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Human response to vibration — Measuring instrumentation —

Part 1:
General purpose vibration meters

Réponse des individus aux vibrations — Appareillage de mesure —

Partie 1: Instrument de mesure à usage général

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Foreword

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

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

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

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 $a_{\mathrm{w}}(t)$ in m/s^{1,5} as defined by the expression

$$\mathrm{MSDV} = \left(\int_0^{\Phi} a_{\mathrm{w}}^2 \left(\xi\right) \mathrm{d}\xi \right)^{1/2}$$

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 $a_{\mathrm{w}}(t)$ in m/s^{1,75} as defined by the expression

$$\mathrm{VDV} = \left(\int_0^{\Phi} a_{\mathrm{w}}^4 \left(\xi\right) \mathrm{d}\xi \right)^{1/4}$$

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

$$a_{\mathrm{wv}} = \sqrt{k_x^2\, a_{\mathrm{w}x}^2 + k_y^2\, a_{\mathrm{w}y}^2 + k_z^2\, a_{\mathrm{w}z}^2}$$

where

$a_{\mathrm{w}x}$, $a_{\mathrm{w}y}$ and $a_{\mathrm{w}z}$	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
ΔP_{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

