A Guide to: Hand-arm Vibration

Off-highway Plant and Equipment Research Centre (OPERC)
Acknowledgement

The authors extend a thank you to Mr Brian Coles of the Vibration Policy, Physical Agents Policy Unit, Hazards and Technical Policy Division, Health and Safety Executive, for being an invaluable source of information during compilation of this Guide.
List of Acronyms used

CTS      Carpal Tunnel Syndrome
EAV      Exposure Action Value
ELV      Exposure Limit Value
HAV      Hand-arm Vibration
HAVS     Hand-arm Vibration Syndrome
HSE      [The] Health and Safety Executive
HSC      [The] Health and Safety Commission
SWS      [The] Stockholm Workshop Scales
VWF      Vibration White Finger

In order that the reader may follow-up specific aspects of the discussion as and if required, the text has been referenced throughout using the Harvard convention of author name, year of publication, and (if applicable) page number(s). For example, (Smith, 2004, p3). Full bibliographic listings of cited references, along with other useful sources of further information, are provided in the References and Bibliography.

List of Figures

Figure 1. Calculation of vibration exposure using just one vibrating tool in a day
Figure 2. Calculation of vibration exposure using more than one vibrating tool in a day

List of Tables

Table 1. Industries with the greatest prevalence of VWF
Table 2. The Stockholm Workshop Scales used for classifying HAVS symptoms
Table 3. ‘Typical’ vibration magnitude data for a range of hand-held power tools
Table 4. Maximum ‘trigger’ times for a range of average vibration magnitudes at source, to reach the A(8) exposure action and limit values

List of Appendices

Appendix A. Comparison of some different manufacturers’ tools: Amounts of work that can be done before EAV is reached
Appendix B. Formulae for calculation of daily and weekly HAV exposure [A(8)]
About OPERC

The Off-highway Plant and Equipment Research Centre (OPERC) is renowned for being the leading international centre of excellence for plant and equipment science. OPERC represents both those employed in the off-highway plant and equipment industry and academics working in the field. This combination of experience, knowledge and academic research ensures that information produced by the co-operative is of the highest quality and may be shared by all.

OPERC is a non-partisan and non-profit making organisation. Its main objective is to advance off-highway plant and equipment knowledge and share this among all interested parties. Funds generated by the association are used to produce, publish and make available information (such as Voluntary Codes of Practice) that would otherwise be too time consuming and/or expensive for a single member to produce in isolation.

To find out more about OPERC or for details of how to apply for membership, please do visit our official web site at: http://www.operc.com
Introduction

Hand-arm vibration (HAV) is concerned with the transmission of vibration into operatives’ hands and (typically, lower) arms (HSE, 2003A, p27). Usually, though not exclusively, this results from using vibration-emitting hand-held tools at work such as drills, saws and grinders.

The risk to operatives from regular, frequent or continued exposure to HAV is negative health effects. These effects tend to be related to impaired blood circulation and damage to nerves and muscles (HSE, 2003B, p3), particularly in the hands and arms. More specific medical symptoms resulting from HAV exposure are looked at in further detail under the section Health Effects from Exposure to HAV, but the most commonly known conditions from exposure are Vibration White Finger (VWF) (Hughes and Ferret, 2003, p283) and Carpal Tunnel Syndrome (CTS).

VWF, or Secondary Raynaud’s Phenomenon to give it its medical name, was first linked to the use of pneumatic tools in 1911. Awareness of VWF and its causes subsequently grew with the increasing use of electrical power (tools) and other forms of mechanisation through the early part of the 20th century (HSE, 2004A). Knowledge of HAV increased throughout the century and in 1985 VWF became a reportable disease under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations [as amended by RIDDOR, (1995)]. A survey by the Medical Research Council during 1997-98 estimated that 288,000 people suffered from VWF in Great Britain (HSE, 2004B). Of course, maybe not all of these cases were directly attributable to HAV but equally, VWF is but one of a range of medical conditions that can result from exposure. More detailed statistics on the extent of negative health resulting from vibration exposure are presented later.

Operatives’ exposure to HAV is now considered such a serious health hazard, that the European Community issued a health and safety Directive on it in 2002 (EC, 2002). As a result of that Directive, the Control of Vibration at Work Regulations (CVWR, 2005) have more recently (July, 2005) brought HAV under UK workplace health and safety statute. (These Regulations also relate to whole-body vibration (WBV) but WBV is beyond the scope of this Guide on HAV. A separate OPERC publication (Edwards and Holt, 2005A) deals specifically with WBV).

In view of increased HAV ‘awareness’ and more recently, its ‘formalisation’ under the umbrella of UK workplace health and safety law, this Guide sets about explaining how these issues affect both employers and employees who are ‘associated’ with vibration-emitting hand-held tools and work processes.

---

1 For ease of reading, the term operative is used throughout this Guide to describe any person who through the use of tools, equipment or processes might be subject to HAV at work. The term may therefore be considered as including ‘person’, employee’, ‘worker’ and so on.
In particular, the Guide looks at the following topics:

- a description of HAV and the nature of its sources;
- a description of hand-arm vibration syndrome (HAVS);
- an indication of the potential negative health effects from exposure to HAV;
- an overview of legislation relating to the subject;
- practical guidance for assessing HAV risks; and
- practical guidance for controlling, mitigating or removing HAV risks.

In short, *A Guide to Hand-arm Vibration* provides a concise overview of current HAV knowledge combined with practical advice for meeting the requirements of the *Control of Vibration at Work Regulations 2005* (hand-arm vibration).
A Description of Hand-arm Vibration (HAV) and Hand-arm Vibration Syndrome (HAVS)

Hand-arm vibration is the descriptor given to vibration that is transmitted into the hands and arms, typically of operatives when using hand-held power tools at work. The types of tool that can generate HAV include:

- percussive metal-working tools, such as powered riveting hammers and hammers for caulking, clinching or flanging;
- percussive construction tools, such as breakers, hammers, vibrating pokers and drills;
- percussive tools used in stoneworking and stone quarrying;
- rotary tools, such as disk cutters, grinders, polishers and burring tools; and
- wood machining tools, such as chain saws, cutters, circular saws and powered screwdrivers (cf. HSE, 2003B, p5).

The above list is purely indicative of vibration-emitting tools and is far from exhaustive. HAV exposure may also result from using hand-guided equipment, such as:

- lawn mowers;
- garden strimmers;
- vibrating compaction plates; and
- pedestrian compaction rollers.

The remaining potential source derives from operatives holding materials in the hand(s) that are being worked upon by a mechanical process. For example, by offering a metal casting up to a grinding wheel or by guiding timber through a barking machine or table saw (cf. ibid.; HSC, 2003, p30).

It is generally accepted that prolonged or repeated exposure to HAV causes negative health. However, the use of vibration-emitting tools or processes does not automatically mean that negative health will result, not least because this is a function of many factors including:

- the magnitude of the vibration at source;
- the duration of vibration exposure (the longer the exposure in any given operation or cumulatively over time, the greater the risk);
- the frequency of exposure (the more frequent the greater the risk);
- the way a tool is held (for example, a tighter grip increases risk);
- the area of the hand(s) exposed to vibration; and
- numerous ‘other’ factors, such as temperature, operative posture during tool use and operative susceptibility.

These issues and ways to remove, control or mitigate their risks are looked at in more detail under the section How to Minimise the Risks.
Negative health effects resulting from HAV exposure tend to be grouped under three components, these being: vascular, neurological and ‘other’ (see next section). These effects are often referred to generically as representing ‘Hand-arm Vibration Syndrome’ (HAVS) (HSE, 2003B, p23). That is, exposure to HAV can lead to HAVS, which is considered to exist if (after such exposure), involvement of the vascular and/or peripheral nervous system occurs, with or without musculoskeletal involvement (ibid.).

As mentioned in the introduction, two specific medical conditions associated with HAVS are VWF and CTS. VWF is the most common prescribed disease under the Industrial Injuries Scheme over recent years (HSE, 2004B). Those industries with greatest prevalence of VWF are shown in Table 1, along with their corresponding number of new cases assessed during 2001-03, per 100,000 employees.

With respect to CTS, the number of new cases assessed for disablement benefit rose from 267 in 1993-94 to 797 cases in 2001-02 and 1,035 in 2002-03 (ibid.).

### Table 1. Industries with the greatest prevalence of VWF

<table>
<thead>
<tr>
<th>Industry sector</th>
<th>No. of new cases assessed during 2001-03 per 100,000 employees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraction energy and water supply</td>
<td>489.3 (approx. 0.49%)</td>
</tr>
<tr>
<td>Construction</td>
<td>13.6 (approx. 0.013%)</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>7.4 (approx. 0.007%)</td>
</tr>
<tr>
<td>Agriculture, forestry and fishing</td>
<td>3.3 (approx. 0.003%)</td>
</tr>
</tbody>
</table>

Source: HSE, 2004B
Health Effects from Exposure to HAV

The relationship between operatives’ exposure to HAV (in terms of magnitude of vibration and duration), and the resulting negative health effects as a result of that exposure dosage, is far from definitively understood (cf. BOMEL, 2003, pviii). That is, the cause-effect relationship between exposure and negative health cannot be accurately stated without reference to other influencing factors, such as:

- individuals’ susceptibility [to HAVS];
- posture [when performing work tasks or using tools]; and
- individuals’ exposure history [which may be complex and difficult to account for objectively] (ibid.) [comments in square brackets by present authors].

It should also be borne in mind that certain aspects of negative health in hands, wrists and arms might result from factors totally divorced from HAV exposure; such as previous injuries, strain resulting from physical social activities and so on. It is also the case that Raynaud’s Disease (which causes VWF symptoms) can occur in the general population independently of any vibration exposure (HSE, 2004B). Therefore, HAV exposure and an individual’s negative health must be viewed holistically and it should not be automatically assumed that the latter is entirely a result of the former.

HAVS can have a degenerative effect on sufferers not only at work, but also at any other time, such as when performing hobbies (especially outside in lower temperatures) and when attempting to do anything that requires finger/hand manipulation (cf. HSE, 2003C, p4).

HAVS may be broadly classified under three medical groupings. These are:

- vascular disorders;
- neurological damage; and
- ‘other’ kinds of damage (HSE, 2003B, p3).

Each of these is now discussed in a little more detail.

**Vascular Disorders**

These disorders generally relate to damage of the vessels that circulate blood (in this instance, to the hands and fingers). Perhaps the best known is the condition termed Vibration White Finger (VWF) which results from impaired blood circulation and is typically characterised by ‘blanching’ of the fingers and/or parts of the hand. [Medical definition of VWF: Raynaud’s disease especially when caused by severe vibration as in prolonged and repeated use of a chain saw (Anon, 2004A)].

Early VWF symptoms may be mild. For example, an initial sign is when fingertips become white (HSE, 2003D). Once this stage is reached, continued HAV exposure may lead to progression of the condition and may be evidenced by an increased area of the hand being affected by the blanching and an increased frequency of such occurrence (HSC, 2003, p31). VWF symptoms are typically triggered by exposure of the hand to cold and/or wet conditions (HSE, 2003C, p4). During an attack the fingers might also feel ‘numb’ and a sensation of ‘pins-and-needles’ may also be experienced (HSE, 2003D).

A more progressed state of VWF can be triggered by a less significant reduction in temperature and if left to progress even further the condition will ultimately lead to increased numbness, increased tingling and a significant decrease in manual dexterity of the hands (HSC, 2003, p31). In the most severe cases, damage to blood circulation may become permanent causing fingers to turn ‘blue-black’ in colour. In exceptional cases, gangrene may result (HSE, 2003B, p4).
Neurological Damage

This concerns damage caused to the nervous system (in this instance, relating to the hands and arms). It is characterised by numbness and tingling, a reduction of strength in the hand (e.g. lower grip strength) and reduced sensitivity (e.g. a reduced sense of touch and sensitivity to temperature) (HSE, 2003B, p3). Sensory nerve damage may also lead to permanent numbness and tingling in the fingers (HSE, 2003D).

Carpal Tunnel Syndrome (CTS) is a disorder coming under this group and can cause tingling, numbness and weakness, particularly in the wrist of the hand. [Medical definition of CTS: Chronic pain and paresthesia in the hand in the area of distribution of the median nerve, caused by compression of the median nerve by fibres of the flexor retinaculum and associated with repetitive motion (Anon, 2004B)].

‘Other’ Kinds of Damage

‘Other’ negative health effects and their contributing factors (i.e. the cause-effect relationship) are less well understood than their vascular and neurological counterparts (HSE, 2003B, p3). Generally, such effects include pain and stiffness in the fingers, hands, wrists, lower arms and shoulders (ibid.). These other effects have also been described as resulting from damage to muscles, bones and joints; leading to general loss of strength and increased prevalence of pain in wrists and arms (HSE, 2003D).

Combined, the above HAVS symptoms may be summarised as affecting the:
- fingers;
- hands;
- wrists;
- lower arms; and
- in some cases, upper arms and shoulders.

HAVS symptoms may be summarised as being characterised by:
- pain;
- numbness;
- pins-and-needles;
- loss of senses (touch/temperature);
- loss of strength;
- loss of manual dexterity; and
- VWF and CTS.

Classification of HAVS Symptoms

The diagnosis and medical interpretation of HAVS symptoms is a matter for health professionals, so the following is intended to provide a degree of ‘background’ knowledge on the subject only.

VWF classification (i.e. the vascular aspect alone) has previously been assessed using the Taylor-Pelmear Scale. However, HAVS comprises not one, but two principal aspects (i.e. vascular and neurological), and since these two aspects can progress separately then the Stockholm Workshop Scales (SWS) have now generally replaced the Taylor-Pelmear scale and are the preferred method of classifying vascular and neurological HAVS symptoms (HSE, 2003B, p26). Using the SWS both hands are assessed individually. The vascular aspect is graded by consideration of the number of affected fingers on each hand. Table 2 outlines the stage classifications, grades and descriptions associated
with the SWS. Note however that the HSE are considering the splitting of stage 2 into ‘early’ and ‘late’ stages; the idea being to identify those individuals with ‘early’ stage 2 symptoms and implement control measures to stop (their) progression to ‘late’ stage 2 symptoms. The HSE will be publishing advice on this during 2005.

Table 2. The Stockholm Workshop Scales used for classifying HAVS symptoms

<table>
<thead>
<tr>
<th>Vascular aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage classification*</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>1V</td>
</tr>
<tr>
<td>2V</td>
</tr>
<tr>
<td>3V</td>
</tr>
<tr>
<td>4V</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sensorineural aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage classification*</td>
</tr>
<tr>
<td>0SN</td>
</tr>
<tr>
<td>1SN</td>
</tr>
<tr>
<td>2SN</td>
</tr>
<tr>
<td>3SN</td>
</tr>
</tbody>
</table>

Source: HSE (2003B, p27)
*Note impending HSE guidance on splitting of stage 2 - see commentary

An additional way of assessing the vascular symptoms (i.e. extent of blanching) to complement use of the SWS, is by using the Griffin (1990) method. Here, a numerical value is assigned to each phalanx\(^2\) of each finger; and an overall score for each hand is derived based on the extent of affected area (i.e. extent of affected phalanges). A worked example of this method may be observed in HSE (2003B, p23).

\(^2\) Phalanx: any of the long bones of the fingers (or toes) numbering 14 in total for each hand or foot and comprising two phalanges for the thumb or big toe, and three phalanges each for the other four digits (Anon, 2004C).
Legislation and HAV

There are many International (ISO) and British (BSI) Standards underpinning the legislative aspects of HAV, indeed these are too numerous to discuss individually in a Guide of this (limited) size. However, full bibliographic listings of the most ‘prominent’ HAV Standards are provided in the References and Bibliography; the specific subjects of which are identifiable from their respective titles. An overview of each British Standard may be viewed on the British Standards Institution website at: http://bsonline.techindex.co.uk. Some of these standards are also cited specifically throughout various parts of this Guide.

Both employers’ and employees’ general duties with respect to vibration hazards in the workplace are defined within various UK health and safety Statutory Instruments, which subsequent the new Control of Vibration at Work Regulations 2005 will remain in force. These existing Statutory Instruments include:

- The Health and Safety at Work Act (HASWA, 1974);
- The Management of Health and Safety at Work Regulations (MHWR, 1999);
- The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR, 1995);
- The Provision and Use of Work Equipment Regulations (PUWER, 1998);
- The Supply of Machinery (Safety) Regulations 1992 as amended (SMSR, 1994); and


However, the most comprehensive and specific legislation for HAV is contained within the Control of Vibration at Work Regulations 2005 (CVWR, 2005). These Regulations govern the protection of operatives from HAV in the main by reference to vibration exposure Action and Limit values. These values, which are fundamental to the understanding and implementation of the CVWR, may be defined as follows.

- The Exposure Action Value (EAV) is a level of daily operative exposure, which if exceeded, requires action (i.e. control measures) to be taken to reduce the risk. The daily EAV normalised to an 8-hour reference period is defined as A(8). The action value for HAV expressed in A(8) is 2.5.

- The Exposure Limit Value (ELV) is a level of daily operative exposure, that must not be exceeded. The daily ELV normalised to an 8-hour reference period is also defined as A(8). The limit value for HAV expressed in A(8) is 5.

_N.B. These action and limit values are expressed in fundamental units of m/s² (metres per second, per second), so the EAV for example, is described (in fundamental units) as having an A(8) value of 2.5m/s². For simplicity however, it is easier wherever possible to ‘concentrate’ only on the A(8) descriptor when (as an example) making reference to published vibration data._

---

3 To find a specific Standard, enter the Standard number in the ‘Search’ facility. By registering with the BSI website, users may also view a summary of each Standard showing an abstract of contents, current status (e.g. current, withheld, work-in-hand), availability and cost etc.

4 CVWR (2005) also prescribes duties on employers with respect to whole-body vibration (WBV); but WBV is beyond the scope of this Guide on HAV. OPERC have published a separate Guide in respect of WBV. For details see ‘Bookshop’ on the OPERC website at: www.operc.com.
The following section of this Guide (How to Identify HAV Risks) explains how the EAV and ELV are applied in practice. It also gives examples of calculating A(8) for the purposes of risk assessment (by comparing the derived A(8) value against the EAV and ELV), and for the purposes of deciding upon necessary risk control measures.

Under the CVWR, application of the ELV may be deferred on items of equipment where it is not reasonably practicable to comply with them and where the equipment referred to was provided to an operative before 6 July 2007. There is a transitional period of up to 6 July 2010 for such equipment; this period being designed to allow for the introduction of new machines, new technologies or new working methods that can achieve the ELV.

In the event of new equipment, technologies or working methods becoming available, then the ‘older’ equipment can no longer enjoy the transitional period and must henceforth comply with the ELV. Note however, that the ELV applies to any new equipment provided to an operative after 6 July 2007.
How to Identify HAV Risks

It is a requirement of the Control of Vibration at Work Regulations (CVWR, 2005) that employers who by the nature of their work activities might be exposing operatives to HAV hazards, must carry out an assessment of HAV risks. The principal ambition of this assessment is to enable valid decisions to be made about: i) the extent of the risk(s); and ii) corresponding necessary control measures required to remove or mitigate them (cf. HSC, 2003, p71). The overriding philosophy is one of encouraging a proactive regime; that is, identify the risks and remove or minimise them before they can have any negative effect on operatives’ health.

Risk Assessment

The exact nature and extent of the risk assessment will be a function of the circumstances surrounding the work activity, or activities, under consideration. For example, where it is quite apparent from the assessment that exposure is below and unlikely to exceed the exposure action value (EAV), then it is sufficient to record (i.e. explain and justify) this finding within the risk assessment report (HSC, 2003, p49). However, even in such cases where exposure does not exceed the EAV, it is a requirement of the Regulations that exposure be reduced as much as possible, in situations where further reduction is reasonably practicable.

Where vibration exposure does exceed, or is likely to exceed the EAV, then a more formal and systematic assessment needs to be carried out and the control measures decided upon (as a result of this more systematic assessment) should be specifically designed to address this increased level of exposure.

According to the HSC (HSC, 2003, p73), industries where HAV is a common hazard include:

- general engineering;
- heavy engineering;
- forestry and agriculture;
- foundries;
- construction (building and civil engineering);
- road maintenance; and
- utility services.

Specific work processes that tend to represent a high risk of HAV exposure include:

- drilling hard materials (such as plugging masonry);
- breaking-up of hard materials (such as demolishing concrete structures);
- consolidation or compaction of bulk materials (such as using vibrating rollers);
- mechanical fixing methods (such as riveting);
- mechanical preparation of surfaces (such as scabbling and de-scaling);
- grinding and sanding of various materials;
- cutting of various materials; and
- manually holding or supporting materials that are being worked upon by some other mechanised process.
The risk assessment should identify all sources of HAV and make a reasoned estimate of exposure in respect of all operatives, for comparison with the EAV and ELV. The risk assessment must be ‘suitable and sufficient’ which means that it must:

- identify where the hazard(s) are;
- make a robust estimation of all operatives who might be exposed to the hazard(s);
- for operatives who are exposed, evaluate their risk exposure;
- where appropriate, consider suitable and available control mechanisms; and
- make explicit (through an ‘action plan’ produced as part of the risk assessment) what control measures are going to be implemented to mitigate or control the risk(s); and how these control measures might be monitored over time.

The results of the risk assessment must be recorded along with the action plan. The assessment must be reviewed if there is any reason to suspect that it is no longer valid (e.g. the tools to which it referred have been replaced by different tools), or if there has been any significant change in the work to which it relates (e.g. operatives’ vibration exposure times have increased). Risk assessment results should also be used as a basis for informing operatives of what risks are related to their work and as a starting point for design and development of operatives’ HAV training and education.

Guidance on undertaking health and safety risk assessments in general is available from the HSE (HSE, 2003E).

The process of determining an operative’s HAV risk can be approached using either a ‘rule-of-thumb’ method or from the standpoint of a ‘definitive’ risk assessment that calculates maximum exposure times. One rule-of-thumb method (Construction Confederation, 2004) uses a ‘traffic light’ system where green symbolises ‘low’ risk tools (emitting less than 5 m/s²), orange symbolises ‘medium’ risk tools (vibration between 5 to 10 m/s²) and red represents ‘high’ risk tools (vibration levels exceeding 10 m/s²). The HSE will also be publishing guidance on performing rule-of-thumb risk assessments about mid-2005.

Definitive risk assessment requires calculation of operatives’ daily exposure expressed as A(8) and comparison of that daily exposure value against the action and limit values. This process may be considered in terms of six stages as follows:

1. identify the specific tool(s) or source(s) of HAV that an operative is exposed to;
2. establish a reliable and relevant ‘average’ vibration magnitude for each tool or source;
3. determine reliable estimates of the operatives’ exposure duration(s) for each tool(s);
4. based on (2) and (3), determine the A(8) value;
5. compare the A(8) value from (4) against the EAV and ELV values; and
6. design appropriate control measures based on the results of (5).

In establishing vibration magnitude for a tool, it should be considered that this can vary, sometimes quite significantly, between different operating conditions (e.g. methods of tool use) or between different ‘brands’ of the same type of tool. For example, research being undertaken by the authors at the time of writing has identified variance in maximum exposure times (to ELV) averaging 50 per cent, purely as a result of operative ‘technique’ (i.e. as a result of the way in which a tool is used). Significant variance has also been observed between similar types of tool, but produced by different manufacturers. In practical terms this means that larger vibration levels at source will reduce the amount of work that a tool can do, before its operative’s exposure reaches the EAV or ELV. Appendix A demonstrates some examples of this by comparing different manufacturers’ breakers, combi-hammers and battery drill tools (OPERC, 2005). Not least for these reasons of variance in vibration levels, it is good practice to compare vibration data from at least two sources for use in risk assessments (HSC, 2003, p78).
Table 3 presents some typical vibration magnitude data for a range of hand-held power tools. It is highlighted that this Table is provided solely to provide insight as to ‘typical’ magnitude values; and that for the purposes of accurate risk assessment the most reliable source of such data is arguably from field test vibration measurements in accordance with ISO 5349 Parts 1 and 2 (ISO, 2001A; 2001B). Those data in Table 3 were collected from the Centralised European Hand-arm Vibration Database (CEHVD, 2004). This database allows searches for vibration magnitude data from approximately 2,500 different hand-held power tools. Another such database is available at the Catalogue of Representative Noise and Vibration Data at Workplaces (CRNVD, 2005).

Column four of Table 3 identifies the source of these data as being either ‘ISO 8662’ or ‘Field’. The former are measurements taken in laboratory conditions in accordance with the relevant part of ISO 8662 (or BS EN ISO 8662 equivalent, see full list of standards in References and Bibliography). These are best used for comparison of vibration emissions between tools of the same type, for example, when considering which brand of a certain tool to purchase. These (8662) data may not necessarily however, accurately mirror vibration levels generated by tools when they are actually in use (e.g. in taking into account the sharpness of chisels or cutting edges, the way the operative holds or uses the tool etc.). For this reason ISO 8662 derived values should be used with caution for risk assessment purposes (CEHVD, 2004). Field measured values (i.e. in accordance with ISO 5349, refer above) are more influenced by actual working conditions and may better reflect ‘true’ vibration magnitudes (ibid.).

<table>
<thead>
<tr>
<th>Tool type</th>
<th>Tool make</th>
<th>Power supply</th>
<th>Method of measurement</th>
<th>Vibration Magnitude m/s²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chipping hammer</td>
<td>Hitachi</td>
<td>Electric (1.3Kw)</td>
<td>ISO 8662</td>
<td>12</td>
</tr>
<tr>
<td>Wall chaser</td>
<td>Bosch</td>
<td>Electric (0.9Kw)</td>
<td>ISO 8662</td>
<td>4</td>
</tr>
<tr>
<td>Hammer drill</td>
<td>Hitachi</td>
<td>Battery</td>
<td>ISO 8662</td>
<td>6.5</td>
</tr>
<tr>
<td>Hand drill</td>
<td>Makita</td>
<td>Electric (0.23Kw)</td>
<td>ISO 8662</td>
<td>&lt;2.5</td>
</tr>
<tr>
<td>Angle grinder</td>
<td>Hitachi</td>
<td>Electric (2Kw)</td>
<td>ISO 8662</td>
<td>&lt;2.5</td>
</tr>
<tr>
<td>Belt sander</td>
<td>Makita</td>
<td>Electric (0.85Kw)</td>
<td>ISO 8662</td>
<td>&lt;2.5</td>
</tr>
<tr>
<td>Riveting hammer</td>
<td>Atlas Copco</td>
<td>Pneumatic</td>
<td>ISO 8662</td>
<td>7.8</td>
</tr>
<tr>
<td>Lawnmower</td>
<td>Black &amp; Decker</td>
<td>Combust. engine</td>
<td>ISO 8662</td>
<td>&lt;2.5</td>
</tr>
<tr>
<td>Nibbler</td>
<td>Bahco</td>
<td>Pneumatic</td>
<td>Field</td>
<td>8.6</td>
</tr>
<tr>
<td>Rammer</td>
<td>Atlas Copco</td>
<td>Pneumatic</td>
<td>ISO 8662</td>
<td>4.5</td>
</tr>
<tr>
<td>Jigsaw</td>
<td>Bosch</td>
<td>Electric (0.58Kw)</td>
<td>ISO 8662</td>
<td>4</td>
</tr>
<tr>
<td>Vibrating plate compactor</td>
<td>Vibromax</td>
<td>Combust. engine</td>
<td>Field</td>
<td>8.2</td>
</tr>
<tr>
<td>Wrench</td>
<td>Atlas Copco</td>
<td>Pneumatic</td>
<td>Field</td>
<td>4.6</td>
</tr>
</tbody>
</table>

Source: CEHVD (2004)
In considering an operative’s vibration exposure time, this must be the actual time the tool is held and in use; sometimes referred to as the ‘trigger-time’ (HSC, 2003, p79). It is not therefore the time that an operative might have a tool on site, or on their workbench, but the duration of time that the hand(s) is (are) actually subjected to vibration from it.

To determine A(8), it is convenient to carry out the calculation using a device such as the HSE’s Hand-arm Vibration Exposure Calculator which is publicly available on the HSE website (HSE, 2004C). Examples of how to use this device are given below.

(For the interested reader, the mathematical formulae underpinning A(8) calculations for both daily and weekly HAV exposure values are presented in Appendix B. Note however, that for most cases it is not a requirement to understand these formulae in order to assess HAV risks, for as the worked examples below demonstrate, this can often be done by reference to relevant published data and/or by using the HSE’s web-based vibration exposure calculator).

An alternative approach to determining operative risk from a tool is to compare the average vibration produced by the tool against time-exposure data relating to the EAV and ELV. In this respect, Table 4 shows maximum exposure (trigger) times for a range of vibration magnitudes (at source), required to reach the EAV A(8) value of 2.5 m/s² and the ELV A(8) value of 5 m/s² respectively. An example of how to interpret this information in practice is also given below.

Table 4. Maximum ‘trigger’ times for a range of average vibration magnitudes at source, to reach the A(8) exposure action and limit values

<table>
<thead>
<tr>
<th>Average Vibration Magnitude at source m/s²</th>
<th>Maximum trigger-time to reach exposure ACTION value of 2.5 m/s²</th>
<th>Maximum trigger-time to reach exposure LIMIT value of 5 m/s²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hrs</td>
<td>Mins</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>1.0</td>
<td>&gt;24</td>
<td>-</td>
</tr>
<tr>
<td>1.5</td>
<td>22</td>
<td>13</td>
</tr>
<tr>
<td>2.0</td>
<td>12</td>
<td>30</td>
</tr>
<tr>
<td>2.5</td>
<td>8</td>
<td>00</td>
</tr>
<tr>
<td>3.0</td>
<td>5</td>
<td>33</td>
</tr>
<tr>
<td>3.5</td>
<td>4</td>
<td>05</td>
</tr>
<tr>
<td>4.0</td>
<td>3</td>
<td>08</td>
</tr>
<tr>
<td>4.5</td>
<td>2</td>
<td>28</td>
</tr>
<tr>
<td>5.0</td>
<td>2</td>
<td>00</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>23</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>01</td>
</tr>
<tr>
<td>8</td>
<td>-</td>
<td>47</td>
</tr>
<tr>
<td>10</td>
<td>-</td>
<td>30</td>
</tr>
<tr>
<td>15</td>
<td>-</td>
<td>13</td>
</tr>
<tr>
<td>20</td>
<td>-</td>
<td>08</td>
</tr>
</tbody>
</table>

Source: calculated using HSE’s Hand-arm Vibration Exposure Calculator (HSE, 2004C)
Worked Example 1: Calculating A(8) and Assessment of Risk Where Only One Vibrating Tool is Used a Day

An operative uses just one vibrating tool (an angle grinder) for approximately 3.5 hours per day. Reference to reliable vibration magnitude data for this particular type of grinder has established that the average vibration from it is 4.5m/s². What is the operative’s daily exposure A(8)?

Figure 1 is a screen shot from the web, where the HSE’s Hand-arm Vibration Exposure Calculator (HSE, 2004C) is being used to calculate this operative’s A(8). User input information (such as vibration magnitude) is typed into the white cells and output information is subsequently (automatically) provided in the yellow cells.

Figure 1. Calculation of vibration exposure using just one vibrating tool in a day

![Image of vibration exposure calculator](http://www.hse.gov.uk/vibration/hav.xls)

© Crown copyright material is reproduced with the permission of the Controller of HMSO and Queen’s Printer for Scotland.

So it is shown in this example, that by inserting the average vibration magnitude for the angle grinder of 4.5 in cell C7 and the daily exposure time of 3 hours and 30 minutes in cell L7, that the operative’s daily exposure A(8) is 3.0 m/s² in cell N17. The facility also calculates the time of exposure (for the given tool’s vibration magnitude) that is required to reach both the EAV and the ELV. In this example, the operative would reach the EAV after 2 hours and 28 minutes in cell E7; and reach the ELV after 9 hours and 53 minutes in cell I7.

The latter information regarding EAV and ELV times is similar to that shown in Table 4. That is, if the vibration magnitude (for the angle grinder) of 4.5m/s² is read-off along the eighth row of the Table, it is shown that the EAV is reached after 2 hours and 28 minutes of use; and the ELV would be reached after 9 hours 53 minutes of use.

So for this particular example, it is demonstrated that use of the angle grinder for 3.5 hours a day would mean that the operative would be exceeding the action value (3 > 2.5) but be below the limit value (3 < 5). In practice, to reduce exposure below the EAV while maintaining 3.5 hours of use, would require a lower vibration tool or some other control measure to reduce the magnitude of vibration reaching the operative’s hands. If the same tool were to be used (and no other control measure could be implemented) then the operative’s exposure time to the angle grinder would need to be less than 2.5 hours per day to keep below the EAV.
Worked Example 2: Calculating A(8) and Assessment of Risk Where More Than One Vibrating Tool is Used a Day

An operative uses three vibrating hand-held tools in a typical working day. The first has an average vibration magnitude of 2m/s² and is used for 3 hours; the second has a magnitude of 2.5m/s² and is used for 1.5 hours; and the third has a magnitude of 5m/s² and is used for 45 minutes. What is the operative’s daily exposure A(8)?

The calculation for this scenario using the HSE Hand-arm Vibration Exposure Calculator is shown in Figure 2. As per the previous example, the input data (magnitude and duration) is typed into the white coloured cells for each tool respectively.

Figure 2. Calculation of vibration exposure using more than one vibrating tool in a day

![Hand-arm Vibration Exposure Calculator](http://www.hse.gov.uk/vibration/hav.xls)

The partial exposure values for each tool are subsequently given at the end of each row. These are: for tool 1, 1.2 m/s² [cell N7]; for tool 2, 1.1m/s² [cell N8]; and for tool 3, 1.5m/s² [cell N9]. Based upon these partial exposure values, the overall daily exposure A(8) for this operative is 2.2m/s² [cell N17] which is below the EAV (2.2 < 2.5). Noteworthy here is that total daily exposure A(8) is not simply the sum of partial exposure values - but this need not be of concern - because the exposure calculator works out the total daily exposure value automatically. (Alternatively, the formula for calculating A(8) for two or more operations is provided in Appendix B).

In practice therefore, it would be sufficient to record in the risk assessment documentation that this operative is below the EAV and that no ‘urgent’ control measures are necessary. Nonetheless, the Regulations require that could any control measures be implemented to lower this A(8) value (i.e. 2.2) further, then these should be implemented in order to minimise the risk as much as practicably possible.

Employee Health Surveillance

The CVWR require that in certain circumstances employers need to survey the health of operatives exposed to HAV. The ‘general’ conditions under which a surveillance regime should be implemented include where assessment has indicated a risk to operatives’ health and where operatives are likely to be regularly exposed above the EAV (list not exhaustive). The issue of health surveillance is of course a specialist (medical) topic and to this end the HSE will be publishing specific guidance during 2005.
How to Minimise the Risks

In almost all cases, HAV hazards can be controlled and risks eliminated by good management (HSC, 2003, p27). Neither do the costs of risk controls need to be high (ibid.). There are many actions that can be taken to minimise or remove the risks from HAV and these can be conveniently grouped under the following headings:

- selecting the right equipment;
- encouraging good (equipment) maintenance;
- isolating the vibration;
- changing work processes;
- operative good practice; and
- training and education.

In practice, these headings may experience some overlap. For example, the introduction of a vibration isolating mechanism on a tool may require a slight change in work process (to allow the new mechanism to be used properly). It may also need to be routinely inspected and maintained (to ensure efficiency) and its use adequately explained as part of an operative training and education (or induction) programme. Bearing in mind this potential for overlap, each of these headings will now be discussed separately.

Selecting the Right Equipment

This can be considered in terms of:

i) company purchasing policy, in seeking to only purchase (or lease, hire etc.) equipment that has been engineered to minimise vibration; and

ii) ensuring that equipment selected for use is the most appropriate for the proposed work task(s).

The HSE (HSE, 2003B, p17) suggest that many manufacturers now offer ‘lower-vibration’ versions of certain tools; and go on to state that when considering a purchase, prudent questions to ask manufacturers include such things as:

- “What is the frequency-weighted acceleration producing the highest vibration under ‘typical’ operating conditions?”
- “Under what conditions and in accordance with what published standard were vibration tests made on the equipment?” (Refer to Table 3 and its associated commentary regarding the variance that may exist between laboratory determined vibration levels and actual vibration levels experienced in ‘normal’ use).
- “What additional vibration-reducing measures have been made or are available for the equipment?”
- “What is the maximum vibration level that the equipment can be guaranteed not to exceed?”

Other questions might relate to manufacturer’s advice regarding any additional control(s) or specific maintenance requirement(s) to maintain lower vibration levels or help mitigate exposure even further.

Additionally, all new equipment and machinery on sale within the UK should be ‘CE’ marked - which amongst other things, indicates that the machine meets the relevant health and safety requirements of Schedule 3 of the Supply of Machinery (Safety) Regulations (SMSR, 1994) - and this includes the manufacturer’s duty to minimise risks by design and to provide information on vibration emissions (HSC, 2003, p128).
Regardless of how ‘state-of-the-art’ an item of equipment is, it is important that the tool selected is the most appropriate for the proposed work task(s). An inappropriate tool may increase vibration exposure by:

- taking longer to do the job (e.g. resulting in an increased exposure duration);
- requiring an inappropriate method of being held (e.g. resulting in an increased area of hand exposure);
- requiring an inappropriate operative posture to carry out the work;
- being heavier, or vibrating more (than an appropriate tool); and
- being unsafe in other ways (cf. HSC, 2003, p33).

**Encouraging Good Maintenance**

As with most mechanised processes or equipment, good maintenance is key to efficient and safe working (Edwards et. al., 2003). An efficient tool generally requires less time to complete a task than does an inefficient one. For this reason it is fundamental to maintain equipment well, especially in terms of:

- keeping cutting disks or cutting blades sharp;
- keeping breaking or cutting chisels sharp;
- keeping chain saw teeth sharp and to the correct tension;
- dressing grinding wheels correctly; and
- keeping rotating components well balanced (an unbalanced component will vibrate more, this being analogous to ‘steering-wheel shake’ when a vehicular road wheel is out of balance).

It is equally as important to keep all vibration-reducing measures fitted to equipment in good condition also. This includes checking things such as rubber mountings for cracking, swelling, softening or hardening and anti-vibration or suspended handles for deterioration (cf. HSE, 2003B, pp18-20). Where in doubt about maintenance methods or regimes, ask! Equipment manufacturers or suppliers should be able to advise as appropriate and/or supply maintenance schedules. It is also good practice (in any event, not just in the context of vibration) to encourage operatives to report damaged or suspect aspects of equipment, for example, as part of their vibration training and education (see below).

**Isolating the Vibration**

Isolation can be achieved in part from process change and this is discussed under the next heading. Isolation generally refers to the use of anti-vibration handles, mounts, tension chains or other accessories that reduce the magnitude of vibration reaching the hand, or help remove the need to grip vibrating surfaces (HSE, 2003B, p19).

The selection and use of isolation equipment must be undertaken with care. The retrospective fitting of anti-vibration accessories can sometimes exacerbate the problem if the accessory is not carefully matched to the tool or process. For this reason it is preferable that anti-vibration accessories are an integral, or engineered-in aspect of a tool (refer to the advice of discussion with manufacturers above).

The retrospective application of resilient materials to handles etc. is also uncertain in terms of effectiveness; such materials might reduce high-frequency vibration but generally do little to reduce transmission in the frequencies associated with causing HAVS (HSE, 2003B, p19). The efficiency of anti-vibration gloves is also somewhat open to question. It has been suggested that in some...
instances these gloves may even increase vibration reaching the hand (HSE, 2003B, p20). However, gloves can help to keep hands warm which in turn helps maintain better blood circulation, so their use in colder environments is beneficial.

### Changing Work Processes

The approach here is to remove the need for hand-held vibration-emitting tools or processes in order to avoid operative exposure to vibration. The use of automation or mechanisation for work processes previously or commonly performed by hand-held tools, removes the risk (HSE, 2003B). Such an approach requires careful review of the work tasks, perhaps by asking questions such as: "How can the process be changed to remove the need for hand tools?" Or, "How can the activity be done differently to minimise the need for hand guiding or holding?"

For example, in the case of stonemasons the use of automated planing machines to shape stone or the use of auto-lettering machinery in preference to hand-held tools for the same purpose, have been cited as practical examples (HSE, 1998). Regarding hand-held processes, then the use of guides or jigs to present work materials up to vibrating machinery (such as a grinder) can reduce, or if fully automated remove, vibration transmission.

Due (for example) to practical or technological constraints, there may be instances where the tool(s) used, method of working or work process itself cannot be changed; or where such change (due to similar reasons) is limited in scope. Hence, in these conditions a degree of exposure will remain, so the ‘process’ might be adjusted by introduction of ‘constraints’ or new working ‘parameters’, such as:

- limiting the amount of time (e.g. in any working day) that an operative can use a particular tool or perform a particular process; or
- implementing a rota scheme for hazardous activities whereby operatives perform other (non-vibration exposure) work tasks at all other times.

### Operative Good Practice

The way in which an operative uses their equipment can significantly influence the amount of HAV produced. Indeed, research being carried out by the authors at the time of writing has identified an average 50 per cent ‘variance’ in vibration levels experienced among operatives, resulting solely from operative ‘technique’ (posture, hand grip etc.). Good operative practice results mainly from applying ‘common sense’ which in turn is encouraged by adequate training and education. Good practice includes the following.

- First, many of the issues mentioned elsewhere in this Guide relate to the operative taking some responsibility for vibration risk mitigation. This means adhering to some very basic rules such as selecting the right tool for the job; using low vibration options when available; checking tools regularly (vibration may occur from faults or simple wear-and-tear); not using faulty tools; reporting faults instantly; and ensuring that cutting tools are sharp.
- Tools should be stored such that they do not get cold handles (especially relevant to operatives working outside). Using tools with cold handles magnifies the problems of HAVS.
- The hand-grip of a tool should always be just adequate to safely support the tool and perform the task. A tight grip can place extra strain on the hands and arms and make the problems of HAV worse.
- Correct operative posture is important to avoid placing extra strain on hands and arms. Not using tools that are ‘over-rated’ or too heavy for the task in hand and by using tension chains to support heavier bench tools can help here.
It is important that operatives try to maintain good blood circulation, especially in the hands. Good circulation can be helped by keeping warm and dry, and by the wearing of gloves. Giving up, or cutting down on smoking also helps, because smoking reduces blood flow. It may also help if the fingers are massaged and exercised during periods of rest.

Finally, operatives have a duty to comply with any vibration control measures that the employer has put in place.

Training and Education

It has been highlighted that the use of untrained, or inadequately trained operatives, is a major cause of accidents (Edwards, 2002). It follows therefore, that if operatives possess an understanding of HAV as a result of training and education, then it can help them to look for the risks and try wherever possible to avoid, or minimise them. Operatives should at least understand the level of HAV risk to which they might be exposed, how that risk is caused and what the possible negative health effects might be (HSC, 2003, p65).

Where the EAV is exceeded, CVWR places a duty on employers to provide suitable and sufficient training for operatives such that work equipment may be used correctly and safely in order to minimise their exposure to vibration (CVWR, 2005).

Training can be delivered via any mix of: oral explanations, computer-based training, counselling, leaflets, handouts, films and other recordings, or short dedicated training sessions (HSC, 2003, p66). More comprehensive guidance on the design and delivery of training, specifically for plant operatives, is provided in Edwards (2003).

The specific content of training material will reflect the actual work setting and industry sector, but should include reference to: identification of vibration-emitting work processes; operatives’ personal daily exposure levels as determined by the EAV and ELV; description of HAVS and its symptoms; negative health reporting systems; control measures and their use; and operatives’ general health and safety duties (HSC, 2003).
Conclusion

Hand-arm vibration (HAV) is concerned with the transmission of vibration into operatives’ hands and arms through any combination of:

- contact with vibrating hand-held tools;
- contact with hand-guided equipment; and
- holding materials during vibration-emitting work processes.

Prolonged or repeated exposure to HAV can cause negative health, particularly in the hands and lower arms. These negative health effects are sometimes generically referred to as hand-arm vibration syndrome (HAVS). The medical effects of HAVS tend to be either:

- vascular (related to blood circulation);
- neurological (related to the nervous system); or
- ‘other’ which includes general pain and stiffness.

Probably the most well known medical conditions associated with HAVS are vibration white finger (VWF) and carpal tunnel syndrome (CTS). Finger blanching, tingling, pins-and-needles and general loss of manual dexterity are also symptoms associated with HAVS.

Health and safety legislation relating to HAV are defined among several UK health and safety statutory instruments, the most relevant of which is the Control of Vibration at Work Regulations 2005 (CVWR). Among other things, CVWR places duties on employers in reducing or removing HAV hazards, in the main by reference to an exposure action value (EAV) and exposure limit value (ELV).

- The EAV is a level of daily operative exposure, which if exceeded, requires action to be taken to reduce the risk. The daily EAV normalised to an 8-hour reference period is defined as A(8). The action value for HAV expressed in A(8) is 2.5m/s².
- The ELV is a level of daily operative exposure, that must not be exceeded. The daily ELV normalised to an 8-hour reference period is also defined as A(8). The limit value for HAV expressed in A(8) is 5m/s².

Under CVWR, the ELV may in certain circumstances be deferred (by up to July 2010) on items of equipment supplied to operatives before 6 July 2007, but it applies to any new equipment provided after this date. CVWR also requires employers to assess HAV hazards via a risk assessment process and subsequently take all reasonably practicable steps to control or remove them.

Risk assessment includes determination of operatives’ daily vibration exposure levels by considering exposure times and vibration magnitude data for the tool(s) used. Typically the latter can be done by reference to published data but caution is necessary in considering that often, vibration levels measured ‘in the field’ are greater than those measured under controlled conditions.

HAV hazards can usually be controlled by good management and need not necessarily incur high cost. Control measures can be conveniently grouped under the headings of:

- selecting the right equipment;
- encouraging good (equipment) maintenance;
- isolating the vibration;
- changing work processes;
- operative good practice; and
- training and education.

In practice, aspects of these control measures will most probably overlap to some extent.
References and Bibliography


Appendix A

Comparison of some different manufacturers’ tools: Amounts of work that can be done before EAV is reached

Tools: breakers

This chart shows how many kilograms of concrete can be broken from the edge of a 200mm thick 35N concrete block before reaching the exposure action value.

Tools: combi-hammers and battery drills

The shorter columns on the left of each pair show how many 25mm diameter holes can be drilled using a combi-hammer before reaching the exposure action value.

The taller columns on the right of each pair show how many 12mm diameter holes can be drilled using a battery drill before reaching the exposure action value.

Source: OPERC (2005)

Test parameters

Vibration measurements made in the field to ISO 5349-1. Each tool measured using three different subjects with a minimum of five repeat measurements each. Performance assessed for breakers by measuring mass of concrete broken in 10 minutes using three different subjects. Performance of combi-hammers and drills measured by time taken to drill 100mm deep hole of stated diameter using three different subjects and five repeat measurements each. Results presented above from combining vibration (m/s²) and performance (kg/no./sec) data. Note that repeat results could vary from those shown based on for example, different tools (e.g. manufacturing tolerances, wear and tear, sharpness), different base materials (e.g. hardness) and different operatives (e.g. operating techniques).
Appendix B

Formulae for calculation of daily and weekly HAV exposure [A(8)]

Daily vibration exposure [A(8)]
The daily personal vibration exposure level referred to as A(8) is expressed in metres per second squared (m/s²) and is derived from the formula:

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

where: \( a_{hv} \) is the vibration magnitude, in metres per second squared (m/s²); \( T \) is the duration of exposure to the vibration magnitude \( a_{hv} \); and \( T_0 \) is the reference duration of 8 hours (28,800 seconds).

To avoid confusion between vibration magnitude and daily exposure to vibration, it is conventional to express daily exposure to vibration in m/s² A(8).

The vibration magnitude, \( a_{hv} \), is ascertained using the formula:

\[ a_{hv} = \sqrt{a_{hx}^2 + a_{hy}^2 + a_{hz}^2} \]

where: \( a_{hx} \), \( a_{hy} \) and \( a_{hz} \) are the root-mean-square acceleration magnitudes, in m/s², measured in three orthogonal directions, \( x \), \( y \) and \( z \), at the vibrating surface in contact with the hand, and frequency-weighted using the weighting \( W_h \).

The definition for the frequency weighting \( W_h \) is given in British Standard BS EN ISO 5349-1: 2001 (BSI, 2001).

Where both hands are exposed to vibration, the greater of the two magnitudes \( a_{hv} \) is used to ascertain the daily exposure.

If the work is such that the total daily exposure consists of two or more operations with different vibration magnitudes, the daily exposure (A(8)) for the combination of operations is ascertained using the formula:

\[ A(8) = \sqrt{\frac{1}{T_0} \sum_{i=1}^{n} a_{hv_i} T_i} \]

where: \( n \) is the number of individual operations within the working day; \( a_{hv_i} \) is the vibration magnitude for operation \( i \); and \( T_i \) is the duration of operation \( i \).

Weekly vibration exposure [A(8)week]
The exposure to vibration averaged over one week (A(8)week) is the total exposure occurring within a period of seven consecutive days, normalised to a reference duration of five 8-hour days (40 hours). It is ascertained using the formula:

\[ A(8)_{\text{week}} = \sqrt{\frac{1}{5} \sum_{j=1}^{7} A(8)_j^2} \]

where: \( A(8)_j \) is the daily exposure for day \( j \).