
# Human Vibration

risks, limits, measurement and mitigation

LARSON DAVIS
A PCB DIVISION

# Agenda

- 1:35 pm: Introduction to hand-arm and whole body vibration – **Ken Cox**
- 2:25 pm: Demystifying Noise Exposure Assessment: Top 7 Myths – **Robert Vannice**
- 3:10 pm: Vendor visits
- 3:40 pm: Introduction to EMF Exposure Assessments – **Robert Johnson**
- 4:20 pm: Laser Safety: Incidents, Trends, and Emerging issues – **Eric Lawson**
- 5:00 pm: Exhibitor spotlight

# Who Am I?

**Ken Cox**

- Larson Davis BDM
- 35+ years experience at LD
- Member IEC TC29 for 13 years

# FAQS

- **Agenda**
  - 45 minute presentation
  - 5 minutes for Q/A
- **Is presentation available?**
  - Yes

# Vibration Exposure

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

# US Department of Defense (DOD)

In the U.S. alone, about 2.5 million workers are exposed daily to hand-arm vibration (HAV) from power tools they use on their job. Since 1918, it is documented that daily occupational exposure from many pneumatic, electric, hydraulic or gasoline powered vibrating hand-tools have been causally linked to HAVS. HAVS is an irreversible medical condition of the fingers/hands, which causes loss of sensation and blood supply to the hands and may cause loss of fingers. Because HAVS is often misdiagnosed, it is underreported. The documented workplace prevalence of HAV in the U.S. ranges from 20-50% for certain groups of power tool users. This is believed to be a conservative estimate. Even by conservative estimates, as many as 1.25 million power tool users may be at risk for developing HAVS.



http://www.mcieast.marines.mil/Portals/33/Documents/Safety/OSH/Hand-Arm-Vibration-Syndrome.pdf

# Human Vibration - Classification

Whole Body Vibration

Hand-arm Vibration

# Who is At Risk?

- 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 tools
- Shipyard workers
- Railway workers

# What is Hazardous?

- Routine, long-term exposure to high vibration
- Occasional exposure is unlikely to be harmful
- Risk is higher for
  - People with medical condition such as Reynaud’s disease
  - Workers in cold environments

# Time to Injury


**Figure C.1 — Vibration exposure for predicted 10 % prevalence of vibration-induced white finger in a group of exposed persons**

DELV (PEL)
@ 5.0 m/s$^2$ = 6 years

DEAV (AL)
@ 2.5 m/s$^2$ = ~12 years

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

# What is HAVS?

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

# White Finger Syndrome
# Raynaud's Phenomenon

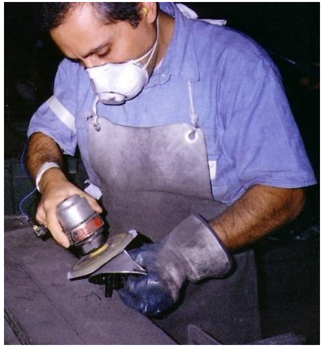
- **Results in poor blood circulation in fingers**
- **Symptoms include:**
  - Cold fingers
  - Tingling or numbness
  - Blanching or whitening of fingers
  - Can lead to permanent damage

# HAVS Limits

| Vibration exposure time (hrs) | TLV (m/s²) | Action Level (m/s²) |
|---|---|---|
| 8 | 5.00 | 2.50 |
| 6 | 5.77 | 2.89 |
| 4 | 7.07 | 3.54 |
| 2 | 10.00 | 5.00 |
| 1 | 14.14 | 7.07 |

**Maximum allowable level for 8 hr avg. exposure:**

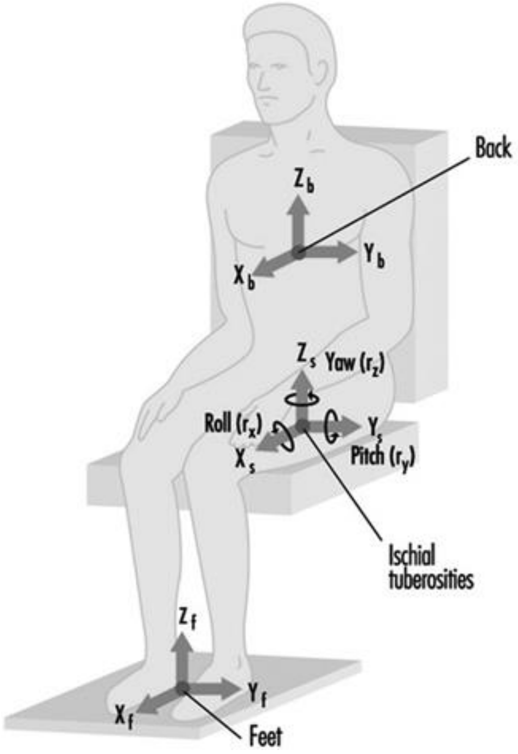
- EU Directive TLV: 5 $m/s^2$
- EU Directive AL: 2.5 $m/s^2$



ACGIH HandArmVibration_2018-10-24.pdf and ANSI S2.70 (2006)

# Whole Body Vibration Effects?

- Lumbar spinal disorders
  - Lower back pain
- Digestive problems
- Urinary problems



# Whole Body Limits

| Vibration exposure time (hrs) | TLV (m/s²) | Action Level (m/s²) |
|---|---|---|
| 8 | 1.15 | 0.50 |
| 6 | 1.33 | 0.58 |
| 4 | 1.63 | 0.71 |
| 2 | 2.30 | 1.00 |
| 1 | 3.25 | 1.41 |

**Maximum allowable level for 8 hr avg. exposure:**

- EU Directive TLV: 1.15 $m/s^2$
- EU Directive AL: 0.5 $m/s^2$




ACGIH HandArmVibration_2018-10-24.pdf and ANSI S2.70 (2006)

# Standards

**ISO 8041**

**Whole Body**
ISO 2631-1, 2, 4 & 5
(Wb, Wc, Wd, Wj, Wk, Wm)

**Earth Moving Equipment**
ISO 7096

**Ships**
ISO 20283-5 (Wm)

**Seats**
ISO 10326

**Hand Arm**
ISO 5349-1 & 2
(Wh)

**Gloves**
ISO 10819

**Forest Machinery – Handles**
ISO 22867

**Hand-held Portable Tools**
ISO 28927

**ANSI Guide**
ANSI S2.60-2006

# What to Do?

A. **Identify areas of concern**
- Power tools in use and/or medical diagnosis of injury
- Workers report tingling or “pins and needles” feeling
- Documented case HAV syndrome

B. **Determine exposure**
- Measure
- Model

C. **Control the risk**
- Limit exposure time
- Lower vibration levels
- Keep workspace warm
- Vibration isolation - like gloves

# Assessment Questions?

- Does your business use hand-held, hand-guided or hand-fed powered equipment?
- Using rotary action tools (e.g. grinders, polishers)?
- Using impact or percussive tools (i.e. hammer-action tools)?
- Manufacturers or suppliers warn of a risk from vibration?
- Tools cause tingling or numbness in the hands during or after use?
- Workers have reported symptoms of hand-arm vibration syndrome?

# Modeling Vibration Exposure

**Use of pre-determined tool vibration data**

**Benefits**

- Informed buying choice
- Easy
- Low cost

**Challenges**

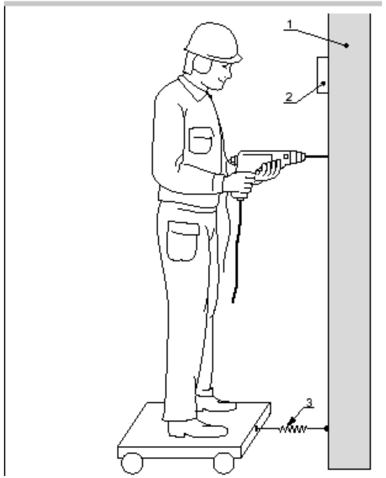
- Lack of data
- Inaccurate
- Not representative of actual conditions

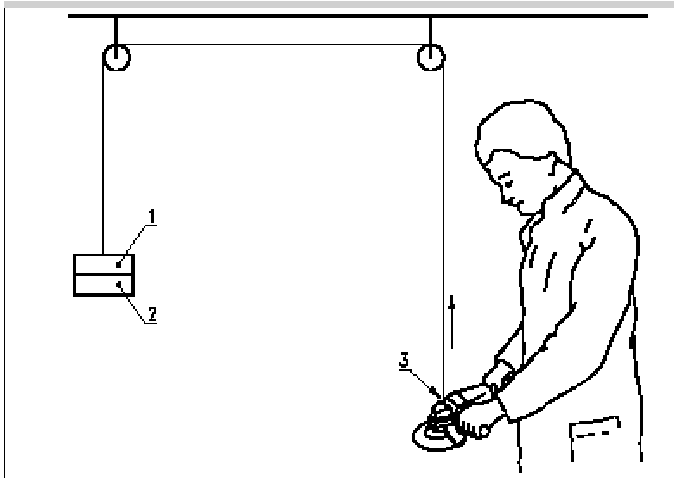
# Reference Measurements

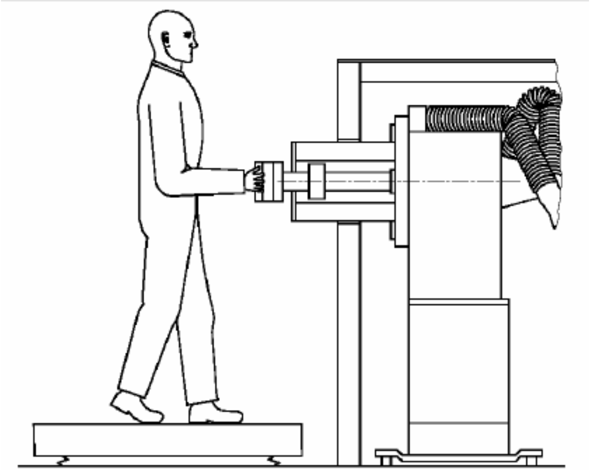
## Standards for measuring tool vibration

- ISO 28927-1: Angle and vertical **grinders**
- ISO 28927-2: **Wrenches, nutrunners,** and **screwdrivers**
- ISO 28927-3: **polishers** and rotary, orbital, and random orbital **sanders**
- ISO 28927-4: **Straight Grinders**
- ISO 28927-5: **Drills** and **impact drills**
- ISO 28927-6: **Rammers**
- ISO 28927-7: **Nibblers** and **shears**
- ISO 28927-8: **Saws**, **polishing, and filing machines** with reciprocating action
- ISO 28927-9: **Scaling hammers** and **needle scalers**
- ISO 28927-10: **Percussive drills, hammers,** and **breakers**
- ISO 28927-11: **Stone hammers**
- ISO 28927-12: **Die grinders**
- ISO 28927-13: **Fastener driving tools**

# Reference Measurement Examples



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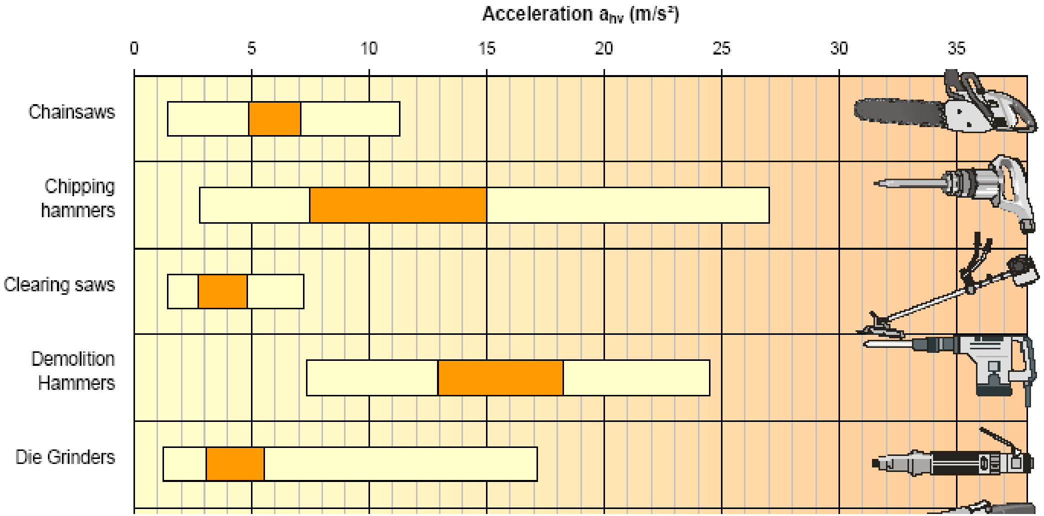
# Measurement Variation




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

# HSE Modeling Spreadsheet

## HAND-ARM VIBRATION EXPOSURE CALCULATOR

Version 3 June 2005

HSE Health & Safety Executive

| | Vibration magnitude $m/s^2$ r.m.s. | Exposure points per hour | Time to reach EAV 2.5 $m/s^2$ $A(8)$ | | Time to reach ELV 5 $m/s^2$ $A(8)$ | | Exposure duration | | Partial exposure $m/s^2$ $A(8)$ | Partial exposure points |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | hours | minutes | hours | minutes | hours | minutes | | |
| Tool or process 1 | 5.4 | 58 | 1 | 43 | 6 | 52 | 1 | 15 | 2.1 | 73 |
| Tool or process 2 | 7.3 | 107 | 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 | | | | | | | | | | |

| Daily exposure $m/s^2$ $A(8)$ | Total exposure points |
|---|---|
| 3.1 | 158 |

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 yelllow areas.
To clear all cells, click on the 'Reset' button.
For more information, click the HELP tab below.

Reset

# Measuring Vibration Exposure

**Benefits**

- More accurate
- Improved risk assessment

**Challenges**

- More expensive
- Measurement sometimes difficult

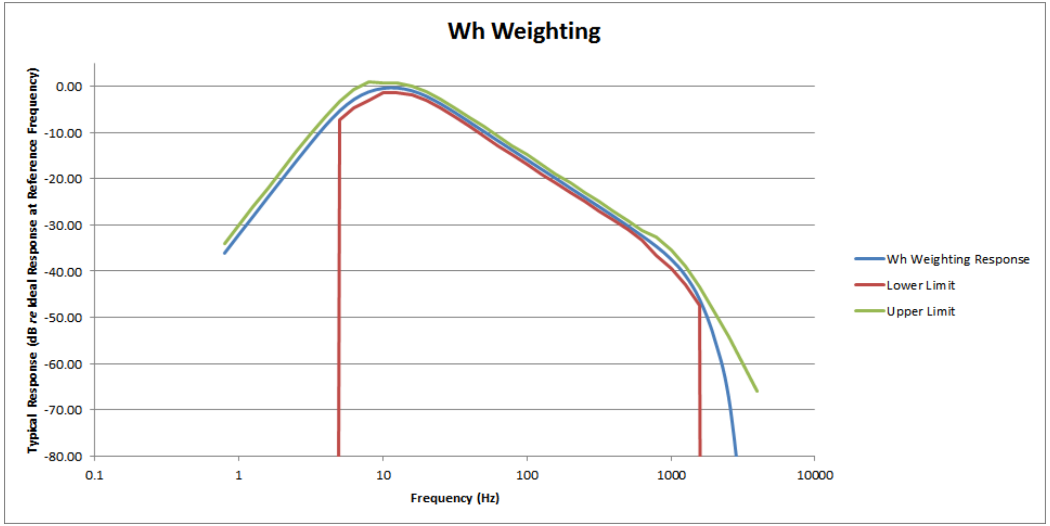
# Natural Frequency

**The frequency range of 0.5 Hz to 80 Hz is significant**

- Individual body members and organs have their own resonant frequencies
- This causes amplification or attenuation of vibration by certain parts of the body due to their own resonance
- The most damaging frequencies for vertical vibration are between 4 and 8 Hz

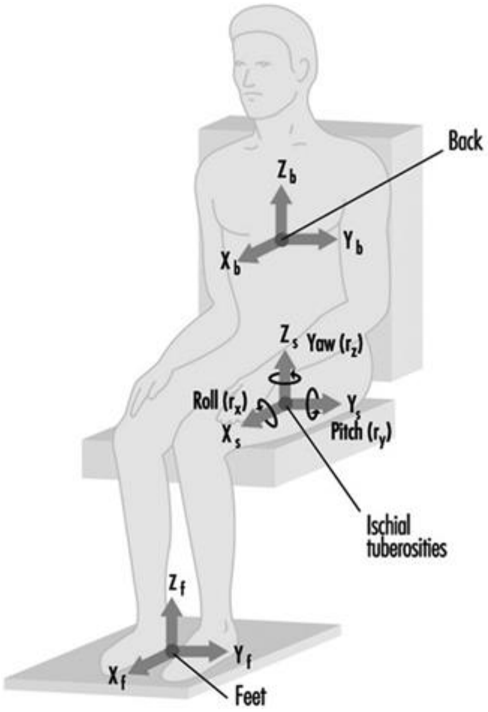
# Frequency Weighting (Hand-Arm)

| Designation | Description | Definition |
|---|---|---|
| $W_h$ | Hand arm vibration (all) | ISO 8041, ISO 5349-1, ANSI S2.70 |



# Frequency Weighting (Whole Body)

| Designation | Description |
|---|---|
| Wb | z-axis vertical vibration |
| Wc | x-axis, seat back |
| Wd | x-axis & y-axis, seat surface |
| We | rotational seat surface |
| Wf | Motion sickness (vertical) |
| Wj | vertical recumbent |
| Wk | z-axis, seat surface |
| Wm | Vibration in buildings |



# Example Measurement System

**The Larson Davis HVM200 is an instrument designed for measurement of human exposure to vibration**

- Complete with instrument, sensor, & software
- Control using app and Wi-Fi

# Adapters and Accessories

A variety of adapters and accessories for attaching the HVM200 and sensors are available





# What is Measured?

**Acceleration** = the rate of change for speed or velocity

**Accelerometer** = used to measure acceleration

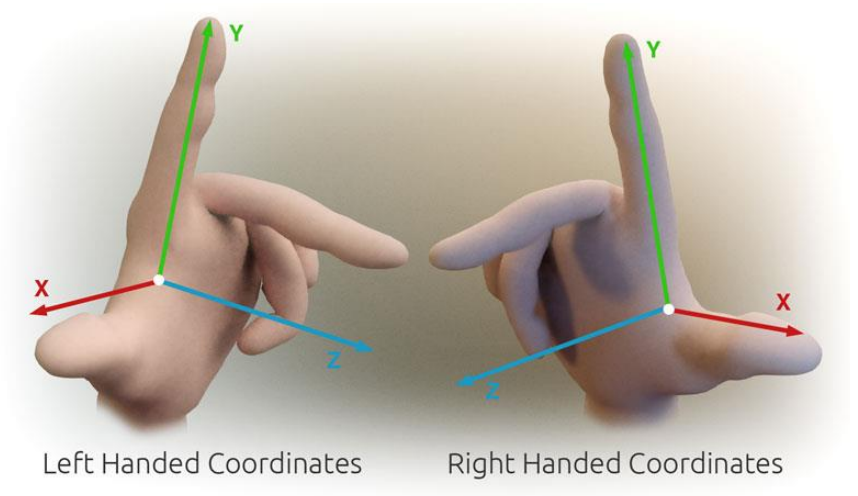
**Units** = $m/s^2$


# What is Triaxial?

Measure in three dimensions commonly labelled x, y, and z.

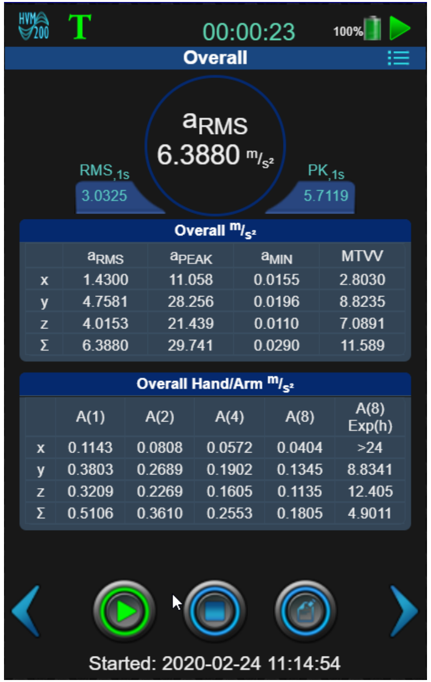
Like height, width, & depth.

- $$Sum = \sqrt{x^2 + y^2 + z^2}$$



# What are the Metrics?

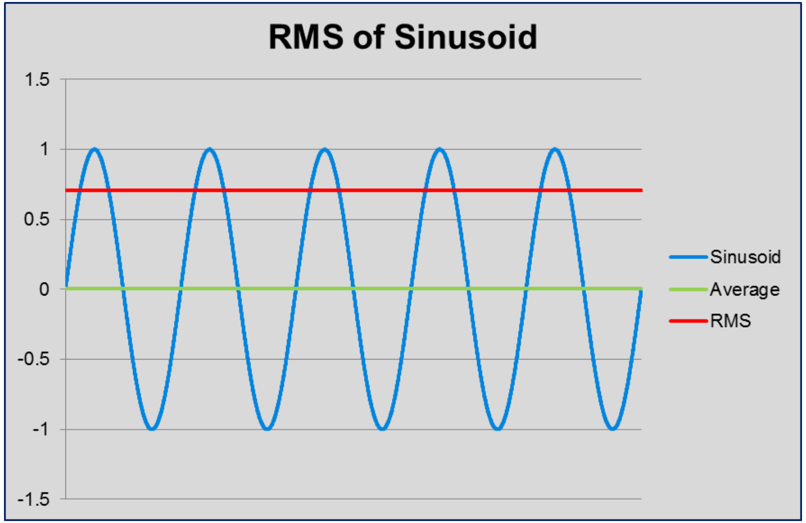
- $A_{rms}$ = rms or “average”
- A(8) = acceleration normalized to 8 hours
- VDV = Vibration Dose Value
  Emphasizes impulses
- Exposure time



# Arms & Apeak

- RMS = Root Mean Square
- Arms commonly used to express vibration magnitude
- RMS level is the constant level that will produce the same amount of energy as the time variant signal
- Not the same as an average

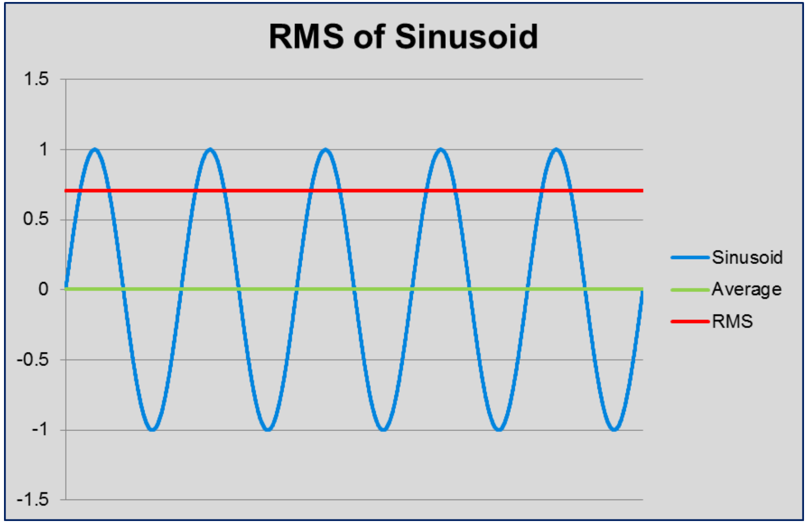
$$a_{rms} = \sqrt{\frac{1}{T} \bullet \int_0^T a(t)^2 \, dt}$$



# Crest Factor

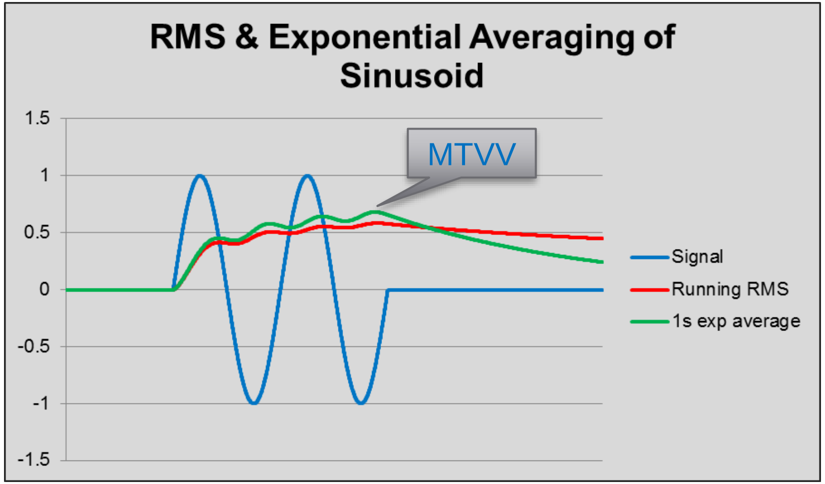
- Ratio of Apeak to Arms
- A measure of impulsivity
- For sinusoids, CF=1.41

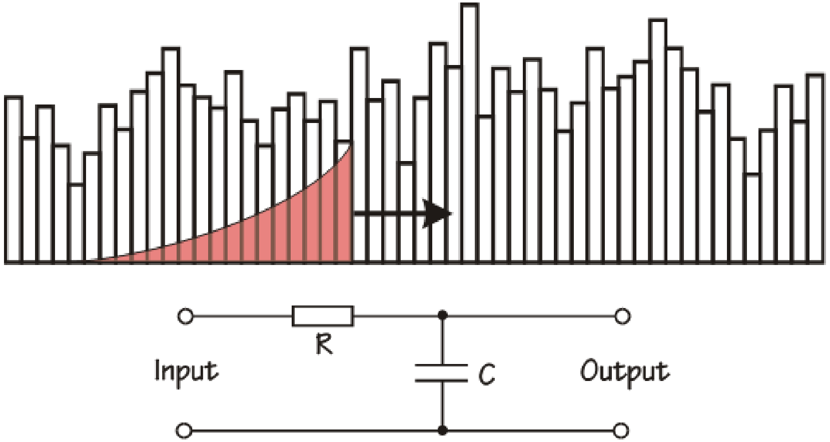
$$CF = \frac{A_{peak}}{a_{rms}}$$



# Amax (MTVV)

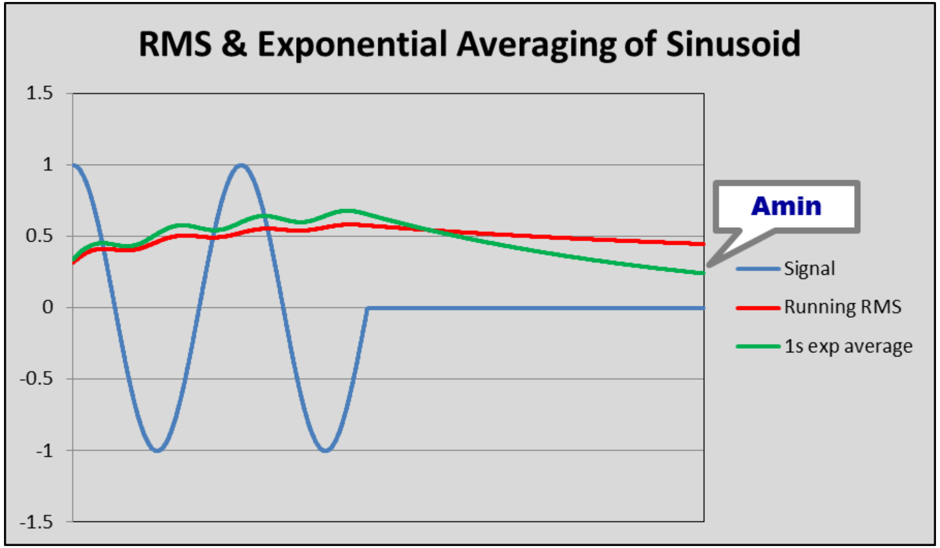
- Maximum time weighted level
  - Time weighting = 1s exponential
- Alternative to Apeak for expression of maximum vibration

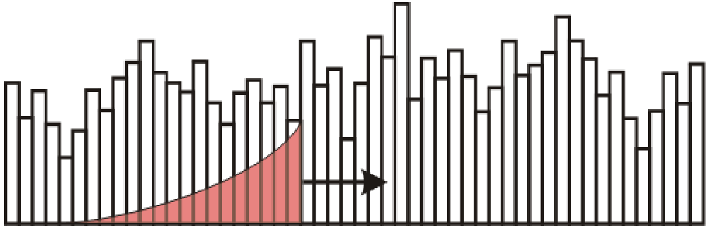


# Amin

- Minimum time weighted level from beginning of measurement period
  - Time weighting = 1s exponential



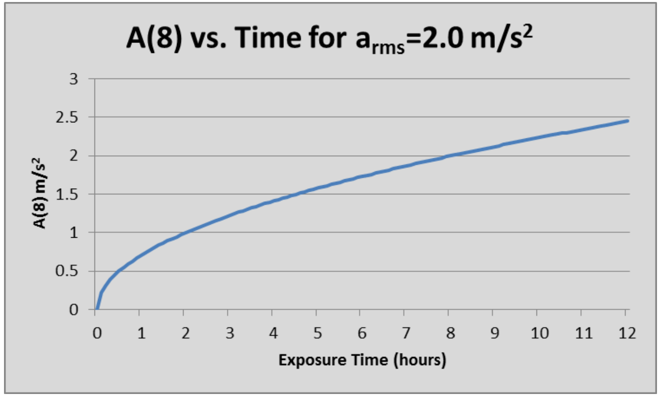
$$L_{a\tau} = \sqrt{\int_{-\infty}^{t} a^2(\xi) \bullet e^{-(t-\xi)} d\xi}$$

# A(1), A(2), A(4), A(8) for Hand-arm Vibration

A(8) = daily vibration exposure

"a continuous equivalent normalized to 8 hours"

- A(8) measurement can be compared - same 8 hour time basis
- Combines time and vibration
- Penalizes exposure > 8 hours
- A(8) measurements can be easily combined




$$A(1) = a_{rms}\sqrt{\frac{T}{1}}$$

$$A(2) = a_{rms}\sqrt{\frac{T}{2}}$$

$$A(4) = a_{rms}\sqrt{\frac{T}{4}}$$

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

*Where*:

$$a_{rms} = \sqrt{a_x^2 + a_y^2 + a_z^2}$$

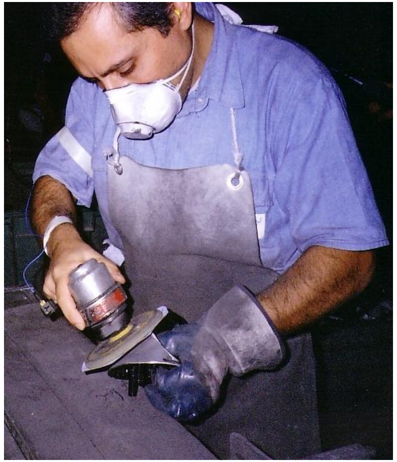
$T$ = exposure time (hours)

$$A(8) = \sqrt{A_1(8)^2 + A_2(8)^2 + A_3(8)^2 + \ldots}$$

# A(8) Hand-arm Example

A worker uses three tools each day

| Tool | $A_{rms}$ (m/s²) | Exposure (hours) |
|---|---|---|
| Angle grinder | 3.5 | 3 |
| Cutting saw | 2.5 | 1 |
| Chipping hammer | 18 | 1/3 (20 min) |



Partial vibration exposures:

$$A(8)_{grinder} = 3.5\sqrt{\frac{3}{8}} = 2.14 m/s^2$$

$$A(8)_{saw} = 2.5\sqrt{\frac{1}{8}} = 0.88 m/s^2$$

$$A(8)_{chipper} = 18\sqrt{\frac{.33}{8}} = 3.66 m/s^2$$

Daily vibration exposure:

$$A(8) = \sqrt{A_{grinder}^2 + A_{saw}^2 + A_{chipper}^2}$$

$$A(8) = \sqrt{2.14^2 + 0.88^2 + 3.66^2}$$

$$A(8) = \sqrt{4.58 + 0.77 + 13.40}$$

$$A(8) = \sqrt{18.75} = 4.33 m/s^2$$

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

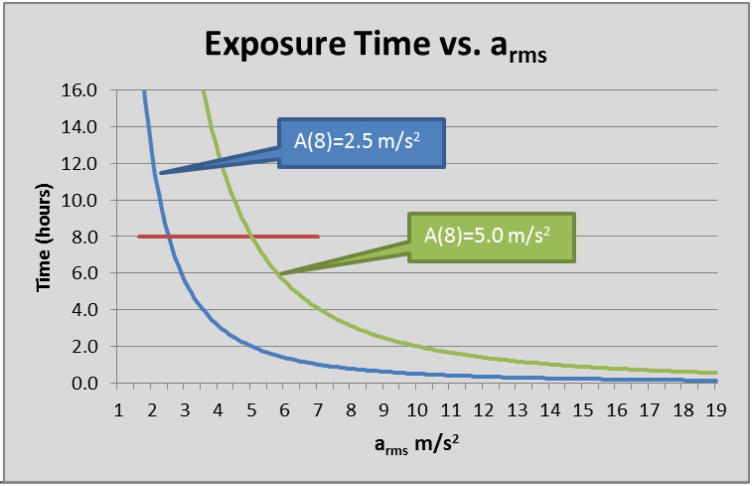
# A(8) Act and Exp for Hand-arm Vibration

A(8) Act is elapsed time until A(8) = Exposure **Act**ion Level
A(8) Exp is elapsed time until A(8) = **Exp**osure Limit Level

- Used to determine how long a worker can continue with the same activity before reaching a predefined limit level
- HVM200 shows "> 24 hours" for periods longer than 1 day
- Default Action Level = 2.5 m/s$^2$
- Default Exposure Limit Level = 5.0 m/s$^2$

$$A(8)Act = \frac{8 \bullet A_{action}^2}{a_{rms}^2} = \frac{8 \bullet 2.5^2}{a_{rms}^2} = \frac{50}{a_{rms}^2}\ hours$$

$$A(8)Exp = \frac{8 \bullet A_{ExpLimit}^2}{a_{rms}^2} = \frac{8 \bullet 5.0^2}{a_{rms}^2} = \frac{200}{a_{rms}^2}\ hours$$



# A(8) for Whole Body Vibration

## A(8) = daily vibration exposure

## “a continuous equivalent normalized to 8 hours”

- A(8) measurement can be compared, same 8 hour time basis
- Combines time and vibration
- Penalizes exposure > 8 hours
- A(8) measurements can be easily combined

$$A(8) = \max\left(a_{x,rms}, a_{y,rms}, a_{z,rms}\right)\sqrt{\frac{T}{8}}$$

$Where:$

$T$ = exposure time (hours)



# A(8) Whole Body Example

A worker uses two devices each day

| Tool | $A_{x,rms}$ (m/s²) | $A_{y,rms}$ (m/s²) | $A_{z,rms}$ (m/s²) | Exposure (hours) |
|---|---|---|---|---|
| Forklift | 0.5 | 0.3 | 0.9 | 1 |
| Truck | 0.2 | 0.2 | 0.4 | 6 |

Partial vibration exposures :

$$A_{x,\,forklift}(8) = 1.4 \bullet 0.5\sqrt{\frac{1}{8}} = 0.25 m/s^2$$

$$A_{y,\,forklift}(8) = 1.4 \bullet 0.3\sqrt{\frac{1}{8}} = 0.15 m/s^2$$

$$A_{z,\,forklift}(8) = 0.9\sqrt{\frac{1}{8}} = 0.32 m/s^2$$

$$A_{x,truck}(8) = 1.4 \bullet 0.2\sqrt{\frac{6}{8}} = 0.24 m/s^2$$

$$A_{y,truck}(8) = 1.4 \bullet 0.2\sqrt{\frac{6}{8}} = 0.24 m/s^2$$

$$A_{z,truck}(8) = 0.4\sqrt{\frac{6}{8}} = 0.35 m/s^2$$

$$A(8) = k \bullet a_{rms}\sqrt{\frac{T}{8}}$$

Daily vibration exposure :

$$A_x(8) = \sqrt{A(8)^2_{x,\,forklift} + A(8)^2_{x,truck}} = \sqrt{0.25^2 + 0.24^2} = 0.35 m/s^2$$

$$A_y(8) = \sqrt{A(8)^2_{y,\,forklift} + A(8)^2_{y,truck}} = \sqrt{0.15^2 + 0.24^2} = 0.28 m/s^2$$

$$A_z(8) = \sqrt{A(8)^2_{z,\,forklift} + A(8)^2_{z,truck}} = \sqrt{0.32^2 + 0.35^2} = 0.47 m/s^2$$

$$A(8) = \max(A_x(8), A_y(8), A_z(8)) = \max(0.35,0.28,0.47) = 0.47 m/s^2$$

# A(8) Act & Exp for Whole Body Vibration

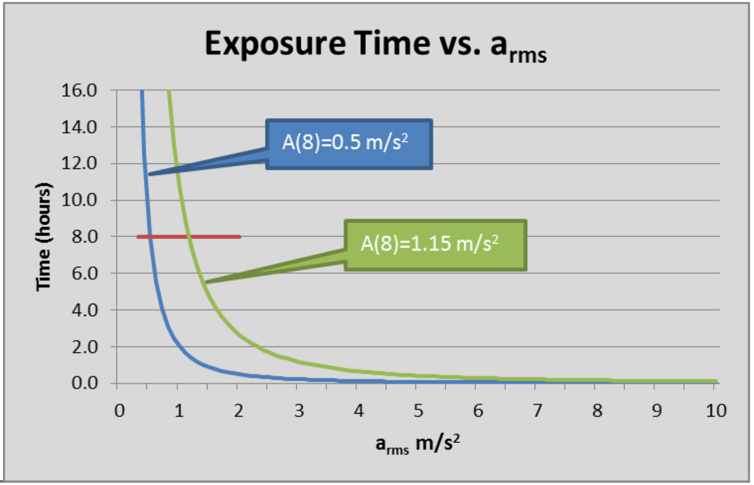
A(8) Act is elapsed time until A(8) = Exposure **Act**ion Level

A(8) Exp is elapsed time until A(8) = **Exp**osure Limit Level

- Used to determine how long a worker can continue with the same activity before reaching a predefined limit level
- HVM200 shows “> 24 hours” for periods longer than 1 day
- Default Action Level = 0.5 m/s$^2$
- Default Exposure Limit Level = 1.15 m/s$^2$

$$A(8)Act = \frac{8 \bullet A_{action}^2}{a_{rms}^2} = \frac{8 \bullet 0.5^2}{a_{rms}^2} = \frac{2}{a_{rms}^2}\ hours$$

$$A(8)Exp = \frac{8 \bullet A_{ExpLimit}^2}{a_{rms}^2} = \frac{8 \bullet 1.15^2}{a_{rms}^2} = \frac{10.58}{a_{rms}^2}\ hours$$



# VDV

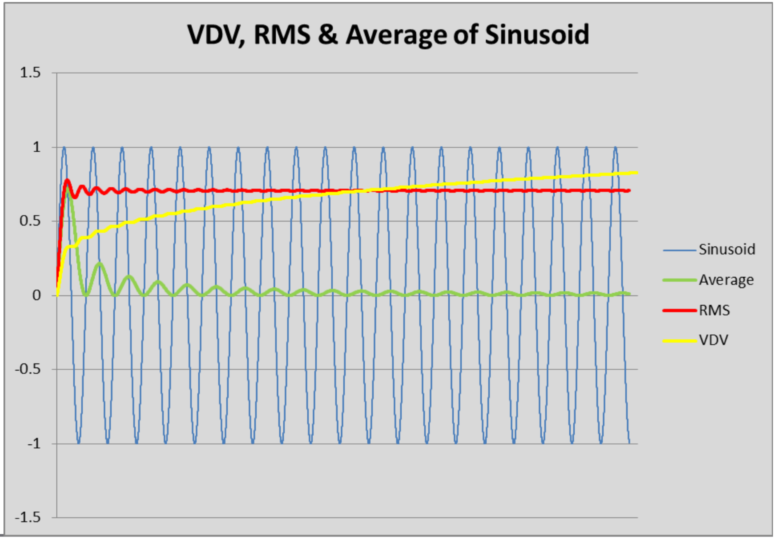
**Vibration Dose Value**

Exposure to intermittent WBV including shocks or jolts is measured using a VDV, which gives a more representative value than the daily vibration exposure A(8).

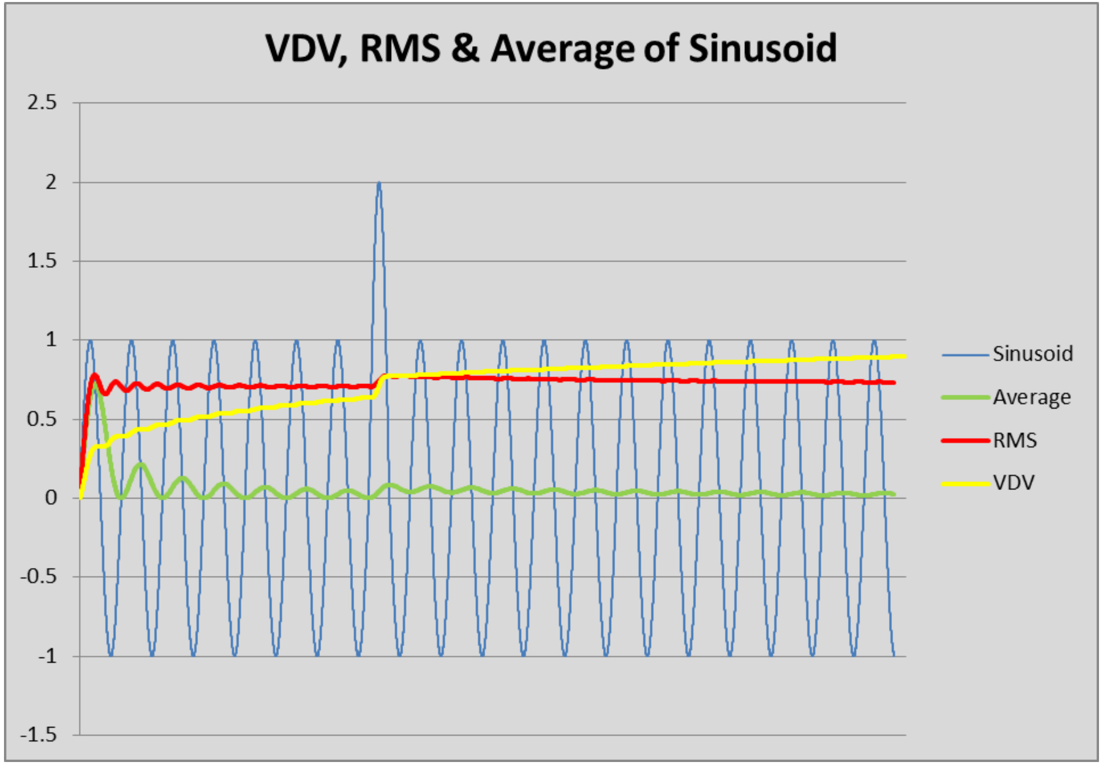
- VDV Exposure Action Level = 9.1 $m/s^{1.75}$
- VDV Exposure Limit Level = 21 $m/s^{1.75}$
- Cumulative metric, not normalized

$$VDV = \left\{ \int_0^T a(t)^4 \, dt \right\}^{\frac{1}{4}}$$

$$a_{rms} = \sqrt{\frac{1}{T} \bullet \int_0^T a(t)^2 \, dt}$$



# VDV with a Pulse



# VDV Example – Part 1

A worker uses two devices each day

| | Forklift | Truck |
|---|---|---|
| $VDV_x$ ($m/s^{1.75}$) | 0.5 | 0.2 |
| $VDV_y$ ($m/s^{1.75}$) | 0.3 | 0.2 |
| $VDV_z$ ($m/s^{1.75}$) | 0.9 | 0.4 |
| Msrmnt time (hrs) | 1 | 1 |
| Duration (hrs) | 1 | 6 |

Partial VDV exposure formulas:

$$VDV_{\exp,x} = 1.4 \bullet VDV_x \left(\frac{T_{\text{exposure}}}{T_{measured}}\right)^{1/4}$$

$$VDV_{\exp,y} = 1.4 \bullet VDV_y \left(\frac{T_{\text{exposure}}}{T_{measured}}\right)^{1/4}$$

$$VDV_{\exp,z} = VDV_z \left(\frac{T_{\text{exposure}}}{T_{measured}}\right)^{1/4}$$

*Where:*

$T_{\text{exposure}}$ = Daily duration of exposure

$T_{\text{measured}}$ = VDV measurement period

Partial VDV exposures:

$$VDV_{\exp,x,\,forklift} = 1.4 \bullet 0.5\left(\frac{1}{1}\right)^{1/4} = 0.70 m/s^{1.75}$$

$$VDV_{\exp,y,\,forklift} = 1.4 \bullet 0.3\left(\frac{1}{1}\right)^{1/4} = 0.42 m/s^{1.75}$$

$$VDV_{\exp,z,\,forklift} = 0.9\left(\frac{1}{1}\right)^{1/4} = 0.90 m/s^{1.75}$$

$$VDV_{\exp,x,truck} = 1.4 \bullet 0.2\left(\frac{6}{1}\right)^{1/4} = 0.44 m/s^{1.75}$$

$$VDV_{\exp,y,truck} = 1.4 \bullet 0.2\left(\frac{6}{1}\right)^{1/4} = 0.44 m/s^{1.75}$$

$$VDV_{\exp,z,truck} = 0.4\left(\frac{6}{1}\right)^{1/4} = 0.63 m/s^{1.75}$$

# VDV Example – Part 2

A worker uses two devices each day

| | Forklift | Truck |
|---|---|---|
| $VDV_x$ ($m/s^{1.75}$) | 0.5 | 0.2 |
| $VDV_y$ ($m/s^{1.75}$) | 0.3 | 0.2 |
| $VDV_z$ ($m/s^{1.75}$) | 0.9 | 0.4 |
| Msrmnt time (hrs) | 1 | 1 |
| Duration (hrs) | 1 | 6 |

Daily VDV exposure:

$$VDV_x = \left(0.70^4 + 0.44^4\right)^{1/4} = 0.73 m/s^{1.75}$$

$$VDV_y = \left(0.42^4 + 0.44^4\right)^{1/4} = 0.61 m/s^{1.75}$$

$$VDV_z = \left(0.90^4 + 0.63^4\right)^{1/4} = 0.95 m/s^{1.75}$$

$$VDV = \max(0.73, 0.61, 0.95) = 0.95 m/s^{1.75}$$

Daily VDV exposure formula:

$$VDV_x = \left(VDV_{\exp,x1}^4 + VDV_{\exp,x2}^4 + VDV_{\exp,x3}^4 + \ldots\right)^{1/4} m/s^{1.75}$$

$$VDV_y = \left(VDV_{\exp,y1}^4 + VDV_{\exp,y2}^4 + VDV_{\exp,y3}^4 + \ldots\right)^{1/4} m/s^{1.75}$$

$$VDV_z = \left(VDV_{\exp,z1}^4 + VDV_{\exp,z2}^4 + VDV_{\exp,z3}^4 + \ldots\right)^{1/4} m/s^{17.5}$$

# Exposure Points (Hand-arm)

"Points" = alternate method that involves simpler math

How to do "points" for hand-arm vibration

1) Convert $a_{rms}$ to points/hour for each tool

$$\boxed{P_{E,hav,1h} = 2a_{hav}^2}$$

2) Multiply points/hour by hours of exposure
3) Add up the points
4) Done!

Exposure action level (2.5 m/s²) = **100 points**
Exposure limit level (5.0 m/s²) = **400 points**

Points general formula :

$$P_{E,hav} = \left(\frac{a_{hav}}{2.5m/s^2}\right)^2 \frac{T}{8hours} 100$$

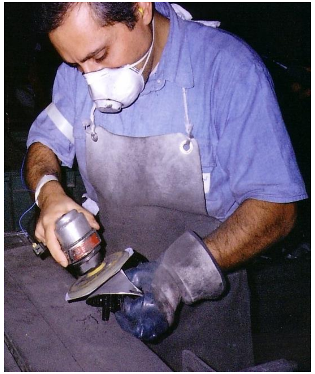
*Where* :

$T$ = Exposure time (hours)

$$A(8) = 2.5m/s^2 \sqrt{\frac{P_E}{100}}$$

# Exposure Points Example (Hand-arm)

| Tool | $A_{rms}$ ($m/s^2$) | $P_{E,1h}$ | Exposure (hours) | $P_E$ |
|---|---|---|---|---|
| Angle grinder | 3.5 | 24.5 | 3 | 73.5 |
| Cutting saw | 2.5 | 12.5 | 1 | 12.5 |
| Chipping hammer | 18 | 648 | 1/3 (20 min) | 213.8 |
| TOTAL POINTS | | | | 299.8 |



$$P_{E,grinder,1h} = 2 \bullet 3.5^2 = 2 \bullet 12.25 = 24.5$$

$$P_{E,saw,1h} = 2 \bullet 2.5^2 = 2 \bullet 6.25 = 12.5$$

$$P_{E,hammer,1h} = 2 \bullet 18^2 = 2 \bullet 324 = 648$$

$$P_{E,grinder} = 24.5 \bullet 3 = 73.5$$

$$P_{E,saw} = 12.5 \bullet 1 = 12.5$$

$$P_{E,hammer} = 648 \bullet 0.33 = 213.8$$

# Exposure Points (Whole Body)

“Points” = alternate method that involves simpler math

How to do “points” for whole body vibration

1) Convert $a_{rms}$ to points/hour for each tool

$$\boxed{P_{E,wbv,1h} = 50\left(k \bullet a_{wbv}\right)^2}$$

2) Multiply points/hour by hours of exposure
3) Add up the points
4) Done!

Exposure action level (0.5 m/s$^2$) = **100 points**
Exposure limit level (1.15 m/s$^2$) = **529 points**

Points general formula:

$$P_E = \left(\frac{k \bullet a_w}{0.5 m/s^2}\right)^2 \frac{T}{8 hours} 100$$

*Where:*

$T$ = exposure time (hours)

$$A(8) = 0.5 m/s^2 \sqrt{\frac{P_E}{100}}$$

# Exposure Points Example (Whole Body)

| Tool | $A_{x,rms}$ (m/s²) | $A_{y,rms}$ (m/s²) | $A_{z,rms}$ (m/s²) | $P_{Ex,1h}$ | $P_{Ey,1h}$ | $P_{Ez,1h}$ | Exposure (hrs) | $P_{Ex}$ | $P_{Ey}$ | $P_{Ez}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Forklift | 0.5 | 0.3 | 0.9 | 24.5 | 8.8 | 40.5 | 1 | 24.5 | 8.8 | 40.5 |
| Truck | 0.2 | 0.2 | 0.4 | 3.9 | 3.9 | 8.0 | 6 | 23.5 | 23.5 | 48.0 |
| subtotal | | | | | | | | 48.0 | 32.3 | 88.5 |
| TOTAL | | | | | | | | | | 88.5 |

$$P_{Ex,\,forklift,1h} = 50 \bullet (1.4 \bullet 0.5)^2 = 50 \bullet 0.7^2 = 24.5$$

$$P_{Ey,\,forklift,1h} = 50 \bullet (1.4 \bullet 0.3)^2 = 50 \bullet 0.4^2 = 8.8$$

$$P_{Ez,\,forklift,1h} = 50 \bullet (0.9)^2 = 50 \bullet 0.81 = 40.5$$

$$P_{Ex,truck,1h} = 50 \bullet (1.4 \bullet 0.2)^2 = 50 \bullet 0.3^2 = 3.9$$

$$P_{Ey,truck,1h} = 50 \bullet (1.4 \bullet 0.2)^2 = 50 \bullet 0.3^2 = 3.9$$

$$P_{Ez,truck,1h} = 50 \bullet (0.4)^2 = 50 \bullet 0.16 = 8$$

# Trading Time for Exposure

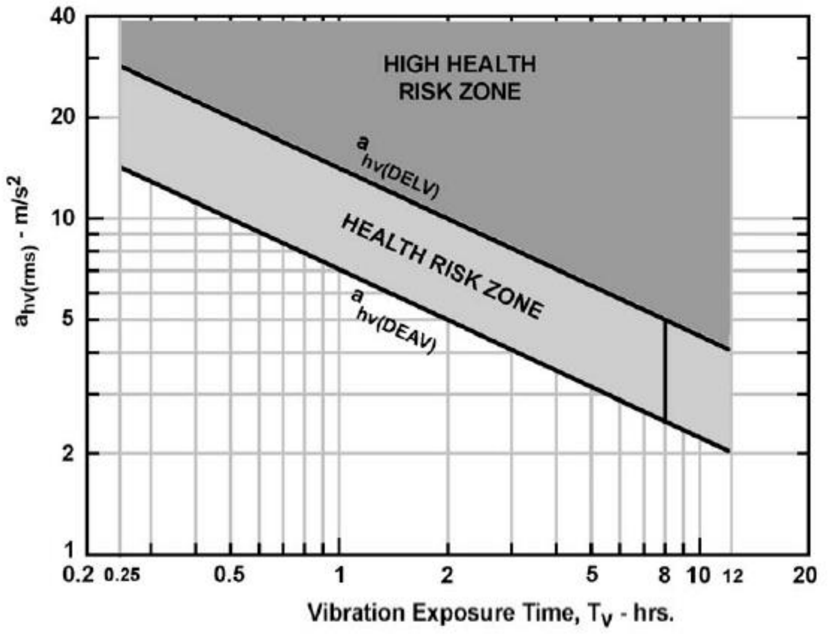



Figure A.1 — Plots of the $a_{hv(DEAV)}$ and $a_{hv(DELV)}$ values for vibration exposure times other than 8 hours

# Sample Data

| | x | y | z | Sum | Units |
|---|---|---|---|---|---|
| $a_{RMS}$ | 0.5308 | 0.0453 | 0.2576 | 0.5918 | $m/s^2$ |
| MTVV | 0.7506 | 0.0546 | 0.3603 | 0.8344 | $m/s^2$ |
| $a_{PEAK}$ | 2.6416 | 0.2351 | 1.2674 | 2.9392 | $m/s^2$ |
| $a_{MIN}$ | 0.4681 | 0.0357 | 0.2248 | 0.5205 | $m/s^2$ |
| A(1) | 0.0177 | 0.0015 | 0.0086 | 0.0197 | $m/s^2$ |
| A(2) | 0.0125 | 0.0011 | 0.0061 | 0.0139 | $m/s^2$ |
| A(4) | 0.0088 | 0.0008 | 0.0043 | 0.0099 | $m/s^2$ |
| A(8) | 0.0063 | 0.0005 | 0.0030 | 0.0070 | $m/s^2$ |
| A(8) Action | >24 | >24 | >24 | >24 | hours |
| A(8) Exposure | >24 | >24 | >24 | >24 | hours |
| Exposure Points | | | | 0 | Points |

# What to Do?

A. **Identify areas of concern**
- Power tools in use and/or medical diagnosis of injury
- Workers report tingling or “pins and needles” feeling
- Documented case HAV syndrome

B. **Determine exposure**
- Measure
- Model

C. **Control the risk**
- Limit exposure time
- Lower vibration levels
- Keep workspace warm
- Vibration isolation - like gloves

# Administrative Controls

- **If vibration levels too high:**
- Rotate workers on high vibration tool
- Break work into multiple shifts

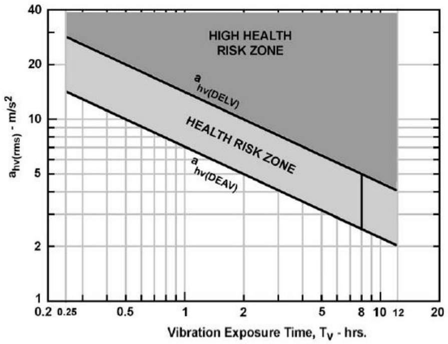
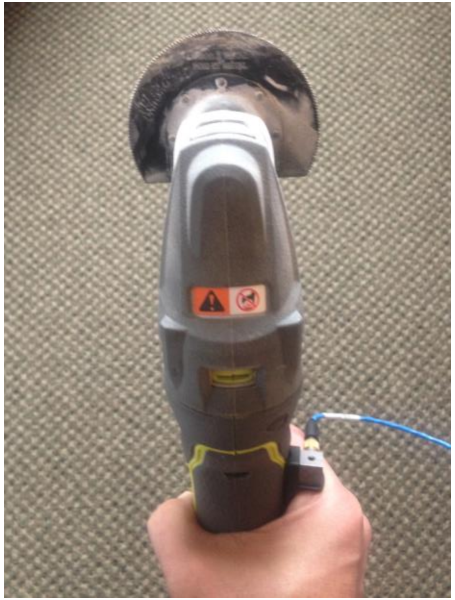


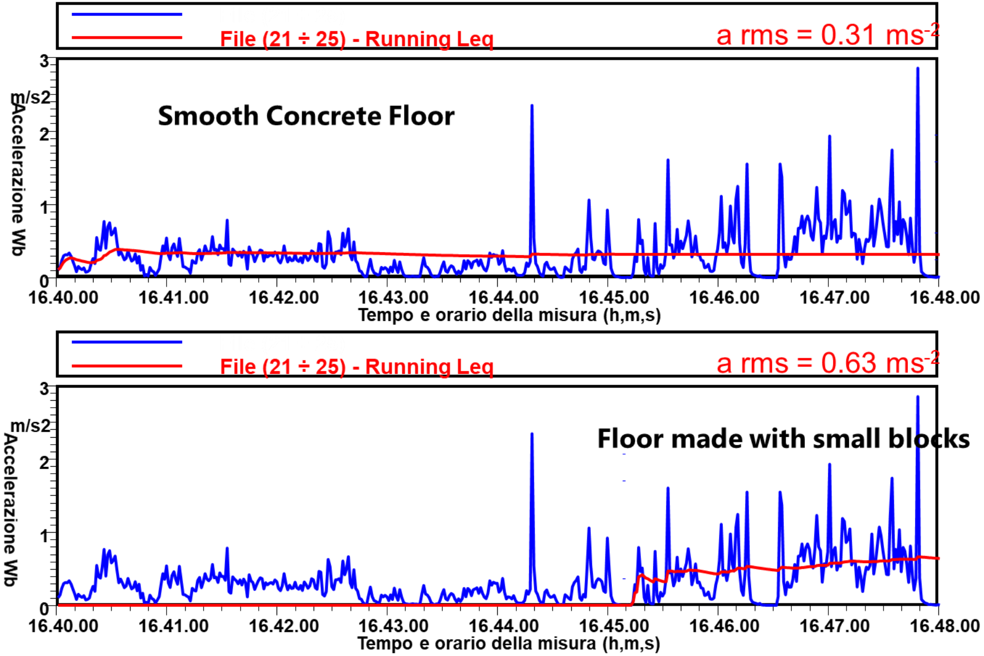

Figure A.1 — Plots of the $a_{hv(DEAV)}$ and $a_{hv(DELV)}$ values for vibration exposure times other than 8 hours

# Engineering Controls

- **If vibration levels too high**
- Training on proper use of tool
- Ensure tool properly maintained
- Replace tool with model producing less vibration
- Use vibration isolation like gloves



# Example
# Whole Body – Forklift Surface

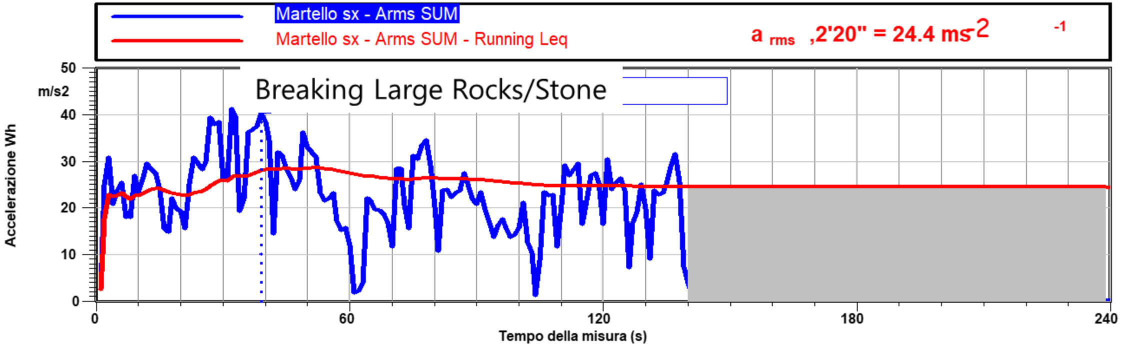



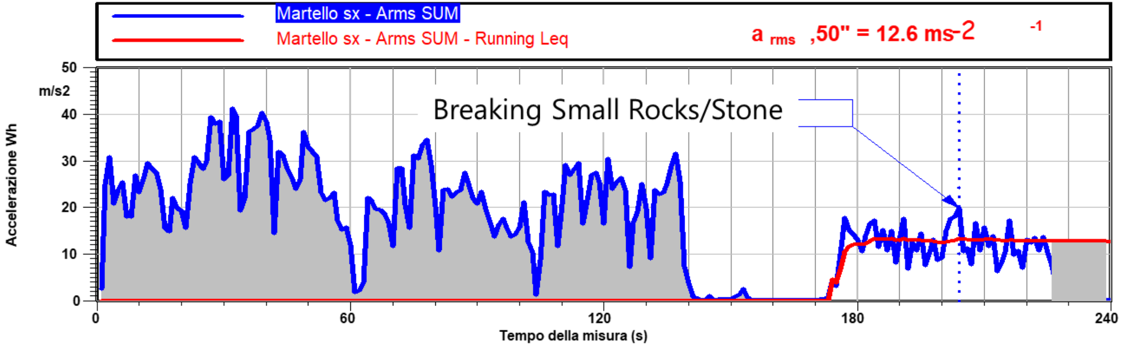
# Example
# Hand-Arm Tool Usage


Breaking Large Rocks/Stone

Breaking Small Rocks/Stone

# Example
# Hand-Arm Tool Usage

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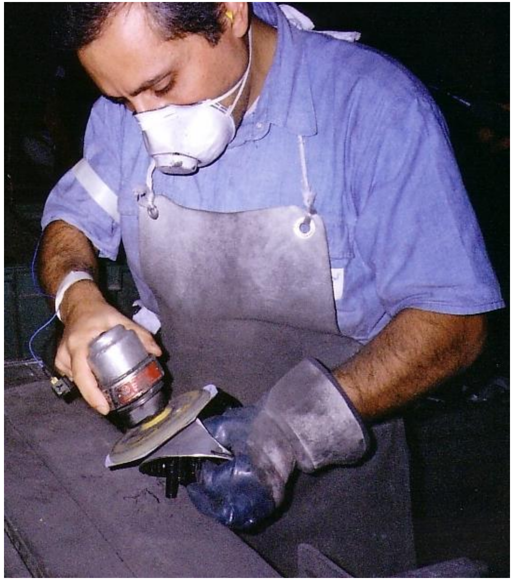
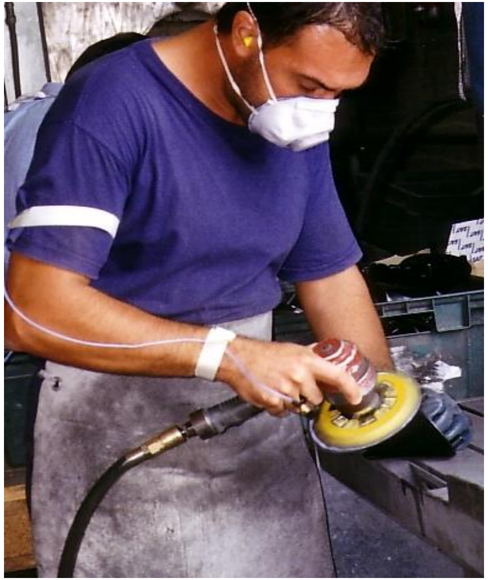
# Example
# Hand-Arm Worker Experience

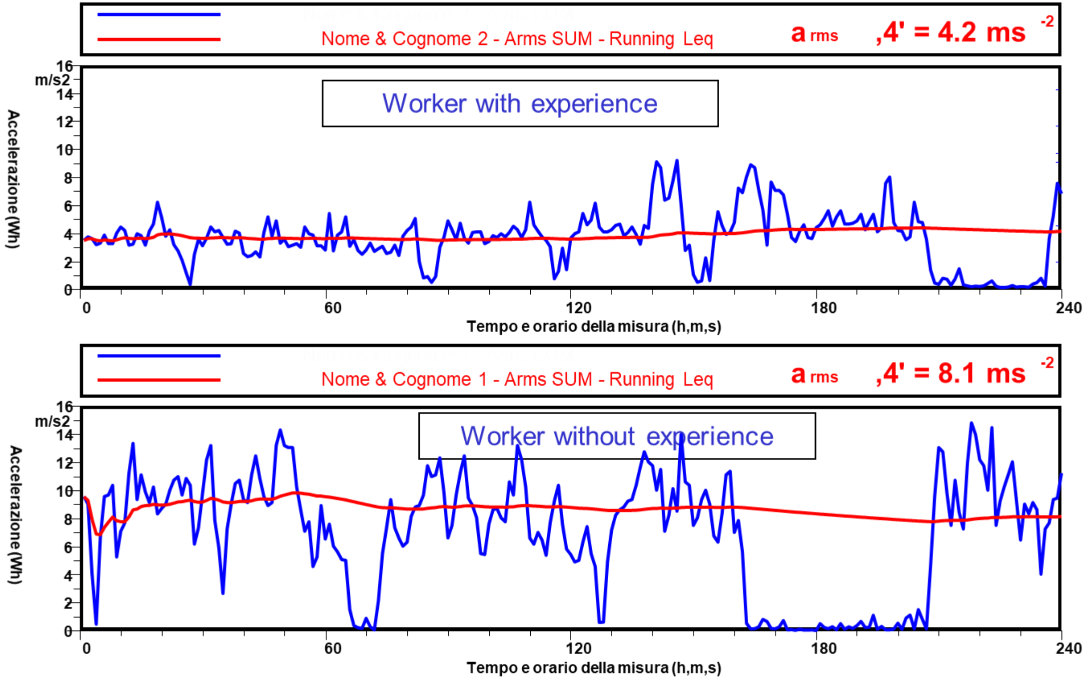


Worker with experience



Inexperienced worker

# Example
# Hand-Arm Worker Experience



# Questions?