INTERNATIONAL STANDARD

ISO 5007

First edition
1990-02-15

Agricultural wheeled tractors — Operator's seat — Laboratory measurement of transmitted vibration

Tracteurs agricoles à roues — Siège du conducteur — Mesurage en laboratoire des vibrations transmises

Reference number
ISO 5007 : 1990 (E)

Contents

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Printed in Switzerland

Foreword

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

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 5007 was prepared by Technical Committee ISO/TC 23, *Tractors and machinery for agriculture and forestry.*

This first edition cancels and replaces the first edition of the Technical Report, ISO/TR 5007 : 1980, of which it constitutes a technical revision.

This page intentionally left blank

Agricultural wheeled tractors — Operator's seat — Laboratory measurement of transmitted vibration

1 Scope

This International Standard specifies a method for measuring and evaluating the effectiveness of the seat in reducing the vertical whole-body vibration transmitted to the operator of an agricultural tractor.

Vibration which reaches the operator other than through his seat, for example that sensed by his feet on the platform or control pedals or by his hands on the steering-wheel, is not covered.

This International Standard applies to seats fitted to agricultural wheeled tractors within specified tractor classes, each class being defined as a group of tractors having similar vibration characteristics (see table 2). Input vibrations for tractors not in a defined class may be measured at the seat attachment point during field operations and used for input to the vibration test table.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 868 : 1985, *Plastics and ebonite — Determination of indentation hardness by means of a durometer (Shore hardness).*

ISO 2041 : 1975, *Vibration and shock — Vocabulary.*

ISO 2631-1 : 1985, *Evaluation of human exposure to whole-body vibration — Part 1: General requirements.*

ISO 4253 : 1977, *Agricultural tractors — Operator's seating accommodation — Dimensions.*

ISO 4865 : — [1], *Vibration and shock — Methods for analysis and presentation of data.*

ISO 5353 : 1978, *Earth-moving machinery and tractors and machinery for agriculture and forestry — Seat index point.*

IEC 225 : 1966, *Octave, half-octave and third-octave band filters intended for the analysis of sounds and vibrations.*

3 General

3.1 A simulated tractor vibration is specified as the test input to the operator seat on a laboratory test stand. This test input is based on measured data from tractors driven on a standardized test track and on data obtained from field tests under various conditions of use. The test input for a particular tractor class is a representative value for the tractors within that class.

3.2 The specification of the procedures, instruments and evaluation methods allows the measurements to be made and reported with acceptable precision.

3.3 The vibration is evaluated in accordance with ISO 2631-1. The procedure includes a means of weighting the vibration level at different frequencies to take account of the frequency sensitivity of the human operator.

4 Definitions

The terminology used in this International Standard is generally in accordance with ISO 2041. For the purposes of this International Standard, the following additional definitions also apply.

1) To be published.

4.1 whole-body vibration : Vibration transmitted to the body as a whole through the buttocks of a seated operator.

4.2 tractor class : Tractors having similar ride vibration characteristics at the seat attachment point, grouped by virtue of various mechanical characteristics.

4.3 unballasted mass : Mass of tractor in working order with full tanks and radiators, but less the mass of the operator and without removable ballast weights, special equipment or other loads. Where relevant the mass of protective structure shall be included.

4.4 operator seat : That portion of the tractor provided for the purpose of supporting the buttocks of the seated operator, including any suspension system and other mechanisms provided, for example for adjusting the seat position.

4.5 frequency analysis : Process of arriving at a quantitative description of a vibration amplitude as a function of frequency.

4.6 measuring period : Time duration in which vibration data for analysis is obtained.

5 Symbols and abbreviations

For the purposes of this International Standard, the following symbols and abbreviations apply :

a = instantaneous acceleration

a_f = r.m.s. value of 1/3 octave acceleration having centre frequency f

a_w = frequency-weighted acceleration signal

a_{wf} = weighted r.m.s. acceleration calculated as described in 6.4.1, 6.4.2 or 6.4.3

a_{wfB} = a_{wf} at base of seat (see 6.2.1)

a_{wfS} = a_{wf} at the operator vibration-sensing disc (see 6.2.2)

a^*_{wfS} = corrected value of a_{wfS} (see 10.2.4)

B_e = resolution bandwidth of a frequency analysis, in hertz

f = frequency, in hertz

T = analysis time duration, in seconds

W_f = frequency-dependent dimensionless weighting factor

g = acceleration due to gravity, by international agreement equal to 9,806 65 m/s^2 at sea level

r.m.s. = root mean square

PSD = power spectral density expressed as mean square acceleration per unit bandwidth (m/s^2)^2/Hz

PDF = probability density function of acceleration amplitudes

SIP = seat index point (see ISO 5353)

6 Instrumentation and frequency analysis

6.1 Acceleration transducers

Vibration at the seat base and vibration transmitted to the operator shall be sensed by acceleration transducers (accelerometers), located as described in 6.2.1 and 6.2.2 respectively.

The accelerometers, together with their amplifiers, shall be capable of measuring r.m.s. acceleration levels ranging from 0,05 m/s^2 to 10 m/s^2 with a crest factor of up to 6. The accelerometers and amplifiers shall be capable of an accuracy of ± 2,5 % of the actual r.m.s. vibration level in the frequency range 0,8 Hz to 80 Hz. The resonant frequency of the accelerometers shall be greater than 300 Hz, and they shall be capable of sustaining instantaneous acceleration levels up to 100 m/s^2 without damage.

6.2 Transducer mounting

6.2.1 Vibration at seat base

This vibration shall be sensed by an accelerometer attached to a rigid portion of the test stand or the seat mounting base. The accelerometer shall be located within the vertical projection of the seat cushion not more than 100 mm from the vertical longitudinal plane through the centreline of the seat, and shall be aligned parallel to the measurement Z-axis (see figure 1).

If the vibration test stand is of the pivoting type illustrated in figure 2, the accelerometers at the seat base and on the disc described in 6.2.2 shall be at the same distance from the pivot ± 20 mm.

6.2.2 Vibration transmitted to operator

This vibration shall be sensed by an accelerometer attached at the centre of a disc 250 mm ± 50 mm in diameter placed between the seated operator and the seat cushion. The disc shall be made of semi-rigid material of A/80 to A/90 (Shore hardness durometer type A) when measured in accordance with ISO 868 with a rigid centre part 75 mm ± 5 mm in diameter to which the accelerometer is attached. A disc design is shown in figure 3.

When the disc is placed on the seat, the accelerometer shall be approximately midway between the ischial tuberosities of the seated operator and aligned parallel to the measurement Z-axis (see figure 1).

6.3 Electronic recorders

The electrical signals generated by the transducers may be recorded on magnetic tape for later analysis. The magnetic tape recorder shall be capable of a replay accuracy of at least ± 3 % of the r.m.s. value of the total signal within the frequency range 1 Hz to 80 Hz.

6.4 Frequency weighting

Frequency weighting may be achieved in any of three ways: by analysis of the acceleration into one-third octave band levels, weighting the levels in individual bands and recombination, by direct use of electrical filters in a broadband method, or by digital analysis of the acceleration into constant bandwidth levels, weighting the levels in individual bands and recombination. The three methods are described in 6.4.1 to 6.4.3.

Small differences in absolute values of weighted vibration may result from the three different weighting methods pending the gathering of further experience, but, providing the same method is used for weighting both input and seat vibration as is required in 10.2.3, these differences are considered unlikely to affect the final result significantly.

6.4.1 One-third octave bandwidth method

Each vibration tape recording, or vibration signal where a tape recorder is not used, shall be analysed into one-third octave component accelerations for the centre frequencies of table 1. (The centre frequencies of table 1 are an extrapolation of IEC 225.) The r.m.s. value of each component, a_f, shall be averaged over the duration specified for the measurement. The one-third octave values shall each be multiplied by the weighting factors, W_f, listed in table 1, and a weighted acceleration value, a_{wf}, calculated for each recording as follows:

$$a_{wf} = \left[\sum_{f=1}^{20} W_f^2 \times a_f^2 \right]^{\frac{1}{2}}$$

Table 1 — Frequency weighting factors (in accordance with ISO 2631-1)

One-third octave centre frequency f	Weighting factor W_f
1	0,5 = − 6 dB
1,25	0,56 = − 5 dB
1,6	0,63 = − 4 dB
2	0,71 = − 3 dB
2,5	0,8 = − 2 dB
3,15	0,89 = − 1 dB
4	1 = 0 dB
5	1 = 0 dB
6,3	1 = 0 dB
8	1 = 0 dB
10	0,8 = − 2 dB
12,5	0,63 = − 4 dB
16	0,5 = − 6 dB
20	0,4 = − 8 dB
25	0,315 = − 10 dB
31,5	0,25 = − 12 dB
40	0,2 = − 14 dB
50	0,16 = − 16 dB
63	0,125 = − 18 dB
80	0,1 = − 20 dB

To satisfy the following,

$$2B_e T \geqslant 140$$

the minimum sampling time, T, is 300 s.

6.4.2 Broadband method

This method, if employed for direct indication of the weighted vibration, shall consist of an electronic weighting network incorporated between the transducer and a time integration stage. The weighting network shall have an insertion loss conforming to the curve in figure 4 for Z-axis (vertical) vibration. The loss shall not deviate from the curve by more than ± 0,5 dB for frequencies between 2 Hz and 4 Hz, and ± 2 dB at any other frequency. The integration stage shall be capable of indicating the integral of the square of weighted acceleration, a_{wf}, for the time period of the test run T. That is,

$$(a_{wf})^2 = \frac{1}{T} \int_{t=0}^{T} a_w^2 \, dt$$

The minimum sampling time, T, is 120 s.

6.4.3 Constant bandwidth method

Each vibration tape recording, or vibration signal where a tape recorder is not used, shall be analysed into constant bandwidth acceleration levels over the frequency range from 1 Hz to 20 Hz by appropriate digital methods (see ISO 4865). The sampling time, T, in seconds, shall satisfy the following :

$$2\,B_e\,T \geqslant 140$$

and resolution bandwidth, B_e, in hertz,

$$B_e \leqslant 0,3$$

The constant bandwidth r.m.s. levels shall be each multiplied by a weighting factor calculated for each centre frequency from figure 4 for Z-axis (vertical) vibration. A weighted acceleration value, a_{wf}, shall be calculated as the square root of the sum of the squares of the weighted constant bandwidth levels over the range 1 Hz to 20 Hz.

6.5 Calibration

6.5.1 General

Acceleration transducers should be calibrated in accordance with a suitable recognized calibration method. In particular, the calibration procedures should ensure that the acceleration sensitivity varies less than ± 2,5 % of a mean value over the frequency range 0 to 40 Hz and less than ± 6,0 % of mean value over the frequency range of 0 to 80 Hz.

The effects of ambient temperature on the performance of all instruments shall be known. Instruments shall be operated within the temperature limits at which the required accuracy can be expected.

6.5.2 Tests

Transducers which have a flat response to 0 Hz shall normally be calibrated by tilting.

The general procedures described in the tilting support method for static calibration of acceleration transducers should be used to obtain overall system acceleration sensitivity. Tilting the sensitive axis of the transducer from the vertical through an angle of 180° in the field of gravity provides a peak-to-peak change in the output representing a 19,61 m/s^2 ($2g$) change in input acceleration. The sensitive axis of the accelerometer should be aligned with the vertical and the 180° inverted position to within ± 4°, and the peak-to-peak change in output voltage should be measured to within ± 0,5 %. Calibration should be made and recorded before and after each test series and at reasonable intervals during any extended test series. Each calibration shall be compared to internal electronic calibration of the overall instrument system.

Transducers which do not have a flat response down to 0 Hz shall be tested with a dynamic calibrator.

An internal electronic calibration of the overall instrument system shall be checked immediately before and after each test run, and corrections made as necessary to maintain the required test accuracy.

The output from each accelerometer amplifier shall be set to zero by proper balancing and zeroing techniques while the accelerometers are in the test position between the seat and the seated operator and on the seat mounting base or test stand.

The zero value of the overall instrument system shall be recorded immediately before and after each test run.

7 Vibration test stand

7.1 Physical characteristics

The minimum requirement is an electro-hydraulic feedback control system with a Z-axis degree of freedom.

Any appropriate digital or analog method may be used to generate the command signal providing that the output PSD and PDF requirements are satisfied at the seat mounting base.

The moving portion of the vibration test stand shall consist of a platform to provide for the seat mounting base, a steering-wheel, and flat floor space for operator foot support. The stand shall be limited to travel essentially vertically and shall be free from resonances and non-linearities which would distort the output vibration beyond the correction capability of signal compensation.

If the platform is carried on an arm, as shown in figure 2, the radius from the arm pivot to the SIP shall be at least 2 000 mm.

7.2 Safety recommendations

The vibration test stand shall have a fail-safe device capable of automatic shut-down when the seat mounting base acceleration exceeds 15 m/s^2 for any reason. It is preferred that this device be hydraulic, such as a supply pressure-relief valve and/or a load-limiting valve across the piston of the actuator cylinder. If an acceleration transducer is used as the sensor for safety purposes, its signal should be passed through a low pass filter with a 20 Hz cut-off frequency to avoid automatic shut-down by high frequency components beyond the hydraulic capability of the test stand. If the test stand is not hydraulic, adequate safety devices should be used.

The pump and/or servo-valves should be appropriate to limit the test stand velocity to 1,3 m/s, and the accumulator should be of the minimum size required to provide the proper system response.

Fail-safe shut-down switches should be provided to both the person in the test seat and the operator of the test facility. The shut-down switches should shut down the hydraulic power supply and actuate a valve to release the system hydraulic pressure.

In all tests, the excitation vibration should be increased slowly to allow the tests to be terminated at the request of the person in the seat.

8 Test conditions

8.1 Test seat

Before the test, suspension seats shall be run-in under the conditions stipulated by the manufacturer. If the manufacturer does not state such conditions, then the seat shall be run-in for 5 h.

For this purpose, the seat shall be loaded with a 75 kg mass such as lead shot, adjusted for this mass in accordance with the manufacturer's instructions, and a sinusoidal input vibration shall be applied at the seat base at approximately the suspension natural frequency and of an amplitude sufficient to cause movement over approximately 75 % of the full suspension stroke. Care shall be taken to ensure against overheating the suspension damper during run-in.

8.2 Test persons

Tests shall be carried out with two test persons.

The light test person shall have a total mass of 59 kg ± 1 kg, of which not more than 5 kg may be carried in a belt around the waist.

The heavy test person shall have a total mass of 98 kg ± 5 kg, of which not more than 8 kg may be carried in a belt around the waist.

The test person shall sit naturally on the seat with feet flat on the floor and hands placed on the steering-wheel as typical of machine operation. The seat shall be set for the driver's mass in accordance with the manufacturer's instructions, and its position relative to the steering-wheel and footrest shall satisfy the requirements of ISO 4253.

9 Test input vibration

9.1 Tractor classes

Basic specifications for tractors defined as having similar vibration characteristics are identified by class in table 2.

Table 2 — Tractor classification 1)

Classification	Unballasted mass kg
Class 1	up to 3 600
Class 2	3 600 to 6 500
Class 3	over 6 500

1) Rear axles unsprung.

9.2 Vibration characteristics

The vibration characteristics for each class of tractor are shown in figures 5 to 7.

Exact equations for the acceleration power spectral density curves of figures 5 to 7 are included in clause 13. The curves defined by these equations are the target values to be produced at the base of the seat for the random vibration test of 10.2.

9.2.1 Table 3 further defines the test input levels and shows the tolerances allowed on the actual test PSD at the base of the seat.

9.2.2 Any means, including double integrators, analog signal generators and filters, and digital signal generators with digital-to-analog converters, may be used to produce the required PSD and r.m.s. characteristics at the base of the seat for the random vibration test.

9.2.3 Table 3 also specifies the probability density function required of the random vibration at the base of the seat during the test.

10 Test procedure

10.1 Damping test

10.1.1 This test is carried out on the test stand as specified in clause 7.

10.1.2 Two tests shall be carried out, the seat being loaded with a mass of 40 kg for the first test and with a mass of 80 kg for the second test.

10.1.3 A sinusoidal vibration of ± 15 mm amplitude is applied to the seat base at frequencies in the range 0,5 Hz to 2 Hz. The frequency range shall be run through at intervals no greater than 0,05 Hz, with increasing frequency, and in an identical manner with decreasing frequency.

10.1.4 The ratio of the r.m.s. values, V, of the vibration acceleration on the seat surface a_{wfS} to those at the seat base a_{wfB}

$$V = \frac{a_{wfS}}{a_{wfB}}$$

shall be determined in the frequency range from 0,5 Hz to 2 Hz at intervals no greater than 0,05 Hz. This ratio shall be given in the test report to two decimal places.

10.1.5 For the purposes of 10.1.4, any of the methods of 6.4 may be used to obtain the frequency-weighted r.m.s. acceleration, the same method being used for determining both a_{wfS} and a_{wfB}.

10.2 Random vibration test

Each test person shall be positioned in the seat according to 8.2. The vibration test stand shall be operated to produce the appropriate test input vibration spectra of clause 9 at the base of the seat according to the class of machine to which the operator seat is to be fitted.

The test input vibration shall be continuous for the minimum sampling time as defined in 6.4. Calibration of the instruments shall be checked before and after each test run in accordance with 6.5.2.

10.2.1 For each mass of test person (see 8.2), the test shall be repeated to obtain three consecutive test runs in which the frequency-weighted r.m.s. acceleration values (a_{wf} in accordance with 6.4) measured at the seat disc of 6.2.2 are within ± 5 % of their arithmetical mean. This arithmetical mean shall be recorded as a_{wfS}.

10.2.2 For the recording runs according to 10.2.1, the vibration at the seat mounting base during each test shall be within the allowed values of table 3. For each test person, the arithmetical mean of the three test values for the frequency-weighted r.m.s. acceleration values (a_{wf} in accordance with 6.4) measured at the base of the seat shall be recorded as a_{wfB}.

10.2.3 For the purposes of 10.2.1 and 10.2.2, any of the methods of 6.4 may be used to obtain the frequency-weighted r.m.s. acceleration, except that the same method shall be used for both.

10.2.4 The frequency-weighted r.m.s. acceleration transmitted to the person, a_{wfS} in accordance with 10.2.1, shall be corrected in the proportion that the actual test input frequency r.m.s. acceleration, a_{wfB} in accordance with 10.2.2, differed from the target value of column 2 of table 3. The calculation is as follows:

$$\text{Corrected operator acceleration, } a^*_{wfS} = a_{wfS} \frac{\text{Target value of table 3}}{a_{wfB}}$$

11 Applicability of test result

A seat submitted to test under Class 2 conditions need not be further tested for use under Class 1 conditions.

12 Test report

The test report should contain the following:

a) name and address of seat manufacturer;

b) model of seat;

c) date of test;

d) tractor class number of test input;

e) value of maximum transmissibility in the test in 10.1.4; frequency and input amplitude at which it was measured;

f) vibration transmitted to the test person:

1) mass of test person in kilograms (including any added mass);

2) vibration (weighted r.m.s.) transmitted to test person in metres per second squared corrected as in 10.2.4;

g) frequency weighting method used;

h) person carrying out test.

13 Equations for PSD curves

Equations for the PSD curves are defined by a simple combination of high pass (HP) and low pass (LP) filters with Butterworth type frequency response function. All filters are of 8 poles, i.e. with attenuation increasing by 48 dB/octave in the stop bands.

Class 1 PSD $= 9{,}25\, H^2 L^2$

Class 2 PSD $= 7{,}22\, H^2 L^2$

Class 3 PSD $= 5{,}85\, H^2 L^2$

where

H is the magnitude of the high-pass filter with Butterworth type frequency response function HP_{48} given below.

$$H = R^8 / \sqrt{(1 - 13{,}137 R^2 + 25{,}688 R^4 - 13{,}137 R^6 + R^8)^2 + (5{,}126 R - 21{,}846 R^3 + 21{,}846 R^5 - 5{,}126 R^7)^2}$$

in which

$R = f/F_c$ and f is the frequency in hertz,
F_c is the HP_{48} cut-off frequency for the particular tractor class from table 4, in hertz;

L is the magnitude of the low-pass filter with Butterworth type frequency response function LP_{48} given below.

$$L = 1 / \sqrt{(1 - 13{,}137 R^2 + 25{,}688 R^4 - 13{,}137 R^6 + R^8)^2 + (5{,}126 R - 21{,}846 R^3 + 21{,}846 R^5 - 5{,}126 R^7)^2}$$

in which

$R = f/F_c$ and f is the frequency in hertz,
F_c is the LP_{48} cut-off frequency for the particular tractor class from table 4, in hertz.

The high-pass filter with Butterworth type frequency response function is:

$$HP_{48} = S^8/(1 + 5{,}126 S + 13{,}137 S^2 + 21{,}846 S^3 + 25{,}688 S^4 + 21{,}846 S^5 + 13{,}137 S^6 + 5{,}126 S^7 + S^8)$$

The low-pass filter with Butterworth type frequency response function is:

$$LP_{48} = 1/(1 + 5{,}126 S + 13{,}137 S^2 + 21{,}846 S^3 + 25{,}688 S^4 + 21{,}846 S^5 + 13{,}137 S^6 + 5{,}126 S^7 + S^8)$$

Where, in both cases

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

in which

$j = \sqrt{-1}$

f is the frequency, in hertz,

F_c is the filter cut-off frequency, from table 4, in hertz.

Table 3 — Test input levels and tolerances

Tractor class	1	2	3	4	5
	True r.m.s. m/s²	**Weighted r.m.s. acceleration, a_{wf}** target m/s²	Tolerance	**Tolerance on test input PSD curve**[1)]	**Minimum % of test true r.m.s. within frequency bands**[1)]
1	2,25	2,05	± 10 %	± 1 dB between 3 and 3,5 Hz ± 2 dB between 2,5 and 4 Hz	65 % between 3 and 3,5 Hz 95 % between 2,5 and 4 Hz
2	1,94	1,5	± 10 %	± 1 dB between 2,1 and 2,6 Hz ± 2 dB between 1,8 and 2,9 Hz	70 % between 2,1 and 2,6 Hz 95 % between 1,8 and 2,9 Hz
3	1,74	1,3	± 10 %	± 1 dB between 1,9 and 2,4 Hz ± 2 dB between 1,6 and 2,7 Hz	70 % between 1,9 and 2,4 Hz 95 % between 1,6 and 2,7 Hz

1) To be analysed in accordance with the restrictions on time, T, and bandwidth, B_e, of 6.4.3.

NOTES

1 For all tests, probability density function : under the condition that the acceleration at the base of the seat shall be sampled at a minimum of 50 data points per second and analysed into amplitude cells of no greater than 50 % of the total true r.m.s. acceleration, the probability density function must be within ± 20 % of the ideal Gaussian function between ± 200 % of the total r.m.s. acceleration, with a minimum of 93 % of the data within ± 200 % of the total true r.m.s. acceleration, and with no data exceeding ± 400 % of the total true r.m.s. acceleration.

2 Column 1 is a reference value for the true r.m.s. acceleration defined by the equations in clause 13. Column 2 is the target value for the frequency-weighted r.m.s. acceleration test input at the base of the seat. Column 3 is the allowed tolerance on column 2. Column 4 is the allowed tolerance on the actual test input PSD curve which contains the major part of the test vibration, and a less restrictive tolerance of ± 2 dB on the PSD curve at the base of the seat. This includes a restrictive tolerance of ± 1 dB on the PSD curve in the stated frequency range over a wider frequency. Column 5 is an additional requirement which states the minimum percent of the actual test true r.m.s. acceleration which must be within the stated range of frequencies. The frequencies stated in columns 4 and 5 are band-edge frequencies.

Table 4 — Filter cut-off frequencies and curve data[1)]

Class	Centre frequency Hz	Value at centre frequency (m/s²)²/Hz	Filter cut-off frequencies F_c Hz (LP_{48})	(HP_{48})	Total weighted r.m.s. acceleration a_{wf} m/s²
1	3,25	5,55	3,5	3	2,05
2	2,35	5,17	2,6	2,1	1,5
3	2,2	4,36	2,45	1,95	1,3

1) HP and LP designate high-pass and low-pass filters with Butterworth type frequency response function. The subscripts state the filter slope in decibels per octave. Therefore the above table completely defines band-pass filters in terms of cut-off frequencies and roll-offs.