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OPERC’s first edition of *A Guide to Hand-arm Vibration*, came about initially in response to Directive 2002/44/EC of the European Parliament on the minimum health and safety requirements regarding exposure of workers to the risks of physical agents (vibration). It was published in timely fashion to coincide with the UK’s health and safety legislation resulting from that Directive, known as the *Control of Vibration at Work Regulations (2005)*.

Since publication, the Guide has become an integral part of the health and safety literature in the field; whilst feedback from health and safety practitioners has confirmed that it also enjoys a place of prominence in the ‘armoury’ of reference material that employers look to, in supporting their legal obligations of the said Regulations. This success is most satisfying because any contribution that can be made to help mitigate the risks to workers from hand-arm vibration (and the often irreversible host of medical conditions that can result from ongoing exposure to them) is a worthy cause indeed.

OPERC has made noteworthy progress in furthering the science of hand-arm vibration (HAV) over the last few years. This progress has been evidenced in numerous complementary products and services, including: published practical workplace guidance, training materials (in DVD, paper and electronic formats), a free web-based HAV database and free online and downloadable HAV calculator and risk assessment aids. A significant amount of academic publications have also resulted directly from OPERC’s applied hand-arm vibration research initiatives, along with the field-testing of tools and equipment using leading-edge science and methods.

This seems a timely juncture therefore to revise this document based on that progress, as a mechanism to disseminate these advancements in knowledge, products and services, for the benefit of all who may gain from them. Accordingly, OPERC is pleased to offer you *A Guide to Hand-arm Vibration (2nd Edition)*.

Mr Graham Eaves
President, The Off-highway Plant and Equipment Research Centre (OPERC), 2007-2008
Welcome to OPERC

The Off-highway Plant and Equipment Research Centre (OPERC) has gained an enviable reputation as the leading international centre of excellence for plant and equipment science. OPERC represents all who are employed in the off-highway plant and equipment industries, including practitioners 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 of relevance to all stakeholders.

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 knowledge among all interested parties. Funds generated by the association are used to help research, author, publish and make available information (such as this Guide), that would otherwise be too time consuming and / or expensive for any single member to produce in isolation.

There are many benefits to be gained from becoming an OPERC member including access to free information and publications; access to teaching, learning and assessment materials; excellent networking opportunities; and attendance at OPERC events. More comprehensive description of these benefits, along with information on how you can join OPERC, can be found on the official OPERC website at: www.operc.com

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List of Acronyms Used

ALARP  As Low As Reasonably Practicable
BSI    [The] British Standards Institution
CTS    Carpal Tunnel Syndrome
CVWR   [The] Control of Vibration at Work Regulations (2005)
        and / or
        [The] Control of Vibration at Work Regulations
        (Northern Ireland) (2005)
EAV    Exposure Action Value
ELV    Exposure Limit Value
HAV    Hand-arm Vibration
HAVCalc [OPERC’s] Hand-arm Vibration Calculator
        [and Risk-assessment Aid]
HAVTEC [OPERC’s] Hand-arm Vibration Test Centre
HAVS   Hand-arm Vibration Syndrome
H&S    Health and Safety
HSE    [The] Health and Safety Executive
HSC    [The] Health and Safety Commission
ISO    [The] International Organization for Standardization
MCG    [The] Major Contractors Group
MHCG   [The] Major Hire Companies Group
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
within this Guide has been referenced throughout using the Harvard convention of author family name,
year of publication, and (if applicable) page number(s). For example, (Smith, 2004, p3). Full
bibliographic details of each reference cited, along with other useful references and additional
sources of information, may be found in the References and Bibliography.
Introduction

What is the Aim of this Guide?

A Guide to Hand-arm Vibration (2nd Edition) aims to provide a clear but succinct overview of the primary issues concerning workplace hand-arm vibration (HAV) and its management, particularly in the context of employers’ duties under the UK’s Control of Vibration at Work Regulations (2005)\(^1\). Its intended readership is principally company owners and senior management who, by nature of their role, need to embrace an awareness of the subject, but who thereafter will typically delegate the implementation of workplace HAV management issues to appropriate health and safety personnel.

In addressing this aim, the discussion that follows will include:

- a definition of HAV and the nature of its sources;
- a description of hand-arm vibration syndrome (HAVS);
- an indication of the negative-health effects that can present as a result of ongoing exposure to HAV;
- an overview of health and safety legislation relating to the subject;
- direction for identifying and assessing HAV risks; and
- guidance on controlling, mitigating or removing said risks.

This Guide is but one tool in a suite of facilities offered by OPERC relating to the subject of hand-arm vibration at the workplace. Complementary tools in this suite include:

- a practical guide (in booklet form) aimed at those directly responsible for managing hand-arm vibration exposure (Edwards and Holt, 2007A);
- a digital versatile disc for self-study, or for teaching and learning about HAV in groups (idem, 2006A);
- a self-study learning and self-assessment module available as downloadable PDF (OPERC, 2006);
- an online HAV register (‘HAVTEC’) (idem, 2007A), holding vibration data for a range of tools tested to ISO 5349 (ISO, 2001A; 2001B);
- an online (and downloadable version) of ‘HAVCalc’ (OPERC, 2007B), this being a unique HAV exposure calculator and risk assessment aid; and
- an online HAV knowledge and competency (multiple-choice) test facility (idem, 2007C).

OPERC has also developed a new risk-management ‘traffic light’ classification system for hand tools, in conjunction with the Construction Confederation, the Major Contractors Group (MCG) and the Major Hire Companies Group (MHCG). Under this new system, hand tools will be labelled with a colour code showing for how long they can be used before defined limits, as set out in the Control of Vibration at Work Regulations (CVWR), are reached or exceeded.

Combined, this suite of OPERC tools offers employers a means to assist with training and education of employees on the subject of hand-arm vibration, while also serving to help manage HAV risks at the workplace.

\(^1\) Note the slight difference in title for the Northern Ireland version, known as The Control of Vibration at Work Regulations (Northern Ireland) (2005) – see References and Bibliography for full listings.
Why is the Subject of HAV Important?

Put succinctly, HAV is concerned with the transmission of vibration into an operative’s hands and (typically, lower) arms (HSE, 2003A, p27). Usually, though not exclusively, this vibration results from using mechanical hand-held tools at work such as drills, saws and grinders. These tools impart such energy as a result of oscillatory motions (Griffin, 2004), normally emanating from their power source.

The ultimate risk to operatives from regular, frequent or ongoing exposure to HAV is negative health effects. These effects tend to be related (but are not limited) to impaired blood circulation (vascular damage), damage to nerves (neurological damage) and muscular or soft tissue damage (HSE, 2003B, p3; HSE, 2005A, §5) particularly, in the hands and arms. More specific medical symptoms resulting from HAV exposure are described under the section Potential Negative Health Effects from Exposure to HAV, but the most commonly ‘recognised’ conditions in this context are ‘Vibration White Finger’ (VWF) (Hughes and Ferret, 2003, p 283) and ‘Carpal Tunnel Syndrome’ (CTS) (HSE, 2005B).

VWF – or Secondary Raynaud’s Phenomenon to use its medical name – was first linked to the use of pneumatic (i.e. vibratory) tools in the early 1900s. Subsequently, general ‘awareness’ of VWF and its causes grew in line 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 in particular 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 later carried out by the Medical Research Council (1997-1998) estimated that 288,000 people suffered from VWF in Great Britain (HSE, 2004B). It may be that not all of these cases were directly attributable to contact with HAV but equally, VWF is but one of a much larger list of medical conditions that can result from HAV exposure. More detailed statistics on the extent of negative health associated with vibration exposure will be presented later.

Vibration is now considered such a serious workplace physical agent, that the European Community issued a health and safety Directive in 2002 (EC, 2002), requiring that member states incorporate into their relevant health and safety law the legislation to formally manage it. As a result, the CVWR (2005A) and their Northern Ireland equivalent (2005B) have done just that within the UK. Note that in addition to HAV, the CVWR also relate to the management of whole-body vibration (WBV) but the subject of WBV is similarly very specific and therefore beyond the scope of this Guide on HAV. A separate OPERC publication on whole-body vibration (Edwards and Holt, 2005A), along with a digital versatile disc on the subject (idem, 2005B), offer a good first point of information and guidance in this respect.

In view of the increased HAV ‘awareness’ outlined above, and more recently its ‘formalisation’ under the umbrella of UK workplace health and safety law by the said Regulations, this Guide explains how HAV issues affect both employers and employees who may use, or come into contact with, vibration-emitting hand-held or hand-guided tools and processes.

In summary, A Guide to Hand-arm Vibration (2nd Edition) provides a concise overview of current HAV knowledge combined with practical indications for meeting the requirements of the Control of Vibration at Work Regulations 2005 (hand-arm vibration).

2 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 exposure at work. The term may therefore be considered to include similar descriptors such as ‘person’, employee’, ‘worker’ and so on.

3 The CVWR define ‘whole-body vibration’ as mechanical vibration which is transmitted into the body, when seated or standing, through the supporting surface, during a work activity. In practice, such activities tend to involve operating or driving self-propelled machinery and vehicles, such as off-highway plant and equipment.
A Description of Hand-arm Vibration and Hand-arm Vibration Syndrome

Hand-arm Vibration (HAV)

Hand-arm vibration is the term used to describe vibration that is transmitted into the hands and arms; typically, of operatives that are using mechanical hand-held power tools or processes while carrying out work activities.

Although such description means that this kind of vibration might emanate from an almost infinite range of tools and processes employed to perform work, the types of tool most associated with HAV tend to include:

- percussive metal-working tools, such as powered riveting hammers or hammers used for caulking, clinching and flanging;
- percussive construction tools, such as (electric, pneumatic, hydraulic) breakers, hammers, vibrating pokers and drills;
- percussive tools used in stoneworking and stone quarrying;
- rotary tools such as disc cutters, disc grinders, polishers of various configurations or burring tools; and
- wood cutting and machining tools such as chain saws, cutters, circular saws, planers, sanders and powered screwdrivers (cf. HSE, 2003B, p5; 2005A).

In addition to these types of tool, HAV exposure may also result from using hand-guided (vis-à-vis held) equipment, such as:

- powered lawn mowers;
- floor polishers and floor sanders;
- garden strimmers of various types and sizes;
- vibrating compaction plates; and
- pedestrian operated compaction rollers.

The remaining potential source of exposure is associated with operatives that need to hold (or guide) materials in (or with) their hand(s), that are being worked upon by a mechanical process. Some examples of this include:

- offering a metal casting up to a grinding wheel;
- holding a component against a pedestal polisher;
- placing and holding steel in a stamping machine;
- guiding logs through a barking machine; and

It is now a well accepted fact that prolonged, ongoing or repeated exposure to HAV causes negative health. However, it is extremely important to clarify that the use of vibration-emitting tools or processes at work does not automatically mean that negative health will result. This is because the presentation of symptoms from HAV exposure is a function of many influencing factors including:

- the magnitude of the vibration at source to which an operative is exposed;
- the duration of exposure (where, as a rule-of-thumb, the longer the exposure in any given operation or cumulatively over time, the greater the risk);
- whether the exposure is continuous or intermittent (where generally, more continuous exposure with minimal breaks presents higher risk);
the frequency of the exposure (the more frequent, the greater the risk);
- the way a tool is held (for example, a tighter hand-grip can exacerbate exposure and increase risk);
- the particular area of the hand(s) exposed to vibration (for example, see Dong et al, 2004A, 2004B; 2005A); and
- numerous ‘other’ factors, such as environmental temperature, operative anthropometry and operative posture during tool use (see Edwards and Holt, 2006B; 2007B).

An operative’s personal susceptibility can also influence matters. Indeed, the vascular symptoms of HAV (Raynaud’s Phenomenon) occur spontaneously in the general population at proportions of approximately 3 per cent of men and 10 per cent of women (Anon, 2007, p12).

With exception to this latter point regarding spontaneity, the influencing factors listed above and ways to remove, control or mitigate their impact are looked at in more detail in the section How to Minimise HAV Risks.

Hand-arm Vibration Syndrome (HAVS)

The negative health effects resulting directly from HAV exposure can be grouped under three components – these being vascular, neurological and ‘other’ – where the latter tend to be concerned with muscular or soft tissue damage. (The next section of this guide discusses these components in more detail).

Combined or singularly, these components are often referred to as ‘Hand-arm Vibration Syndrome’ (HAVS) (HSE, 2003B, p23; 2005A). That is, under certain conditions, 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 quite specific medical conditions associated with HAVS are VWF and CTS. Noteworthy, VWF is the most common prescribed disease under the Industrial Injuries Scheme over recent years (HSE, 2004B). Table 1 indicates the prevalence of this condition, as reported among workers within certain industrial sectors for the period 2003-2005, thereby confirming that the extractive and utility industries continue to host the most cases. Note that for comparison purposes, the Table also contains similar statistics for dermatitis (a skin disorder) and occupational deafness. For all sectors, VWF is quite evidently more prevalent among workers than are the other two forms of occupational ill health.

With respect to CTS, the number of new cases assessed for disablement benefit rose from 267 in 1993-1994 to 797 cases in 2001-2002 and 1,035 in 2002-2003 (ibid.). However, the recent trend is downward with 820 reported cases during 2003-2004 and 680 cases in 2004-2005.

<table>
<thead>
<tr>
<th>Industry Sector</th>
<th>Rank*</th>
<th>Number of cases reported per 100,000 workers</th>
<th>VWF</th>
<th>Dermatitis</th>
<th>Deafness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraction, energy and water supply</td>
<td>1</td>
<td>178.3</td>
<td>7.3</td>
<td>9.8</td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td>2</td>
<td>11.0</td>
<td>1.2</td>
<td>4.1</td>
<td></td>
</tr>
<tr>
<td>Manufacturing</td>
<td>3</td>
<td>6.8</td>
<td>2.5</td>
<td>5.0</td>
<td></td>
</tr>
<tr>
<td>Transport and communication</td>
<td>4</td>
<td>1.5</td>
<td>0.5</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>Agriculture, forestry and fishing</td>
<td>5</td>
<td>1.3</td>
<td>0.3</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>Distribution, hotels and restaurants</td>
<td>6</td>
<td>1.1</td>
<td>0.3</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Public, administration and education</td>
<td>6</td>
<td>1.1</td>
<td>0.1</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>All reported sectors combined</td>
<td>n/a</td>
<td>5.1</td>
<td>0.7</td>
<td>1.4</td>
<td></td>
</tr>
</tbody>
</table>

*Rank: Based on prevalence of VWF in workforce
Source: Derived from HSE published statistics
Potential Negative Health Effects from Exposure to HAV

A Note about Cause and Effect

The relationship between an operative’s exposure to HAV (in terms of the magnitude and duration of the vibration) and any resulting negative health effects is far from definitively understood (cf. BOMEL, 2003, p.viii). That is, the cause-effect relationship between hand-arm vibration exposure and negative health cannot be accurately stated, at least not without reference to other influencing factors such as those identified in the last section. In particular when considering the operative, account should be taken of issues such as:

- personal susceptibility;
- posture and style [when performing work tasks or using tools]; and
- vibration exposure history [which may be complex and difficult to consider objectively]

(ibs.) [comments in square brackets by present authors].

It should also be borne in mind that certain types of negative health in hands, wrists and arms might result from factors totally divorced from HAV exposure. These factors can include things such as previous injuries or illness, earlier medical intervention, strain resulting from physical social activities, onset of other medical conditions not associated with vibration exposure and so on. Further, in that Raynaud’s Phenomenon can occur in the general population independently of vibration exposure (HSE, 2004B), these matters must all be viewed holistically in any assessment of the mentioned cause-effect relationship. That is, under no circumstances should one automatically assume that negative health in the hands and arms is entirely a result of HAV exposure.

While operatives might not want to admit to having symptoms of HAVS (for example, for fear of affecting their employment status), it is important that they are made aware that it is not just their ability to perform work tasks that could be affected. HAVS can also have a degenerative effect on all other (non-work) activities, such as when performing hobbies (especially outside in lower temperatures) or when attempting to do anything that requires dexterous finger and / or hand manipulation (cf. HSE, 2003C, p.4; 2005C). The latter can apply to simple everyday tasks like buttoning-up clothing or counting out money.

The ‘characteristics’ of hand-arm vibration syndrome are generally, broadly classified under three medical components. These are:

- the vascular component;
- the neurological component; and
- the muscular and soft tissue component (HSE, 2005A, p87).

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

The Vascular Component

This generally relates to damage of the vessels that circulate blood; in this instance, to the hands and fingers. Perhaps the best known of vascular problems in this context is the episodic finger blanching termed Vibration White Finger (VWF), which results from impaired blood circulation and is aptly named due to its characteristic "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 the fingertips become white (HSE, 2003D; 2005C). Continued HAV exposure will almost certainly lead to progression of the condition and may be evidenced by an increased area of the hand being affected by the blanching and
increased frequency of such occurrence (HSC, 2003, p31; HSE, 2005A). VWF symptoms are typically triggered by exposure of the hand to cold and / or wet conditions. During an attack the fingers might feel ‘numb’ and a sensation of ‘pins-and-needles’ may also be experienced.

A more progressed state of VWF can be triggered by a less significant reduction in temperature and if left to progress even further (through ongoing HAV exposure and / or no medical intervention) 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 (HSE, 2005A, p87) causing fingers to turn ‘blue-black’ in colour. In the most exceptional of cases, gangrene may result (HSE, 2003B, p4).

The Neurological Component

This is concerned with damage caused to the peripheral 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), making it difficult to feel and work with small objects (HSE, 2005A, p87). CTS (Carpal Tunnel Syndrome) is another, separate kind of disorder, related to this component. It can cause tingling, numbness and weakness, particularly in the wrist of the hand. Pain and night waking (disturbed sleep) are also CTS symptoms (ibid.). [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)].

The Muscular and Soft Tissue Component

‘Other’ negative health effects (and their contributing factors i.e. their cause-effect relationship), are less well understood than their vascular and neurological counterparts (HSE, 2003B, p3). Generally, such effects give rise to symptoms that include pain and stiffness in the fingers, hands, wrists, lower arms and shoulders (HSE, 2005A). These HAVS muscular and soft tissue 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 the 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.

HAV symptoms may be summarised as being characterised by:

- pain;
- numbness;
- blanching;
- pins-and-needles;
- loss of senses (touch / temperature);
- loss of strength (grip / wrist);
- loss of manual dexterity; and
- VWF and CTS.

The aspects discussed above are summarised in Figure 1.
Classification and Diagnosis of HAVS Symptoms

The medical interpretation and / or diagnosis of HAVS symptoms is a matter for health professionals only, so this section of the Guide is provided solely to furnish the reader with a degree of ‘background’ knowledge to the subject.

Vibration white finger classification (i.e. the vascular aspect alone) was in the past assessed using the Taylor-Pelmear Scale. However, HAVS comprises not one, but two principal components, i.e. vascular and neurological – the latter sometimes also being defined as the sensorineural aspect. Since these two components can progress separately, use of the Stockholm Workshop Scales (SWS) has now generally replaced the Taylor-Pelmear scale and is the preferred method of classifying vascular and neurological HAVS symptoms (HSE, 2003B, p26; 2005A, pp101-104).

Using the SWS, the two hands are assessed individually (for classifying both vascular and neurological aspects). The vascular component is assessed against five stages (designated 0, 1v, 2v, 3, and 4v) and the sensorineural component against four stages (designated 0sn, 1sn, 2sn and 3sn). Previous criticism of these scales has included the fact that they lack precise information for some of the terms used (such as ‘frequent’ – see HSE, 2005A, p101) and that the second stages (2V and 2SN respectively) are quite broad in their definitions. Hence, a method was developed to divide the second stages of the scales into ‘early’ and ‘late’ (Lawson and McGeoch, 2003), thereby allowing a more accurate diagnosis and subsequent management of stage 2 cases.

Table 2 (columns 1, 2 and 3) describes the stages in the original SWS along with their respective grades and descriptions. The Table also lists the ‘additional’ guide to vascular and sensorineural staging (shown in columns 4 and 5), including early and late criteria for diagnosis of the second stages, as published in HSE guidance (HSE, 2005A, p104). Hence, vascular second stage on the original SWS (i.e. 2v) can now be diagnosed as early or late (i.e. 2v(early) and 2v(late)); as can the sensorineural second stage (i.e. 2sn(early) and 2sn(late)).
Table 2. The Stockholm Workshop Scales and additional guide to staging, for classifying HAVS symptoms

<table>
<thead>
<tr>
<th>Stockholm Workshop Scales</th>
<th>Additional Guide to Staging</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vascular component</strong></td>
<td></td>
</tr>
<tr>
<td>Stage</td>
<td>Grade</td>
</tr>
<tr>
<td>0</td>
<td>n/a</td>
</tr>
<tr>
<td>1&lt;sub&gt;v&lt;/sub&gt;</td>
<td>Mild</td>
</tr>
<tr>
<td>2&lt;sub&gt;v&lt;/sub&gt;</td>
<td>Moderate</td>
</tr>
<tr>
<td>2&lt;sub&gt;v&lt;/sub&gt;</td>
<td>(late)</td>
</tr>
<tr>
<td>3&lt;sub&gt;v&lt;/sub&gt;</td>
<td>Severe</td>
</tr>
<tr>
<td>4&lt;sub&gt;v&lt;/sub&gt;</td>
<td>Very severe</td>
</tr>
<tr>
<td><strong>Sensorineural Component</strong></td>
<td></td>
</tr>
<tr>
<td>Stage</td>
<td>Description</td>
</tr>
<tr>
<td>0&lt;sub&gt;sn&lt;/sub&gt;</td>
<td>Vibration-exposed but no symptoms</td>
</tr>
<tr>
<td>1&lt;sub&gt;sn&lt;/sub&gt;</td>
<td>Intermittent numbness with or without tingling</td>
</tr>
<tr>
<td>2&lt;sub&gt;sn&lt;/sub&gt;</td>
<td>Intermittent or persistent numbness, reduced sensory perception</td>
</tr>
<tr>
<td>2&lt;sub&gt;sn&lt;/sub&gt;</td>
<td>(late)</td>
</tr>
<tr>
<td>3&lt;sub&gt;sn&lt;/sub&gt;</td>
<td>Intermittent or persistent numbness, reduced tactile discrimination and / or manipulative dexterity</td>
</tr>
</tbody>
</table>

<sup>1</sup> The schemes indicated to separate stages 2<sub>v</sub> and 2<sub>sn</sub> into ‘early’ and ‘late’ are indicative only and may require health professionals to use their judgement in allocating an individual to either early or late stage 2 (cf. HSE, 2005A, p103).

<sup>2</sup> The advice given regarding scores relates to specific medical tests undertaken only by health professionals.
An additional way of assessing the vascular symptoms, to complement use of the SWS, is by using the Griffin (1990) method to score the extent of blanching. Here, a numerical value is assigned to each phalanx of each finger and thumb and an overall score for each hand is derived based on the extent of the affected area (i.e. extent of affected phalanges). Further explanation of the Griffin method and of how the scoring is carried out, may be observed in HSE (2005A, p102).

4 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).
Standards, Legislation and HAV

British and International Standards

There are many British Standards (BSI) and International Standards (ISO) that relate to, or support, the legislative aspects of hand-arm vibration health and safety (H&S) at the workplace. Although these would be too numerous to discuss individually in a Guide of this (limited) size, full bibliographic listings of the most ‘prominent’ Standards are provided in the References and Bibliography; the specific subjects of which are identifiable from their titles.

An overview of British Standards may also be viewed on the British Standards Institution website at: http://www.bsonline.bsi-global.com/server/index.jsp. Similarly, the ISO website can provide additional information, see: http://www.iso.org/iso/en/ISOOnline.frontpage. Some of these British and International Standards are also referred to throughout various parts of this Guide.

Legislation

Both employers’ and employees’ general H&S duties, with respect to vibration hazards at the workplace, are defined among various UK health and safety Statutory Instruments which, following implementation of the Control of Vibration at Work Regulations 2005, remain in force. Some of these Statutory Instruments, and their main relevance to HAV, include the following (note that this is not an exhaustive list).

- The Health and Safety at Work etc. Act (1974) (HASWA, 1974) – which (inter-alia) places a duty upon employers to provide safe systems of work and this includes systems that involve the use of plant and equipment.
- The Management of Health and Safety at Work Regulations (1999) as amended (MHSWR, 1999) – which (inter-alia) emphasises proactive and systematic health and safety management, that strives to identify risks (through risk assessments) and eliminate them (through controls). Equally, this applies to mechanical equipment and its use.
- The Provision and Use of Work Equipment Regulations (1998) as amended (PUWER, 1998) – which require (inter-alia) that all equipment used in the workplace is safe, regardless of its age, condition or origin.
- The Workplace (Health, Safety and Welfare) Regulations (1992) as amended (WHSWR, 1992) – that (inter-alia) impact upon the environmental aspects of a workplace within which, for example, mechanical equipment might be used.


5 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.
6 Accessible on the website in http and in some cases also as downloadable PDF documents.
The most comprehensive and specific legislation relating to management of HAV at the workplace is contained within the Control of Vibration at Work Regulations 2005 (CVWR, 2005A; 2005B). The principal way these Regulations govern the protection of operators from HAV is by reference to defined amounts of vibration exposure called exposure Action and Limit values. These values are fundamental to the understanding and implementation of the CVWR, and we will look next at their definitions.

First, we need to know that the action and limit values are expressed in fundamental units of acceleration, that is, m/s² (metres per second, per second). Given this, then:

- The Exposure Action Value (EAV) is a level of daily operator vibration exposure, which if exceeded, requires specified action (i.e. control measures) to be taken to reduce the associated 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. (See footnote).

Put another way, we may say therefore, that the EAV is equal to an average hand-arm vibration exposure of 2.5m/s² over a continuous eight hour period. Hence, an average exposure magnitude which is greater than this for eight hours, or, an exposure of average magnitude 2.5m/s² over more than eight hours, will represent an exposure in excess of the EAV. The converse logic also applies.

- The Exposure Limit Value (ELV) is a level of daily operator vibration 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. (See footnote).

We may state therefore, that the ELV is equal to an average hand-arm vibration exposure of 5m/s² over a continuous eight hour period. Hence, an average exposure magnitude which is greater than this for eight hours, or, an exposure of average magnitude 5m/s² over more than eight hours, will represent an exposure in excess of the ELV. The converse logic also applies.

The following section of this Guide (How to Identify HAV Risks) explains how the EAV and ELV are applied in practice to manage vibration exposure. It gives examples of calculating A(8) for the purposes of risk assessment (by comparing an operator’s 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 and where the equipment 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 (for that equipment) that can (i.e. will mean the equipment will subsequently be able to) achieve the ELV.

Under such circumstances, 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 that is provided to an employee after July 6 2007.

Figure 2 gives a graphical summary of employers’ responsibilities under the CVWR. Matters here such as risk assessment, risk controls, and employee health surveillance, will be discussed in the following two sections of the Guide.

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1 CVWR also places duties on employers with respect to whole-body vibration (WBV); but WBV is beyond the scope of this Guide on HAV. OPERC has published separate Guidance in respect of WBV. For complete details see the References and Bibliography – also see the OPERC online bookshop at: www.operc.com.

2 This value can be expressed as either A(8)2.5m/s² or A(8)2.5. In this Guide, the latter convention will be given preference for simplicity.

3 This value can be expressed as either A(8)5m/s² or A(8)5. In this Guide, the latter convention will be given preference for simplicity.
Figure 2. Graphical summary of employers’ responsibilities under the CVWR

Key

a ALARP: As low as reasonably practicable

- Denotes sequential logic
- Denotes communication flow

Source: Adapted from Edwards and Holt (2007C).
How to Identify and Assess HAV Risks

Rationale

It is a requirement of the Control of Vibration at Work Regulations that employers, who by the nature of their work activities might be exposing employees to HAV hazards, must carry out an assessment of HAV risks. The principal aim of this assessment is to enable valid decisions to be made about:

■ the location, extent and nature of the risks; and
■ the appropriate risk control measures that are to be designed and implemented, to remove or mitigate them.

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 to levels as low as reasonably practicable (ALARP). That is, any level of exposure must be reduced ALARP in situations where such reduction is reasonably practicable10.

Where vibration exposure does exceed, or is likely to exceed the EAV, then a more formal and systematic assessment of the risks(s) associated with that exposure needs to be carried out. The control measures to be implemented as a result of this should be specifically designed to address such increased level of exposure.

According to the HSC (2003, p73), industries where HAV is accepted as a common hazard (and hence present the greatest degree of risk) include:

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

The extractive industries, such as quarrying and mining, also have a long-standing reputation for high risk of HAV exposure – the prevalence of VWF claims in the mining industry has been well documented in the past.

Similarly, specific work processes that tend to represent a high risk of hand-arm vibration exposure can also be identified, and include:

■ drilling hard materials (such as plugging into masonry or drilling for service access);
■ breaking-up of hard materials (such as demolishing concrete or masonry structures);
■ consolidation or compaction of bulk materials (such as when using hand-guided vibrating rollers or compaction plates);

10 Here, ‘reasonably practicable’ means to make a judgement: where the extent of the risk is considered against the sacrifice (e.g. cost, time, inconvenience) needed to avert that risk. Unless there is gross disproportion between these two considerations, then generally the risk should be averted or mitigated in order to satisfy the relevant health and safety law.
■ mechanical fixing methods (such as riveting);
■ mechanical preparation of surfaces (such as scabbling, de-scaling or cleaning);
■ surface finishing materials and components (such as grinding and sanding);
■ cutting of various materials (such as with power shears or a circular saw); and
■ manually holding or supporting materials that are being worked upon by some other mechanised process (such as against a polisher or a grinding wheel).

Taking these ‘broad’ indicators into account, the risk assessment should identify all sources of HAV and then, for all operatives at the workplace, make a reasoned estimate of their exposure 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;
■ consider the extent of these hazards;
■ make a robust estimation of all operatives who might be exposed to the hazard(s), either now, or at any time in the foreseeable future;
■ evaluate the extent of the risk exposure, for operatives who are (or who may become) exposed;
■ 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 to be implemented;
■ a time-line for the implementation of the control measures; and
■ how the 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. This may be because the tools to which it referred have been replaced by different tools or there has been significant change to the work to which it relates (e.g. where operatives’ vibration exposure times have increased as a result of changes in working methods).

The risk assessment results should also be used as a basis for informing operatives of the risks related to their work and considered as a starting point for the design and development of operative HAV training and education. Guidance on undertaking health and safety risk assessments in general is available from the HSE (2003E).

The process of determining an operative’s HAV risk can be achieved using either a ‘rule-of-thumb’ method or a more ‘objective’ risk assessment that calculates maximum exposure times (by mathematically combining objective inputs of vibration magnitude(s) to yield objective outputs such as daily exposure time limits).

The HSE’s rule-of-thumb guidance states that employees at ‘higher risk’ are those who regularly operate:
■ hammer-action tools – such as pneumatic breakers – for more than about an hour each day; or
■ rotary and other non-percussive tools – such as disc-cutters, orbital sanders or chainsaws – for more than about four hours each day.

The guidance states that employees are at ‘medium risk’ are those who regularly operate:
■ hammer-action tools for more than about 15 minutes each day; or
■ rotary or other non-percussive tools, for more than about one hour a day (HSE, 2005B).

Very often, the rule-of-thumb method will suffice but in more complex work situations, for example where numerous different exposures occur in a working day or where exposure is considered to be approaching (or in excess of) the EAV, then a more objective assessment may be more suitable. This
requires calculation of an operator’s average daily exposure, expressed as A(8), and comparison of this against the CVWR action and limit values. The process to achieve this may be considered in six stages which are:

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 operative’s exposure duration(s) for each tool(s);
4. based on (2) and (3), determine the A(8) value;
5. compare the A(8) value against the EAV and ELV values; and
6. design appropriate control measures based on the results of this comparison.

In establishing the vibration magnitude for a tool, it should be remembered that this can vary, sometimes quite significantly, between different operating conditions (e.g. methods of tool use), different ‘brands’ of the same type of tool and where a particular type of tool uses different appendages (such as drill bits with varying diameters) (Edwards and Holt, 2005C; 2006B; 2007B). In practical terms this means that larger vibration levels at source will reduce the amount of work that a tool can do, before its operator’s exposure reaches the EAV or ELV. Appendix A demonstrates some examples of this by comparing amounts of work performed by different manufacturers’ breakers, combi-hammers and battery drill tools before CVWR limits are reached (OPERC, 2005).

There are basically two types of vibration data. The first is manufacturers’ own data, which usually results from tests performed on tools in laboratory, not real work, 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 kinds of data are sometimes called ‘8662 data’.

Vibration data measured according to ISO 8662 is sometimes unreliable for risk assessments because it may not accurately represent vibration levels generated by tools when they are actually in use, for example when taking into account the sharpness of chisels or cutting edges, the way the operator holds or uses the tool, and so forth. For this reason, it has been stated that 8662 derived values should be used with caution for risk assessment purposes (CEHVD, 2004). They are best used for respective comparisons of vibration emissions between tools of the same type, for example, when considering which brand of a certain tool to purchase.

The second type of data is field measured values, that have been measured in accordance with ISO 5349 and are therefore, sometimes called ‘5349 data’. These data are more influenced by actual working conditions and usually better reflect ‘true’ vibration magnitudes of tools, when being used by operators to carry out real work tasks (ibid.). Note that 5349 data are suitable for use in objective risk assessments.

A useful source of 5349 data is the OPERC HAVTEC register. This is a web-hosted facility that makes freely available (upon registration), vibration data that has been measured from tools while being used to carry out real work. A comprehensive range of tools is available including angle grinders, breakers, saws, combi-hammers, planers, scabblers and so forth. In many cases, variants of these tools as defined by power source, are also listed such as battery, electric, pneumatic, hydraulic and combustion engine options. Note that the HAVTEC register is constantly being expanded, so additional tools may be listed on subsequent visits. (To register and subsequently view the HAVTEC register in its entirety go to: http://operc.com/pages/havtecwelcome.asp).

Figure 3 shows a sample screen from the HAVTEC register showing a partial listing of electric breakers and chipping hammers, whilst Table 3 gives some examples of tool vibration magnitudes that have been abstracted from the register (these are a small sample of what is available, included here for information and tool comparison purposes).

When considering an operator’s vibration exposure time for a tool, this must be the time that the tool is actually being held in use while mechanically activated; otherwise often referred to as the ‘trigger-time’ (HSC, 2003, p79). It is not, for example, the time that an operative might have a tool
Assuming that the vibration magnitude and trigger-time have been reliably established for risk assessment purposes, the next step is to determine the A(8) value. In doing this it is convenient to carry out the “calculation” using a device such as the HAVCalc Hand-arm Vibration Calculator and Risk-assessment Aid. This hand-arm vibration calculator is freely available on the OPERC website (see http://operc.com/pages/havewelcome.asp). Examples of how to use HAVCalc’s various options are given below.

(For the interested reader, the mathematical formulae underpinning A(8) calculation for both daily and weekly HAV exposure values are presented in Appendix B. Note however, that 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 a vibration exposure calculator).

An alternative approach to assessing an operative’s risk from a tool is to compare that tool’s vibration magnitude against maximum daily time-exposure data relating to the EAV and ELV (and in turn compare the operative’s trigger time for this tool with these maximums). In this respect, Table 4 shows, for a range of vibration magnitudes (at source), maximum exposure (trigger) times that are allowable before the EAV A(8) value of 2.5m/s² and the ELV A(8) value of 5m/s² would be reached. An example of how to interpret this information in practice is also given below in the examples.
Table 3. Examples of vibration magnitudes for a range of tools

<table>
<thead>
<tr>
<th>Tool Type</th>
<th>Weight magnitude deviation</th>
<th>Power source (kg)</th>
<th>Manufacturer</th>
<th>Nature of work</th>
<th>Appliance (m/s*s)</th>
<th>Nature of work</th>
<th>Appliance (m/s*s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle grinder</td>
<td>17</td>
<td>230v electric</td>
<td>DeWalt</td>
<td>Grinding steel plate</td>
<td>230mm grinding disc</td>
<td>4.8</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cutting groove in concrete</td>
<td>230mm cutting disc</td>
<td>6.6</td>
<td>0.9</td>
</tr>
<tr>
<td>Angle grinder</td>
<td>110v electric</td>
<td>1.6</td>
<td>Hilti</td>
<td>Grinding steel pipe</td>
<td>125mm abrasive disc</td>
<td>4.0</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cutting metal pipe</td>
<td>125mm steel cutting disc</td>
<td>6.8</td>
<td>1.1</td>
</tr>
<tr>
<td>Breaker/chipping hammer</td>
<td>32.0</td>
<td>Makita</td>
<td>Breaking 40N concrete</td>
<td>Moil point</td>
<td>10.5</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Breaking 40N concrete</td>
<td>Moil point</td>
<td>8.7</td>
<td>0.3</td>
</tr>
<tr>
<td>Breaker/chipping hammer</td>
<td>18.0</td>
<td>MacDonald</td>
<td>Breaking 40N concrete</td>
<td>Moil point</td>
<td>5.0</td>
<td>0.57</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cutting 90x40mm wood blade</td>
<td>125mm steel cutting disc</td>
<td>12.5</td>
<td>2.1</td>
</tr>
<tr>
<td>Circular saw</td>
<td>4.3</td>
<td>Milwaukee</td>
<td>Cutting 42mm chipboard</td>
<td>150mm wood blade</td>
<td>1.3</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>Floor grinder</td>
<td>76</td>
<td>SPE</td>
<td>Grinding conc. surface</td>
<td>Carbon rubber block</td>
<td>5.6</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Mini hand-guided dumper</td>
<td>43</td>
<td>Milwaukee</td>
<td>Traversing soft &amp; round</td>
<td>Half Loaded bucket</td>
<td>5.0</td>
<td>0.57</td>
<td></td>
</tr>
<tr>
<td>Mini hand-guided dumper</td>
<td>32.0</td>
<td>MacDonald</td>
<td>Breaking 40N concrete</td>
<td>Moil point</td>
<td>6.6</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>Mini hand-guided dumper</td>
<td>16</td>
<td>Hilli</td>
<td>Breaking 40N concrete</td>
<td>Moil point</td>
<td>6.6</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>Mini hand-guided dumper</td>
<td>10</td>
<td>MacDonald</td>
<td>Breaking 40N concrete</td>
<td>Moil point</td>
<td>6.6</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>Mini hand-guided dumper</td>
<td>4</td>
<td>MacDonald</td>
<td>Breaking 40N concrete</td>
<td>Moil point</td>
<td>6.6</td>
<td>0.9</td>
<td></td>
</tr>
</tbody>
</table>

Source: HAVTEC database at: http://operc.com/pages/havtecwelcome.asp (viewed January 2007). The above is a random selection of tools drawn from the database for demonstration and information purposes only. Other tools of similar type may be available from alternative manufacturers and may have different vibration characteristics to those listed here. All vibration data were measured in accordance with ISO 13349. Data are representative of measurements taken on the day and could vary as a function of tool age and condition, operator style, ambient conditions and so on.
### Table 4. Maximum trigger-times for a range of vibration magnitudes, before the CVWR exposure action and limit values would be reached

<table>
<thead>
<tr>
<th>Average vibration magnitude at source (m/s²)</th>
<th>Maximum trigger-time to reach exposure ACTION value of 2.5m/s²</th>
<th>Hrs.</th>
<th>Mins.</th>
<th>Maximum trigger-time to reach exposure LIMIT value of 5m/s²</th>
<th>Hrs.</th>
<th>Mins.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td></td>
<td>&gt;24</td>
<td></td>
<td>&gt;24</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td></td>
<td>22</td>
<td>13</td>
<td>&gt;24</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>2.0</td>
<td></td>
<td>12</td>
<td>30</td>
<td>&gt;24</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td></td>
<td>8</td>
<td>00</td>
<td>&gt;24</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>3.0</td>
<td></td>
<td>5</td>
<td>33</td>
<td>22</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>3.5</td>
<td></td>
<td>4</td>
<td>05</td>
<td>16</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>4.0</td>
<td></td>
<td>3</td>
<td>08</td>
<td>12</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>4.5</td>
<td></td>
<td>2</td>
<td>28</td>
<td>9</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>5.0</td>
<td></td>
<td>2</td>
<td>00</td>
<td>8</td>
<td>00</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>1</td>
<td>23</td>
<td>5</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>1</td>
<td>01</td>
<td>4</td>
<td>05</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>-</td>
<td>47</td>
<td>3</td>
<td>08</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>-</td>
<td>30</td>
<td>2</td>
<td>00</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>-</td>
<td>13</td>
<td>-</td>
<td>53</td>
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</tr>
<tr>
<td>20</td>
<td></td>
<td>-</td>
<td>08</td>
<td>-</td>
<td>30</td>
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<td>25</td>
<td></td>
<td>-</td>
<td>04</td>
<td>-</td>
<td>19</td>
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<td>-</td>
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<td></td>
</tr>
<tr>
<td>35</td>
<td></td>
<td>-</td>
<td>02</td>
<td>-</td>
<td>09</td>
<td></td>
</tr>
</tbody>
</table>

Worked Example 1: Calculating $A(8)$ and Assessment of Risk Where Only One Vibrating Tool is Used in a Day

Scenario: 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 $4.5 \text{m/s}^2$. What is the operative’s daily exposure $A(8)$ and how does this relate to the CVWR?

Figure 4 is a screen shot showing Part 1 and Part 2 of HAVCalc. 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 4. Calculation of maximum trigger times and exposure points for the angle grinder in worked example (1) using HAVCalc

So it is shown in this example, that by inserting the average vibration magnitude for the angle grinder of 4.5 in cell E20 [cell E20], Part 1 of HAVCalc calculates the maximum trigger-time (for this 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 28 minutes [cells G20 and H20] and the ELV after 9 hours 53 minutes [cell J20 and K20].
Part 2 of HAVCalc calculates the exposure in points, which in this example is 10.1 points per 15 minutes of use [cell H28] or 41 points per hour of use [cell K28]. These exposure points can be used to facilitate an alternative way of totalling several different exposures in a working day. The relationship between vibration magnitude and points is: points of exposure per hour = 2(vibration magnitude)^2. More complete description of the points risk assessment method along with worked examples of how to apply it, is provided in Edwards and Holt (2007A).

The above derived maximum trigger-times with respect to EAV and ELV are similar to those shown in Table 4. That is, if the vibration magnitude (for the angle grinder) of 4.5m/s^2 is read-off along the eighth row of Table 4, it is shown that the EAV is reached after 2 hours 28 minutes of use and the ELV would be reached after 9 hours 53 minutes of use.

Figure 5 shows that when the vibration magnitude for the angle grinder is entered into Part 3 of HAVCalc [cell E37], along with the trigger time of three hours 30 minutes [cell G37 and H37], then the average daily operative exposure in this scenario is A(8)3.0 [cell K46] (or 142 points [cell J44]). This demonstrates that use of the angle grinder for 3.5 hours a day would cause the operative to exceed the action value (as 3 is greater than 2.5) but remain below the limit value (as 3 is less than 5). 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.

Figure 5. Calculation of average daily exposure for the angle grinder in worked example (1) using HAVCalc

Source: http://operc.com/pages/havtecwelcome.asp
Worked Example 2: Calculating $A(8)$ and Assessment of Risk Where More Than One Vibrating Tool is Used in a Day

Scenario: An operative uses three vibrating hand-held tools in a typical working day. The first has an average vibration magnitude of $2\text{m/s}^2$ and is used for 3 hours, the second has a magnitude of $2.5\text{m/s}^2$ and is used for 1.5 hours and the third has a magnitude of $5\text{m/s}^2$ and is used for 45 minutes. What is the operative’s daily exposure $A(8)$ and how does this relate to the CVWR?

The calculation for this scenario using Part 3 of HAVCalc is shown in Figure 6. As per the previous example, the input data (the vibration magnitude and duration of exposure) is entered into the white coloured cells for each tool respectively.

Figure 6. Calculation of average daily exposure for the three tools used in worked example (2) using HAVCalc

The partial exposure value for each tool (in m/s²) is given at the end of each row. These are: for tool 1 - 1.2 m/s² [cell K37], for tool 2 - 1.1 m/s² [cell K38] and for tool 3 - 1.5 m/s² [cell K39]. Based upon these partial exposure values, the overall daily exposure A(8) for this operative is 2.2 m/s² [cell K46] which is below the EAV (as 2.2 is less than 2.5). Note that the total daily exposure A(8) is not simply the sum of the 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 m/s²) further, then these should be implemented in order to minimise the risk as much as reasonably practicable (refer to discussion on ‘ALARP’ earlier).

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 such a surveillance regime should be implemented include where the risk assessment has indicated that there is a risk to an operative’s health from exposure to HAV and where the operative is likely to be regularly exposed above the EAV. The issue of health surveillance is a specialist medical topic and because of this, the following information is for background knowledge only.

The HSE advocate a tiered system of health surveillance starting with an initial baseline assessment at tier 1, followed by annual screening, clinical assessment, formal diagnosis and finally, optional standardised tests.

The baseline assessment (tier 1) should provide a ‘datum’ against which an operative’s future routine health surveillance (e.g. tier 2 - annual screening) may be compared. The process might form part of employee induction, or part of HAV education and training. It will typically be carried out using a self-administered questionnaire.

Annual screening (tier 2) is routine health surveillance for operatives who have been identified as being at risk, but who have not reported any symptoms suggestive of HAVS (since the last screening or baseline assessment). A self-administered annual screening questionnaire may be used for this purpose.

Clinical assessment (tier 3) is carried out by a qualified health professional or doctor. This will normally follow tier 1 or tier 2 in cases where symptoms have been reported or have been noticed by a health professional. A presumptive diagnosis may be recorded in tier 3 by a qualified person, but formal diagnosis (tier 4) can only be made by a doctor. The formal diagnosis will be required for certain actions, such as reporting by the employer of cases under the requirements of RIDDOR (1995) and for employee ‘fitness for work’ recommendations.

The standardised tests (tier 5) are not compulsory under health surveillance, but may be requested by a doctor to help with the diagnosis in tier 4. It involves the use of standardised tests for a worker who has HAVS symptoms and can provide quantitative assessments that may also be used to monitor progression of the condition over time.

Employers will need to maintain certain records connected with an operative’s health surveillance, normally, for at least as long as the operative is under that surveillance regime. Note also, that the enforcing authority, for example an HSE inspector, may ask employers for access to some of those records as part of checks for CVWR compliance, but medical confidentiality will be respected as appropriate. Figure 7 summarises the above issues regarding health surveillance.

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11 Note that HAVCalc calculates partial and total exposures both in points and in m/s²; but the examples presented here are using the m/s² and A(8) values only, to avoid discussing two different methods and possibly therefore, causing confusion. If the reader does want to learn more about using the points system for risk assessments, see Edwards and Holt (2007A) and HSE (2005A, p78).
Figure 7. The tiered system of operative health surveillance

- Is there an indication of risk to operative health from exposure?
- Will the operative be exposed at or above the CVWR action value?

Implement Health Surveillance

**Tier 1**
*Baseline Assessment*

**Tier 2**
*Annual Screening*

**Tier 3**
*Clinical Assessment*

**Tier 4**
*Formal Diagnosis*

**Tier 5**
*Standardised tests (optional tier)*

**Risk Assessment**
*Findings*

1. sfgiasflauhfa bjdljg sf
2. agfilsflasfl

**Confidential**
*Employee Health Record*

jglsdgj abrlkja ahflk zbml
ajnfgoi shis showi

**Determine a baseline:** new employees; employees changing job; self-administered questionnaire

**Check for non-reported symptoms by ‘qualified person’**

**Investigate reported symptoms by ‘qualified person’ or doctor**

**Formally diagnose condition; must be done by doctor**

**Quantitative assessment; not essential but useful to study disease progression etc**
How to Minimise the Risks

Overview

In almost all cases, HAV hazards can be controlled and their risks reduced (or eliminated) by good management; and neither does the cost of risk controls need to be high. 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 (hiring / purchasing) the right equipment;
- encouraging good (equipment) maintenance;
- isolating the vibration;
- changing work processes;
- operative good practice; and
- training and education.

In practice, there may be some overlap between these headings. For example, the introduction of a vibration isolating mechanism on a tool may also require a slight change in the work process (to allow the new mechanism to be used properly), additional routine inspection and maintenance (to ensure efficiency) and an addition to the employee training and education (or induction) programme, so that its use is adequately explained. 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:

- company purchasing policy, in seeking to only purchase (or lease, hire etc.) equipment that has been designed, engineered and manufactured to minimise vibration; and
- ensuring that equipment selected for use is the most appropriate for the proposed work task(s) to be performed by it.

The HSE (2003B, p17) suggest that many manufacturers offer ‘lower-vibration’ versions of certain tools and 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’ tool use).
- “What additional vibration-reducing measures have been engineered-in or are available for the equipment?
- “What is the maximum vibration level that the equipment can be guaranteed not to exceed?”

When considering the vibration magnitude of a tool, remember that this can vary between similar types of tool produced by different manufacturers and be sure to check whether the vibration magnitude quoted for the tool is ‘ISO8662’ or ‘ISO5349’ (the former usually understates exposure under real work conditions). Other questions might relate to the tool manufacturer’s advice regarding any additional risk control(s) (that are available or desirable); or specific maintenance requirement(s) that are required to maintain lower vibration levels or help mitigate exposure even further.
All new equipment and machinery on sale within the UK should be ‘CE’ marked – which among 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.

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) to be carried out by it. 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 the fingers or hand being exposed);
- requiring an inappropriate operator posture to carry out the work (which can affect vibration exposure significantly);
- being heavier, or vibrating more (than an appropriate tool); and
- being unsafe in other ways (cf. HSC, 2003, p33).

Generally, an under-powered tool will take longer to do a unit of work (which extends exposure time) and will probably encourage a tighter hand-grip and / or some ‘forcing’ of the tool. A larger or over-powered tool will probably be heavier and possibly require greater effort to hold during use. However, it is wrong to automatically assume that a larger or heavier tool will generate more vibration as very often the converse is true.

**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, well maintained tool usually 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 discs (for example on angle grinders) or cutting blades (for example on circular saws) sharp;
- keeping breaking or cutting chisels sharp;
- keeping chain saw teeth sharp and to the correct tension;
- dressing grinding wheels correctly (to ensure concentricity and / or balance); 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 too. This includes checking for things such as:

- cracking, swelling, softening or hardening of rubber mountings;
- deterioration of ‘anti-vibration’ or suspended handles; and /or
- any other physical damage to any component of the equipment, especially anything used to hold or guide it with the hands when it is being used.

Where there might be any doubt about maintenance methods or regimes, ask! Equipment manufacturers or suppliers should be able to advise as appropriate and / or supply (for example, ‘fixed-time-to’) 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 their work equipment, for example, as part of their vibration training and education (see below).
Isolating the Vibration

Isolation of the vibration 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, jigs or other accessories that reduce (or remove) the magnitude of vibration reaching the hand(s), or help remove the need to grip, hold or guide vibrating surfaces (HSE, 2003B, p19).

The selection and use of isolation equipment must be undertaken with care. This is because the retrospective fitting of anti-vibration accessories can sometimes exacerbate the vibration if the accessory is not carefully matched to (or specifically designed for) the tool or process to which it is fitted. For this reason it is preferable that anti-vibration accessories are an integral or ‘engineered-in’ aspect of a tool. (Alternatively, refer to the advice of discussing specific requirements with manufacturers as mentioned above).

The retrospective application of resilient materials (like rubber or foam) to parts such as tool handles is also uncertain in terms of effectiveness. Such materials might reduce high-frequency vibration but generally do little to reduce transmission of vibration to the operator at the frequencies associated with causing HAVS (HSE, 2003B, p19). The efficiency of anti-vibration gloves is also somewhat open to question (HSE, 2005A, p57). 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 in ‘vascular’ terms.

Changing Work Processes

The basic aim in changing a process must be to remove the need for hand-held vibration-emitting tools or work methods in order to avoid operative vibration exposure. The use of automation or mechanisation for work processes previously or commonly performed by hand-held tools, removes the risk altogether (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 instance, 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 or a cutting tool) can reduce, or if fully automated remove, vibration transmission into operatives. Another recent innovation involves ‘fly-by-wire’ compaction tools, that take away completely the requirement for an operative to hold and guide vibrating (roller, or compaction plate) equipment with their hands.

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. 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 that an operative can use a particular vibrating tool, or carry out a particular process, for example in any working day; or
- implementing a timed rota scheme for hazardous activities whereby operatives perform other (non-vibration exposure) work tasks at all other times in the working day; or
- requiring that a particularly hazardous tool or process can only be used under very specific circumstances, such as following issue of a permit-to-work.
Operative Good Practice

The way in which operatives use their equipment can significantly influence the amount of HAV produced from it (Edwards and Holt, 2006B; 2007B). Good operative practice results mainly from applying ‘common sense’ which in turn is encouraged by adequate training and education. Good practice includes the following:

- 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 they are available, checking tools regularly (vibration may occur from faults or simple wear-and-tear), not using faulty tools, reporting faults in equipment instantly and ensuring that all cutting tools or other appendages are sharp / or appropriate for the intended use.

- Tools should be stored in such a way that they do not get cold handles (this is 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 grip that is too tight can especially place extra strain on the hands and arms and make the problems of HAVS exposure worse.

- Correct operative posture is important to avoid placing extra strain on the hands and /or arms. Not using tools that are ‘over-rated’ or too heavy for the task or using tension chains to support heavier bench tools might also help here. It may be useful for employers to discuss the latter with operatives, to solicit opinions or suggestions from those that most regularly operate such tools.

- It is important that operatives try to maintain good blood circulation in their hands. Good circulation can be helped by keeping warm and dry and by the wearing of gloves where possible, especially when working outside or in cold environments. An operative 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 as a means to helping maintain blood circulation in them.

- Operatives have a duty under health and safety law to comply with any vibration control measures that the employer has put in place.

Training and Education on HAV

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 that 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, the CVWR places a duty on employers to provide suitable and sufficient training for employees 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). OPERC has a self-study module on HAV (OPERC, 2006) and hosts a dedicated HAV competence test facility (OPERC, 2007C). More comprehensive guidance on the design and delivery of training, specifically for plant operators, 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;
- HAV control measures and their use; and
- operatives’ general health and safety duties (HSC, 2003).

The importance of operatives reporting any HAVS symptoms to their employer should represent a particularly important part of training and education schemes. This is because operatives may be reluctant to highlight symptoms for fear of losing their job, but the progression of unreported HAVS and its often irreversible medical effects needs to be highlighted, in helping workers appreciate why reporting is so important.
Conclusion

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

- contact with vibrating hand-held tools;
- use of hand-guided mechanical equipment; and
- holding or guiding raw materials, that are being subjected to vibration-emitting work processes.

Prolonged or repeated exposure to HAV can cause negative health, particularly in the hands and lower arms; although the cause-effect relationship between exposure and ill-health is a complex one and exposure does not automatically mean that ill-health will result.

The negative health effects of HAV are sometimes generically referred to as hand-arm vibration syndrome (HAVS). The medical symptoms of HAVS present in the hands and arms and tend to be any combination of:

- vascular (related to blood circulation);
- neurological (related to the nervous system); or
- musculoskeletal (which includes damage to muscles and soft tissue) symptoms.

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

Health and safety legislation relating to HAV is defined among several health and safety statutory instruments, the most relevant of which is the Control of Vibration at Work Regulations 2005. Among other things, CVWR places duties on employers in managing, 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 operator exposure, which if exceeded, requires specified 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 operator 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 that date. The CVWR also requires employers to assess HAV hazards via an appropriately administered risk assessment process; and subsequently take all reasonably practicable steps to control or remove identified HAV risks.

Objective risk assessment involves determination of operatives’ daily vibration exposure levels by considering exposure (trigger) times and vibration magnitude data for any tool(s) or process(es) used by workers. 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.
A useful source of ‘real life’ data appropriate for risk assessment purposes, may be found within the OPERC’s online HAVTEC register. Similarly, OPERC’s HAVCalc tool can be useful in helping to conduct objective risk assessments and to generate (assessment) reports for record keeping purposes.

HAV hazards can usually be controlled by good management and this 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;
- operator good practice; and
- training and education.

In practice, a well designed and managed HAV risk control system, will mean that many aspects of these listed 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, by each of three different manufacturers’ breakers of similar configuration, 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 three different manufacturers’ combi-hammers, before reaching the exposure action value. Similarly, the taller columns on the right of each pair show how many 12mm diameter holes can be drilled using three different manufacturers’ battery drills, 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 operators (e.g. operating techniques).
Appendix B

Daily vibration exposure \([A(8)]\)

The daily personal vibration exposure level referred to as \(A(8)\) is expressed in metres per second squared \((\text{m/s}^2)\) 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 \((\text{m/s}^2)\);
- \(T\) 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 \(\text{m/s}^2\) \(A(8)\).

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

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

where:
- \(a_{hwx}\), \(a_{hwy}\) and \(a_{hwz}\) are the root-mean-square acceleration magnitudes, in \(\text{m/s}^2\), 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:

\[
A(8) = \sqrt{\frac{1}{T_0} \sum_{i=1}^{n} a_{hv_i}^2 T_i}
\]
where:

\( n \) is the number of individual operations within the working day;

\( a_{hv} \) is the vibration magnitude for operation \( i \); and

\( T_i \) is the duration of operation \( i \).

**Weekly vibration exposure \([A(8)_{\text{week}}]\)**

The exposure to vibration averaged over one week \((A(8)_{\text{week}})\) 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:

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

where:

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