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Mechanical vibration — Laboratory method for evaluating vehicle seat vibration —

Part 1: Basic requirements

Vibrations mécaniques — Méthode en laboratoire pour l'évaluation des vibrations du siège de véhicule —

Partie 1: Exigences de base

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Contents

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).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on 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.

The committee responsible for this document is ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 4, *Human exposure to mechanical vibration and shock*.

This second edition cancels and replaces the first edition (ISO 10326-1:1992), which has been technically revised. It also incorporates the amendments ISO 10326-1:1992/Amd 1:2007 and ISO 10326-1:1992/Amd 2:2011.

A list of all parts in the ISO 10326 series can be found on the ISO website.

Introduction

Drivers, staff and passengers of vehicles (land, air or water) and mobile machinery are exposed to mechanical vibration which interferes with their comfort, working efficiency and, in some circumstances, safety and health. Such vehicles and mobile machines are often fitted with seats that are designed and made in accordance with current state-of-the-art with regard to their capacity to control or reduce transmitted whole-body vibration.

To assist in the development of such seats, specific test codes have been, or are being, produced to evaluate the performance of seats. The following basic requirements have therefore been developed to give guidance for the specification of laboratory testing of vibration transmission through a vehicle seat to the occupant and for the evaluation of the ability of a seat to control the shock arising from over-travel of the suspension.

The seat constitutes the last stage of suspension before the driver. To be efficient at attenuating the vibration, the suspension seat should be chosen according to the dynamic characteristics of the vehicle. Any performance criteria provided should be set in accordance with what is attainable using best design practice. Such criteria do not necessarily ensure the complete protection of the operator against risks associated with exposure to vibration and shock which are generally believed to be risk of spinal injury.

Mechanical vibration — Laboratory method for evaluating vehicle seat vibration —

Part 1: Basic requirements

1 Scope

This document specifies basic requirements for the laboratory testing of vibration transmission through a vehicle seat to the occupant. These methods for measurement and analysis make it possible to compare test results from different laboratories for equivalent seats.

It specifies the test method, the instrumentation requirements, the measuring assessment method and the way to report the test result.

This document applies to specific laboratory seat tests which evaluate vibration transmission to the occupants of any type of seat used in vehicles and mobile off-road machinery.

Application standards for specific vehicles refer to this document when defining the test input vibration that is typical for the vibration characteristics of the type or class of vehicle or machinery in which the seat is to be fitted.

NOTE Examples of application standards are given in the bibliography.

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 2631-1, *Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration — Part 1: General requirements*

ISO 5347 (all parts), *Methods for the calibration of vibration and shock pick-ups*

ISO 8041, *Human response to vibration — Measuring instrumentation*

ISO 13090-1, *Mechanical vibration and shock — Guidance on safety aspects of tests and experiments with people — Part 1: Exposure to whole-body mechanical vibration and repeated shock*

ISO 16063 (all parts), *Methods for the calibration of vibration and shock transducers*

3 Terms and definitions

No terms and definitions are listed in this document.

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 http://www.iso.org/obp

4 General

The measurement and assessment methods given in this document comply with the present practice standardized in ISO 2631-1. The measuring equipment and the frequency weightings shall be in accordance with ISO 8041.

The primary test for the vibration characteristics of the seat involves measurements under conditions which simulate the range of actual uses of a vehicle or machine. For applications where occasional severe shocks or transient vibration can be expected (and in particular for seats whose suspension travel is short, such as those intended for use on industrial trucks or off-road vehicles), in addition to the damping test, a secondary test is required to ensure that the seat responds acceptably. Machinery-specific standards shall give guidance on the need for this secondary test which comprises a method for assessing the accelerations associated with impact with the suspension end-stops when over-travel occurs. The test is described in Annex A.

5 Instrumentation

5.1 Acceleration transducers

The measuring systems selected for the evaluation of vibration at the seat mounting base or platform of the vibration simulator and that selected for the evaluation of vibration transmitted to the seat occupant, or to an inert mass when used, shall have similar characteristics.

The characteristics of the vibration measuring system, accelerometers, signal conditioning and data acquisition equipment, including recording devices, shall be specified in the relevant application standard, especially the dynamic range, sensitivity, accuracy, linearity and overload capacity.

5.2 Transducer mounting

5.2.1 General

One accelerometer for each required test direction shall be located on the platform (P) at the place of the vibration transmission to the seat. The other accelerometer(s) shall be located at the interface between the human body and the seat, at either the seat pan (S) and/or the backrest (B) (see Figure 1).

Dimensions in millimetres

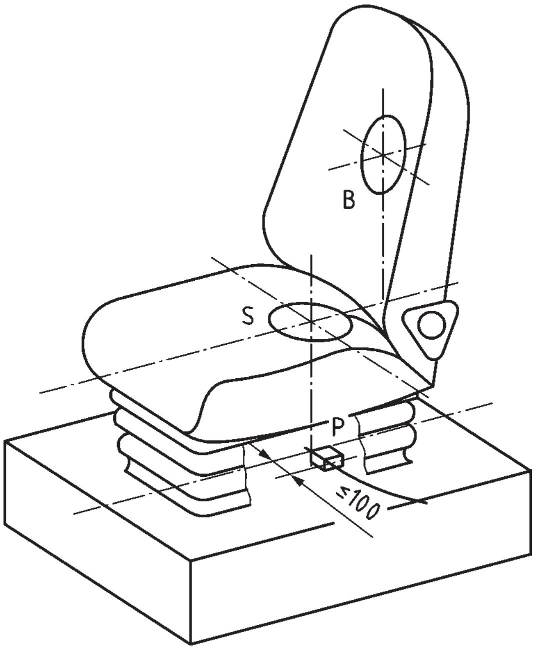


Figure 1 — Location of the accelerometers on the platform (P), on the seat pan (S) and on the backrest (B)

5.2.2 Transducer mounting on the platform

The accelerometer(s) on the platform shall be located within a circle with a diameter of 200 mm centred directly below the seat accelerometer(s). The measuring directions shall be aligned parallel to the movement of the platform.

5.2.3 Transducer mounting on the seat pan and/or backrest

The accelerometers on the seat pan shall be attached in the centre of a mounting disc with a total diameter of 250 mm ± 50 mm. The disc shall be as thin as possible (see Figure 2). The height shall not be more than 12 mm. This semi-rigid mounting disc of approximately 80 durometer to 90 durometer units (A-scale) moulded rubber or plastics material shall have a centre cavity in which to place the accelerometers. The accelerometers shall be attached to a thin metal disc with a thickness of 1,5 mm ± 0,2 mm and a diameter of 75 mm ± 5 mm.

The mounting disc shall be placed on the surface of the seat pan and taped to the cushion in such a way that the accelerometers are located midway between the ischial tuberosities of the seat occupant with a tolerance to be defined in the relevant application standards. Alternative positioning of the disc may be recommended for certain applications. Any variation from the position here defined shall be specified in application standards.

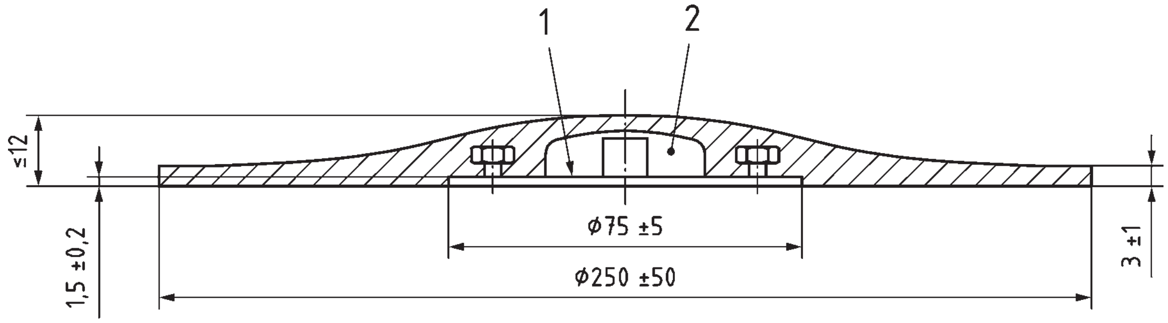
When tests are performed without a person sitting on the seat, e.g. during damping tests, the disc shall be placed in the same position as if a person were seated in the seat.

If measurements are made on the backrest, the accelerometers shall be (horizontally) located in the vertical longitudinal plane through the centre-line of the seat. The relevant application standards shall specify the vertical position of the accelerometers. The measurement axes shall be aligned parallel to the basicentric coordinate system.

Besides the semi-rigid mounting disc recommended for soft or highly contoured cushions, a rigid disc with a generally flat surface or an individual-form design may be used. Such discs may be, for instance, required for testing rail vehicle passenger seats. The transducer mounting should be made of low-mass materials, so that the resonant frequency of the mounting is at least four times the highest frequency specified for the test.

For practical reasons, it is usually not possible to align perfectly the accelerometers in the disc with the axes of motion of the platform. In a tolerance range within 15° of the appropriate axes, the accelerometers may be considered as aligned parallel to the axes of interest. For deviations greater than 15°, acceleration should be measured along two axes and the acceleration vector sum along the axis of interest should be calculated.

Dimensions in millimetres



Key

1 thin metal disc for accelerometer mount and added centre rigidity

2 appropriate cavity for accelerometer(s)

Figure 2 — Semi-rigid mounting disc

5.3 Frequency weighting

Frequency weighting shall be in accordance with ISO 8041.

5.4 Calibration

The instrumentation shall be calibrated in accordance with ISO 16063-1 and, depending on the type of measuring system used, to the relevant part of ISO 5347 or ISO 16063.

It is recommended to check the whole measuring chain following the specifications given in ISO 8041.

Calibration shall be made before and after each test series.

Where necessary, the output from each accelerometer amplifier shall be zeroed after mounting the accelerometers in the test position.

6 Vibration equipment

6.1 Physical characteristics

The minimum equipment required is a vibrator capable of driving the platform in the vertical and/or horizontal directions. Application standards may define situations where it is appropriate to turn the seat by 90° on the platform to account for excitations in *x*- and *y*-axis (as opposed to a combined axes excitation). The dynamic response of the exciter shall be capable of exciting the seat with the seated test person and additional equipment, in accordance with the specified test input vibration.

Attributes of performance to be specified include frequency range and displacement capability in each of the required directions.

Application standards shall specify the lowest acceptable resonance frequency of the platform, the acceptable cross-axis motion of the platform and the frequency range for which this applies.

Application standards shall specify requirements for test stand dimensions and equipment to ensure that these are adequate for each particular application.

It has been observed that the use of certain equipment (e.g. a steering wheel, pedals, etc.) may lower the repeatability of the results.

6.2 Control system

The frequency response characteristics of the vibration test system shall be compensated for to ensure that the power spectral density (PSD) and the probability density function (PDF) of the acceleration amplitudes of the vibration at the seat mounting base comply with the requirements of the specified test input vibration.

7 Safety requirements

The guidance on safety requirements with regard to tests in which people are exposed to mechanical vibration and repeated shock as given in ISO 13090-1 shall be followed.

Specific safety requirements shall be considered when the relevant application standard is being developed.

8 Test conditions

8.1 Test seat

8.1.1 General

The seat to be tested shall be representative of actual or intended production models with regard to design, construction, mechanical and geometrical characteristics, and any other factors which may affect the vibration test results.

The performance may vary between seats of the same type. Therefore, it is recommended to test more than one seat.

8.1.2 Run-in periods for suspension seats

Suspension seats require a run-in period prior to exposure to vibration in order to free the moving parts of the suspension. This period shall be long enough for the seat performance to stabilize.

Any required air, hydraulic or electric power shall be supplied to the seat at the pressure and flow rate, or voltage, recommended by the seat manufacturer and shall be connected to the seat in the manner recommended by the seat manufacturer. The test seat shall be loaded with an inert mass of 75 kg ± 1 % placed on the seat cushion, and the seat shall be adjusted according to the manufacturer's instructions for a nominal value of 100 kg operator mass.

NOTE A suitable inert mass consists of lead shot. The lead shot can be contained within thin cushions which are sewn so as to form a quilt. About 10 such cushions are sufficient to obtain a 75 kg mass.

During the run-in period, the test seat shall be excited by a sinusoidal input vibration at approximately the natural frequency of the suspension. The amplitude of the applied sinusoidal vibration shall be 75 % of the full amplitude of the seat suspension.

The damper may overheat during the run-in period. Therefore, use an automatic shutdown and monitor the temperature of the damper.

If additional vibration tests in the horizontal direction are planned, the run-in procedure shall be followed under the same conditions separately for each direction.

Deviations from this run-in method for the seat suspension may be specified in relevant application standards for individual seat tests.

8.1.3 Measurement of suspension travel and adjustment to weight of test person

Differences in the setting of ride height when testing suspended seats can have significant effects on test results. Therefore, the test standard should include guidance on how the height should be adjusted, such as

— with seats where the suspension stroke available is *affected* by the adjustment of the seat height or by the test person weight, including where the height adjustment is integrated into the suspension travel, testing shall be performed in the lowest position that provides the full working suspension stroke as specified by the seat manufacturer, and

— with seats where the suspension stroke available is *unaffected* by the adjustment of the seat height or by test person weight, testing shall be performed with the seat adjusted to the centre of stroke.

Determination of the ride position requires location of the upper and the lower ends of travel for the suspension, as follows.

a) For suspensions with manual weight adjustment, the following procedure is recommended.

   The upper end of travel should be determined with no load on the seat, and with the suspension weight adjustment set approximately to suit the heavy test person (e.g. 100 kg).

   The lower end of travel, including compression of the lower bump stop, should be determined with a load of 1 500 N, and with the suspension weight adjustment set approximately to suit the light test person (e.g. 55 kg).

b) For suspensions with automatic weight adjustment, which usually are air suspensions, the following procedure is recommended.

   To determine the upper end of travel, a dynamic test is needed. Starting with a heavy (e.g. 100 kg) test person sitting on the seat, the height should be adjusted to mid-ride (in cases where the height adjustment is integrated into the suspension travel, adjust to the upmost mid-ride position). The test person rises from the seat very quickly, so that the suspension is compressed into the upper end-stop. The highest position measured gives the upper end of travel. In this context, mid-ride means the mid-point of the working stroke.

   To determine the lower end of travel, first exhaust the suspension completely so that the suspension is just resting on the lower end-stop. If necessary, add weight to the seat to bring the suspension into contact with the end-stop. Then, compress the suspension further with a force of 1 000 N (or load with a mass of 100 kg). This lowest position gives the lower end of travel.

   For a suspension that cannot be measured in this way, an alternative method that has the same basic objectives should be devised.

The following information should be included in the report:

— full working stroke (as given by the manufacturer);

— measured working stroke (suspension without integral height adjustment) or full measured suspension travel (suspension with integral height adjustment);

— position used during the vibration test (distance above lower end of travel);

— available height adjustment (suspension with integral height adjustment) being the full measured suspension travel less the working stroke as specified by the manufacturer.

NOTE 1 Use of a continuous visual indication of ride height position for the test controller or engineer can aid reproducibility by enabling any variations in ride height to be corrected, e.g. resulting from changing damper temperature. Such indications can be electrical or mechanical. It is also necessary for determining the upper end of travel for a suspension with automatic weight adjustment.

NOTE 2 Use of a brief burst of sinusoidal vibration, coupled with visual indication of ride height, can help to reduce the error in setting ride height that can be introduced by friction, particularly in suspensions with low spring rates.

8.1.4 Inclination of backrest

When the inclination of the backrest is adjustable, it shall be set approximately upright, inclined slightly backwards (if possible: 10° ± 5°).

8.2 Test persons and posture

Application standards for suspended seats shall specify the masses of two test persons to be used for the test. These masses will normally be based on the 5th and the 95th percentile masses of the population of vehicle or machinery users for which the seat is intended. The tolerance shall be low, preferably ${}^{\ 0}_{-5\,\%}$ of the required mass for the low-mass test person. For the heavy test person, a greater tolerance is permissible, up to ${}^{+5\,\%}_{\ \ 0}$ of the required mass.

Whereas existing test standards for suspension seats specify test persons by total clothed weight, measured standing, reproducibility of test results might be improved by specifying sitting weight, measured as below. Some test standards for suspension seats (e.g. ISO 5007, ISO 7096, EN 13490) consistently specify light persons with total mass of 52 kg to 55 kg, and heavy persons with total mass of 98 kg to 103 kg. Specification by sitting weight, based on the approximate assumption that this is 75 % of total weight, would thus become 39 kg to 41 kg for the light person and 74 kg to 77 kg for the heavy person.

In order to check the sitting weight, the test person should sit in an erect upright posture on a hard, flat seat with no backrest on the weighing platform, with feet and legs supported separately, and hands resting on top of the thighs. There should be no contact between the seat and the thighs. For this measurement, the upper leg should be approximately horizontal and the lower leg approximately vertical. The value weighed should be that supported by the test person's ischial tuberosities.

Test persons should be weighed immediately before each continuous series of test runs.

To meet the required mass of the test persons, added masses may be used. Where this is allowed, and to aid reproducibility, these should be in the form of inert discs (or sheets) placed between the seat cushion and the test person. The mounting disc should be placed under the added mass between the added mass and the seat cushion. The added mass should be no more than 5 kg for a light test person, and no more than 8 kg for a heavy test person. The use of added masses and other optional possibilities (such as carrying out the test with only one test person) should be dealt with in application standards.

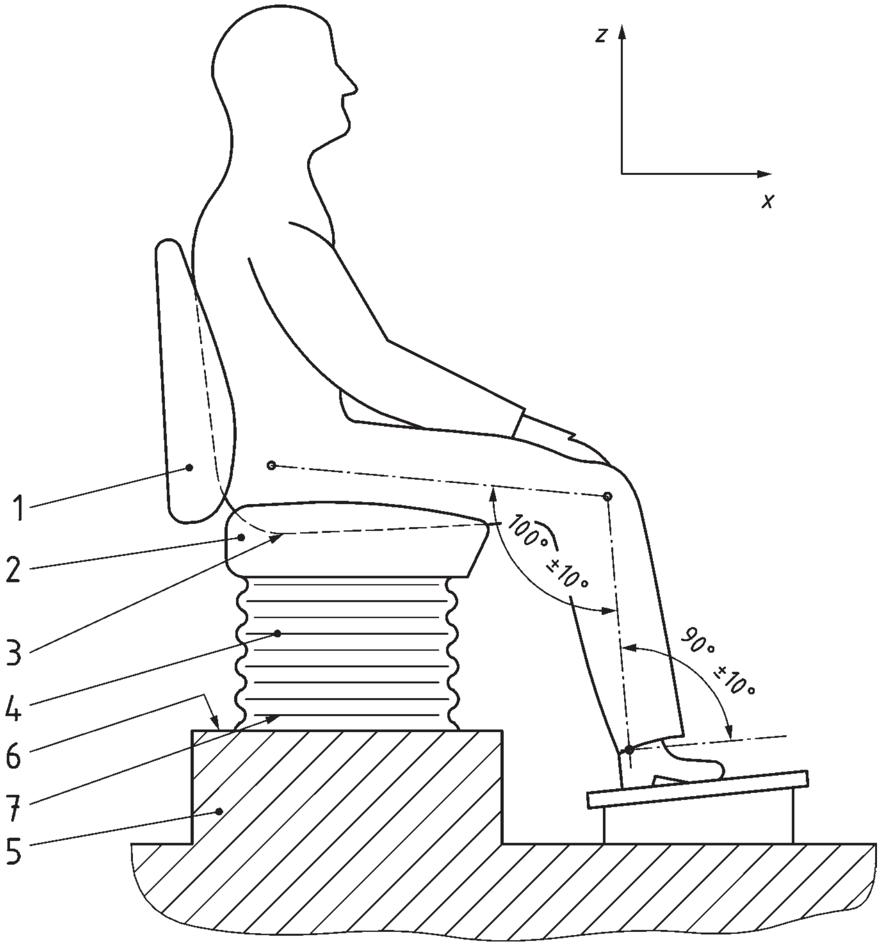
Laboratories are encouraged to gather data to correlate the sitting and standing weights of their test persons.

The application standards shall also define a posture appropriate to the application. This could include some relationship between seat height and longitudinal footrest position, absence or presence of a steering wheel (and its position), and some guidance as to how the correct posture can be ensured, e.g. by measurement of certain limb or joint angles. An example of a suitable posture for testing of suspension seats is shown in Figure 3.

In the testing of suspension seats, vibration at the test person's feet can contribute to the acceleration measured on the seat cushion. It is necessary to minimize this consistently. Therefore, the height of the feet support should be adjusted so that, when the seat height position is set to the position to be used for the tests (usually mid-ride), there is no pressure between the front of the seat cushion and the thighs of the test person. This may be confirmed subjectively, or by simple means such as sliding a piece of paper between the cushion and the thighs.

NOTE It is usually more convenient to set the foot position after first setting the mid-ride height of the suspension.

The test persons shall be trained in preliminary tests until they have become accustomed to maintaining a normal, inactive behaviour and posture with respect to the seat throughout the test.



Key

1 seat backrest
2 seat pan
3 accelerometer disc on the seat pan (S)
4 seat suspension
5 platform
6 accelerometer on the platform (P)
7 base of the seat

Figure 3 — Suitable posture for testing suspension seats

8.3 Other possibilities

In order to avoid the exposure of human beings to testing, it may in future application standards be possible to recommend other solutions.

9 Test input vibration

9.1 General

The application standards shall specify one or more dynamic tests, designed to ensure that a seat is suitable for the intended purpose. As a minimum, there shall be a test using an input representative of severe but not abnormal use, in the course of which the vibration transmitted to the interface between the seat and the operator is measured, as the basic performance parameter of the seat.

In order to specify the transmission characteristics of seats with regard to different input frequencies (e.g. for tuning the vibration response of seats on different types of vehicle, such as foam seats in passenger cars), an alternative method is recommended in 9.4 for the determination of the transfer function for the relevant frequency range with a sinusoidal vibration input.

For seats with suspension systems used in off-road machinery, there should be a test of the effectiveness of the suspension damper in controlling occasional large-amplitude vibrations or shocks. This can take the form of a sinusoidal test to determine the maximum response of the seat at a frequency close to its resonant frequency when carrying a simple load equivalent to an average operator (e.g. the inert mass as specified in 8.1.2).

In some cases, such as suspensions with short travel as used on industrial trucks or off-road vehicles, a further test may be needed to ensure that, under conditions of excessive suspension travel, the suspension end-stops are so constructed as to keep the resulting shock acceleration at an acceptable level. Annex A contains the specification for such a test which may be specified in more detail in an application standard (type-C standard) if needed.

9.2 Simulated input vibration test

The simulated input test vibration shall be specified in accordance with the vehicle or machinery groups defined either by the acceleration power spectral density function or by the time history of an actual and representative signal.

When the input vibration is defined by PSD, the relevant application standard should give the formula describing the PSD and its tolerance. The equation for the PSD may be in the form of filter formulae, which should be those of a low-pass filter and a high-pass filter (the pair constituting a band-pass filter), both of the Butterworth type. The cut-off frequencies and the slopes of the filters shall be clearly defined.

When the input vibration is defined by a time history, the application standard shall specify the number of measured (calculated) points, frequency and amplitude spacing and the sampling rate.

A tolerance on this level shall also be specified when the input vibration is defined by a time history.

The probability density function of the random vibration at the mounting base of the seat during the test may be required in application standards.

For both types of input vibration, the required root mean square (r.m.s.) acceleration on the platform, a_{wP}, shall be specified in application standards.

NOTE 1 Annex B shows an example of a simulated input test vibration defined by the power spectral density (PSD).

NOTE 2 Interlaboratory differences might be reduced through sharing input signals generated at one “reference” laboratory. Application standards can include the definition of such reference signals in annexes.

9.3 Tolerances on input vibration

To aid reproducibility in testing suspended seats, application standards should specify tolerances on input vibration in accordance with the following.

a) **r.m.s. values:** A tolerance should be defined for r.m.s. accelerations for the overall test signal (broadband) measured between set frequencies (f_1 and f_2; see Annex B) and for that associated with the dominant spectral peak (f_3 to f_4). Experience with existing test standards has shown that ±5 % of the target r.m.s. values is generally achievable.

b) **amplitude distribution function:** For simulated input test vibrations that are intended to have a Gaussian, or normal, amplitude distribution the following specification has been found to be practicable.

   Under the condition that the acceleration on the platform shall be sampled at a minimum of 50 data points per second, and analyzed into amplitude cells of not greater than 20 % of the total true r.m.s. acceleration, the probability density function shall be within ±20 % of the ideal Gaussian function between ±200 % of the total true r.m.s. acceleration, and with no data exceeding ±450 % of the total true r.m.s. acceleration.

c) **power spectral density:** Providing that the combination of sample time (duration of single test measurement), T_s, and resolution bandwidth, B_e, is as given in Formula (1):

$$2B_eT_s > 140 \tag{1}$$

   it should be possible to maintain the PSD function within ±10 % of the desired target curve. The desired target value has to be specified in the application standard, which can be, for example, 10 % of the maximum value of the target PSD.

NOTE Power spectral density estimates can vary, depending on how they are calculated. For typical input vibration signals, the following parameters have been found to be suitable:

— sampling rate: 200 Hz (Δt = 0,005 s);

— block length: 512 samples (Δf = 0,391 Hz, and therefore $2BT$ = 140 for 180 s record);

— window: Hanning, applied in the time domain so that an overlap of 50 % gives the same weight to each time sample.

For calculating the r.m.s. values, as in 9.3 a), the frequencies f_1, f_2, f_3 and f_4 should be chosen to allow simple interpolation of the power spectral density estimates. Alternatively, a re-analysis using a block length of 2 048 samples ($\Delta f \approx$ 0,1 Hz) might provide sufficiently precise frequency range limits.

9.4 Transfer function with sinusoidal vibration input

The vibration transfer function test shall be carried out with two persons, as specified in 8.2. Input vibration magnitude and phase versus frequency, frequency spacing, transient time and duration of vibration input per frequency step shall be specified in application standards.

9.5 Damping test

9.5.1 Suspension seats

Application standards shall specify the characteristics of either a sinusoidal vibration or a random vibration to be used to assess the damping of suspension seats. The sine-wave test shall be conducted at the resonance frequency of the seat suspension. This resonance frequency shall be determined by exciting the seat in the frequency range from 0,5 to 2,0 times the expected resonance frequency. The total displacement for both the damping test and the determination of the resonance frequency shall be 40 % of the full travel available or 50 mm, whichever is the smaller. All measurements shall be made with an inert mass (see 8.1.2, Note) of 75 kg ± 0,75 kg on the seat, adjusted in accordance with 8.1.3.

For suspensions fitted with active damping, it is possible that this test is not appropriate. In such cases, the test mass or the input excitation can be reduced. A mass of 60 kg has been found to be appropriate.

9.5.2 Other seats

Application standards may specify damping tests for non-suspension seats in a manner similar to that described above, with appropriate modifications.

10 Test procedure

10.1 General

Mount the seat to be tested on the platform of the vibration simulator, in accordance with the specified test seat arrangement. Check the safety requirements and calibrate the instruments. Prior to the damping test and simulated input vibration test, carry out the run-in procedure on the test seat (see 8.1.2).

10.2 Simulated input vibration test

10.2.1 Position a test person in the seat. Operate the vibration simulator to produce the appropriate test input vibration.

The test input vibration, during each test run, shall be continuous to provide an analysing time sufficient to be specified in application standards.

Repeat the test to obtain three consecutive test runs in which the frequency-weighted r.m.s. acceleration values, a_{w}, measured at the seat are within ±5 % of their arithmetic mean. Record this arithmetic mean as the frequency-weighted r.m.s. acceleration at the seat, a_{wS}.

For the tests described above, the vibration at the platform during each test shall be within the PSD tolerances mentioned in 9.2. The arithmetic mean of the three test values measured at the platform shall be recorded as the frequency-weighted r.m.s. acceleration values at the platform, a_{wP}.

It has been found that a short period of running to warm up the seat, up to 10 min, improves the repeatability. It is recommended that a short warm-up should take place immediately before each series of measurements. The seat might be loaded with either a test person or an inert load. (For inert load, see 8.1.2.) A suitable warmup might be to run and then discard the first reading of each series.

10.2.2 If the purpose of the simulated input vibration test of the relevant application standard is to obtain the seat effective amplitude transmissibility (SEAT) factor of the seat, calculate the ratio of the recorded values as given in Formula (2):

$$\mathrm{SEAT} = \frac{a_{\mathrm{wS}}}{a_{\mathrm{wP}}} \qquad (2)$$

where a_{wS} and a_{wP} are as defined in 10.2.1.

10.2.3 If the purpose of the simulated input vibration test is to obtain the absolute magnitude for vibration to be transmitted to a person in a vehicle or machinery, the magnitude on the seat, a_{wS}, shall be corrected according to the ratio between the measured test input magnitude, a_{wP}, and the intended input value a_{wP}^*. The corrected magnitude on the seat, a_{wS}^*, is given in Formula (3):

$$a^*_{wS} = \frac{a^*_{wS} \cdot a^*_{wP}}{a^*_{wP}} \quad (3)$$

or in Formula (4):

$$a^*_{wS} = \text{SEAT} \cdot a^*_{wP} \quad (4)$$

where SEAT is as defined in 10.2.2.

10.3 Damping test

Load the seat with an inert mass of 75 kg ± 1 % (see 8.1.2).

Apply the required peak-to-peak displacement amplitude to the base of the seat at the resonance frequency, f_r, of the suspension.

Repeat the test to obtain three consecutive test runs in which the r.m.s. acceleration values, $a_S(f_r)$, measured at the disc are within ±5 % of their arithmetic mean. Record this arithmetic mean, $a_S(f_r)$.

Note the arithmetical mean of the three values of the r.m.s. acceleration values, $a_P(f_r)$, measured on the platform.

Calculate the transmissibility, T, at resonance of the seat as the ratio of the registered values, as follows:

$$T = \frac{a_S(f_r)}{a_P(f_r)} \quad (5)$$

11 Acceptance

Under the test procedures of this document, acceptance values from the simulated input vibration test and/or damping test can be defined. Application standards shall state the acceptance values relevant to the specific seat test.

The acceptance value for the simulated input vibration test shall be given either as the maximum value of the SEAT or the maximum corrected magnitude on the seat, a^*_{wS}. To pass the test, lower values than this maximum shall be obtained for each test person.

The acceptance value for the damping test shall be defined as transmissibility at resonance.

12 Test report

The test report should contain the following:

a) the name and address of seat manufacturer;

b) the model of seat, product and serial number;

c) the date of test;

d) the duration of run-in period, in hours;

e) the type of measurement equipment and mounting disc used (semi-rigid or rigid);

f) the characteristics of the simulated input vibration test;

g) the vibration transmission to the test persons during the simulated input vibration test:

   1) mass of test persons, in kilograms,

   2) SEAT factor, and/or

   3) corrected magnitude on the seat surface;

h) the transmissibility at resonance during the damping test and the resonance frequency (alternatively, the transfer function with sinusoidal-vibration input);

i) the name of person responsible for the test;

j) the identification of test laboratory.

Annex A
(informative)

Test method for assessing the ability of a seat suspension to control the effects of impacts caused by over-travel

A.1 General

This annex specifies a laboratory test method for measuring and evaluating the effectiveness of a suspension seat in controlling the whole-body vertical vibration transmitted to the operator of an industrial truck or off-road vehicle in conditions that can cause excessive suspension travel.

The test method may be applicable to operator seats in the following types of vehicles:

a) industrial trucks;

b) earth-moving machines (restricted to classes defined in ISO 7096);

c) agricultural tractors;

d) forestry forwarders.

At the discretion of the standards committee responsible for the relevant type-C standard, the test method may supplement, but does not replace, the tests for vertical vibration isolation defined in, for example, ISO 5007, ISO 7096 and EN 13490.

A.2 Symbols

a_{arb}	Arbitrary acceleration amplitude applied to the seat base (vibration exciter platform), in metres per second squared
a_w	W_k frequency-weighted acceleration, in metres per second squared (W_k is defined in ISO 2631-1)
f	Frequency of the input vibration, in hertz
t	Time, in seconds
t_0	Time at the start of the test stimulus
t_1	Time at the end of the test stimulus
t_M	Time at the end of the measurement
VDV	Vibration dose value, in metres per second to the power of 1,75
x	Displacement of the seat base (vibration exciter platform), in metres
$\ddot{x}$	Acceleration of the seat base (vibration exciter platform), in metres per second squared
$L_{2,5}$	Seat load vibration dose value of 2,5 m/s^{1,75} ($L_{2,5}$ = 2,5 m/s^{1,75})
$B_{2,5}$	Seat base vibration dose value corresponding to a seat load vibration dose value of 2,5 m/s^{1,75}

$L_{7,5}$	Seat load vibration dose value of 7,5 m/s^{1,75} ($L_{7,5}$ = 7,5 m/s^{1,75})
$B_{7,5}$	Seat base vibration dose value corresponding to a seat load vibration dose value of 7,5 m/s^{1,75}
L_1, B_1	Seat load and seat base vibration dose values for the measurement with a load VDV in the range 2,375 m/s^{1,75} to 2,5 m/s^{1,75}
L_2, B_2	Seat load and seat base vibration dose values for the measurement with a load VDV in the range 2,5 m/s^{1,75} to 2,625 m/s^{1,75}
L_3, B_3	Seat load and seat base vibration dose values for the measurement with a load VDV in the range 7,125 m/s^{1,75} to 7,5 m/s^{1,75}
L_4, B_4	Seat load and seat base vibration dose values for the measurement with a load VDV in the range 7,5 m/s^{1,75} to 7,875 m/s^{1,75}
R	Rate of increase of the load VDV relative to the base VDV between load VDVs of 2,5 m/s^{1,75} and 7,5 m/s^{1,75}

A.3 Test conditions and test procedure

A.3.1 Seat mounting

The seat to be tested shall be mounted on a horizontal platform of a vibration exciter, which shall have movements in the vertical direction (z-axis), as specified in the application standards. The dimensions of the mounting platform shall be sufficient to adequately support the seat.

The vibration exciter shall be capable of generating sinusoidal peak-to-peak displacement of at least 60 mm at 2 Hz.

A.3.2 Seat adjustment

The seat shall be run in as specified by its manufacturer.

The seat shall be adjusted to a mid-ride position appropriate to the mass of a test person of 98 kg (equivalent to a load on the seat of 75 kg) in accordance with the seat manufacturer's instructions. If no instructions are available, the seat shall be adjusted to the force mid-point of the suspension force-deflection characteristic measured over a range from zero to 1 500 N with the seat in a specified configuration.

NOTE Many seats have mass adjusters that are marked according to the total driver (operator) mass, but only approximately 75 % of this mass is actually carried by the seat.

The seat shall be adjusted to the desired mid-ride position and then subjected to a low peak-to-peak (less than 5 mm) sinusoidal vibration at the base of the seat at a frequency approximately three times the seat resonance frequency. This process shall be repeated as necessary until the seat settles to the intended mid-ride position.

With seats where the stroke available is unaffected by the adjustment for seat height or test person mass, testing shall be performed with the seat adjusted to the centre of the stroke. With seats where the stroke available is affected by the adjustment of the seat height or by test person mass, testing shall be performed at both the maximum and minimum height adjustment with the seat required to pass both tests. The manufacturer should specify what influence different combinations of mass and seat height adjustments will have on the stroke available during testing.

The fore and aft adjustment of the seat shall be in the centre of the available travel.

The inclination of the cushion surface (if adjustable) shall be nominally horizontal.

Where the inclination of the backrest is adjustable, the angle shall be approximately 10° behind the vertical.

If the seat is capable of rotation, it shall be locked facing forward (i.e. towards the vehicle controls when the vehicle is travelling).

Additional suspension systems (fore-and-aft and/or lateral) shall be disabled.

A.3.3 Test load

The test load shall have a total mass of 75 kg and shall be rigid. The centre of mass shall act downwards through a point at the centre of the seat in the (lateral) y-axis and a point 40 mm forward of the seat index point (SIP), as defined in ISO 5353, when the load is correctly positioned on the seat surface. The surface area of the test load in contact with the seat cushion shall be as defined in ISO 5353. Friction between the load and the backrest shall be minimized by using muslin sheet or similar material.

Care shall be taken that the load cannot fall off the seat, in particular during severe top end-stop impacts. The method of securing the load shall not impede the movement of the load in the (vertical) z-axis.

The position of the load on the seat shall be monitored throughout the test, and the load shall be repositioned if it deviates from the desired position by more than an amount to be defined in the machinery-specific standard.

The test load shall be in place on the seat surface for at least 3 min and not more than 4 h before beginning the test.

A.3.4 Test environment

The air temperature shall be maintained at (20 ± 8) °C.

The seat shall be allowed to acclimatize to these conditions for at least 4 h.

No part of the seat shall exceed 40 °C during the tests.

A.3.5 Input vibration

The input vibration shall consist of the following waveform, defined from $t = 0$ to $t = 4{,}5/f$:

a) in terms of acceleration (see Figure A.1) as given in Formula (A.1):

$$\ddot{x}(t) = a_{\text{arb}} \sin(2\pi f t) \cdot \sin\left(\frac{\pi f t}{4{,}5}\right) \qquad \text{(A.1)}$$

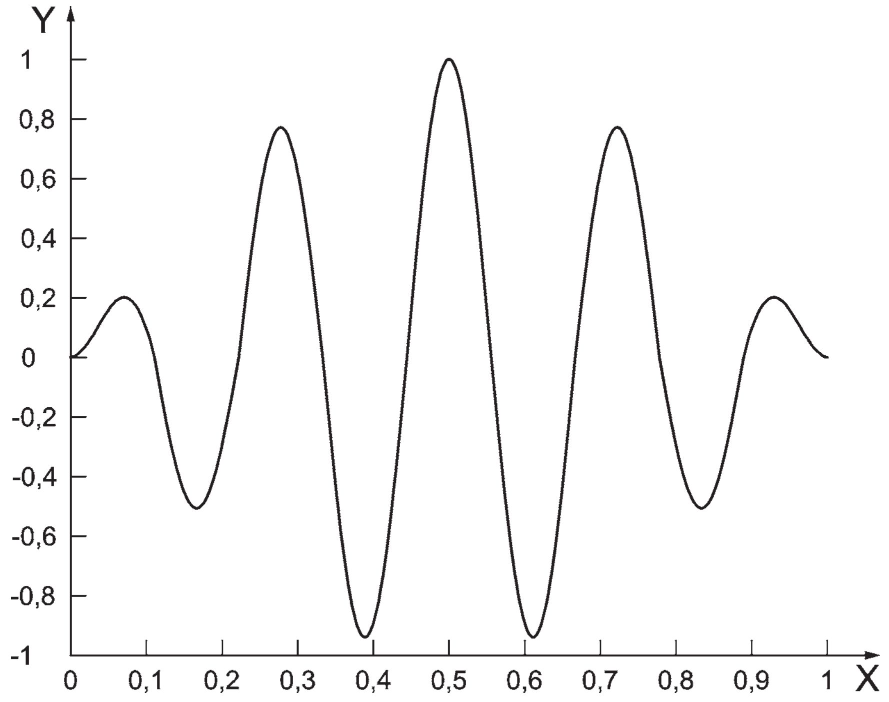
b) in terms of displacement as given in Formula (A.2):

$$x(t) = \frac{1}{2} a_{\text{arb}} \left[\frac{\cos(2{,}22\pi f t) - 1}{(2{,}22\pi f)^2} - \frac{\cos(1{,}78\pi f t) - 1}{(1{,}78\pi f)^2} \right] \qquad \text{(A.2)}$$

The frequency, f, shall be the centre frequency of the spectra of the vibration test input signal relevant to the seat under test, as defined in ISO 5007, ISO 7096 or EN 13490.

A.3.6 Tolerance on input vibration

The tolerance should be specified in terms of deviation from the ideal waveform in the time domain.



Key

X time, t, normalized to $4{,}5/f$

Y platform acceleration, $\ddot{x}(t)$, normalized to a_{arb}

Figure A.1 — Vibration exciter platform acceleration waveform $\ddot{x}(t)$

A.3.7 Measuring instrumentation

A.3.7.1 Transducers

The acceleration shall be measured on the vibration exciter platform with transducers mounted as specified in 5.2.2.

The acceleration of the load shall be measured using an accelerometer rigidly attached to the load mass. The accelerometer shall be in line with the centre of mass in the (vertical) z-axis and shall be as close as possible to the surface of the seat.

A.3.7.2 Data acquisition system

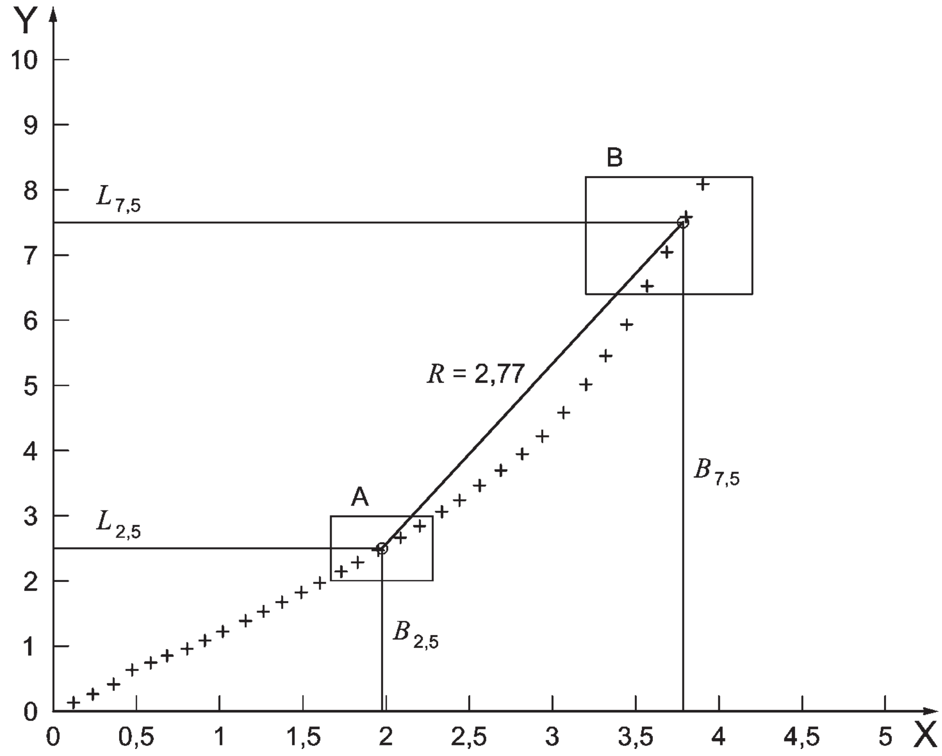
The data acquisition system shall be in accordance with ISO 8041.

A.3.8 Test procedure

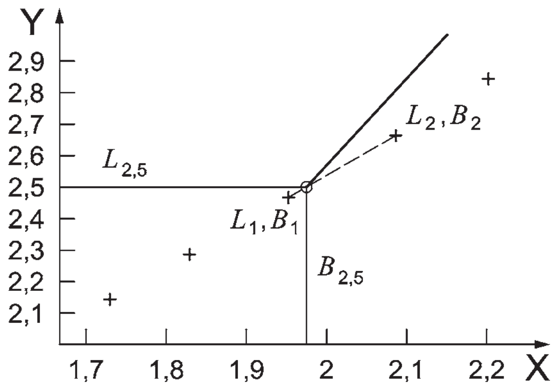
The test procedure determines the slope between two specified points on a graph of the vibration dose value (VDV) at the seat load plotted against the VDV at the seat base. These points are specified to be descriptive of the response when suspension over-travel is likely to cause the end-stop to be compressed. The points are specified according to the VDV at the seat load. It is therefore necessary to determine each point by interpolation between two measured points, as illustrated in Figure A.2 where one point causes a higher VDV at the seat load, and one a lower VDV than the target value.

The test stimulus shall be repeatedly reproduced at the vibration exciter platform at varying magnitudes until two values for the load VDV are obtained in the range 2,375 m/s^{1,75} to 2,625 m/s^{1,75}. One measured load VDV shall be in the range 2,375 m/s^{1,75} to 2,5 m/s^{1,75}. This load VDV shall be recorded as L_1 and the corresponding seat base VDV as B_1. Another measured load VDV shall be in the range 2,5 m/s^{1,75} to 2,625 m/s^{1,75}. This load VDV shall be recorded as L_2 and the corresponding seat base VDV as B_2.

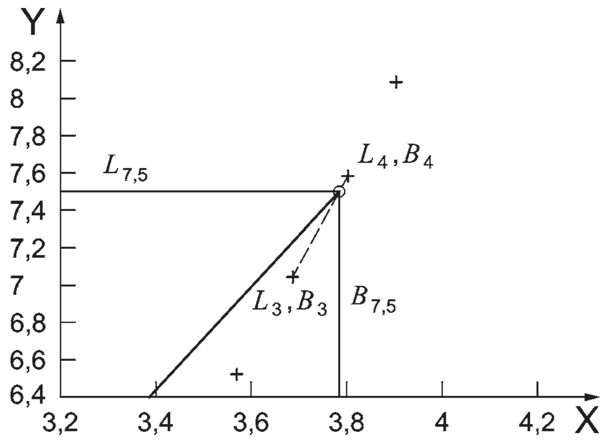
The magnitude of the test stimulus shall be adjusted such that two values for the load VDV are obtained in the range 7,125 m/s^{1,75} to 7,875 m/s^{1,75}. One measured load VDV shall be in the range 7,125 m/s^{1,75} to 7,5 m/s^{1,75}. This load VDV shall be recorded as L_3 and the corresponding seat base VDV as B_3. Another measured load VDV shall be in the range 7,5 m/s^{1,75} to 7,875 m/s^{1,75}. This load VDV shall be recorded as L_4 and the corresponding seat base VDV as B_4. This procedure is illustrated in Figure A.2.



a) Total diagram



b) Detail A



c) Detail B

Key

X W_k frequency weighted base VDV

Y W_k frequency weighted load VDV

Figure A.2 — Example illustration of the test procedure

The vibration dose value shall be calculated as given in Formula (A.3):

$$\mathrm{VDV} = \left[\int_{t_0}^{t_M} a_w^4(t)\, dt \right]^{1/4} \quad \text{(A.3)}$$

where

a_w	is calculated by frequency weighting the recorded acceleration with the W_k frequency weighting;
$t_\mathrm{M} = t_1 + 1$	is the time, in seconds, at the end of the measurement, i.e. the measurement duration is 1 s longer than the stimulus signal lasts.

The test shall be discontinued if the maximum displacement amplitude of the vibration exciter platform exceeds a specified value as given in the relevant type-C standard.

A procedure may be specified whereby the seat is subjected to a standard input signal before and after the test to confirm that the seat performance has not altered during the test.

Curve fitting or smoothing methods may be used in place of linear interpolation in situations involving substantial scattering of data points.

A.4 Evaluation procedure

The seat base VDVs corresponding to the target seat load VDVs shall be calculated by linear interpolation as given in Formulae (A.4) and (A.5):

$$B_{2,5} = (B_2 - B_1) \cdot \frac{L_{2,5} - L_1}{L_2 - L_1} + B_1 \quad \text{(A.4)}$$

$$B_{7,5} = (B_4 - B_3) \cdot \frac{L_{7,5} - L_3}{L_4 - L_3} + B_3 \quad \text{(A.5)}$$

The test result is the rate of increase of the load VDV relative to the base VDV as defined by Formula (A.6):

$$R = \frac{L_{7,5} - L_{2,5}}{B_{7,5} - B_{2,5}} \quad \text{(A.6)}$$

A.5 Acceptance values

The rate of increase of the VDV, R, as defined in Formula (A.6) shall be reported. This value shall not exceed a specified acceptance value, which should be defined for each vehicle class in the relevant type-C standard.

A.6 Test report

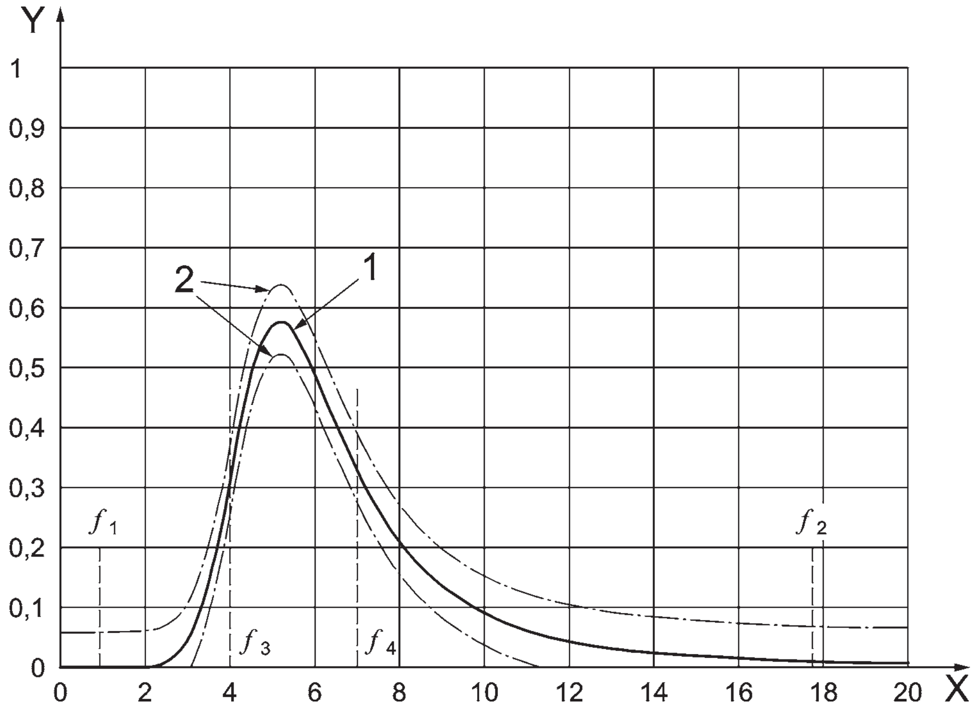
In addition to the provisions of Clause 12, the test report shall include the values for R, $L_{2,5}$ and $L_{7,5}$. The report may also include the graph of the measured load and base vibration dose values.

The travel and mid-ride position of the seat shall be reported. The methods used to determine these values should also be reported.

Annex B
(informative)

Example of a simulated input test signal specified by the PSD

This example reflects the expected low-frequency excitation of forklift trucks with tyre diameters less than 645 mm in severe but typical operating conditions (input spectral class IT 1 according to EN 13490:2001).



Key

Y $G_P^*(f)$ power spectral density, $(m/s^2)^2/Hz$

X f frequency, Hz

1 reference value

2 allowable limits

Figure B.1 — Example of a simulated input test signal

The power spectral density (PSD) of the simulated input test signal shown in Figure B.1 is given by Formula (B.1)

$$G_P^*(f) = 1{,}66(HP_{24})^2(LP_{12})^2 \quad \text{(B.1)}$$

where

$$HP_{24} = \frac{S^4}{1 + 2{,}613S + 3{,}414S^2 + 2{,}613S^3 + S^4}$$

$$LP_{12} = \frac{1}{1 + 1,414S + S^2}$$

in which

$$S = \frac{jf}{f_c}$$

where

j is equal to $\sqrt{-1}$;

f is the frequency, in Hertz;

f_c is the filter cut-off frequency, in Hertz - for HP_{24}, f_c = 4,5 Hz; for LP_{12}, f_c = 5 Hz.

The maximum value of $G^*_P(f)$ is 0,58 $(m/s^2)^2/Hz$. The allowable limits in Figure B.1 are given by 10 % of the maximum value of $G^*_P(f)$, i.e. Δ = 0,058 $(m/s^2)^2/Hz$.

So,

$G_{upper}(f) = G^*_P(f) + \Delta$ and

$G_{lower}(f) = G^*_P(f) - \Delta$, if $G_{lower}(f) > 0$, or

$G_{lower}(f) = 0$ otherwise.

The frequency range limits are

— f_1 = 0,89 Hz

— f_2 = 17,78 Hz

— f_3 = 4,00 Hz

— f_4 = 7,00 Hz

The target r.m.s. acceleration on the platform is as given in Table B.1.

Table B.1 — Target r.m.s. acceleration on the platform

Frequency range	Unweighted m/s^2	Frequency weighted m/s^2
f_1 to f_2	1,58	1,59
f_3 to f_4	1,20	1,25
NOTE These values were calculated using Δf = 0,001 Hz and the complex analytical functions (with band-limiting) given in ISO 2631-1. The use of other Δf values can give slightly different values.		

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