different from a permanent magnet motor, this measurement can be omitted.

— Position sensor origin position check and waveform check

The difference in the back-EMF waveform of the reference phase and the origin position of the position sensor at the 10 % of maximum speed driven externally shall be measured. They shall be within 5° difference in electrical angle before and after the test.

— Torque-speed characteristics

The motor torque, motor input voltage, inverter output current, and motor speed shall be measured using the load test bench at the operating point "a" and "c" of ISO 21782-1:2019, Figure 1. The difference in torque before and after the test shall be within 5 %.

— Measurement of vibration

The generated vibrations of the motor during acceleration by the inverter to the maximum speed shall be measured. The acceleration rate shall be adequately slow. The vibration data before and after the test shall be compared for no significant increase. The difference in the vibration values shall be judged by an agreement between the supplier and customer.

Criteria of energizing is shown in Table 5.

Table 5 — Criteria of energizing

Measurement items	Condition	Criteria
Back-EMF	10 % of maximum speed	Within 5 % difference before and after the test
Origin position and waveform of position sensor	Specified speed	Within 5° difference in electrical angle before and after the test
Torque-speed characteristics	Operating point "a" and "c"	Within 5 % difference in the torque before and after the test
Vibration	During acceleration to the maximum speed by inverter (acceleration rate: adequately slow)	No significant increase

5.1.5.3 Disassembling (option)

After the energizing tests, the motor system may be disassembled and investigated according to Table 6.

Disassembling is agreed by the supplier and customer in case of abnormalities in the non-destructive examinations.

Table 6 — Criteria of disassembling

Parts/places	Details of investigation	Criteria
Motor shaft key	Deformation, wear	No large deformation No large wear
Rotor magnet fixture (adhesive)	Peeling off of adhesive deformation	No peeling
Shaft tightening part (spline, etc.)	Deformation, wear	No large deformation No large wear
Stator fixtures (thermal insert, bolt)	Wear, deviation, loosening	No large wear No large deviation No loosening
Power semiconductor chip	Electrical resistance and thermal resistance	Within 10 % difference before and after the test
DC bus capacitor	Capacitance and impedance characteristics at the typically used frequency	Within 10 % difference before and after the test

NOTE In case of insulated gate bipolar transistor (IGBT), the resistance between the collector and the emitter is measured. In case of field effect transistor (FET), the resistance between the drain and the source is measured.

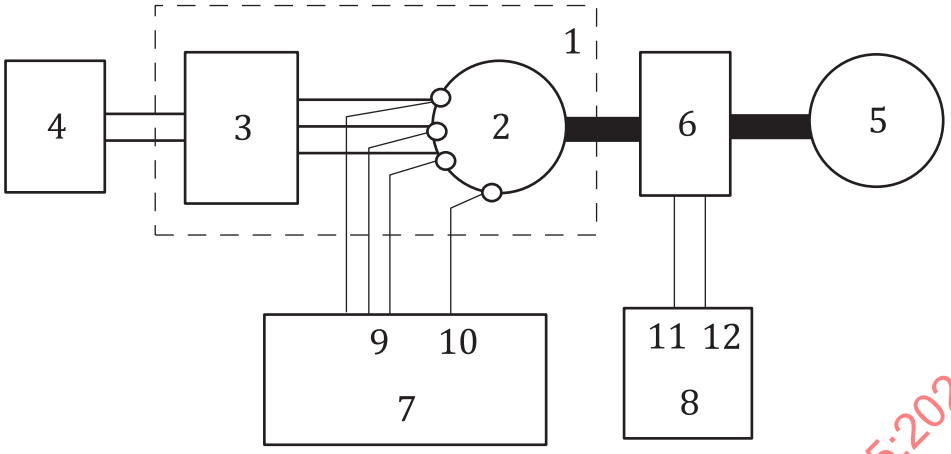
5.2 Surge voltage measurement test

5.2.1 General

The purpose of this test is to ensure that the voltage applied to motor input terminal is below the withstand voltage specified by the motor manufacturer in consideration of temperature, humidity, barometric pressure and durability. The paired motor and inverter shall be used in the test.

5.2.2 Test diagram

The test diagram is shown in Figure 4.



Key

1 DUT
2 motor
3 inverter
4 DC power supply
5 load
6 torque/speed detector
7 storage oscilloscope
8 torque/speed meter
9 motor input voltage (in V)
10 case voltage (in V)
11 motor torque (in Nm)
12 motor speed (in min^{-1})

Figure 4 — Diagram for the surge voltage measurement test of the motor system

5.2.3 Test conditions

Test conditions are shown in Table 7.

Table 7 — Conditions for surge voltage measurement test of the motor system

Items		Value	Remark
Inverter input voltage		Maximum voltage for unlimited operating capability as defined in ISO 21498-1	— DC voltage tolerance, see ISO 21782-1:2019, 5.3
Ambient conditions		RT and humidity as defined in ISO 21782-1:2019, 5.4	
Coolant temperature	Liquid	Maximum temperature for unlimited operating capability	— Ethylene glycol and propylene glycol as example of coolant
	Air	Maximum temperature for unlimited operating capability	
Coolant flow rate	Liquid	Minimum flow rate for unlimited operating capability	
	Air	Minimum flow rate for unlimited operating capability	
Operating point		The points as defined in ISO 21782-1:2019, Figure 1 — “a”, “a'”	

5.2.4 Test procedure

The test the motor system shall be operated at specified operating point and condition as shown in Table 7. During the specified operating point, the motor input voltage and the voltage between the motor case and input terminals shall be measured.

The surge voltages shall be the peak values (V_{0p}) of recorded waveforms.

5.2.5 Test requirements

The surge voltages shall be below the withstand voltage specified by the motor manufacturer in consideration of temperature, humidity, barometric pressure and durability.

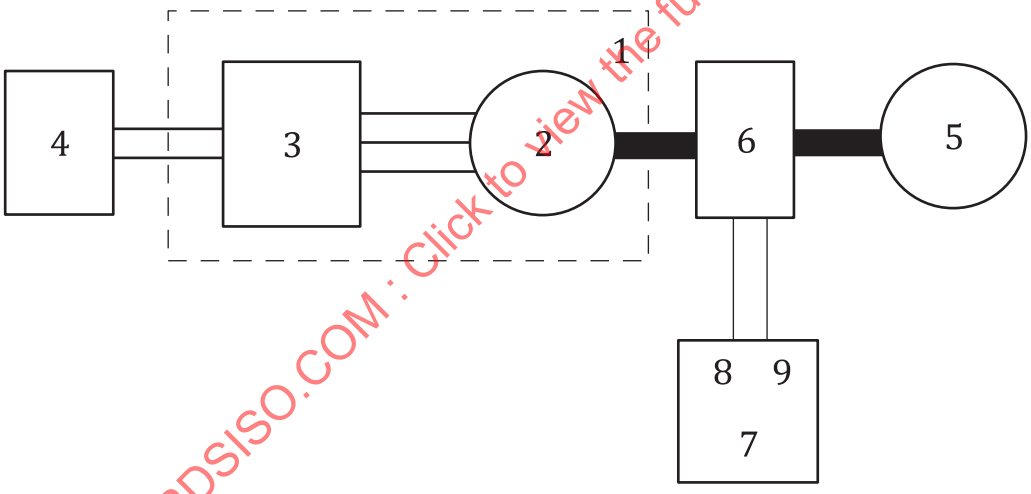
5.3 Over speed test

5.3.1 General

The purpose of this test is to ensure that no control failure occurs in the motor system within the required speed range under operating conditions that exceed the maximum operating speed of the motor system.

5.3.2 Test diagram

The test diagram is shown in Figure 5.



Key

1 DUT
2 motor
3 inverter
4 DC power supply
5 dynamo meter
6 torque / speed detector
7 torque / speed meter
8 motor torque (in Nm)
9 motor speed (in min^{-1})

Figure 5 — Diagram for the over-speed test of the motor system

5.3.3 Test conditions

Test conditions are shown in Table 8.

Table 8 — Conditions for over speed test of the motor system

Items		Value	Remark
Inverter input voltage		Rated voltage as defined in ISO 21782-1:2019, 3.22	— DC voltage tolerance, see ISO 21782-1:2019, 5.3
Ambient conditions		RT and humidity as defined in ISO 21782-1:2019, 5.4	
Coolant temperature	Liquid	Value of design specification	— Ethylene glycol and propylene glycol as example of coolant
	Air	RT	
Coolant flow rate	Liquid	Value of design specification	
	Air	Value of design specification	
Operating point		The points as defined in Table 9	

5.3.4 Test procedure

The motor shall be accelerated to the selected over speed and then continuously operated at this speed for 2 min via the dynamometer only.

There are two methods for determining the rank of the test the motor system, given Annex A.

Table 9 — Test condition of over speed strength

Ranks	Over speed
S	>125 % of n_m
A	120 % of n_m
B	115 % of n_m
C	110 % of n_m
D	105 % of n_m

Test results shall be indicated with alphabetical characters indicating the over speed strength according to Table 9.

5.3.5 Test requirements

Control failure should not occur during over speed test. Examples of control failures include the occurrence of overcurrent or overvoltage due to incorrect energization of the motor, stop of energization, and unintended drive/regenerative torque generation of the motor system.

Before conducting the test, the torque-speed characteristics of the motor system shall be obtained in order to compare the data before and after this test.

After the over speed test for each rank, the motor torque shall be measured using the load test bench at the operating point "a" and "c" of ISO 21782-1:2019, Figure 1. The difference in torque before and after the test shall be within 5 %. The energizing result is considered as passed when both results are passed.

6 Test report

Each test shall be reported with a test report, containing information on test conditions and results.

Examples for a test reports on conditions and results are given in Tables B.1 to B.3.

Annex A
(informative)

Methods for determining the rank for over speed test

A.1 Target rank verification method

Before starting the test, the target rank which is listed in Table 9 can be decided by the supplier and customer. Confirmation by energizing can be conducted after the test with the target rank as shown in Figure A.1.

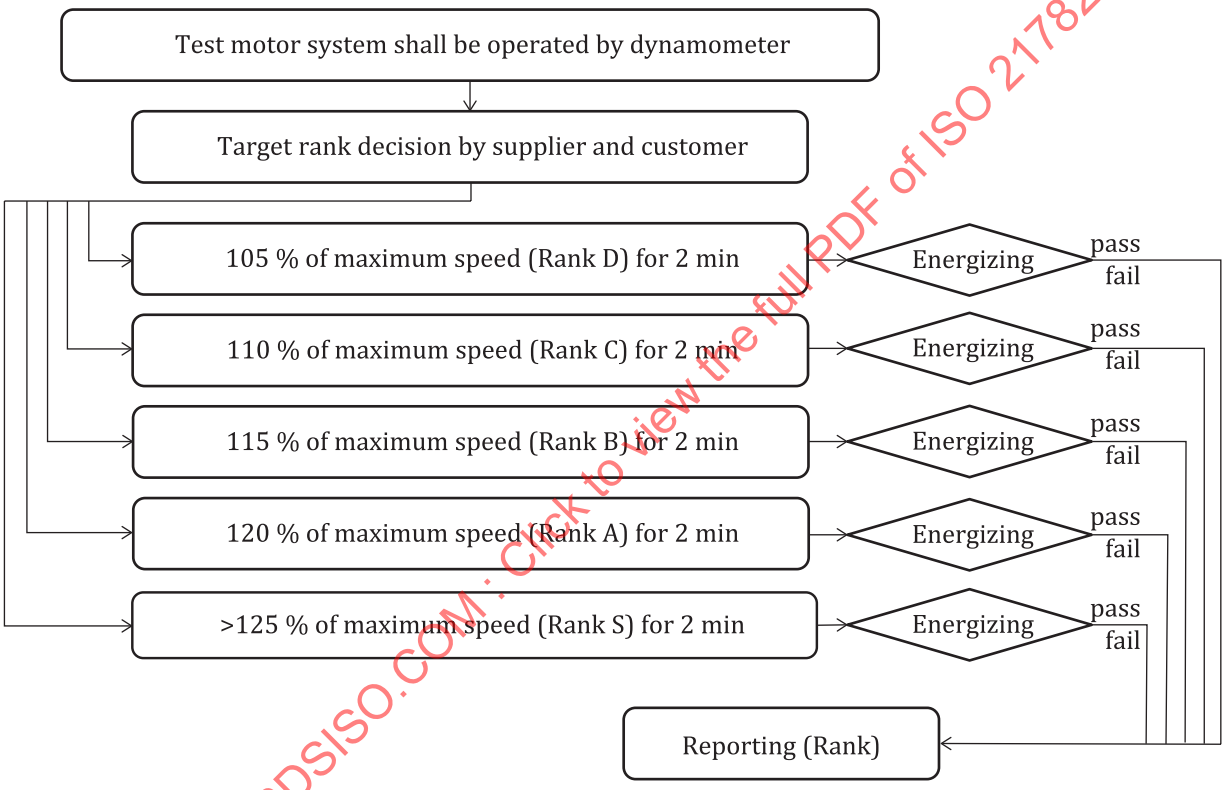


Figure A.1 — Flowchart for the target rank verification method

A.2 Rank search method

The test can be started from rank D which is listed in Table 9. Confirmation by energizing can be conducted after each test as shown in Figure A.2. If the energizing result is pass, the test at the upper rank can be done step by step or can be stopped at that stage. If the energizing result is fail, the highest rank which is passed is the rank of the motor system.