

## **Hand Arm Vibration: A Simplified Approach to Risk Assessment and Prevention**

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### **Overview and Background**

Many employers recognize that their workers have some degree of exposure to hand-arm vibration (HAV). However, they rarely have the technical experience or equipment to evaluate and mitigate these risks. The objectives of this paper are for the reader to:

- Learn the updates on relevant standards and guidelines for hand-arm vibration.
- Understand the principles of vibration and the effect of vibration on the human body.
- Discover how to control HAVs through technical, administrative, and medically related measures.
- Learn about the tools for calculating risk exposure and available Web resources for product information.

The medical and HSE community know several things about HAV exposures that make this an important and emerging risk in the worker population.

#### Hand-Arm Vibration Effects

The effects of HAV include:

- Reynaud's Syndrome (vascular degeneration aka white fingers) from cumulative, long term vibration exposure with greater risk for those with medical conditions affecting the circulatory system (e.g. diabetes)
- Musculoskeletal Disorders including carpal tunnel syndrome
- Degenerative joint disease
- Safety incidents due to proprioceptive loss.

There are several relevant guidelines and standards regarding HAV, including:

- ISO 5349, Parts 1 and 5 (2001)
- European Union (EU), *Physical Agents (Vibration) Directive* (2002)
- ANSI, *Guide for Evaluation of Human Exposure* 1986
- ACGIH TLV regarding Hand Arm Vibration (2001)
- Various state OSHA guidelines and training (e.g., Washington, Oregon, and California)

Currently, the EU Directive published in 2002 seems to be the easiest standard/guideline for employers to understand and apply. The EU Risk Assessment methodology is discussed in more detail in the “Risk Assessment Approaches for Employers to Consider” section below.

## Applications

Opportunities for applying HAV exposure knowledge cover a wide range of employer decisions and practices, including:

- Determining low, medium, and high risks associated with:
  - Jobs and work processes
  - Tool models
- Tool selection criteria and purchasing policy
- Compliance with published tool/equipment maintenance schedules
- Job content and rotation plans
- Training for employees, supervisors, engineers, and ergonomists
- Determining job tasks and tool use that need more detailed evaluation
- Medical pre-placement and return-to-work decisions

## Risk Assessment Approaches for Employers to Consider

There are several approaches that employers or their consultants can take to evaluate HAV risk levels. Three different methods are discussed briefly below:

- Use the WISHA (Washington State) trigger level values to identify high risk.
  - 30 minutes per day for tools like impact wrenches and rivet hammers (high-vibration tools).
  - > 2 hours per day for grinders and sanders (moderate vibration tools).
- Apply the ACGIH TLVs, based on ANSI Guidelines and ISO Standards
- Apply the European Union (EU) *Physical Agents Directive*

The WISHA threshold values are very general and do not account for significant variations within a specific tool class (e.g., grinders) or the cumulative effect of multiple tool use over the course of a day. It is also difficult for employers in certain industries (e.g., construction) to stay below these threshold levels.

The ACGIH TLV shown below are technically sound but have a couple drawbacks for most employers:

1. It requires the ability to measure specific tool/material vibration characteristics
2. It requires significant and sometimes complex calculations to determine the time-weighted average (TWA) for the vibration exposure when multiple tools are used for varying amounts of time

**TABLE 1. TLVs for Exposure of the Hand to Vibration in Either  $X_h$ ,  $Y_h$ , or  $Z_h$  Directions**

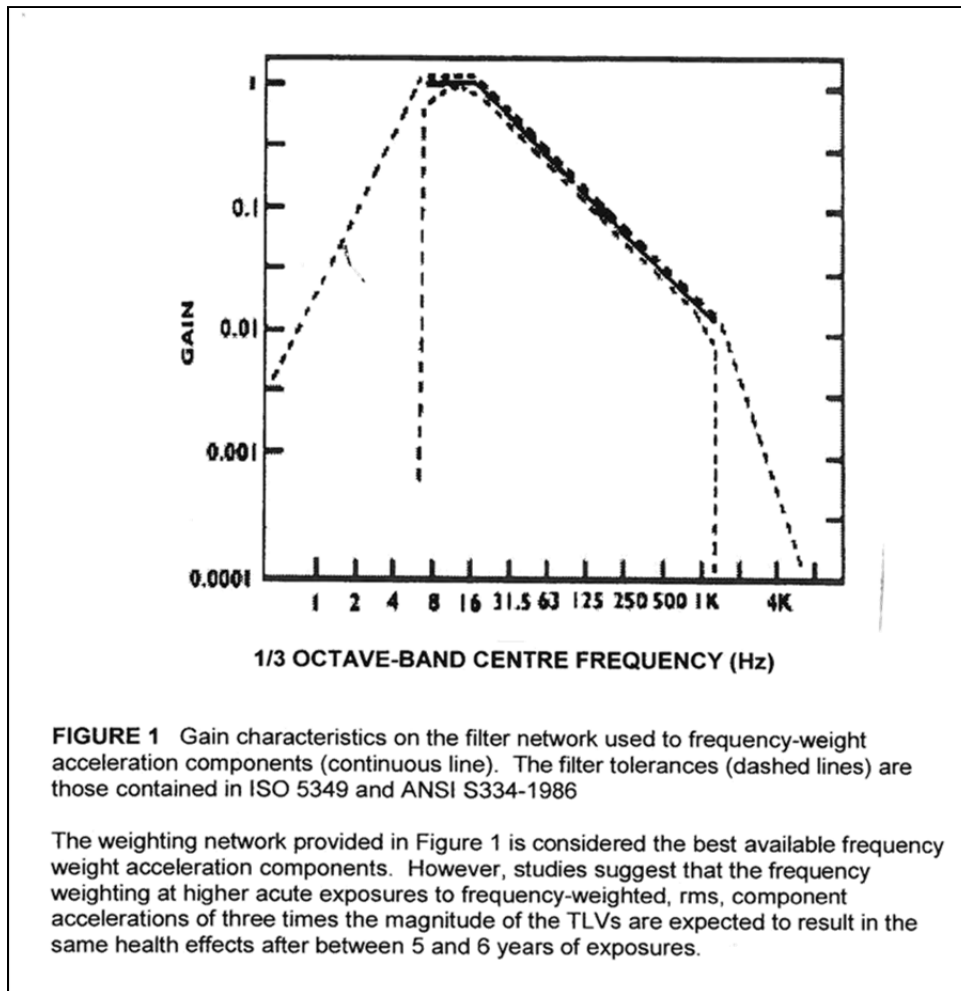
Total Daily Exposure Duration <sup>A</sup>	Values of the Dominant, <sup>B</sup> Frequency-Weighted, RMS, Component Acceleration Which Shall Not Be Exceeded	
	$a_K, (a_{K_{eq}})$	
	$m/s^2$	$g^C$
4 hours and < 8	4	0.40
2 hours and < 4	6	0.61
1 hours and < 2	8	0.81
< 1 hour	12	1.22

<sup>A</sup>The total time vibration enters the hand per day, whether continuously or intermittently.

<sup>B</sup>Usually one axis of vibration is dominant over the remaining two axes. If one or more vibration axes exceed the Total Daily Exposure, then the TLV has been exceeded.

<sup>C</sup> $g = 9.81 m/s^2$ .

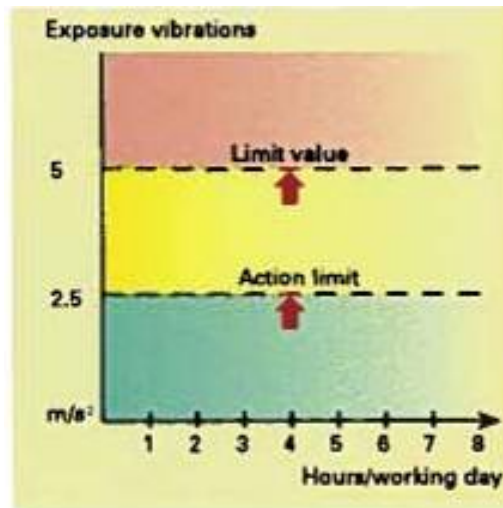
Table 1. TLVs for Exposure to the Hand to Vibration (Source: ACGIH)



**Figure 1. Gain Characteristics on the Filter Network used to Frequency-Weight Acceleration Components (Continuous Line)** (Source: ISO 5349 and ANSI S334-1986)

The remainder of this section will show and discuss the *EU Directive*, which suggests the following approach:

- Gather manufacturers' (no load) vibration information (m/sec) for existing power tools, if possible, and require this for all new tool purchases.
- Multiply no load values by 1.5 to get an estimated loaded value.
- Use 2.5 m/sec.<sup>2</sup> as the Action Limit (moderate-risk threshold) for tool vibration exposure and 5.0 m/sec.<sup>2</sup> for the Limit Value (high-risk threshold), as shown in Figure 2 below
- Apply eight-hour average exposure limit values, using the publish tables or the calculator



**The directive is introducing two values for A(8). The action value is 2.5 m/s<sup>2</sup> and the limit value is 5 m/s<sup>2</sup>.**

**Figure 2. Risk assessment approach by EU (Source: EU Physical Agents Directive)**

This method will not be as technically accurate as directly measuring the vibration using accelerometer equipment, but is a much easier way to get started for those employers that want to initiate an HAV prevention program. The *EU Directive* gives guidance for single-tool exposures using the following process.

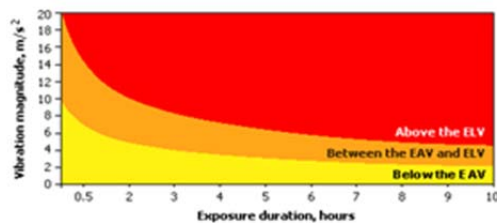
## **Determining Tool and Job Exposure Levels Using the EU Directive**

Similar to the ACGIH method, known exposures based on the magnitude and duration of exposure levels can be placed into Figure 3 below. In addition, the EU methodology provides a points-based rating scale that allows for employers to add multiple exposures together to find the cumulative points-based exposure level.

## Calculating Average Exposures for Jobs



- ▶ Compare result to action and threshold limits.
  - Below  $2.5\text{m/sec}^2$  = Low (<100 pts)
  - Between  $2.5\text{-}5.0\text{m/sec}^2$  = Medium (100-400 pts)
  - Above  $5.0$  = High (>400 pts)



23

## Calculating Average Exposures for Jobs



- ▶ Define tool usage
  - Types of tools (sander, grinder, riveter).
  - Utilization time (average hours per day) for each tool.
- ▶ Calculate exposure points using table.

Vibration Value m/s	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
5.0	4	8	17	42	50	100	250	400
10.0	17	33	67	167	200	400	1000	1600
20.0	67	133	267	667	800	1600	4000	6400
30.0	150	300	600	1500	1800	3600	9000	14400

22

Figure 3. Calculating average exposures for jobs.

For example:

- 60 minutes, using a tool with a vibration value of  $5.0 = 50$  points
- 5 hours (300 minutes), using a tool with a vibration value of  $2.5 = 63$  points
- 20 minutes, using a tool with a vibration value of  $10 = 67$  points

- Total points = 180, which is above the 100-point threshold (8 hour Action Limit for a tool with 2.5 vibration rating) but below the 400-point threshold (8 hour Limit Value at 5.0 vibration rating)

Therefore, the individual tool exposures are low risk but the aggregate exposure, given the three tools, is moderate risk.

Rather than using the table values as above, a calculator has been developed so that the vibration levels and duration of use for each tool are input, and the aggregate value is calculated for the evaluator. The calculator blank is shown below.

## Calculating Average Exposures for Jobs



### Hand-Arm Vibration Exposure Calculator

	In-use vibration m/s <sup>2</sup> r.m.s.	Trigger time		Partial exposure m/s <sup>2</sup> A(8)
		Hours	minutes	
Tool 1				
Tool 2				
Tool 3				
Tool 4				
Tool 5				
Tool 6				
				Daily exposure m/s <sup>2</sup> A(8)

Instructions for use:  
 Enter in-use vibration and trigger time in the white cells.  
 To calculate, press the Enter key, or move to a different cell.  
 The results are displayed in the yellow areas.

24

Figure 4. Blank hand-arm vibration exposure calculator.

## Calculating Average Exposures for Jobs by Determining Magnitude Levels

Without vibration magnitude levels, the only remaining variable is time (current state), which is not an accurate criteria by itself. So, gathering magnitude data without engaging in a time-consuming and expensive project is essential. Therefore, the following is proposed:

- Gather manufacturers' "no load" data as part of or as an addition to an ergonomics project. Without specific-use data, a 1.5 multiple can be applied to these values as an approximation of operational data (per the EU directive).
- Utilize information in existing databases:

- NIOSH: <http://www.cdc.gov.niosh-sound-vibration/>
- Swedish: <http://www.vibration.db.umu.se/hav.asp?lang>
- Use any specific study data being collected by other employer sites, using the same type of tools or jointly used by other similar employers. This database can be used by the shop and ergonomists who are evaluating HAV exposure.
- Augment all of these as necessary with a literature search that would/can contribute the following:
  - Vibration data for tool classes (e.g., sanders, flat grinders, angle grinders).
  - Document differences based on use (e.g., materials, surface).
  - Document difference between vibration-damped designs versus undamped designs.
  - Comparisons between using anti-vibration gloves and vibration-damped tool designs.

## HAV Measurement Equipment Providers

Direct measurement of HAV exposures has become more accessible to employers and HSE professionals in recent years because the technology is simpler to use and less costly to rent or buy. Several HAV equipment providers are listed below, but not all of them have been used by this author. Therefore, their inclusion does not constitute an endorsement.

- Scantek, Inc. ([www.scantekinc.com](http://www.scantekinc.com))
- PQ Testing and Rentals, Inc. ([www.pqtesting.com](http://www.pqtesting.com))
- Automatic Controls ([www.autoctrls.com](http://www.autoctrls.com))
- Reliability Direct ([www.reliabilitydirectstore.com](http://www.reliabilitydirectstore.com))
- Ashtead Technology ([www.ashtead-technology.com](http://www.ashtead-technology.com))

## Controlling HAVs

As with most musculoskeletal disorders, use of a multi-tiered intervention approach is most effective. Therefore, this section discusses three general improvement strategies:

- Technical
- Administrative, including training
- Medical

### Technical Preventative Measures

The technical preventative measures are generally the most effective because they reduce or eliminate the HAV exposure:

1. Substitute other working methods.
2. Use tools with the lowest vibration when there is a choice.
3. Maintain equipment carefully in accordance with the manufacturer's instructions.
4. Improve workstation design and fixtures.

#### *Technical Preventative Measures #1: Substitution*

Find alternative work methods that eliminate or reduce exposure to HAV such as:

- Mechanization or automation of tasks, such as numerically controlled drilling.
- Use of different materials in product or tool (e.g., type of abrasive cutter or carbide vs. steel drill).
- Substitution of alternative work processes (e.g., pre-drilling holes rather than drill in-place operations).



The substitution method requires good knowledge of manufacturing process and a working knowledge about “best practices” within the specific industry (e.g., construction, aerospace). This knowledge is gained by experience but is also readily available from sources outside the company.

- Trade association
- Industry contacts
- Equipment suppliers
- Trade magazines

#### *Technical Preventative Measures #2: Tool Selection*

When considering tool selection as an improvement option, there are several factors to consider:

1. Use the right tool for the right job:
  - Avoid unsuitable tools for the task.
  - Avoid tools of insufficient capacity, e.g., not powerful enough.
  - Even the correct tools may work at insufficient capacity if the power source is insufficient (e.g., insufficient air supply).
2. Different tools of the same type (impact wrench) have different vibration characteristics
  - Impact vs. impulse tools.
  - Design characteristics regarding vibration isolation and handle designs.
  - Designed for different frequency and duration of use, e.g. light vs. moderate vs. heavy use.
3. Tools of the same type from different manufacturers have different vibration profiles.
4. Careful selection of consumables (abrasives for grinders and sanders) or tool accessories (drill bits, chisels and saw blades) can impact the overall tool performance.

#### *Technical Preventative Measure #3: Tool Purchasing*

When purchasing tools, there are several factors to consider:

1. Purchasing policy is necessary that considers both the operating requirements and vibration exposures from the tools.
2. Power tool manufacturers usually have experts who can help in choosing the right tool for the operation, with low vibration risks.
3. Declared vibration values for tools are required in Europe (EU Directive); ask your suppliers for values.
4. Other ergonomic factors to consider include: tool weight, handle design, grip force, trigger type, trigger activation force, ease of use and handling, hot/cold surface exposures, noise control, and dust control

Anti-vibration tool manufacturers include:

1. Atlas Copco USA: [www.atlascopco.us](http://www.atlascopco.us)
2. [www.boschtool.com](http://www.boschtool.com)
3. [www.dewalt.com](http://www.dewalt.com)
4. [www.makita.com](http://www.makita.com)

#### *Technical Preventative Measures #4: Tool Maintenance*

The following are factors to consider in maintaining tools:

1. Keep cutting tools sharp.
2. Dress grinding wheels correctly by following the manufacturer’s recommendations.

3. Lubricate any moving parts in accordance with manufacturer's recommendations.
4. Replace worn parts.
5. Carry out necessary balance checks and corrections.
6. Replace anti-vibration mounts and suspended handles before they deteriorate.
7. Check and replace defective vibration dampers, bearings, and gears.
8. Sharpen chainsaw teeth and keep the correct chain tension.
9. Tune engines.

#### *Technical Preventative Measures #5: Work Station Design and Fixtures*

The following are considerations for workstation design and fixtures:

1. Provide jigs and similar aids that incorporate anti-vibration mounts.
2. Provide anti-vibration handles endorsed by the tool manufacturer.
3. Be careful when wrapping rubber or other resilient materials around tool handles, which may improve comfort but not reduce the vibration of harmful frequencies.
4. Reduce gripping or pushing forces as well whenever possible:
  - Guide rather than hold/support the tool.
  - Use tool balancers and manipulators to support the tool.
  - Maintain proper texture and material of tool grip surface.

#### Administrative Preventive Measures

A couple general guidelines for controlling HAV exposure are:

1. Provide adequate training on the proper use of the equipment.
2. Arrange vibration-free periods in work schedules.

#### *Administrative Preventive Measures: Workers' Training*

The following are considerations for workers' training:

1. Provide vibration exposure risk information to the workers and supervisors.
2. Use the right work techniques; avoid excessive gripping, pushing and guiding forces.
3. Ensure the tools are operated safely and with optimum efficiency.
4. Recognize and report when a tool needs maintenance, then act.
5. Report any symptoms that may be associated with use of power tools.
6. Include a reminder that vibration from leisure activities (home projects and motorcycle riding) may also increase HAV exposure risks.

#### *Administrative Preventive Measures: Work Schedules*

The following are considerations for work schedules:

1. Arrange task activities to limit the time workers are exposed to vibrating tool use.
2. Ensure improved work patterns are followed.
3. Enforce restrictions on HAV exposure, especially for workplaces where piecework is practiced.

## **Medical Preventive Measures**

Because of the long-term aggregate exposure of HAV, good work histories and medical evaluations can provide valuable information to both the employer and the employees:

1. For new employees, their previous history of exposure should be recorded.
2. All workers should be advised of the risk of exposure to HAV.
3. Workers with certain medical conditions should be carefully assessed before using vibrating equipment, such as:

- Primary Reynaud's disease.
- Diseases causing impairment of blood circulation in the hands.
- Past injuries to the hand, causing circulatory defects or deformity of bones and joints.
- Other causes of secondary Reynaud's phenomenon.
- Disorders of the peripheral nervous system

Ways that employers can reduce the risk of HAVs are to:

1. Implement a symptom reporting system and a regular medical check-up program for at-risk workers, similar to hearing conservation.
2. Advise employees to wear adequate clothing to keep dry and maintain body core temperature.
3. If anti-vibration gloves are used, they need to meet the requirements of ISO 10819 (or carry the CE mark).
4. Emphasize the importance of letting the tool do the work and gripping the tool as lightly as possible (consider work safety and tool control at the same time).
5. Avoid or minimize tobacco use and excessive caffeine intake (constricts blood vessels).

## **Conclusion**

The development of severe HAV syndromes, such as Reynaud's (white fingers), has generally been problematic in only a few industries that involve multiple exposures over many years. However, more recent studies link incidents involving mishandling of materials, parts and equipment and more generalized musculoskeletal disorders to shorter term HAV exposures. These injuries and incidents are occurring in younger workers with less exposure and in older workers in a variety of industries that utilize power, hand-held tools.

As a result, HAV injury and incident prevention has become more important to a wider range of employers and HSE consultants over the last few years. This paper was intended to give employers who choose to begin or expand their response to this issue some methods and resources to do so. However, this is far from a definite work on the subject, which has numerous subtleties and variances. Therefore, this should be considered as a starting point for beginning or expanding your HAV injury prevention program.