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Road vehicles — Environmental conditions and testing for electrical and electronic equipment for drive system of electric propulsion vehicles —

Part 3: Mechanical loads

Véhicules routiers — Spécifications d'environnement et essais de l'équipement électrique et électronique pour les véhicules à propulsion électrique —

Partie 3: Contraintes mécaniques

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 32, *Electrical and electronic components and general system aspects*.

A list of all parts in the ISO 19453 series can be found on the ISO website.

Road vehicles — Environmental conditions and testing for electrical and electronic equipment for drive system of electric propulsion vehicles —

Part 3: Mechanical loads

1 Scope

This document specifies requirements for the electric propulsion systems and components with maximum working voltages according to voltage class B. It does not apply to high voltage battery packs (e.g. for traction) and systems or components inside. It describes the potential environmental stresses and specifies tests and requirements recommended for different stress levels on/in the vehicle.

This document describes mechanical loads.

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 16750-1, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 1: General*

ISO 19453-1, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment for drive system of electric propulsion vehicles — Part 1: General*

ISO 19453-4:2018, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment for drive system of electric propulsion vehicles — Part 4: Climatic loads*

IEC 60068-2-14, *Environmental testing — Part 2-14: Tests — Test N: Change of temperature*

IEC 60068-2-27, *Environmental testing — Part 2-27: Tests — Test Ea and guidance: Shock*

IEC 60068-2-31, *Environmental testing — Part 2-31: Tests — Test Ec: Rough handling shocks, primarily for equipment-type specimens*

IEC 60068-2-64, *Environmental testing — Part 2-64: Tests — Test Fh: Vibration, broadband random and guidance*

IEC 60068-2-80, *Environmental testing — Part 2-80: Tests — Test Fi: Vibration — Mixed mode*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 16750-1 and ISO 19453-1 apply.

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

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

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

4 Tests and requirements

4.1 Vibration

4.1.1 General

The vibration test methods specified consider various levels of vibration severities applicable to on-board electrical and electronic equipment. The customer and the supplier should choose the test method, environmental temperature and vibration parameters depending on the specific mounting location.

The following basic idea of environmental test methods is expressed in MIL-STD-810G:2008, Foreword.

When applied properly, the environmental management and engineering processes described in this document can be of enormous value in generating confidence in the environmental worthiness and overall durability. However, it is important to recognize that limitations inherent in laboratory testing make it imperative to use proper caution and engineering judgment when extrapolating these laboratory results to results that can be obtained under actual service conditions. In many cases, real world environmental stresses (singularly or in combination) cannot be duplicated practically or reliably in test laboratories. Therefore, users of this document should not assume that a system or component that passes laboratory tests of this document would also pass field/fleet verification trials.

The specified values are the best estimation one can get up to the moment when results from measurements in the vehicle are received, but they do not replace a vehicle measurement.

The specified values apply to direct mounting in defined mounting locations. The use of a bracket for mounting can result in higher or lower loads. Vibration tests shall be carried out according to actual vehicle conditions.

Carry out the vibration with the DUT suitably mounted on a vibration table. The mounting method(s) used shall be noted in the test report. Carry out the frequency variation by logarithmic sweeping of 0,5 octave/min for the sinusoidal vibration part of sine-on-random tests. The scope of the recommended vibration tests is to avoid malfunctions and breakage mainly due to fatigue in the field. Testing for wear has special requirements and is not covered in this document.

Loads outside the designated test frequency ranges shall be considered separately.

NOTE Deviations from the load on the DUT can occur, should vibration testing be carried out according to this document on a heavy and bulky DUT, as mounting rigidity and dynamic reaction on the vibrator table excitation are different compared to the situation in the vehicle. Such deviations can be minimized by applying the average control method (see A.3).

The application of the weighted average control method in accordance with IEC 60068-2-64 may be agreed upon.

During the vibration test, subject the DUT to the temperature cycle in accordance with IEC 60068-2-14, with electric operation according to Figure 1. Alternatively, a test at constant temperature may be agreed on.

Operate the DUT electrically as indicated in Figure 1 at T_{min} (short functional test after the DUT completely reached T_{min}). This functional test shall be as short as possible — only long enough to check the proper performance of the DUT. This minimizes self-heating of the DUT. A long period of electric operation is started at room temperature (RT) in order to allow possible condensation of humidity on the DUT. A permanent operation starting at T_{min} would prevent this due to the electric power dissipation.

Additional drying of test chamber air is not permitted.

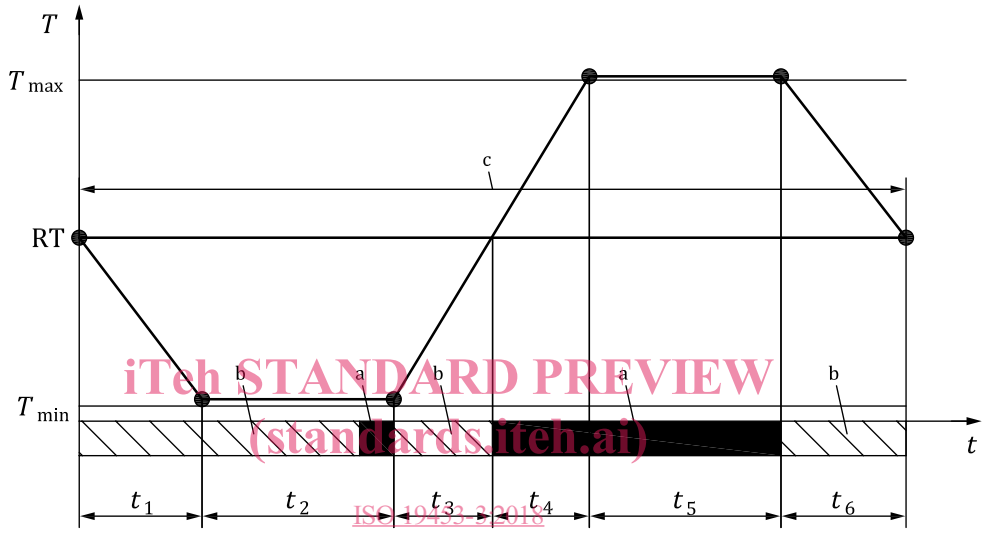
In the vehicle, vibration stress can occur together with extremely low or high temperatures; for this reason, this interaction between mechanical and temperature stress is simulated in the test, too. A

failure mechanism occurs, for example, when a plastic part of a system/component mellows due to the high temperature and cannot withstand the acceleration under this condition.

In case of doubt, a separate measurement shall be performed to determine what soak time at max. or min. ambient temperature is necessary to warrant that this desired temperature is also reached in the core of the DUT. The core temperature shall be maintained for at least one hour during the vibration test; therefore the temperature cycle shall be adjusted accordingly.

Measures regarding the functional performance are allowed to avoid overheating of the DUT during high-temperature operation with self-heating effects.

The complete profile of temperature cycle duration of T_{min} and that of T_{max} shall be more than 1 h. The supplier and the customer shall agree on a complete profile of temperature cycle.



Key

T	temperature, in °C
t	time, in h
T_{min}	minimum operating temperature as defined in ISO 19453-4
T_{max}	maximum operating temperature as defined in ISO 19453-4
RT	room temperature as defined in ISO 19453-1
t_1, t_2, t_3, t_4, t_5, t_6	time parameter (as defined in Table 1)
a	Operating mode 4.2 as defined in ISO 19453-1.
b	Operating mode 2.1 as defined in ISO 19453-1.
c	One cycle.

Figure 1 — Temperature profile for the vibration test

If operating mode 4.2 is not technically feasible, operating mode 3.2 may be used. For electric motors, active operation in operating mode 3.2 or 4.2 can be performed in order to avoid unrealistic failure mechanisms, e.g. wear in the bearings due to the vibration input.

Table 1 — Temperature versus time for the vibration test

Parameter	Duration h	Temperature
t_1	As agreed	From RT to T_{min}
t_2	> 1	Stabilized time at T_{min}
t_3	As agreed	From T_{min} to RT
t_4	As agreed	From RT to T_{max}
t_5	> 1	Stabilized time at T_{max}
t_6	As agreed	From T_{max} to RT
NOTE T_{min} and T_{max} are defined in ISO 19453-4:2018, Table 1. (codes A to X). In the vehicle environment, some equipment can experience different conditions regarding temperature, temperature gradients and duration: in all these cases, code Z is used.		

4.1.2 Tests

4.1.2.1 Test I — Passenger car, powertrain (combustion engine, gearbox)

4.1.2.1.1 Purpose

This test checks the DUT on the powertrain for malfunctions and/or breakage caused by vibration.

The vibrations on the powertrain can be split up into three kinds:

— sinusoidal vibration that results from the unbalanced mass forces in the cylinders;

— random vibration due to all other vibration schemes of an engine, e.g. closing of valves; and

— random vibration due to the influence of rough-road conditions.

NOTE If the DUT needs to be tested for a specific resonance effect, then a resonance dwell test in accordance with 8.3.2 of IEC 60068-2-6:2007 can also be applied.

4.1.2.1.2 Test

4.1.2.1.2.1 General

Vibration of powertrain is the sine-on-random vibration induced by crankshaft rotation and engine combustion. A separate test condition covers random vibration from road surface. The test duration shall be at least as long as one temperature cycle necessary to ensure thermal stability in the DUT.

NOTE 1 The test duration is based on A.4.1.2 and A.4.1.3. The test duration and vibration load level can be adjusted accordingly based on the Basquin's equation given in A.6.

NOTE 2 When agreed between the supplier and the customer, the test duration can be adjusted based on Basquin's model by taking into account the slope k of the S-N curve specific to this component (see also A.6). For the component which is freely placed or is not anticipated to be installed in a certain position and orientation (e.g. inverter), the maximum profile out of all three axes can be applied to all three axes.

NOTE 3 As the driveshaft of an electric motor is always parallel to the ground floor, it is reasonable to have a direction-specific profile, separating vertical excitations from horizontal ones.

The definition of the coordinate system is shown in Table A.3.

4.1.2.1.2.2 Sine-on-random vibration

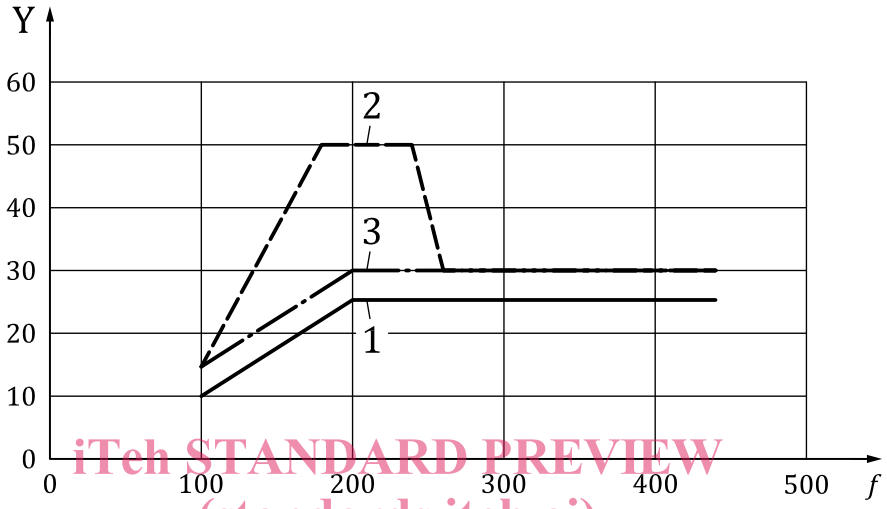
This test shall be performed as a mixed mode vibration test in accordance with IEC 60068-2-80.

a) Sinusoidal vibration part

A sweep rate of 0,5 octave/min or less shall be used.

The test duration is 33 h for each axis of the DUT.

The profiles in Table 2 and Figure 2 show the sinusoidal vibration part of the sine-on-random profile.



Key

Y acceleration amplitude, in m/s^2

f frequency, in Hz

1 curve for X axis

2 curve for Y axis

3 curve for Z axis

Figure 2 — Acceleration versus frequency

Table 2 — Values for maximum acceleration versus frequency

X axis		Y axis		Z axis	
Frequency	Acceleration amplitude	Frequency	Acceleration amplitude	Frequency	Acceleration amplitude
Hz	m/s^2	Hz	m/s^2	Hz	m/s^2
100	10	100	15	100	15
200	25	180	50	200	30
440	25	240	50	440	30
—	—	260	30	—	—
—	—	440	30	—	—

b) Random vibration part

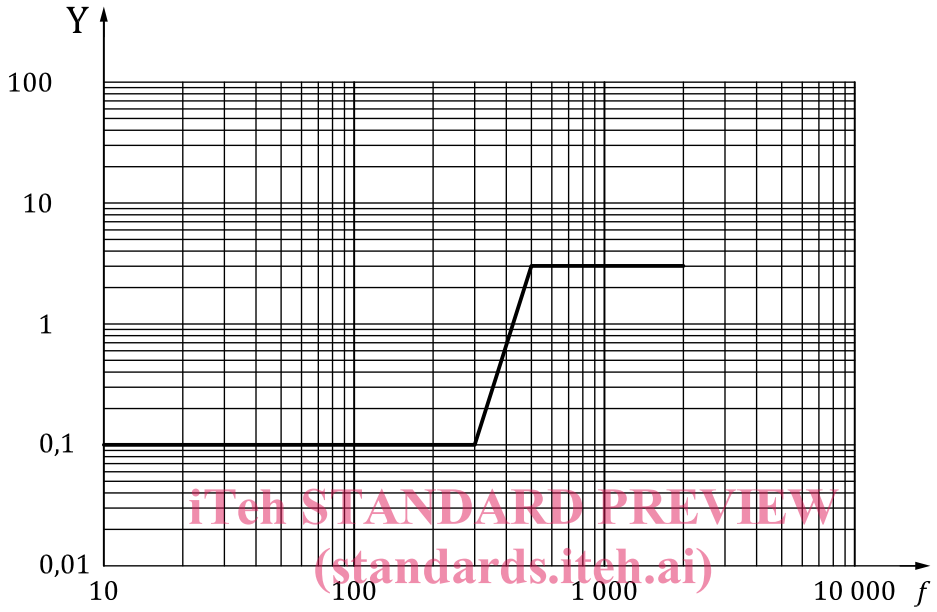
Perform the test in accordance with IEC 60068-2-64.

The test duration is 33 h for each axis of the DUT.

The RMS acceleration value shall be 68,7 m/s^2. For the random part of the sine-on-random profile, the vibration loads are equivalent for all three primary axes. Therefore, only one profile for all three axes shall be used.

The power spectral density (PSD) versus frequency is illustrated in Figure 3 and Table 3.

NOTE The PSD values (random vibration) are reduced in the frequency range of the sinusoidal vibration test of 100 to 500 Hz as well as in the low-frequency range of 10 to 100 Hz as the rough-road influence has been eliminated (see A.4.1.1).



Key

Y PSD, in $(m/s^2)^2/Hz$

f frequency, in Hz

Figure 3 — PSD of acceleration versus frequency

Table 3 — Values for PSD and frequency

Frequency Hz	PSD $(m/s^2)^2/Hz$
10	0,1
300	0,1
500	3
2 000	3

4.1.2.1.2.3 Random vibration

As the excitation from the combustion engine and gearbox at high engine speeds usually does not occur simultaneously with rough-road excitation, a separate test with a broadband random profile has been created.

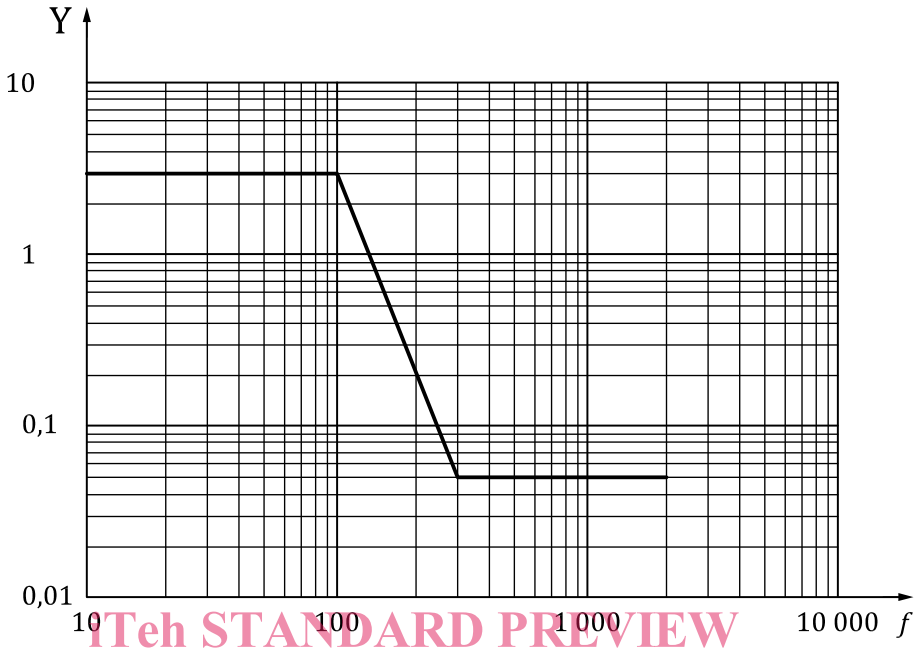
In the lowest frequency range from 10 Hz to 100 Hz, the influence of rough-road conditions is taken into account. The main failures to be identified by this test are malfunctions and/or breakage due to fatigue.

This rough-road profile shall be applied to the very same DUT that has been submitted to the sine-on-random test described above. After the mixed mode vibration test, a random vibration test is performed in accordance with IEC 60068-2-64.

The test duration is 10 h for each axis of the DUT.

The RMS acceleration value for all three primary axes shall be 21,4 m/s^2.

The PSD versus frequency is illustrated in Figure 4 and Table 4.



Key

Y PSD, in $(m/s^2)^2/Hz$

f frequency, in Hz

Figure 4 — PSD of acceleration versus frequency

Table 4 — Values for PSD versus frequency

Frequency Hz	PSD $(m/s^2)^2/Hz$
10	3
100	3
300	0,05
2 000	0,05

4.1.2.1.3 Requirements

Malfunctions and/or breakage shall not occur.

Functional status class A as defined in ISO 19453-1 is required during operating mode 3.2 and/or 4.2 as defined in ISO 19453-1, and functional status C is required during periods with other operating modes.

4.1.2.2 Test II — Passenger car, sprung masses (vehicle body)

4.1.2.2.1 Purpose

This test checks the DUT on the vehicle body for malfunctions and/or breakage caused by vibration.

4.1.2.2.2 Test

4.1.2.2.2.1 General

Vibration of the vehicle body is the random vibration induced by rough-road driving. The main failure to be identified by this test is breakage due to fatigue.

NOTE 1 The test duration is based on A.5.1.2 and A.5.1.3. According to Annex A, 20 h of test duration per axis are equivalent to 6 000 h (240 000 km at 40 km/h average speed) lifetime requirement of the vehicle.

NOTE 2 When the test conditions cannot be realized as the test system is not capable of exciting a heavy DUT with the given profile, the load and duration can be adjusted according to the Basquin model (see A.6).

The definition of the coordinate system is shown in Table A.2.

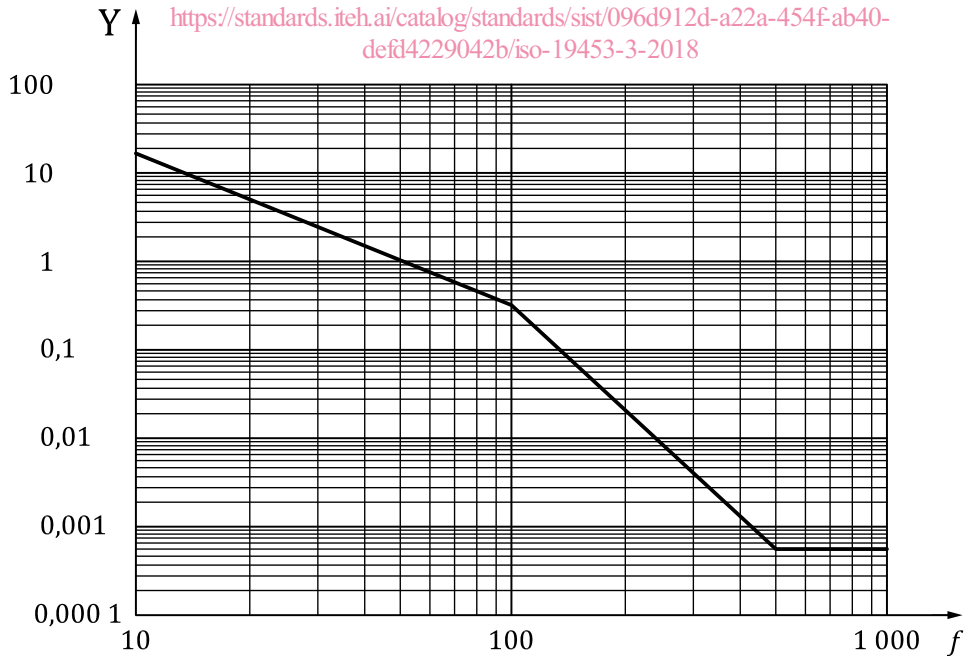
4.1.2.2.2.2 Random vibration

Perform the test in accordance with IEC 60068-2-64 (random vibration).

The test duration is 20 h for each axis of the DUT.

The RMS acceleration value for all three primary axes shall be 13,3 m/s^2.

The PSD versus frequency is illustrated in Figure 5 and Table 5.



Key

Y PSD, in $(m/s^2)^2/Hz$

f frequency, in Hz

Figure 5 — PSD of acceleration versus frequency

Table 5 — Values for PSD and frequency

Frequency Hz	PSD $(m/s^2)^2/Hz$
10	17
100	0,33
500	0,000 6
1 000	0,000 6

4.1.2.2.3 Requirements

Malfunctions and/or breakage shall not occur.

Functional status class A as defined in ISO 19453-1 is required during operating mode 3.2 and/or 4.2 as defined in ISO 19453-1, and functional status C is required during periods with other operating modes.

4.1.2.3 Test III — Electric vehicle, (directly equipped with) electric motor

4.1.2.3.1 Purpose

This test checks the DUT for malfunctions and/or breakage caused by vibration.

4.1.2.3.2 Test

4.1.2.3.2.1 General

Vibration of electric motors is the random vibration induced by rough-road driving. The main failure to be identified by this test is breakage due to fatigue.

NOTE 1 The test duration is based on A.5.1.2 and A.5.1.3. According to Annex A, 20 h of test duration per axis are equivalent to 6 000 h (240 000 km at 40 km/h average speed) lifetime requirement of the vehicle.

NOTE 2 When the test conditions cannot be realized as the test system is not capable of exciting a heavy DUT with the given profile, the load and duration can be adjusted according to the Basquin model (see A.6).

NOTE 3 As the driveshaft of an electric motor is always parallel to the ground floor, it is reasonable to have a direction-specific profile, separating vertical excitations from horizontal ones.

The definition of the coordinate system is shown in Table A.4.

4.1.2.3.2.2 Random vibration

Perform the test in accordance with IEC 60068-2-64 (random vibration).

The test duration is 20 h for each axis of the DUT.

The RMS acceleration values for all three primary axes shall be:

— X: 35,1 m/s^2,

— Y: 20,5 m/s^2,

— Z: 36,2 m/s^2.

The PSD versus frequency is illustrated in Figure 6 and Table 6.

For the component which is freely placed or is not anticipated to be installed in a certain position and posture (e.g. inverter), the maximum profile out of all primary three axes shall be applied to all primary three axes.