



VIBRATION EXPOSURE ASSESSMENT FOR INDUSTRIAL POWERTOOLS

A pocket guide based on the Physical
Agents (Vibration) Directive (2002/44/EC)

Atlas Copco

ERGONOMICS AT ATLAS COPCO INDUSTRIAL TECHNIQUE

As a leading supplier of handheld power tools, Atlas Copco has long been aware of the importance of ergonomics in design. We began our research into noise and vibration in the 50's during the development of a pistol-grip drill. Since then a comprehensive series of noise and vibration controlled tools has been introduced to the market.

Since the late seventies Atlas Copco has been an active member of standardization groups regarding hand-arm vibrations.



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1. INTRODUCTION



The European Union will have a unified approach towards vibration exposure.

In July 2002 the European Union published the Directive 2002/44/EC the Physical Agents (Vibration) Directive (PA(V)D). It outlines new guidelines for exposure to vibration in the workplace. It sets action and limit values for vibration exposure and it describes the employer's obligations to manage the risk from exposure to vibration. The national regulations based on The Directive have been in force since July 6, 2005.

This booklet is intended as a guide for the employer who has employees using vibrating handheld power tools. It explains what is covered by the national regulations following the PA(V)D, with the UK and Sweden as examples. We explain what is meant by the different requirements. We give guidance in assessing the in-use vibration and how exposure time can be estimated. We also give practical tips regarding what can be done to reduce vibration exposure from handheld power tools.

Hand-arm vibrations are regarded as a serious work-related disorder. The Physical Agents (Vibration) Directive is intended to introduce into national regulations controls which aim to reduce ill health caused by exposure to hand-arm vibration and reduce costs for sick leave and workers' compensation.

The Physical Agents (Vibration) Directive was developed from an original proposal made by the European Commission in 1993. This proposal was revised, amended and eventually agreed by Member States and the European Parliament and came into force on July 6, 2002.

The Directive lays down the minimum standards for the health and safety of workers exposed to hand-arm vibration and supports the general requirements for improving health and safety that are outlined in the Framework Directive (89/391/EEC).



Vibration induced white fingers and/or nerve damage are serious work related disorders.

How severe is the problem? The following estimate is made in the proposal for the UK Regulation. HAV stands for Hand-Arm Vibration and HAVS means Hand-Arm Vibration Syndrome.

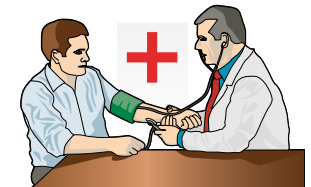
Some 5 million people in Britain are regularly exposed to HAV through their work activities. It is estimated that as many as 2 million of these are at risk of developing diseases caused by exposure to HAV. A survey published in 1999 estimated that around 800 000 people in Britain had some symptoms of vibration white finger (a form of HAVS) linked to HAV exposure at work. Of these, some 300 000 were estimated to have advanced symptoms of the disease. These figures emphasize the need for industry to redouble its efforts to improve control of these risks.



The employer has a responsibility to inform and train his employees on risks and their control.

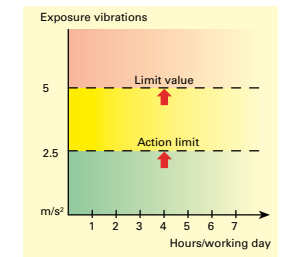
The Directive specifically requires employers, where there is likely to be a risk from exposure to vibration, to:

- a. Reduce exposure to a minimum (Article 5.1)
- b. Assess risks (Article 4.1)
- c. Carry out a program of measures to reduce risks (Article 5.2)
- d. Keep exposure below the exposure limit value (Article 5.3)
- e. Provide information and training on the risks and their control (Article 6)
- f. Provide appropriate health surveillance when exposure reaches the exposure action value (Article 8)



Employees exposed above the action value should be provided with appropriate health surveillance.

Exposure action and limit values are introduced. The action value is set to 2.5 m/s² and the limit value to 5 m/s². Both values are A(8) values, meaning they are rms average values over the 8h working day. These values should not be confused with the declared vibration values given for all tools. The difference will be fully explained later in this document.



The directive is introducing two values for A(8). The action value is 2.5 m/s² and the limit value is 5 m/s².

2. THE DIRECTIVES AND RELATED STANDARDS

This part presents the basic content of the PA(V)D 2002/44/EC. It explains the interaction between the different directives, and European and International Standards. A detailed presentation of the different articles in the directive follows afterwards. The last part contains technical definitions for some of the expressions used in the text.

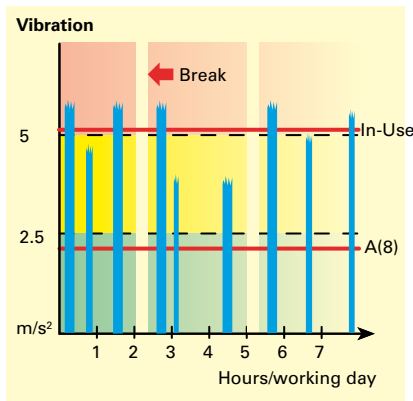
2.1 Three different vibration values

Understand the difference

Manufacturer's declared vibration is the value that must be supplied with all tools sold within the European Union. It is based on measurements performed in accordance with the procedures described in emission standards. Declared values are measured under repeatable conditions so that they can be compared and checked. Prior to 2010, the declared values for most pneumatic tools were measured according to the ISO 8662-series. From 2010 the ISO 28927-series is used. Electric tools are measured according to the EN 60745-series (previously the EN 50144-series). Vibration values measured in the workplace are not the same as those declared by manufacturers.

In-use vibration is the vibration the operator experiences when the tool is running in a real work situation in a specific workplace. In-use vibration varies a lot over time. It depends not only on the vibration produced by the tool, but also on the type, condition and quality of the inserted tool, the state of maintenance of the power tool, the design of the workpiece, the worker's posture, technique and physique. The

estimated in-use vibration used in vibration exposure assessments must be an estimate of the average in-use vibration during the work task for which the exposure assessment is made.



Vibration varies a lot during a workday. The in-use vibration is the rms average of the blue bars over the time represented by the blue bars. This value is the upper red line in the graph. The $A(8)$ value is the rms average of the blue bars over the whole day, including planned breaks, and the time when non-vibrating tasks are performed. The lower red line is the $A(8)$ value resulting from the blue work pattern.

The vibration exposure $A(8)$ is the rms average of the in-use vibration over the whole 8-hour working day.

The Vibration Directive requires workers' exposure to be assessed according to the latest edition of ISO 5349-1 and, if necessary, measured according to ISO 5349-2. Such measurements, performed in the workplace, are costly and time-consuming and have a measurement uncertainty of 20% to 40%, in some cases higher (ref. ISO 5349-2: 2001, Clause 8).

2.2 The Physical Agents (Vibration) Directive:

A summary

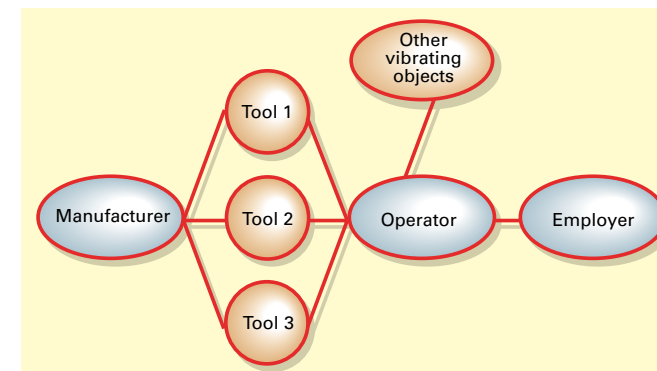
The vibration directive was published on July 6, 2002. The directive came into force as national law on July 6, 2005.

In the directive there is one action and one limit value defined. These values refer to the "daily exposure." The action value is 2.5 m/s² averaged over an 8-hour working day. For employees exposed to vibrations higher than the action value an action plan must be initiated to reduce the vibration exposure. A health surveillance program also has to be incorporated in the action plan. The action value is active from the day the national law took effect.

The limit value is 5 m/s² averaged over an 8-hour working day. It will not be allowed to expose an operator to vibrations that exceed the limit value.



There is also a Physical Agents (Noise) Directive (2003/10/EC). It should have been adopted into national law by February 15, 2006.



Operators are exposed to vibrations from different sources and from power tools. Manufacturers are responsible for marketing tools designed for low vibration. Employers are responsible for protecting their operators from excessive exposure to vibration.



2.3 Current standards and directives related to hand-arm vibration

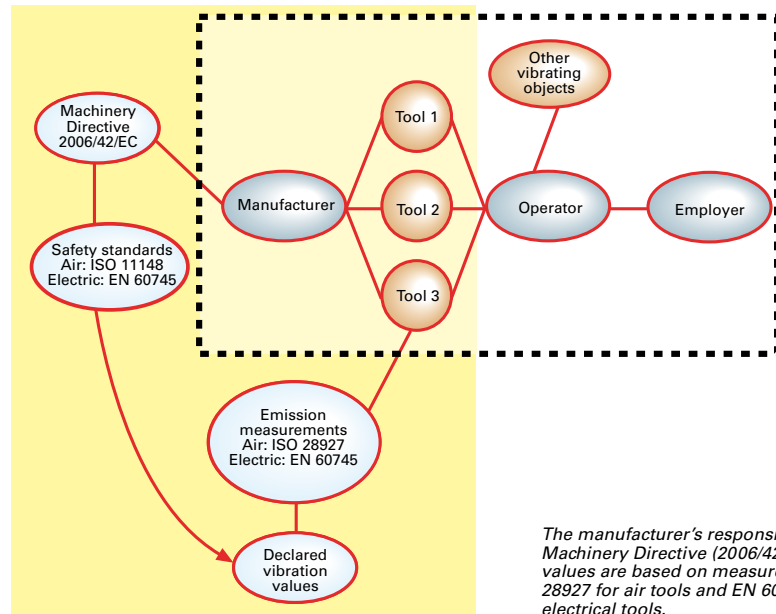
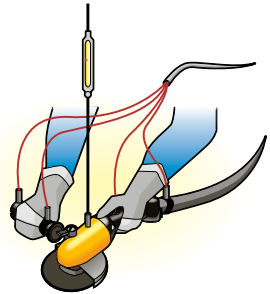
Three groups of people are involved. **The Manufacturer** of the power tools is responsible for developing and marketing tools and equipment that do not create unnecessary vibrations. **The Employer** is responsible for the safety of his employees. As part of that he should, whenever possible, choose tools that give low vibration exposure. **The Operator** is responsible for using the tools according to the given instructions and to react when he or she has reason to believe that vibrations are unusually high. The operator is also the person exposed to vibrations and therefore the one that should be protected from unnecessary vibration exposure.

The exposure comes from working with vibrating tools and from other objects such as vibrating handles or controls on larger equipment. Exposure could also be from vibrating workpieces that are hand-held during a process. Such objects often expose the operator to high vibrations.

The responsibility of the manufacturer

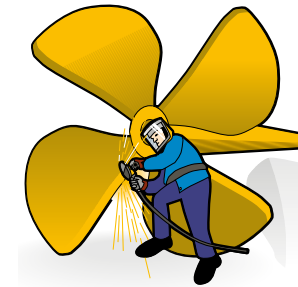
The manufacturer's responsibility is regulated according to

Declared vibration values are based on measurements made under laboratory conditions. The tool is often run under artificial conditions. The aim is repeatable and reproducible results.



The manufacturer's responsibility is regulated in the Machinery Directive (2006/42/EC). Declared vibration values are based on measurements according to ISO 28927 for air tools and EN 60745 or ISO 28927 for electrical tools.

Machinery Directive (2006/42/EC). The directive deals with essential health and safety requirements of machinery. The safety standard ISO 11148 explains in more detail what the manufacturers have to do to comply with the directive. The Machinery Directive requires the manufacturer to declare the vibration emission from his tools. The values shall be declared in accordance with the appropriate test code. Pneumatic tools are declared according to ISO 28927, and electric tools according to EN 60745 or ISO 28927.



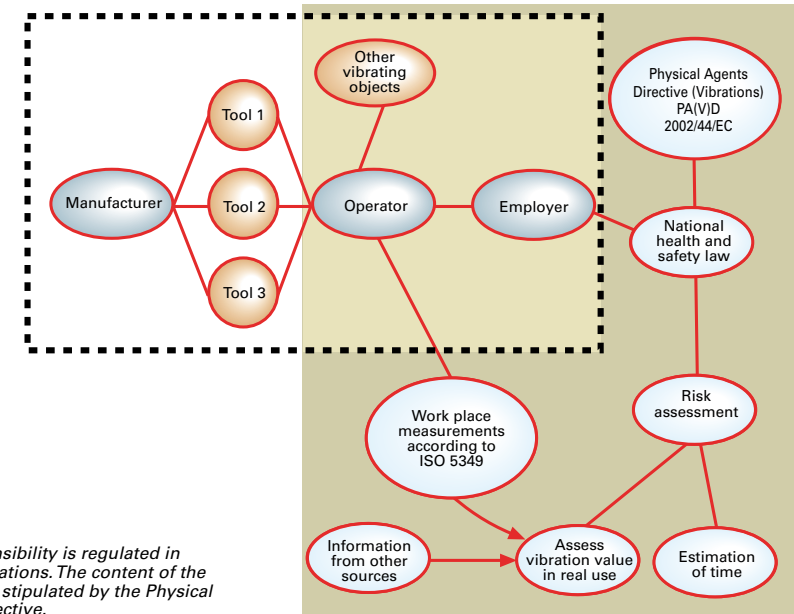
Vibrations in real work situations vary a lot depending on operator skill, workplace, workpiece and inserted tools.

The responsibility of the employer

The employer is responsible for the safety of his employees. The employer must follow the national law regarding health and safety for his operators. With the new directive the law is basically the same in all countries in the European union. The employer should keep the vibration exposure to a minimum.



Workplace measurements are made according to ISO 5349-1 and -2.



The employer's responsibility is regulated in national law and regulations. The content of the national regulations is stipulated by the Physical Agents (Vibration) Directive.

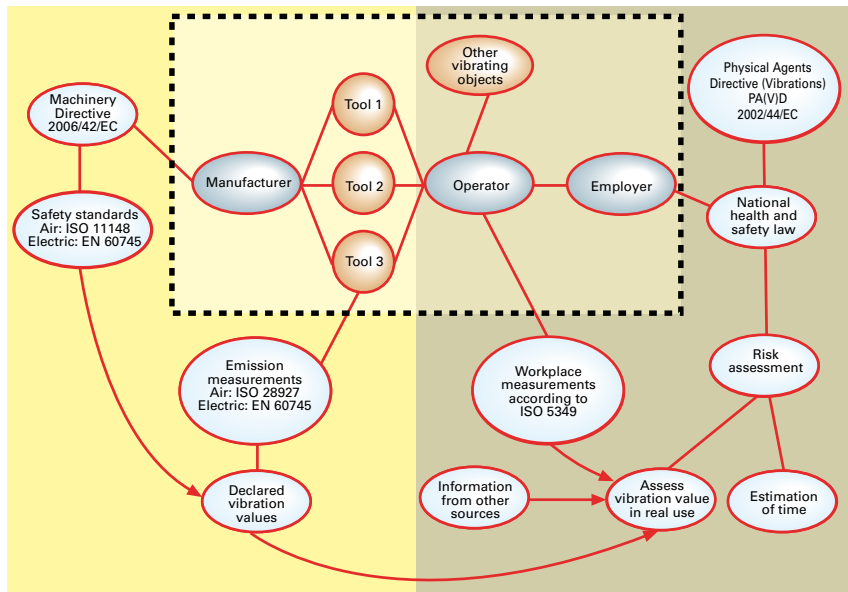
The responsibility of the operator

The operator is responsible for using the tools according to the instructions provided and to react when he or she has reason to believe that vibrations are unusually high.

The Physical Agents (Vibration) Directive (2002/44/EC)

With the new PA(V)D the responsibilities of employers are the same throughout Europe. The employers will be required to make an action program for all operators exposed above the action value 2.5 m/s². The program shall contain information on how and when the vibration exposure shall be reduced and a plan for health surveillance.

Measurements according to ISO 5349 are expensive and difficult to perform if the result is to be a reasonably reliable representation of the in-use vibration for a certain tool in a certain workplace. It is therefore an attractive alternative to use the declared values given by the manufacturer. The problem is that the declared values are measured according to the relevant emission standard. Those standards are designed to give values with good repeatability and reproducibility – but measurements are taken in special well-defined



The complete picture of the relationships between the different standards shows a complicated pattern. To avoid unnecessary misunderstandings and to avoid confusion it is essential to understand how the directives and standards are linked together.

work situations that do not necessarily represent the values for the specific work situation.

There can also be considerable differences between workplaces and operators. That means that exposures based on declared values can only be rough estimations of the values that an operator will be exposed to when using the tool in real situations. Many manufacturers will try to give additional information about in-use vibrations.

It is also possible to seek information from other sources such as databases on the internet. However, those values must be used with care; it is difficult to know if they are representative for the particular workplace being investigated.

2.4 The Physical Agents (Vibration) Directive: in detail

In this part we examine the different articles in the directive. We quote the heading and the essential part of the text. Where necessary, we also add explanations as to what lies behind the text. Quoted parts are in italic.

Article 1. Aim and scope.

This Directive lays down minimum requirements for the protection of operators from risk to their health and safety arising or likely to arise from exposure to mechanical vibration.

The Physical Agents (Vibration) Directive is the first in a series of directives. The reason the vibration directive comes first is that this part was judged to be the most important.

Article 3. Exposure limit values and action values

The daily exposure limit value standardised to an eight-hour reference period shall be 5 m/s².

The daily exposure action value standardised to an eight-hour reference period shall be 2.5 m/s².

Article 4. Determination and assessment of risks

The employer shall assess and, if necessary, measure the levels of mechanical vibration to which operators are exposed.

The assessment is based on the calculation of the daily exposure value normalized to an eight-hour reference period A(8) as defined in ISO standard 5349-1.

The level of exposure may be assessed by means of reference to relevant information including such information provided by the manufacturer.

Relevant information from the manufacturers is the declared values or additional information about typical vibration values for different types of work tasks.

Assessment and measurements shall be carried out by competent services or persons.

In the headings below all points in the directive are quoted but in the following text only the points relevant for this document are quoted.

The employer shall pay particular attention to the following:

Points a-h.

- a) The level, type and duration of the exposure;
- e) Information provided by manufacturers of work equipment in accordance with the relevant Community Directive;
- h) Specific working conditions such as temperature;

The risk assessment shall be recorded on a suitable medium. The risk assessment shall be kept up to date on a regular basis.

Article 5. Provisions aimed at avoiding or reducing exposure

1. Taking account of technical progress and of the availability of measures to control the risk at source, the risks arising from exposure to mechanical vibration shall be eliminated at their source or reduced to a minimum.
2. Once the action value is exceeded, the employer shall establish and implement a program of technical and/or organisational measures intended to reduce to a minimum exposure to mechanical vibration and the attendant risks, taking into account in particular:

Points a-g.

- a) Other working methods that require less exposure to mechanical vibration;

- b) The choice of appropriate work equipment of appropriate ergonomic design producing the least possible vibration;
 - c) The provision of auxiliary equipment that reduces the risk of injury;
 - d) Appropriate maintenance programs for work equipment;
 - g) limitation of duration and intensity of the exposure
3. In any event, workers shall not be exposed above the exposure limit value.

Article 6. Operator information and training

The employer shall ensure that operators and/or their representatives receive information and training relating to the outcome of the risk assessment, concerning in particular:

Points a-f.

- a) The measures taken to implement this Directive in order to eliminate or reduce to a minimum the risk from vibration.
- c) The result of the assessment and the potential injury arising from the work equipment in use.
- f) Safe working practices to minimise exposure to mechanical vibration.

Article 7. Consultation and participation of operators

Consultation and participation of operators and/or of their representatives shall take place.

Article 8. Health surveillance

This is a long article that establishes when and how health surveillance shall take place. Basically it says that operators shall have appropriate health surveillance when the assessment indicates a risk for vibration disorders.

Article 9. Transitional period

Member states shall be entitled to make use of a maximum transitional period of five years from July 6, 2005 where work equipment is used which was given to workers before July 6, 2007 and which does not permit the exposure limit values to be respected, taking into account the latest technical advances and/or the organisational measures taken.

How a transitional period is implemented into national regulations is different in different countries.

Article 10. Derogations

In cases where the exposure of an operator to mechanical vibration is usually below the exposure action value but varies from time to time and may occasionally exceed the exposure limit value, Member States may also grant derogations from Article 5(3). However the exposure value averaged over 40 hours must be less than the exposure limit value.

This derogation will also be implemented differently in different states.

Article 14. Transposition

The Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive not later than July 6, 2005.

2.5 Definitions

Daily personal vibration exposure

The daily personal vibration exposure $A(8)$ of an employee is expressed in meters per second squared (m/s^2) and is defined using the formula:

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

where:

a_{hv} is the vibration magnitude, in m/s^2

T is the duration of exposure to the vibration magnitude a_{hv}

T_0 is the reference duration of 8 hours

The vibration magnitude a_{hv} is defined using the formula:

$$a_{hv} = \sqrt{a_{hvx}^2 + a_{hvy}^2 + a_{hvw}^2}$$

where;

a_{hvx} , a_{hvy} and a_{hvw} are the root-mean-square acceleration values, in 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 function W_h .

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

The definition for the frequency weighting function W_h is given in standard EN ISO 5349.

If the work is such that the total daily exposure consists of two or more operations with different vibration magnitudes, the daily exposure, $A(8)$, is defined using the equation:

$$A(8) = \sqrt{\frac{1}{T_0} \sum_{i=1}^n a_{hvi}^2 T_i}$$

where:

n is the number of individual operations within the working day

a_{hvi} is the vibration magnitude for operation i

T_i is the duration of operation i

The weekly average personal vibration exposure $A(8)_{week}$ is the total exposure occurring within a period of seven consecutive days, normalised to a reference duration of 40 hours. It is expressed in m/s^2 and is defined using the formula:

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

where:

$A(8)_j$ is the daily exposure for day j . As mentioned above the weekly average daily personal vibration exposure is used only in special circumstances.

3. HOW WILL THE DIRECTIVE INFLUENCE YOUR BUSINESS?

In this part we first explain how the regulations in Sweden and the UK are written. We note what is common and what are national differences. We also give explanations regarding the employer's duties.

3.1 Examples of National law

3.1.1 UK

The EU Physical Agents (Vibration) Directive is incorporated in Great Britain under the terms of the Control of Vibration at Work Regulations 2005.

The Regulations are needed to implement the specific and detailed requirements set out in the Directive. However, the general duties in previous health and safety legislation, which are relevant to vibration hazard, will continue to apply.

The UK implemented a transitional period that ran to July 6, 2010 for equipment sold before July 6, 2007. The UK regulation has the words "reasonably practicable" in the text. The transitional period could therefore be used in cases where it was not reasonably practicable to lower the exposure to values below the limit. The regulation left the employer to judge what was not reasonably practicable. In the UK regulations the transitional period also applied to second-hand or rented equipment as long as it was first given to operators before July 6, 2007.

Also implemented is the option to use a 40 hour average instead of an 8 hour day for situations including occasional high exposures. However, it must only be used when the exposures are otherwise below the action value. It will be up to the employer to judge if it is acceptable to use weekly averaging or not.

The requirement for health surveillance in the PA(V)D will be handled in the UK through a tiered system beginning with a questionnaire to identify possible symptoms. This is believed to concentrate the resources where they are needed.

3.1.2 Sweden

The EU Physical Agents (Vibration) Directive is incorporated in Sweden under the terms of Regulation AFS 2005:15 Vibrationer. It is supported by the law SFS 1997:1166.

As in the UK the regulation is valid for all enterprises where someone might be exposed to vibrations at work.

The risk assessment shall include an estimate of the daily vibration exposure and shall be revised on a regular basis. One-year intervals are a recommendation, preferably more often. The risk assessment must be filed for later reference.

Employees shall be informed and trained how to minimise the exposure to vibration.

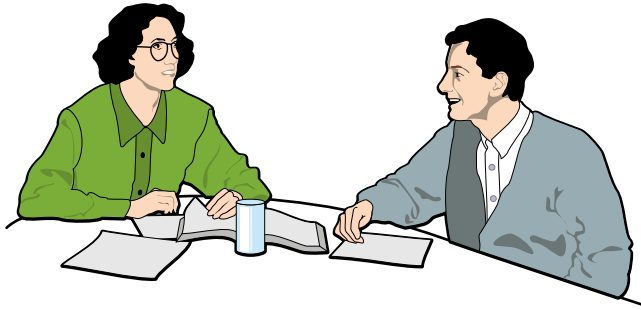
The vibration limit value may never be exceeded.

The big difference between Sweden and the UK is that there was no transitional period. The reason being that it is in all cases possible to reduce hand-arm vibration to below the limit value by reducing the exposure time. Therefore very few working situations exist where it is not possible to reduce vibration below the limit value "taking into account the latest technical advances and/or organisational measures" quoted from the Directive. Sweden has not accepted the UK approach involving the words "reasonably practicable".

The possibility of averaging over a 40 hour week instead of an 8-hour day is not implemented in Sweden.



The employer is expected to know the exposure for all his operators and that information should be shared with the employees or their organizations.



3.2 What is expected from the employer according to the PA(V)D

The employer is expected to know the level of exposure for all his employees, and is expected to act to manage the risk of exposure to vibration.

Assessment of exposure to vibration is a central part in the Directive. It shall be carried out for all employees that might be at risk, at least to a level where they are not exposed to vibrations above the action value. In the UK regulations this list can be found describing what a suitable risk assessment should include:

- In what situations an employee is exposed to risk from vibration.
- A soundly-based estimate of the exposure and comparison with the action and limit values.
- What measures can be taken to reduce the risk.
- Identify other information that might be important when an action plan is made.

The assessments shall be stored for later reference.

The most simple risk assessment is a document just saying that the operator is probably not at risk. He is not using work processes involving vibrations to an extent that might expose him above the action value.

When the action value is exceeded an action plan must be made up, kept updated and filed for later use. The plan shall contain planned measures to control the risk and a timetable for them to be carried out. It shall also contain a plan for medical surveillance of the operators.

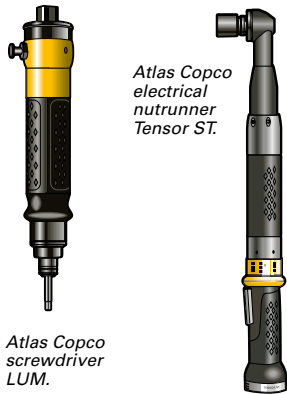
The action plan shall include a plan to control the risk. Possible measures to control the risk could involve:

- Changing to other equipment, which can do the same job with less exposure to vibration. The important thing is to look for equipment that produces less vibration or that can do the job faster.
- Training the operators to avoid unnecessary exposure to vibration.
- Increase productivity of the present equipment to reduce exposure time. Check the air installation. Check that you are using the most effective inserted tools.
- Using job rotation to decrease exposure time.
- Changing process completely to get rid of the vibrating task.
- Changing the design of the product to reduce the need for tasks involving exposure to vibration.

Under no circumstances, except for cases where one of the exceptions is valid, can an operator be exposed to vibrations exceeding the limit value. If this should happen, the employer must take immediate action to reduce the exposure to below the limit value. He must also investigate the reasons why the limit was exceeded and take action to make sure that this does not happen again.



Graph showing the 3 step workflow described in this chapter.

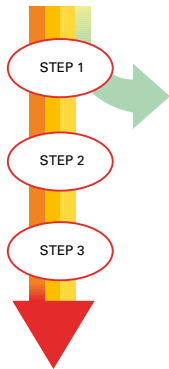


4. WORKFLOW TO MANAGE YOUR RISK

The first and obvious action is, of course, to reduce the risk from vibration exposure in workplaces where hand-arm vibration disorders are already reported or known to exist. This chapter suggests a workflow in three major steps that you can follow in order to manage the risk from exposure to vibration for workstations where you have no reports of vibration disorders. The steps are only briefly explained. More detailed information can be found in Chapters 5 and 6.

4.1 Step 1: Find the operators with low risk

Among all operators at a work-site there are always groups of operators that are not exposed to vibrations. **In this first step of the workflow situations are identified where you can find the operators who are most probably exposed well below the action value 2.5 m/s².**



Some types of tools have low vibrations. The action value will probably not be exceeded also if the tools are used intensively for the whole working day. This is not valid if the operator mixes the use of such tools with the use of other tools with higher vibration values. You also have to make sure the tool is used under normal working conditions. The aim is to exclude the operator from further investigations.

Based on experience from tools manufactured by Atlas Copco the tools with low vibrations can be found in the following groups:

- Angle nutrunners, screwdrivers and pistol grip nutrunners when they are the only types of tool used. This is only valid when the tools are used without extensions. Slip-clutch screwdrivers cannot be regarded as non-critical.
- Non-hammering drills used with normal length drill bits of standard type.
- Pistol grip impulse nutrunner for up to M10 bolts used with good quality sockets without extensions if less than 1 000 bolts are tightened per day and the correct size tool is used (see recommendations in the selection guide for pulse tools).

Holding the socket while the tool is operating, either running free or in tightening operations, will always expose that hand to unnecessary high vibrations. **This must be completely avoided** if impulse nutrunners shall be regarded as a low risk application.

There are applications where the exposure time is normally very short. In these cases quite high vibration values can be accepted. Again, these applications can only be regarded as non-critical if they are not mixed with other tasks with higher vibrations that add to the A(8) value.

For short exposure times a quick estimation of exposure time is often enough to judge if there is a risk. The following relationships between time and possible in-use vibration can be of help:

- When exposure time is known to be shorter than 30 minutes the in-use vibration can be 10 m/s² before the action value is exceeded and 20 m/s² before the limit value is exceeded.
- When exposure time is known to be shorter than 10 minutes the in-use vibration can be 17 m/s² before the action value is exceeded and 35 m/s² before the limit value is exceeded.

4.2 Step 2: Make a rough exposure assessment

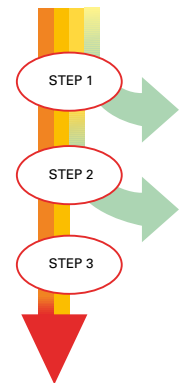
The aim of this second step in the workflow is to make a rough vibration-exposure assessment based on available information. This assessment is then used to eliminate a second group of operators from further actions.

Instead of initially concentrating your resources on finding the best estimate of the vibration exposure, consider instead obtaining a rough estimate and using that estimate to assess roughly whether the operator's exposure is likely to exceed the

Daily Limit Value or Daily Action Value. If it is, you may find it is better to use your resources to reduce the exposure.

The first rough exposure assessment consists of 3 parts:

1. Find a vibration value that is an estimate of the in-use vibration value.
2. Estimate the exposure time.
3. Calculate the vibration exposure.





Operators tend to overestimate the exposure time. It is often better to measure the actual trigger time.

4.2.1 Find a vibration value that is an estimate of the in-use vibration

It is important that this first rough estimate is on the safe side. It is better to choose a value known to be an over-estimation than to risk under-estimating the in-use vibration. For tools used in their normal application the declared value can in many cases be used as estimations of the in-use vibration value. This roughly estimated in-use vibration value is used together with the estimated trigger time as input for an exposure calculation.

Declarations according to the ISO 28927-series or EN 60745-2-x referring to EN 60745-1:2006 can be used as a rough estimate without any correction. Tools made/manufactured before January 1, 2010 are declared with single axis vibration values according to ISO 8662. These values can only be used with correction factors according to the latest edition of CEN/TR 15350.

4.2.2 Estimate the exposure time

When exposure time is investigated we often refer to it as trigger time. This explains what we are looking for. Only the time when the tool is actually triggered and working on the job shall be taken into account. Experience tells us that, when asked, operators tend to highly overestimate the exposure time.

Methods of making estimates of the actual exposure time are shown in chapter 6.

4.2.3 Calculate the vibration exposure

When vibration value and exposure time are known the calculation of vibration exposure is made with the formulas given in chapter 2. In many cases operators use more than one tool during a shift. The exposure from each tool should then be combined to a total daily exposure. The simplest way is to use one of the exposure calculators (examples are shown in chapter 6) that can be found on the Internet. The different methods of combining estimations for the vibration value and the exposure times to a daily vibration exposure are described in chapter 5.

4.3 Step 3: Manage the risk

For the remaining part, where the rough estimate made in step 2 shows that your operators are close to or above the action value you have two possibilities. Either you manage the risk or you do a more precise assessment to find if you are above the action value or not. **Our experience clearly shows that in most cases it is more cost effective to manage the risk directly on the indication from the first rough estimate rather than to spend a lot of money on a workplace measurement.**

Managing the risk is the most central part of the whole directive. If you suspect you have operators exposed to vibrations to an extent where they are at risk of getting vibration induced disorders, you have to manage the risk by reducing the exposure to vibrations.

You have basically four possibilities:

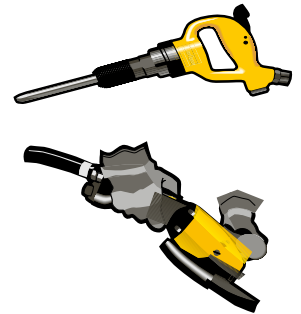
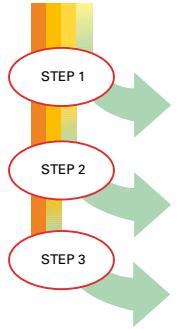
- Change to a tool or work process that has lower vibrations.
- Change to a tool or work process that can do the job in a shorter time.
- Check your installation to make sure you use the tool in the most effective way.
- Use job rotation to reduce the trigger time.

4.3.1 Change to a tool or work process that has lower vibrations

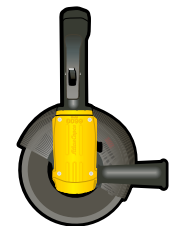
Today most types of tools are available in versions that have lower vibrations. In applications where those tools are suitable, they can often reduce the exposure considerably. It is important, however, to make sure the tools have equal or better performance. Otherwise you might end up with longer exposure times that reduce or eliminate the effect of the reduced vibration value.

4.3.2 Change to a tool or work process that can do the job faster

In many material removal processes the time to do the job is inversely proportional to the power used. It is therefore often worthwhile to investigate the possibility of doing the job with a more powerful tool to be able to reduce exposure time.

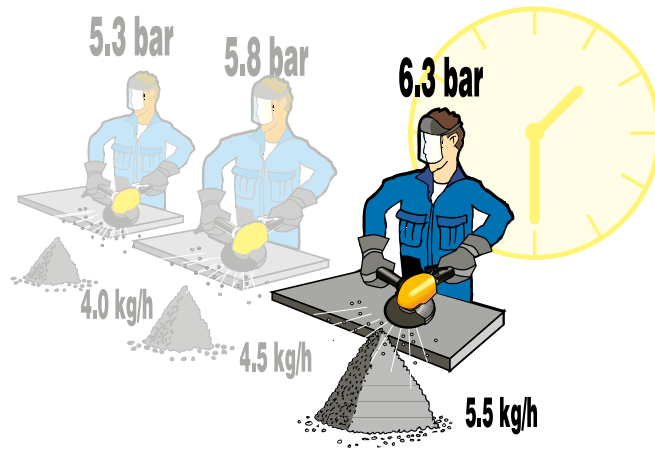


Modern low vibration tools have vibrations considerably lower than conventional tools. For example, Atlas Copco vibration controlled chipping hammers and grinders.



Roughly speaking, the grinding time is inversely proportional to the power of the tool. With the powerful turbo grinders process time can be shortened.

Grinding with 1 bar lower pressure than prescribed leads to a 40% longer process.



4.3.3 Check your installation to make sure you use the tool in the most effective way

Too often in industry hand-held power tools are not used efficiently because the air installation does not give enough air for the tool to run at maximum power. Power drops quickly with pressure loss and the insufficient power makes the process time unnecessarily long. The most common reason for pressure drop is too long hoses or too small diameter and quick-couplings with insufficient flow capacity. For more information, see the Pocket Guide to Air Line Distribution (ordering No. 9833 1266 01).

4.3.4 Use job rotation to reduce the trigger time

In cases where there are no means of reducing the vibration exposure enough to allow an operator to work a full shift without exceeding the action value there is always a possibility to introduce job rotation to reduce exposure time.

5. VIBRATION EXPOSURE ASSESSMENT

In this chapter working procedures used to assess exposure to vibration are described in detail. The 4 steps covered are:

- Finding the in-use vibration values representing your work.
- Estimating exposure time.
- Combining vibration magnitudes and daily vibration exposure time.
- Combined vibration from more than one source.

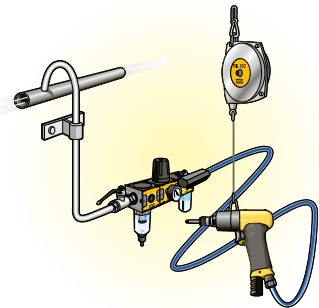
5.1 Finding vibration values representing your work

5.1.1 Manufacturers' declared values

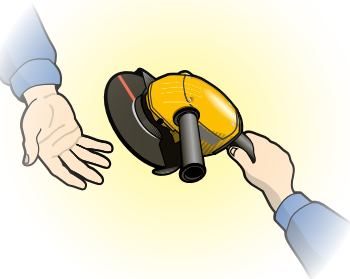
All equipment sold within the European market must have a declaration of vibration emission in its documentation. The value is measured using an emission test code that is harmonized within the European Community.

A declared value measured using the ISO 28927-series, or the EN 60745-series standards, will in most cases be representative of the in-use vibration values which are likely to be experienced in the workplace when the tool is in normal use. According to CEN/TR 15350 a rough assessment can be made using the values obtained using the ISO 28927-series, or the EN 60745-series standards.

If necessary, single-axis values can be used to roughly estimate the in-use vibration value after correction by a correction factor. Information about how to do this is given in the latest edition of CEN/TR 15350, "Mechanical vibration – Guideline for the assessment of exposure to hand-transmitted vibration using available information including that provided by manufacturers of machinery."



Often air tools cannot be used at their full power because of restrictions in the air installation.



Job rotation is always a possibility to reduce exposure time for an operator.



Increased risks from vibration exposure are likely to result from failing to follow the manufacturer's instructions on the correct way of using the tool and applying the feed force, or from not maintaining the tool and its accessories so that they work efficiently. Worn power tools and accessories should be serviced to maintain their original performance, or replaced.

If the declared value has been measured using the ISO 28927-series, or the EN 60745-series standards, it will be a "vibration total value" (i.e., a three-axes value) and will also be more representative of vibration values which are likely to be experienced in the workplace. Therefore, these declared values do not need to have a correction factor applied and can be entered directly into the vibration calculator, together with the estimated daily exposure time.

5.1.2 Additional information given by manufacturers

Some manufacturers have started to give information regarding vibration values for their products in real use.

It is important to note that even if vibration values are given for a specific task, the actual values that an operator is exposed to vary a lot depending on factors that can be influenced by users of the tool.

Giving vibration values for specific work tasks is a difficult task for manufacturers. Due to the considerable variation in real use it is very time consuming to measure to an extent that will result in a value that statistically represents a good average of the vibration in the performed task.

5.1.3 Workplace measurements

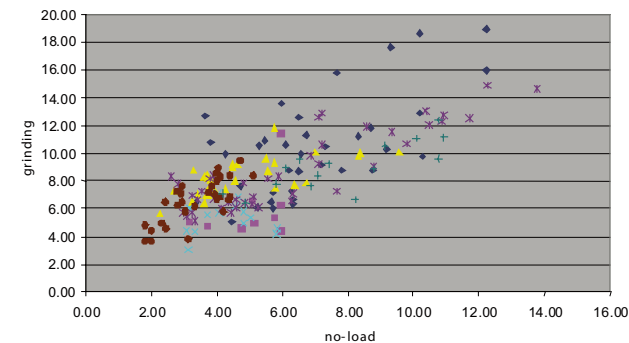
In some cases it might be necessary to take vibration measurements in the specific workplace – but this can be an expensive and time-consuming task. Many parameters can influence the result, and some of them will have a large variation over time. Measurements need to be taken over long periods of time to create a reasonably representative average vibration value.

Many published workplace measurements have failed to take this into account, resulting in values representative only of the few minutes during which the measurement was performed. Good advice can be found in ISO 5349-2. Also important is the use of competent services with proven experience in conducting measurements that can be used for vibration exposure assessment.

As part of the preparation of the new grinder test code ISO 28927-1 a Round-Robin test has been done. In this test a number of grinders has been sent around to independent laboratories in Europe. Among other things the laboratories also did real grinding with the tools in a well defined grinding operation. Still the result shows big spread.

Seven laboratories have together performed at least 105 grinding operations with each tool. The vibration in free running was measured before and after each grinding operation. Vibrations were measured in 3 directions on both handles. The locations of the accelerometers were precisely described in the test instruction. Still the spread between different one minute grinding operations varies in the range of 1 to 10. In the example below the variation is from 2 to 20 m/s².

125 mm pneumatic grinder, support handle



An example of all tests made on one handle on one of the test tools. Grinding values are plotted versus the mean value of the free running vibrations measured before and after each 1 minute grinding test. The different shapes and colours of the dots represent the different laboratories.

In this text the Round-Robin test is mentioned to exemplify the difficulties of performing workplace measurements and getting values that can be used as representative mean values for the vibration that an operator will be exposed to over a longer period of time.

5.1.4 How to find the first rough estimate of the vibration value

From the text above it can be concluded that there is no such thing as a precise value of the vibration that an operator is exposed to. The value will vary a lot from time to time and from one operator to another.

The declared vibration total value (3-axes value) is, for the time being, a cost-effective way of estimating the in-use vibration. The value can be used as input in a rough vibration exposure assessment.

Single-axis values together with the proper correction factor can also be used in cases where no declared vibration total value can be found.

Instead of initially concentrating your resources on finding the best estimate of the vibration exposure, consider instead obtaining a rough estimate and using that estimate to assess roughly whether the operator's exposure is likely to exceed the Daily Limit Value or Daily Action Value. If it is, you may find it is better to use your resources to reduce the exposure.



Using the tool for a sole specialist task, or in a way which is not represented by the quoted standard (i.e. ISO 28927 or EN 60745), or with accessories or consumables other than those which have been recommended or supplied by the manufacturer, may produce a different average emission and in such cases it is strongly recommended that a specific evaluation of the vibration emission is performed according to ISO 5349.

5.2 Estimating exposure time

The in-use vibration value and the exposure duration are both needed to complete the exposure assessment. Note that the exposure duration is not the overall time spent on a specific job. The exposure duration is only the trigger time during which the hands are actually exposed to vibration.

When asked, operators tend to overestimate the exposure duration. Therefore it is better to estimate the exposure duration by observation of a sample of typical work. There are a

5.3 Combining vibration values and exposure times to daily vibration exposure

The daily vibration exposure is expressed in m/s^2 and is shown as $A(8)$. It is the vibration value averaged over an 8 hour working day, and is defined by the formula:

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

number of ways that can be used to estimate trigger time, and examples for different types of tools are given in chapter 6.

Where: $A(8)$ is the daily vibration exposure. a_{hv} is the in-use vibration value. T is the actual exposure time. T_0 is 8h (480 min).

Daily vibration exposure varies linearly with the vibration value and with the square root of time. The table below gives maximum daily exposure times for a number of different vibration magnitudes.

In-use vibration value	Max daily exposure time before exceeding:	
	action value 2.5m/s ²	limit value 5m/s ²
1.8 m/s ²	15 h	62 h
2.5 m/s ²	8 h	32 h
3.5 m/s ²	4 h	16 h
5 m/s ²	2 h	8 h
7 m/s ²	1h	4 h
10 m/s ²	30 min	2 h
14 m/s ²	15 min	1 h
20 m/s ²	8 min	30 min

5.3.1 Partial exposure

Operators often use more than one tool or vibrating process in the same working day. The calculated daily vibration exposure from each tool is called "partial exposure." The total daily exposure is thus the sum of all the partial exposures combined. Calculation methods are given for cases where more than one tool is used.

5.4 Combined vibration exposures from more than one source

5.4.1 Calculation using the basic equations

In section 2.5 of this booklet you will find the definitions of daily vibration exposure. Use that formula and the formula for combining partial exposures to calculate the total daily exposure. This is easily done using a spreadsheet program such as Excel.

Some calculators also show points for different combinations of vibration magnitude and exposure duration.

5.4.2 Using the point system

With this method you define a number of exposure points (PE) for each combination of vibration value and exposure duration. This is done using the formula:

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

Where: P_E is the number of exposure points. a_{hv} is the in-use vibration value for one operation. T is the exposure duration for that operation.

This gives the partial exposure for each vibrating tool or process used by an operator during the working day expressed as a number of exposure points. The total daily exposure expressed in exposure points is the sum of the points for all the processes involved.

$P_E < 100$ means the exposure action value of 2.5 m/s² will not be exceeded.

$100 < P_E < 400$ means you have a daily exposure between that action value and the limit value.

$P_E > 400$ mean that the limit value of 5 m/s² has been exceeded.

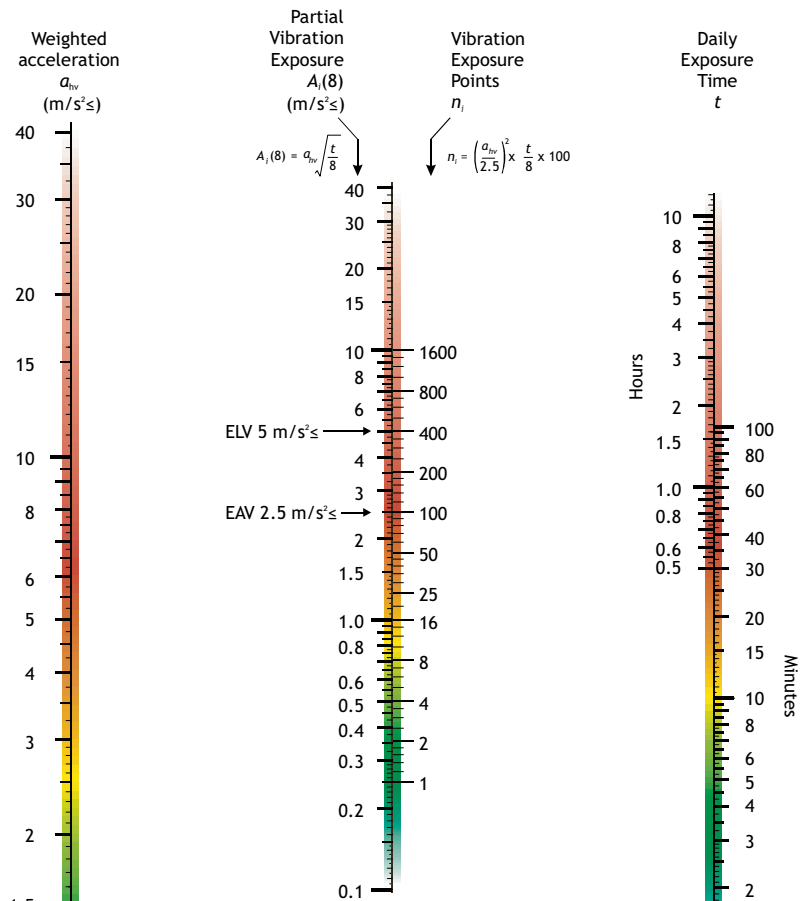
The partial vibration exposure for all tools and processes involved can be found in different ways.

The nomogram on the next page can be found in the proposed UK regulation:

By drawing a straight line through the vibration magnitude on the left side and the exposure time on the right side, the daily exposure and the exposure points can be read in the middle.

Another alternative is to use the table 5.1 at the end of this chapter to get the exposure points for the combination of vibration magnitude and exposure time that best corresponds to the values you have.

When using these tools for calculation, do remember that the precision and usefulness of the results are only as good as the accuracy of the data that has been gathered. Assessments of in-use vibration values and of exposure duration are always estimations of parameters that vary considerably. Therefore use the results with common sense: it can never be claimed that the exposure is known to a fraction of a decimal.



$$A_i(8) = a_w \sqrt{\frac{t}{8}}$$

$$n_i = \left(\frac{a_w}{2.5}\right)^2 \times \frac{t}{8} \times 100$$

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

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

For n_i values:
Add the score values to give a total daily score, n

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

	n_i	
Exposure 1		
Exposure 2		
Exposure 3		
Exposure 4		
Exposure 5		
$n = n_i =$		

In-use vibration value	Exposure duration							
	5 min	10 min	20 min	50 min	1 h 60 min	2 h 120 min	5 h 300 min	8 h 480 min
2.5	1	2	4	10	13	25	63	100
3.0	2	3	6	15	18	36	90	144
3.5	2	4	8	20	25	49	123	196
4.0	3	5	11	27	32	64	160	256
4.5	3	7	14	34	41	81	203	324
5.0	4	8	17	42	50	100	250	400
5.5	5	10	20	50	61	121	303	484
6.0	6	12	24	60	72	144	360	576
6.5	7	14	28	70	85	169	423	676
7.0	8	16	33	82	98	196	490	784
7.5	9	19	38	94	113	225	563	900
8.0	11	21	43	107	128	256	640	1024
8.5	12	24	48	120	145	289	723	1156
9.0	14	27	54	135	162	324	810	1296
9.5	15	30	60	150	181	361	903	1444
10.0	17	33	67	167	200	400	1000	1600
11.0	20	40	81	202	242	484	1210	1936
12.0	24	48	96	240	288	576	1440	2304
13.0	28	56	113	282	338	676	1690	2704
14.0	33	65	131	327	392	784	1960	3136
15.0	38	75	150	375	450	900	2250	3600
16.0	43	85	171	427	512	1024	2560	4096
17.0	48	96	193	482	578	1156	2890	4624
18.0	54	108	216	540	648	1296	3240	5184
19.0	60	120	241	602	722	1444	3610	5776
20.0	67	133	267	667	800	1600	4000	6400
21.0	74	147	294	735	882	1764	4410	7056
22.0	81	161	323	807	968	1936	4840	7744
23.0	88	176	353	882	1058	2116	5290	8464
24.0	96	192	384	960	1152	2304	5760	9216
25.0	104	208	417	1042	1250	2500	6250	10000
26.0	113	225	451	1127	1352	2704	6760	10816
27.0	122	243	486	1215	1458	2916	7290	11664
28.0	131	261	523	1307	1568	3136	7840	12544
29.0	140	280	561	1402	1682	3364	8410	13456
30.0	150	300	600	1500	1800	3600	9000	14400

Table 5.1 Use this table to find exposure points when you know in-use vibration value and time. To reach times other than the ones tabled just add points from more than one column.

Exposure points	Total daily exposure m/s ²	Exposure points	Total daily exposure m/s ²	Exposure points	Total daily exposure m/s ²	Exposure points	Total daily exposure m/s ²
50	1.8	210	3.6	620	6.2	1050	8.1
55	1.9	220	3.7	640	6.3	1100	8.3
60	1.9	240	3.9	660	6.4	1150	8.5
65	2.0	260	4.0	680	6.5	1200	8.7
70	2.1	280	4.2	700	6.6	1250	8.8
75	2.2	300	4.3	720	6.7	1300	9.0
80	2.2	320	4.5	740	6.8	1350	9.2
85	2.3	340	4.6	760	6.9	1400	9.4
90	2.4	360	4.7	780	7.0	1450	9.5
95	2.4	380	4.9	800	7.1	1500	9.7
100	2.5	400	5.0	820	7.2	1550	9.8
110	2.6	420	5.1	840	7.2	1600	10.0
120	2.7	440	5.2	860	7.3	1650	10.2
130	2.9	460	5.4	880	7.4	1700	10.3
140	3.0	480	5.5	900	7.5	1750	10.5
150	3.1	500	5.6	920	7.6	1800	10.6
160	3.2	520	5.7	940	7.7	1850	10.8
170	3.3	540	5.8	960	7.7	1900	10.9
180	3.4	560	5.9	980	7.8	1950	11.0
190	3.4	580	6.0	1000	7.9	2000	11.2
200	3.5	600	6.1	1020	8.0	2050	11.3

Table 5.2 Use this table to convert exposure points to Total Daily Exposure.

6. EXPOSURE ASSESSMENT AND RISK MANAGEMENT FOR DIFFERENT TYPES OF TOOLS

This chapter presents the most common types of tools in use today. The sources for the vibration are explained. Guidance regarding vibration magnitudes and exposure time in real work situations is given. You will also find advice about what can be done to control the exposure.

6.1 Sources of vibration

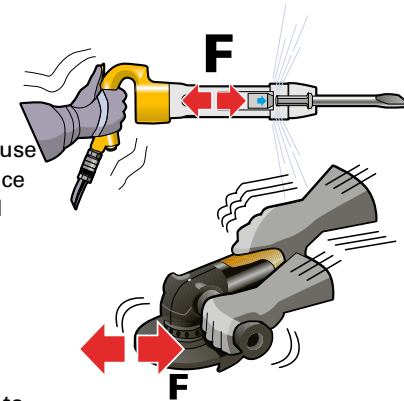
Tools for industrial use must be of very robust design to withstand the sometimes very hard use they are exposed to. From a vibration point of view this means that most tools can be regarded as rigid bodies. Oscillating forces act on this body and the result is vibration. The oscillating forces are either internal or process forces.

Internal forces are independent of the process and originate from, e.g., the imbalance of internal parts in rotating machines or the imbalance of inserted tools. The forces necessary to accelerate the piston in a percussive tool are also examples of internal forces.

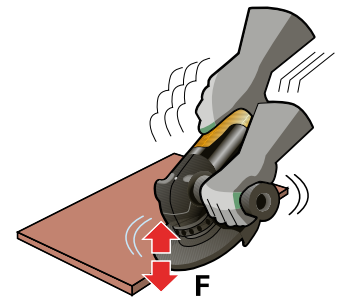
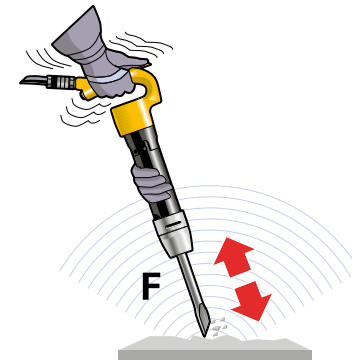
Process forces are, for example, generated when a grinding wheel is in contact with the workpiece or when the shockwave in a chisel to a percussive tool is reflected back into the tool from the workpiece. The contact forces between the bolt and the socket when an impact wrench is tightening a bolt is another example of a process force.

In all cases we are talking about forces as the source of vibration. This leads to the three basic principles to control vibration:

- Control the magnitude of the vibrating forces. Examples are the autobalancer on a grinder or the differential piston in a chipping hammer.
- Make the tool less sensitive to the vibrating forces. Examples can be when the mass of the guard on a grinder is rigidly connected to the tool to increase its inertia.
- Isolate the vibrations in the tool from the grip surfaces. Examples are vibration-dampening handles on grinders or pavement breakers and the air-spring behind the blow-mechanism in a riveting gun or the mass spring system in a chipping hammer.



Oscillating forces act on the tools resulting in vibrations. Internal forces come from unbalanced inserted tools or from forces accelerating the piston in a percussive tool.



Process forces from the grinding wheel working on the workpiece or from shock waves in a chipping hammer.

6.2 Vibration exposure assessment

In this part some advice is given on how to estimate vibration values and exposure time. Both values are important when estimating the exposure and when managing the risk. The best tool for an operation has low vibrations and is also a productive tool that can get the job done in the shortest possible time.

6.2.1 Make a rough estimate of the vibration value in real use

The declared vibration emission value supplied with the tool is intended primarily to compare tools under similar conditions.

Chapter 5 contains a detailed description of how to use declared values to obtain rough estimates of the in-use vibration. With the exceptions mentioned, this is by far the most cost-effective way to make a first rough assessment of the vibration exposure.

6.2.2 Find the exposure time

For grinders and sanders an estimate of the exposure time can be calculated when the number of wheels or sanding discs used during a shift is known together with an estimate of the time a wheel or disc lasts. If this type of information cannot be used it is always possible to use a stopwatch and make a time study. It is important to study a time period long enough to be a representative average.

For tightening tools the time to tighten a bolt multiplied by the number of bolts per shift is often a good estimate. In line production the trigger time for each item produced times number of items per shift can be used.

Machine type	Hours/day	Spread + / - hours
Grinders	3	1.5
Drills	1	0.5
Chipping hammers	2	1.5
Riveters	1	0.5
Screwdrivers	2	1
Impact wrenches	1	0.5
Impulse nutrunners	2	1
Angle nutrunners	2	1
Stall torque nutrunners	1	0.5

Average trigger times per shift for different types of tools. As indicated in the table, variations are big and it is therefore better to measure trigger time in the real situation whenever possible.

6.2.3 Examples of vibration exposure calculations

With the information given in chapters 5 and 6.2 estimates of the in-use vibration and the trigger time can be made. With this as the input it is possible to calculate the exposure. The examples below show how this is done. In the examples, vibration total values measured according to ISO 28927 are used. If single axis values according to obsolete ISO 8662 are used, a correction must first be performed according to CEN/TR 15350.

Example 1

A conventional (not vibration controlled) vertical grinder is used to clean castings. The tool is used with a 180 mm depressed center wheel. The declared vibration value is given by the manufacturer as 6.0 m/s². An investigation shows a trigger time per day of 2 hours based on a wheel-consumption of 20 wheels per week and an average lifetime of a wheel, when used by this operator, of 30 minutes. From table 5.1, using 6.0 m/s² and 2 hours as input, a total daily exposure of 144 points is found. 144 points can then be recalculated to 3.0 m/s² using table 5.2. An action program needs to be started.

	Vibration value m/s ²	Exposure duration hours	minutes	Partial exposure A(8) m/s ²
Conventional grinder	6.0	2	-	3.0
Total daily exposure A(8) m/s²				3.0

Using the Atlas Copco exposure calculator will give the same result.

Example 2

Again, an operator is cleaning castings. This time he works with the same grinder and the same trigger time, but he is also using a conventional (not vibration controlled) chipping hammer. The declared value for the hammer is 7 m/s². A time study shows that the trigger time for the hammer is 15 minutes per shift. During the time study it is noticed that the operator is guiding the chisel with his left hand. In this case the declared value cannot be used as an estimate of the in-use vibration. Instead a value of at least 30 m/s² should be used according to the text in the vibration test code ISO 28927-10 clause 8.4.4.4. If 30 m/s² is used, together with the exposure time of 15 min., Table 5.1 gives 450 points. The two tools together are then 144+450 = 594 points. Table 5.2 gives a total daily exposure of 6.1 m/s². The limit value is exceeded and immediate action should be taken.

	Vibration value m/s ²	Exposure duration hours	minutes	Partial exposure A(8) m/s ²
Conventional grinder	6.0	2	–	3.0
Conventional chipping hammer	30	–	15	5.3
Total daily exposure A(8) m/s²				6.1

Using the Atlas Copco exposure calculator will give the same result.

6.3 Actions to control the risk

To control the risk you have only two possibilities, lower the vibration value or decrease the exposure time. Time can be reduced by changing to a more efficient process or by introducing job rotation. Modern tools with vibration control often show considerably lower vibration values. In many cases they are also more efficient and the job will therefore be done faster.

There are also other things that can be done to improve the situation.

Choosing modern grinding wheels of the most suitable type for the job will both decrease vibration values and grinding time. In many cases the grinding wheels used are too hard. Choosing a wheel that is hard makes the wheel last longer, but it also makes the grinding much more time consuming.

Material removal rate for grinders is directly proportional to power. Therefore, choosing a grinder with the highest possible power will decrease grinding time.

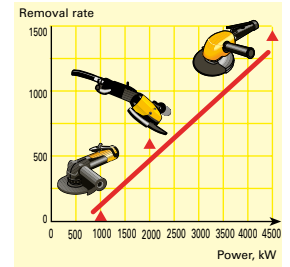
Remember that a good air installation that also gives the tool full air supply when it is loaded is necessary to be able to use the power of the tool. Bad installations are the most common reason grinders do not perform as expected.

6.3.1 Examples

What can be done to control the risk in the two examples above?

Example 1

First let's assume we change to a turbo grinder. The GTG 40 has a declared vibration value of 3.5 m/s². The tool is twice as powerful as the vertical grinder. Theoretically that should mean that it is possible to reduce the process time by 50%. Let us in this example be conservative and assume that the process time is reduced by 25% to 1h 30 minutes. This gives a daily exposure of approximately 37 points.



Tests show an almost straight line correlation between power and material removal rate. Choosing a more powerful grinder will have a big impact on exposure time.



GTG 40. Power 4.5 kw. Declared vibration value 3.5 m/s².

Recalculated to exposure, that would be 1.5 m/s². That is well below the action value.

	Vibration value m/s ²	Exposure duration hours	minutes	Partial exposure A(8) m/s ²
GTG 40 vibration-controlled grinder	3.5	1	30	1.5
Total daily exposure A(8) m/s ²				1.5

Using the Atlas Copco exposure calculator will give the same result.



RRD 57 vibration-controlled chipping hammer. Declared vibration value < 2.5 m/s².

Example 2

In the second example we change the grinder to a GTG 40 and the chipping hammer to an RRD 37 (vibration-controlled). The RRD has a sleeve that can be used to guide the chisel. The vibration value in the sleeve varies a lot depending on the application. In this case it is estimated to 10 m/s². The trigger time is assumed to be the same because the tools have similar blow energy. In Table 5.1 the exposure from the RRD using 10 m/s² for 15 minutes can be found to be 50 points. The total daily exposure is then 45 points from the grinder + 50 points from the chipping hammer. 95 points can be recalculated to exposure using table 5.2 to be 2.4 m/s². By changing to low vibrating tools the daily exposure could in this case be reduced from a value above the limit value to a value below the action value.

	Vibration value m/s ²	Exposure duration hours	minutes	Partial exposure A(8) m/s ²
GTG 40 vibration-controlled grinder	3.5	1	30	1.5
Vibration-controlled chipping hammer with sleeve	10	–	15	1.8
Total daily exposure A(8) m/s ²				2.3

Using the Atlas Copco exposure calculator will give the same result.

The above examples show how the tables in chapter 5 can be used to make rough estimates of the total daily exposure using the corrected declared values and a proper estimation of trigger time valid for the operator being studied.

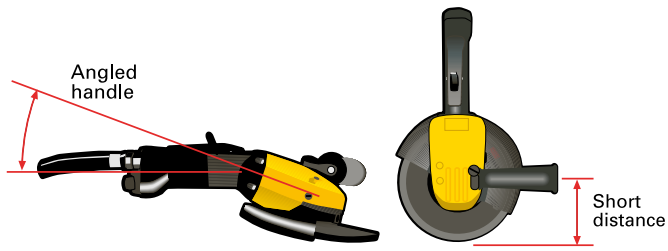
Remember that the estimates made using the declared values are very rough. The actual in-use vibration depends on several factors such as quality of inserted tools and operator skill. To keep the exposure low, always use good quality inserted tools and give your operators proper training in how to use the tools in the most effective and low vibrating way.

When choosing a power tool there are things to consider other than the declared vibration value if you want to reduce exposure to a minimum. The tool must be suitable for the job. The wrong tool may increase exposure time considerably, thereby increasing the exposure. The tool should only be used for the operation it is intended for.

A number of ergonomic factors should be considered to minimize exposure:

- The power-to-weight ratio should be as high as possible. Grinders equipped with turbine motors usually have the highest power-to-weight ratio.
- Good ergonomic design of the tool is important. This includes, good grip comfort, optimal angle of the main handle and short distance between the support handle and the front of the wheel. When using tools with good ergonomic design it is possible to maintain a high feed force with less operator fatigue.
- Low temperature of the handles when the tool is in use is believed to affect the development of white fingers and should be avoided.

When the support handle is designed so that the feed force can be applied near the grinding point, then it will be easier for the operator to apply the feed force and thereby utilize the full power of the tool.



When you select a handheld power tool, you not only influence the task the tool is intended to perform, but also the operator's work situation and the entire working environment. Combined, these factors influence operator health, safety and productivity. This book, *Power Tool Ergonomics*, examines the interaction between these factors.

Noise and dust control are also important factors to consider to improve the overall working environment. This is important as a good working environment makes the job more efficient. Shorter exposure time is one important way to reduce exposure.

6.3.2 Soft materials and gloves

Soft material between the hand and the tool is often used for vibration isolation. However, wrapping rubber or other resilient materials on handles to reduce vibration is unlikely to reduce the vibration in the frequency range involved when the exposure is calculated. It might reduce some high frequency vibration and may increase comfort.

Also anti-vibration gloves should be used with care. You can not generally rely on gloves to reduce the exposure. They have an effect on high frequencies and they might improve comfort, but their effect on exposure to vibration is limited.

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