OSC | 11
Ohio Safety Congress & Expo

#929 Application of human vibration

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Tuesday, March 29, 2011
9 a.m. to 4 p.m.

Ohio | Bureau of Workers' Compensation

Preventing Hand-arm Vibration Injuries

Ohio Safety Conference
March 22nd, 2011

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Larson Davis
A Division of PCB Piezotronics

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Preventing Vibration Injuries

Part 1

Introduction to Hand-arm Vibration

Occupational Vibration Exposure

Every day, human beings interact with machinery. Contact with vibration is commonplace!

Unfortunately, continuous exposure to mechanical vibration can lead to physical injury…

Types of Vibration Exposure

Whole-body Vibration (WBV)

Hand-Arm Vibration (HAV)

What is HAVS?

Hand-Arm Vibration Syndrome is a general term used to broadly describe the physical damage to the hand, fingers, and related structures resulting from chronic exposure to excessive vibration.

- Vascular and neuropathic effects
- Contributing factor to CTS (NIOSH 1998)

To fully understand the nature and scope of HAVS, it is important to review medical conditions with similar symptoms

Raynaud's Disease

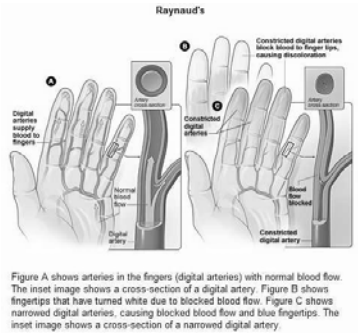


Figure A shows arteries in the fingers (digital arteries) with normal blood flow. The inset image shows a cross-section of a digital artery. Figure B shows fingertips that have turned white due to blocked blood flow. Figure C shows narrowed digital arteries, causing blocked blood flow and blue fingertips. The inset image shows a cross-section of a narrowed digital artery.

1. Raynaud's Disease
2. Raynaud's Phenomenon (disease, secondary)
3. Raynaud's Syndrome of Occupational Origin (Vibration White Finger Disease)

History

Dr. Alice Hamilton (1869 – 1970)

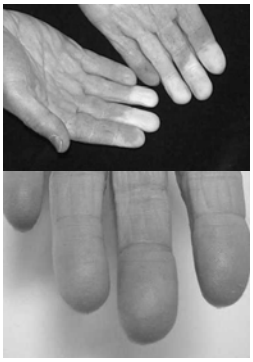
Bedford, Indiana, 1918:

"Among men who use the air hammer for cutting stone there appears very commonly a disturbance in the circulation of the hands which consists of spasmodic contraction of the blood vessels of certain fingers, making them blanched, shrunken, and numb...these attacks come on under the influence of cold, and are most marked, not while the man is at work with the hammer, but usually in the early morning or after work...the fingers affected are numb and clumsy while the vascular spasm persists...the condition is undoubtedly caused by the use of the air hammer...stonecutters who do not use their hammer do not have this condition of the fingers...the trouble seems to be caused by three factors - long continued muscular contraction of the fingers in holding the tool, the vibrations of the tool, and cold. It is increased by too continuous use of the air hammer, and by cold in the working place. If these features can be eliminated the trouble can be decidedly lessened."

Health Effects: HAVS / VWF

Symptoms include tingling and/or numbness in the fingers followed by attacks of finger blanching – often occurring at nighttime, or while not at work

In addition to these painful attacks of tingling and numbness, other problems include loss of dexterity and changes to grip strength



Health Effects: HAVS / VWF

Left untreated, VWF becomes progressively worse; it becomes irreversible, and in extreme cases can lead to very serious problems, such as gangrene.

Scope and Economic Impact

- Affected Industries: Foundries, Shipbuilding, Oil/Gas, Logging/Forestry, Mining, Transportation, Defense, Metalworking
- Currently one of the top three most compensated injuries in some countries (examples include UK and Italy)

Estimates of Workers Exposed

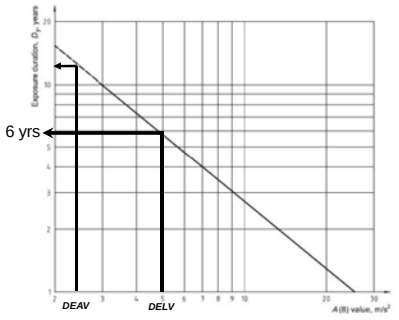
CDC/NIOSH estimates that as many as 2 million workers in the United States alone are exposed to excessive vibration

Over 250,000 construction workers are exposed to HAV above the current recommended Daily Exposure Limit Value

Typical at-risk Job Descriptions

- Forestry workers
- Stone drillers, stone cutters and chippers
- Quarry drillers
- Aircraft engine workers
- Farmers
- Sheet metal workers
- Polishers
- Oil Rig workers
- Grinders
- Molders
- Maintenance and Janitorial workers
- Welders
- Riveters
- Dental technicians
- Orthopedists
- Sewing machine operators
- Chainsaw operators
- Construction workers
- Pedestal grinder operators
- Auto / truck / bus mechanics and other users of impact power tools
- Shipyard workers
- Railway workers

Time to injury presentation



Vibration exposure for predicted 10 % prevalence of vibration-induced white finger in a group of exposed persons

*From ANSI S2.70-2006 and ISO 5349

Compensation Awards

A man who developed hand arm vibration syndrome (HAVS) because of work **has been awarded compensation of £8,500.**

Anthony B. was employed by XXXXX Motor Company for 33 years and used a variety of vibrating tools each day, the *St. Helens Star* reports.

Due to the continual vibration, he began suffering problems with his hands. He took early retirement from the organisation nine years ago and now no longer works with vibrating equipment.

Also known as **vibration white finger**, the condition typically occurs in people who use such things as chainsaws, hammer drills, concrete breakers, etc.

Employers have a legal responsibility to protect workers from the ailment. Mr B. said: *"I was never warned about the dangers of developing this condition. I met some former work colleagues in 2005 who told me it was HAVS."*

"VWF victims win compensation"

Monday August 14th, 2000

Eight former employees of North West Water have been awarded £1.2M compensation after they contracted Vibration White Finger at work. The men, from Merceyside, stopped working for the company in 1998 when they developed symptoms including loss of feeling, loss of grip, bleeding fingers and constant pain

The union said that during legal proceedings, North West water admitted negligence in exposing the workers to excessive vibratoin while they operated machinery.

Litigation and Compensation

Litigation and Compensation

What can we do about it?

There are Standards, Directives and Best Practices for reducing risk of injury

A program to ASSESS, MITIGATE and MONITOR risk, exposure levels and health effects can be developed and implemented

...IF we know the facts....

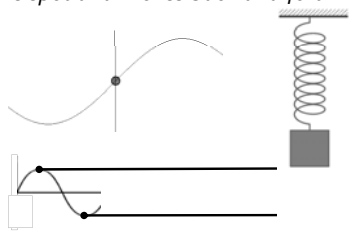
Preventing Vibration Injuries

Part 2

Vibration Characteristics

The Nature of Vibration

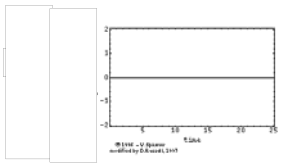
Vibration can be described as the *periodic movement* (acceleration +/-) of an object in relation to its original resting point; i.e, a motion *which starts in one spot and moves back and forth*



Types of Vibration

Free vibration occurs when a mechanical system is set off with an initial input and then allowed to vibrate freely.

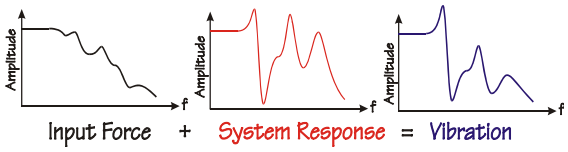
Examples include pulling a child back on a swing and letting go or hitting a tuning fork and letting it ring. The system will vibrate at one or more of its "natural frequencies" and damp down to zero.



Types of Vibration

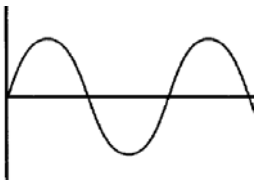
Forced vibration is when an alternating force or motion is applied to a mechanical system.

Examples include a shaking washing machine with an imbalanced load, vehicle vibration or a building during an earthquake. In forced vibration the frequency of the vibration is a combination of the force modified by the resonance of the mechanical system.



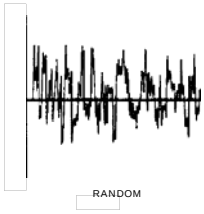
The Nature of Vibration

So...vibration refers to mechanical oscillations about an equilibrium point; but these oscillations are not *always* periodic...



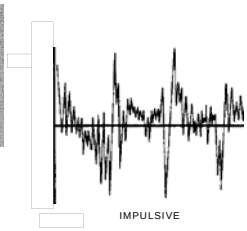
The Nature of Vibration

They may be random like the movement of a tire on a washboard gravel road.



The Nature of Vibration

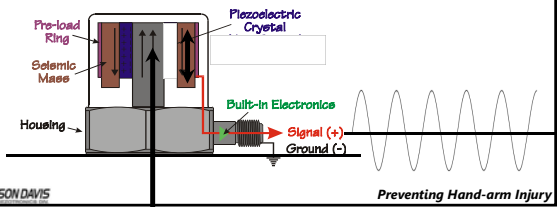
They may be impulsive such as those from a hammer drill



How Vibration Levels are Sensed

Accelerometer:

- Simple single degree-of-freedom device which converts the acceleration aspect of motion into a proportional electrical signal
- Triaxial Accelerometer contains 3 sensing elements



Acceleration Units of Measurement

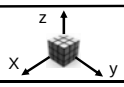
g - a unit equal to that produced by Earth's gravity on a free-falling object

1g = 9.807 m/s^2

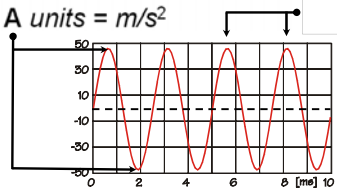
Acceleration Levels Quantified

Vibration measurement consists of three main components – Direction, Amplitude and Frequency

Direction of movement: x,y,z



A *units* = m/s^2

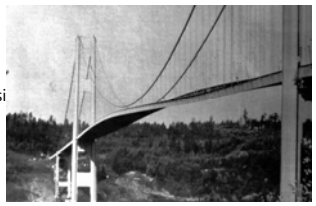


Amplitude and Frequency

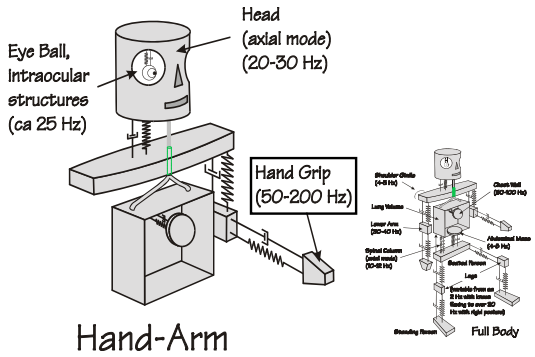
Physics 101 – Tacoma Narrows

November 7, 1940

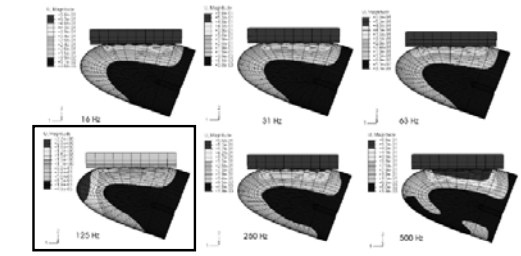
Uncontrolled resonance was excited by wind currents in the channel – resulting in overstressi and failure...



Human Body - Resonant Frequencies



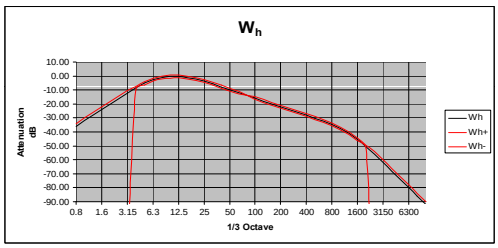
Resonance illustrated



The distributions of the vibration magnitude in the longitudinal section for six different vibration frequencies (f= 15.6, 31.3, 62.5, 125, 250, and 500 Hz). The fingertip is pre-compressed by 2.0 mm before being subjected to harmonic vibrations (magnitude 0.5 mm).

Frequency Weighting for HAV

Hand Arm Frequency Weighting (per ISO 5349 and 8041)



Applies to all directions: x, y, z

Preventing Vibration Injuries

Part 3

Measurement Standards & Exposure Guidelines

Standards, Directives & Guidelines

Measurement Standards

- Typically define HOW the measurement should be performed; define the methods to be used and metrics that result

Regulatory Compliance Directives/Guidelines

- Define responsibilities of employers and workers for ensuring a safe workplace
- Recognize and reference accepted action levels and exposure limits

Measurement Standards: HAV

- **ISO 5349:2001** Measurement and evaluation of Human Exposure to Hand Transmitted Vibration
  - Part 1 – General Requirements
  - Part 2 – Practical Guidance for Measurement at the Workplace
- **ANSI S2.70-2006** Guide for the Measurement and Evaluation of Human Vibration Exposure to Vibration Transmitted to the Hand (previous ANSI 3.34 1986)

What the Standards Provide

Everything needed to make good measurements!

- Measuring equipment for hand-transmitted vibration
- Frequency-weighting filter characteristics
- Location and orientation of sensors
- Mounting of sensors
- Quantity to be measured
- Information to be reported

They also give you:

- Relationship between vibration exposure and effects on health
- Guidance regarding health effects of vibration

Measurement Standards provide

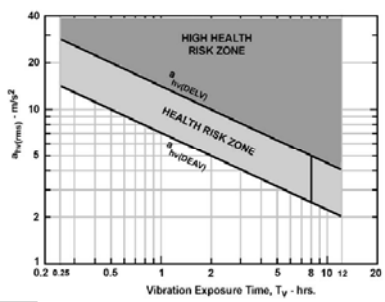
Terms, Definitions, and Conventions

$a_{hw}(t)$	instantaneous single-axis acceleration value of the frequency-weighted hand-transmitted vibration at time t, in metres per second squared (m/s^2);
a_{hw}	root-mean-square (r.m.s.) single-axis acceleration value of the frequency-weighted hand-transmitted vibration, in metres per second squared (m/s^2);
a_{hwx}, a_{hwy}, a_{hwz}	values of a_{hw}, in metres per second squared (m/s^2), for the axes denoted x, y and z respectively;
a_{hv}	vibration total value of frequency-weighted r.m.s. acceleration (sometimes known as the vector sum or the frequency-weighted acceleration sum); it is the root-sum-of-squares of the a_{hw} values for the three measured axes of vibration, in metres per second squared (m/s^2);
$a_{hv(eq,8h)}$	daily vibration exposure (8-h energy-equivalent vibration total value), in metres per second squared (m/s^2);
$A(8)$	a convenient alternative term for the daily vibration exposure $a_{hv(eq,8h)}$;
D_y	group mean total (lifetime) exposure duration, in years;

Integration and Characterization of Vibration Exposure

$$a_{hv} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2} \qquad A(8) = a_{hv}\sqrt{\frac{T}{T_0}} \qquad A(8) = \sqrt{\frac{1}{T_0}\sum_{i=1}^{n} a_{hvi}^2 T_i}$$

Exposure Limits and Action Levels

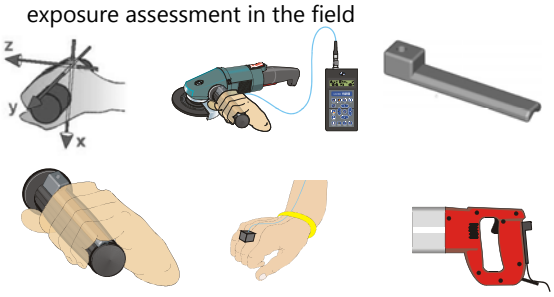


Plots of the $a_{hv(DEAV)}$ and $a_{hv(DELV)}$ values for vibration exposure times other than 8 hours

**From ANSI S2.70-2006 and ISO 5349*

Standards also provide

Methods and techniques for accurate and repeatable exposure assessment in the field



Measure per ISO 5349/ANSI S2.70

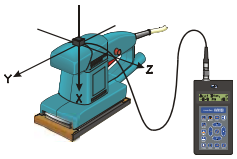
Other Measurement Standards:

Related and Relevant Standards:

- ISO 8041:2005
  - Measuring instrumentation *(performance specification)*
- ISO 10819:1996 (ANSI S3.40:2002)
  - Measurement and evaluation of vibration transmissibility of gloves (*performance of anti-vibration gloves)*
- ISO 8662:1988
  - Hand-held portable power tools: Measurement of vibrations at the handle *(for Tool Manufacturers)*
- ISO 22867:2004
  - Forestry machinery -- Vibration test code for portable hand-held machines with internal combustion engine -- Vibration at the handles *(for Tool Manufacturers)*

Reference Conditions Measurements

Used, by a buyer, to compare the vibration level of different machinery, or different models of machinery of the same family. The results are reproducible because they are not influenced by human presence.



Reference Conditions Measurements

Goal

- Machine Evaluation
- Research & Development
  - Design and Quality of vibrating machinery
  - Products development of vibrating machinery
  - Ride Confort
  - Improvement of products (safety and comfort)

Reference Conditions Measurements

Customers

- Consultants
- Manufacturers of machinery and components in transportation, agriculture and construction (WB)
- Manufacturers of hand tools (HA)

Anyone interested in reducing, measuring

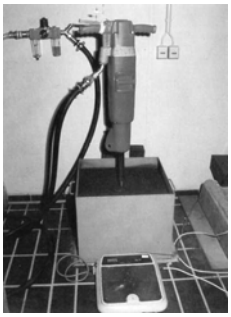
or certifying the vibration levels of their product.

Reference Conditions

The measurements on "reference conditions" don't consider connection between the machinery and the man and don't express judgment about the vibrations limits.

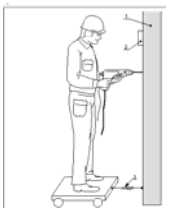
Reference Conditions Standards

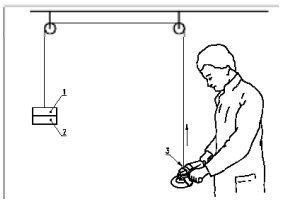
- Operation conditions
- Cycle of job
- Position of the accelerometers
- Measure methods to be used
- Indications for the use of results
- Compilation of the report



Reference Condition Testing

Specific reference conditions are given for testing various tool types





Reference Conditions Standards

Standards that specify the operating conditions of the devices to be measured. ISO 8662 part 1 is the general standard for hand-held power tools, and parts 2-14 cover specific types of hand-held power tools.

- ISO 8662-1:1988 **Hand-held portable power tools** -- Measurement of vibrations at the handle -- Part 1: General
- ISO 8662-2: **Chipping hammers** and **riveting hammers**
- ISO 8662-3: **Rock drills** and **rotary hammers**
- ISO 8662-4: **Grinders**
- ISO 8662-5: **Pavement breakers** and **hammers for construction work**
- ISO 8662-6: **Impact drills**
- ISO 8662-7: **Wrenches**, **screwdrivers** and **nut runners with impact**, **impulse or ratchet action**
- ISO 8662-8: **Polishers** and **rotary orbital**, or **random orbital sanders**
- ISO 8662-9: **Rammers**
- ISO 8662-10: **Nibblers** and **shears**
- ISO 8662-11: **Fastener driving tools**
- ISO 8662-12:**Saws** and **files with reciprocating action** and **saws with oscillating** or **rotating action**
- ISO 8662-13: **Die grinders**
- ISO 8662-14:**Stone-working tools** and **needle scalers**

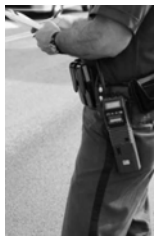
Preventing Vibration Injuries

Part 4

Regulatory Compliance

Compliance is Required

- Regulatory Compliance Directives
  ... enforced in European Union:
  - Exposure Directive
  - Machinery Directive
- Recommended ACGIH* TLV's
  ...often used in United States
  - OSHA General Duty Clause



*American Conference of Governmental Industrial Hygienists

Vibration Exposure Directive

- EU Directive 2002/44/EC

OBLIGATION OF EMPLOYERS

Article 4

Determination and assessment of risks

1. In carrying out the obligations laid down in Article 6(3) and Article 9(1) of Directive 89/391/EEC, the employer shall assess and, if necessary, measure the levels of mechanical vibration to which workers are exposed. Measurement shall be carried out in accordance with Point 2 of Part A or Point 2 of Part B of the Annex to this Directive, as appropriate.

2. The level of exposure to mechanical vibration may be assessed by means of observation of specific working practices and reference to relevant information on the probable magnitude of the vibration corresponding to the equipment or the types of equipment used in the particular conditions of use, including such information provided by the manufacturer of the equipment. That operation shall be distinguished from measurement, which requires the use of specific apparatus and appropriate methodology.

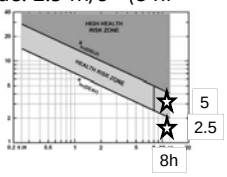
3. The assessment and measurement referred to in paragraph 1 shall be planned and carried out by competent services at suitable intervals, taking particular account of the provisions of Article 7 of Directive 89/391/EEC concerning the necessary competent services or persons. The data obtained from the assessment and/or measurement of the level of exposure to mechanical vibration shall be preserved in a suitable form so as to permit consultation at a later stage.

Allowable Exposure Limits

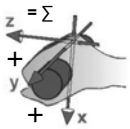
EU Directive 2002/44/EC

- Exposure limit values and action values
  - Daily Exposure Limit Value: 5.0 m/s^2 *(8hr DELV)*
  - Daily Exposure Action Value: 2.5 m/s^2 *(8 hr DEAV)*

EU Good Practice Guide



Allowable Exposure Limit



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

...is based on calculation of daily exposure value normalized to an eight-hour reference period A(8), *expressed as the sum* of the acceleration values...

ACGIH Recommended TLV

Hand Vibration

Threshold Limit Values for Exposure of the Hand to Vibration in Either X, Y, or Z Directions	
Total Daily Exposure Duration	Dominant Frequency-Weighted Component of Acceleration Which Shall Not be Exceed (RMS)
	m/s^2
4 to 8 hours	4
2 to 4 hours	6
1 to 2 hours	8
less than 1 hour	12

COMPARISON:

EU DELV/ US TLV

Maximum allowable level for 8hr avg. exposure:

EU Directive: 5 m/s^2 *(combined)*

ACGIH TLV: 4 m/s^2 *(dominant axis: x,y or z)*

Other Relevant Directives

DIRECTIVE 2006/42/EC
OF THE EUROPEAN PARLIAMENT

- *Vibration levels must be disclosed by Manufacturers*

Preventing Vibration Injuries

Part 5

Risk and Exposure Assessment

Employer Obligations

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

1. Estimate, using Manufacturer's supplied vibration level data
2. Measure the Vibration level as the work is performed

Risk Assessment

Identify where there may be a risk

- Are hand-held or hand-fed power tools part of the work?
- Have workers complained of tingling, numbness, or other symptoms of HAVS?

Detail all the work processes, tools, work-piece types etc.

Develop "Rough Estimate of exposure and compare this to the recommended action levels and exposure limits

Building an Exposure Model

- Task Based Exposure Assessment Method (T-BEAM)
- Variables are many; such as 'trigger time', and can include complex variations of:
  - Operator Technique (force, throughput)
  - Tool Condition
  - Material being worked, (e.g. Tile vs. Concrete)
  - Tool media (wheels, bits, grits)

Estimating Duration and Level

Ascertain the duration of exposure

- Continuous vs. intermittent operation

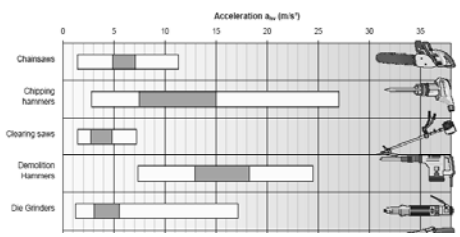
Obtain representative data of vibration levels:

1. Manufacturer's supplied data
   - Relatively high uncertainty
   - Use (DE)RATING factors from CEN/TR 15350:2006
2. Measurement data

Manufacturers' disclaimer - excerpt

The declared vibration emission level represents the main applications of the tool.

Manufacturers' data: vibration levels

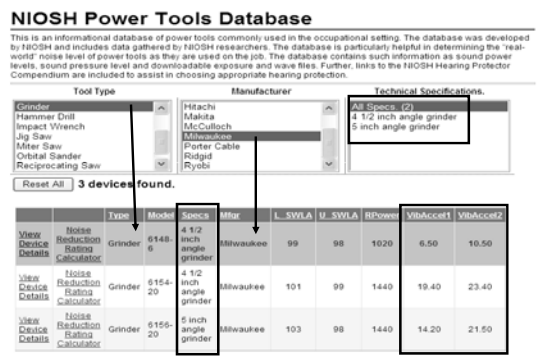


CEN/TR 15350 advises that for estimating risk, the manufacturer's declared emission value should in most cases be multiplied by a factor depending on the type of tool:

Pneumatic tools: ×1.5 to ×2 Electric tools: ×1.5 to ×2

And, provides data of typical tool use per day – e.g Rotary Hammer: 3 hours

Other Sources of Level Data



NIOSH Power Tools Database

This is an informational database of power tools commonly used in the occupational setting. The database was developed by NIOSH and includes data gathered by NIOSH researchers. The database is particularly helpful in determining the 'real-world' noise level of power tools as they are used on the job. The database contains such information as sound power levels, sound pressure level and downloadable exposure and wave files. Further, links to the NIOSH Hearing Protector Compendium are included to assist in choosing appropriate hearing protection.

Tool Type: Grinder, Hammer Drill, Impact Wrench, Jig Saw, Miter Saw, Orbital Sander, Reciprocating Saw

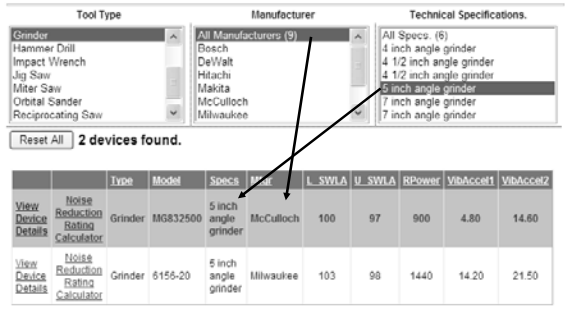
Manufacturer: Hitachi, Makita, McCulloch, Milwaukee, Porter Cable, Ridgid, Ryobi

Technical Specifications: All Specs. (2), 4 1/2 inch angle grinder, 5 inch angle grinder

Reset All 3 devices found.

		Type	Model	Specs	Mfgr	L_SWLA	U_SWLA	RPower	VibAccel1	VibAccel2
View Device Details	Noise Reduction Rating Calculator	Grinder	6148-6	4 1/2 inch angle grinder	Milwaukee	99	98	1020	6.50	10.50
View Device Details	Noise Reduction Rating Calculator	Grinder	6154-20	4 1/2 inch angle grinder	Milwaukee	101	99	1440	19.40	23.40
View Device Details	Noise Reduction Rating Calculator	Grinder	6156-20	5 inch angle grinder	Milwaukee	103	98	1440	14.20	21.50

Other Sources of Level Data



Tool Type: Grinder, Hammer Drill, Impact Wrench, Jig Saw, Miter Saw, Orbital Sander, Reciprocating Saw

Manufacturer: All Manufacturers (9), Bosch, DeWalt, Hitachi, Makita, McCulloch, Milwaukee

Technical Specifications: All Specs. (6), 4 inch angle grinder, 4 1/2 inch angle grinder, 4 1/2 inch angle grinder, 5 inch angle grinder, 7 inch angle grinder, 7 inch angle grinder

Reset All 2 devices found.

		Type	Model	Specs	Mfgr	L_SWLA	U_SWLA	RPower	VibAccel1	VibAccel2
View Device Details	Noise Reduction Rating Calculator	Grinder	MG832500	5 inch angle grinder	McCulloch	100	97	900	4.80	14.60
View Device Details	Noise Reduction Rating Calculator	Grinder	6156-20	5 inch angle grinder	Milwaukee	103	98	1440	14.20	21.50

Exposure from Multiple Tasks

Measured Value Ahv = 5.2 m/s²

Time on Task = 2.5h

$$A(8) = A_{(w)sum}\sqrt{\frac{T_e}{8}}$$

$$A(8) = 5.2\sqrt{\frac{2.5}{8}}$$

A(8) = 2.9 m/s²

Grinder

(7 m/s² for 2½ hours):

$A_1(8)$ = 3.9 m/s²

Chipping hammer

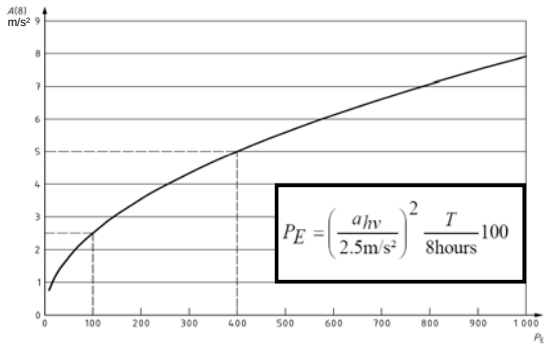
(16 m/s² for 15 minutes):

$A_2(8)$ = 2.8 m/s²

Total exposure:

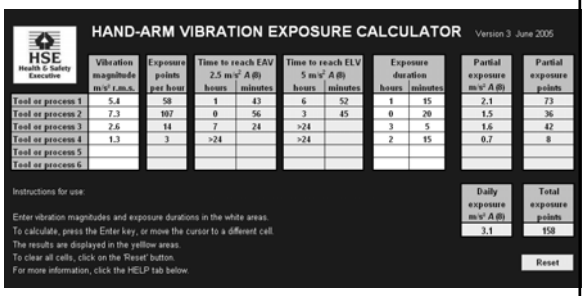
A(8) = 4.8 m/s²

The 'Points System' (8 hour ex.)



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

Assembling the Exposure Model



HAND-ARM VIBRATION EXPOSURE CALCULATOR Version 3 June 2005

HSE Health & Safety Executive

	Vibration magnitude m/s² r.m.s.	Exposure points per hour	Time to reach EAV 2.5 m/s² A(8) hours	minutes	Time to reach ELV 5 m/s² A(8) hours	minutes	Exposure duration hours	minutes	Partial exposure m/s² A(8)	Partial exposure points
Tool or process 1	5.4	58	1	43	6	52	1	15	2.1	73
Tool or process 2	7.3	197	0	56	3	45	0	20	1.5	36
Tool or process 3	2.6	14	7	24	>24		3	5	1.6	42
Tool or process 4	1.3	3	>24		>24		2	15	0.7	8
Tool or process 5										
Tool or process 6										

Instructions for use:

Enter vibration magnitudes and exposure durations in the white areas.
To calculate, press the Enter key, or move the cursor to a different cell.
The results are displayed in the yellow areas.
To clear all cells, click on the 'Reset' button.
For more information, click the HELP tab below.

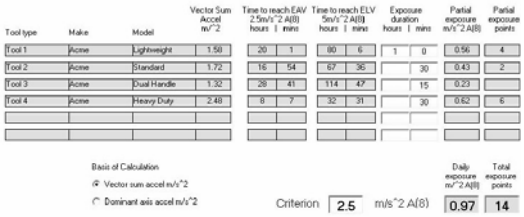
Daily exposure m/s² A(8)	Total exposure points
3.1	158

Reset

"Tool Timers"

Simple vibration measurement device used to access "time on task"

Database tools can be a big help



Tool type	Make	Model	Vector Sum Accel m/s^2	Time to reach EAV 2.5m/s^2 A(8) hours	mins	Time to reach ELV 5m/s^2 A(8) hours	mins	Exposure duration hours	mins	Partial exposure m/s^2 A(8)	Partial exposure points
Tool 1	Acme	Lightweight	1.58	20	1	80	6	1	0	0.56	4
Tool 2	Acme	Standard	1.72	16	54	67	36		30	0.43	2
Tool 3	Acme	Dual Handle	1.32	28	41	114	47		15	0.23	
Tool 4	Acme	Heavy Duty	2.48	8	7	32	31		30	0.62	6

Basis of Calculation
- (•) Vector sum accel m/s^2
- ( ) Dominant axis accel m/s^2

Criterion 2.5 m/s^2 A(8)

Daily exposure m/^2 A(8)	Total exposure points
0.97	14

Preventing Vibration Injuries

Part 6

Exposure Measurements

Standards Vibration Measurement Instruments

In order to design vibration-measuring apparatus to give results which are comparable, for all types of vibration, observed by human beings, there is the **ISO 8041**.

The instruments specified in this standard cover the needs for at least one of the methods of measurements according to **ISO 2631** and **ISO 5349**

Standards Vibration Measurement Instruments

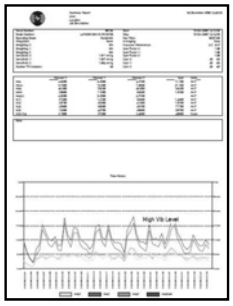
ISO 8041: Human response to vibration Measuring instrumentation

Scope:

- applies to instrumentation for the measurements of hand arm vibration and whole-body vibration
- specifies electrical, vibration and environmental tests to verify compliance with the characteristics specified and determines the methods for sensitivity calibration
- defines the tolerances consequently the class of the instruments (type 1 or type 2)
- ensures consistency and compatibility of results and reproducibility of measurements realized with different measuring instruments

Exposure Measurement

HAV instruments perform the frequency weighting and amplitude integration automatically – and store data for later analysis and reporting



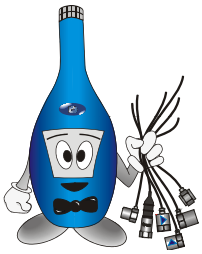
Preparing for a test…

- Define sampling strategy – e.g. task based
- Tests should be performed under realistic conditions
- Accelerometer should be mounted correctly
- Cables need to be routed safely

Accelerometers

Resolution or Noise-Floor

- Smallest acceleration value distinguishable by the sensor
- Gain Settings in the Amplifier Stage of the Instrument can compensate for this
- Inappropriate sensor selection and Gain Settings are often responsible for BAD DATA!



Accelerometers

Typical Measurement Ranges

	1 mV/g		10 mV/g		100 mV/g	
GAIN	RMS Range m/s^2	PEAK Range m/s^2	RMS Range m/s^2	PEAK Range m/s^2	RMS Range m/s^2	PEAK Range m/s^2
0 dB	50 – 50,000	900 – 70,000	5 – 5000	90 - 7000	0.5 – 500	9 - 700
20 dB	5 – 5000	90 - 7000	0.5 – 500	9 - 700	0.05 - 50	0.9 - 70
40 dB	0.5 – 500	9 - 700	0.05 - 50	0.9 - 70	0.005 - 5	0.09 - 7

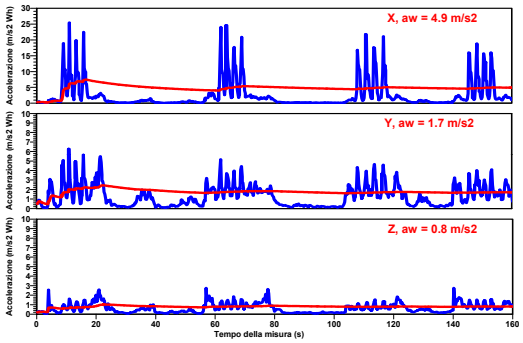
Calibration

HA Measurement Examples

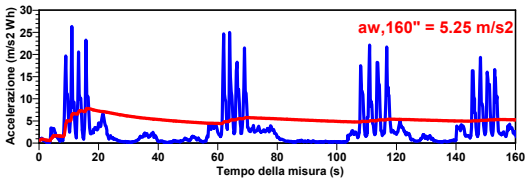
HA Measurement Examples

HA Measurement Examples

Measurement Results



Measurement Results



$$a_w = \sqrt{4.9^2 + 1.7^2 + 0.8^2} = 5.247 \text{ms}^{-2}$$

Hand-Arm Vibration Mounting Adapters

Mounting Adapter in use

LARSON DAVIS

Preventing Hand-arm Injury

Mounting Adapter in use

LARSON DAVIS

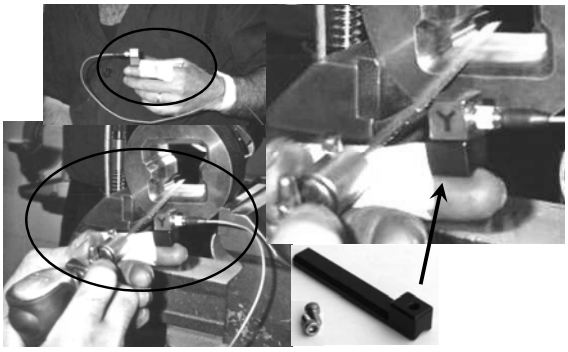
Preventing Hand-arm Injury

Adapter in use

LARSON DAVIS

Preventing Hand-arm Injury

Adapter in use



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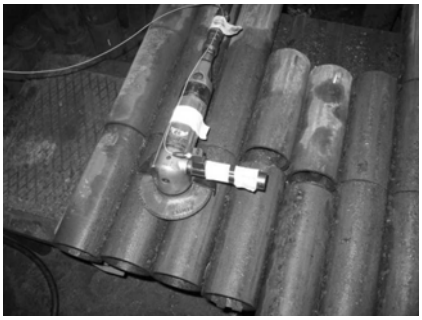
Preventing Hand-arm Injury

Handle Adapter



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Clamp Adapter

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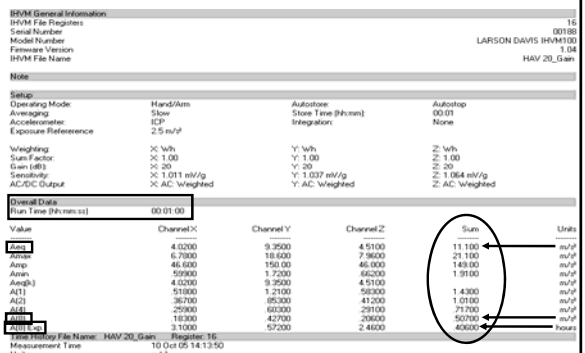
Palm Adapter

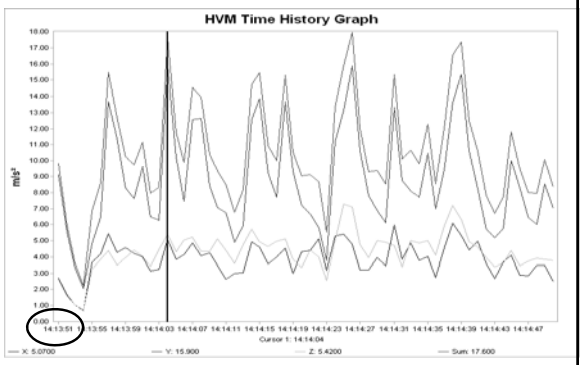
Task / Tool Data from HVM100



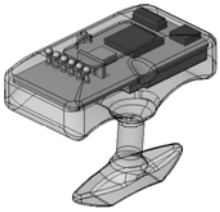
HVM General Information			
HVM File Registers			16
Serial Number			00188
Model Number			LARSON DAVIS IHVM100
Firmware Version			1.04
HVM File Name			HAV 20_Gain
Note			
Setup			
Operating Mode:	Hand/Arm	Autostore:	Autostop
Averaging:	Slow	Store Time (hh:mm):	00:01
Accelerometer:	ICP	Integration:	None
Exposure Reference	2.5 m/s²		
Weighting:	X: Wh	Y: Wh	Z: Wh
Sum Factor:	X: 1.00	Y: 1.00	Z: 1.00
Gain (dB):	X: 20	Y: 20	Z: 20
Sensitivity:	X: 1.011 mV/g	Y: 1.037 mV/g	Z: 1.064 mV/g
AC/DC Output	X: AC Weighted	Y: AC Weighted	Z: AC Weighted
Overall Data			
Run Time (hh:mm:ss)	00:01:00		

Value	Channel X	Channel Y	Channel Z	Sum	Units
Avg	4.0200	9.3500	4.5100	11.100	m/s²
Amax	6.7800	18.600	7.9600	21.100	m/s²
Amp	46.600	150.00	46.000	149.00	m/s²
Amin	.59900	1.7200	.66200	1.9100	m/s²
Aeq(t)	4.0200	9.3500	4.5100		m/s²
A(1)	.51800	1.2100	.58300	1.4300	m/s²
A(2)	.36700	.85300	.41200	1.0100	m/s²
A(4)	.25900	.60300	.29100	.71700	m/s²
A(8)	.18300	.42700	.20600	.50700	m/s²
A(8) Exp	3.1000	.57200	2.4600	.40600	hours
Time History File Name: HAV 20_Gain	Register: 16				
Measurement Time	10 Oct 05 14:13:50				
Units:	m/s²				

Time History Data from HVM100



What's next?



"Wearable" Vibration Dosimeters

Types of Instruments + Methods Used

NOISE

TYPE 1
Sound Level Meter:

TYPE 2
Noise Dosimeter:

METHOD: ***Level x TASK*** | ***Level x TIME***

VIBRATION

Human Vibration Monitor:

Vibration Dosimeter:

- **INTRINSICALLY SAFE**
- **PRACTICAL (no WIRES)**
- ***CONTINUOUS EXPOSURE DATA***

Vibration Dosimeter Overall Data

VibTrack General Information

Serial Number	001:39
Color	Yellow
Firmware Version	0.48
User	
Job Description	
Location	
Start Time	Monday, 30 November 2009 14:27:17
Stop Time	Monday, 30 November 2009 14:29:24
Run Time	00:02:07
Weighting	1vib
Sample Interval	1 Sec.
Stem Size	21 mm
Overload Time	0 s

Note

Results

Value	Channel X	Channel Y	Channel Z	Sum	Units
Ahv	-	-	-	9.7	m/s²
Ahwx	5.9	-	-	-	m/s²
Ahwy	-	5.0	-	-	m/s²
Ahwz	-	-	6.0	-	m/s²
A(8)	0.4	0.3	0.4	0.6	m/s²
A(8) Exp.	1.5	2.0	1.4	0.5	hours
Exposure Points				6.7	Points

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Preventing Hand-arm Injury

Continuous Time History Data

VibTrack Time History

Serial Number	139
User	
Color	Yellow
Start Time	Monday, 23 November 2009 10:29:11
Stop Time	Monday, 23 November 2009 10:39:09
Run Time	00:09:58

Time	Sum	X	Y	Z	A(8)	Points	Overload?
10:29:11	32.6	13.5	16.0	25.0	0.2	0.6	
10:29:12	29.5	9.3	15.0	22.3	0.3	1.0	
10:29:13	27.5	19.0	11.1	16.8	0.3	1.5	
10:29:14	24.5	22.4	7.2	6.7	0.3	1.8	
10:29:15	20.6	10.0	15.7	8.9	0.4	2.0	
10:29:16	25.4	14.8	12.0	18.2	0.4	2.4	
10:29:17	28.9	11.9	13.9	22.4	0.4	2.9	
10:29:18	23.6	8.3	11.1	19.1	0.4	3.2	
10:29:19	19.0	9.9	7.3	14.5	0.5	3.4	
10:29:20	21.3	15.6	11.2	9.2	0.5	3.6	
10:29:21	19.0	9.1	13.7	9.4	0.5	3.8	
10:29:22	3.0	1.7	2.3	1.1	0.5	3.9	
10:29:23	11.9	5.9	7.7	6.9	0.5	3.9	
10:29:24	16.8	4.8	13.5	8.8	0.5	4.1	
10:29:25	11.4	4.4	8.6	5.9	0.5	4.2	
10:29:26	23.8	10.1	17.2	13.0	0.5	4.5	
10:29:27	19.5	10.0	12.4	11.2	0.5	4.7	
10:29:28	9.8	5.5	4.3	6.9	0.5	4.7	
10:29:29	18.6	7.1	5.8	16.1	0.6	4.9	
10:29:30	24.0	11.6	11.0	18.0	0.6	5.3	
10:29:31	24.9	10.2	13.7	18.1	0.6	5.6	
10:29:32	19.9	12.7	10.6	11.2	0.6	5.8	
10:29:33	18.4	12.3	10.1	9.4	0.6	6.0	
10:29:34	17.5	6.4	10.9	12.2	0.6	6.2	
10:29:35	15.9	8.5	9.0	10.0	0.6	6.3	

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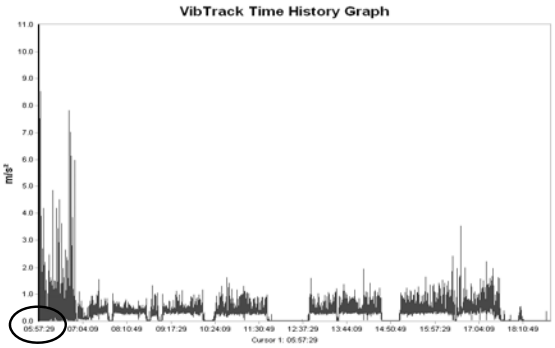
Preventing Hand-arm Injury

12 hours continuous exposure data



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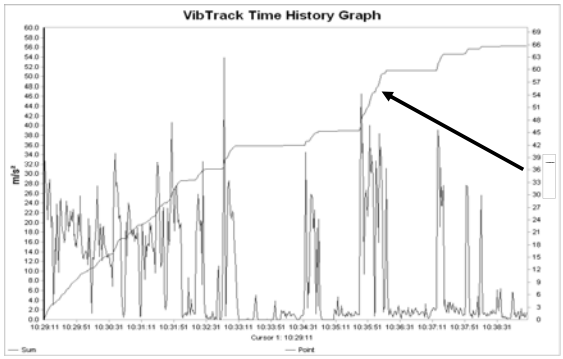
Preventing Hand-arm Injury

Exposure Points displayed



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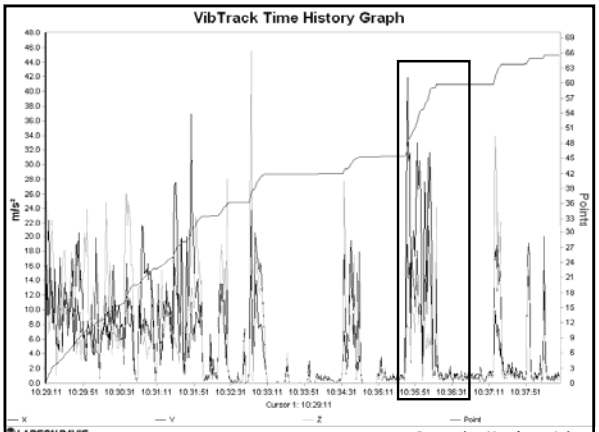
Preventing Hand-arm Injury



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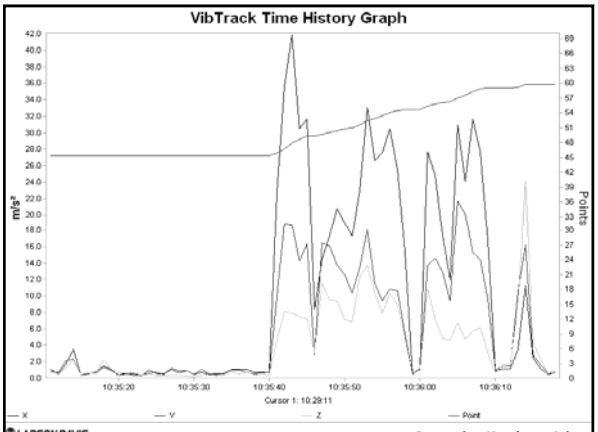
Preventing Hand-arm Injury



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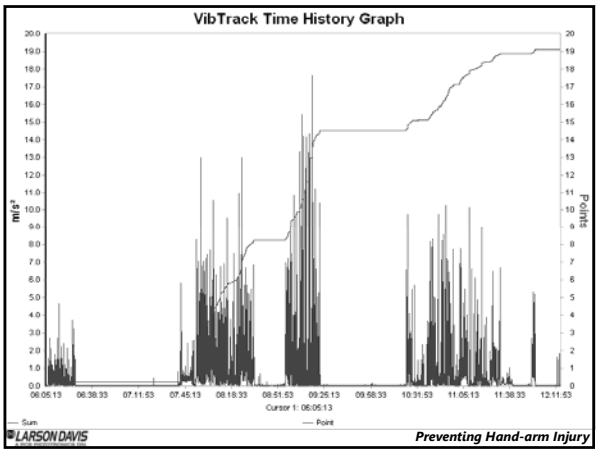
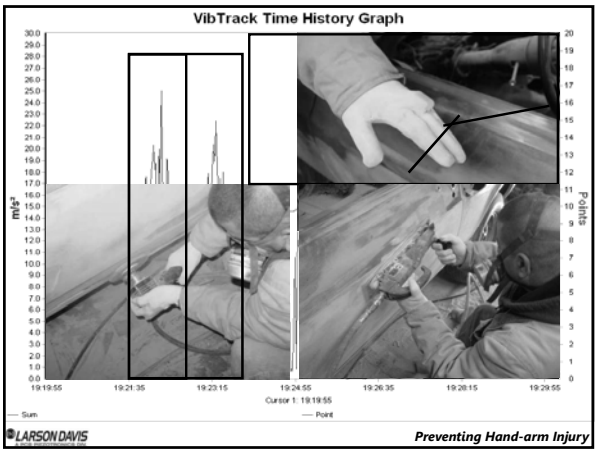
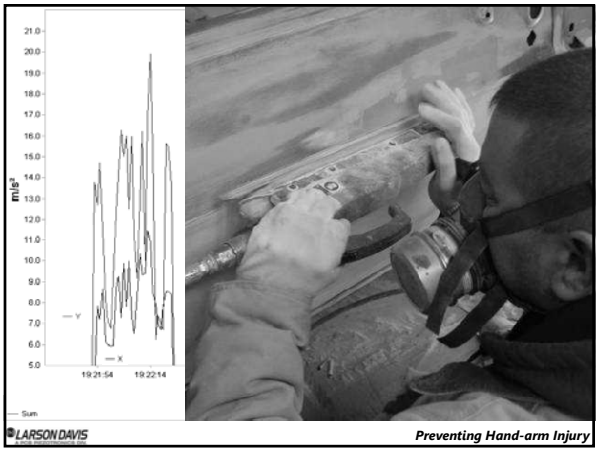
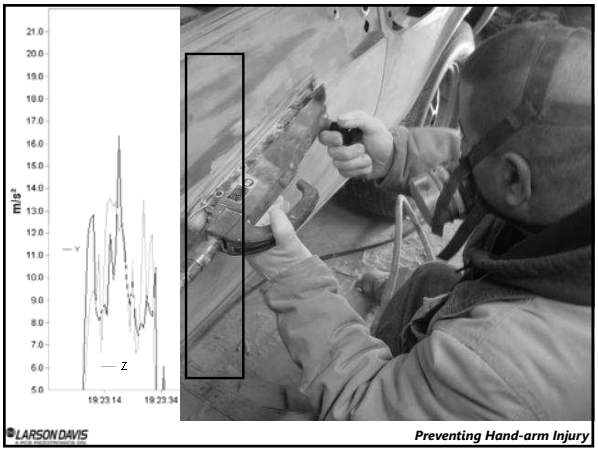
Preventing Hand-arm Injury









Worker Experience

Worker with experience

Worker without experience

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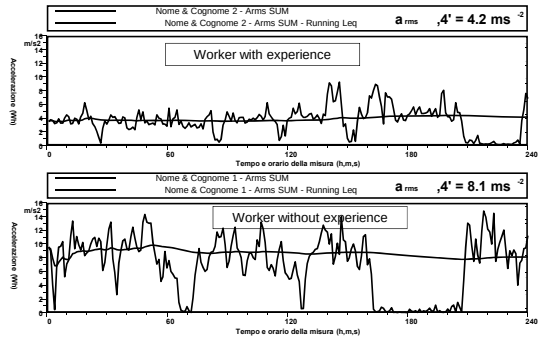
Preventing Hand-arm Injury

Worker Experience



Vibration level declare by the manifacture:<2,5 ms^{-2}

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Preventing Hand-arm Injury

Preventing Vibration Injuries

Part 7

HAVS Prevention Programs

Assess – Mitigate - Monitor

Consider the following as you develop a program:

- Perform risk and exposure assessments
- Identify risk operations, tools and processes
- Engineer out or reduce the vibration sources
- Limit time of exposure – consider color banding tools

Create a cross-departmental task force to include:

- Occupational health professionals
- Ergonomists
- Industrial / Occupational Hygienists
- Maintenance / Tool Repair Technicians
- Manufacturing Engineers
- Management
- Workers

Risk/Exposure Assessment Programs

Good

- Basic Risk Assessment plus Exposure Estimates compiled using Manufacturer's Data

Better

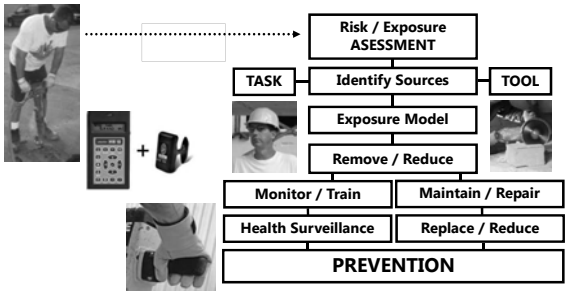
- Above, plus Exposure Model built on representative samples of Measured Vibration Level using Human Vibration Monitor

Best

- All of Above, plus targeted continuous sampling using Vibration Dosimeter to verify and adjust Exposure Model

Assess / Mitigate / Monitor: Prevent

Evaluate Tasks, Tools, and Training and *strive for continuous improvement in all areas.*



Simple Tips for Workers

- Try to keep warm at work.
- Wear warm gloves and extra clothing if working in the cold.
- Nicotine is a vasoconstrictor - so do not smoke or try to cut down.
- Exercise hands and fingers to improve the circulation.

In Conclusion

- Hand-Arm Vibration = Ongoing Risk Issue
- Measurement Standards, Exposure Limits and Guidelines exist for assessing risk
- Best Practice has been established and continues to evolve
- Dosimeter technology developed to allow continuous personal exposure data to be gathered
- Exposure models can be verified

HAVS Related Resources

HAV Good Practice Guide:

- Evaluation of Risk
- Removing or Reducing Exposure
- Health Surveillance

http://www.arbetsliv.de/Region_9/PDF/kontaktdag20091028/HAV_good%20practice.pdf
http://www.hse.gov.uk/vibration/hav/index.htm
http://wwwn.cdc.gov/niosh-sound-vibration/
http://www.cdc.gov/niosh/az/h.html
http://www.acgih.org/
http://www.iso.org/iso/home.htm
http://www.ansi.org/
http://www.cen.eu/cenorm/homepage.htm
http://www.nhlbi.nih.gov/health/dci/Diseases/raynaud/ray_what.html/

Whole Body Vibration

Ohio Safety Conference
March 22nd, 2011

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Reference Conditions Standards

WB and HA

Human response to vibration
Frequency Weighting

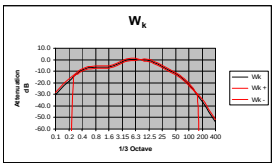
Weighting	Name	Frequency Range (Hz)	Standard
Whole body vibration			
Principal weighting			
Whole body, vertical direction *z*	W_k	0,5 to 80	ISO 2631-1
Whole body, horizontal directions x, y	W_d	0,5 to 80	ISO 2631-1
Whole body, motion sickness,vertical direction *z*	W_f	0,1 to 0,5	ISO 2631-1
Whole body, combined directions	W.B. combined	1 to 80	ISO 2631-2
Additional weighting			
Whole body, seat back horizontal directions x	W_c	0,5 to 80	ISO 2631-1
Whole body, rotational vibration r_x, r_y, r_z	W_e	0,5 to 80	ISO 2631-1
Head of recumbent person, vertical direction *x*	W_j	0,5 to 80	ISO 2631-1
Hand arm vibration			
All direction x, y, z	W_h	8 to 1000	ISO 5349

Human Response to Vibration

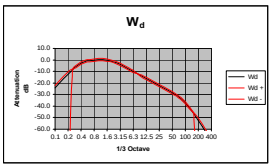
Whole Body Frequency Weighting (ISO 8041)

For a standing person most sensitive

- 4-8Hz in the vertical direction
- 1-2Hz in the horizontal direction.



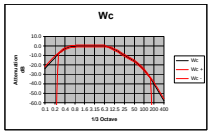
Whole body, vertical direction z



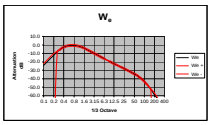
Whole body, horizontal directions x, y

Human Response to Vibration

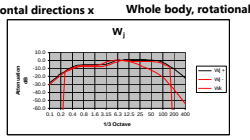
Whole Body Frequency Weighting (ISO 8041)



Whole body, seat back horizontal directions x



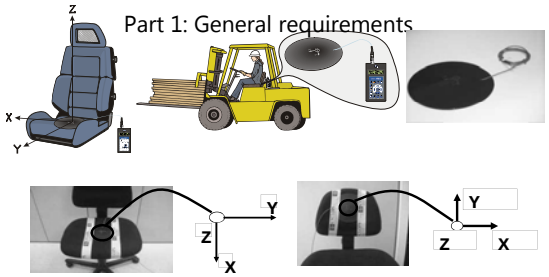
Whole body, rotational vibration rx, ry, rz



Head of recumbent person, vertical direction x

ISO 2631-1 WB Vibration Standard

Evaluation of human exposure to whole-body vibration
Part 1: General requirements



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Whole body, vertical direction *z*	W_k	0,5 to 80
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Additional weighting		
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Head of recumbent person, vertical direction *x*	W_j	0,5 to 80

ISO 2631-1 WB Vibration Standard

Evaluation of human exposure to whole-body vibration
Part 1: General requirements

A_{rms} Linearly averaged acceleration (60 seconds) $a_w = \sqrt{\frac{1}{T}\int_0^T a_w^2(t)dt}$

Sum $\Sigma = \sqrt{k_x a_{wx}^2 + k_y a_{wy}^2 + k_z a_{wz}^2}$ $\quad k_x = k_y = 1{,}4 \quad k_z = 1$

Maximun Peak acceleration

CF Crest Factor (ratio of Peak to A_{rms}) $\Rightarrow$ if $CF \geq 9$ then VDV

VDV = Vibration Dose Value $\quad VDV = \sqrt[4]{\int_0^T a_w^4(t)dt}$

ISO 2631-1 WB Vibration Standard

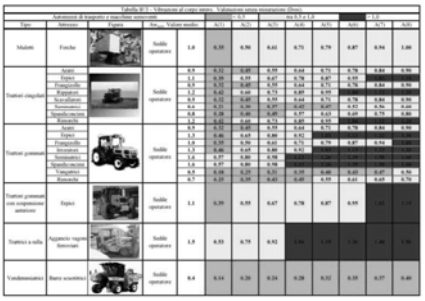
Risk Levels

Risk for the exposure to vibrations Whole Body fixed from the Proposal of Directive EC on the Physical Agents 2002/44/CE

- ➔Level of Action A(8) = 0,5 m/s ^{2} or
- ➔Level of Action VDV = 9,1 m/s ^{1,75}
- ➔Value Limit A(8) = 1,15 m/s ^{2} or
- ➔Value Limit VDV = 21 m/s ^{1,75}

ISO 2631-1 WB Vibration Standard

Risk Levels



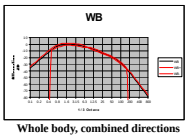
ISO 2631-2 WB Vibration Standard

Evaluation of human exposure to whole-body vibration
Part 2: Continuous and shock-induced vibrations in buildings

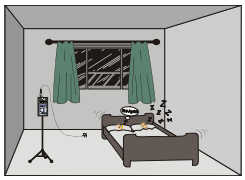
Parameter:

MTVV Maximum Transient Vibration Value (Max Slow)

Frequency weighting: Whole Body Combined direction **WB** (1 to 80 Hz)



Whole body, combined directions



EU Occupational Health Directives

Vibration at Work Directive 2002-44-EC

Risk for the exposure to vibrations Whole Body	**Risk for the exposure to vibrations Hand Arm**
Level of Action A(8) = 0,5 m/s ^{2} or	Level of Threshold A(8) = 1 m/s ^{2}
Level of Action VDV = 9,1 m/s ^{1,75}	Level of Action A(8) = 2,5 m/s ^{2}
Value Limit A(8) = 1,15 m/s ^{2} or	Value Limit A(8) = 5 m/s ^{2}
Value Limit VDV = 21 m/s ^{1,75}	Level of Remarkable Risk A(8) = 20 m/s ^{2}

http://europa.eu.int/eurlex/pri/en/oj/dat/2002/l_177/l_17720020706en00130019.pdf.

Standards Vibration Measurement Instruments

In order to design vibration-measuring apparatus to give results which are comparable, for all types of vibration, observed by human beings, there is the **ISO 8041**.

The instruments specified in this standard cover the needs for at least one of the methods of measurements according to **ISO 2631** and **ISO 5349**

Standards Vibration Measurement Instruments

ISO 8041: Human response to vibration
Measuring instrumentation

Scope:

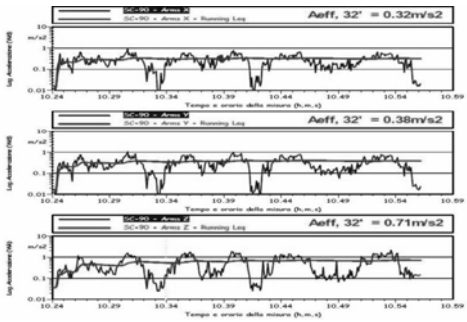
- applies to instrumentation for the measurements of hand arm vibration and whole-body vibration
- specifies electrical, vibration and environmental tests to verify compliance with the characteristics specified and determines the methods for sensitivity calibration
- defines the tolerances consequently the class of the instruments (type 1 or type 2)
- ensures consistency and compatibility of results and reproducibility of measurements realized with different measuring instruments

Seatpad Triaxial Accelerometer

Seatpad Triaxial Accelerometer

WB Measurement Examples

Examples - Crane



WB Measurement Examples

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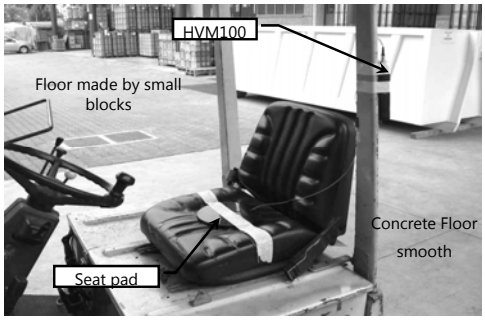
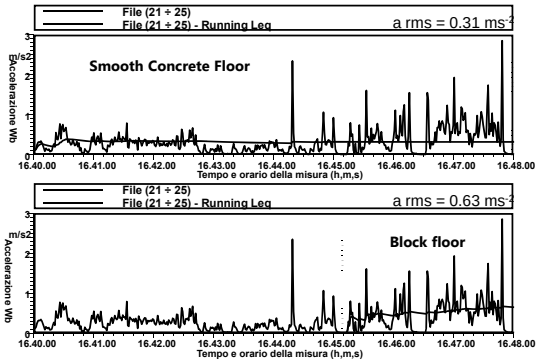
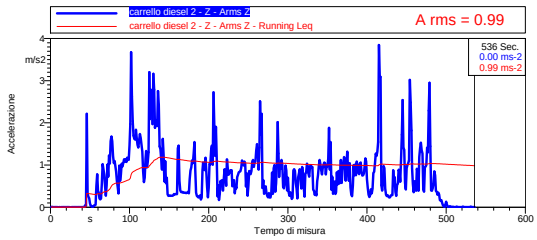


WB Measurement Examples

Measurement Results



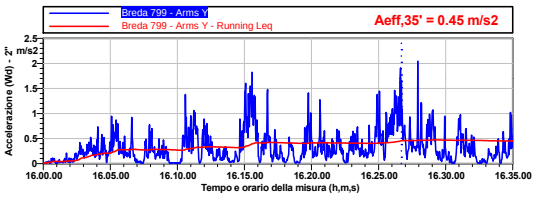
Measurement Results



Fork lift with several steps

WB Measurement Examples

Measurement Results



WB Measurement Examples

WB Measurement Examples

Prevention *is* Possible!

Thank you for your attention today.

LARSON DAVIS

Preventing Hand-arm Injury

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