Guide to good practice on

Hand-Arm Vibration

Non-binding guide to good practice with a view to implementation of Directive 2002/44/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibrations).

CONTENTS

FOREWORD

Directive 2002/44/EC of the European Parliament and of the Council on the exposure of workers to the risks arising from physical agents (vibration) seeks to introduce, at Community level, minimum protection requirements for workers when they are exposed, in the course of their work, to risks arising from vibration.

Directive 2002/44/EC gives ‘exposure limit values’ and ‘exposure action values’. It also specifies employers' obligations with regard to determining and assessing risks, sets out the measures to be taken to reduce or avoid exposure and details how to provide information and training for workers. Any employer who intends to carry out work involving risks arising from exposure to vibration must implement a series of protection measures before and during the work. The Directive also requires the Member States of the EU to put in place a suitable system for monitoring the health of workers exposed to risks arising from vibration.

The evaluation and assessment of risks arising from exposure to vibration and the implementation of protection measures can be complicated. This non-binding "guide to good practice" will facilitate the assessment of risks from exposure to hand-arm vibration, the identification of controls to eliminate or reduce exposure, and the introduction of systems to prevent the development and progression of injury.

This guide on hand-arm vibration, together with its companion guide on whole-body vibration (Whole-body vibration non-binding guide to good practice with a view to implementation of Directive 2002/44/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibrations)), has been prepared under contract VC/2004/0341 for the European Commission Directorate General Employment, Social Affairs and Equal Opportunities.

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CHAPTER 1 INTRODUCTION

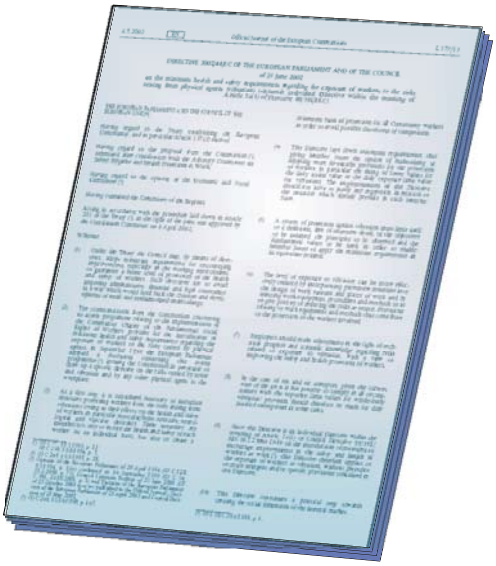
EU Directive 2002/44/EC (the 'Vibration Directive') places responsibilities on employers to ensure that risks from hand-arm vibration are eliminated or reduced to a minimum (these responsibilities are summarised in Annex A).

This guide is intended to help employers identify hand-arm vibration hazards, assess exposures and risks and identify measures for safeguarding the health and safety of workers exposed to hand-arm vibration risks.

The guide should be read in conjunction with the Vibration Directive or national legislation based on the requirements of that Directive.

Hand-arm vibration is caused by vibration transmitted into the hand and arms through the palm and fingers (see Annex B). Workers whose hands are regularly exposed to hand-arm vibration may suffer from damage to the tissues of the hands and arms, which cause the symptoms collectively known as hand-arm vibration syndrome, see Annex C.

The risks from hand-arm vibration affect people across many industries and occupations. The risks are greatly increased with use of higher vibration equipment and with prolonged and regular use of the equipment. However, investigations have shown that vibration hazards can be controlled and risks reduced by good management. They have also shown that the costs of such controls need not be high and can usually be offset by the benefits of keeping workers healthy. Additionally, the vibration control measures have, in many cases, led to improved efficiency.



The 'Vibration Directive' (Directive 2002/44/EC - see "Further reading" box) sets minimum standards for controlling the risks from hand-arm vibration. The Vibration Directive requires that member states of the European Union implement national legislation to implement the requirements of the Directive by 6th July 2005. National legislation may apply more favourable provisions than those required by the Directive, and should not reduce the protection afforded to workers by any pre-existing national legislation.

The Vibration Directive sets an exposure action value for daily vibration exposure, above which it requires employers to control the hand-arm vibration risks of their workforce and an exposure limit value above which workers must not be exposed[1]:

- a daily exposure action value of 2.5 m/s²
- a daily exposure limit value of 5 m/s².

However, there is some risk of hand-arm vibration injury where exposures are below the exposure action value. The Vibration Directive places responsibilities on employers to ensure that risks from hand-arm vibration are eliminated or reduced to a minimum. These responsibilities are summarised in Annex A.

The Vibration Directive is a daughter Directive of the Framework Directive (Directive 89/391/EEC - see "Further reading" box) as such many of the requirements of the Vibration Directive are derived from, and make specific reference to, the Framework Directive.

This guide will help employers comply with the Vibration Directive as it applies to hand-arm vibration. The guide is intended to cover the methodology used for determining and evaluating risks; dealing with the choice and correct use of work equipment, the optimisation of methods and the implementation of protection measures (technical and/or organisational measures) on the basis of a prior risk analysis. This guide also gives details of the type of training and information to be provided to the workers concerned and proposes effective solutions for the other matters raised in Directive 2002/44/EC. The structure for this guide is shown in the flow diagram of Figure 1.

Further reading:
Vibration Directive: Directive 2002/44/EC 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).* ***Framework Directive:*** Directive of 89/391/EEC of the European parliament and of the Council of 12 June 1989 *on the introduction of measures to encourage improvements in the safety and health of workers at work.*

[1] Member states are entitled (after consultation with the two sides of industry) to apply transitional periods to the exposure limit value for a period of 5 years from 6th July 2005 (Member States are entitled to extend this period for a further 4 years for agricultural and forestry machinery). The transitional periods only apply to the use of machinery supplied prior to 6th July 2007 for which (taking into account all available technical or organisational means to control the risk) the exposure limit value cannot be respected.

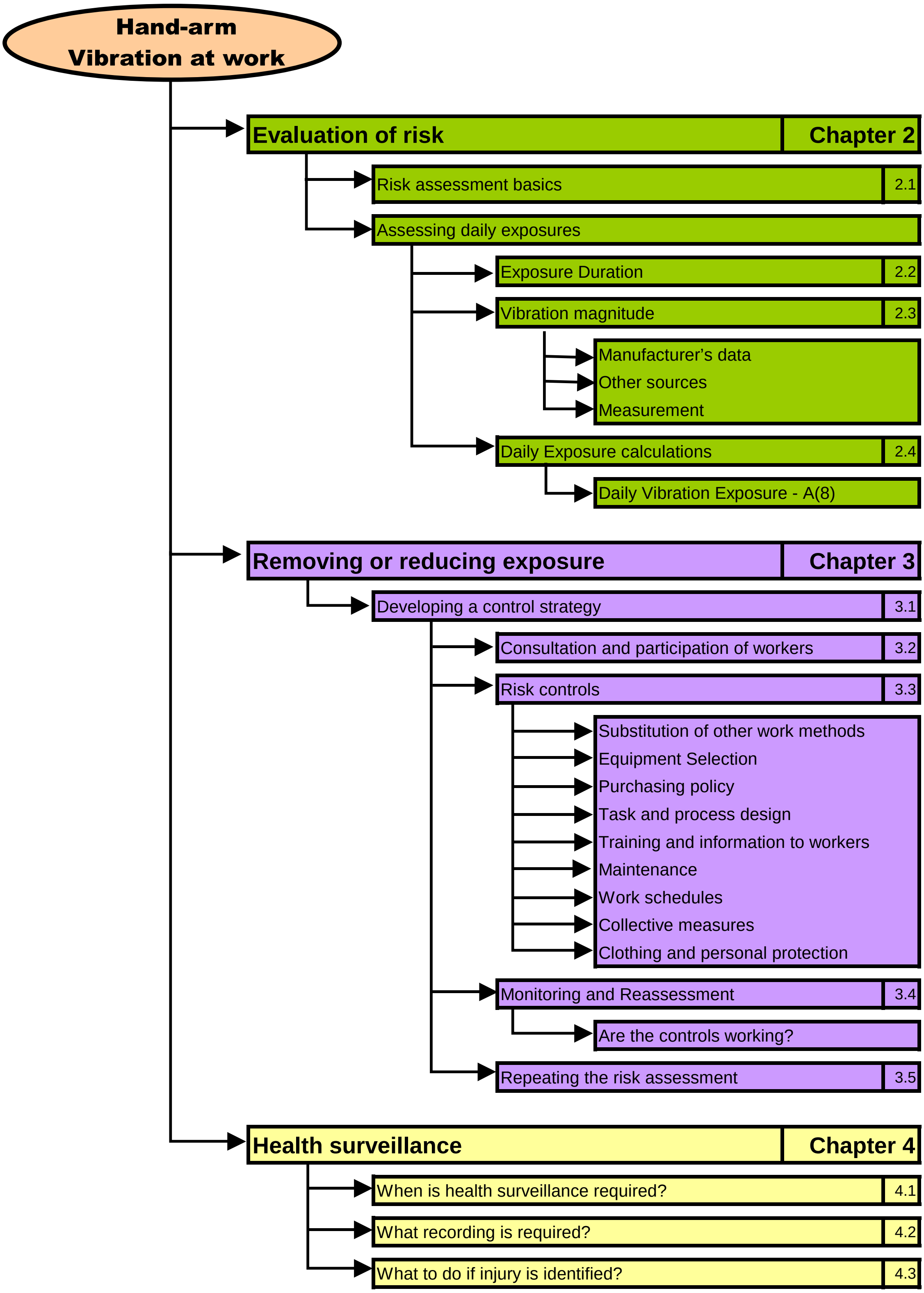


Figure 1 Hand-arm vibration flow diagram

CHAPTER 2 EVALUATION OF RISK

The purpose of the hand-arm vibration risk assessment is to enable you as the employer to make a valid decision about the measures necessary to prevent or adequately control the risks from exposure of workers to hand-arm vibration.

In this chapter we show how you can decide whether you may have a problem with hand-arm vibration exposures in your workplace without the need for measurement or any detailed knowledge of exposure assessment

2.1 The basics of risk assessment

The risk assessment should:

- identify where there may be a risk from hand-arm vibration;
- estimate workers' exposures and compare them with the exposure action value and exposure limit value;
- identify the available risk controls;
- identify the steps you plan to take to control and monitor hand-arm vibration risks; and
- record the assessment, the steps that have been taken and their effectiveness.

A starting point is to consider the work being carried out, the processes involved and the tools and equipment used, and ask: "Does your business use hand-held, hand-guided or handfed powered equipment?" If so, you may need to manage exposures to vibration. Some questions to help you decide whether further action is required are shown in Table 1. Figure 2, shows sample vibration magnitudes of some of the tools and machines that create the risks.

It is important to keep workers and their representatives involved and informed in the assessment of vibration risk. An effective partnership with workers will help to ensure the information used for the risk assessment is based on realistic assessments of the work being carried out and the time taken to do that work.

The factors that govern a person's daily vibration exposure are the frequency-weighted magnitude (level) of vibration and the length of time the person is exposed to it. The greater the magnitude or the longer the duration of exposure, the greater will be the person's vibration exposure.

Table 1 Some questions to help decide whether further action is needed

Do you use rotary action tools (e.g. grinders, polishers)?

Some rotary action tools can exceed the exposure action value within about half an hour, and you should certainly be taking action if individual workers are using them for more than about 2 hours per day.

Do you use impact or percussive tools (i.e. hammer-action tools)?

With impact or percussive tools the levels of vibration are likely to be much higher than rotary tools. Some hammer action tools can exceed the exposure action value within a few minutes, and you should certainly be taking action if individual workers are using them for more than about half an hour per day.

Do the manufacturers or suppliers of your tools warn of a risk from vibration?

If you are using hand-held power tools that may put the users at risk of vibration injury, the manufacturer should warn you about it in the handbook.

Do any vibrating tools cause tingling or numbness in the hands during or after use?

Tingling or numbness of the hands may be noticeable during or after use of a power tool and is an indicator of hand-arm vibration risk from long-term tool use.

Have any vibration-exposed workers already reported symptoms of hand-arm vibration syndrome?

Evidence of hand-arm vibration syndrome means that vibration exposures need to be managed. Where symptoms are linked to exposures that are below the action value, it may identify workers who are particularly susceptible to hand-arm vibration risks.

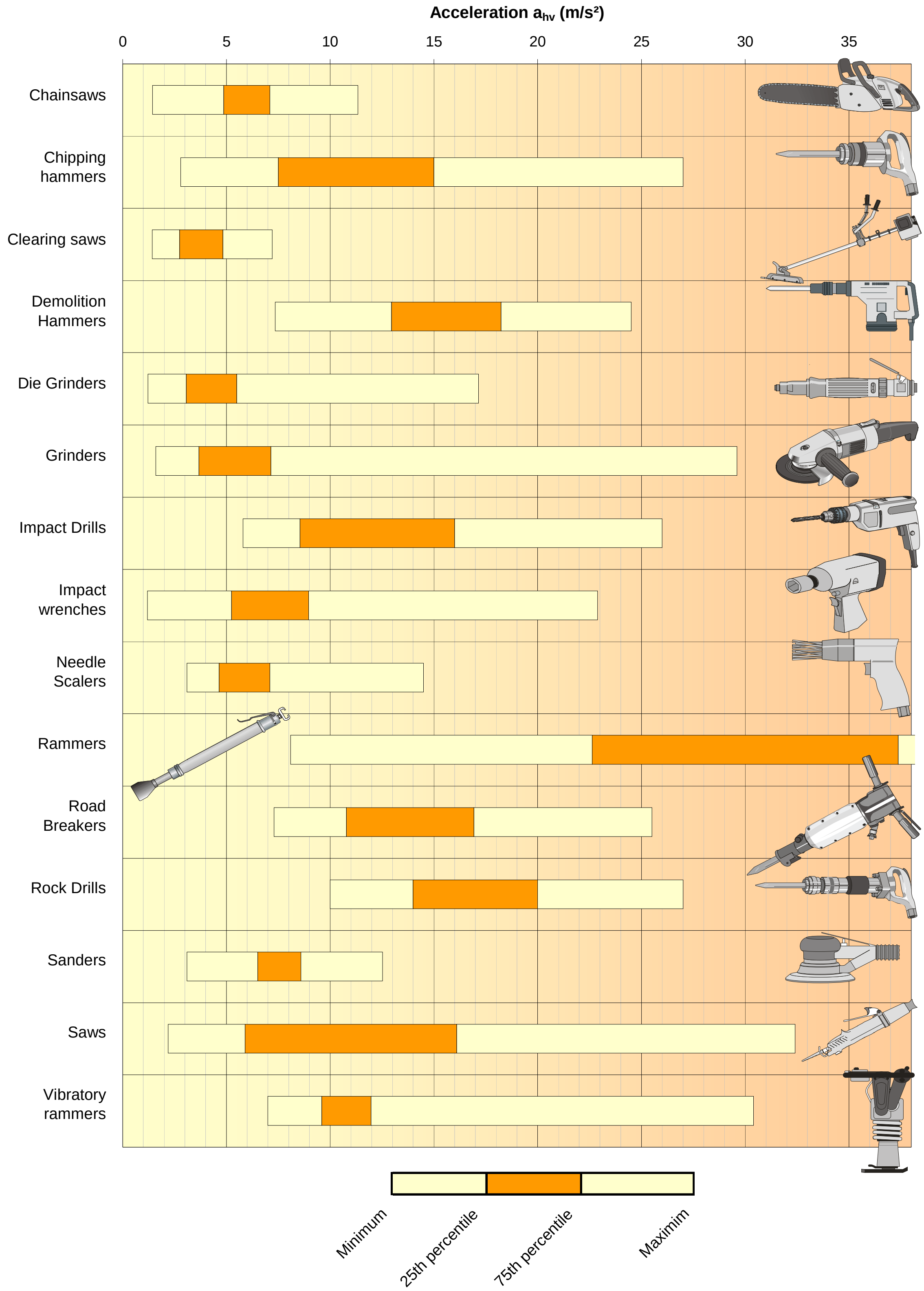
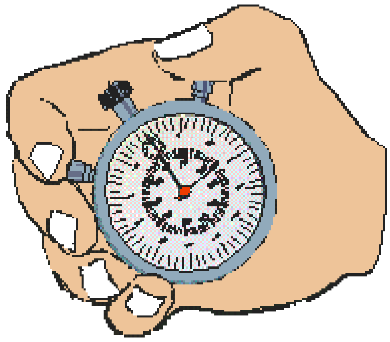


Figure 2 Examples of vibration magnitudes for common tools

Ranges of vibration values for common equipment on the EU market. These data are for illustration only. For more details see Annex B.

2.2 Determining exposure duration



To assess the daily vibration exposure an estimate is required of the time that the tool operators are exposed to the vibration. Experience has shown that this is often overestimated during the risk assessment.

In this chapter we look at what exposure time information is needed and how it can be determined.

Before the *daily vibration exposure*, *A*(8), can be estimated, you need to know the total daily duration of exposure to the vibration from each tool or process being used. You should be careful to count only the time that the worker is exposed to vibration; a period when a worker has put the equipment down or is holding it but not operating it should not be counted.

The contact time or trigger time is the time that the hands are actually exposed to the vibration from the tool or workpiece. The trigger time is often very much shorter than the overall "time on the job" and is usually over-estimated by operators. The method used for estimating trigger times often depends on whether the tool usage is continuous or intermittent:

Continuous tool operation:

> Example: the use of a grinder to remove large amounts of material over several hours.
>
> Observe work during a representative part of the working day and record how much of the time the tool is operating. A stopwatch or video recording can be useful for this.

Intermittent tool operation:

> Example: Use of impact wrench to tighten wheel-nuts on vehicles.
>
> You may have access to information on the number of operations that occur during the working day (e.g. the number of components completed per day). If an average duration for an operation is estimated by observing the work rate over a sample work period then the total daily duration can be calculated.
>
> For our example of an impact wrench, you may know the number of wheels removed and replaced per day and the number of wheel-nuts per wheel, you will also need to know how long it typically takes to remove or replace one wheel-nut.

Work patterns also need careful consideration. For example some workers may only use vibrating tools for certain periods in a day or week. Typical usage patterns should be established, as these will be an important factor in calculating a person's likely vibration exposure.

Further reading:
EN ISO 5349-2:2001 Mechanical vibration — Measurement and evaluation of human exposure to hand-transmitted vibration. Part 2: Practical guidance for measurement at the workplace CEN/TR 15350 Mechanical vibration — Guideline for the assessment of exposure to hand-transmitted vibration using available information including that provided by manufacturers of machinery

2.3 Vibration magnitude

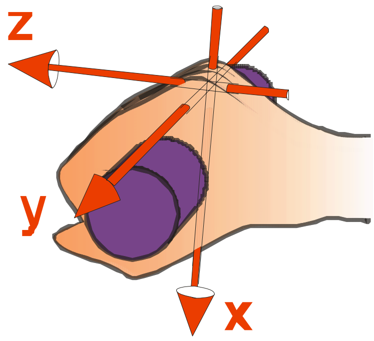
Hand-arm vibration risk is based on the frequency-weighted acceleration total value a_{hv}, given by the root-sum-of-squares of the frequency-weighted acceleration from the three orthogonal axes, x, y and z:

$$a_{hv} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2}$$

The value is assessed at the point where the vibration enters the hand (see Annex B).

The vibration information you use to do your vibration assessment needs to match as closely as possible the likely vibration emissions of the equipment you plan to use in the way you plan to use it.

In this chapter we look at how vibration can be estimated from manufacturer's data, other published data sources and from workplace measurement.



2.3.1 Use of manufacturer's emission data

The European "Machinery Directive" (Directive 98/37/EC) defines essential health and safety requirements for machinery supplied within the European Union, including specific requirements regarding vibration.

Amongst other requirements, the Machinery Directive requires manufacturers, importers and suppliers of machines to provide information on vibration emissions at the hand. This vibration emission information should be given in the information or instructions that accompany the machine.

Manufacturer's *declared vibration emission* values are usually obtained according to harmonised European vibration test codes produced by European or International standards bodies, and (from 2005) these are based on EN ISO 20643. Examples are the EN ISO 8662 series for pneumatic and other non-electric tools and the EN 60745 series for electric tools.

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

Emission data from manufacturers can also tell you how much vibration is likely to enter a person's hands when using a particular power tool. This may be useful to help make an estimate of daily exposure and an assessment of risk.

At present, the vibration test codes tend to under-estimate the vibration of tools when they are being used in the workplace, and are usually based on measurements in a single vibration axis. CEN/TR 15350 advises that for estimating risk, the manufacturer's declared emission value should in most cases be multiplied by a factor depending on the type of tool:

Combustion engine tools:	$\times 1$
Pneumatic tools:	$\times 1.5$ to $\times 2$
Electric tools:	$\times 1.5$ to $\times 2$

Where manufacturers declare emission values less than 2.5m/s², then a value of 2.5m/s² should be used and multiplied by the appropriate factor.

More information on these multiplication factors is given in CEN/TR 15350. Where there is no better information and a range of multiplying factors is given, the higher value should be used.

Many harmonised European vibration test codes are currently (in 2005) under review The revised test codes should result in improved emission values that will not be directly comparable with older emission data, but should provide a more accurate guide to the vibration experienced in the workplace.

Further reading:
EN 12096:1997 Mechanical vibration — Declaration and verification of vibration emission values EN ISO 20643:2005 Mechanical vibration — Hand-held and hand-guided machinery. Principles for evaluation of vibration emission CEN/TR 15350: 2005 Mechanical vibration — Guideline for the assessment of exposure to hand-transmitted vibration using available information including that provided by manufacturers of machinery

2.3.2 Use of other data sources

There are other sources of information on vibration magnitudes, which are often sufficient to allow you to decide whether the exposure action value or the exposure limit value is likely to be exceeded.

Your trade association or equivalent may also have useful vibration data and there are international vibration databases on the Internet, which may meet your needs. This may be suitable for some employers to do an initial vibration risk assessment.

Other sources of vibration data include specialist vibration consultants and government bodies. Some data can also be found in various technical or scientific publications and on the Internet and some data on typical real-use vibration may be available on manufacturer's web sites. Two European websites that hold manufacturers' standard vibration emission data along with some values measured in "real use" for a range of machines are:

http://vibration.arbetslivsinstitutet.se/eng/havhome.lasso

http://www.las-bb.de/karla/index_.htm

Ideally you should use vibration information for the equipment (make and model) you plan to use. However, if this is not available you may need to use information relating to similar equipment as a starting point, replacing the data with more accurate values when this becomes available.

When choosing published vibration information the factors you need to take account of in making your choice include:

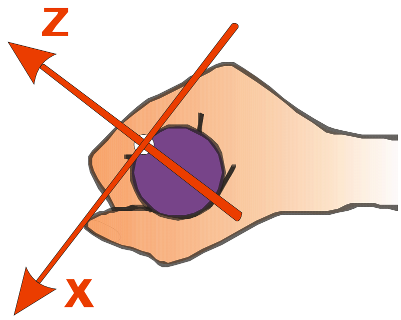
- the type of equipment (e.g. road breaker),
- the class of equipment (e.g. power or size),
- the power source (e.g. pneumatic, hydraulic, electric or combustion engine)
- any anti-vibration features (e.g. suspended handles),
- the task the equipment was used for when producing the vibration information,
- the speed at which it was operated,
- the type of material on which it was used.

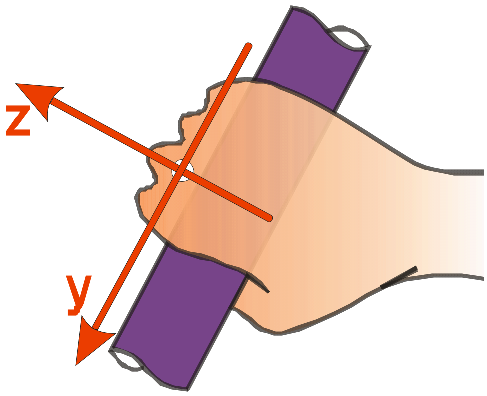
When using published vibration data it is good practice to try to compare data from two or more sources.

2.3.3 Measurement of vibration magnitude

In many situations it will not be necessary to measure vibration magnitudes. However, it is important to know when to conduct measurements.

In this chapter we look what how and where vibration is measured and how measurements are reported.





Sometimes it may not be possible to obtain adequate information (from equipment suppliers or other sources) on the vibration produced by a tool or work process. It may then be necessary to make measurements of vibration in the workplace.

Vibration measurement is a difficult and complex task. You may choose to make the measurements in-house, or to employ a specialist consultant. In either case, it is important that whoever makes the measurements has sufficient competence and experience.

What is measured?

Human exposure to hand-arm vibration should be evaluated using the method defined in European Standard EN ISO 5349-1:2001 and detailed practical guidance on using the method for measurement of vibration at the workplace is given in EN ISO 5349-2:2001.

The vibration magnitude is expressed in terms of the frequency-weighted acceleration of the surface of the tool-handle or workpiece that is in contact with the hand (see Annex B) it is expressed in units of metres per second squared (m/s^2).

Making vibration measurements

Measurements should be made to produce vibration values that are representative of the average vibration for a tool or process throughout the operator's working period. It is therefore important that the operating conditions and measurement periods are selected to achieve this.

Where tools are held in both hands, measurements must be made at both hand positions and the highest value used for determining vibration exposure.

Further reading:
EN ISO 5349-1:2001 Mechanical vibration — Measurement and evaluation of human exposure to hand-transmitted vibration — Part 1: General requirements EN ISO 5349-2:2001 Mechanical vibration — Measurement and evaluation of human exposure to hand-transmitted vibration — Part 2: Practical guidance for measurement at the workplace

2.4 Calculating daily vibration exposures

A daily vibration exposure assessment depends on both the level of vibration and the duration of exposure.

In this chapter we look at how daily vibration exposure is calculated from vibration magnitude information and exposure times.

Some tools for simplifying the calculation of daily exposures and managing exposure times are given in Annex D and worked examples of calculating daily vibration exposures are given in Annex E.

2.4.1 Daily Vibration Exposure

The *daily vibration exposure*, *A*(8), is calculated from a magnitude and exposure time. Like the vibration magnitude, the daily vibration exposure has units of metres per second squared (m/s²). Examples of the calculation of daily vibration exposures are given in Annex E

2.4.2 Partial Vibration Exposures

If a person is exposed to more than one source of vibration (perhaps because they use two or more different tools or processes during the day) then the *partial vibration exposures* are calculated from the magnitude and duration for each one. The partial vibration values are combined to give the overall daily exposure value, *A*(8), for that person. An example of the calculation of daily vibration exposures is given in Annex E

Each partial vibration exposure represents the contribution of a particular source of vibration (tool or process) to the worker's total daily exposure. Knowledge of the partial exposure values will help you decide on your priorities: the tools or processes with the highest partial vibration exposure values are those that should be given priority for control measures.

2.4.3 Uncertainty of daily exposure evaluations

The uncertainty of vibration exposure evaluation is dependent on many factors, see EN ISO 5349-2:2001, including:

- Instrument / calibration uncertainty,

- Accuracy of source data (e.g. manufacturer's emission data),
- Variation of machine operators (e.g. experience, operating technique or physique),
- Ability of the worker to reproduce typical work during measurements,
- Repeatability of the work task,
- Environmental factors (e.g. noise, temperature),
- Variations in the machine (e.g. is there a need for maintenance, has the machine been warmed-up?).
- Wear of inserted components or abrasives (e.g. is the saw-blade sharp, is the abrasive disc worn?)

Where vibration magnitude and exposure time are measured the uncertainties associated with the evaluation of $A(8)$ can mean that the calculated value can be as much as much 20% above the true value to 40% below. Where either the exposure time or the vibration magnitude is estimated — e.g. based on information from the worker (exposure time) or manufacturer (magnitude) — then the uncertainty in the evaluation of daily exposure can be much higher.

Further reading:
EN ISO 5349-2:2001 Mechanical vibration — Measurement and evaluation of human exposure to hand-transmitted vibration — Part 2: Practical guidance for measurement at the workplace

CHAPTER 3 REMOVING OR REDUCING EXPOSURE

Your risk assessment will help you plan the measures necessary to prevent or adequately control the exposure of workers to hand-arm vibration.

In this chapter we show how you can develop a control strategy, prioritise your control activities, implement risk controls and monitor the effectiveness of those controls.

3.1 Developing a control strategy

To control risk you must have a strategy that can effectively deliver reduced exposure to hand-arm vibration.

In this chapter we look at the process of developing a control strategy, including how to prioritise your control activities.

Your risk assessment should enable methods for controlling exposure to be identified. While you are assessing the vibration exposures, you should be thinking about the work processes that cause them. Understanding why workers are exposed to vibration will help identify methods for reducing or eliminating them.

The important stages in this management process are:

- identifying the chief sources of vibration,
- ranking them in terms of their contribution to the risk,
- identifying and evaluating potential solutions in terms of practicability and cost,
- establishing targets which can be realistically achieved.
- allocating priorities and establishing an 'action programme';
- defining management responsibilities and allocating adequate resources;
- implementing the programme;
- monitoring progress;
- evaluating the programme.

The approach you take to reduce risks from hand-arm vibration will depend on the practical aspects of your particular processes and on the current levels of exposure.

Example: use of partial vibration exposure to rank risks

A steel worker uses two tools, a grinder with an in-use vibration emission of 7m/s² and a chipping hammer with an in-use emission of 16m/s². The grinder is used for a total of 2½ hours per day, the chipping hammer for 15 minutes:

- Grinder (*7 m/s² for 2½ hours*): $A_1(8)$ = 3.9 m/s²
- Chipping hammer (*16 m/s² for 15 minutes*): $A_2(8)$ = 2.8 m/s²

Total exposure: ***A*(8) = 4.8 m/s**

Although the chipping hammer has a greater vibration magnitude than the grinder, the partial exposure values show that the use of the grinder accounts for the greater proportion of the worker's overall vibration exposure. Therefore, initially, the grinder should be the main focus for risk reduction.

You may also need to adapt your controls for workers who are at particular risk of injury, e.g. those workers who are more susceptible to vibration injury and show signs of developing injury at exposures below the exposure action value.

The Framework Directive provides the following hierarchy for implementing a programme of preventative measures:

1. avoiding risks;
2. evaluating the risks which cannot be avoided:
3. combating the risks at source;
4. adapting the work to the individual, especially as regards the design of work places, the choice of work equipment and the choice of working and production methods, with a view, in particular, to alleviating monotonous work and work at a predetermined work-rate and to reducing their effect on health.
5. adapting to technical progress;
6. replacing the dangerous by the non-dangerous or the less dangerous;
7. developing a coherent overall prevention policy which covers technology, organization of work, working conditions, social relationships and the influence of factors related to the working environment;
8. giving collective protective measures priority over individual protective measures;
9. giving appropriate instructions to the workers.

3.2 Consultation and Participation of Workers

The successful management of risks relies on the support and involvement of workers, and in particular their representatives. Representatives can provide an effective channel of communication with the workforce and assist workers in understanding and using health and safety information.

While some hand-arm vibration control solutions will be quite straightforward, others will require changes to the way in which work is organised. Such changes can only be effectively dealt with in consultation with workplace representatives.

Effective consultation relies on:

- the sharing of relevant information about health and safety measures with workers;
- workers being given the opportunity to express their views and to contribute in a timely fashion to the resolution of health and safety issues;
- the views of workers being valued and taken into account

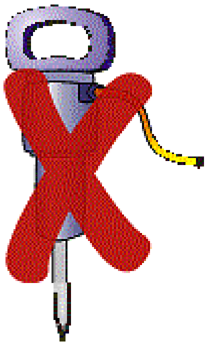
Consultation can result in better control solutions being identified that are well understood by the workers. You will be relying on workers to make the control measures effective. Subject to adequate training and supervision, workers have a duty to make correct use of machinery and to cooperate with the employer to enable them to ensure that their environment and working conditions are safe, such that risks to safety and health are minimised and where possible eliminated. The process of consultation encourages worker involvement and co-operation with control measures and so ensures that controls are more likely to be successfully implemented.

3.3 Risk controls

To control risk you must remove or reduce exposure to hand-arm vibration. It may also be possible to take actions that reduce the likelihood of developing injury. It is likely that effective control will be based on a combination of several methods.

In this chapter we look at the engineering, management and other methods that should be considered when looking for control solutions.

3.3.1 Substitution of other working methods

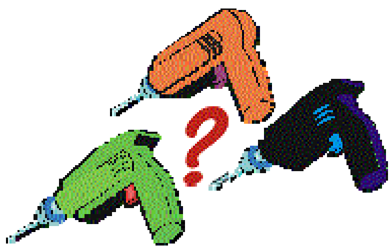


It may be possible to find alternative work methods that eliminate or reduce exposure to vibration. This may involve mechanisation or automation of tasks, or substitution of alternative work processes. To keep up-to-date on the methods available you should check regularly with:

- your trade association;
- other industry contacts;
- equipment suppliers;
- trade journals.

3.3.2 Equipment selection

You should make sure that equipment selected or allocated for tasks is suitable and can do the work efficiently. Equipment which is unsuitable or of insufficient capacity is likely to take much longer to complete the task and expose workers to vibration for longer than is necessary.



Careful selection of consumables (e.g. abrasives for grinders and sanders) or tool accessories (such as drill bits, chisels and saw blades) can affect vibration exposure. Some manufacturers supply accessories designed to reduce vibration exposure.

To keep up-to-date on the tools, consumables and accessories available you should check regularly with:

- equipment suppliers;
- your trade association;
- other industry contacts;
- trade journals.

3.3.3 Purchasing policy

Make sure your purchasing department has a policy on purchasing suitable equipment, that takes into account both vibration emission, and your operating requirements.

Power tool manufacturers (and importers, suppliers and tool hire firms) should be able to help you select the most suitable and safest tools for your particular needs. They should provide useful information and advice about tool vibration, selection and management. They have duties to reduce risks from vibration to a minimum and to help you with information on managing vibration risks that they have been unable to eliminate by design.

Anyone supplying power tools for use in Europe must comply with the Machinery Directive (Directive 98/37/EC), which requires them to provide information on:

- the vibration emission (as reported in the instruction handbook);
- how the emission value has been obtained.

The supplier may also be able to offer technical support where required, including advice on:

- any applications of the equipment that are believed to increase the risk of hand-arm vibration injury;
- how to use the equipment safely and any training requirements for this;
- any training (to operators, maintenance staff etc.) recommended to control hand-arm vibration exposures;
- how to use the equipment for specific tasks;
- the need for any personal protective equipment when operating the machinery;
- how to maintain the tool in good condition;
- any vibration reduction features.

The Machinery Directive requires that manufacturers or suppliers of machinery provide the following in the instructions:

"information concerning vibrations transmitted by hand-held and hand-guided machinery:

- *the weighted root mean square acceleration value to which the arms are subjected, if it exceeds 2.5 m/s² as determined by the appropriate test code. Where the acceleration does not exceed 2.5 m/s², this must be mentioned."*

When selecting tools, you should also consider ergonomic factors and other hazards such as:

- tool weight,
- handle design and comfort,
- grip forces,
- ease of use and handling
- cold from grip surfaces or from exhaust air on pneumatic tools
- noise and
- dust.

Manufacturers or suppliers may be willing to loan sample tools on trial. Make use of this opportunity and take account of workers' opinions based on practical trials. The efficiency of the tool is important: a tool that takes a long time to do the job will not be popular, and could result in a higher vibration exposure than an efficient tool with a greater vibration magnitude. However, tools that are too powerful for the job could result in exposure to unnecessarily high vibration magnitudes.

3.3.4 Workstation design

Jigs and anti-vibration handles

Jigs and similar aids incorporating anti-vibration mounts can help avoid the need to hold vibrating surfaces.

'Anti-vibration' handles may reduce the vibration, but incorrect selection of this type of handle may actually increase the vibration at the hand, so only use handles that are endorsed by the tool manufacturer.

Resilient materials

Wrapping rubber or other resilient materials around vibrating handles may improve comfort but it is unlikely to reduce significantly the vibration at frequencies that contribute most when the exposure is calculated. Unless carefully selected, resilient materials may amplify vibration at some frequencies and actually increase vibration exposure.

Grip and push forces

Reducing the gripping or pushing forces exerted through the hand reduces the vibration passing into the user's hand and arm. These forces may be required to support the tool or workpiece, to control or guide the machine, or to achieve high work-rates. However, the actual forces applied can be greater than is necessary for efficient work because of incorrect equipment selection, inadequate maintenance, insufficient training or poor workstation design.

Some methods of reducing grip and push forces are:

- where heavy workpieces are ground by hand at pedestal grinders, support for the whole piece will mean that the worker needs only to guide it onto the wheel, rather than support all the weight;
- tension chains (sometimes called balancers) and manipulators can be used to support vibrating tools such as heavy drills, grinders, nut runners, nailing guns (in some cases) and pneumatic chisels, thus relieving the operator from supporting the tool's weight;
- changes in the texture and material of a grip surface may allow the operator to use a smaller grip force to hold and control the tool;
- use of techniques such as bench-felling in forestry, where the chainsaw slides along the log during de-branching, rather than holding the full weight of the saw at all times.

3.3.5 Training and information to workers

It is important that you provide operators and supervisors with information on:

- the potential injury arising from the work equipment in use;
- the exposure limit values and the exposure action values;
- the results of the vibration risk assessment and any vibration measurements;
- the control measures being used to eliminate or reduce risks from hand-arm vibration;
- safe working practices to minimise exposure to mechanical vibration;
- why and how to detect and report signs of injury
- why and how to report machines in need of maintenance;
- how and when to scrap inserted tools or consumables that contribute to excessive vibration exposures;
- the circumstances in which workers are entitled to health surveillance.

You will be relying on the operators of vibrating tools and processes to make your control measures effective. You should consult with the workers and their representatives when implementing control measures. Workers have a duty to cooperate when you take action to comply with European health and safety directives.

Workers should be trained in working techniques, for example to help avoid excessive gripping, pushing and guiding forces and to ensure the tools are operated safely and with optimum efficiency. They will also need to be trained to recognise when a machine is in need of maintenance.

With some tools, the operator’s hands must be in the correct position to avoid increased vibration exposure. Many vibration-reduced tools, such as breakers with suspended handles, produce high vibration emissions if the operator pushes down too hard while operating the tool (road breakers can also produce high vibration emission if the tool is pulled up whilst operating, e.g. to remove the pick from a hole)

The manufacturer should advise you of any training requirements, and may offer training for operators. Workers can also be encouraged to rest the tool as much as possible on the material being worked (or in the case of hand-held workpieces, on any support provided) and to hold it with a light but safe grip.

Training and supervision will be required to ensure that workers are protecting themselves against the development of vibration-related disease. They should be encouraged to report any symptoms that may be associated with vibration or the use of power tools, etc. If they are taking part in a health surveillance scheme then this may provide a regular opportunity for one-to-one discussion of the vibration hazard and how to reduce the risk of injury.

Workers should also be advised on the impact of non-work activities on the risks to their health. They should be encouraged to stop or cut-down and smoking, which can impair blood circulation. Workers should also be aware that the use of power tools for do-it-yourself work in the home or activities such as motorbike riding will add to daily vibration exposures and so increase the risk of developing hand-arm vibration injury.

3.3.6 Work schedules

To control the risks from hand-arm vibration you may need to limit the time workers are exposed to vibration from some tools or processes. It is recommended that you plan work to avoid workers being exposed to vibration for long, continuous periods.

Make sure that new work patterns are adequately supervised, to ensure that workers do not drift back to the older work patterns. If workers are paid by results, the systems should be designed to avoid intensive working by individual workers with few breaks in exposure.

3.3.7 Collective measures

Where several undertakings share a work place, the various employers are required to cooperate in implementing the safety and health provisions. This may mean, for example, one company taking responsibility for purchasing or hiring low-vibration machinery, where the machines are shared amongst many contractors working on a construction site.

3.3.8 Clothing and personal protection

Personal protective equipment is a last resort for protection against hazards at work, and should only be considered as a long-term means of control after all other options have been explored.

Protection from vibration

Gloves marketed as ‘anti-vibration’ should carry the CE mark, indicating they have been tested and found to meet the requirements of EN ISO 10819:1997. However, this standard does not provide detailed performance data for gloves, therefore you must separately assess the protection offered by anti-vibration gloves, as required by the Personal Protective Equipment at Work Directive 1992.

Anti-vibration gloves do not provide significant risk reduction at frequencies below 150Hz (9000 revs per minute). This means that, for most powered hand tools, the reduction in frequency-weighted vibration magnitude provided by anti-vibration gloves is negligible. Anti-vibration gloves may provide some vibration risk reduction for tools that operate at high rotational speeds (or produce vibrations at high frequencies) and are held with a light grip. However this risk reduction cannot easily be quantified and so gloves should not normally be relied upon to provide protection from hand-arm vibration.

Protection from cold

Low body temperature increases the risk of finger blanching because of the reduced blood circulation. You should therefore avoid outdoor working in cold weather if you can. If you have to work outside, then some machines, such as chainsaws, are available with heated handles to help keep the hands warm.

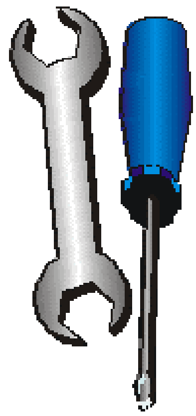
The temperature in an indoor workplace should provide reasonable comfort without the need for special clothing and should normally be at least 16ºC. You should avoid machines that might make the hands cold, e.g. steel-bodied machines or pneumatic tools that blow exhaust air over the operator’s hands.

You should provide warm clothing and gloves if there is an increased hand-arm vibration risk due to the cold. Gloves and other clothing should be assessed for good fit and for effectiveness in keeping the hands and body warm and dry in the working environment.

3.3.9 Maintenance

Regular servicing of power tools and other work equipment will often help keep vibration magnitudes down to the minimum necessary, so:

- keep cutting tools sharp;
- dress grinding wheels correctly by following the manufacturer’s recommendations;
- lubricate any moving parts in accordance with manufacturer’s recommendations
- replace worn parts;
- carry out necessary balance checks and corrections;
- replace anti-vibration mounts and suspended handles before they deteriorate. (look for deterioration or the cracking, swelling and softening, or hardening, of rubber mounts);
- check and replace defective vibration dampers, bearings and gears;
- sharpen chainsaw teeth and keeping the correct chain tension;
- tune engines.



3.4 Monitoring and reassessment

Management of vibration exposure is an ongoing process. You need to ensure that the control systems are being used and that they are giving the expected results

In this chapter we look at how to monitor the vibration controls and when to repeat the risk assessment.

3.4.1 How do I know if my hand-arm vibration controls are working?

You will need to review your hand-arm vibration controls periodically to ensure they are still relevant and effective. You should:

- Check regularly that managers and workers are still carrying out the programme of controls you have introduced;
- Talk regularly to managers, supervisors, workers and safety or worker representatives about whether there are any vibration problems with the equipment or the way it is being used;
- Check the results of health surveillance and discuss with the occupational health provider whether the controls appear to be effective or need to be changed.

3.4.2 When do I need to repeat the risk assessment?

You will need to reassess risks from vibration, and how you control them, whenever there are changes in the workplace that may affect the level of exposure, such as:

- the introduction of different machinery or processes
- changes in the work pattern or working methods
- changes in the number of hours worked with the vibrating equipment
- the introduction of new vibration control measures.

You will also need to reassess the risks if there is evidence (e.g. from health surveillance) that your existing controls are not effective.

The extent of the reassessment will depend on the nature of the changes and the number of people affected by them. A change in hours or work patterns may require a recalculation of the daily exposure for the people affected, but will not necessarily alter the vibration magnitudes. The introduction of new machinery or processes may require a full reassessment.

It is good practice to review your risk assessment and work practices at regular intervals, even if nothing obvious has changed. There may be new technology, tool designs or ways of working in your industry that would allow you to reduce risks further.

CHAPTER 4 HEALTH SURVEILLANCE

Health surveillance is about putting in place systematic, regular and appropriate procedures for the detection of work-related ill health, and acting on the results. The aims are primarily to safeguard the health of workers (including identifying and protecting individuals at increased risk), but also to check the long-term effectiveness of control measures.

It is impossible to provide definitive guidance on health surveillance in this guide, due the to differences in health surveillance practices across the European Union. In this chapter we re-state the requirements for health surveillance given in the vibration directive and review some of the assessment techniques available.

Some health surveillance techniques related to hand-arm injury are described in *Annex F*.

4.1 When is health surveillance required?

Member States shall adopt provisions to ensure the appropriate health surveillance of workers where the hand-arm vibration risk assessment indicates a risk to their health. The provision of health surveillance, including the requirements specified for health records and their availability, shall be introduced in accordance with national laws and/or practice.

Employers should provide appropriate health surveillance where the risk assessment indicates a risk to workers' health. Health surveillance should be instituted for workers who are at risk from vibration injury, where:

- the exposure of workers to vibration is such that a link can be established between that exposure and an identifiable illness or harmful effects on health,
- it is probable that the illness or the effects occur in a worker's particular working conditions, and
- there are tested techniques for the detection of the illness or the harmful effects on health.

In any event, workers whose daily vibration exposure exceeds the daily exposure action value are entitled to appropriate health surveillance.

4.2 What recording is required?

Member States shall establish arrangements to ensure that, for each worker who undergoes health surveillance individual health records are made and kept up-to-date. Health records shall contain a summary of the results of the health surveillance carried out. They shall be kept in a suitable form so as to permit any consultation at a later date, taking into account any confidentiality.

Copies of the appropriate records shall be supplied to the competent authority on request. The individual worker shall, at their request, have access to the health records relating to them personally.

4.3 What to do if injury is identified?

Where, as a result of health surveillance, a worker is found to have an identifiable disease or adverse health effect that is considered by a doctor or occupational health-care professional to be the result of exposure to mechanical vibration at work:

Information for the worker

The worker shall be informed, by the doctor or other suitably qualified person, of the results of their own personal health surveillance. In particular, workers shall be given information and advice regarding any health surveillance that they should undergo following the end of exposure.

Information for the employer

The employer shall be informed of any significant findings from the health surveillance, taking into account any medical confidentiality.

Employer actions

- Review the hand-arm vibration risk assessment,
- Review the measures provided to eliminate or reduce risks from hand-arm vibration exposure,
- Take into account the advice of the occupational healthcare professional or other suitably qualified person or the competent authority in implementing any measures required to eliminate or reduce risks from hand-arm vibration exposure, including the possibility of assigning the worker to alternative work where there is no risk of further exposure, and
- Arrange continued health surveillance and provide for a review of the health status of any other worker who has been similarly exposed. In such cases, the competent doctor or occupational health care professional or the competent authority may propose that exposed persons undergo a medical examination.

ANNEX A SUMMARY OF RESPONSIBILITIES DEFINED BY DIRECTIVE 2002/44/EC

Table A.1 Summary of responsibilities defined by Directive 2002/44/EC

Directive Article	*Who*	*When*	*Requirement*
Article 4	Employer	Potential risk from hand-arm vibration	***Determination and assessment of risk:*** ▪ Use someone who is competent to assess the hand-arm vibration risk. ▪ Be in possession of the risk assessment. ▪ Identify measures required for control of exposure and worker information and training. ▪ Keep the risk assessment up to date.
Article 5	Employer	Risks from vibration	***Avoiding or reducing exposure:*** ▪ Take general actions to eliminate exposures or reduce them to a minimum
		Exposures above the **exposure action value**	▪ Establish and implement programme of measures to eliminate, or reduce to a minimum, exposures to hand-arm vibration risks
		Exposures above the **exposure limit value**	▪ Take immediate action to prevent exposure above the limit value ▪ Identify why exposures limit value has been exceeded
		Workers at particular risk	▪ Adapt to requirements of workers at particular risk
Article 6	Employer	Workers at risk from hand-arm vibration	***Worker information and training:*** ▪ For all workers exposed to hand-arm vibration risks.
Article 7	Employer	Workers at risk from hand-arm vibration	***Worker consultation and participation:*** ▪ To consult, in a balanced way and in good time, workers and their representatives on risk assessment, control measures health surveillance and training.
Article 8	Doctor or suitably qualified person	Where ill health is identified	***Health Surveillance:*** ▪ Inform worker of results of health surveillance ▪ Provide information and advice to worker regarding any health surveillance which he should undergo following the end of exposure ▪ Provide significant findings of health surveillance to employer
	Employer	Where ill health is identified	▪ Review risk assessment ▪ Further eliminate or reduce risks ▪ Review the health status of similarly exposed workers.
	Employer	Exposures above the **exposure action value**	▪ Workers entitled to appropriate health surveillance

ANNEX B WHAT IS VIBRATION?

B.1 What is vibration?

Vibrations arise when a body oscillates due to external and internal forces Figure B.1. In the case of hand-arm vibration, the handle of a machine or the surface of a work piece vibrates rapidly, and this motion is transmitted into the hand and arm.

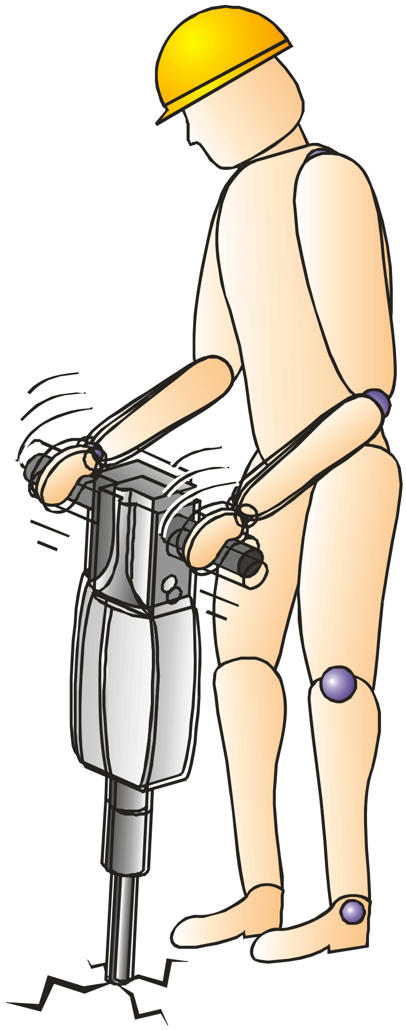


Figure B.1 Hand-arm vibration

B.2 What is measured?

Vibration is defined by its magnitude and frequency. The magnitude of vibration could be expressed as the vibration displacement (in meters), the vibration velocity (in meters per second) or the vibration acceleration (in meters per second per second or m/s^2). Most vibration transducers produce an output that is related to acceleration; so acceleration has traditionally been used to describe vibration.

To get a complete picture of the vibration on a surface, vibration must be measured in three axes, as illustrated in Figure B.2.

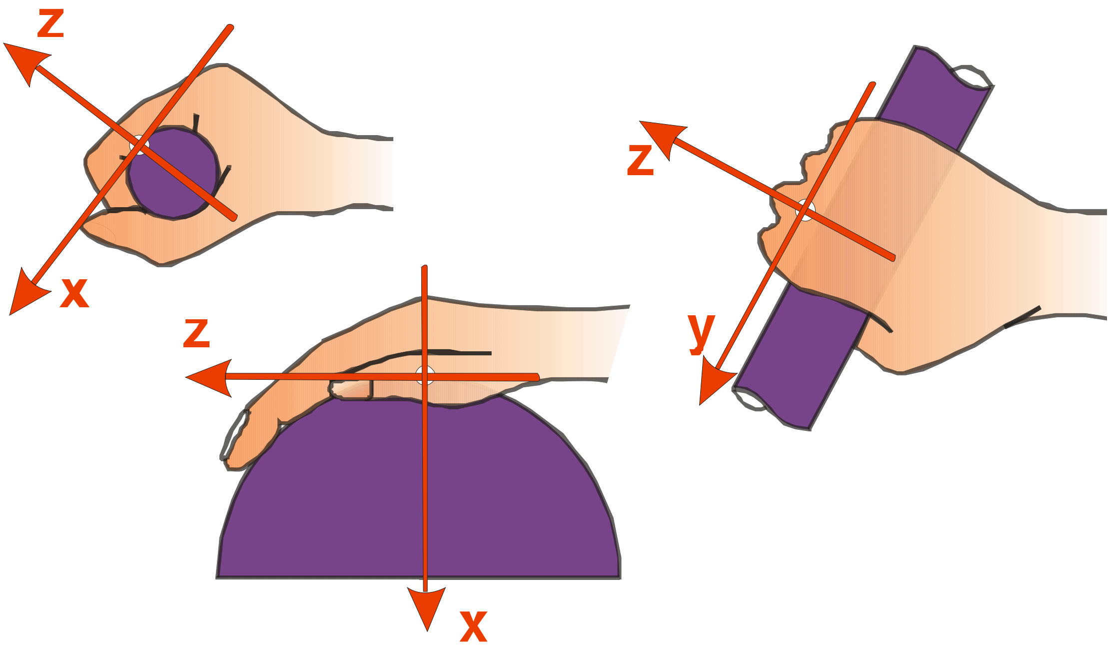


Figure B.2 Axes of hand-arm vibration measurement

B.3 What is frequency and frequency-weighting?

Frequency is the number of times per second the vibrating body moves back and forth. It is expressed as a value in cycles per second, more usually known as hertz (abbreviated to Hz). For rotating tools the dominant frequency is usually determined by the speed at which the tool rotates (usually expressed as the number of revolutions per minute or rpm; dividing the rpm by 60 gives the frequency in Hz).

For hand-arm vibration, the frequencies thought to be important range from about 8 Hz to 1000 Hz. However, because the risk of damage to the hand is not equal at all frequencies a *frequency-weighting* is used to represent the likelihood of damage from the different frequencies. As a result, the weighted acceleration decreases when the frequency increases. For hand-arm vibration, only one frequency-weighting curve is used for all three axes.

B.4 What vibration parameters are used for exposure assessment?

From each vibration axis a frequency-weighted root-mean-square average acceleration is measured. This is referred to as a_{hw}. The value used for assessment of exposure is the *vibration total value*, which combines the three a_{hw} values for the axes x, y and z, using:

$$a_{hv} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2}$$

Some examples of *vibration total values* for common hand-held power tools are shown in Figure B.3.

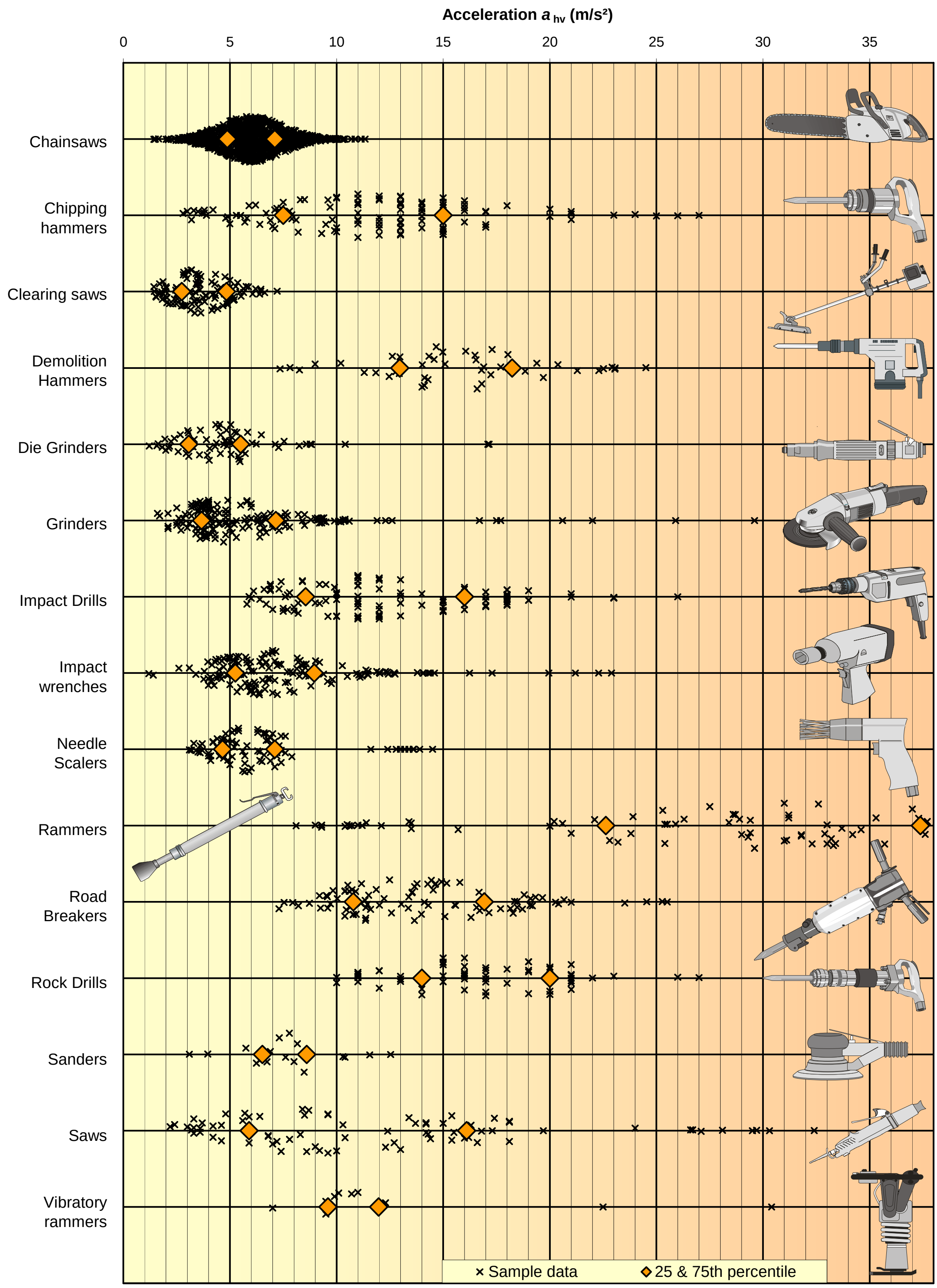


Figure B.3 Examples of vibration magnitudes for common tools

Sample data based on workplace vibration measurements of total vibration values a_{hv} (see Chapter 2.3) by HSL and INRS between 1997 and 2005. These data are for illustration only and may not be representative of machine use in all circumstances.

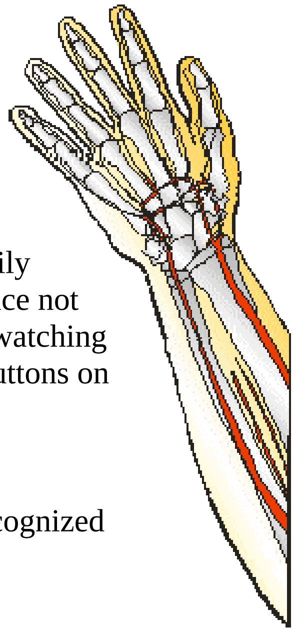
The 25th and 75th percentile points show the vibration magnitude that 25% or 75% of samples are equal to or below

B.5 What instrumentation should be used?

Hand-arm vibration measuring equipment should comply with the EN ISO 8041:2005 specifications for hand-arm vibration measuring instruments. It is important that accelerometers (vibration transducers) are carefully selected. The vibration on hand-held and hand-guided machines can be very high and can easily overload unsuitable transducers. Fixing transducers to the machine handles requires mounting systems that are rigid, lightweight and compact. Further information and guidance on transducer selection and mounting methods can be found in EN ISO 5349-2:2001.

Further reading:
EN ISO 5349-2:2001 Mechanical vibration — Measurement and evaluation of human exposure to hand-transmitted vibration — Part 2: Practical guidance for measurement at the workplace

ANNEX C HEALTH RISKS, SIGNS AND SYMPTOMS



Workers exposed regularly to excessive hand-arm-transmitted vibration may be suffer in the long term with disturbances to finger blood flow and to the neurological and locomotor functions of the hand and arm. The term *hand-arm vibration syndrome* is used to refer to these complex disorders.

Hand-arm vibration syndrome has an impact on social and family life. Periodic attacks of impaired blood circulation will take place not only at work, but also during activities such as car washing or watching outdoor sports. Everyday tasks, for example managing small buttons on clothes may become difficult.

Vascular disorders, neurological disorders and bone and joints abnormalities caused by hand-transmitted-arm vibration are recognized occupational diseases in several European countries.

C.1 Vascular disorders

Workers exposed to hand-transmitted-arm vibration may complain of episodes of whitening (blanching) of the fingers, usually triggered by cold exposure. This symptom is caused by temporary closing down of blood circulation to the fingers.

Various terms have been used to describe vibration-induced vascular disorders:

- dead or white finger,
- Raynaud's phenomenon of occupational origin,
- vibration-induced white finger.

Initially attacks of blanching involve the tips of one or more fingers, but, with continued exposure to vibration, the blanching can extend to the base of the fingers. As the blood flow returns to the fingers (this is commonly initiated by warmth or local massage) the fingers turn red, and are often painful. The blanching attacks are more common in winter than in summer. The duration varies with the intensity of the vibration stimuli from a few minutes to more than one hour.

If vibration exposure continues, the blanching attacks become more frequent affecting more of the fingers. The attacks may occur all year around with quite small reductions of temperature. During a blanching attack the affected worker can experience a complete loss of touch sensation and manipulative dexterity, which can interfere with work activity increasing the risk for acute injuries due to accidents.

Epidemiological studies have demonstrated that the probability and severity of blanching is influenced by the characteristics of vibration exposure and duration of exposure, the type of tool and work process, the environmental conditions (temperature, air flow, humidity, noise), some biodynamic and ergonomic factors (grip force, push force, arm position), and various individual characteristics (individual susceptibility, diseases and agents such as smoking and certain medicines that affect peripheral circulation).

C.2 Neurological disorders

Workers exposed to hand-transmitted arm vibration may experience tingling and numbness in their fingers and hands. If vibration exposure continues, these symptoms tend to worsen and can interfere with work capacity and life activities. Vibration-exposed workers may exhibit a reduction in the normal sense of touch and temperature as well as an impairment of manual dexterity.

C.3 Carpal-tunnel syndrome

Epidemiological research in workers has also shown that use of vibrating tools in combination with repetitive movements, forceful gripping, awkward postures may increase the risk of carpal tunnel syndrome.

C.4 Musculoskeletal disorders

Workers with prolonged exposure to vibration may complain of muscular weakness, pain in the hands and arms, and diminished muscle strength. These disorders seem to be related to ergonomic stress factors arising from heavy manual work.

Excess occurrence of wrist and elbow osteoarthritis as well as hardening of soft tissue (ossification) at the sites of tendon attachment, mostly at the elbow, have been found in miners, road construction workers and metal-working operators of percussive tools.

Other work-related disorders have been reported in vibration-exposed workers, such as inflammation of tendons (tendonitis) and their sheaths in the upper limbs, and Dupuytren's contracture, a disease of the fascial tissues of the palm of the hand.

ANNEX D TOOLS FOR CALCULATING DAILY EXPOSURES

D.1 Web-based tools

Some web-based calculators are available that simplify the process of doing daily vibration exposure calculations, e.g.:

www.hse.gov.uk/vibration/calculator.htm

http://vibration.arbetslivsinstitutet.se/eng/havcalculator.lasso.

http://www.hvbg.de/d/bia/pra/softwa/kennwertrechner/index.html

D.2 Daily exposure graph

The graph in Figure D.1 gives a simple alternative method for looking up daily exposures or partial vibration exposures without the need for a calculator.

Simply look on the graph for the *A*(8) line at or just above where your vibration magnitude value and exposure time lines meet.

The green area in Figure D1 indicates exposures likely to below the exposure action value. These exposures must not be assumed to be “safe”. There may be a risk of hand-arm vibration injury for exposures below the exposure action value, and so some exposures within the green area may cause vibration injury in some workers, especially after many years of exposure.

D.3 Daily exposure nomogram

The nomogram in Figure D.2 provides a simple alternative method of obtaining daily vibration exposures, without using the equations. For each tool or process:

1. Draw a line from a point on the left hand scale (representing the vibration magnitude) to a point on the right hand scale (representing the exposure time);
2. Read off the partial exposures where the lines cross the central scale;
3. Square each partial vibration exposure value;
4. Add the squared values together;
5. Take the square root of the result to give the overall *A*(8) daily vibration exposure value.

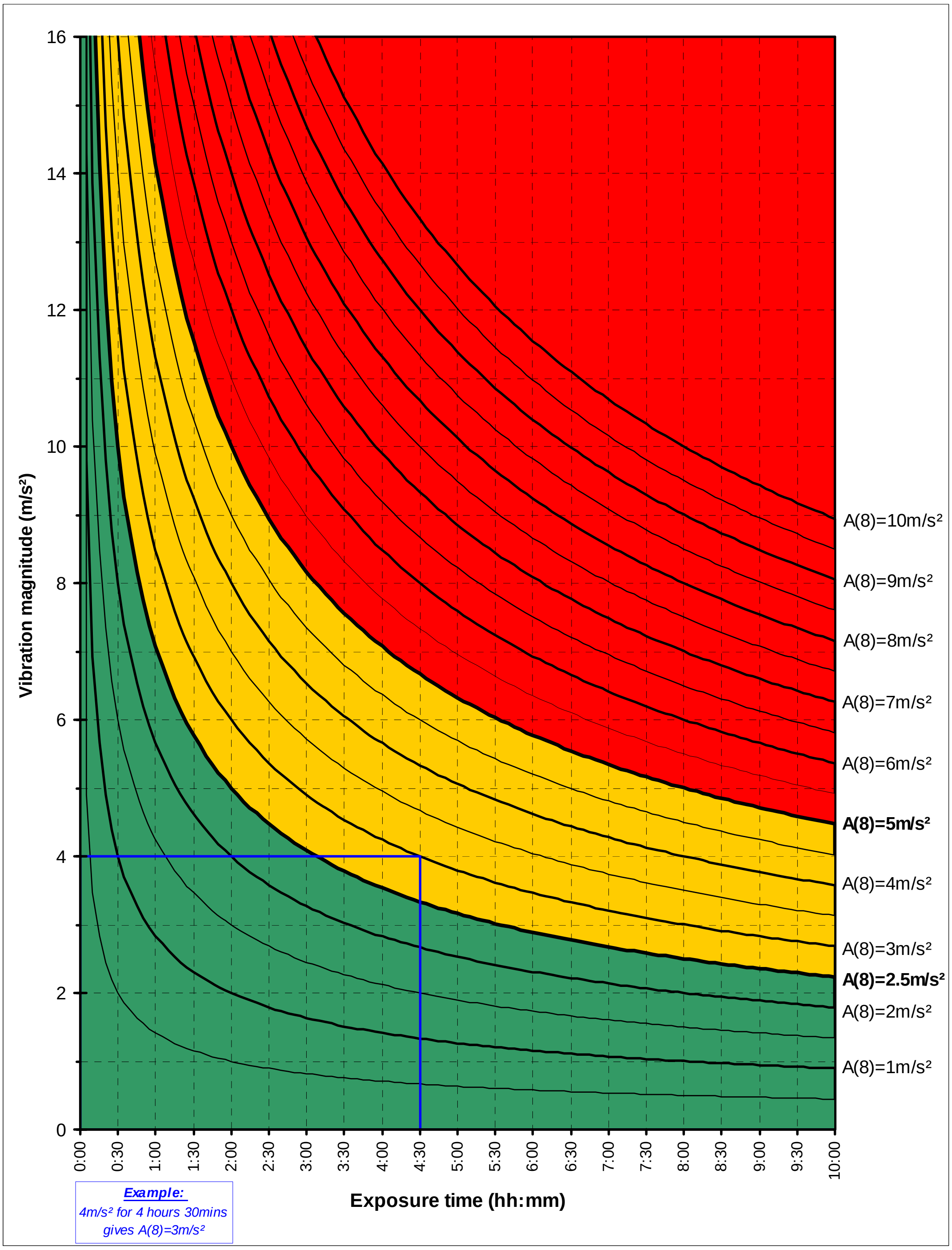
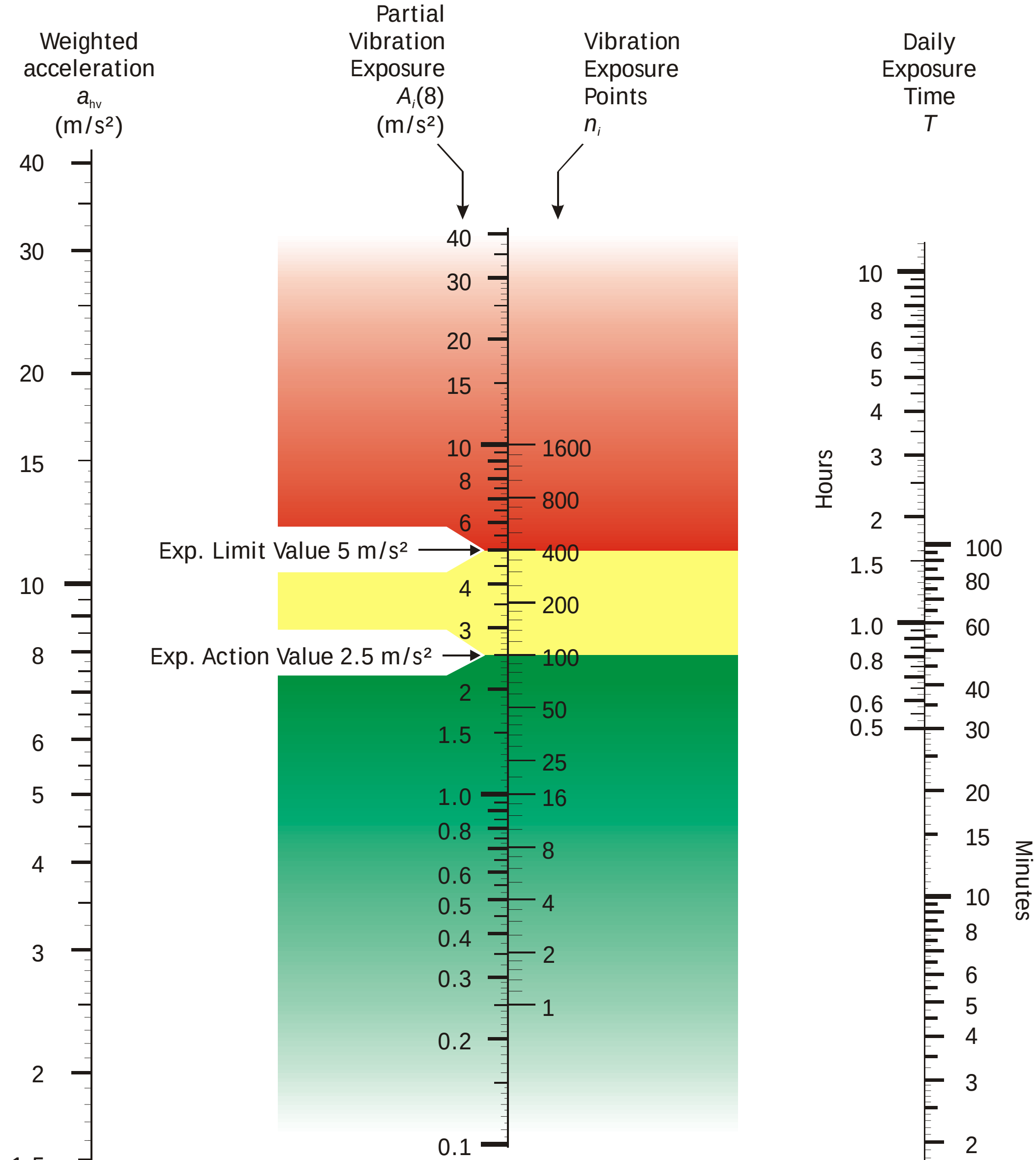


Figure D.1 Daily exposure graph



Instructions:
For each exposure, draw a line between the weighted acceleration and the exposure time. Read off either the partial vibration exposure $A(8)_i$, or the exposure points n_i, from the point where the line crosses the centre scale. Enter the values in the appropriate table below.

For $A(8)_i$ values:
Square and add the $A(8)_i$ values
Square-root the result to give the daily vibration exposure $A(8)$.

	$A_i(8)$	$A_i(8)^2$
Exposure 1		
Exposure 2		
Exposure 3		
Exposure 4		
Exposure 5		
$\sum A_i(8)^2 =$		
$A(8) = \sqrt{\sum A_i(8)^2} =$		

For n_i values:
Add the score values to give a total daily points, n
Use the centre scale to convert *the* n value to $A(8)$

	n_i
Exposure 1	
Exposure 2	
Exposure 3	
Exposure 4	
Exposure 5	
$n = \sum n_i =$	
$A(8) =$	

Figure D.2 Hand-arm vibration exposure nomogram

D.4 Exposure points system

Hand-arm vibration exposure management can be simplified by using an exposure "points" system. For any tool or process, the number of exposure points accumulated in an hour ($P_{E,1h}$ in points per hour) can be obtained from the vibration magnitude a_{hv} in m/s² using:

$$P_{E,1h} = 2a_{hv}^2$$

Exposure points are simply added together, so you can set a maximum number of exposure points for any person in one day.

The exposure scores corresponding to the exposure action and limit values are:

- exposure action value (2.5 m/s²) = 100 points;
- exposure limit value (5 m/s²) = 400 points.

In general the number of exposure points, P_E, is defined by:

$$P_E = \left(\frac{a_{hv}}{2.5\text{m/s}^2}\right)^2 \frac{T}{8\text{hours}} 100$$

Where a_{hv} is the vibration magnitude in m/s² and T is the exposure time in hours.

Alternatively Figure D.3 gives a simple method for looking up the exposure points.

The daily exposure $A(8)$, can be calculated from the exposure point using:

$$A(8) = 2.5\text{m/s}^2 \sqrt{\frac{P_E}{100}}$$

Acceleration (m/s²)	5m	15m	30m	1h	2h	3h	4h	5h	6h	8h	10h
20	67	200	400	800	1600	2400	3200	4000	4800	6400	8000
19.5	63	190	380	760	1500	2300	3050	3800	4550	6100	7600
19	60	180	360	720	1450	2150	2900	3600	4350	5800	7200
18.5	57	170	340	685	1350	2050	2750	3400	4100	5500	6850
18	54	160	325	650	1300	1950	2600	3250	3900	5200	6500
17.5	51	155	305	615	1250	1850	2450	3050	3700	4900	6150
17	48	145	290	580	1150	1750	2300	2900	3450	4600	5800
16.5	45	135	270	545	1100	1650	2200	2700	3250	4350	5450
16	43	130	255	510	1000	1550	2050	2550	3050	4100	5100
15.5	40	120	240	480	960	1450	1900	2400	2900	3850	4800
15	38	115	225	450	900	1350	1800	2250	2700	3600	4500
14.5	35	105	210	420	840	1250	1700	2100	2500	3350	4200
14	33	98	195	390	785	1200	1550	1950	2350	3150	3900
13.5	30	91	180	365	730	1100	1450	1800	2200	2900	3650
13	28	85	170	340	675	1000	1350	1700	2050	2700	3400
12.5	26	78	155	315	625	940	1250	1550	1900	2500	3150
12	24	72	145	290	575	865	1150	1450	1750	2300	2900
11.5	22	66	130	265	530	795	1050	1300	1600	2100	2650
11	20	61	120	240	485	725	970	1200	1450	1950	2400
10.5	18	55	110	220	440	660	880	1100	1300	1750	2200
10	17	50	100	200	400	600	800	1000	1200	1600	2000
9.5	15	45	90	180	360	540	720	905	1100	1450	1800
9	14	41	81	160	325	485	650	810	970	1300	1600
8.5	12	36	72	145	290	435	580	725	865	1150	1450
8	11	32	64	130	255	385	510	640	770	1000	1300
7.5	9	28	56	115	225	340	450	565	675	900	1150
7	8	25	49	98	195	295	390	490	590	785	980
6.5	7	21	42	85	170	255	340	425	505	675	845
6	6	18	36	72	145	215	290	360	430	575	720
5.5	5	15	30	61	120	180	240	305	365	485	605
5	4	13	25	50	100	150	200	250	300	400	500
4.5	3	10	20	41	81	120	160	205	245	325	405
4	3	8	16	32	64	96	130	160	190	255	320
3.5	2	6	12	25	49	74	98	125	145	195	245
3	2	5	9	18	36	54	72	90	110	145	180
2.5	1	3	6	13	25	38	50	63	75	100	125
	5m	**15m**	**30m**	**1h**	**2h**	**3h**	**4h**	**5h**	**6h**	**8h**	**10h**

Daily Exposure time

Figure D.3 Exposure points table (rounded values).

D.5 Traffic light system

Some employers, working with machine manufacturers and suppliers, have developed a green / amber/ red "traffic light" system, where each tool is clearly marked with a hand-arm vibration colour coding, dependent on the expected in-use vibration magnitude of each machine, one example of this coding scheme is illustrated in Table D.1.

Workers are given training in the colour-coding scheme, so that they can select vibration tools at a glance and know how long they can use the tool.

Table D.1 Example of colour coding scheme for traffic-light system

Colour code	Time to reach EAV (2.5m/s²)	Time to reach ELV (5m/s²)
Red	Less than 30 mins	Less than 2 hours
Amber	30 minutes to 2 hours	2 to 8 hours
Green	More than 2 hours	More than 8 hours

The success of the traffic light system is dependent on the quality of data used to determine the colour rating of each machine. The traffic light scheme may be based on measurements or manufacturer's declaration of vibration emission. If the vibration emission value is used, it should be multiplied by a factor of between 1 and 2, to account for uncertainty in the results from the standardised emission tests (see Chapter 2.3.1).

The use of a 'green' machine indicates that exposures are likely to below the exposure action or limit value. These exposures must not be assumed to be "safe". There may be a risk of hand-arm vibration injury for exposures below the exposure action value and other management controls must be used to ensure that workers are trained to understand and operate the system correctly, that the systems are actually correctly used and that workers at risk do not develop symptoms of hand-arm vibration syndrome.

ANNEX E WORKED EXAMPLES

E.1 Where just one machine is used

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

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

where a_{hv} is the vibration magnitude (in m/s²), T is the daily duration of exposure 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/s²).

> ***Example***
>
> A forest worker uses a brush cutter for a total of 4½ hours a day. The vibration on the brush cutter when in use is 4m/s². The daily exposure $A(8)$ is:
>
> $$A(8) = 4\sqrt{\frac{4.5}{8}} = 3\,\text{m/s}^2$$
>
> This daily exposure of 3m/s² is above the exposure action value but below the exposure limit value.

E.2 Where more than one machine is used

If a person is exposed to more than one source of vibration 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:

$$A(8) = \sqrt{A_1(8)^2 + A_2(8)^2 + A_3(8)^2 + \ldots}$$

where $A_1(8)$, $A_2(8)$, $A_3(8)$, etc. are the partial vibration exposure values for the different vibration sources.

Example

A fettler uses three tools during a working day:

1. An angle grinder: 4m/s² for 2½ hours
2. An angle cutter for 3 m/s² for 1 hour
3. A chipping hammer 20 m/s² for 15 minutes

The partial vibration exposures for the three tasks are:

1. Grinder: $A_{Grind}(8) = 4\sqrt{\frac{2,5}{8}} = 2.2$ m/s²
2. Cutter: $A_{Cut}(8) = 3\sqrt{\frac{1}{8}} = 1.1$ m/s²
3. Chipper: $A_{Chip}(8) = 20\sqrt{\frac{15}{8 \times 60}} = 3.5$ m/s²

The daily vibration exposure is then:

$$A(8) = \sqrt{A_{Grind}(8)^2 + A_{Cut}(8)^2 + A_{Chip}(8)^2}$$
$$= \sqrt{2.2^2 + 1.1^2 + 3.5^2}$$
$$= \sqrt{4.8 + 1.2 + 12.3} = \sqrt{18.3} = 4.3 \text{m/s}^2$$

This daily exposure of 4.3m/s² is above the exposure action value but below the exposure limit value.

E.3 Daily exposure: A(8), using the exposure points system

(Note: this is the same worked example as Annex E.2 using the exposure points method)

If you have acceleration values in m/s²:

Step 1: Determine points values for each task or machine, using Figure D.3 to look-up the exposure points based on the acceleration value and the exposure time.

Step 2: Add the points per machine to give a total daily points.

Step 3: The highest value of the three axis values is the daily vibration exposure in points

Example

A fettler uses three tools during a working day:

1. An angle grinder: 4m/s² for 2½ hours
2. An angle cutter for 3 m/s² for 1 hour
3. A chipping hammer 20 m/s² for 15 minutes

Step 1: The exposure points are, from Figure D.3:

Angle grinder *(2½ hours use)*	4m/s² for 3* hours = 96 points
Angle cutter *(1 hours use)*	3m/s² for 1 hour = 18 points
Chipping hammer *(15 minutes use)*	20 m/s² for 15 minutes = 200 points

** 2½ hours not shown in Figure D.3, therefore nearest higher value of 3 hours is used.*

Step 2: Daily vibration exposure points, for each machine are:

96 + 18 + 200 = 298 points

Step 3: The daily vibration exposure is 314 points, i.e. above the 100 points exposure action value, but below the 400 points exposure limit value.

If you have points-per-hour data:

<u>Step 1:</u> Determine points-per-hour values for each machine or operation, from manufacturer's data, other sources, or measurement.

<u>Step 2:</u> For each machine or operation, find the daily points for by multiplying the number of points-per-hour by the number of hours use of the machine:

<u>Step 3:</u> The sum of the points values for the individual machines or operations is the daily vibration exposure in points.

Example

A fettler uses three tools during a working day:

1. An angle grinder: 4m/s² for 2½ hours
2. An angle cutter for 3 m/s² for 1 hour
3. A chipping hammer 20 m/s² for 15 minutes

<u>Step 1:</u> The points per hour values for the machines are:

Angle grinder	Angle cutter	Chipping hammer
32 points	18 points	800 points

<u>Step 2:</u> The exposure points are then:

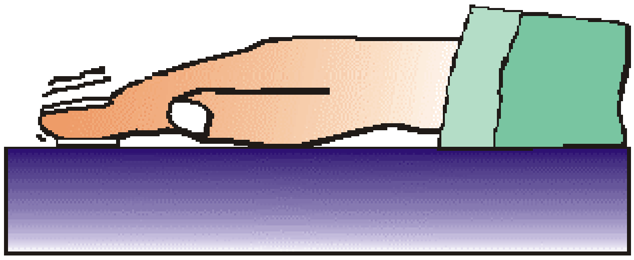
Angle grinder *(2½ hours use)*	Angle cutter *(1 hours use)*	Chipping hammer *(15 minutes use)*
32 *x* 2.5 = 80	18 *x* 1 = 18	800 *x* 0.25 = 200

<u>Step 3:</u> Daily vibration exposure points, for each machine are:

<u>Step 4:</u> 80 + 18 + 200 = 298 points

<u>Step 5:</u> The daily vibration exposure is 298 points, i.e. above the 100 points exposure action value, but below the 400 point exposure limit value.

ANNEX F HEALTH SURVEILLANCE TECHNIQUES



Health surveillance may consist of an evaluation of the case history for a worker in conjunction with a physical examination conducted by a doctor or suitably qualified health-care professional.

Questionnaires for hand-arm vibration health surveillance are available from various sources (e.g. the VIBGUIDE section of:
http://www.humanvibration.com/EU/EU_index.htm).

F.1 The case history

The case history should focus on:

- family history,
- social history, including smoking habit and alcohol consumption.
- work history, including past and current occupations with exposure to hand-arm vibration, previous jobs with exposure to neurotoxic or angiotoxic agents and any leisure activities involving the use of vibrating tools or machines.
- personal health history.

F.2 The physical examination

A physical examination should look in detail at the peripheral vascular, neurological, and musculoskeletal systems, and should be performed by a qualified physician

F.3 Clinical tests

In general, clinical tests do not provide reliable proof of vibration injury, however, they may be helpful to exclude other causes of symptoms similar to those of hand-arm vibration syndrome or to monitor progression of injury.

Tests for the peripheral vascular system include the Lewis-Prusik test, the Allen test, and the Adson test.

Tests for the peripheral nervous system include the evaluation of manual dexterity (e.g. coin recognition and pick up), the Roos test, the Phalen's test and the Tinel's sign (for carpal tunnel compression).

F.4 Vascular investigations

The vascular assessment of the hand-arm vibration syndrome is mainly based on cold provocation tests: assessing changes in finger colour, recording recovery times of finger skin temperature, and measuring finger systolic blood pressure. Other non-invasive diagnostic tests, such as Doppler recording of arm and finger blood-flow and pressure, may also be useful.

F.5 Neurological investigations

The neurological assessment of the hand-arm vibration syndrome includes several tests:

- Vibration perception thresholds
- Tactile sensitivity (gap detection, monofilaments)
- Thermal perception thresholds
- Nerve conduction velocities in the upper and lower limbs.
- Electromyography.
- Fingertip dexterity (Purdue pegboard).

F.6 Muscle strength investigations

The evaluation of muscle force in the hand can be performed by means of a dynamometer to measure grip strength and a pinch gauge to measure pinch strengths.

F.7 Radiological investigations

X-rays of the shoulders, elbows, wrists and hands for a radiological diagnosis of bone and joint disorders are usually required in those countries in which vibration-induced osteoarthropathy in the upper limbs is recognised as an occupational disease.

F.8 Laboratory tests

Blood and urine analyses may be necessary in some case to distinguish vibration injury from other vascular or neurological disorders.

Further reading:
ISO 13091-1:2001 Mechanical vibration — Vibrotactile perception thresholds for the assessment of nerve dysfunction — Part 1: Methods of measurement at the fingertips ISO 14835-1:2005 Mechanical vibration and shock — Cold provocation tests for the assessment of peripheral vascular function — Part 1: Measurement and evaluation of finger skin temperature ISO 14835-2:2005 Mechanical vibration and shock — Cold provocation tests for the assessment of peripheral vascular function — Part 2: Measurement and evaluation of finger systolic blood pressure

ANNEX G GLOSSARY

Hand-arm vibration....... The mechanical vibration that, when transmitted to the human hand-arm system, entails risks to the health and safety of workers, in particular vascular, bone or joint, neurological or muscular disorders

Declared vibration emission
The vibration value provided by machine manufacturers to indicate the vibration likely to occur on their machines. The declared vibration emission value should be obtained using a standardised test code, and has to be included in the machine's instructions.

Frequency-weighting .... A correction applied to vibration measurements (often using a filter) to allow for the assumed frequency dependence of the risk of damage to the body. The W_h weighting (defined in EN ISO 5349-1:2001) is used for hand-arm vibration.

Daily vibration exposure, $A(8)$
The 8-hour energy equivalent vibration total value for a worker in meters per second squared (m/s^2), including all hand-arm vibration exposures during the day.

Partial vibration exposure, $A_i(8)$
The contribution of operation *i* to the daily vibration exposure in m/s^2. The *partial vibration exposure* relates to the daily exposure from an individual tool or process, *i* (where a worker is only exposed to vibration form one tool or process then the *daily vibration exposure* is equal to the *partial vibration exposure*).

Health surveillance........ A programme of health checks on workers to identify early effects of injury resulting from work activities.

Exposure action value ... A value for a workers daily vibration exposure of $2.5 m/s^2$, above which the risks from vibration exposure must be controlled.

Exposure limit value ..... A value for a workers daily vibration exposure of $5 m/s^2$, above which workers should not be exposed.

Exposure time .... The duration per day that a worker is exposure to a vibration source.

ANNEX H BIBLIOGRAPHY

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Directive 2002/44/EC 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)

Directive of 89/391/EEC of the European parliament and of the Council of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work

Directive 98/37/EC 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

Directive 89/686/EEC: Council Directive of 21 December 1989 on the approximation of the laws of the Member States relating to personal protective equipment as amended by Directives 93/68/EEC, 93/95/EEC and 96/58/EC

Council Directive 89/656/EEC of 30 November 1989 on the minimum health and safety requirements for the use by workers of personal protective equipment at the workplace (third individual directive within the meaning of Article 16 (1) of Directive 89/391/EEC)

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EN ISO 5349-2:2001.

European Committee for Standardization (1996) Mechanical vibration and shock — Hand-arm vibration — Method for the measurement and evaluation of the vibration transmissibility of gloves at the palm of the hand
EN ISO 10819:1996

European Committee for Standardization (1997) Mechanical vibration — Declaration and verification of vibration emission values
EN 12096:1997

European Committee for Standardization (2005) Mechanical vibration — Hand-held and hand-guided machinery — Principles for evaluation of vibration emission
EN ISO 20643:2005

European Committee for Standardisation (1995) Hand-arm vibration — Guidelines for vibration hazards reduction — Part 1: Engineering methods by design of machinery
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http://vibration.arbetslivsinstitutet.se/eng/wbvhome.lasso	Vibration emission data
http://www.las-bb.de/karla/index_.htm	Vibration emission data
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http://vibration.arbetslivsinstitutet.se/eng/havcalculator.lasso.	Exposure calculator
http://www.hvbg.de/d/bia/pra/softwa/kennwertrechner/index.html	Exposure calculator

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