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Fourth edition
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Road vehicles — Environmental conditions and testing for electrical and electronic equipment —

Part 3:
Mechanical loads

Véhicules routiers — Spécifications d'environnement et essais de l'équipement électrique et électronique —

Partie 3: Contraintes mécaniques

Reference number
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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 document 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).

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For an explanation of 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 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*.

This fourth edition cancels and replaces the third edition (ISO 16750-3:2012), which has been technically revised.

The main changes are as follows:

— integrating and harmonizing content from ISO 19453-3:2018;

— distinction between small and lightweight versus large and heavy DUTs;

— revising vibration profiles where necessary due to extended datasets of and experience from vehicle measurements;

— addition of vibration test for rotating machines on combustion engines and Annex C;

— addition of vibration tests for hybrid-electric/fully-electric commercial vehicles;

— addition of guided fall test description and Annex D;

— addition of Annex E as guidance for 3D shaker testing;

— test order appearing in the document has been changed for a logical grouping depending on test type, however test numbers have been kept for backwards compatibility.

A list of all parts in the ISO 16750 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Road vehicles — Environmental conditions and testing for electrical and electronic equipment —

Part 3: Mechanical loads

1 Scope

This document applies to electric and electronic systems and components for vehicles including electric propulsion systems and components with maximum working voltages according to voltage class B. It describes the potential environmental stresses and specifies tests and requirements recommended for the specific mounting location on/in the vehicle.

This document describes mechanical loads.

This document is not intended to apply to environmental requirements or testing for systems and components of motorcycles and mopeds.

Systems and their components released for production, or systems and their components already under development prior to the publication date of this document, can be exempted from fulfilling the changes in this edition compared to the previous one.

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 16750-1:2023, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment — Part 1: General*

ISO 16750-4:2023, *Road vehicles — Environmental conditions and testing for electrical and electronic equipment— Part 4: Climatic loads*

IEC 60068-2-6, *Environmental testing — Part 2-6: Testing, Test Fc: Vibration (Sinusoidal)*

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*

UL 969:2017, *Standard for Marking and Labeling Systems*

ISO 20567-1:2017, *Paints and varnishes — Determination of stone-chip resistance of coatings — Part 1: Multi-impact testing*

3 Terms and definitions

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

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

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

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

4 Tests and requirements

4.1 Vibration

4.1.1 Testing conditions during the vibration test

4.1.1.1 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.

A clear dependence of the typical vibration load on the size and mass of the DUT is evident from vehicle measurements. This applies to all mounting locations due to dynamic system coupling. That is why in this document a distinction is made between small and lightweight E/E components (typically <2 kg, unless stated otherwise in the individual test description, e.g. sensors, ECUs or fuel injection equipment), mostly belonging but not limited to ICE vehicles, and much larger and heavier components (typically ≥2 kg, unless stated otherwise in the individual test description, e.g. electric motors, inverters, DC/DC converters or alternators), mostly belonging but not limited to electric powertrains in electric propulsion vehicles. In each application the applicability of the intended vibration profile should be verified with a vehicle measurement. See a mass classification example in ISO 16750-1:2023, Annex C. For further information and guidance please refer to Tables 38-40 (code letters).

The following basic idea of environmental test methods is expressed in the Foreword of Reference [7].

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 of the tested equipment. 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 that can be obtained 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 specified vibration profiles apply to direct mounting in defined mounting locations. Since the use of an installation support (e.g. mounting bracket) can influence test vibration loads on the shaker to be much higher or much lower than actual vehicle loads, in principle, each vibration test should be carried out with only DUT itself. If using an installation support, the applied loads on the shaker should be checked to reproduce the actual vehicle loads as realistically as possible.

Carry out the vibration with the DUT rigidly mounted on a vibration table for reasons of comparability and reproducibility (see also IEC 60068-2-47:2005, Clauses 5 and 6). If using a bracket is technically unavoidable in order to fix the DUT to the shaker instead of a rigid mounting, then the transfer functions from the excitation to the DUT compared to vehicle measurements as well as a proper control strategy shall be considered. For further information refer to A.3. The mounting method(s) used shall be noted in the test report. 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.

If active operation and/or signal monitoring is applied during the test, extra care shall be taken with respect to the fixation of the power cables and the wiring harnesses. This aims at avoiding signal disturbances and negative mechanical impact on the connector, caused by dynamic motion of the harness itself. The routing, rigidity, mass and fixation of wire harness in vehicle installation should also be considered when deciding on the fixation of wire harness in a test setup in order to avoid a wrong testing load for the DUT.

Loads outside the designated test frequency ranges can be considered separately if agreed between the customer and the supplier. If it is known that resonance frequencies of the DUT are present that are critical for fatigue and are not covered by the test frequency ranges, then it is recommended to perform separate durability tests, such as resonance dwell testing.

NOTE Deviations from the load on the DUT can occur if vibration testing is carried out according to this document on a large and heavy 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.

4.1.1.2 Overlaid temperature cycles during vibration testing

4.1.1.2.1 General

Vibration tests are typically run with an overlaid temperature cycle. The intention is not to create additional aging of the DUTs, but to induce a temperature-dependent dynamic response of or within the DUT that might otherwise not occur if only tested at room temperature.

In the vehicle, vibration stress can occur together at low or high temperatures; for this reason, this interaction between mechanical and temperature stress is simulated in the test, too. A failure mechanism occurs when material characteristics of components change and cannot withstand the acceleration under this condition. For example, a plastic part may mellow due to the high temperature.

The mass of the DUT as well as the installation area are the main influence factors that determine the design of the temperature cycle which is why in the following clauses the different use cases are distinguished.

For longer test durations of the vibration test the test cycles can be either repeated for a sufficient number of times or stretched to fit the test duration. None of the following temperature cycles shall be further compressed in their duration, otherwise a temperature equilibrium within the DUT might not be ensured.

Depending on the failure mode of the DUT, a deviating temperature profile may be used if agreed between the customer and the supplier.

Intentional humidity control is not permitted even if water condensation on the DUT occurs during temperature cycles.

4.1.1.2.2 Temperature profile for small and lightweight components not mounted on the combustion engine

During the vibration test, for small and lightweight DUT not mounted on the combustion engine, perform the temperature cycling in accordance with IEC 60068-2-14, Test Nb, not using its specified temperature changing rates, but using the variant given in Figure 1 and Table 1.

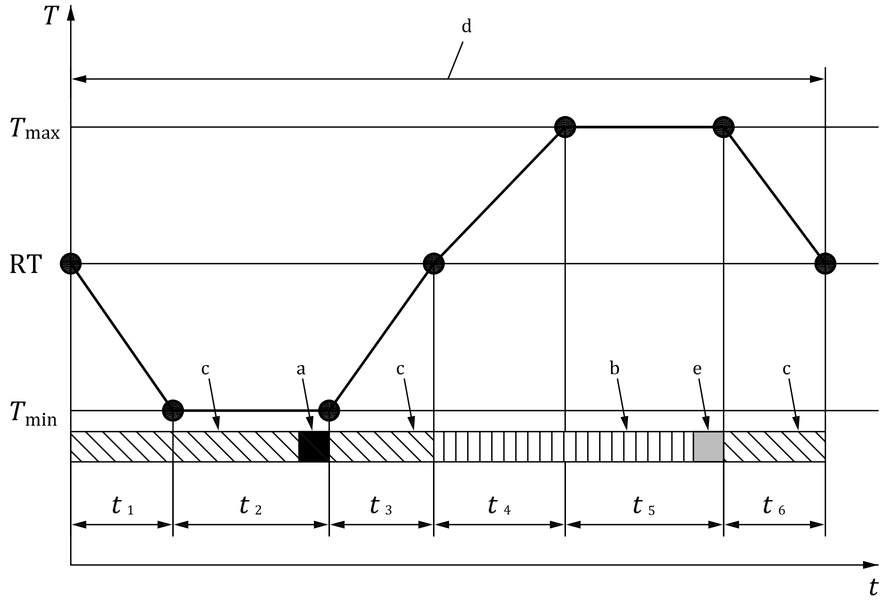
NOTE 1 This temperature profile can also be applied to small and lightweight components mounted on electric drive systems or components.

Perform temperature cycling with the following as one cycle. Decrease ambient temperature from RT to T_{min}, expose the DUT at T_{min}, increase ambient temperature from T_{min} to T_{max}, expose the DUT at T_{max} and then decrease ambient temperature from T_{max} to RT (see Figure 1).

Perform a functional test at the end of T_{min} and T_{max} as short as possible with operating mode 3.3 or 4.3 as defined in ISO 16750-1 (see key a in Figure 1). In addition, operate with operating mode 3.4 or 4.4 as defined in ISO 16750-1 (see key b in Figure 1) during the section from room temperature (RT) to T_{max}. During the other sections, operate with operating mode 2.1 as defined in ISO 16750-1 (see key c in Figure 1). If operating mode 4.3/4.4 is not technically feasible, operating mode 3.3/3.4 may be used if agreed between the customer and the supplier.

NOTE 2 A permanent operation starting at T_{min} prevents possible condensation of humidity on DUT because the self-heating of the DUT occurs. An electrical operation starting at RT allows this phenomenon.

NOTE 3 Condensation can lead to swelling of plastic sub-components of the DUT and therefore, influence the dynamic behaviour under vibrational load.



Key

T	temperature [°C]
t	time
T_{min}	minimum operating temperature as defined in ISO 16750-4
T_{max}	maximum operating temperature as defined in ISO 16750-4
RT	room temperature as defined in ISO 16750-1
t_1, t_2, t_3, t_4, t_5, t_6	time parameter as defined in Table 1
a	Functional test with operating mode 3.3 or 4.3 as defined in ISO 16750-1.
b	Operating mode 3.4 or 4.4 as defined in ISO 16750-1.
c	Operating mode 2.1 as defined in ISO 16750-1.
d	One cycle.
e	Functional test with operating mode 3.4 or 4.4 as defined in ISO 16750-1.

Figure 1 — Temperature cycle with specified change rate for the vibration test of a small and lightweight DUT

Table 1 — Temperatures versus time duration for temperature cycling for the vibration test of a small and lightweight DUT

Parameter	**Duration** [min]	**Temperature** [°C]
t_1	60	From RT to T_{min}
t_2	90	Exposure time at T_{min}
t_3	60	From T_{min} to RT
t_4	90	From RT to T_{max}
t_5	110	Exposure time at T_{max}
t_6	70	From T_{max} to RT
NOTE T_{min} and T_{max} are defined in ISO 16750-4:2023, Table 1.		

4.1.1.2.3 Temperature profile for large and heavy components not mounted on the combustion engine

During the vibration test, for large and heavy DUT not mounted on the combustion engine, perform the temperature cycling in accordance with IEC 60068-2-14, Test Nb, not using its specified temperature changing rates, but using the variant given in Figure 2 and Table 2.

Perform temperature cycling with the following as one cycle. Decrease ambient temperature from RT to T_{min}, expose the DUT at T_{min}, increase ambient temperature from T_{min} to T_{max}, expose the DUT at T_{max} and then decrease ambient temperature from T_{max} to RT (see Figure 2).

Before performing this test, a separate temperature measurement (with DUT in operating mode 2.1 as defined in ISO 16750-1) shall be performed to determine what exposure time at T_{max}, T_{min} (see Figure 2) is necessary to warrant that this desired temperature is also reached in DUT temperature. The measuring point of the DUT shall be agreed between the customer and the supplier, considering a target device (e.g. microprocessor, motor coil) which is temperature-influenced in functionality or performance.

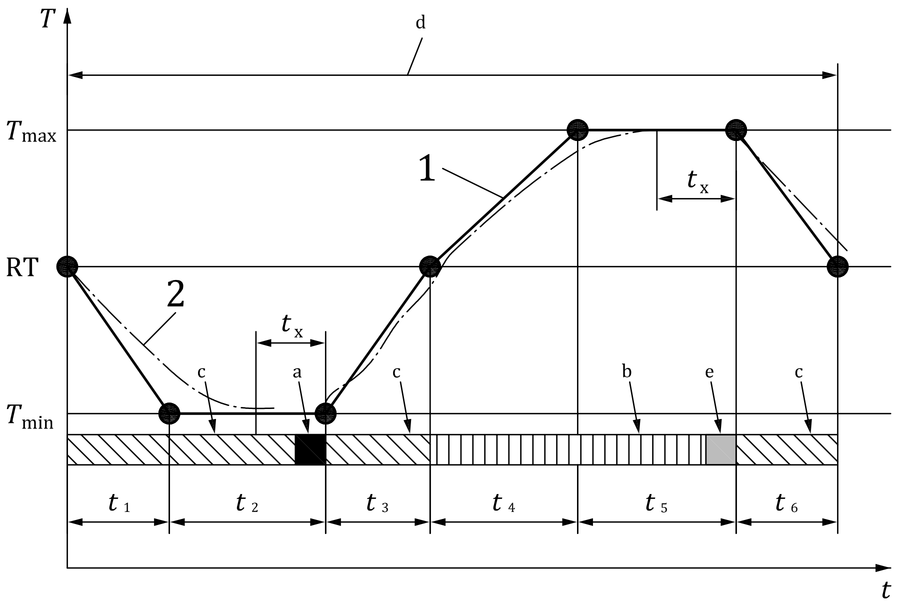
If operating mode 2.1 is technically not feasible for the separate temperature measurement, operating mode 1.2 as defined in ISO 16750-1, can be used as agreed between the customer and the supplier.

Measures regarding the functional performance, for example, de-rating of the e-motor, are allowed to avoid overheating of the DUT during high-temperature operation with self-heating effects.

The dwell time t_x of the DUT at T_{min} and T_{max} shall be more than 30 min each per temperature cycle; therefore, exposure time shall be adjusted accordingly depending on the size and other characteristics of the DUT. The customer and the supplier shall agree on a complete profile of temperature cycle including dwell time and stabilisation time depending on the size and other properties of the DUT.

NOTE This temperature profile can also be applied to large and heavy components mounted on electric drive systems or components.

Perform a functional test at the end of T_{min} and T_{max} as short as possible with operating mode 3.3 or 4.3 as defined in ISO 16750-1 (see key a in Figure 2). In addition, operate with operating mode 3.4 or 4.4 as defined in ISO 16750-1 (see key b in Figure 2) during the section from room temperature (RT) to T_{max}. During the other sections, operate with operating mode 2.1 as defined in ISO 16750-1 (see key c in Figure 2). If operating mode 4.3/4.4 is not technically feasible, operating mode 3.3/3.4 may be used if agreed between the customer and the supplier. For electric motors, active operation in operation mode 3.3 or 4.3 instead of 2.1 can be performed in order to avoid unrealistic failure mechanism, e.g. wear in the bearing of an e-motor due to the vibration input.



Key

T	temperature [°C]
t	time
1	ambient temperature
2	DUT temperature, exemplary for non-heat dissipating DUTs
T_{min}	minimum operating temperature as defined in ISO 16750-4
T_{max}	maximum operating temperature as defined in ISO 16750-4
RT	room temperature as defined in ISO 16750-1
t_1, t_2, t_3, t_4, t_5, t_6	time parameter as defined in Table 2
t_x	dwell time at T_{min} or T_{max}
a	Functional test with operating mode 3.3 or 4.3 as defined in ISO 16750-1.
b	Operating mode 3.4 or 4.4 as defined in ISO 16750-1.
c	Operating mode 2.1 as defined in ISO 16750-1.
d	One cycle.
e	Functional test with operating mode 3.4 or 4.4 as defined in ISO 16750-1.

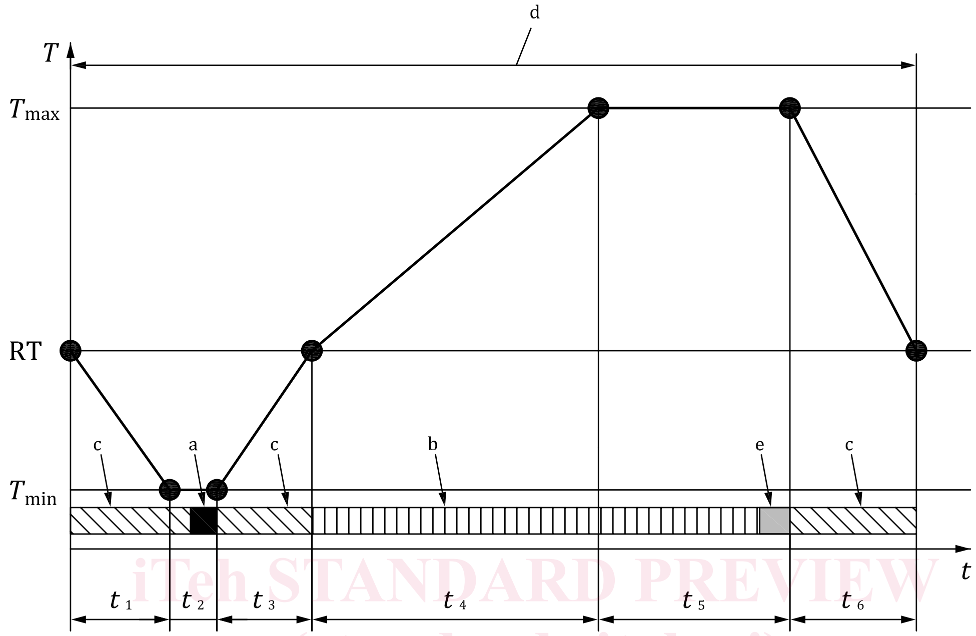
Figure 2 — Temperature cycle with specified change rate for the vibration test of large and heavy DUTs

Table 2 — Temperatures versus time duration for temperature cycling for the vibration test of large and heavy DUTs

Parameter	Duration [min]	Temperature [°C]
t_1	60	From RT to T_{min}
t_2	As agreed	Exposure time at T_{min}
t_3	60	From T_{min} to RT
t_4	90	From RT to T_{max}
t_5	As agreed	Exposure time at T_{max}
t_6	70	From T_{max} to RT
t_x	> 30	Dwell time at T_{min} or T_{max}
NOTE T_{min} and T_{max} are defined in ISO 16750-4:2023, Table 1.		

4.1.1.2.4 Temperature profile for components mounted on the combustion engine

In case of combustion engine-mounted DUTs (e.g. ECUs) a dwell time at T_{min} as given in Table 1 can lead to a failure mode that is not occurring under field conditions as the combustion engine will warm up any attached components quickly, so that an extended superposition of vibration load and T_{min} is unrealistic. Therefore, the temperature profile shall be changed as given in Figure 3 and Table 3.



Key

T	temperature [°C]
t	time
T_{min}	minimum operating temperature as defined in ISO 16750-4
T_{max}	maximum operating temperature as defined in ISO 16750-4
RT	room temperature as defined in ISO 16750-1
t_1, t_2, t_3, t_4, t_5, t_6	time parameter as defined in Table 3
a	Functional test with operating mode 3.3 or 4.3 as defined in ISO 16750-1.
b	Operating mode 3.4 or 4.4 as defined in ISO 16750-1.
c	Operating mode 2.1 as defined in ISO 16750-1.
d	One cycle.
e	Functional test with operating mode 3.4 or 4.4 as defined in ISO 16750-1.

Figure 3 — Temperature cycle for DUTs mounted on the combustion engine

Table 3 — Temperatures versus time duration for temperature cycling for the vibration test of a combustion engine-mounted DUT

Parameter	Duration [min]	Temperature [°C]
t_1	60	From RT to T_{min}
t_2	20	Exposure time at T_{min}
t_3	60	From T_{min} to RT

NOTE 1 T_{min} and T_{max} are defined in ISO 16750-4:2023, Table 1.

NOTE 2 The exposure time at T_{min}, t_2, can be shortened if agreed between the customer and the supplier based on justification from their field experience.

Table 3 *(continued)*

Parameter	Duration [min]	Temperature [°C]
t_4	160	From RT to T_{max}
t_5	110	Exposure time at T_{max}
t_6	70	From T_{max} to RT

NOTE 1 T_{min} and T_{max} are defined in ISO 16750-4:2023, Table 1.

NOTE 2 The exposure time at T_{min}, t_2, can be shortened if agreed between the customer and the supplier based on justification from their field experience.

Similar to the profile given in Table 1 also for the overlaid temperature profile for a combustion engine-mounted DUT, a short functional test at the end of the low temperature phase shall be done as well as for the duration in which room temperature or above is given. If experience from the field justifies to change the exposure time at T_{min} to avoid unrealistic failure modes during shaker testing, then this exposure time shall be adjusted accordingly.

4.1.2 Test Ia - Passenger car, combustion engine, small and lightweight DUT

4.1.2.1 Purpose

This test checks the small and lightweight DUT (e.g. small sensors and ECUs) for malfunctions and breakage caused by vibration.

The vibrations of a piston engine can be split up into two kinds: sinusoidal vibration which results from the unbalanced mass forces in the cylinders and random noise due to all other vibration-schemes of an engine, e.g. closing of valves. In the lowest frequency range from 10 Hz to 100 Hz the influence of rough-road conditions is taken into account. The main failure to be identified by this test is breakage due to fatigue.

NOTE 1 Road profile usually has a negligible impact on combustion engine-mounted components. Shock inputs are effectively isolated by suspension, and combustion engine-mounting systems.

The test profiles specified in the following clauses apply to loads generated by (four stroke) reciprocating combustion engines.

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

4.1.2.2 Test

4.1.2.2.1 General

This test shall be performed as a mixed mode vibration test according to IEC 60068-2-80.

4.1.2.2.2 Sinusoidal vibration

Perform the test according to IEC 60068-2-6, but using a sweep rate of ≤ 0,5 octave/min. Use a test duration of 30 h for each axis of the DUT.

NOTE The test duration is based on A.4.

Use curve 1 in Table 4/Figure 4 for the DUT intended for mounting on combustion engines with five cylinders or fewer.

Use curve 2 in Table 4/Figure 4 for the DUT test intended for mounting on combustion engines with six cylinders or more.

Both curves may be combined to cover all combustion engine types in one test.

