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**Human response to vibration —  
Guidance and terminology for  
instrumentation and equipment for  
the assessment of daily vibration  
exposure at the workplace according to  
the requirements of health and safety**

*Réponse des individus aux vibrations — Lignes directrices et terminologie pour l'instrumentation et l'équipement d'évaluation de l'exposition journalière aux vibrations sur le lieu de travail selon les exigences de santé et de sécurité*

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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](http://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](http://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](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*.

## Introduction

Several kinds of device can be used to measure or estimate the vibration magnitude and exposure duration needed for the assessment of daily vibration exposure at the workplace.

Measuring instrumentation conforming to the requirements of ISO 8041-1 allows the user to perform good quality repeatable measurements. Measurements using a general-purpose vibration meter are typically undertaken when equipment (like a hand-held machine or a fork-lift truck) is in operation allowing attended, direct readings to be taken providing information regarding possible errors and transient acceleration artefacts. Unattended measurements can be taken using a personal vibration exposure meter, logging readings taken, for example, over a full working day to provide information regarding work patterns including transient acceleration artefacts. Using such instrumentation, the result is always a vibration value or a vibration dose based on vibration readings as taken by the instrumentation.

In addition, there exists auxiliary equipment which can support risk assessment. Such equipment might measure the duration of exposure or estimate the instantaneous vibration dose, using, for example, the information given by the manufacturer on the vibration emission of the machinery used, and might give information when vibration limits are approached or exceeded. Even though such auxiliary equipment does not constitute measuring instrumentation conforming to ISO 8041-1, it is currently used and can be advantageous for keeping occupational vibration limits and for systematic health and safety monitoring. When using such equipment, usually vibration is not really measured.

However, the differences between the instrumentation and equipment features lead to results of varying reliability. By giving guidance and explaining terminology, this document provides clarity regarding the limitations that can be expected when using different instrumentation and equipment for the assessment of daily vibration exposure at the workplace.

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# Human response to vibration — Guidance and terminology for instrumentation and equipment for the assessment of daily vibration exposure at the workplace according to the requirements of health and safety

## 1 Scope

The assessment of human exposure to vibration, to both the hand-arm system and the whole body, at the workplace relies on the combined evaluation of both vibration magnitudes and exposure times. Determining these values can employ various instrumentation types and data sources. This document provides guidance and explanation of concepts used for the following:

- measurement processes;
- instrumentation types;
- vibration magnitude source.

## 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 2041, *Mechanical vibration, shock and condition monitoring — Vocabulary*

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

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

ISO 8041-1, *Human response to vibration — Measuring instrumentation — Part 1: General-purpose vibration meters*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2041, ISO 2631-1, ISO 5349-1 and ISO 8041-1 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

#### assessment

<vibration exposure> process of determining whether a worker (machine user) is at risk from exposure to vibration

**3.2  
evaluation**

<vibration exposure> process of determining a value of vibration exposure

Note 1 to entry: This process is often specified in standards.

**3.3  
estimation**

<vibration exposure> process of evaluating a worker's (machine user's) exposure where estimates and assumptions are made about vibration magnitudes and exposure durations

**4 Explanation of concepts used for the measurement process**

The measurement of human exposure to vibration requires evaluation of vibration magnitudes (weighted acceleration values) and vibration exposure times. The daily vibration exposure  $A(8)$  is defined as:

$$A(8) = \sqrt{\frac{1}{T_0} \int_0^T a_w^2 dt} \tag{1}$$

where

- $a_w$  is the relevant weighted acceleration value as a function of time (for hand-arm vibration,  $a_w$  is as defined in ISO 5349-1; for whole-body vibration,  $a_w$  is as defined in ISO 2631-1 or ISO 2631-2);
- $t$  is the time;
- $T$  is the total daily duration of exposure to vibration;
- $T_0$  is the reference exposure duration of 8 h (28 800 s).

For most practical measurements, the value of  $A(8)$  is determined as a series of distinct evaluations, e.g. for different hand-held machines, different operating conditions, different vehicles.  $A(8)$  is then determined as:

$$A(8) = \sqrt{\frac{1}{T_0} \sum_{i=1}^N a_{wi}^2 T_i} \tag{2}$$

where

- $a_{wi}$  is the relevant weighted r.m.s. acceleration value for operation  $i$  (for hand-arm vibration,  $a_{wi}$  is as defined in ISO 5349-1, for whole-body vibration,  $a_{wi}$  is as defined in ISO 2631-1 or ISO 2631-2);
- $N$  is the number of operations,  $i$ ;
- $T_i$  is the daily duration of exposure to vibration,  $a_{wi}$ ;
- $T_0$  is the reference exposure duration of 8 h (28 800 s).

It should be ensured that the exposure time represents the period over which the measurement is made, for example, a measurement that includes breaks in operation represents a longer period of working time than one which only measures during machine operation (see ISO 5349-2 or EN 14253).

NOTE Additional quantities are possible, e.g. for whole-body vibration, the vibration dose value (root-mean-quad; see ISO 2631-1) is as follows:

$$VDV = \left( \int_0^T a_w^4 dt \right)^{1/4}$$

For most evaluations of daily vibration exposure,  $A(8)$ , there are three steps consisting of evaluating the weighted vibration magnitude,  $a_w$ , evaluating the exposure time,  $T$ , and finally calculating the daily vibration exposure. It is also possible (although less common) that  $A(8)$  is obtained directly, in one step.

The following concepts a) to d) are used to describe these four basic processes.

a) **Magnitude evaluation**

Magnitude evaluation is the process to determine a value for the weighted acceleration magnitude(s),  $a_{wi}$ .

b) **Exposure duration evaluation**

Exposure duration evaluation is the process to determine a value for the operator's exposure time(s),  $T_i$ .

NOTE The terms "duration" and "time" often have the same meaning.

The daily exposure duration for each relevant machine or process can be determined. This should generally be done directly by observing the work since workers tend to report a wrong estimation of their exposure durations.

c) **Exposure calculation**

Exposure calculation is the process to combine weighted acceleration value(s) and exposure time(s) to calculate the daily vibration exposure,  $A(8)$ , using [Formula \(2\)](#).

d) **Exposure evaluation**

Exposure evaluation is the process to determine the daily vibration exposure value,  $A(8)$ , directly, using [Formula \(1\)](#).

NOTE The calculation can be based on measured or estimated values. Some indication of the associated uncertainty can be found in CEN/TR 1030-2.

## 5 Explanation of concepts used for instrumentation types

### 5.1 General

Instruments can provide all or part of the information required to evaluate the daily vibration exposure, providing one or more of the following functions:

- vibration magnitude evaluation;
- exposure time evaluation;
- exposure calculation based on external data;
- exposure evaluation by measurements.

### 5.2 Vibration magnitude evaluation

A human vibration meter is an instrument that conforms to ISO 8041-1 for measurement of the vibration magnitude.

## 5.3 Exposure time evaluation

### 5.3.1 Machine timer

A machine timer uses some characteristics of the machine being operated to provide an indication of the vibration exposure time of the operator. Characteristics currently used are the following.

- Power usage. In-line power usage detectors to monitor when and for how long a machine is operated. Systems are applied to both electrical and pneumatic machines.
- Vibration. The vibration signal of a transducer fitted to the machine is monitored to measure when and for how long a machine is operated.
- Other parameters (e.g. noise). The noise level close to the machine is used to measure when and for how long a machine is operated.

In all cases it is assumed that the machine operating time is equivalent to the operator exposure time.

NOTE Where operators don't keep two hands on the machine at all times, these devices can, for example, overestimate the real exposure time.

### 5.3.2 Exposure timer

An exposure timer uses sensors attached to, or observing, the machine operator to determine when (s) he is in contact with the machine. The sensors can determine vibration exposure times by the following.

- Coupling force. Force at the interface between the operator and the machine is monitored. When the coupling force exceeds a threshold value, it is assumed that there is contact with the machine.
- Vibration. The vibration signal of a transducer fitted to the operator is monitored to measure when and for how long (s) he is operating a vibrating machine.
- Other parameters (e.g. optical). Video recordings are used to evaluate exposure time (e.g. frame-by-frame analysis).

In many cases, exposure timers rely on combinations of sensors to determine exposure times, of vibration transducers on the machine to determine when it is operating and of sensors on the operator to determine when there is contact with the machine. In some cases, communication between these systems provides a facility for identifying which machine is being operated.

## 5.4 Exposure calculation based on external data

### 5.4.1 Vibration exposure calculator

A vibration exposure calculator is a device or system for calculating the daily vibration exposure based on user-entered values for vibration magnitude and exposure time. Such systems have no measurement capability and can be computer-based systems.

### 5.4.2 Vibration meter with exposure calculation

A vibration meter with exposure calculation is an instrument in accordance with ISO 8041-1 for measurement of vibration magnitude which also includes a facility for the user to enter values for exposure time and then to calculate the daily vibration exposure.

### 5.4.3 Exposure timer with exposure calculation

An exposure timer with exposure calculation is an instrument for measurement of vibration exposure time or duration which also includes a facility for the user to enter values for vibration magnitude and then to calculate the daily vibration exposure.

NOTE 1 There exist versions with and without recognition of vibrating machines.

NOTE 2 A guideline for the use of vibration emission data provided by the machine manufacturer is contained in CEN/TR 15350.

## 5.5 Exposure evaluation by measurement

### 5.5.1 Personal vibration exposure meter (PVEM)

A PVEM is an instrument that simultaneously measures personal vibration magnitudes and associated exposure times, which provides a direct evaluation of the daily vibration exposure based on [Formula \(1\)](#).

NOTE An International Standard for personal vibration exposure meters is under preparation.

### 5.5.2 Vibration exposure meter (VEM)

A VEM is an instrument that measures vibration magnitudes and exposure times, which provides a facility to evaluate contributions to the daily vibration exposure based on [Formula \(2\)](#).

## 6 Explanation of concepts used for the vibration magnitude source

### 6.1 General

Vibration exposure calculators and exposure timers with exposure calculation require user-entry of values for vibration magnitude. These vibration magnitude values can be obtained from measurements using vibration meters or can come from other sources.

### 6.2 Manufacturer emission value

This is a vibration magnitude value provided by the machine manufacturer or supplier determined from standardized or specified tests. These data are primarily intended to allow comparison between machines of the same type, but can also be indicative of normal use of the machine.

NOTE A guideline for the use of vibration emission data provided by the machine manufacturer is contained in CEN/TR 15350.

### 6.3 Manufacturer supplementary values

These are vibration magnitude values provided by the machine manufacturer or supplier to supplement emission data, particularly where the manufacturer emission data are not likely to be indicative of the normal use of the machine, or where specific applications of the machine generate vibration magnitudes significantly different from the manufacturer emission data.

EXAMPLE The vibration magnitudes transmitted through the held workpiece or tool can be higher than those on the machine.

#### 6.4 Comparable machine values

These are vibration magnitude values obtained for a machine similar, but not identical, to that being evaluated.

NOTE For more information, see CEN/TR 1030-2 or EN 12096.

#### 6.5 Machine-specific vibration database values

These are vibration magnitude values obtained from a published database or other list of vibration magnitude values for the specific machine being evaluated at a workplace.

NOTE At present, there exist databases in Germany, Italy and Sweden.

#### 6.6 Type-specific vibration database values

These are vibration magnitude values obtained from a published database or other list of vibration magnitudes where collated values are available for the type of machine being evaluated.

NOTE For earth-moving machinery, ISO/TR 25398 contains machine-related vibration values.

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## Annex A (informative)

### Examples of equipment for the evaluation of daily vibration exposure

#### A.1 General

To give a better understanding of the various types of measurement device available, this annex presents the typical features of certain devices with their pros and cons and their practical limitations.

It is generally easier to measure whole-body vibration than hand-arm vibration because of the lower vibration magnitude and frequency range, the defined measuring point and the coupling. Instruments for measuring whole-body vibration acquire and process vibration data in accordance with ISO 2631-1, ISO 2631-2 and ISO 8041-1.

Instruments for measuring hand-arm vibration acquire and process vibration data in accordance with ISO 5349-1 and ISO 8041-1.

#### A.2 Measuring instruments for good quality measurements

Instruments fulfilling all the requirements according to ISO 8041-1 and beyond can have additional functions for detection and elimination of transient acceleration artefacts.

Such additional functions can be, for example:

- vibration history logging capabilities;
- automatic exposure evaluation based on measured vibration data;
- operator presence detection;
- contact force measurement;
- worker identification.

NOTE An International Standard for personal vibration exposure meters is under preparation.

#### A.3 Machine timer — Machine operation timer

By installing a timer in the supply line to a machine, it is possible to measure the times that a machine is switched on. This is practical for pneumatically or electrically powered machines. The devices usually enable times to be read-off to the nearest second and have a reset function and a key switch to prevent tampering.

##### Practical limitations

These devices are unable to distinguish variations in vibration exposure, for example, in different operating conditions or when different tools are used with the machine.

These devices are also unable to identify whether the worker's hand comes into contact with the machine or whether the machine is operated by other workers. Observance of these preconditions needs to be ensured by visual monitoring or by a combination of several other detectors, for example, by identifying the worker or with contact sensors on the grip.

## A.4 Machine timer — Vibration exposure timer

A distinction needs to be made between timers attached to the machine or to the operator's wrist.

- a) **Vibration exposure timers** are attached to a vibrating part of the machine. From a trigger threshold, machine operation times are usually timed to the nearest second. These devices have a reset function and a display or read-out function.

These devices are suitable for machines without an external energy supply or if the energy supply is not easy to measure, e.g. on impact machinery.

### Practical limitations

Variations in vibration exposure can only be detected to a limited extent, assuming that vibration thresholds can be set. Without additional detectors, it is not possible to detect a hand coming into contact with the machine or to assign the worker to the machine.

- b) **Automated vibration exposure calculators** are attached to a vibrating part of the machine. They use vibration to detect machine operation. Times are usually timed to the nearest second. They are allocated to an individual worker and record the usage time for each machine and use pre-set vibration values to estimate the exposure. The user and/or the worker is informed of the cumulative exposure and can be warned when pre-set limit values are reached.

These devices are suitable for machines without an external energy supply or if the energy supply is not easy to measure, e.g. on impact machinery.

### Practical limitations

Variations in vibration exposure can only be detected to a limited extent, assuming that vibration thresholds can be set.

- c) **Personal vibration exposure timers** are usually attached to the worker's wrist like a watch. These timers can usually detect vibration at the wrist to time the exposure to the nearest second. They are capable of manually or automatically assigning vibration to a wide range of machines or work processes. These devices also typically have a reset and trigger function. They include functions for suppressing transient acceleration artefacts, e.g. the hand's own movement (<5 Hz).

### Practical limitations

The timer cannot be worn for all tasks and is a hindrance for some workers or tasks. Its use is impossible for low-vibration machines because of the high impedance of the hand-arm system.

## A.5 Vibration exposure calculator

Vibration exposure calculators are used for estimating the daily vibration dose. The exposure time is typically determined with the different methods described in [A.3](#) and [A.4](#), and the daily dose is calculated with fixed or user-entered characteristic values for vibration.

The user and/or the worker can be informed when specific values (trigger, action and limit values) are reached.

NOTE 1 As an option, a permanent display of the actual value can be useful.

PC-based systems can have a function for analysing the distribution of vibration exposure of individual workers or in connection with certain tasks over time. This analysis can serve as the basis for or as a help in protecting workers from vibration by organizational measures.

NOTE 2 Organizational measures are dealt with in CEN/TR 1030-2 and CEN/TR 15172-2.