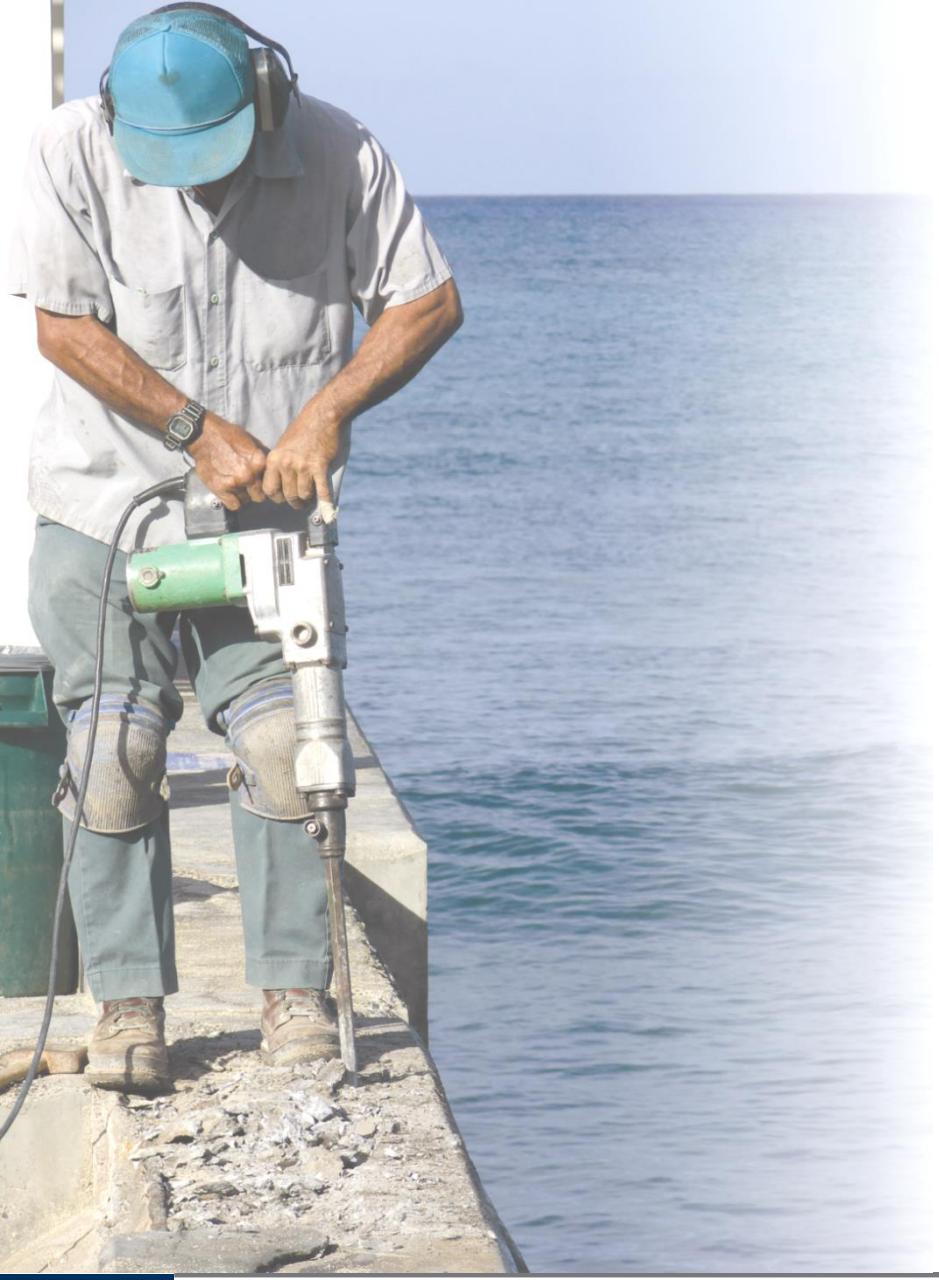


HUMAN VIBRATION

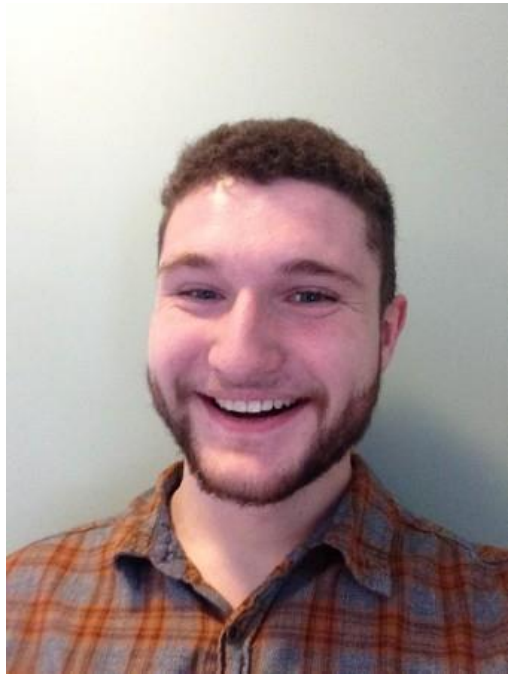
RISKS, LIMITS, MEASUREMENT AND MITIGATION

JAKE NURRE

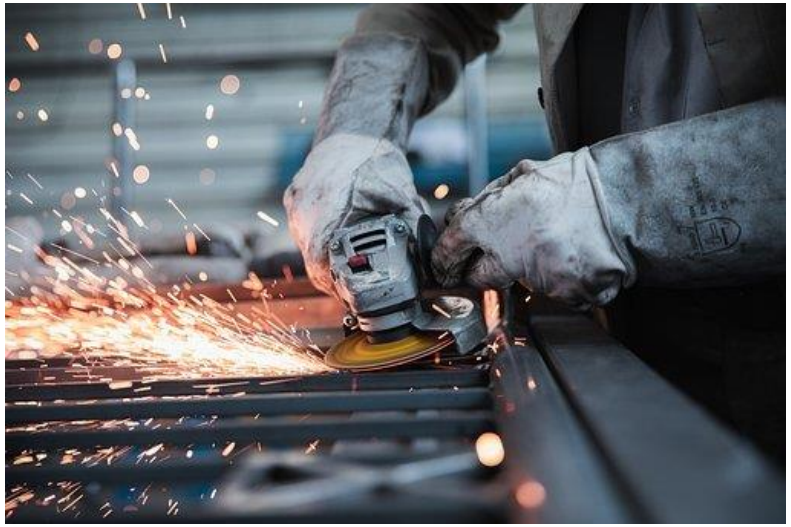
WHO AM I?

Jake Nurre

- Larson Davis Technical Specialist
- Process Safety – Duke Energy
- Audio / Signal Processing Technician



VIBRATION EXPOSURE



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

REFERENCE MATERIALS

- U.S Department of Defense
- European Union Directive, HSE
  - The Control of Vibration at Work Regulations – 2005
- Canadian CREOD
  - Center for Research Expertise in Occupational Disease
  - 10% of Canadian Manual Workers Exposed and at risk

HUMAN VIBRATION - CLASSIFICATIONS

Whole Body Vibration

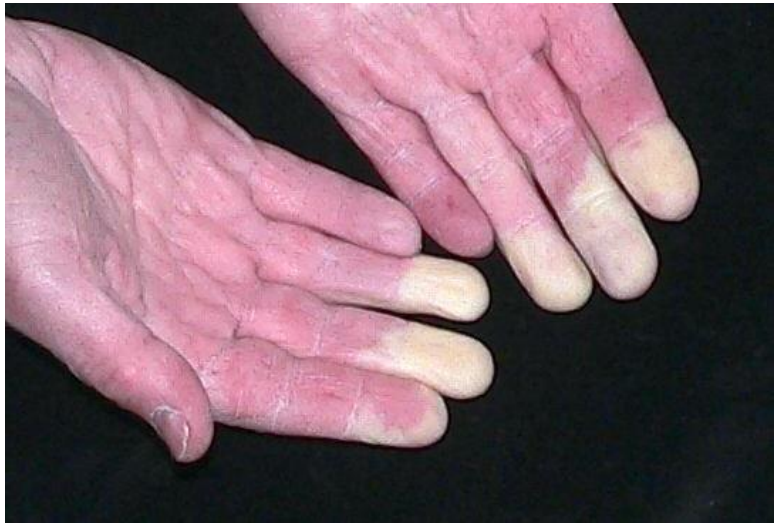
Hand-Arm Vibration

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 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 VIBRATION 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

WHOLE BODY EFFECTS

- **Muscular back pain, spinal deformation or sciatica**
- **Short term effects include fatigue, stomach problems, shakiness**

Studies on long term bus and truck drivers have shown contributions to bowl and respiratory disorders

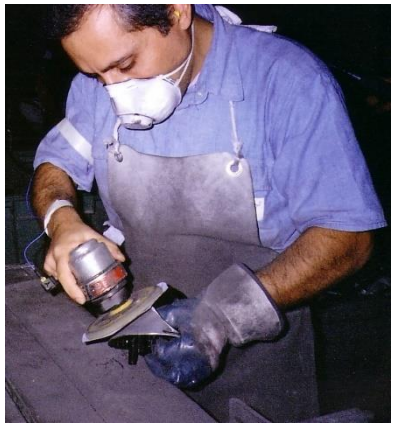
https://www.ccohs.ca/oshanswers/phys_agents/vibration/vibration_effects.html

RECOMMENDED HAV LIMITS

Vibration exposure time (hrs)	TLV (m/s^2)	Action Level (m/s^2)
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)

WHAT TO DO?

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

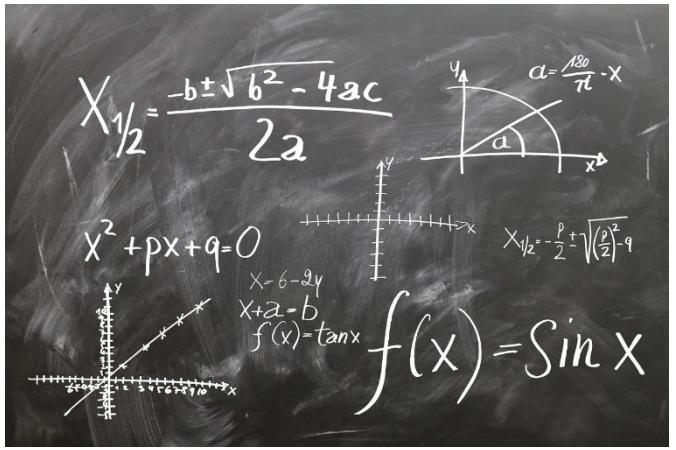
B. **Determine exposure**
   a) Measure
   b) Model

C. **Control the risk**
   a) Limit exposure time
   b) Lower vibration levels
   c) Keep workspace warm
   d) 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 to assess exposure risk

Benefits

- Informed buying choice
- Easy
- Low cost

Challenges

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

DoD Environmental Health Readiness System – Industrial Hygiene

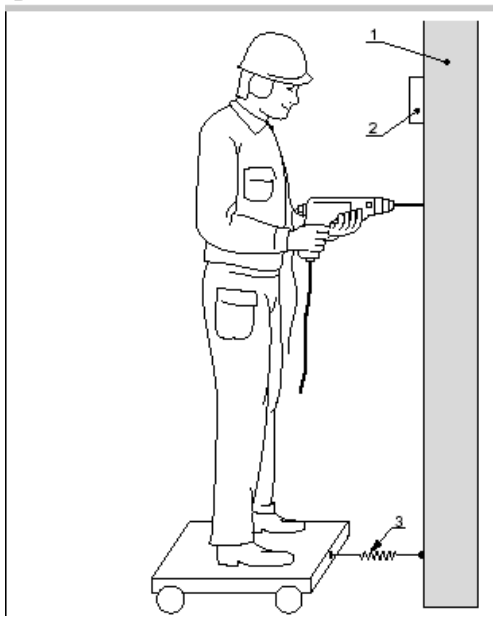
Home Page - HVED - HVED (army.mil) - **DoD Human Vibration Exposure Directory**

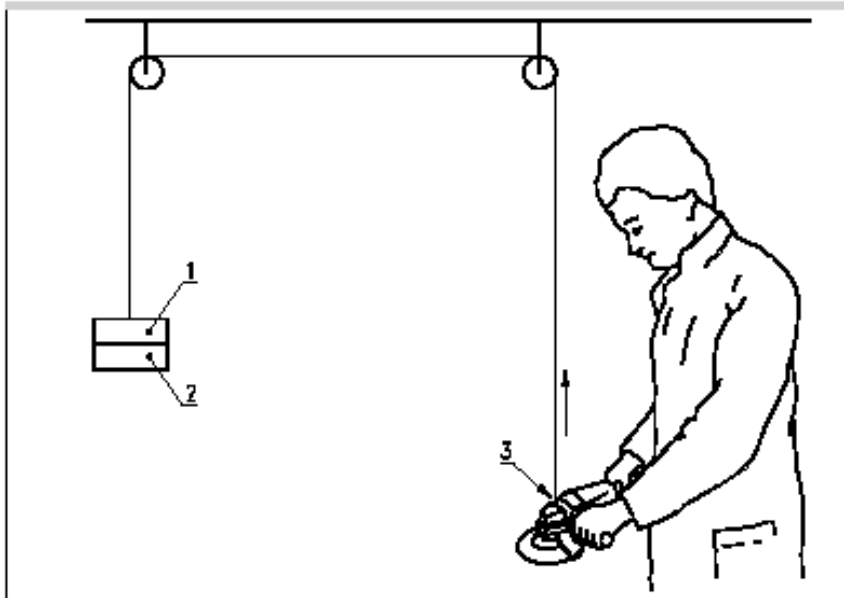
REFERENCE MEASUREMENTS

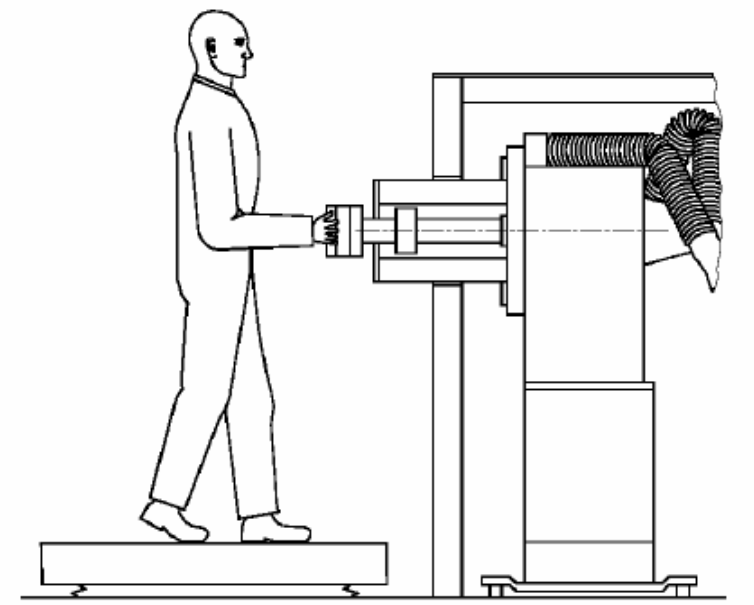
Standards for measuring tool vibration

- ISO 8662-1:1988 **Hand-held portable power tools** -- Measurement of vibrations at the handle
- 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 8662-11: **Fastener driving tools**

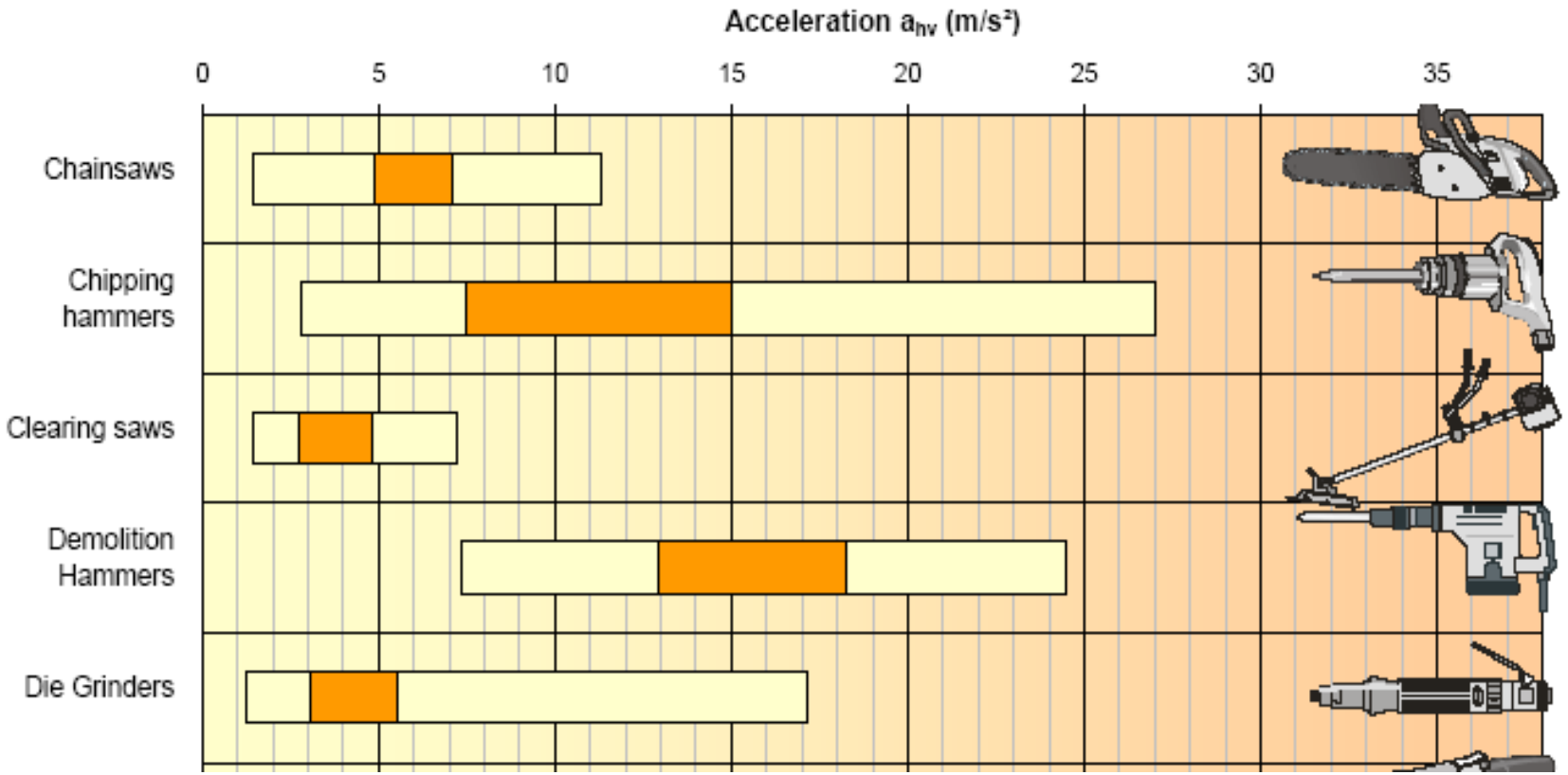
REFERENCE MEASUREMENT EXAMPLES







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

HSE Health & Safety Executive

HAND-ARM VIBRATION EXPOSURE CALCULATOR

Version 3 June 2005

	Vibration magnitude m/s^2 r.m.s.	Exposure points per hour	Time to reach EAV 2.5 m/s^2 A (8) hours	Time to reach EAV 2.5 m/s^2 A (8) minutes	Time to reach ELV 5 m/s^2 A (8) hours	Time to reach ELV 5 m/s^2 A (8) minutes	Exposure duration hours	Exposure duration minutes	Partial exposure m/s^2 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	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										

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.

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

Reset

MEASURING VIBRATION EXPOSURE

Benefits

- More accurate
- Improved risk assessment

Challenges

- More expensive
- Measurement sometimes difficult

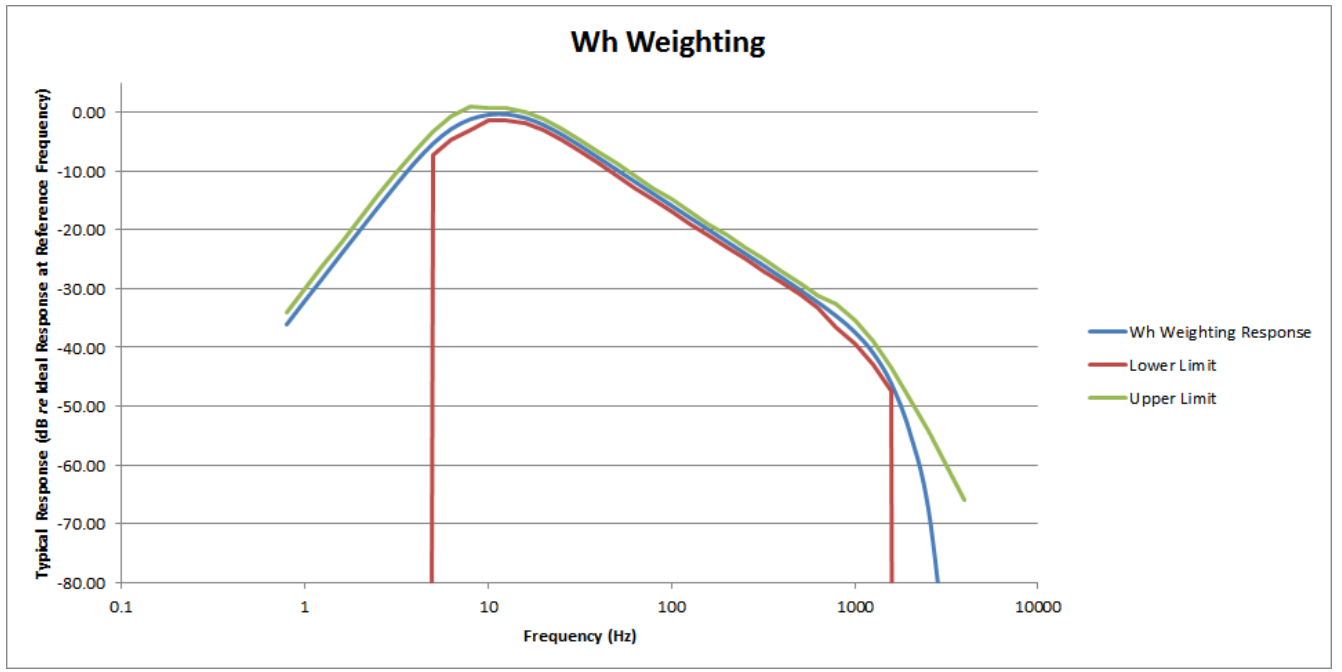
NATURAL FREQUENCY

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

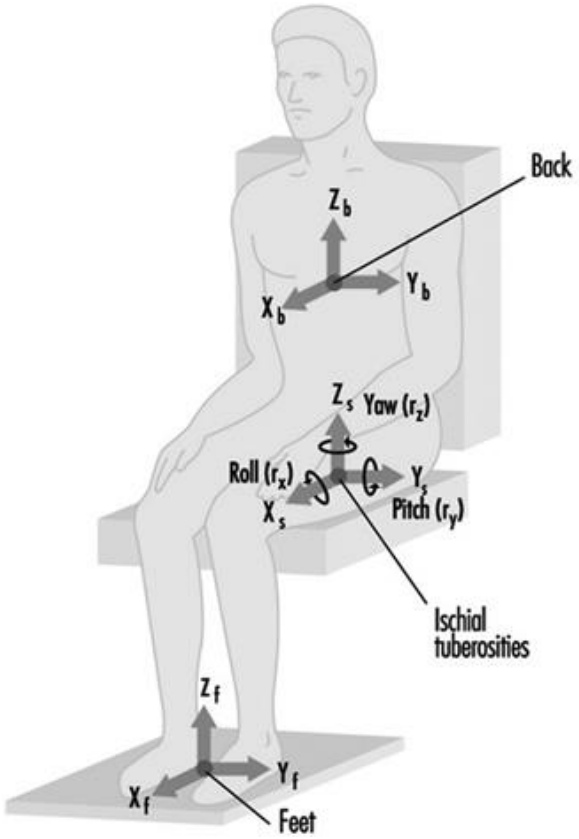
FREQUENCY WEIGHTING (HAND-ARM)

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

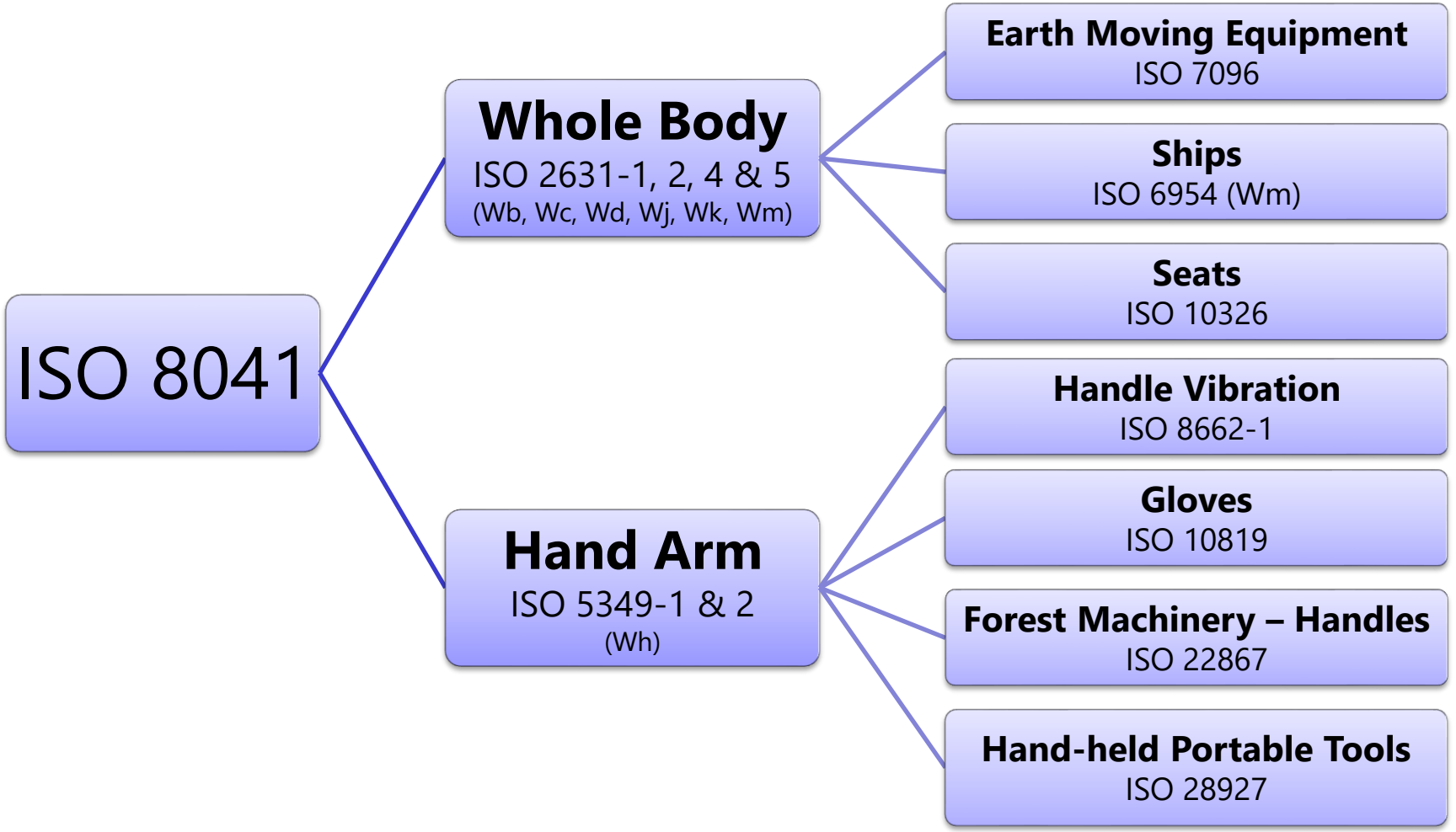


FREQUENCY WEIGHTING (WHOLE BODY)

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



STANDARDS


ISO 8041
Whole Body
ISO 2631-1, 2, 4 & 5
(Wb, Wc, Wd, Wj, Wk, Wm)
Hand Arm
ISO 5349-1 & 2
(Wh)
Earth Moving Equipment
ISO 7096
Ships
ISO 6954 (Wm)
Seats
ISO 10326
Handle Vibration
ISO 8662-1
Gloves
ISO 10819
Forest Machinery – Handles
ISO 22867
Hand-held Portable Tools
ISO 28927

EXAMPLE MEASUREMENT SYSTEM

Components

- **Meter**
- **Accelerometer**
- **Adapter or mount**
- **Software**

Features

- Wireless control

ADAPTERS & ACCESSORIES

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

WHAT IS MEASURED? ACCELERATION

Acceleration = the rate of change for speed or velocity

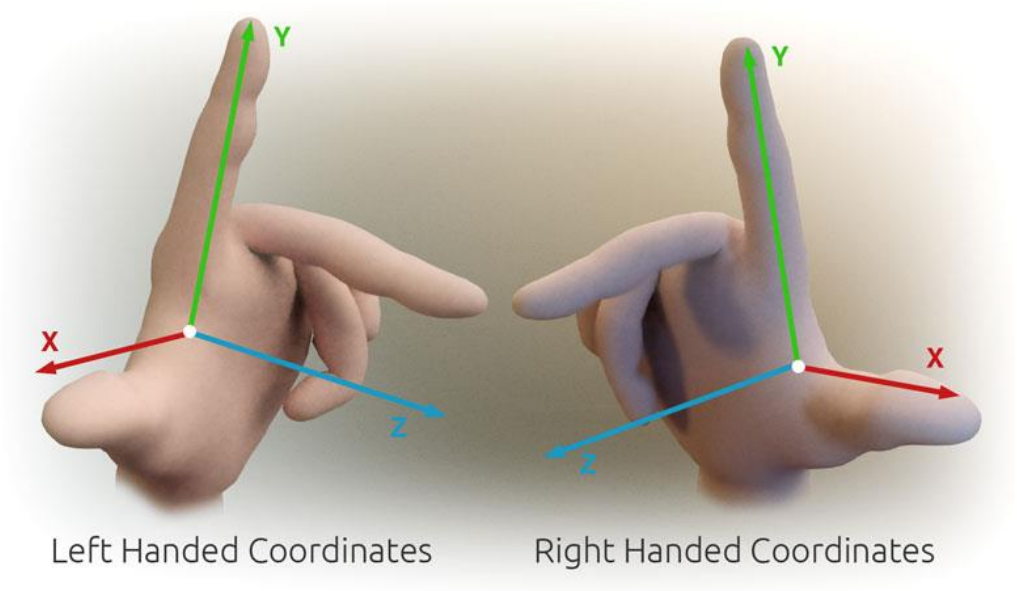
Accelerometer = used to measure acceleration

Units = m/s^2

WHAT IS MEASURED? TRIAXIAL

Measure in three dimensions commonly labelled x, y, and z. Like height, width, & depth.

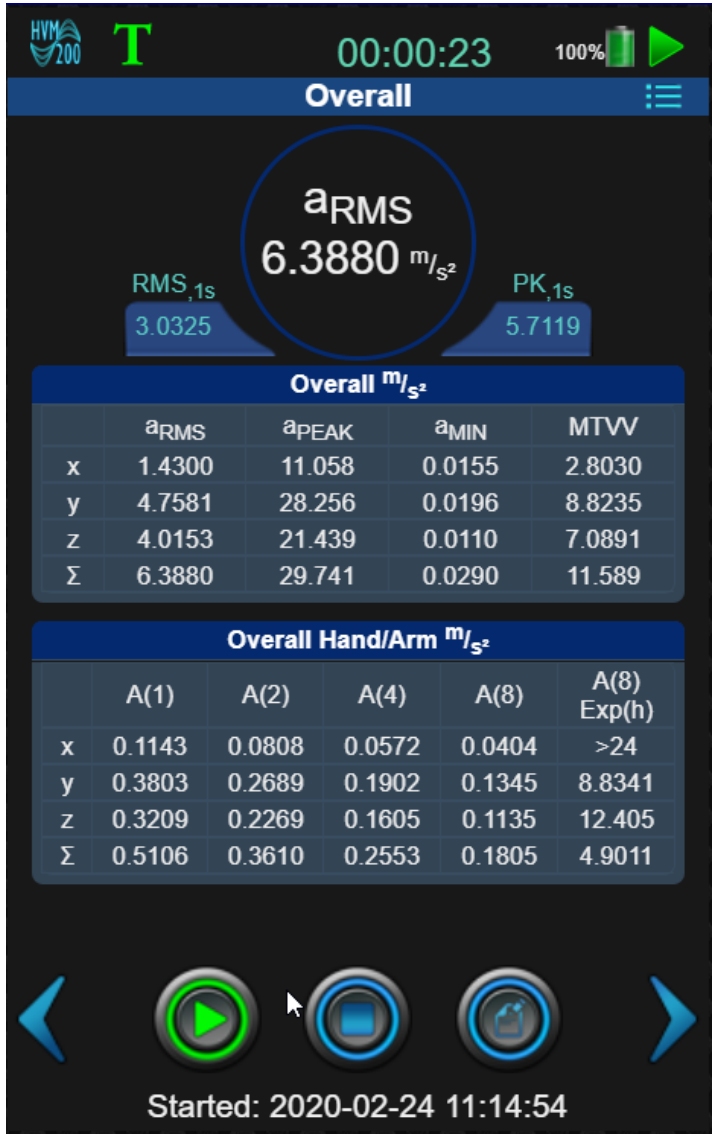
$$Sum = \sqrt{x^2 + y^2 + z^2}$$



By Primalshell - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=27531327

WHAT IS MEASURED? METRICS

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



TRADING TIME FOR EXPOSURE

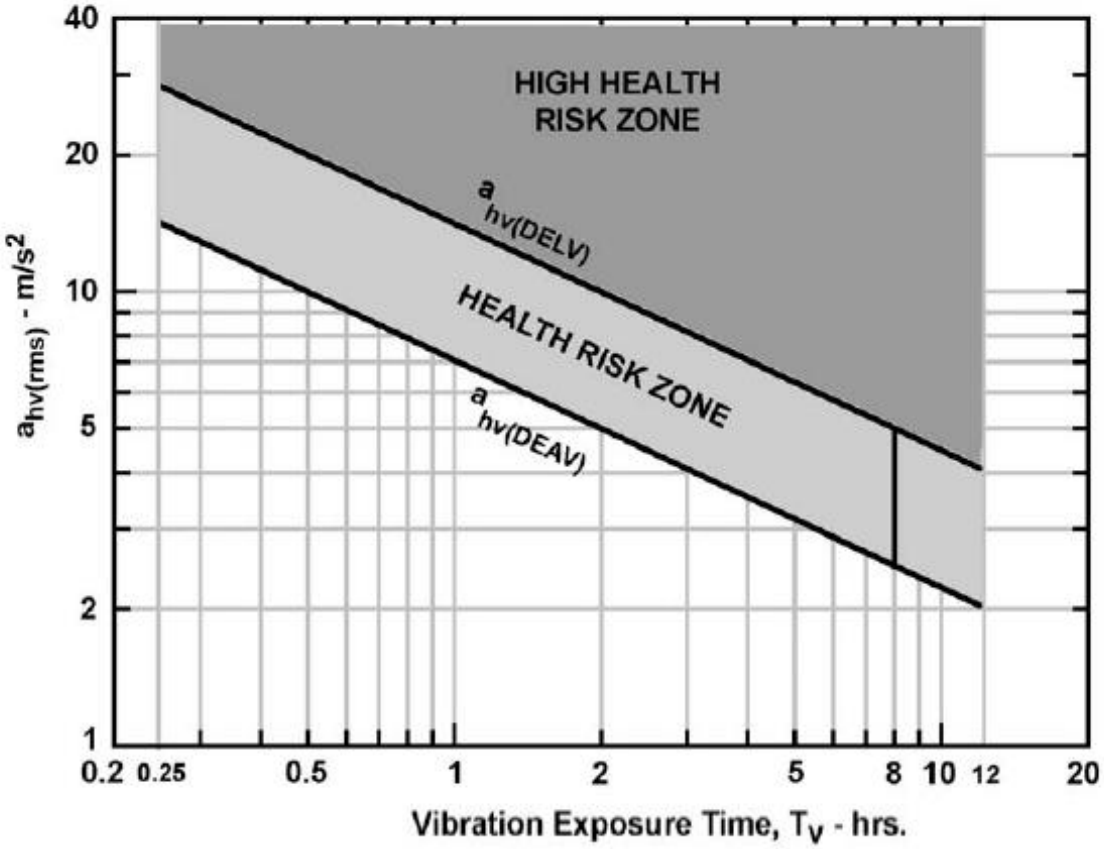


Figure A.1 — Plots of the $a_{hv(DEAV)}$ and $a_{hv(DELV)}$ values for vibration exposure times other than 8 hours

From ANSI S2.70-2006 and ISO 5349

SAMPLE DATA

	x	y	z	Sum	Units
a_{RMS}	0.5308	0.0453	0.2576	0.5918	m/s²
MTVV	0.7506	0.0546	0.3603	0.8344	m/s²
a_{PEAK}	2.6416	0.2351	1.2674	2.9392	m/s²
a_{MIN}	0.4681	0.0357	0.2248	0.5205	m/s²
A(1)	0.0177	0.0015	0.0086	0.0197	m/s²
A(2)	0.0125	0.0011	0.0061	0.0139	m/s²
A(4)	0.0088	0.0008	0.0043	0.0099	m/s²
A(8)	0.0063	0.0005	0.0030	0.0070	m/s²
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**
   a) Power tools in use and/or medical diagnosis of injury
   b) Workers report tingling or “pins and needles” feeling
   c) Documented case HAV syndrome

B. **Determine exposure**
   a) Measure
   b) Model

C. **Control the risk**
   a) Limit exposure time
   b) Lower vibration levels
   c) Vibration isolation - like gloves

LIMIT EXPOSURE TIME

If vibration levels too high:

- Rotate workers on high vibration tool
- Break work into multiple shifts

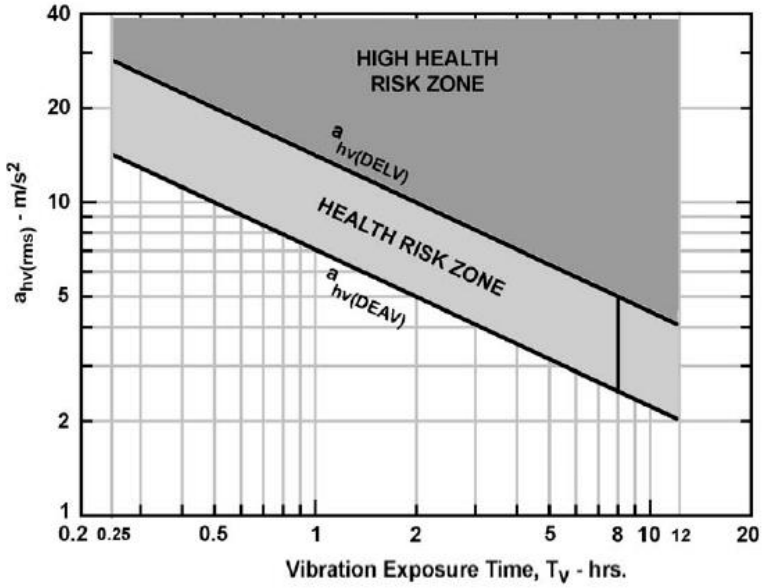
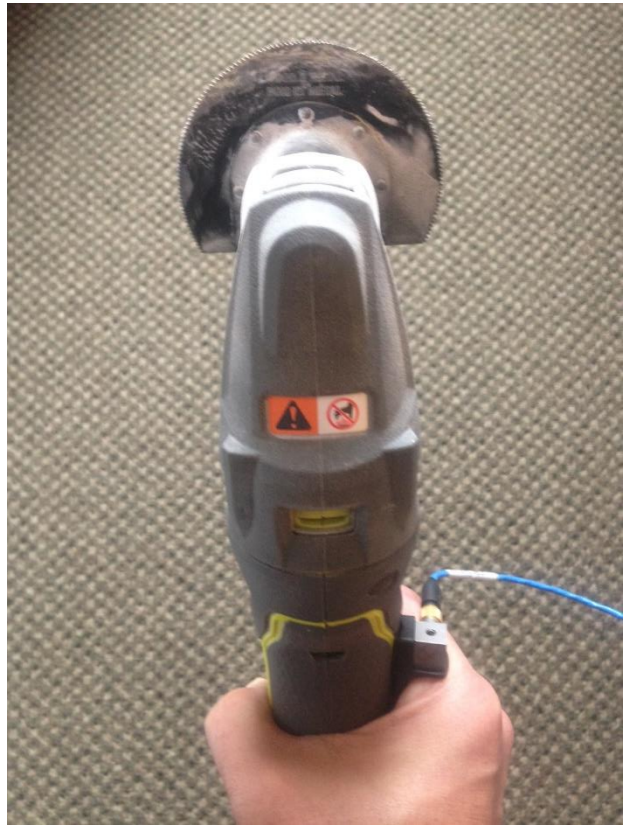


Figure A.1 — Plots of the $a_{hv(DEAV)}$ and $a_{hv(DELV)}$ values for vibration exposure times other than 8 hours

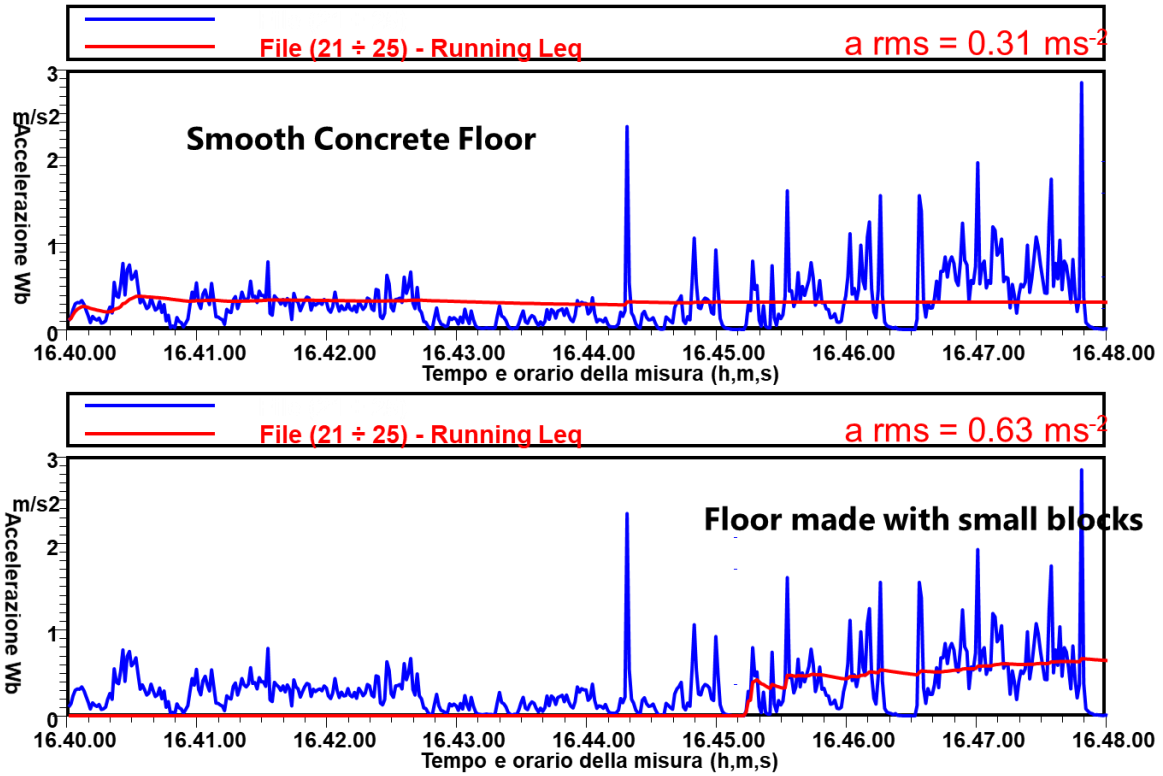
LOWER VIBRATION LEVELS

If vibration levels too high

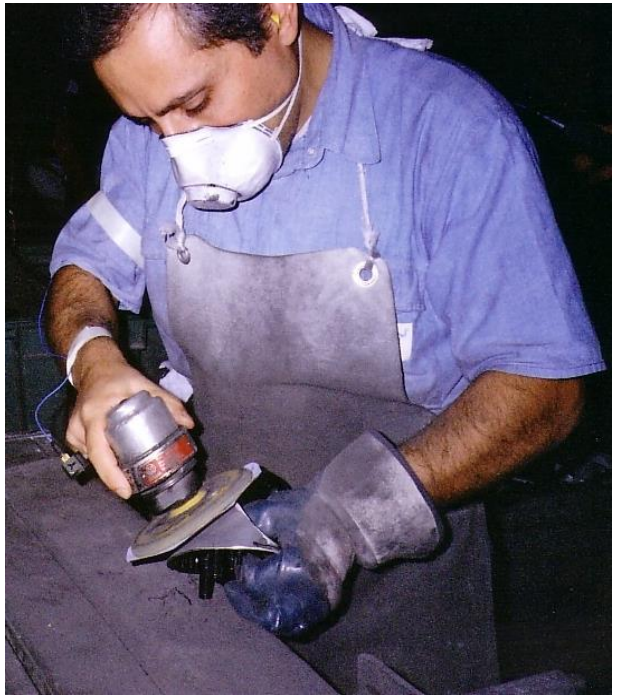
- Training on proper use of tool
- Ensure tool properly maintained
- Replace tool with model producing less vibration
- Use vibration isolation like gloves



EXAMPLE
WHOLE BODY – FORKLIFT SURFACE



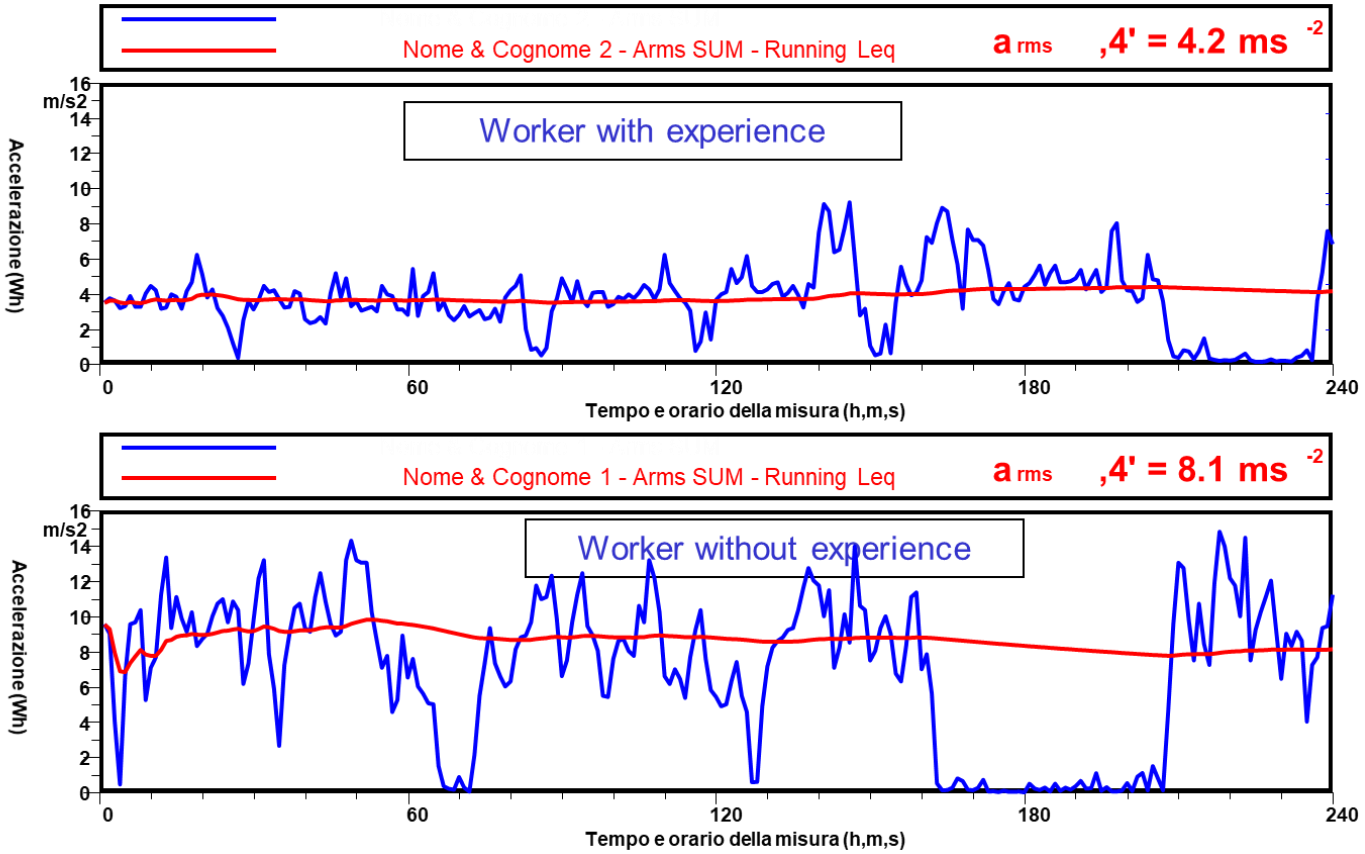
EXAMPLE
HAND-ARM, WORKER EXPERIENCE



Worker with experience

Inexperienced worker

EXAMPLE
HAND-ARM, WORKER EXPERIENCE



QUESTIONS?

Jake Nurre

jnurre@pcb.com

513-658-1986