TECHNICAL REPORT

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Earth-moving machinery — Guidelines for assessment of exposure to whole-body vibration of ride-on machines — Use of harmonized data measured by international institutes, organizations and manufacturers

Engins de terrassement — Lignes directrices pour l'évaluation de l'exposition des vibrations à l'ensemble du corps sur les machines à conducteur porté — Utilisation des données harmonisées mesurées par des instituts internationaux, des organisations et des fabricants

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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.

ISO/TR 25398 was prepared by Technical Committee ISO/TC 127, *Earth-moving machinery*, Subcommittee SC 2, *Safety requirements and human factors*.

Introduction

This Technical Report provides information on how to assess the whole-body vibration exposure of operators of earth-moving machines. The method is based on measured vibration emission under real working conditions. It needs to be noted that vibration emissions are influenced by many different parameters, originating from

— operator (e.g. training, behaviour, mode, stress),

— jobsite (e.g. organization, preparation, environment, weather, material), and

— machine (e.g. type, quality of seat and suspension system, attachment, equipment, condition).

It is therefore not possible to obtain precise exposure figures. The values given in this Technical Report need to be used with great care since they were measured for a limited number of operators, defined work situations, and machine types.

On the one hand, the actual work situation for a specific machine operator can be very different, thus creating different vibration. On the other hand, values from real work that can be found in the literature are only correct for the specific work situation and time when they were measured. The user of this Technical Report needs to be aware that the exposure to vibration depends not only on the machine used but also to a large extent on the operator, jobsite and machine, and other factors. All these factors need to be taken into account in order to make a practical assessment of vibration magnitude.

There are typical operating conditions for machine types in accordance to ISO 6165 identified and listed in Annex A. This list may not be complete, but it represents most of the real working conditions.

Properly adjusting and maintaining machines, operating machines smoothly, and maintaining the terrain conditions can reduce whole-body vibrations. The guidelines given in Annex E can help users of earth-moving machines reduce the whole-body vibration levels.

The daily vibration exposure to be assessed depends on both the magnitude of vibration at the surface in contact with the whole body and the total daily duration for which an employee is in contact with that vibration.

The vibration levels for the same type of machine are assumed to be the same. If a vibration-reduction feature is added to the machine, then a lower vibration level can be used. In order to determine the reduction in vibration levels for a machine vibration-reduction feature, the appropriate vibration measurements must be made. Annex F provides guidelines for vibration measurements.

Earth-moving machinery — Guidelines for assessment of exposure to whole-body vibration of ride-on machines — Use of harmonized data measured by international institutes, organizations and manufacturers

1 Scope

This Technical Report provides guidelines for those such as employers, national authorities and manufacturers of earth-moving machinery who are required to determine, assess and document the daily whole-body vibration exposure for ride-on machines as defined in ISO 6165. It also provides guidelines for reducing vibration levels on machines and for determining the vibration reduction from machine improvements to reduce vibration levels. It is intended to assist in establishing documentation for specific earth-moving machinery under typical operating conditions.

It gives guidance on determining the daily vibration exposure A(8), in accordance with ISO 2631 and EN 14253, offering a simple method for determining the daily vibration exposure by means of a table which indicates the daily exposure as a function of the equivalent vibration total value and the associated exposure duration. Both methods can be used even in cases of multiple exposures on the same day.

Methods are provided for calculating exposure using reported emission values, valid for machines equipped with a seat in accordance to ISO 7096.

NOTE Additional information is given in the EN 474 and EN 500 series of standards.

Workplace measurements are required where suitable data are unavailable to represent the vibration under the specific working conditions, or if the calculation results are not useful for determining whether or not the vibration exposure limit value or exposure action value is likely to be exceeded.

It is important that the vibration values used in the exposure assessment are representative of those in the specific use of the machines.

This Technical Report does not deal with assessments of exposure to shock.

NOTE The guidelines for determining, assessing and documenting the daily vibration exposure from use of ride-on operated earth-moving machinery also cover the requirements of the European Physical Agents Directive (Vibration) 2002/44/EC.

2 Normative references

The following referenced documents are indispensable for the application 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 2631-1:1997, *Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration — Part 1: General requirements*

ISO 6165: 2001, *Earth-moving machinery — Basic types — Vocabulary*

ISO 7096:2000, *Earth-moving machinery —- Laboratory evaluation of operator seat vibration*

EN 14253:2003, *Mechanical vibration — Measurement and calculation of occupational exposure to whole-body vibration with reference to health — Practical guidance*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2631 and ISO 6165 and the following apply.

3.1
operating time
ride-on time
daily duration of the operating time on the earth-moving machinery

NOTE It includes the interruptions required by the operating conditions and the break periods directly related to use.

3.2
exposure duration
T
total duration during which the whole body is in direct contact with the vibrating surface (seat) and exposed to relevant vibration

NOTE It is often confused with the operating time when determining the daily exposure duration, T. For example, the operating time on a wheel loader in a quarry is estimated by the operator at 7,5 h per day. However, the exposure duration is 5 h loading dumper (e.g. waiting for dumpers) and 1 h mining application (e.g. waiting for detonation), which yields T = 6,0 h.

3.3
equivalent vibration value
$a_{\mathrm{w,eq}}$
maximum of the time-averaged totals of the vibration values of the various machines and their typical operating conditions, $a_{\mathrm{w}i,\mathrm{x,y,z}}$, during their associated exposure durations, T_i

NOTE 1 It is the maximum of $a_{\mathrm{w,eqx}}$, $a_{\mathrm{w,eqy}}$ or $a_{\mathrm{w,eqz}}$, calculated using Equation (1):

$$a_{\mathrm{w,eqx}} = \sqrt{\frac{1}{T}\sum_{i=1}^{n}(a_{\mathrm{wx}i})^2 \cdot T_i}$$

$$a_{\mathrm{w,eqy}} = \sqrt{\frac{1}{T}\sum_{i=1}^{n}(a_{\mathrm{wy}i})^2 \cdot T_i} \qquad (1)$$

$$a_{\mathrm{w,eqz}} = \sqrt{\frac{1}{T}\sum_{i=1}^{n}(a_{\mathrm{wz}i})^2 \cdot T_i}$$

where n is the number of partial equivalent vibration values considered.

NOTE 2 Vibration values for the x and y directions are multiplied by a factor of 1,4, and this is included in the data in Annex B. If data are used from another source, care needs to be taken to ensure that the factor is included there also.

3.4
daily vibration exposure
A(8)
value on which assessment of the level of exposure to vibration is based, expressed as the equivalent continuous acceleration over an 8 h period and calculated as the highest (rms) value of the frequency-weighted accelerations determined on the three orthogonal axes ($1{,}4a_{\mathrm{wx}}$, $1{,}4a_{\mathrm{wy}}$ and a_{wz} for a seated operator)

NOTE 1 For the determination of A(8), see Clauses 5, 6 and 7, Annex A and Annex B, and ISO 2631-1.

NOTE 2 It is the maximum of the $\mathrm{A}(8)_{\mathrm{x,y,z}}$ values, calculated using Equation (2):

$$\mathrm{A}(8)_{\mathrm{x}} = \sqrt{\frac{1}{8\,\mathrm{h}}\sum_{i=1}^{n}\left(a_{\mathrm{wx}i}\right)^2 \cdot T_i}$$

$$\mathrm{A}(8)_{\mathrm{y}} = \sqrt{\frac{1}{8\,\mathrm{h}}\sum_{i=1}^{n}\left(a_{\mathrm{wy}i}\right)^2 \cdot T_i} \qquad (2)$$

$$\mathrm{A}(8)_{\mathrm{z}} = \sqrt{\frac{1}{8\,\mathrm{h}}\sum_{i=1}^{n}\left(a_{\mathrm{wz}i}\right)^2 \cdot T_i}$$

where n is the number of partial equivalent vibration values considered, $a_{\mathrm{w,x,y,z},i}$ is the equivalent vibration value and T_i is the associated exposure duration.

NOTE 3 Vibration values for the x and y directions are multiplied by a factor of 1,4, and this is included in the data in Annex B. If data are used from another source, care needs to be taken to ensure that the factor is included there also.

3.5
partial vibration exposure points
$P_{\mathrm{E}i\mathrm{x,y,z}}$
index describing the vibration exposure from a single machine and operating condition during the associated exposure duration in the x,y and z directions

NOTE 1 It is calculated for the corresponding direction using Equation (3):

$$P_{\mathrm{E}i\ \mathrm{x}} = \left(\frac{a_{\mathrm{wx}i}}{0{,}5\,\mathrm{m/s}^2}\right)^2 \cdot \frac{T_i}{8\ \mathrm{h}} \cdot 100$$

$$P_{\mathrm{E}i\ \mathrm{y}} = \left(\frac{a_{\mathrm{wy}i}}{0{,}5\,\mathrm{m/s}^2}\right)^2 \cdot \frac{T_i}{8\ \mathrm{h}} \cdot 100 \qquad (3)$$

$$P_{\mathrm{E}i\ \mathrm{z}} = \left(\frac{a_{\mathrm{wz}i}}{0{,}5\ \mathrm{m/s}^2}\right)^2 \cdot \frac{T_i}{8\ \mathrm{h}} \cdot 100$$

where $a_{\mathrm{w,x,y,z},i}$ is the equivalent vibration value and T_i is the associated exposure duration.

NOTE 2 Equation (3) sets a value of 100 points for a vibration exposure of 0,5 m/s^{2}A(8). Another vibration exposure value A(8) can be set to 100 points by substituting it for 0,5m/s^2 in the equation.

NOTE 3 Vibration values for the x and y directions are multiplied by a factor of 1,4, and this is included in the data in Annex B. If data are used from another source, care needs to be taken to ensure that the factor is included there also.

3.6
total vibration exposure points
P_{Etot}
maximum of the totals of the partial vibration exposure points $P_{\mathrm{E}i\mathrm{x,y,z}}$ within one day

NOTE 1 It is the maximum of $P_{\mathrm{E,totx}}$, $P_{\mathrm{E,toty}}$ or $P_{\mathrm{E,totz}}$, calculated using Equation (4):

$$P_{\mathrm{E\,totx}} = \sum_{i=1}^{n} P_{\mathrm{E}\,i\mathrm{x}}$$

$$P_{\mathrm{E\,toty}} = \sum_{i=1}^{n} P_{\mathrm{E}\,i\mathrm{y}} \qquad (4)$$

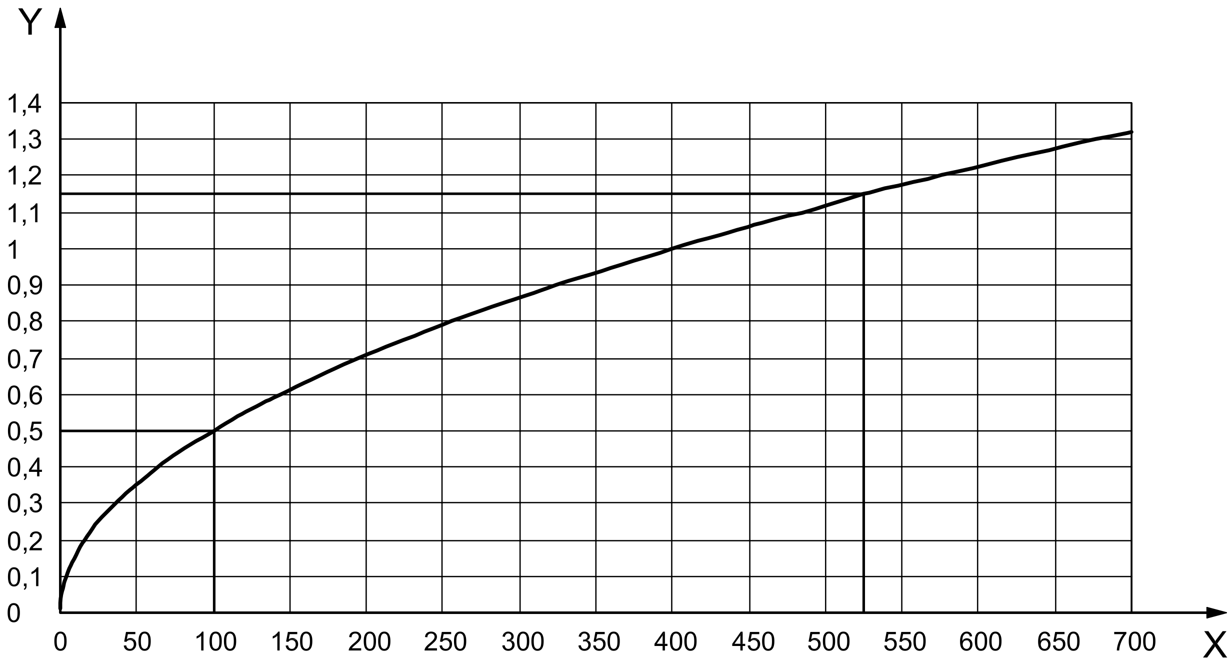
$$P_{\mathrm{E\,totz}} = \sum_{i=1}^{n} P_{\mathrm{E}\,i\mathrm{z}}$$

where n is the number of partial equivalent vibration values considered.

NOTE 2 Vibration exposure points are a simple alternative to determining the A(8) value of an operator’s total daily or partial vibration exposure. An example of the relationship is given by Equation (5), in accordance with the European Physical Agents Directive (vibration) 2002/44/EC:

$$A(8) = 0{,}5\,\mathrm{m/s}^2 \sqrt{P_{\mathrm{Etot}}/100} \qquad (5)$$

A score of 100 points for the total vibration exposure in a day is equal to the exposure action value of A(8) = 0,5 m/s^2 and a score of 529 points is equal to the exposure limit value of A(8) = 1,15 m/s^2. The example is plotted in Figure 1.



Key

X total vibration exposure points, P_{Etot}

Y daily vibration exposure A(8), m/s^2

Figure 1 — Example of relationship between vibration exposure points and daily vibration exposure for whole-body vibration

4 Estimation of vibration magnitude

4.1 General

Data for estimating vibration levels are provided in Annex B. The vibration magnitude is expressed as a frequency-weighted root-mean-square acceleration value in metres per second squared (m/s^2), in accordance with ISO 2631.

The vibration magnitude for a machine can be highly variable. For example, an operator and his driving style (e.g. aggressive, smooth), different operating conditions, ground conditions, machine speeds or different materials all influence the actual magnitude. The magnitude also often varies over time. It is usually difficult or even impossible to obtain a precise value or narrow value range. The average value and a description of its uncertainty is the best reflection of the real, typical operating conditions. When estimating exposure, account should be taken of the fact that values are obtained within a range of uncertainty (see Clause 6).

4.2 Additional sources of information

Vibration magnitudes may be measured at the operator’s position by the employer, or on his behalf. However, this can be difficult, non-reproducible and uneconomical, and is not always necessary.

Other sources of vibration data include specialist vibration consultants, employers’ organisations (trade associations) and government bodies. Data can also be found in various technical or scientific publications and on the Internet. If an employer uses data from one of these sources, the quality and accuracy of the data should be checked. Comparing data from two or more sources is thus recommended. Employers should try to find a value (or range of values), which represents the likely vibration magnitude for the particular machine and operating conditions.

5 Estimation of daily exposure duration

The employer should determine the daily exposure duration for each operator and the relevant machines and operating conditions.

This may be based on

a) measurement of the actual exposure durations of a small number of operations or work cycles and calculating the average, and

b) information on the number of operations or work cycles per working day.

The first of these will be a measurement to determine how long an operator is exposed to vibration, and from what source, during a specified period. Various techniques may be used, for example:

— use of a stopwatch;

— analysis of video recordings;

— activity sampling.

A source of information may be work records, e.g. the number of lorries loaded and unloaded by fork-lift trucks.

However, it is important to ensure that the information is compatible with the information required for an evaluation of daily vibration exposure. For example, work records might give very accurate information on the number of completed work items at the end of each day, but where there is more than one operator, or unfinished work items at the end of a shift, this information might not be directly applicable to a vibration exposure evaluation.

NOTE Operators asked for information on their typical daily vibration exposure duration will normally give an estimate which includes periods of time when there is no vibration (e.g. idling, lifting for a fork-lift truck). Therefore, such an approach often results in an overestimation of the exposure duration.

It should be recognised that for most machines the vibration exposure duration is shorter than the operating time.

6 Consideration of uncertainties

The accuracy of the overall assessment of the exposure depends on the accuracy of the established vibration value and its ability to represent the actual vibration value. It also depends on the accuracy of the exposure duration as estimated. The datasets given in Annex B are based on from at least five and to more than 100 measurements under typical operating conditions. The standard deviation gives information about the distribution of the measured values.

The uncertainty in the estimation of exposure duration is affected by the uncertainty of

— measurements of the duration of operations or work cycles,

— estimates of the number of operations or work cycles per day,

— exposure time estimates supplied by the operators (see Note to Clause 5), and

— variability of the working task from one day to another.

The uncertainty in the evaluation of daily vibration exposure is affected by the uncertainty of

— evaluation of vibration magnitude, and

— evaluation of exposure duration.

NOTE Additional information about uncertainties of the measured vibration emission value is given in EN 14253.

The accuracy of the vibration value has more influence on the accuracy of the daily vibration exposure than that of the exposure duration because the vibration exposure is proportional to the vibration value and to the square root of the exposure duration.

The average values given in Annex B are likely to be exceeded in about half of all conditions. When making an initial estimate of exposure or where it is suspected that the conditions for a machine operation are particularly severe, it is recommended that the values used be the mean plus one standard deviation. There will be cases when even the value of the mean plus one standard deviation is exceeded. This is likely to occur in the 17 % most severe cases, i.e. the value (mean plus one standard deviation) will cover 83 % of all conditions. Machine vibration values will be less than the average values given in Annex B in about half of all conditions.

Conditions likely to lead to variability in levels of whole-body vibration include roughness or smoothness of terrain, driving speeds (adequate or inadequate), and adequate or inadequate operator skill and training.

Vibration levels can be reduced by following the guidelines given in Annex E.

7 Determination and assessment of vibration exposure

7.1 General

The daily vibration exposure depends on two key elements:

a) the average magnitude of whole-body vibration transmitted through the seat;

b) the total daily duration for which an operator is in contact with that vibration.

The daily vibration exposure is determined from vibration magnitude and exposure duration values obtained according to Clauses 4 and 5.

The magnitude of the daily vibration exposure has to be calculated with the vibration values measured under real, typical operating conditions (see Annex B) and the exposure duration, T. Determination and assessment can be performed using either A(8) values or, more easily, total vibration exposure points (P_{Etot}).

7.2 Using daily vibration exposure A(8)

7.2.1 General procedure

The daily vibration exposure A(8) can be calculated by using the equivalent vibration value $a_{\mathrm{w,eq}}$ and the daily exposure duration T for the specific machine and operating condition according to Equation (6):

$$\mathrm{A}(8) = a_{\mathrm{w,eq}} \sqrt{\frac{T}{8\,\mathrm{h}}} \tag{6}$$

If the work of the day consists of operating n machines and/or n typical operating conditions with the partial equivalent vibration values of $a_{\mathrm{w}i,\mathrm{x,y,z}}$ and individual exposure durations T_{i}, calculate the daily vibration exposure A(8) according to Equation (7):

$$\mathrm{A}(8)_{\mathrm{x,y,z}} = \sqrt{\frac{1}{8\,\mathrm{h}} \sum_{i=1}^{n} \left(a_{\mathrm{w}i\mathrm{x,y,z}}\right)^2 \cdot T_i} \tag{7}$$

A(8), expressed as the equivalent continuous acceleration over an 8 h period, is the maximum of the $\mathrm{A}(8)_{\mathrm{x,y,z}}$ values.

This procedure, an example of which is given in 7.2.2, is according to EN 14253:2003, and further guidance is given in ISO 2631-1:1997, Annex B.

The daily vibration exposure can be compared with exposure criteria.

The Physical Agents Directive 2002/44/EC, for example, defines the exposure action value as A(8) = 0,5 m/s^2 and the exposure limit value as A(8) = 1,15 m/s^2, so that the necessary action by the employer (see Table 2) can be established. The daily exposure values have a level of uncertainty. If the estimated value is close to the exposure action value or the exposure limit value, it is better to assume that the value is likely to be exceeded and the employer should take the necessary action in conseqence.

7.2.2 Example — Wheel loader in three different operating conditions

7.2.2.1 Parameters:

— good operating conditions (smooth ground conditions, soft terrain, handled material: gravel);

— highly experienced operator;

— first typical operating condition: transfer movement, 1 h;

— second typical operating condition: v-shaped motion, 3,5 h.

Use the values of x, y and z direction, according to Annex B, depending on the parameters (e.g. working condition, experience of operator). In the example below, the average values minus standard deviation are used. Calculate for each direction the daily vibration exposure, $A(8)_x$, $A(8)_y$ and $A(8)_z$, using the values from Annex B and the associated exposure durations T_i, according to Equation (2):

$$A(8)_x = \sqrt{\frac{1}{8\,\mathrm{h}} \sum_{i=1}^{n} \left(a_{\mathrm{wx}i}\right)^2 \cdot T_i}$$

$$A(8)_y = \sqrt{\frac{1}{8\,\mathrm{h}} \sum_{i=1}^{n} \left(a_{\mathrm{wy}i}\right)^2 \cdot T_i}$$

$$A(8)_z = \sqrt{\frac{1}{8\,\mathrm{h}} \sum_{i=1}^{n} \left(a_{\mathrm{wz}i}\right)^2 \cdot T_i}$$

A(8), expressed as the equivalent continuous acceleration over an 8 h period, is the maximum of $A(8)_x$, $A(8)_y$ or $A(8)_z$.

Transfer movement (example):

$1{,}4 * a_{\mathrm{wx}} = 0{,}43\ \mathrm{m/s^2}$ $T_i = 1\ \mathrm{h}$

$1{,}4 * a_{\mathrm{wy}} = 0{,}56\ \mathrm{m/s^2}$ $T_i = 1\ \mathrm{h}$

$a_{\mathrm{wz}} = 0{,}32\ \mathrm{m/s^2}$ $T_i = 1\ \mathrm{h}$

V-shaped motion (example):

$1{,}4 * a_{\mathrm{wx}} = 0{,}7\ \mathrm{m/s^2}$ $T_i = 3{,}5\ \mathrm{h}$

$1{,}4 * a_{\mathrm{wy}} = 0{,}52\ \mathrm{m/s^2}$ $T_i = 3{,}5\ \mathrm{h}$

$a_{\mathrm{wz}} = 0{,}40\ \mathrm{m/s^2}$ $T_i = 3{,}5\ \mathrm{h}$

$$A(8)_x = \sqrt{\frac{1}{8\ \mathrm{h}}\left[\left(0{,}43\ \mathrm{m/s^2}\right)^2 * 1\,\mathrm{h} + \left(0{,}7\ \mathrm{m/s^2}\right)^2 * 3{,}5\ \mathrm{h}\right]} = 0{,}49\ \mathrm{m/s^2}$$

$$A(8)_y = \sqrt{\frac{1}{8\ \mathrm{h}}\left[\left(0{,}56\ \mathrm{m/s^2}\right)^2 * 1\,\mathrm{h} + \left(0{,}52\ \mathrm{m/s^2}\right)^2 * 3{,}5\ \mathrm{h}\right]} = 0{,}4\ \mathrm{m/s^2}$$

$$A(8)_z = \sqrt{\frac{1}{8\ \mathrm{h}}\left[\left(0{,}32\ \mathrm{m/s^2}\right)^2 * 1\,\mathrm{h} + \left(0{,}4\ \mathrm{m/s^2}\right)^2 * 3{,}5\ \mathrm{h}\right]} = 0{,}29\ \mathrm{m/s^2}$$

A(8) = maximum of $A(8)_x$, $A(8)_y$, $A(8)_z$ = $A(8)_x$ = 0,49 $\mathrm{m/s^2}$

Conclusion:

According to the European Physical Agents Directive 2002/44/EC, the daily vibration exposure value should not exceed the vibration exposure action value of (A8) = 0,5 m/s^2. If the results are close to the action value, take reasonable action to reduce risks from vibration exposure to a minimum and provide worker information and training on vibration reduction.

7.2.2.2 Parameters:

- normal operating conditions (normal ground conditions, hard terrain, handled material: gravel);
- highly experienced operator;
- first typical operating condition: transfer movement, 1 h;
- second typical operating condition: v-shaped motion, 4 h.

Use the values of x, y and z direction, according to Annex B, depending on the parameters (e.g. working condition, experience of operator). In the example below, the average values are used. Calculate for each direction the daily vibration exposure, $A(8)_x$, $A(8)_y$ and $A(8)_z$, using the values from Annex B and the associated exposure durations T_i, according to Equation (2):

$$A(8)_x = \sqrt{\frac{1}{8\text{h}}\sum_{i=1}^{n}\left(a_{\text{wx}i}\right)^2 \cdot T_i}$$

$$A(8)_y = \sqrt{\frac{1}{8\text{h}}\sum_{i=1}^{n}\left(a_{\text{wy}i}\right)^2 \cdot T_i}$$

$$A(8)_z = \sqrt{\frac{1}{8\text{h}}\sum_{i=1}^{n}\left(a_{\text{wz}i}\right)^2 \cdot T_i}$$

A(8), expressed as the equivalent continuous acceleration over an 8 h period, is the maximum of $A(8)_x$, $A(8)_y$ or $A(8)_z$.

Transfer movement (example)

1,4*a_{wx} = 0,76 m/s^2 T_i = 1 h

1,4*a_{wy} = 0,91 m/s^2 T_i = 1 h

a_{wz} = 0,49 m/s^2 T_i = 1 h

V-shaped motion (example)

1,4*a_{wx} = 0,99 m/s^2 T_i = 4 h

1,4*a_{wy} = 0,84 m/s^2 T_i = 4 h

a_{wz} = 0,54 m/s^2 T_i = 4 h

$$A(8)_x = \sqrt{\frac{1}{8\text{ h}}\left[\left(0{,}76\text{ m/s}^2\right)^2 * 1\text{ h} + \left(0{,}99\text{ m/s}^2\right)^2 * 4\text{ h}\right]} = 0{,}75\text{ m/s}^2$$

$$A(8)_y = \sqrt{\frac{1}{8\text{ h}}\left[\left(0{,}91\text{ m/s}^2\right)^2 * 1\text{ h} + \left(0{,}84\text{ m/s}^2\right)^2 * 4\text{ h}\right]} = 0{,}68\text{ m/s}^2$$

$$A(8)_z = \sqrt{\frac{1}{8\text{ h}}\left[\left(0{,}49\text{ m/s}^2\right)^2 * 1\text{ h} + \left(0{,}54\text{ m/s}^2\right)^2 * 4\text{ h}\right]} = 0{,}42\text{ m/s}^2$$

A(8) = maximum of $A(8)_x$, $A(8)_y$, $A(8)_z$ = $A(8)_x$= 0,75 m/s^2

Conclusion:

According to the European Physical Agents Directive 2002/44/EC, the daily vibration exposure value should not exceed the vibration exposure action value of (A8) = 0,5 m/s^2. Therefore, implement a programme of measures to reduce exposure and risks to a minimum. Ensure health surveillance is provided for exposed workers.

7.2.2.3 Parameters:

- difficult operating conditions (severe ground conditions, hard terrain, handled material: rocks);
- operator with limited experience;
- first typical operating condition: transfer movement, 1 h;
- second typical operating condition: v- shaped motion, 6 h.

Use the values of x, y and z direction, according to Annex B, depending on the parameters (e.g. working condition, experience of operator). In the example below, the average values plus standard deviation are used. Calculate for each direction the daily vibration exposure, $A(8)_x$, $A(8)_y$ and $A(8)_z$, using the values from Annex B and the associated exposure durations T_i, according to Equation (2):

$$A(8)_x = \sqrt{\frac{1}{8\text{h}}\sum_{i=1}^{n}\left(a_{\text{wx}i}\right)^2 \cdot T_i}$$

$$A(8)_y = \sqrt{\frac{1}{8\text{h}}\sum_{i=1}^{n}\left(a_{\text{wy}i}\right)^2 \cdot T_i}$$

$$A(8)_z = \sqrt{\frac{1}{8\text{h}}\sum_{i=1}^{n}\left(a_{\text{wz}i}\right)^2 \cdot T_i}$$

A(8), expressed as the equivalent continuous acceleration over an 8 h period, is the maximum of $A(8)_x$, $A(8)_y$ or $A(8)_z$.

Transfer movement (example):

1,4*a_{wx} = 1,09 m/s^2 T_i = 1 h

1,4*a_{wy} = 1,26 m/s^2 T_i = 1 h

a_{wz} = 0,66 m/s^2 T_i = 1 h

V-shaped motion (example):

$1{,}4{*}a_{wx}$ = 1,28 m/s² T_i = 6 h

$1{,}4{*}a_{wy}$ = 1,16 m/s² T_i = 6 h

a_{wz} = 0,68 m/s² T_i = 6 h

$$A(8)_x = \sqrt{\frac{1}{8\ h}\left[\left(1{,}09\ m/s^2\right)^2 * 1\ h + \left(1{,}28\ m/s^2\right)^2 * 6\ h\right]} = 1{,}17\ m/s^2$$

$$A(8)_y = \sqrt{\frac{1}{8\ h}\left[\left(1{,}26\ m/s^2\right)^2 * 1\ h + \left(1{,}16\ m/s^2\right)^2 * 6\ h\right]} = 1{,}1\ m/s^2$$

$$A(8)_z = \sqrt{\frac{1}{8\ h}\left[\left(0{,}66\ m/s^2\right)^2 * 1\ h + \left(0{,}68\ m/s^2\right)^2 * 6\ h\right]} = 0{,}63\ m/s^2$$

A(8) = maximum of $A(8)_x$, $A(8)_y$, $A(8)_z$ = $A(8)_x$= 1,17 m/s²

Conclusion:

According to the European Physical Agents Directive 2002/44/EC, the daily vibration exposure value exceeds the vibration exposure action value of (A8) = 0,5 m/s². Therefore, take immediate action to bring exposure below the exposure limit value.

7.3 Using only vibration exposure points, P_E, for European Directive

7.3.1 General procedure

This procedure allows a simple determination of the vibration exposure by using the equivalent vibration value, $a_{w,eq,x,y,z}$, for the specific machine (see Clause 4) and the associated exposure duration, T_i (see Clause 5). The corresponding vibration exposure points, $P_{Ei,x,y,z}$, can be read directly from Table 1.

In cases of multiple exposure (i.e. the operating of two or more machines and/or different operating conditions in one day), the total vibration exposure points, $P_{E\ tot,x,y,z}$, can be determined by simple summation of all n partial vibration exposure points, $P_{Ei,x,y,z}$, for each exposure, i, considered.

For the assessment, the total vibration exposure points are allocated to the corresponding exposure range (see Table 2) which implies further action by the employer according to the Physical Agents Directive 2002/44/EC, as appropriate.

Examples of use of the vibration exposure points are given in Annexes D, E and F.

Table 1 — Determination of vibration exposure points, P_E, from the equivalent vibration value and associated exposure duration for whole-body vibration

Equivalent vibration value $a_{w,eq}$ m/s²	Exposure duration T									
	0,1 h 6 min	0,2 h 12 min	0,5 h 30 min	1 h 60 min	2 h 120 min	3 h 180 min	4 h 240 min	5 h 300 min	6 h 360 min	8 h 480 min
0,2	0	0	1	2	4	6	8	10	12	16
0,25	0	1	2	3	6	9	13	16	19	25
0,3	0	1	2	5	9	14	18	23	27	36
0,35	1	1	3	6	12	18	25	31	37	49
0,4	1	2	4	8	16	24	32	40	48	64
0,45	1	2	5	10	20	30	41	51	61	81
0,5	1	3	6	13	25	38	50	63	75	100
0,55	2	3	8	15	30	45	61	76	91	121
0,6	2	4	9	18	36	54	72	90	108	144
0,65	2	4	11	21	42	63	85	106	127	169
0,7	2	5	12	25	49	74	98	123	147	196
0,75	3	6	14	28	56	84	113	141	169	225
0,8	3	6	16	32	64	96	128	160	192	256
0,85	4	7	18	36	72	108	145	181	217	289
0,9	4	8	20	41	81	122	162	203	243	324
0,95	5	9	23	45	90	135	181	226	271	361
1	5	10	25	50	100	150	200	250	300	400
1,05	6	11	28	55	110	165	221	276	331	441
1,1	6	12	30	61	121	182	242	303	363	484
1,15	7	13	33	66	132	198	265	331	397	529

Table 1 (*continued*)

Equivalent vibration value $a_{w,eq}$	Exposure duration T									
	0,1 h	0,2 h	0,5 h	1 h	2 h	3 h	4 h	5 h	6 h	8 h
m/s^2	6 min	12 min	30 min	60 min	120 min	180 min	240 min	300 min	360 min	480 min
1,2	7	14	36	72	144	216	288	360	432	576
1,25	8	16	39	78	156	234	313	391	469	625
1,3	8	17	42	85	169	254	338	423	507	676
1,35	9	18	46	91	182	273	365	456	547	729
1,4	10	20	49	98	196	294	392	490	588	784
1,45	11	21	53	105	210	315	421	526	631	841
1,5	11	23	56	113	225	338	450	563	675	900
1,55	12	24	60	120	240	360	481	601	721	961
1,6	13	26	64	128	256	384	512	640	768	1024
1,65	14	27	68	136	272	408	545	681	817	1089
1,7	14	29	72	145	289	434	578	723	867	1156
1,75	15	31	77	153	306	459	613	766	919	1225
1,8	16	32	81	162	324	486	648	810	972	1296
1,85	17	34	86	171	342	513	685	856	1027	1369
1,9	18	36	90	181	361	542	722	903	1083	1444
1,95	19	38	95	190	380	570	761	951	1141	1521
2	20	40	100	200	400	600	800	1000	1200	1600
2,05	21	42	105	210	420	630	841	1051	1261	1681
2,1	22	44	110	221	441	662	882	1103	1323	1764
2,15	23	46	116	231	462	693	925	1156	1387	1849
2,2	24	48	121	242	484	726	968	1210	1452	1936
2,25	25	51	127	253	506	759	1013	1266	1519	2025
2,3	26	53	132	265	529	794	1058	1323	1587	2116
2,35	28	55	138	276	552	828	1105	1381	1657	2209
2,4	29	58	144	288	576	864	1152	1440	1728	2304
2,45	30	60	150	300	600	900	1201	1501	1801	2401
2,5	31	63	156	313	625	937	1250	1563	1875	2500

Table 2 — Action required by the employer due to the vibration exposure

Total vibration exposure points $P_{\text{E tot}}$ [a]	Daily vibration exposure A(8)	Vibration exposure range	Action required by the employer
$P_{\text{E tot}} \leqslant 100$	$A(8) \leqslant 0{,}5\ \text{m/s}^2$	Exposure action value not exceeded	If the results are close to the action value, take reasonable action to reduce risks from vibration exposure to a minimum and provide worker information and training on vibration reduction.
$100 < P_{\text{E tot}} \leqslant 529$	$0{,}5\ \text{m/s}^2 < A(8) \leqslant 1{,}15\ \text{m/s}^2$	Above exposure action value, but exposure limit value not exceeded	Implement a programme of measures to reduce exposure and risks to a minimum. Ensure health surveillance is provided for exposed workers.
$529 < P_{\text{E tot}}$	$1{,}15\ \text{m/s}^2 < A(8)$	Above exposure limit value	Take immediate action to bring exposure below the exposure limit value.

[a] Regarding values 100 and 529, see Note 2 to 3.6.

7.3.2 Examples

7.3.2.1 General

When operating a machine or machines, or when operating under different operating conditions on the same working day, or in both cases, the total vibration exposure points $P_{\text{E tot,x,y,z}}$ can be determined by summation of the vibration exposure points $P_{\text{Eix,y,z}}$ of the individual machines and their operating conditions using Annex B.

Identify the different machine(s) and/or their different operating conditions and the associated exposure duration, T_i.

Use, for simplification purposes, the calculation form provided in Annex C.

Depending on the different parameters (e.g. working condition, experience of operator), determine the appropriate value (average, average plus or minus standard deviation, or between) to use for each of the directions x,y and z.

See Table 1 for the corresponding vibration exposure points $P_{\text{Eix,y,z}}$ for this exposure magnitude $a_{\text{w,eq,x,y,z}}$ and duration T_i.

Sum up the exposure points $P_{\text{Eix,y,z}}$ for each direction, x, y and z.

The maximum result P_{Etot} has to be compared with the values in Table 2 and further action taken if necessary. Alternatively, Figure 1, or the shaded areas of Table 1 can be used.

7.3.2.2 Example 1 — Compact wheel loader

Parameters:

— good working conditions (smooth ground condition);

— highly experienced operator;

— typical operating condition: load and carry motion, 4h.

Use the average values minus standard deviation from Annex B.

Machine working condition	T_i h	1,4*$a_{w,eqx}$ m/s^2	P_{Ex}	1,4*$a_{w,eqy}$ m/s^2	P_{Ey}	$a_{w,eqz}$ m/s^2	P_{Ez}
Compact wheel loader (load and carry motion)	4	0,67	85	0,57	61	0,52	50
			$\sum$ = 85		$\sum$ = 61		$\sum$ = 50

P_{Etot} = max. $\sum P_{Ex}$, $\sum P_{Ey}$ or $\sum P_{Ez}$ = 85

Conclusion:

Since the daily total vibration exposure points are below 100, the vibration exposure action value is not exceeded. If the results are close to the action value, take reasonable action to reduce risks from vibration exposure to a minimum, and provide worker information and training on vibration reduction.

7.3.2.3 Example 2 — Wheeled loader and crawler excavator

Parameters:

— normal working conditions (smooth ground condition);

— highly experienced operator;

— typical operating condition of wheeled loader: v-shaped motion (loading dumpers), 4h;

— typical operating condition of crawler excavator: mining application, 2,5 h.

Use the average values from Annex B.

Machine working condition	T_i h	1,4*$a_{w,eqx}$ m/s^2	P_{Ex}	1,4*$a_{w,eqy}$ m/s^2	P_{Ey}	$a_{w,eqz}$ m/s^2	P_{Ez}
Wheeled loader (v-shaped motion)	4	0,99	200	0,84	145	0,54	61
Crawler excavator (mining application)	2,5	0,65	53	0,42	20	0,61	45
			$\sum$ = 253		$\sum$ = 165		$\sum$ = 106

P_{Etot} = max. $\sum P_{Ex}$, $\sum P_{Ey}$ or $\sum P_{Ez}$ = 253

Conclusion:

Since the daily total vibration exposure points are between 100 and 529, the vibration exposure action value is exceeded, but not the exposure limit value. Implement a suitable programme of control measures and health surveillance if the exposure remains above the exposure action value.

7.3.2.4 Example 3: Compact skid steer loader

Parameters:

— difficult working conditions (severe ground condition);

— operator with limited experience;

— typical operating conditions: load and carry motion, 7 h.

Use the average values plus standard deviation from Annex B.

Machine working condition	T_i h	1,4*$a_{w,eqx}$ m/s^2	P_{Ex}	1,4*$a_{w,eqy}$ m/s^2	P_{Ey}	$a_{w,eqz}$ m/s^2	P_{Ez}
Compact skid wheel loader (load and carry motion)	7	1,16	463	1,06	386	1,28	592
			Σ = 463		Σ = 386		Σ = 592

P_{Etot} = max. Σ P_{Ex}, Σ P_{Ey} or Σ P_{Ez} = 592

Conclusion:

Since the daily total vibration exposure points are above 529, the vibration exposure limit value is exceeded. Take immediate action to bring exposure below the exposure limit value and implement a suitable programme of control measures and health surveillance if the exposure remains above the exposure action value.

8 Documentation

EN 14253 contains a list of information to be reported when assessing vibration exposure.

Where data from Annex B have been used and whole-body vibration is not measured *in situ*, the following information should also be documented:

a) sources of vibration data used and observations on their quality;

b) description of vibration data (see also Annex D), e.g.

— machine type,

— machine manufacturer,

— machine mass,

— year of manufacture,

— working hours;

c) description of exposure duration and how it was determined;

d) periods of observation.

Annex A
(informative)

Machine types and their typical operating conditions

Tractor dozer Crawler dozer	dozing material through forward/reversing motion
	tear up by scarifier
	transfer movement
Tractor dozer Wheeled dozer	dozing material through forward/reversing motion
	transfer movement
Loader crawler loader	load and carry motion
	V-shaped motion
	mining application (excavation of minerals; rocky application)
	transfer movement
Loader compact skid steer loader with (rubber) tracks (service weight ⩽ 4 500 kg)	load and carry motion
	V-shaped motion
	transfer movement
Loader wheeled loader	load and carry motion
	V-shaped motion
	mining application (excavation of minerals; rocky application)
	transfer movement
Loader compact wheel loader (service weight ⩽ 4 500 kg)	load and carry motion
	V-shaped motion
	transfer movement
Loader compact skid steer loader (service weight ⩽ 4 500 kg)	load and carry motion
	V-shaped motion
	transfer movement

Wheeled backhoe loader	load and carry motion
	V-shaped motion
	excavating
	transfer movement
Excavator crawler excavator	excavating (shovel or grab type attachment)
	mining application (excavation of materials)
	hydraulic breaker application
	transfer movement
Excavator compact crawler excavator (Service weight $\leqslant$ 6 000 kg)	excavating (bucket or grab type attachment)
	hydraulic breaker application
	transfer movement
Excavator wheeled excavator	excavating (bucket or grabtype attachment)
	hydraulic breaker application
	transfer movement
Excavator compact wheel excavator (Service weight $\leqslant$ 6 000 kg)	excavating (bucket or grabtype attachment)
	hydraulic breaker application
	transfer movement
Excavator crawler cable-operated excavator	excavating (bucket or grab type attachment)
	mining application (excavation of materials)
	transfer movement

Excavator wheeled cable-operated excavator	excavating (bucket or grab type attachment)
	mining application (excavation of materials)
	transfer movement
Trencher crawler trencher	work cycle
	transfer movement
Trencher compact crawler trencher	work cycle
	transfer movement
Trencher wheel trencher	work cycle
	transfer movement
Trencher compact wheel trencher (Service weight $\leqslant$ 4 500 kg)	work cycle
	transfer movement
Dumper rigid frame dumper	loading process
	travel with load
	unloading
	travel without load
Dumper compact frame dumper (site dumper) (service weight $\leqslant$ 4 500 kg)	work cycle
	transfer movement
Dumper articulated frame dumper	loading process
	travel with load
	unloading
	travel without load
Dumper compact articulated frame dumper (service weight $\leqslant$ 4 500 kg)	work cycle
	transfer movement
Dumper crawler dumper	work cycle
	transfer movement
Dumper compact crawler dumper (service weight $\leqslant$ 4 500 kg)	work cycle
	transfer movement

Wheel scraper	work cycle
	transfer movement
Motor grader	finish grading
	hard grading
	transfer movement
Landfill compactor	work cycle
Compactor single drum vibrating compactor	soil compaction with vibration (boulder)
	soil compaction with vibration (coarse gravel)
	soil compaction with vibration (silt)
	asphalt compaction with vibration
	asphalt compaction without vibration
	transfer movement
Roller pneumatic tire roller	soil compaction (sand)
	asphalt compaction
	transfer movement
Roller static 3-wheel roller	soil compaction (sand)
	asphalt compaction
	transfer movement
Roller tandem roller with vibration	soil compaction with vibration
	soil compaction without vibration

Annex B
(informative)

Equivalent vibration values of whole-body vibration emission of earth-moving machinery

Machine family	Machine kind	Typical operating condition	Average			Standard deviation		
			$1{,}4{*}a_{w,eqx}$	$1{,}4{*}a_{w,eqy}$	$a_{w,eqz}$	$1{,}4{*}s_x$	$1{,}4{*}s_y$	s_z
			m/s^2					
compactor	single-drum vibrating compactor	compaction (boulder)	0,47	0,53	0,41	0,17	0,22	0,12
		compaction (silt)	0,29	0,28	0,28	0,08	0,17	0,11
	tandem roller with vibration	asphalt with vibration	0,33	0,40	0,48	0,11	0,08	0,14
		asphalt without vibration	0,35	0,43	0,36	0,13	0,20	0,19
dumper	articulated frame dumper	loading process	0,29	0,41	0,24	0,17	0,23	0,16
		travel with load	0,64	0,89	0,67	0,21	0,29	0,21
		travel without load	0,82	1,02	0,81	0,26	0,26	0,28
		unloading	0,49	0,42	0,30	0,25	0,33	0,18
	compact articulated frame dumper	work cycle	0,49	0,61	0,48	0,08	0,07	0,05
	rigid frame dumper	loading process	0,20	0,22	0,21	0,19	0,17	0,19
		travel with load	0,61	0,63	0,82	0,21	0,24	0,34
		travel without load	0,73	0,73	0,87	0,20	0,25	0,33
		unloading	0,37	0,37	0,33	0,14	0,13	0,08
excavator	compact crawler excavator	excavating	0,33	0,21	0,19	0,19	0,12	0,10
		hydraulic breaker app.	0,49	0,28	0,36	0,20	0,13	0,17
		transfer movement	0,45	0,39	0,62	0,17	0,18	0,28
	crawler excavator	excavating	0,44	0,27	0,30	0,24	0,16	0,17
		hydraulic breaker app.	0,53	0,31	0,55	0,30	0,18	0,28
		mining application	0,65	0,42	0,61	0,21	0,15	0,32
		transfer movement	0,48	0,32	0,79	0,19	0,20	0,23
	wheeled excavator	excavating	0,52	0,35	0,29	0,26	0,22	0,13
		transfer movement	0,41	0,53	0,61	0,12	0,20	0,19
landfill compactor	landfill compactor	work cycle	0,55	0,83	0,34	0,17	0,33	0,15

Table (continued)

Machine family	Machine kind	Typical operating condition	Average			Standard deviation		
			1,4*$a_{w,eqx}$	1,4*$a_{w,eqy}$	$a_{w,eqz}$	1,4*s_x	1,4*s_y	s_z
			m/s^2					
loader	compact skid steer loader	load and carry motion	0,86	0,73	0,93	0,30	0,33	0,35
	compact wheel loader	load and carry motion	0,94	0,86	0,65	0,27	0,29	0,13
	crawler loader	load and carry motion	0,89	0,67	0,52	0,12	0,16	0,10
		transfer movement	0,58	0,49	0,60	0,18	0,12	0,15
		v-shaped motion	1,24	0,93	0,63	0,41	0,35	0,18
	skid steer loader (tracks)	v-shaped motion	1,21	1,00	0,82	0,30	0,84	0,32
	wheel backhoe loader	excavating	0,28	0,26	0,20	0,09	0,16	0,06
	wheel loader	load and carry motion	0,84	0,81	0,52	0,23	0,20	0,14
		mining application	1,27	0,97	0,81	0,47	0,31	0,47
		transfer movement	0,76	0,91	0,49	0,33	0,35	0,17
		v-shape motion	0,99	0,84	0,54	0,29	0,32	0,14
motor grader	motor grader	finish grading	0,41	0,48	0,38	0,22	0,26	0,14
		hard grading	0,61	0,64	0,78	0,21	0,21	0,30
		transfer movement	0,39	0,36	0,58	0,25	0,25	0,34
pipe layer	pipe layer	work cycle	0,21	0,23	0,24	0,09	0,11	0,14
scraper	wheel scraper	work cycle	1,05	1,18	1,12	0,34	0,40	0,42
tractor-dozer	crawler dozer	dozing	0,74	0,58	0,70	0,31	0,25	0,31
		tear up by scarifier	1,25	1,19	1,02	0,40	0,41	0,28
		transfer movement	0,87	0,80	0,97	0,43	0,40	0,34
NOTE As at April, 2005.								

Annex C
(informative)

Calculation form for total vibration exposure points

Machine working condition	T_i h	1,4*$a_{w,eqx}$ m/s^2	P_{Ex}	1,4*$a_{w,eqy}$ m/s^2	P_{Ey}	$a_{w,eqz}$ m/s^2	P_{Ez}
			Σ =		Σ =		Σ =

P_{Etot} = max. $\Sigma\, P_{Ex}$, $\Sigma\, P_{Ey}$ or $\Sigma\, P_{Ez}$ =

Annex D
(informative)

Example documentation form for whole-body vibration exposure

Date:

Machine kind:

Machine type:

Machine manufacturer:

Serial number:

Power (KW):

Machine mass (t):

Year of manufacture:

Working hours:

Machine condition:

Tyre pressure (bar):

Type of work site:

Seat type:

Seat manufacturer:

Seat suspension system:

Seat meets ISO 7096:

Seat stroke (mm):

Seat condition:

Driver mass (kg):

Seat adjusted to mass?:

Dimension of tyre/track. etc.:

Experience of driver:

Typical operating condition	**Ground conditions**	**Hardness of terrain**	**Material to be handled**	**Driving style**	**Exposure time** h

Remarks:

Annex E
(informative)

Guidelines for use and working conditions of earth-moving machinery to reduce vibration levels

Properly adjusting and maintaining machines, operating machines smoothly, and maintaining the terrain conditions can reduce whole-body vibrations. The following can help the users of earth-moving machinery reduce whole-body vibration levels.

a) Use the right type and size of machine, equipment, and attachments.

b) Maintain machines according to the manufacturer's recommendations:

- tire pressure;
- brake and steering systems;
- controls, hydraulic system and linkages.

c) Keep the terrain where the machine is working and travelling in good condition:

- remove any large rocks or obstacles;
- fill any ditches and holes;
- provide machines and schedule time to maintain terrain conditions.

d) Use a seat in conformance with ISO 7096 and keep the seat maintained and adjusted:

- adjust the seat and suspension for the weight and size of the operator;
- inspect and maintain the seat suspension and adjustment mechanisms.

e) Steer, brake, accelerate, shift gears, and move the attachments smoothly.

f) Adjust the machine speed and travel path to minimize the vibration level:

- drive around obstacles and rough terrain conditions;
- slow down when it is necessary to go over rough terrain.

g) Minimize vibrations for long work cycle or long distance travelling:

- use machines equipped with suspension systems;
- use lift arm suspensions on wheel loaders;
- if no suspension system is available, reduce speed to prevent bouncing;
- haul machines long distances between worksites.

h) Back pain associated with whole-body vibrations can be caused by other risk factors. To minimize the risk of back pain:

— adjust the seat and controls to achieve good posture;

— adjust the mirrors to minimize twisted posture;

— provide breaks to reduce long periods of sitting;

— avoid jumping down from the cab or access system;

— minimize repeated handling and lifting of loads;

— minimize any shocks and jolts during sports and leisure activities.

Annex F
(informative)

Guidelines for establishing and reporting vibration reduction of earth-moving machinery

F.1 General

The effectiveness of vibration reduction devices (specific hardware or software components) in reducing the whole-body vibrations transmitted to the operator of a machine is difficult to accurately establish. Vibration levels on earth-moving machinery vary significantly as a function of operator technique, terrain conditions and the specific machine application. These variables can have a significantly greater impact on measured vibration levels than machine modifications that are made to reduce vibration levels. In order to establish the vibration reduction of any machine improvement, a thorough design of experiments is required that controls the variables during the vibration measurements. The projected vibration reduction also needs to be measured for each of the machine applications listed in Annex A.

F.2 Design of experiments for measuring vibration data

The measurement of the operator vibration level is affected by many factors. These could include seat adjustments, operator body mass index, operator style, operator skill, operator tolerance of vibration, productivity requirements, type of operation, ground conditions, machine condition and machine settings. Any experiment to demonstrate that a particular machine design can reduce the operator vibration level must use an experiment method design that will demonstrate that the control factor (the design or machine in question) is the cause of the reduction rather than these noise factors (see conditions described above). A proper design (e.g. Taguchi design) for robust experiments should be used to control the noise factors during the vibration measurements to compare two machine configurations. Noise factors for the outer array should be carefully selected and could require preliminary experimentation. The repeating of each experiment will be required to further establish the effect of the noise factors. Careful attention should be given to the operators during the experiments. An operator skilled on one machine might not be as skilled on another model or make of machine.

F.3 Reporting vibration reductions

The following information should be reported for the vibration testing to establish the vibration reduction of machine improvements to reduce vibration levels.

a) Describe the vibration reduction device and the general manner in which it reduces transmitted vibration.

b) Identify the machine families that could benefit from the device.

c) Report the following vibration levels and percent whole-body vibration reduction for each machine family, each application from Annex A and for all three vibration directions:

— mean measured vibration levels and standard deviations for the vibration measurements of the machine with and without the improvement;

— expected per cent vibration reduction.

d) Detailed information about test conditions (e.g. surface, operating conditions, skill of the operator, operating speed).

Bibliography

[1] 98/37/EC, Directive of the European Parliament and of the Council of 22 June 1998 on the approximation of the laws of the member states relating to machinery

[2] 2002/44/EC, Directive of the European Parliament and of the Council of 25 June 2002 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration) (sixteenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC)

[3] EN 474 (all parts), *Earth moving machinery — Safety*

[4] EN 500 (all parts), *Mobile road construction machinery — Safety*

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