



BSI Standards Publication

Human response to vibration — Measuring instrumentation

Part 1: General purpose vibration meters

National foreword

This British Standard is the UK implementation of EN ISO 8041-1:2017. It supersedes BS EN ISO 8041:2005 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GME/21/2, Mechanical vibration, shock and condition monitoring - Vibration and shock measuring instruments and testing equipment.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2017
Published by BSI Standards Limited 2017

ISBN 978 0 580 93316 5

ICS 13.160

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 July 2017.

Amendments/corrigenda issued since publication

Date	Text affected
------	---------------

English Version

**Human response to vibration - Measuring instrumentation
- Part 1: General purpose vibration meters (ISO 8041-
1:2017)**

Réponse des individus aux vibrations - Appareillage de
mesure - Partie 1: Instrument de mesure à usage
général (ISO 8041-1:2017)

Schwingungseinwirkung auf den Menschen -
Messeinrichtung - Teil 1: Schwingungsmesser für
allgemeine Anwendungen (ISO 8041-1:2017)

This European Standard was approved by CEN on 22 April 2017.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.



EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

European foreword

This document (EN ISO 8041-1:2017) has been prepared by Technical Committee ISO/TC 108 "Mechanical vibration, shock and condition monitoring" in collaboration with Technical Committee CEN/TC 231 "Mechanical vibration and shock" the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by November 2017 and conflicting national standards shall be withdrawn at the latest by November 2017.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN ISO 8041:2005.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Endorsement notice

The text of ISO 8041-1:2017 has been approved by CEN as EN ISO 8041-1:2017 without any modification.

Contents

Page

Foreword	vi
Introduction	vii
1 Scope	1
2 Normative references	1
3 Terms, definitions and symbols	2
3.1 Terms and definitions	2
3.1.1 General	2
3.1.2 Frequency-weighted values	4
3.2 Symbols	6
4 Reference environmental conditions	8
5 Performance specifications	8
5.1 General characteristics	8
5.2 Display of signal magnitude	10
5.2.1 General	10
5.2.2 Resolution and refresh rate	10
5.2.3 Stabilization, measurement start and display times	11
5.3 Electrical output	11
5.4 Vibration sensitivity	11
5.5 Accuracy of indication at reference frequency under reference conditions	12
5.6 Frequency weightings and frequency responses	12
5.6.1 Parameters	12
5.6.2 Band-limiting filter	13
5.6.3 a-v transition filter	13
5.6.4 Upward-step filter	14
5.6.5 Overall frequency weighting	14
5.6.6 Tolerances	14
5.7 Amplitude linearity	15
5.8 Instrument noise	16
5.9 Signal-burst response	16
5.10 Overload indication	19
5.11 Under-range indication	20
5.12 Time averaging	20
5.13 Running r.m.s. acceleration	20
5.14 Reset	21
5.15 Timing facilities	21
5.16 Electrical cross-talk	21
5.17 Vibration transducer characteristics	21
5.18 Power supply	21
6 Mounting	22
7 Environmental and electromagnetic criteria	22
7.1 General	22
7.2 Air temperature	22
7.3 Surface temperature	23
7.4 Electrostatic discharge	23
7.5 Radio-frequency emissions and public-power-supply disturbances	23
7.6 Immunity to AC power-frequency fields and radio-frequency fields	24
7.7 Ingress of water and dust	24
8 Provision for use with auxiliary devices	25
9 Instrument marking	25
10 Instrument documentation	25

11	Testing and calibration	25
12	Pattern evaluation	28
12.1	General	28
12.2	Testing requirements	28
12.3	Submission for testing	29
12.4	Marking of the vibration meter and information in the instrument documentation	29
12.5	Mandatory facilities and general requirements	29
12.6	Initial instrument preparation	29
12.7	Indication at the reference frequency under reference conditions	29
12.8	Electrical cross-talk	30
12.9	Vibration transducer	30
12.10	Amplitude linearity and under-range indication	31
12.10.1	Electrical tests of amplitude linearity	31
12.10.2	Mechanical tests of amplitude linearity	32
12.11	Frequency weightings and frequency responses	33
12.11.1	General	33
12.11.2	Mechanical tests of frequency response	33
12.11.3	Electrical tests of frequency response	34
12.11.4	Conformance	35
12.12	Instrument noise	35
12.13	Signal-burst response	36
12.14	Overload indication	36
12.15	Reset	36
12.16	Combined axis outputs	37
12.17	AC electrical output	37
12.18	Timing facilities	37
12.19	Power supply	37
12.20	Environmental, electrostatic and radio-frequency tests	37
12.20.1	General	37
12.20.2	Expanded uncertainties for measurements of environmental conditions	38
12.20.3	Acclimatization requirements for tests of the influence of air temperature and relative humidity	38
12.20.4	Test of the influence of air temperature and relative humidity combined	38
12.20.5	Influence of surface temperature	39
12.20.6	Influence of electrostatic discharges	39
12.20.7	Radio-frequency emissions and public-power-supply disturbances	39
12.20.8	Immunity to AC power-frequency fields and radio-frequency fields	40
12.21	Test report	41
13	Validation of one-off instruments	42
13.1	General	42
13.2	Testing requirements	42
13.3	Test object	42
13.4	Submission for testing	43
13.5	Marking of the one-off instrument and information in the instrument documentation	43
13.6	Mandatory facilities and general requirements	43
13.7	Initial instrument preparation	43
13.8	Test procedure	43
13.9	Indication at the reference frequency under reference conditions	44
13.10	Test parameters	45
13.10.1	Vibration measurement chain for hand-arm vibration	45
13.10.2	Vibration measurement chain for whole-body vibration	45
13.10.3	Vibration measurement chain low-frequency whole-body vibration	46
13.11	Conducting the test	46
13.12	Instrument noise	47
13.13	Electrical cross-talk	47
13.14	Overload indication	47
13.15	Timing facilities	47

13.16	Test report.....	48
14	Periodic verification	48
14.1	General.....	48
14.2	Testing requirements	48
14.3	Test object.....	48
14.4	Submission for testing.....	48
14.5	Preliminary inspection.....	49
14.6	Marking of the vibration meter and information in the instrument documentation	49
14.7	Test procedure.....	49
14.8	Test parameters.....	50
	14.8.1 Vibration measurement chain for hand-arm vibration.....	50
	14.8.2 Vibration measurement chain for whole-body vibration.....	50
	14.8.3 Vibration measurement chain low-frequency whole-body vibration.....	50
14.9	Conducting the test	51
14.10	Test report.....	51
15	<i>In situ</i> checks	51
15.1	General.....	51
15.2	Preliminary inspection.....	52
15.3	Vibration sensitivity (field calibration).....	52
	Annex A (normative) Specification for field vibration calibrator	53
	Annex B (informative) Frequency weightings.....	55
	Annex C (informative) Realization of frequency weighting filters	74
	Annex D (informative) Running r.m.s. time averaging	78
	Annex E (informative) Vibration transducer characteristics.....	81
	Annex F (informative) Tests for mounting systems	84
	Annex G (normative) Instrument documentation.....	87
	Annex H (normative) Phase response requirements for measurement of non-r.m.s. quantities.....	92
	Annex I (informative) Guidelines for the estimation of the instrumental measurement uncertainty.....	100
	Bibliography	106

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

This document was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 3, *Use and calibration of vibration and shock measuring instruments*.

This first edition cancels and replaces ISO 8041:2005, which has been technically revised. It also incorporates the Technical Corrigendum ISO 8041:2005/Cor. 1:2007. The following main changes have been made:

- addition of an Introduction explaining the reasons for this revision;
- addition of a validation test for one-off instruments;
- revision and simplification of the verification test;
- addition of Annex I, which gives example estimates of the instrumental measurement uncertainty;
- correction of errors in formulae, numbers and figures.

A list of parts in the ISO 8041 series can be found on the ISO website.

Introduction

Until 2005, when the previous edition of this document was published, measuring instrumentation for human response to vibration (vibration meters) normally consisted of a signal processing unit and a detachable vibration transducer. According to recent developments, however, part of the signal processing steps can be integrated in the transducer unit, so that the signal coming out of the transducer's sensing element and going into the signal conditioning unit is not accessible any more. These transducer units include, for example, IEPE and MEMS transducers.

Some of the test procedures specified in this document, however, presume that this point in the signal path is accessible (electrical input). Since such an input is not mandatory these tests can only be performed on a vibration meter having an electrical input or after some technical modifications to the instrumentation, e.g. internal access to signal paths. Or those tests can only be performed mechanically, which in certain cases requires modifications to some test procedures. Such modifications to test procedures, however, are beyond the present scope of this document.

Some of the test procedures specified in this document can only be performed if an electrical output is available, see for example [5.13](#). Since such an output is not mandatory these tests can only be performed on a vibration meter having an electrical output or after some technical modifications to the instrumentation, e.g. internal access to signal paths.

The verification test now specified in this document is practicable and has the objective of identifying an instrument which is adequately calibrated for the intended applications and is suitable for its purpose, at a cost reasonable for the calibration laboratory and affordable for the end user. Therefore, the verification test is strongly reduced in its extent compared to the full pattern evaluation, or validation, and only tests the most relevant characteristics of a vibration meter.

Human response to vibration — Measuring instrumentation —

Part 1: General purpose vibration meters

1 Scope

This document specifies the performance specifications and tolerance limits for instruments designed to measure vibration values, for the purpose of assessing human response to vibration. It includes requirements for pattern evaluation, or validation, periodic verification and *in situ* checks, and the specification of vibration calibrators for *in situ* checks.

Vibration instruments specified in this document can be single instruments, combinations of instrumentation or computer-based acquisition and analysis systems.

Vibration instruments specified in this document are intended to measure vibration for one or more applications, such as the following:

- hand-transmitted vibration (see ISO 5349-1);
- whole-body vibration (see ISO 2631-1, ISO 2631-2 and ISO 2631-4);
- low-frequency whole-body vibration in the frequency range from 0,1 Hz to 0,5 Hz (see ISO 2631-1).

Vibration instruments can be designed for measurement according to one or more of the frequency weightings defined within each of these applications.

Three levels of performance testing are defined in this document:

- a) pattern evaluation or validation:
 - 1) pattern evaluation, i.e. a full test of the instrument against the specifications defined in this document;
 - 2) validation of one-off instruments, i.e. a limited set of tests of an individual vibration measuring system against the relevant specifications defined in this document;
- b) periodic verification, i.e. an intermediate set of tests designed to ensure that an instrument remains within the required performance specification;
- c) *in situ* checks, i.e. a minimum level of testing required to indicate that an instrument is likely to be functioning within the required performance specification.

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 2631-2, *Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration — Part 2: Vibration in buildings (1 Hz to 80 Hz)*

ISO 2631-4:2001, *Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration — Part 4: Guidelines for the evaluation of the effects of vibration and rotational motion on passenger and crew comfort in fixed-guideway transport systems*

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

ISO 5348, *Mechanical vibration and shock — Mechanical mounting of accelerometers*

ISO 5349-1:2001, *Mechanical vibration — Measurement and evaluation of human exposure to hand-transmitted vibration — Part 1: General requirements*

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

ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

IEC 61000-4-2:2008, *Electromagnetic compatibility (EMC) — Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3:2006, *Electromagnetic compatibility (EMC) — Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-6, *Electromagnetic compatibility (EMC) — Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-6-2:2005, *Electromagnetic compatibility (EMC) — Part 6-2: Generic standards – Immunity for industrial environments*

CISPR 22:2008, *Information technology equipment — Radio disturbance characteristics — Limits and methods of measurement*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2041, ISO/IEC Guide 99 and the following apply.

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

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1.1 General

3.1.1.1 vibration acceleration

component of acceleration, where the axis of measurement is specified by application standards

3.1.1.2 band-limiting frequency weighting

component of a frequency weighting defined by the high- and low-pass band-limiting filters

3.1.1.3 band-limited frequency range

frequency range defined by the band-limiting component of a frequency weighting

3.1.1.4 nominal frequency range

frequency range of interest, as defined in the relevant measurement standard

3.1.1.5**linear operating range**

range between lower and upper boundaries, on each measurement range, over which the linearity errors do not exceed the applicable tolerance limits specified in this document

3.1.1.6**overload**

condition that occurs when the upper boundary of the linear operating range is exceeded

3.1.1.7**under-range**

condition that occurs when the vibration value is below the lower boundary of the linear operating range

3.1.1.8**reference measurement range**

level range specified for testing the characteristics of the vibration instrumentation

Note 1 to entry: This range is used for measuring the reference vibration.

3.1.1.9**reference vibration signal**

sinusoidal vibration signal, the magnitude and frequency of which are specified in this document for testing the electromechanical performance of a human-vibration meter

Note 1 to entry: Different reference vibration signals are specified according to the application of the instrumentation.

3.1.1.10**calibration check frequency**

frequency specified for providing a check of the vibration sensitivity of the instrument

3.1.1.11**tone burst**

one or more complete cycles of a sinusoidal signal that start and end at a zero crossing of the waveform

3.1.1.12**signal burst**

one or more complete cycles of a periodic signal (such as saw tooth) that start and end at a zero crossing of the waveform

3.1.1.13**vibration measuring instrumentation**

combination of a vibration transducer, signal processor and display, being any single instrument, or a collection of instruments, which is/are capable of measuring parameters relating to human response to vibration

Note 1 to entry: See [Figures 1](#) and [2](#).

3.1.1.14**instrument documentation**

instruction manual, operating procedure or other documentation provided for the use of users of the vibration measurement instrument

3.1.2 Frequency-weighted values

3.1.2.1

time-averaged weighted acceleration value

frequency-weighted root-mean-square (r.m.s.) vibration acceleration value in a specified axis, a_w , in metres per second squared or radians per second squared, as defined by the expression

$$a_w = \left(\frac{1}{T} \int_0^T a_w^2(\xi) d\xi \right)^{1/2}$$

where

$a_w(\xi)$ is the translational or rotational, frequency-weighted vibration acceleration in a specified direction or around a specified axis as a function of the instantaneous time, ξ in metres per second squared (m/s^2) or radians per second squared (rad/s^2), respectively;

T is the duration of the measurement.

3.1.2.2

time-averaged weighted acceleration level

frequency-weighted r.m.s. vibration acceleration level expressed in decibels, as defined by

$$L_w = 20 \lg \frac{a_w}{a_0} \text{ dB}$$

where

a_w is the frequency-weighted r.m.s. acceleration value;

a_0 is the reference acceleration (in ISO 1683 for translational acceleration defined as 10^{-6} m/s^2).

3.1.2.3

running r.m.s. acceleration value

frequency-weighted running r.m.s. vibration acceleration, in metres per second squared, defined by the expression

$$a_{w,\theta}(t) = \left(\frac{1}{\theta} \int_{t-\theta}^t a_w^2(\xi) d\xi \right)^{1/2}$$

where

$a_w(\xi)$ is the frequency-weighted instantaneous vibration acceleration at time ξ , in metres per second squared or radians per second squared (rad/s^2), respectively;

θ is the integration time of the measurement;

t is the instantaneous time.

Note 1 to entry: Exponential averaging may be used for the running r.m.s. method, as an approximation of the linear averaging. The exponential averaging is defined as follows:

$$a_{w,\tau}(t) = \left(\frac{1}{\tau} \int_{-\infty}^t a_w^2(\xi) \exp\left(\frac{\xi-t}{\tau}\right) d\xi \right)^{1/2}$$

where τ is the time constant.

3.1.2.4**maximum transient vibration value****MTVV**

maximum value of the running r.m.s. vibration acceleration value when the integration time is equal to 1 s

3.1.2.5**motion sickness dose value****MSDV**

integral of the squared frequency-weighted instantaneous vibration acceleration $a_w(t)$ in $\text{m/s}^{1,5}$ as defined by the expression

$$\text{MSDV} = \left(\int_0^{\Phi} a_w^2(\xi) d\xi \right)^{1/2}$$

where Φ is the total period during which motion could occur

Note 1 to entry: The motion sickness dose value can be obtained from the frequency-weighted r.m.s. vibration acceleration through multiplication by $\Phi^{1/2}$.

Note 2 to entry: For measurement instrumentation, the exposure period, Φ , is likely to be assumed to be equal to the measurement period, T , unless otherwise indicated.

3.1.2.6**vibration dose value****VDV**

integral of the fourth power of the frequency-weighted instantaneous vibration acceleration $a_w(t)$ in $\text{m/s}^{1,75}$ as defined by the expression

$$\text{VDV} = \left(\int_0^{\Phi} a_w^4(\xi) d\xi \right)^{1/4}$$

where Φ is the total (daily) period for which vibration exposure occurs

Note 1 to entry: The vibration dose value is more sensitive to peaks than is the r.m.s. value.

Note 2 to entry: For measurement instrumentation, the exposure period, Φ , is likely to be assumed to be equal to the measurement period, T , unless otherwise indicated.

3.1.2.7**vibration total value**

combined vibration from three axes of translational vibration, as defined by the expression

$$a_{wv} = \sqrt{k_x^2 a_{wx}^2 + k_y^2 a_{wy}^2 + k_z^2 a_{wz}^2}$$

where

a_{wx} , a_{wy} and a_{wz} are the weighted vibration values in the three orthogonal axes x , y and z ;

k_x , k_y and k_z are multiplying constants whose values depend on the measurement application

3.1.2.8**peak vibration value**

maximum modulus of the instantaneous (positive and negative) peak values of the frequency-weighted acceleration

3.1.2.9

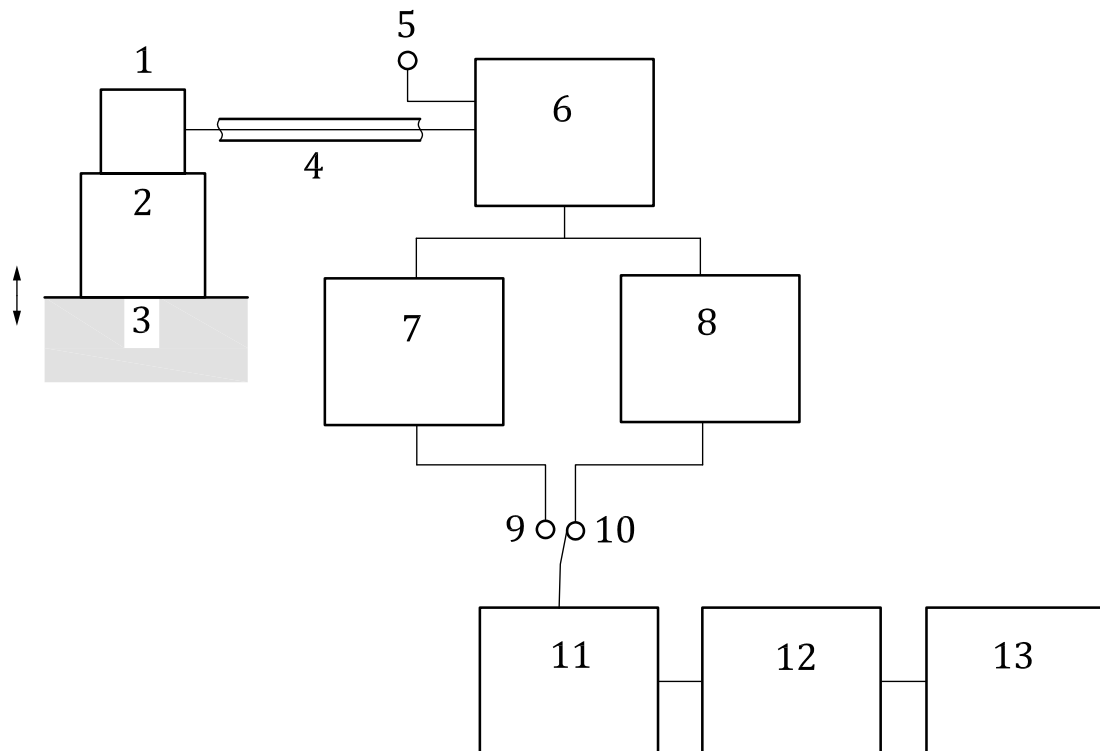
crest factor

parameter for a measurement period, given by the peak vibration value divided by the r.m.s. vibration value, with both values having the same frequency weighting

3.2 Symbols

For the purposes of this document, the following symbols and abbreviated terms apply.

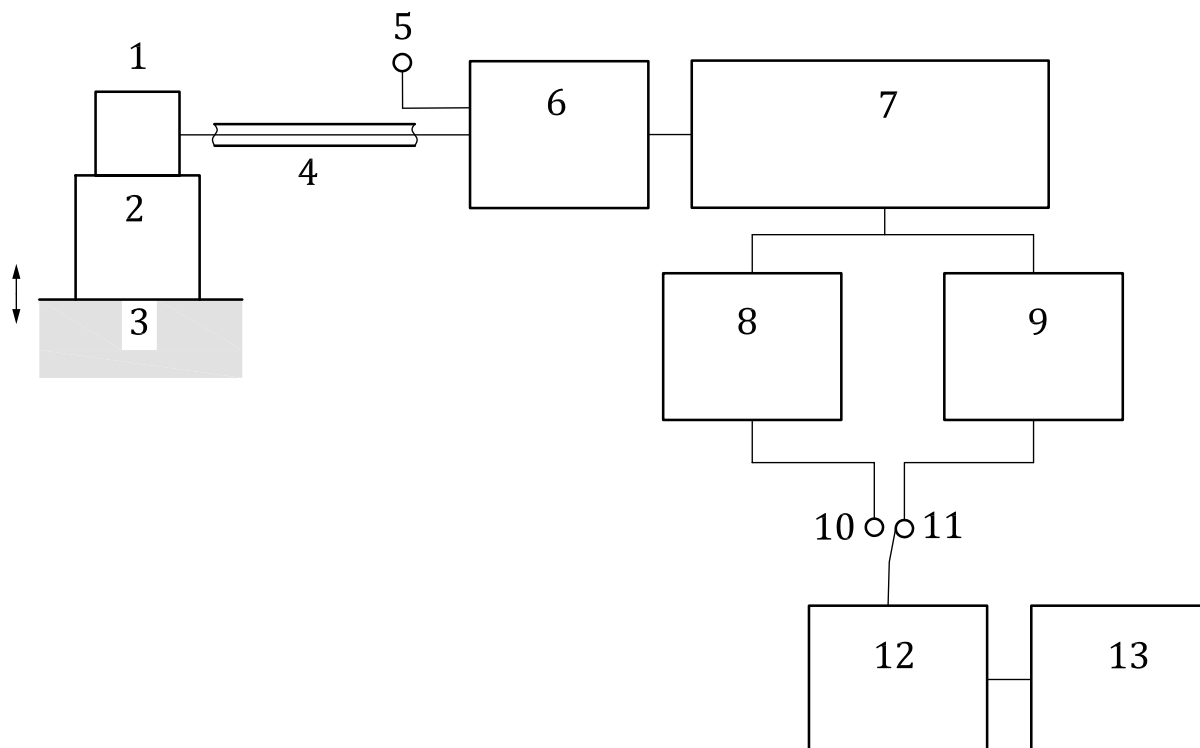
a_w	time-averaged frequency-weighted single-axis vibration acceleration
$a_w(t), a_w(\xi)$	instantaneous frequency-weighted translational or rotational single-axis acceleration at time t , or time ξ
f	frequency
H	overall frequency weighting function
k_i	multiplying constants applied to the whole-body frequency-weighted acceleration value for axis i
n	one-third-octave band number
s	variable of the Laplace transform
t or ξ	instantaneous time
T	measurement duration
W_x	frequency weighting
Φ	exposure duration
$\Delta P_{\max}$	maximum peak value deviation
$\Delta\varphi$	phase error
$\Delta\vartheta$	phase delay time difference
τ	exponential averaging time constant
θ	linear averaging time
MSDV	motion sickness dose value
MTVV	maximum transient vibration value
VDV	vibration dose value



Key

- | | | | |
|---|---------------------|----|---|
| 1 | transducer | 8 | frequency weighting — including band-limiting |
| 2 | mounting system | 9 | band-limited output |
| 3 | vibrating surface | 10 | frequency-weighted output |
| 4 | cable | 11 | time weighting |
| 5 | electrical input | 12 | additional processing |
| 6 | signal conditioning | 13 | display |
| 7 | band limiting | | |

Figure 1 — Example of the basic functional path of a vibration measurement instrument or measurement system — time-domain signal processing



Key

1	transducer	8	band limiting (calculation)
2	mounting system	9	frequency weighting — including band limiting (calculation)
3	vibrating surface	10	band-limited output
4	cable	11	frequency-weighted output
5	electrical input	12	accumulation of frequency bands
6	signal conditioning	13	display
7	frequency analysis time weighting time averaging		

Figure 2 — Example of the basic functional path of a vibration measurement instrument or measurement system — frequency-domain signal processing (not applicable to VDV processing)

4 Reference environmental conditions

Reference environmental conditions for specifying the performance of a vibration meter are

- air temperature: 23 °C, and
- relative humidity: 50 %.

5 Performance specifications

5.1 General characteristics

The performance specifications of this clause apply under the reference environmental conditions.

As a minimum, human-vibration measuring instrumentation shall provide a means of displaying

- time-averaged weighted vibration acceleration value over the measurement duration, a_w ,
- time-averaged band-limited vibration acceleration value over the measurement duration, and
- measurement duration, T .

The human-vibration measuring instrument shall also provide a means of indicating whether an overload occurred at any time within the measurement duration.

The human-vibration measuring instrument shall provide a method for setting and adjusting the vibration sensitivity.

Human-vibration measuring instruments may contain any or all of the design features for which performance specifications are given in this document. An instrument shall conform to the applicable performance specifications for those design features that are provided.

If the instrument has more than one measurement range, the instrument documentation shall describe the measurement ranges that are included and the operation of the measurement range control. The instrument documentation shall also identify which is the reference measurement range.

The reference vibration signal values and frequencies are given in [Table 1](#).

Table 1 — Reference vibration values and frequencies

Application	Fre- quency weighting	Reference	Nominal frequency range Hz	Reference		Weighting factor at reference frequency	Weighted acceleration at reference frequency and r.m.s. acceleration value m/s ²
				Frequency	r.m.s. accelera- tion value m/s ²		
Hand-transmitted	W_h	Table B.6	8 to 1 000	500 rad/s (79,58 Hz)	10	0,202 0	2,020
Whole-body	W_b	Table B.1	0,5 to 80	100 rad/s (15,915 Hz)	1	0,812 6	0,812 6
	W_c	Table B.2				0,514 5	0,514 5
	W_d	Table B.3				0,126 1	0,126 1
	W_e	Table B.4				0,062 87	0,062 87
	W_j	Table B.7				1,019	1,019
	W_k	Table B.8				0,771 8	0,771 8
	W_m	Table B.9	1 to 80			0,336 2	0,336 2
Low-frequency whole-body	W_f	Table B.5	0,1 to 0,5	2,5 rad/s (0,397 9 Hz)	0,1	0,388 8	0,038 88

If the instrument is capable of measuring the maximum (e.g. MTVV) and peak vibration values, a “hold” function shall be provided. The instrument documentation shall describe the operation of the hold feature and the method for clearing a display that is held.

Many of the specifications and tests in this document require the application of electrical signals substituting for the signal from the vibration transducer. The instrument documentation shall specify a means for substituting an electrical signal, equivalent to the signal from the vibration transducer, for performing electrical tests on the complete instrument without the vibration transducer. If appropriate,

the instrument documentation may describe alternative methods to test the specified operations of the human-vibration meter.

NOTE The manufacturer of the human-vibration meter is free to provide an input test point, or a dummy vibration transducer of specified electrical impedance (termination), or an equivalent input adapter (electrical or non-electrical) to perform electrical tests on the instrument.

The instrument documentation shall specify the maximum peak vibration at the vibration transducer and the maximum peak-to-peak signal (e.g. charge or voltage) that can be applied at the electrical input facility. The maximum vibration value and the maximum peak-to-peak voltage shall not cause damage to the instrument.

The tolerance limits given in this document include the associated expanded uncertainties of measurement, calculated for a coverage factor of 2, corresponding to a coverage probability of approximately 95 %, in accordance with the guidance given in ISO/IEC Guide 98-3. Guidelines for estimating instrumental measurement uncertainty are provided in [Annex I](#).

5.2 Display of signal magnitude

5.2.1 General

For instruments that can display more than one measurement quantity, a means shall be provided to ascertain clearly the measurement quantity that is being displayed, preferably indicated by standard abbreviations or letter symbols.

The quantities that can be displayed by the human-vibration meter shall be described in the instrument documentation, along with a description of the corresponding indications on each display device.

The instrument shall display the frequency-weighted acceleration values. Optionally, it may also display the frequency-weighted acceleration value multiplied by a factor k , as defined in ISO 2631-1. Where multiplying factors are used, this shall be clearly indicated on the instrument and the instrument shall be capable of displaying the multiplying factors.

Where a combined axis output is displayed (e.g. vibration total value, [3.1.2.7](#)), the instrument shall be capable of displaying the values of the multiplying factors used.

When results of a measurement are provided at a digital output, the instrument documentation shall describe the method for transferring or downloading the digital data to an external data storage or display device. The instrument documentation shall identify the computer software as well as the hardware for the interface. Internationally standardized interface bus compatibility is recommended.

Each alternative device for displaying the signal value, stated in the instrument documentation as conforming to the specifications of this document, is considered an integral part of the instrument. Each such alternative device shall be included as part of the components required for conformance to the performance specifications in this clause and the applicable environmental specifications of [Clause 7](#). Examples of alternative display devices include level recorders or computers with monitor screens.

For an instrument that uses a display device with a range less than the linear operating range specified in [5.7](#), the instrument documentation shall describe a means to test the linearity beyond the limits of the indicator range.

5.2.2 Resolution and refresh rate

The display device(s) specified in the instrument documentation shall permit measurements with a resolution of not more than 1 % of the indicated value.

If an instrument only has an analogue, or simulated analogue, display device that provides a continuous indication, the display shall be a logarithmic display of the vibration value. The range of the analogue display device shall include a display of at least 2 decades, with each decade being at least 10 mm wide.

Where the display range does not encompass the whole of the linearity range of the instrument, then the display range shall be switchable to allow for the whole of the linearity range to be viewed.

If a digital indicator is provided, and the measurement quantity displayed is a vibration parameter, the display shall be updated at regular time intervals. The time interval between updates shall be appropriate to the measurement being displayed. The extent of the range of a digital display shall be at least sufficient to cover the linear operating range.

For instruments with digital display devices updated at periodic intervals, the indication at each display update shall be the value of the user-selected quantity at the time of the display update. Other modes of indication at the time of the display update may be identified in the instrument documentation and, if so, the operation of such modes shall be explained in the instrument documentation. The instrument documentation shall state which modes conform to the specifications of this document and which do not conform.

5.2.3 Stabilization, measurement start and display times

Within the prevailing environmental conditions, the time interval required for stabilizing and being ready to use shall be no greater than 2 min from switching on the instrument.

The display shall indicate when the instrument is ready for use following switch-on, range change or changes to filter selection.

The time between a user initiating a measurement and the start of that measurement shall be no greater than 0,5 s.

NOTE This can require an initialization procedure, particularly for low-frequency whole-body vibration: an operating phase prior to measurement initiation that ensures that the instrument has settled following the end of a previous measurement.

Prior to a measurement result being available, the instrument display shall clearly indicate whether a measurement is in progress, or whether an initialization stage is underway.

5.3 Electrical output

If an AC electrical output is provided, the instrument documentation shall state the characteristics of the output signals. The characteristics shall include

- the range of peak-to-peak voltages, which shall be not less than 1 V,
- the internal electrical impedance at the output,
- the minimum load impedance, and
- the frequency weightings applied to the output signals.

Connection of passive impedance without stored electrical energy, including a short circuit, to the electrical output shall not affect any measurement in progress by more than 2 %.

5.4 Vibration sensitivity

The instrument documentation shall specify at least one model of field vibration calibrator as a means to check and maintain the mechanical sensitivity of the human-vibration instrument. The field vibration calibrator shall conform to the specifications given in [Annex A](#).

The instrument documentation for the vibration instrument shall describe the procedure for adjusting the indicated vibration to conform to the specifications in this document by application of the specified field vibration calibrator. The adjustment shall apply to the models of vibration transducers recommended in the instrument documentation for use with the vibration meter. The adjustment shall also apply to any cables, connectors and other accessories provided by the manufacturer of the vibration meter for connecting a vibration transducer to the vibration meter.

5.5 Accuracy of indication at reference frequency under reference conditions

The requirements for tolerance of the displayed results are given in [Table 2](#). The tolerance of indication is specified at the appropriate reference frequency and reference vibration value specified in [Table 1](#) with the instrument switched to the reference measurement range, with sinusoidal mechanical vibration applied to the base of the vibration transducer or specified mounting device. The requirements apply to all frequency weightings specified in this document and after applying adjustments described in [5.4](#) and after the specified stabilization time interval has elapsed.

Table 2 — Tolerances of indication at reference frequency and reference vibration value

Parameter	Tolerance
Tolerance of indication at the reference frequency under reference environmental conditions	±4 % for hand-transmitted and whole-body vibration
	±5 % for low-frequency whole-body vibration
The difference between the indicated value of any frequency-weighted measurement quantity and the indicated value of the corresponding band-limiting measurement multiplied by the appropriate weighting factor (for a steady sinusoidal input vibration signal at the reference frequency and reference vibration value)	±3 %
The difference between the indication of the running r.m.s. vibration value with a band-limiting frequency weighting, and the indication of the band-limiting frequency-weighted vibration value with the linear time-averaged r.m.s. value over any measurement time (for a steady sinusoidal input vibration signal at the reference frequency and reference vibration value)	±2 %

5.6 Frequency weightings and frequency responses

5.6.1 Parameters

A human-vibration meter shall have one or more of the frequency weighting or weightings listed in [Table 1](#), including the appropriate band-limiting weightings. The frequency weightings are defined by [Formulae \(1\) to \(5\)](#) and the parameters given in [Table 3](#).

Table 3 — Parameters and transfer functions of the frequency weightings

Weighting	Band-limiting				a-v transition			Upward step				Gain <i>K</i>
	<i>f</i> ₁ Hz	<i>Q</i> ₁	<i>f</i> ₂ Hz	<i>Q</i> ₂	<i>f</i> ₃ Hz	<i>f</i> ₄ Hz	<i>Q</i> ₄	<i>f</i> ₅ Hz	<i>Q</i> ₅	<i>f</i> ₆ Hz	<i>Q</i> ₆	
<i>W</i> _b	0,4	1/√2	100	1/√2	16	16	0,55	2,5	0,9	4	0,95	1,024
<i>W</i> _c	0,4	1/√2	100	1/√2	8	8	0,63	∞	1	∞	1	1
<i>W</i> _d	0,4	1/√2	100	1/√2	2	2	0,63	∞	1	∞	1	1
<i>W</i> _e	0,4	1/√2	100	1/√2	1	1	0,63	∞	1	∞	1	1
<i>W</i> _f	0,08	1/√2	0,63	1/√2	∞	0,25	0,86	0,062 5	0,80	0,10	0,80	1
<i>W</i> _h	10 ^{8/10}	1/√2	10 ^{31/10}	1/√2	100/(2π)	100/(2π)	0,64	∞	1	∞	1	1

NOTE 1 For weighting *W*_b, ISO 2631-4:2001, Table A.1, rounds the value of parameter *Q*₁ to two decimal places. The parameter specified here is the exact value.

NOTE 2 For weighting *W*_h, ISO 5349-1:2001, Table A.1, rounds the values of parameters *f*₁, *f*₂, *f*₃ and *f*₄ to five significant figures and parameter *Q*₁ to two decimal places. The parameters specified here are the exact values.

Table 3 (continued)

Weighting	Band-limiting				a-v transition			Upward step				Gain <i>K</i>
	<i>f</i> ₁ Hz	<i>Q</i> ₁	<i>f</i> ₂ Hz	<i>Q</i> ₂	<i>f</i> ₃ Hz	<i>f</i> ₄ Hz	<i>Q</i> ₄	<i>f</i> ₅ Hz	<i>Q</i> ₅	<i>f</i> ₆ Hz	<i>Q</i> ₆	
<i>W</i> _j	0,4	1/√2	100	1/√2	∞	∞	1	3,75	0,91	5,32	0,91	1
<i>W</i> _k	0,4	1/√2	100	1/√2	12,5	12,5	0,63	2,37	0,91	3,35	0,91	1
<i>W</i> _m	10 ^{-0,1}	1/√2	100	1/√2	1/(0,028 × 2 π)	1/(0,028 × 2 π)	0,5	∞	1	∞	1	1

NOTE 1 For weighting *W*_b, ISO 2631-4:2001, Table A.1, rounds the value of parameter *Q*₁ to two decimal places. The parameter specified here is the exact value.

NOTE 2 For weighting *W*_h, ISO 5349-1:2001, Table A.1, rounds the values of parameters *f*₁, *f*₂, *f*₃ and *f*₄ to five significant figures and parameter *Q*₁ to two decimal places. The parameters specified here are the exact values.

The angular frequencies $\omega_1, \dots, \omega_6$ (given by $\omega_i = 2\pi f_i$ where f_i are the frequencies $f_1, \dots, f_6$ in Table 3) and the resonant quality factors Q_1, Q_2, Q_4, Q_5 and Q_6 are parameters of the transfer functions in Formulae (1) to (5) which determine the overall vibration acceleration frequency weightings. The overall frequency weighting function is a product of band-limiting, a-v transition and upward-step filters.

5.6.2 Band-limiting filter

The band-limiting element is a combination of high- and low-pass second-order Butterworth filter characteristics. These components are defined as shown by Formulae (1) and (2):

a) High pass

$$H_h(s) = \frac{1}{1 + \frac{\omega_1}{Q_1 s} + \left(\frac{\omega_1}{s}\right)^2} \quad (1)$$

b) Low pass

$$H_l(s) = \frac{1}{1 + \frac{s}{Q_2 \omega_2} + \left(\frac{s}{\omega_2}\right)^2} \quad (2)$$

The product $H_h(s) \cdot H_l(s)$ represents the band-limiting transfer function.

5.6.3 a-v transition filter

The a-v transition filter is proportional to acceleration at lower frequencies and to velocity at higher frequencies, as shown by Formula (3):

$$H_t(s) = \frac{\left(1 + \frac{s}{\omega_3}\right)K}{1 + \frac{s}{Q_4 \omega_4} + \left(\frac{s}{\omega_4}\right)^2} \quad (3)$$

NOTE $H_t(s) = 1$ when both f_3 and f_4 (ω_3 and ω_4) equal infinity.

5.6.4 Upward-step filter

The upward-step filter has a steepness of approximately 6 dB per octave and is proportional to jerk, as shown by [Formula \(4\)](#):

$$H_s(s) = \frac{1 + \frac{s}{Q_5\omega_5} + \left(\frac{s}{\omega_5}\right)^2}{1 + \frac{s}{Q_6\omega_6} + \left(\frac{s}{\omega_6}\right)^2} \left(\frac{\omega_5}{\omega_6}\right)^2 \quad (4)$$

NOTE $H_s(s) = 1$ when both f_5 and f_6 (ω_5 and ω_6) equal infinity.

5.6.5 Overall frequency weighting

The overall frequency weighting function for each weighting W_x is the product of band-limiting, a-v transition and upward-step filters, as shown by [Formula \(5\)](#):

$$H(s) = H_h(s) \cdot H_l(s) \cdot H_t(s) \cdot H_s(s) \quad (5)$$

The most common interpretation of these formulae is in the frequency domain, where they describe the modulus (magnitude) and phase of the frequency weightings as functions of the imaginary angular frequency $s = j2\pi f$.

NOTE 1 Sometimes the letter p is used instead of s .

NOTE 2 s can be interpreted as the variable of the Laplace transform.

The tables and weighting curves given in [Annex B](#) illustrate the magnitude and phase of the frequency weightings defined by [Formulae \(1\) to \(5\)](#) and [Table 3](#), as functions of frequency f .

If a human-vibration meter provides one or more optional frequency responses, the instrument documentation shall state the design-goal frequency response and the tolerance limits that are maintained around the design goal(s). If an optional frequency response is specified in an International Standard, the design-goal frequency response shall be as specified in that International Standard.

The filters defined by [Table 3](#) and [Formulae \(1\) to \(5\)](#) may be realized by combinations of simple analogue filters. [Annex C](#) provides an example of how the frequency weightings can be realized digitally in the time and frequency domains.

5.6.6 Tolerances

The tolerances on the frequency weightings are given in [Tables 4](#) and [5](#). The tolerance limits in [Table 5](#) apply to the weightings, including the corresponding band-limiting weightings, on all measurement ranges. Tolerance limits include the applicable maximum expanded uncertainties of measurement.

The phase response of vibration instrumentation is critical to measured parameters not based on the r.m.s. average value, e.g. peak, MTVV and VDV. The phase response is given by [Formulae \(1\) to \(5\)](#). However, the errors in measurement due to errors in the phase response are dependent on the rate of

change in phase error with frequency, rather than the absolute phase error itself. For this reason, the phase response is assessed using the characteristic phase deviation, $\Delta\phi_0$, defined as by [Formula \(6\)](#):

$$\Delta\phi_0 = \left| \frac{f_n \Delta\phi_{n+1} - f_{n+1} \Delta\phi_n}{f_{n+1} - f_n} \right| \quad (6)$$

where

f_n is the centre frequency at one-third-octave band number n ;

$\Delta\phi_n$ is the phase error at frequency corresponding to one-third-octave band number n .

Table 4 — Transition frequencies for frequency weighting tolerances

Weighting	Tolerance transition frequencies Hz			
	f_{t1}	f_{t2}	f_{t3}	f_{t4}
W_b	10 ^{-6/10} (0,2512)	10 ^{-2/10} (0,631)	10 ^{18/10} (63,1)	10 ^{22/10} (158,5)
W_c	10 ^{-6/10} (0,2512)	10 ^{-2/10} (0,631)	10 ^{18/10} (63,1)	10 ^{22/10} (158,5)
W_d	10 ^{-6/10} (0,2512)	10 ^{-2/10} (0,631)	10 ^{18/10} (63,1)	10 ^{22/10} (158,5)
W_e	10 ^{-6/10} (0,2512)	10 ^{-2/10} (0,631)	10 ^{18/10} (63,1)	10 ^{22/10} (158,5)
W_f	10 ^{-13/10} (0,05012)	10 ^{-9/10} (0,1259)	10 ^{-4/10} (0,3981)	10 ^{0/10} (1)
W_h	10 ^{6/10} (3,981)	10 ^{10/10} (10)	10 ^{29/10} (794,3)	10 ^{33/10} (1995)
W_j	10 ^{-6/10} (0,2512)	10 ^{-2/10} (0,631)	10 ^{18/10} (63,1)	10 ^{22/10} (158,5)
W_k	10 ^{-6/10} (0,2512)	10 ^{-2/10} (0,631)	10 ^{18/10} (63,1)	10 ^{22/10} (158,5)
W_m	10 ^{-3/10} (0,5012)	10 ^{1/10} (1,259)	10 ^{18/10} (63,1)	10 ^{22/10} (158,5)

Table 5 — Tolerances on frequency weightings

Frequency f	Magnitude tolerance	Characteristic phase deviation ^a $\Delta\phi_0$
$f \leq f_{t1}$	+26 %, -100 %	$\pm\infty$
$f_{t1} < f < f_{t2}$	+26 %, -21 %	$\pm 12^\circ$
$f_{t2} \leq f \leq f_{t3}$	+12 %, -11 %	$\pm 6^\circ$
$f_{t3} < f < f_{t4}$	+26 %, -21 %	$\pm 12^\circ$
$f_{t4} \leq f$	+26 %, -100 %	$\pm\infty$
^a Characteristic phase deviation tolerances only apply to instruments that provide measurement parameters that are not based on r.m.s. values.		

5.7 Amplitude linearity

Over the entire measurement range, the indicated signal value shall be a linear function of the mechanical vibration value at the vibration transducer. This design goal applies at any frequency within the frequency range of the instrument at any frequency weighting or frequency response method.

linearity specifications apply to the whole instrument, including the transducer, and to all measured vibration parameters.

Over the full extent of all the measurement ranges, the linearity error shall not exceed 6 % of the input value. On the reference measurement range and at the reference frequency, the linear operating range shall be at least 60 dB.

NOTE For hand-arm vibration, a greater linearity range can be necessary for the measurement of highly impactful vibration signals.

The instrument documentation shall state the range of vibration values within which the linearity error does not exceed 6 % without indication of under-range or overload. This requirement applies for steady sinusoidal signals at any frequency in the nominal frequency range.

For instruments with multiple and manually selected measurement ranges, the overlap of vibration values indicated on adjacent measurement ranges shall be at least 40 dB.

For each measurement range, the instrument documentation shall state the range of vibration values that can be measured without under-range or overload, i.e. the lower and upper boundaries of the linear operating ranges.

5.8 Instrument noise

For time-averaged frequency-weighted vibration, the instrument documentation shall state the typical indications that will be observed on the display device when the vibration transducer of the instrument is fitted to a non-vibrating object that does not add significantly to the indications. The indications shall correspond to the total inherent noise from the combination of the recommended vibration transducer(s) and the other components in the human-vibration meter, at least for reference environmental conditions.

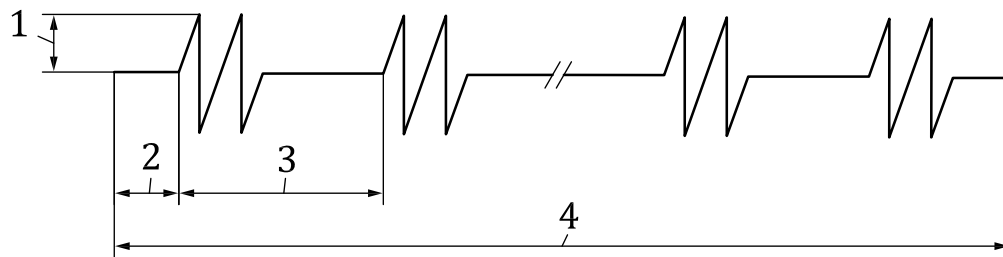
5.9 Signal-burst response

The specification of human-vibration instruments for the response to signal bursts is given in terms of the response to saw-tooth signals at the reference frequency.

The saw-tooth test signal is illustrated in [Figure 3](#). The tests are carried out using saw-tooth burst with the characteristics given in [Table 6](#). The responses given in [Tables 7](#) to [9](#) are relative to a 1 m/s² amplitude signal and shall be multiplied by the amplitude of the actual test signal.

NOTE 1 The response to the saw-tooth signal burst is determined by digital simulation of the filter characteristics.

NOTE 2 The saw-tooth wave shape has been chosen to ensure that the signal burst contains combinations of frequencies with known phase relationships. The saw-tooth burst test therefore ensures that the relative phase response of the frequency weighting at different frequencies is tested.

**Key**

- 1 amplitude
- 2 start time
- 3 repeat time
- 4 duration

Figure 3 — Saw-tooth burst test signal (2-cycle bursts illustrated)**Table 6 — Saw-tooth signal burst test signal characteristics**

Application	Weighting	Angular frequency rad/s	Start time s	Number of cycles	Repeat time s	Duration s
Hand-arm	W_h	500 (79,58 Hz)	0,2	1, 2, 4, 8, 16	2	12
Whole-body	$W_b, W_c, W_d, W_e, W_j, W_k, W_m$	100 (15,915 Hz)	1		10	60
Low-frequency whole-body	W_f	2,5 (0,3979 Hz)	40		400	2 400

Table 7 — Saw-tooth signal burst response for hand-arm vibration measurements

Weighting	Number of saw-tooth cycles per burst	r.m.s. value	Tolerance %
Band limiting	1	0,044 8	10
	2	0,063 3	10
	4	0,089 5	10
	8	0,127	10
	16	0,179	10
	Continuous	0,565	10
W_h	1	0,010 3	10
	2	0,013 3	10
	4	0,016 8	10
	8	0,022 4	10
	16	0,030 9	10
	Continuous	0,094 6	10

Table 8 — Saw-tooth signal burst response for whole-body vibration measurements

Weighting	Number of saw-tooth cycles per burst	r.m.s. value	Tolerance %	VDV	Tolerance %	MTVV linear	Tolerance %	MTVV exponential	Tolerance %
Band limiting	1	0,043 3	10	0,498	12	0,137	10	0,135	10
	2	0,061 2	10	0,593	12	0,193	10	0,188	10
	4	0,086 5	10	0,705	12	0,274	10	0,258	10
	8	0,122	10	0,838	12	0,387	10	0,344	10
	16	0,173	10	0,996	12	0,547	10	0,437	10
	Continuous	0,546	10	1,77	12	0,547	10	0,549	10
W_b	1	0,031 4	10	0,342	12	0,099 1	10	0,096 8	10
	2	0,043 5	10	0,403	12	0,137	10	0,132	10
	4	0,061 4	10	0,482	12	0,194	10	0,182	10
	8	0,086 7	10	0,575	12	0,274	10	0,243	10
	16	0,123	10	0,685	12	0,387	10	0,309	10
	Continuous	0,387	10	1,22	12	0,388	10	0,388	10
W_c	1	0,022 2	10	0,244	12	0,070 3	10	0,068 4	10
	2	0,029 2	10	0,275	12	0,092 3	10	0,088 5	10
	4	0,039 7	10	0,318	12	0,126	10	0,117	10
	8	0,055	10	0,374	12	0,174	10	0,153	10
	16	0,077	10	0,445	12	0,243	10	0,192	10
	Continuous	0,24	10	0,788	12	0,243	10	0,242	10
W_d	1	0,006 69	10	0,077 9	12	0,021 2	10	0,019 7	10
	2	0,009 06	10	0,085 2	12	0,028 6	10	0,026 4	10
	4	0,011 6	10	0,092 3	12	0,036 6	10	0,033	10
	8	0,014 8	10	0,101	12	0,046 9	10	0,04	10
	16	0,019 7	10	0,115	12	0,061 1	10	0,048 1	10
	Continuous	0,059	10	0,197	12	0,061 1	10	0,059 4	10
W_e	1	0,003 42	10	0,040 9	12	0,010 8	10	0,009 92	10
	2	0,004 78	10	0,045 2	12	0,015 1	10	0,013 5	10
	4	0,006 37	10	0,049 3	12	0,020 1	10	0,017 6	10
	8	0,008 16	10	0,053 5	12	0,025 5	10	0,021 4	10
	16	0,010 2	10	0,059 2	12	0,031 1	10	0,024 4	10
	Continuous	0,029 5	10	0,098 7	12	0,031 1	10	0,029 7	10
W_j	1	0,043 5	10	0,517	12	0,138	10	0,135	10
	2	0,0616	10	0,609	12	0,195	10	0,189	10
	4	0,0874	10	0,723	12	0,277	10	0,261	10
	8	0,124	10	0,859	12	0,392	10	0,349	10
	16	0,175	10	1,02	12	0,554	10	0,443	10
	Continuous	0,554	10	1,81	12	0,555	10	0,557	10

Table 8 (continued)

Weighting	Number of saw-tooth cycles per burst	r.m.s. value	Tolerance %	VDV	Tolerance %	MTVV linear	Tolerance %	MTVV exponential	Tolerance %
W_k	1	0,0299	10	0,323	12	0,094 4	10	0,092 2	10
	2	0,0411	10	0,38	12	0,13	10	0,125	10
	4	0,0577	10	0,455	12	0,182	10	0,171	10
	8	0,0814	10	0,543	12	0,257	10	0,228	10
	16	0,115	10	0,648	12	0,363	10	0,289	10
	Continuous	0,362	10	1,15	12	0,364	10	0,363	10
W_m	1	0,0149	10	0,165	12	0,047 2	10	0,045 6	10
	2	0,0197	10	0,185	12	0,062 3	10	0,059 4	10
	4	0,0264	10	0,211	12	0,083 6	10	0,077 5	10
	8	0,0363	10	0,247	12	0,115	10	0,101	10
	16	0,0507	10	0,294	12	0,16	10	0,126	10
	Continuous	0,158	10	0,52	12	0,16	10	0,159	10

Table 9 — Saw-tooth signal burst response for low-frequency whole-body vibration measurements

Weighting	Number of saw-tooth cycles per burst	r.m.s. value	Tolerance %	MSDV	Tolerance %
Band limiting	1	0,034 1	10	1,671	10
	2	0,048 7	10	2,386	10
	4	0,069	10	3,38	10
	8	0,098 2	10	4,811	10
	16	0,139	10	6,81	10
	Continuous	0,439	10	21,51	10
W_f	1	0,019 7	10	0,965 1	10
	2	0,023 6	10	1,156	10
	4	0,030 4	10	1,489	10
	8	0,041 6	10	2,038	10
	16	0,057 1	10	2,797	10
	Continuous	0,176	10	8,622	10

5.10 Overload indication

The human-vibration meter shall have an overload indicator that shall be operative for each applicable display and shall be capable of detecting overloads at all critical points in the vibration signal path. Overloading the transducer shall be avoided by appropriate means (e.g. selection of suitable transducer for the intended measurement, electrical overload detectors incorporated into the transducer, use of mechanical filter).

Overload shall be indicated before the tolerance limits for linearity or the signal-burst response tolerances are exceeded for increasing signal values above the specified upper boundary. This requirement applies for any frequency within the nominal frequency range.

The overload indicator shall operate for both positive and negative one-half-cycle signals. The difference between the positive and negative one-half-cycle signal values that just cause an overload indication shall be not more than 15 %.

When a vibration meter is used to measure time-averaged vibration values, the overload indicator shall latch on when an overload condition occurs. The latched condition shall remain on until the measurement results are reset. This requirement also applies to measurements of maximum vibration values, peak vibration values, or other quantities calculated during, or displayed after, the measurement duration.

When a vibration meter is used to measure running r.m.s. time-weighted vibration values, the overload indicator shall remain on while the overload condition exists and for any period during which the overload condition affects the displayed measurement (a period equivalent to the integration time for linear running r.m.s. acceleration values or twice the integration time for exponential averaging). Following the overload, the indicator shall remain on for at least 1 s for hand-arm vibration, 8 s for whole-body and low-frequency whole-body applications.

The instrument documentation shall describe the operation and interpretation of the overload indication and the method for clearing a latched indication.

NOTE It is useful that the vibration meter is capable of indicating how long (in relation to the measurement duration) in each channel overload took place.

5.11 Under-range indication

If the time-weighted human vibration or time-averaged human vibration is less than the lower boundary of the linear operating range, an under-range indication shall operate before the tolerance limits on linearity are exceeded. The under-range indication shall remain on as long as the under-range condition exists or affects the displayed measurement. The minimum time for indication is 1 s for hand-arm vibration, 8 s for whole-body and low-frequency whole-body applications.

5.12 Time averaging

The instrument shall allow the measurement duration of the time-averaged weighted acceleration value to be selected or controlled by the user.

5.13 Running r.m.s. acceleration

For instruments that provide the running r.m.s. acceleration, the time constant shall be checked. A steady reference frequency sinusoidal electrical signal shall be applied to the input and then suddenly shut off. Before being shut off, the steady signal shall be applied for a period of at least 5 times the integration time for linear time averaging or for 20 times the integration time for exponential time averaging. See [Annex D](#) for details of linear and exponential running r.m.s. time averaging.

The indicated output signal value shall reduce at the rates specified in [Table 10](#) for linear time averaging and [Table 11](#) for exponential time averaging (if available). The decay rate shall be measured from the start of the decay to the time at which the indicated value is less than 10 % of the initial value. This requirement applies for the reference measurement range.

Table 10 — Time-weighting decay rates, linear time averaging

Time constant	Time to 10 % of original signal value
s	s
0,125	0,124 ± 0,005
1	0,99 ± 0,05
8	7,92 ± 0,2

Table 11 — Time-weighting decay rates, exponential time averaging

Time constant s	Time to 10 % of original signal value s	Equivalent decay rate dB/s
0,125	$0,58 \pm 0,03$	31 to 40
1	$4,61 \pm 0,25$	3,8 to 4,9
8	$36,8 \pm 2$	0,48 to 0,62

5.14 Reset

For all frequency weightings provided, instruments intended for the measurement of time-averaged human vibration, maximum transient vibration value and vibration dose value shall contain a facility to clear the data-storage device and reinitiate a measurement. The instrument documentation shall state whether the reset facility clears the overload indication. The instrument documentation also shall describe the operation of the reset facility and state the nominal delay time between the operation of a manual or remote reset facility and the initiation of a measurement.

Use of a reset facility shall not give rise to spurious indications on the display device(s).

5.15 Timing facilities

An instrument that measures time-averaged human vibration shall display the duration of the time elapsed since the start of integration. The capability to preset an integration time interval in 1 s increments may also be provided.

The tolerance limit for the indicated elapsed time is 0,1 %. The resolution of the display of elapsed time shall not be coarser than 1 s.

The instrument documentation shall state the minimum and the maximum integration times for the measurement of time-averaged vibration values for any signal value within the range of a display device.

5.16 Electrical cross-talk

Where an instrument provides simultaneous signal inputs for more than one axis (or channel) of vibration, then the response on any one channel to a signal on any of the other input channels shall be less than 0,5 % of the input signal magnitude.

This electrical cross-talk between measurement channels should be distinguished from transducer transverse sensitivity which typically is greater than 0,5 %, see [Table E.1](#). The transverse sensitivity can become relevant especially with multi-axial transducers.

5.17 Vibration transducer characteristics

Vibration transducer characteristics shall be selected according to the measurement application, see [Annex E](#) for additional guidance.

5.18 Power supply

For battery-powered instruments, an indication shall be provided to confirm that the power supply is sufficient to operate the instrument within the specifications of this document. A check of the power supply condition shall not disturb any measurements that are underway.

When a vibration calibration signal is applied to the vibration transducer, the change in the indicated signal value shall not exceed 3 % when the supply voltage to operate the vibration instrument is reduced from the nominal value to the minimum voltage specified in the instrument documentation.

If internal batteries power the human-vibration meter, the instrument documentation shall recommend acceptable battery types and state the corresponding continuous instrument operating time, under reference environmental conditions, to be expected when full-capacity batteries are installed.

For battery-powered instruments designed to be able to measure vibration values over durations that exceed the nominal battery life, the instrument documentation shall describe suitable means for operating the instrument from an external power supply, including specifications for the acceptable voltage range and ripple content (including high-frequency spikes) of the supply.

6 Mounting

If a specific mechanical filter, mounting system or cable is required, or supplied, the instrument documentation shall state that the instrument conforms to the applicable frequency weighting specifications only when the specified devices are installed.

The mounting methods provided with the instrument, or recommended for use, shall comply with the general requirements of ISO 5348. Guidance for testing mounting systems can be found in [Annex F](#).

The instrument documentation shall state the range of applications for which any supplied mounting system is suitable, and shall specify any circumstances in which use of the mounting system is likely to result in greater uncertainty of measurement.

7 Environmental and electromagnetic criteria

7.1 General

All specifications for the sensitivity to various operating environments apply to, and are relative to, the mechanical sensitivity under the reference environmental conditions and at the calibration check frequency. The instrument documentation shall state the typical time interval that is required for the vibration meter to stabilize after changes in environmental conditions.

One-off vibration instruments may have a restricted range of environmental application; where such a restricted range applies, this shall be stated in the instrument documentation.

NOTE One-off vibration measurement systems are systems made up of separate signal processing, analysis (recording) and display elements, with each element of the system having been pattern evaluated, or validated, in accordance with appropriate standards or to manufacturer's specifications, see [13.1](#).

7.2 Air temperature

The influence of variations in air temperature on the mechanical sensitivity is specified over the range of air temperatures from $-10\text{ }^{\circ}\text{C}$ to $50\text{ }^{\circ}\text{C}$. The influence of variations in air temperature on the vibration sensitivity shall be no more than $\pm 5\%$ over the specified temperature ranges.

The specification for the influence of variations in air temperature applies to a complete vibration meter or to those components of a vibration meter that may be exposed routinely to large variations in air temperature.

For those components of a vibration meter designated in the instrument documentation as intended to be located in an environmentally controlled enclosure (e.g. indoors), the temperature range may be restricted to $5\text{ }^{\circ}\text{C}$ to $30\text{ }^{\circ}\text{C}$. The restricted range of temperature does not apply to a complete vibration meter.

Over the ranges of air temperature specified, the linearity error at the reference frequency and the extent of the linear operating range on the reference measurement range shall remain within the tolerance limits given in [5.7](#).

7.3 Surface temperature

The influence of variations in measurement surface temperature on the vibration sensitivity is specified over the range of surface temperatures from $-10\text{ }^{\circ}\text{C}$ to $50\text{ }^{\circ}\text{C}$. The influence of variations in surface temperature on the vibration sensitivity shall be no more than $\pm 4\%$ over the specified temperature range.

The specification for the influence of variations in surface temperature applies to the accelerometer, cables and mounting systems that may come into direct contact with vibrating surfaces.

Over the range of surface temperature given in this clause, the linearity error at the reference frequency and the extent of the linear operating range on the reference measurement range shall remain within the tolerance limits given in [5.7](#).

7.4 Electrostatic discharge

The influence of electrostatic discharges on the operation of a vibration meter, or applicable components of a vibration meter system, shall be reduced as far as is practicable.

A vibration meter shall continue to operate as intended after exposure to a contact discharge of electrostatic voltage of up to $\pm 4\text{ kV}$ or to an air discharge of electrostatic voltage of up to $\pm 8\text{ kV}$. The polarity of the electrostatic voltage is relative to earth ground.

Exposure to the electrostatic discharges specified in this clause shall cause no degradation of performance or loss of function in the vibration meter, except as may be specified in the instrument documentation. The instrument documentation may specify that the performance or function of a vibration meter can be degraded or lost because of electrostatic discharges. The specified degradation or loss of function shall not include any change of operating state, change of configuration, corruption or loss of any stored data, or permanently reduced operation.

7.5 Radio-frequency emissions and public-power-supply disturbances

The radio-frequency emissions from a vibration instrument shall be reduced as far as is practicable.

If the human-vibration meter allows the connection of interface or interconnection cables, the instrument documentation shall recommend typical cable lengths and shall describe the nature of all devices to which the cables may be attached.

The level of the radio-frequency electric field strength emitted by the instrument's enclosure ports shall not exceed 30 dB (relative to $1\text{ }\mu\text{V/m}$) for frequencies from 30 MHz to 230 MHz, and shall not exceed 37 dB for frequencies above 230 MHz and up to 1 GHz. The instrument documentation shall state the operating mode(s) of the instrument, and any connecting devices, which produce the greatest emission of radio-frequency fields.

The maximum disturbance conducted to the public supply of electric power shall be within the quasi-peak and average voltage limits given in [Table 12](#) at an AC power port. If the vibration instrument conforms to the limit on the average voltage of conducted disturbance when using a quasi-peak measuring device, the human-vibration meter shall be deemed to conform to both the quasi-peak and average voltage limits.

Table 12 — Limits for conducted disturbance to the voltage of a public supply of electric power

Frequency range MHz	Limits on voltage level of disturbance dB (re 1 μ V)	
	Quasi-peak	Average
0,15 to 0,50	66 to 56	56 to 46
0,50 to 5	56	46
5 to 30	60	50
NOTE 1 See CISPR 16-1-1 for characteristics of quasi-peak measuring receivers.		
NOTE 2 The lower limits of voltage level apply at the transition frequencies.		
NOTE 3 The voltage level limits decrease linearly with the logarithm of the frequency in the range from 0,15 MHz to 0,50 MHz.		

7.6 Immunity to AC power-frequency fields and radio-frequency fields

Exposure of the complete instrument (or applicable components designated in the instrument documentation) to specified AC power-frequency and radio-frequency fields shall not cause any change in the operating state, or change of configuration, or corruption or loss of any stored data. This requirement applies for any operating mode consistent with normal operation. The instrument documentation shall state the operating mode(s) of the instrument, and any connecting devices, that have the minimum immunity (are most sensitive) to AC power-frequency and radio-frequency fields.

Immunity to AC power-frequency fields applies to exposure to a uniform r.m.s. magnetic field strength of 80 A/m at frequencies of 50 Hz and 60 Hz. The uniformity of the magnetic field strength is established before immersion of the vibration meter. The orientation of the vibration meter in the field shall be that specified in the instrument documentation for maximum sensitivity to AC power-frequency fields.

Immunity to radio-frequency fields applies over the carrier frequencies range from 26 MHz to 1 GHz, with the signal at the carrier frequency of the radio-frequency field amplitude modulated by a sinusoidal signal at the reference frequency (or frequencies) appropriate to the application of the instrument to a depth of 80 %. When unmodulated and in the absence of a vibration meter, the radio-frequency field shall have a uniform r.m.s. electric field strength of 10 V/m.

NOTE The instrument documentation can state that the vibration meter conforms to the specifications of this document at an unmodulated r.m.s. electric field strength greater than 10 V/m.

When an AC power-frequency or radio-frequency field is applied, the change in the indicated vibration value shall not exceed ± 10 %.

For meters with an AC input power port or an AC output power port, immunity to radio-frequency common-mode interference applies over the frequency range from 0,15 MHz to 80 MHz.

For meters with signal or control ports, where any interconnecting cable between any part of the system exceeds a length of 3 m, immunity to radio-frequency common-mode interference applies over the frequency range from 0,15 MHz to 80 MHz.

7.7 Ingress of water and dust

The vibration meter shall be capable of resisting ingress of water and dust. The manufacturer shall specify the IP rating of the instrument. The instrument's IP rating shall be suited to the planned application (e.g. human-vibration exposure assessments in factories might require a rating of IP 65; measurements in laboratory conditions can only require a rating of IP 42).

NOTE IP ratings for instrument enclosures are specified in IEC 60529.

8 Provision for use with auxiliary devices

If an optional extension cable provided by the manufacturer of the vibration meter can be placed between the accelerometer and the other components of the vibration meter, the instrument documentation shall provide details of any corrections to be applied to the results of measurements made in this manner.

The instrument documentation shall provide data on the nominal effect of optional accessories supplied by the manufacturer of the vibration meter. The data shall apply to all relevant characteristics of the vibration meter resulting from installation of the accessories. Optional accessories include accelerometer mounting devices and mechanical filters. The instrument documentation shall provide data on the typical effect on sensitivity and frequency responses.

The instrument documentation shall state whether the vibration meter conforms to the specifications required by this document when the optional accessory is installed.

If connections are provided for external filters, the instrument documentation shall describe how the connections shall be made and how the instrument is to be used to measure externally filtered vibration signals.

The instrument documentation shall provide details regarding the connection of auxiliary devices to the vibration meter and the effects, if any, of such devices on the electrical characteristics of the instrument. Auxiliary devices include printers, computers and recorders.

9 Instrument marking

An instrument that conforms to all applicable specifications of this document shall be marked, or shall display a reference to this document by number and publication date. The marking shall indicate the name or trademark of the supplier responsible for the technical specifications applicable to the complete instrument. In addition, the marking shall include the model designation and the serial number.

If the instrument consists of several separate units, each principal unit or component shall be marked as described in this clause, as practicable. All principal units comprising a complete instrument shall be identified.

10 Instrument documentation

Instrument documentation shall be supplied with each vibration meter or equivalent instrument that conforms to the specifications of this document.

If the instrument consists of several separate components, instrument documentation shall be available for the combination that forms the complete vibration meter. The instrument documentation shall describe all necessary components as well as their mutual influence.

All instrument specifications shall be given in SI units.

The instrument documentation shall contain the information specified in [Annex G](#), where they apply to the instrument.

11 Testing and calibration

Three levels of performance testing are defined in this document.

a) Pattern evaluation or validation:

- 1) pattern evaluation (targeted at manufacturers) is a full set of tests to be performed on samples of an instrument type. This test is used for product type testing or pattern approval of a production series of vibration measuring instruments. The objective of this test is to demonstrate an instrument design can meet the specifications defined in this document.

- 2) validation of one-off instruments (targeted at laboratory users or research users) is a limited set of tests to demonstrate that an individual vibration measuring system complies with the relevant specifications defined in this document.
- b) Periodic verification (targeted at manufacturers and users) is an intermediate set of tests to be performed
 - periodically (e.g. prior to, or at the time of purchase, and at least every 2 years thereafter) to verify that the performance remains within the specifications of this document, or
 - following modification (e.g. use of another transducer) or repair that might affect the performance of the instrument.
- c) *In situ* check (targeted at users) is a minimum level of testing, indicating that a vibration measuring instrument is likely to be functioning within the required performance specification. These tests shall be carried out immediately before and after measurements are made.

The tests are designed to assess the performance characteristics and specifications defined in [Clauses 5](#) to [10](#). [Table 13](#) shows the relationship between the specifications and associated test clauses.