This Guide provides information for occupational hygienists, ergonomists and other professionals involved in the measurement and assessment of workplace vibration exposures from vibrating plant, in particular hand-held and hand-guided power tools. 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 hand-arm vibration in workplaces*
- *Managing risks of exposure to whole-body vibration in workplaces*, and
- *Measuring and assessing workplace exposure to whole-body vibration.*

What is hand-arm vibration?

Hand-arm vibration (HAV) is vibration transmitted to a person's hand and arm when using hand-held power tools. HAV can occur when using hand-guided plant like powered lawn-mowers and while holding materials being processed by plant. HAV is commonly experienced by people who use jack-hammers, chainsaws, grinders, drills, riveters and impact wrenches.

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 HAV 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 (vibration total value) and the daily exposure duration.

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

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

Measuring vibration levels

Measurement of HAV can be difficult and complex. When workers report symptoms like tingling and numbness after using vibrating tools it is likely their exposure to HAV is reaching a level which could lead to Hand-Arm Vibration Syndrome (HAVS). This may be an indicator of a HAV problem and controls should be put in place to eliminate or minimise exposure, so far as is reasonably practicable.

Assessment by a competent person may be needed if there is no information about the vibration emission of the tool, the tool is being used in an unusual way or if you are uncertain about the effectiveness of controls.

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

Exposure to HAV should be evaluated using the method in ISO 5349-1:2013: *Mechanical vibration – Measurement and evaluation of human exposure to hand-transmitted vibration – Part 1: General requirements*.

Detailed practical guidance on this is available in ISO 5349 2:2013: *Mechanical vibration – Measurement and evaluation of human exposure to hand-transmitted vibration – Part 2: Practical guidance for measurement at the workplace*.

While there is no Australian workplace exposure standard for HAV, it is useful to make a comparison to an accepted standard in order to work out how much HAV exposure is likely to pose a risk. This can be done using the daily vibration exposure A(8).

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

Table 1 EU Directive

Exposure action value and exposure limit value for HAV 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 2.5 m/s^2 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 5.0 m/s^2.

EXPOSURE TO HAND-ARM VIBRATION

Daily vibration exposure A(8)

Exposure to HAV depends on both the magnitude (intensity) of vibration expressed as acceleration in metres per second squared (m/s^2) and the duration of exposure.

The daily vibration exposure A(8) for a worker carrying out one process or operating one tool can be calculated from magnitude and exposure duration using the equation:

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

where:

- a_{hv} is the vibration magnitude (in m/s^2)

- T is the actual duration of exposure – trigger time to the vibration magnitude a_{hv}, and

- T_0 is the reference duration of eight hours.

Like vibration magnitude, the daily vibration exposure has units of metres per second squared (m/s^2).

The duration of exposure or trigger time is the time the hands and arms are actually exposed to the vibration from the tool or work piece. The trigger time is often much shorter than the overall time on the job and is usually over-estimated by workers. The method used for estimating trigger times often depends on whether the tool usage is continuous or intermittent.

The value of a_{hv} 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 HAV, then partial vibration exposures are calculated from the magnitude and duration for each source.

The overall daily vibration exposure can be calculated from the partial vibration exposure values using the equation:

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

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

An easy way of working out the daily vibration exposure and comparing it to the exposure action value and exposure limit value is to use the exposure points system (see Table 3). This system can be used regardless of the source of the vibration magnitude.

Adjustment for extended working days

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

Uncertainty in assessment of exposure

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

There are a number of ways to estimate the daily vibration exposure A(8) based on data available from manufacturers or other sources.

Measurement axes

For HAV the triaxial sum of the acceleration experienced by the worker in the three axes (x, y and z) as shown in Figure 1, is used in calculating the daily vibration exposure A(8).

This is different from whole-body vibration (WBV) where the axis with the highest average root mean square acceleration is used in the calculation.

Figure 1 Measurement axes for HAV
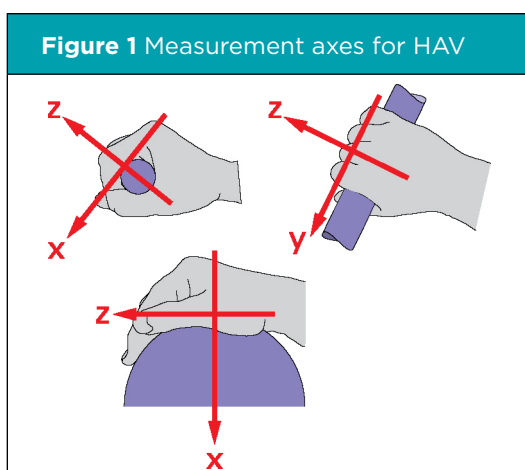
Sources of information on emission values

Manufacturers, importers and suppliers of tools should be able to provide information on vibration emissions. This may be in the information or instructions accompanying the tools or on the manufacturer's website. Declaration of vibration emission values is not mandatory in Australia but manufacturers who supply tools to the European market may be able to supply this information.

Declared emission values allow purchasers to compare tools tested to the same standardised test code. The emission values can help when there are large differences between tools so high-vibration tools can be avoided.

When considering the vibration emitted by a tool during a specific task, try to find data which is measured while carrying out the same task as your intended use. This data will provide a better guide to the levels likely to be found in practice when the task is performed in your workplace.

If a manufacturer declares an emission value of less than 2.5 m/s² then a value of 2.5 m/s² should be used.

Other sources of information on vibration magnitudes include:

- trade associations or equivalent
- online international vibration databases which may be suitable for an initial vibration risk assessment
- specialist vibration consultants, and
- government bodies.

Table 2 provides examples of vibration magnitudes measured by the Health and Safety Executive (HSE) UK.

Table 2 Examples of vibration magnitudes

Class of plant	Type of plant	Vibration magnitude
Road breakers	Typical	12 m/s²
	Modern tool designs, good operating conditions and trained operators	5 m/s²
	Worst tools and operating conditions	20 m/s²
Demolition hammers	Modern tools	8 m/s²
	Typical	15 m/s²
	Worst tools	25 m/s²
Hammer drills/combi hammers	Typical	9 m/s²
	Best tools and operating conditions	6 m/s²
	Worst tools and operating conditions	25 m/s²
Needle scalers	Modern tool designs	5-7 m/s²
	Older tool designs	10-25 m/s²
Scabblers (hammer type)	Typical	20-40 m/s²
Angle grinders (large)	Modern vibration-reduced designs	4 m/s²
	Other types	8 m/s²
Angle grinders (small)	Typical	2-6 m/s²
Clay spades/jigger picks	Typical	16 m/s²
Chipping hammers (metal-working, foundries)	Typical fettling	18 m/s²
	Modern tool designs	10 m/s²
Pneumatic stone-working hammers	Vibration-reduced hammers and sleeved chisels	8-12 m/s2
	Older tools, conventional chisels	30 m/s²
Chainsaws	Typical	6 m/s²
Brushcutters	Typical	4 m/s²
	Best	2 m/s²
Sanders (random orbital)	Typical	7-10 m/s²

Daily vibration exposure A(8) using the exposure points system

A simple method of determining vibration exposure is the use of a points based system. The exposure scores corresponding to the exposure action value and exposure limit value are in Table 3.

The exposure action value of 2.5 m/s^2 is assigned 100 exposure points and the exposure limit value of 5 m/s^2 is assigned a value of 400 points for an eight hour exposure.

Where the vibration exposure point is:

■ Between the exposure action value and the exposure limit values (yellow and orange) monitoring is required to ensure controls remain appropriate so the exposure limit value is not passed.

■ Greater than the action limit value (red) then controls must be implemented to ensure workers are not exposed under any circumstances.

Table 3 Exposure points - Ready Reckoner

Vibration magnitude m/s^2	15m	30m	1h	2h	3h	4h	5h	6h	8h	10h
40	800									
30	450	900								
25	315	625	1250							
20	200	400	800							
19	180	360	720	1450						
18	160	325	650	1300						
17	145	290	580	1150						
16	130	255	510	1000						
15	115	225	450	900	1350					
14	98	195	390	785	1200					
13	85	170	340	675	1000	1350				
12	72	145	290	575	865	1150	1450			
11	61	120	240	485	725	970	1200	1450		
10	50	100	200	400	600	800	1000	1200		
9	41	81	160	325	485	650	810	970	1300	
8	32	64	130	255	385	510	640	770	1000	1200
7	25	49	98	195	295	390	490	590	785	865
6	18	36	72	145	215	290	360	430	575	720
5.5	15	30	61	120	180	240	305	365	485	605
5	13	25	50	100	150	200	250	300	400	500
4.5	10	20	41	81	120	160	205	245	325	405
4	8	16	32	64	96	130	160	190	255	320
3.5	6	12	25	49	74	98	125	145	195	245
3	5	9	18	36	54	72	90	110	145	180
2.5	3	6	13	25	38	50	63	75	100	125
2	2	4	8	16	24	32	40	48	64	80
1.5	1	2	5	9	14	18	23	27	36	45
1	1	1	2	4	6	8	10	12	16	20
	15m	30m	1h	2h	3h	4h	5h	6h	8h	10h

Daily exposure time

EXAMPLES USING THE EXPOSURE POINTS SYSTEM

Example 1

An exposure to a vibration magnitude of 7 m/s^2 for 15 minutes while using a hammer drill results in 25 points. Use of an angle grinder with a vibration magnitude of 6 m/s^2 for one hour results in 72 points.

If these were the only exposures for the day the worker would have a total exposure of 97 points, which is under the exposure action value (100 points). No further action is required unless the worker reports discomfort or shows signs of injury, where reasonably practicable steps could be taken to reduce exposure.

This example is reproduced in Table 4.

Table 4 Example 1

Activity	Vibration Magnitude (m/s^2)	Exposure time (min)	Exposure Points
Hammer drill	7	15	25
Angle grinder	6	60	72
TOTAL			*97*

Example 2

An exposure to a vibration magnitude of 12 m/s^2 for three hours while using a jack-hammer results in 865 points.

This is over double the recommended exposure limit value of 400 points (5 m/s^2 A(8)).

Options include substituting the jack-hammer with a breaker attached to mobile plant. If not reasonably practicable, another option would be to use a more modern, better designed jack-hammer and train the operator on correct techniques. This could reduce the vibration magnitude to around 6 m/s^2, reducing the exposure points for this activity from 865 to 215 which is below the exposure limit value.

Job rotation reducing exposure time from three hours for one worker to one hour each for three workers is not as effective. The exposure is still 290 points per worker for this activity.

Both control options result in exposures above the action value (100 points) so monitoring is required to ensure exposures do not creep upwards.

Table 5 shows the exposure point values for the different control options.

Table 5 Example 2

|	Activity	Vibration magnitude (m/s^2)	Exposure time (hrs)	Exposure Points
	Road breaker (jack-hammer)	12	3	865
Control Option 1 – reduce vibration magnitude	Road breaker (jack-hammer)	6	3	215
Control Option 2 – reduce exposure time	Road breaker (jack-hammer)	12	1	*290*

Daily vibration exposure A(8) – an alternative method of calculation

The graph in Figure 2 provides another method of working out daily vibration exposures.

To use the graph draw a line horizontally from the point on the left hand scale representing the vibration magnitude and another from the point on the bottom scale representing the exposure time. Where they intersect is the daily vibration exposure for the activity.

For example, a tool emitting a vibration magnitude of 4 m/s^2 and used by a worker for 30 minutes per day gives a daily exposure A(8) of 1 m/s^2. If the same tool is used for 4 hours and 30 minutes per day the daily vibration exposure A(8) would be 3 m/s^2. Therefore control measures would be required as this is above the action value (2.5 m/s^2).

Figure 2 Graph for determining daily vibration exposure A(8) from vibration magnitude and exposure time
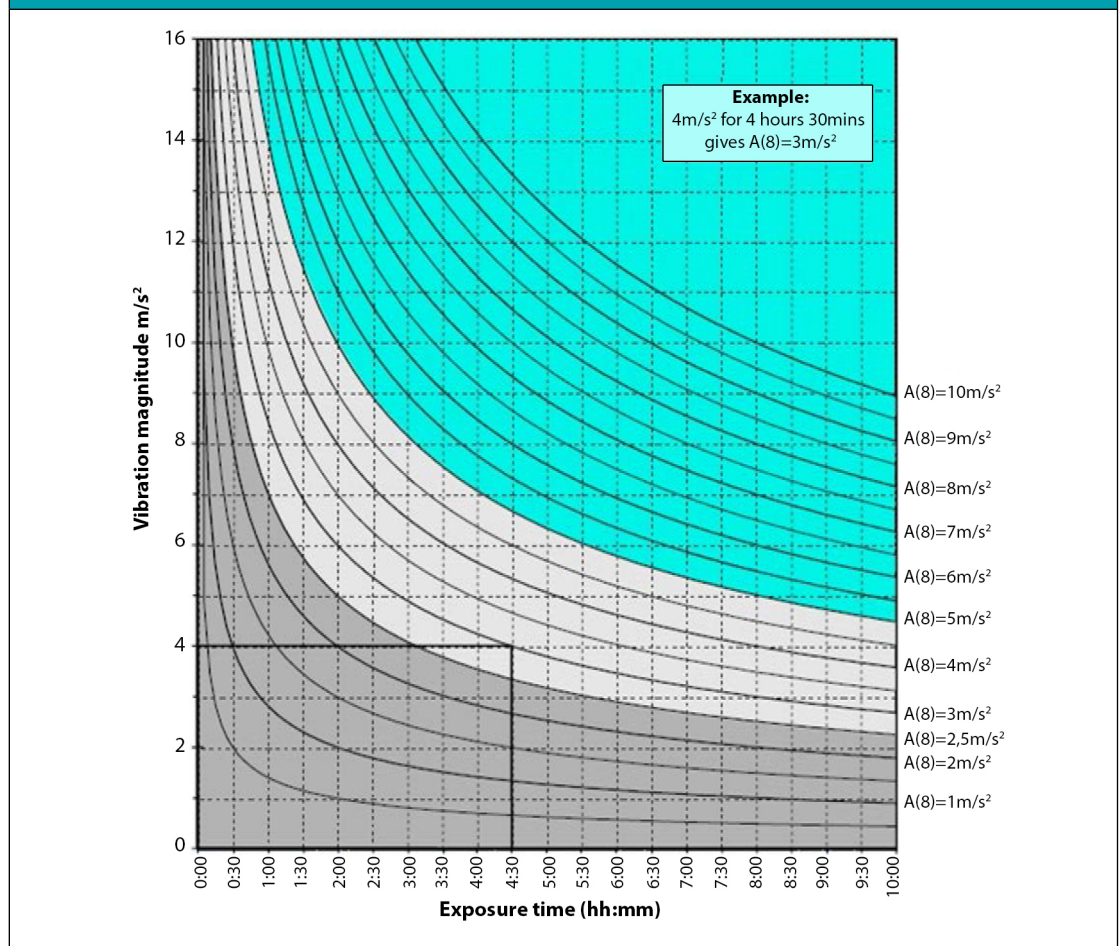
Working out the total daily vibration exposure A(8) where more than one item of plant is used is more complicated using this graph than using the exposure points system shown in Table 1. Individual vibration exposures from each tool need to be:

- squared
- added together, and
- the square root of the total taken as described above in the section on daily vibration exposure A(8).

In Example 1 from Table 3 above:

- A(8) from the hammer drill = 1
- A(8) from the angle grinder = 2.25
- $1^2 + 2.25^2 = 6.06$, and
- the square root of 6.06 = 2.46 m/s^2 A(8).

This is below the action value. No further action is required.

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*
- Calculating HAV exposure - Health and Safety Executive (UK):
  - *Ready Reckoner* using the exposure points system
  - *Exposure calculator*
- Sources of emissions data:
  - *Hire Association Europe* – navigate to Support >> HAV
  - *Hand-Arm Vibration Database* - for English version please click on flag icon
  - *NIOSH power tools database*
- Standards for measurement and assessment:
  - AS ISO 5349-1:2013: *Mechanical vibration - Measurement and evaluation of human exposure to hand-transmitted vibration - Part 1: General requirements*, and
  - AS ISO 5349-2:2013 *Mechanical vibration - Measurement and evaluation of human exposure to hand-transmitted vibration - Part 2: Practical guidance for measurement at the workplace*

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