GUIDE TO MEASURING AND ASSESSING WORKPLACE EXPOSURE TO WHOLE-BODY VIBRATION

This Guide provides information for occupational hygienists, ergonomists and other professionals involved in the measurement and assessment of workplace vibration exposures from vibrating plant that affects the whole body. It also provides technical information on how exposures are to be measured and calculated.

This Guide is part of a series of guidance material on:

- *Managing risks of exposure to whole-body vibration in workplaces*
- *Managing risks of exposure to hand-arm vibration in workplaces*, and
- *Measuring and assessing workplaces exposure to hand-arm vibration*.

What is whole-body vibration?

Whole-body vibration (WBV) is vibration transmitted to the whole body by the surface supporting it, for example through a seat or the floor. It is commonly experienced by drivers, operators and passengers in mobile plant when travelling over uneven surfaces. WBV may also be experienced while standing, for example standing on platforms attached to concrete crushing plant. WBV includes sharp impact-like shocks and jolts.

Key terms used in this Guide

Competent person means a person who has acquired through training, qualification or experience the knowledge and skills to carry out the task.

Daily vibration exposure A(8) means the quantity of WBV a worker is exposed to during a working day, normalised to an eight hour reference period, which takes account of the magnitude and duration of vibration. Daily vibration exposure is derived from the magnitude of the vibration on the axis which has the highest weighted vibration magnitude and the daily exposure duration.

Exposure action value means the level of daily vibration exposure to WBV for a worker above which steps should be taken to minimise exposure.

Exposure limit value means the level of daily vibration exposure to WBV for a worker which should not be exceeded.

Vibration dose value (VDV) is a preferred measurement for exposure to jolts, shocks and intermittent vibration because it is sensitive to peaks in acceleration levels.

Measuring vibration levels

Measurement of WBV can be difficult and complex. If workers report WBV as uncomfortable, it is likely their exposure to vibration is reaching levels which could affect their health. This may also be used as an indicator of a WBV problem requiring controls to be put in place to eliminate or minimise exposure, so far as is reasonably practicable.

Assessment of WBV by a competent person may be required if there is no adequate information about vibration emission available, the plant is being used differently from the way it was when previously tested or if you are uncertain about the effectiveness of controls.

It is important that the measurement equipment is fit for purpose.

Exposure to WBV should be evaluated using the method in AS 2670.1: *Evaluation of human exposure to whole-body vibration - General requirements*.

Detailed practical guidance on this is available in *EN 14253:2003: Mechanical vibration – Measurement and calculation of occupational exposure to whole-body vibration with reference to health - Practical guidance*.

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Safe Work Australia Contact Information
Phone 1300 551 832 | **Email** info@swa.gov.au | **Web** www.swa.gov.au

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While there is no Australian workplace exposure standard for WBV it is useful to make a comparison to an accepted standard in order to work out how much WBV exposure is likely to cause a risk. This can be done using daily vibration exposure A(8) or vibration dose value (VDV).

The European Union has established a widely used and accepted exposure action value and exposure limit value for WBV. The EU Directive limits are shown in Table 1.

Table 1 EU Directive

Exposure action value and exposure limit value for WBV under the EU 2002/44/EC Physical Agents (Vibration) Directive

Exposure Action Value

If daily vibration exposure is likely to exceed an A(8) of 0.5 m/s^2 or a vibration dose value of 9.1 $m/s^{1.75}$ action should be taken to reduce exposure to below this value.

Exposure Limit Value

Controls must be put in place to ensure a worker is not exposed under any circumstances to a daily vibration exposure A(8) of more than 1.15 m/s^2 or vibration dose value of 21 $m/s^{1.75}$.

EXPOSURE TO WHOLE-BODY VIBRATION

Daily vibration exposure A(8)

Exposure to individual sources of constant WBV is calculated from the magnitude of vibration expressed as acceleration in metres per second squared (m/s^2) and the duration of exposure.

The daily vibration exposure A(8) is expressed in m/s^2 and is the amount of vibration to which a worker is exposed during a working day, normalised to an eight hour reference period.

Vibration Dose Value

Exposure to intermittent WBV including shocks or jolts is measured using a VDV, which gives a more representative value than the daily vibration exposure A(8).

The VDV is a cumulative value, which increases with measurement duration. It is assessed using the length of time of the measurement and the total time a worker is exposed to the source of vibration per day.

Daily vibration exposure A(8) and VDV measures are dependent on measured actual vibration values for the item of plant.

Adjustment for extended working days

Longer shifts are already taken into account in the calculation of A(8) so no further adjustment to the calculation of the daily vibration exposure A(8) is needed for shifts longer than eight hours.

Calculation of VDV includes duration of measurement and duration of exposure. As long as the VDV is calculated taking exposure duration into account, there is no need to adjust the value for different shift lengths.

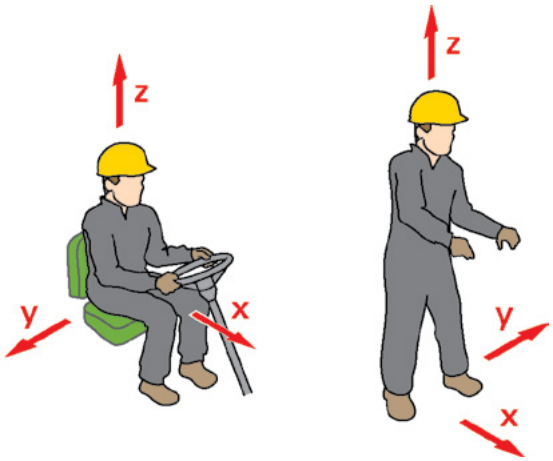
Uncertainty in assessment of exposure

Uncertainties associated with the evaluation of daily vibration exposure A(8) can mean the calculated value is as much as 20 per cent above the true value, to 40 per cent below. If either the exposure duration or the vibration magnitude is estimated, for example based on information from the worker (exposure duration) or manufacturer (magnitude), then the uncertainty can be much higher.

Measurement axes

For WBV the axis with the highest average root mean square acceleration is used to calculate the daily vibration exposure A(8). Figure 1 shows the standard orientation of the x, y, and z axes. The measurements taken on the x and y axes are given a weighting, k, of 1.4 times the measured value to reflect their contribution to health effects. This is different from hand-arm vibration assessment in which the vibration measurement is the triaxial sum of the acceleration experienced by the worker in the three axes.

Figure 1 Vibration measurement axes in both seated and standing positions



Calculating the daily vibration exposure A(8)

Exposure to WBV should be evaluated using the methods in AS 2670.1: *Evaluation of human exposure to whole-body vibration – General requirements*.

The daily vibration exposure A(8) for a worker carrying out one process or operating one item of plant can be calculated using the equation:

$$A(8) = a_w \sqrt{\frac{T}{T_0}}$$

where:

- a_w is the vibration magnitude (in m/s^2) on the axis which measured highest, including the weighting factor, k=1.4, for the x and y axes
- T is the actual duration in hours of exposure to the vibration magnitude a_w, and
- T_0 is the reference duration of eight hours.

The vibration magnitude, a_w, may come from measured data, manufacturer's information or other sources like online databases.

If a person is exposed to more than one source of WBV then partial vibration exposures are calculated from the magnitude and duration for each source.

The overall daily vibration exposure A(8) can be calculated from the partial vibration exposure values using the equation:

$$A(8) = \sqrt{A_1(8)^2 + A_2(8)^2 + \ldots}$$

where $A_1(8)$, $A_2(8)$, etc. are the partial vibration exposure values for the different vibration sources.

The daily vibration exposure A(8) is worked out separately for each of the three axes. The total on the highest axis the worker is exposed is then compared to the exposure action value and exposure limit value.

A simple exposure points system (see Table 2) can be used to work out the daily vibration exposure A(8). It can then be compared to the exposure action value and exposure limit value in Table 1.

Calculating the Vibration Dose Value

VDV is calculated as the root mean quad of the acceleration and is more sensitive to peaks in acceleration than the root mean square acceleration. This gives a result in $m/s^{1.75}$. Weighting factors of 1.4 apply on the x and y axes.

VDV is not usually publicly available so measurements have to be taken to determine the VDV for each piece of plant.

If VDVs are available, the daily VDV (VDV_{exp}) can be worked out for each axis using the equation:

$$VDV_{exp,x} = 1.4\, VDV_x \left(\frac{T_{exp}}{T_{meas}}\right)^{1/4}$$

Where:

- VDV_x is the measured or otherwise found VDV on the x-axis
- T_{exp} is the daily duration of exposure to the source of WBV, and
- T_{meas} is the time over which the VDV_x was measured.

An equivalent equation is used on the y-axis while the equation for z-axis does not have the 1.4 weighting factor. The highest value of $VDV_{exp,x}$, $VDV_{exp,y}$ and $VDV_{exp,z}$ is the daily VDV to be compared to the exposure action level (9.1 $m/s^{1.75}$) and exposure limit value (21 $m/s^{1.75}$).

If a worker is exposed to more than one source of WBV and VDVs are available, the total VDV for each axis is calculated using the equation:

$$VDV_{exp,x} = \left(VDV_{exp,x1}^4 + VDV_{exp,x2}^4 + VDV_{exp,x3}^4 + \ldots\right)^{1/4}$$

where $VDV_{exp,x1}$, $VDV_{exp,x2}$ etc. are the partial VDVs for each source on the x-axis. The VDV_{exp}, which is highest of the x, y and z axes is the daily VDV to be compared to the exposure action value and exposure limit value.

There is no simple exposure points system that can be used instead of this method. The Health and Safety Executive (UK) has a downloadable tool to help with the calculations.

Manufacturer declared emission values and other data sources

Manufacturer's data may give a useful indication of the vibration exposure of workers. Initial exposure assessments may need to be verified by measuring vibration magnitudes where WBV exposure depends on external factors like:

- the quality of road surfaces
- plant speeds
- how the plant is operated, and
- plant attachments

Ideally you should use WBV information for the plant, make and model you plan to use. If this is not available, you may need to use information relating to similar plant as a starting point and replace the data with more accurate values when it becomes available.

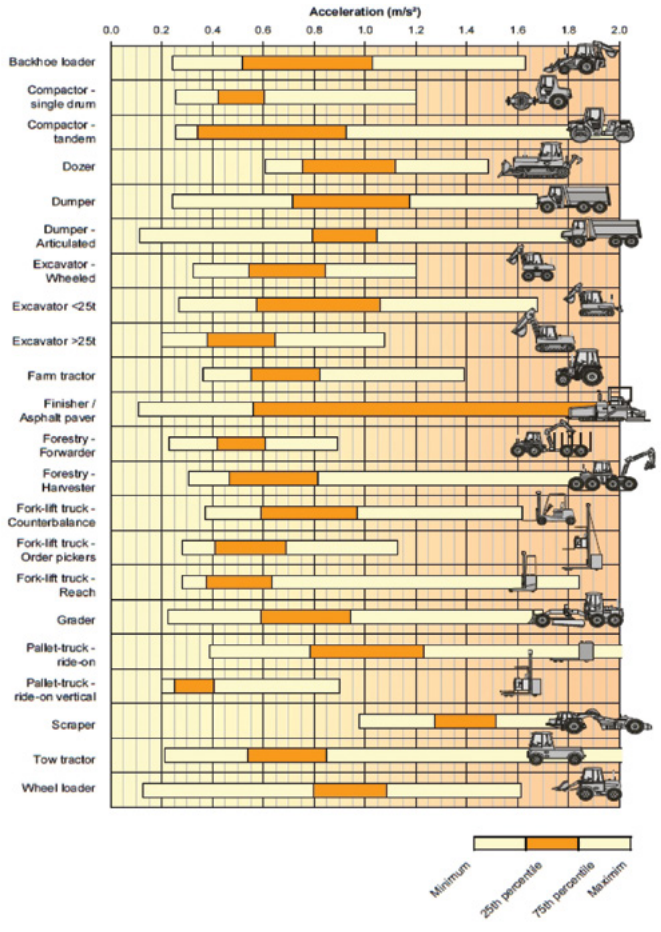
A key indicator of when the exposure limit value may be exceeded is if workers report discomfort or temporary lower back pain.

More information on whether the exposure action value or the exposure limit value is likely to be exceeded may be obtained from:

- specialist vibration consultants
- trade associations
- government bodies
- technical or scientific publications, and
- online.

Figure 2 includes examples of vibration magnitude for common mobile plant.

Figure 2 Examples of vibration magnitude for common mobile plant[1]



1 From the European Union's *Guide to good practice on Whole-Body Vibration (2006)*.

When estimating WBV consider all relevant factors like:

- the type of plant e.g. fork-lift trucks
- the class of plant e.g. power or size
- the power source e.g. electric or combustion engine
- anti-vibration features e.g. suspension systems, suspended cab and seats
- the task the plant was used for when producing the vibration information
- the speed it was operated at, and
- the type of surface it was driven on.

It is good practice to compare data from two or more sources.

Duration of exposure

To estimate the daily vibration exposure A(8) you need to work out the total daily duration of exposure to the vibration emitted from the plant.

The exposure duration is not the overall time spent on a specific job. The exposure duration is only the time during which the body is actually exposed to vibration. When asked, operators may overestimate the exposure duration as they may only be thinking of the whole task duration. It is better to estimate the exposure duration by observation and measurement of a sample period of typical work. For example, a stopwatch may be used to determine the average duration required to perform the work task when using the plant being evaluated.

While workers are usually exposed to vibration while plant is travelling, this is not always the dominant source. For some kinds of plant more exposure occurs while it is stationary, for example excavators and tree harvesters.

Daily vibration exposure using the exposure points system

A simple method for determining daily WBV exposure is the use of a points based system (see Table 2). The exposure scores corresponding to the exposure action value and exposure limit value are:

- Exposure action value (0.5 m/s^2) = 100 points, and
- Exposure limit value (1.15 m/s^2) = 529 points

Once you have worked out the whole-body vibration acceleration $\mathbf{a_W}$, which axis it was determined on and the duration of exposure, you can work out a worker's total exposure points using Table 2.

Where the vibration exposure point is:

- between the exposure action value and the exposure limit values (yellow), action to control exposure should be carried out where practicable, and
- greater than the exposure limit value (red), controls should be implemented to ensure workers are not exposed above the limit under any circumstances.

Table 2 Exposure points[2]

Acceleration x k (m/s²)	15m	30m	1h	2h	3h	4h	5h	6h	8h	10h	12h
2	50	100	200	400	600	800	1000	**1200**	**1600**	**2000**	**2400**
1.9	45	90	180	360	540	720	905	**1100**	**1450**	**1800**	**2150**
1.8	41	81	160	325	485	650	810	**970**	**1300**	**1600**	**1950**
1.7	36	72	145	290	435	580	725	**865**	**1150**	**1450**	**1750**
1.6	32	64	130	255	385	510	640	**770**	**1000**	**1300**	**1550**
1.5	28	56	115	225	340	450	565	**675**	**900**	**1150**	**1350**
1.4	25	49	98	195	295	390	490	**590**	**785**	**980**	**1200**
1.3	21	42	85	170	255	340	425	505	**675**	**845**	**1000**
1.2	18	36	72	145	215	290	360	430	**575**	**720**	**885**
1.1	15	30	61	120	180	240	305	365	485	**605**	**725**
1	13	25	50	100	150	200	250	300	400	500	**600**
0.9	10	20	41	81	120	160	205	245	325	405	485
0.8	8	16	32	64	96	130	160	190	255	320	385
0.7	6	12	25	49	74	98	125	145	195	245	295
0.6	5	9	18	36	54	72	90	110	145	180	215
0.5	3	6	13	25	38	50	63	75	100	125	150
0.4	2	4	8	16	24	32	40	48	64	80	96
0.3	1	2	5	9	14	18	23	27	36	45	54
0.2	1	1	2	4	6	8	10	12	16	20	24

Daily Exposure Duration

EXAMPLE USING THE EXPOSURE POINTS SYSTEM

A worker spends:

- one hour driving a grader to repair a dirt road, and
- then five hours ploughing a paddock.

The measured vibration magnitudes were greatest on the z-axis, that is, up and down for both activities.

Table 3 Calculations using the exposure points system

Activity	Measured vibration on highest axis m/s²	Exposure duration (hours)	Exposure Points
Grader – road repair	1.2 (z)	1	72
Tractor – ploughing	0.8 (z)	5	160
TOTAL			**232**

The worker's total exposure for the day is 232 points. This is above the exposure action value but below the exposure limit value. The business should take action to reduce the worker's exposure, for example by reducing the amount of time the worker spends ploughing, requiring lower speeds over rough areas of the paddock or making adjustments to the tractor's suspension seat. A combination of these is probably required to reduce the worker's exposure to below the exposure action value.

2 Based on the European Union's *Guide to good practice on Whole-Body Vibration (2006)*.

More information

- Safe Work Australia reports on vibration:
  - *Implementation and Effectiveness of the European Directive Relating to Vibration in the Workplace*
  - *National Hazard Exposure Worker Surveillance: Vibration exposure and the provision of vibration control measures in Australian Workplaces*
- European Union *Guide to good practice on Whole-Body Vibration (2006)*
- UK Health and Safety Executive:
  - HSE Information Sheet Whole-body Vibration in Agriculture AIS20 (revision)
  - Control back-pain risks from whole-body vibration - Advice for employers on the Control of Vibration at Work Regulations 2005 INDG 242
  - Drive away bad backs - Advice for mobile machine operators and drivers IND404
  - Whole-body vibration. Control of Vibration at Work Regulations 2005
- Web-based tools:
  - Web-based calculators are available which simplify the process of doing daily vibration exposure calculations
- Sources of emissions data:
  - Whole-Body Vibration Database - for English version please click on flag icon
  - ISPESL Physical Agents Portal
- Standards for measurement and assessment:
  - AS 2670.1-2001: *Evaluation of human exposure to whole-body vibration - General requirements*, and
  - AS 2670.1-2001/Amdt 1-2013 *Evaluation of human exposure to whole-body vibration - General requirements*
  - EN 14253:2003: *Mechanical vibration – Measurement and calculation of occupational exposure to whole-body vibration with reference to health - Practical guidance*

For further information see the Safe Work Australia website (www.swa.gov.au).