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Pilanesberg, South Africa

Occupational Vibration Exposure

Canadian Centre for Occupational Health and Safety

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Acknowledgements

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- Richard Neitzel, MS, IHIT
- Michael Yost, PhD
- University of Washington
- Department of Environmental Health
- Queensland University Au website

Occupational Vibration Exposure

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Occupational Vibration Exposure

1. Introduction
2. Vibration Basics
3. Types of Vibration Exposure - Hand Arm and Whole Body Vibration Exposure
4. Why Worry About Vibration Exposure

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Occupational Vibration Exposure

5. Hand Arm Vibration Exposure
6. Whole Body Vibration Exposure
7. Vibration Exposure Standards
8. Exposure Control
9. Case Examples

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Introduction: The Work of Health and Safety

- Identify the Hazard
- Evaluate the Risk
- Develop a Program: Eliminate or Reduce Risk
- Implement the Program
- Evaluate Effectiveness
- Improve Continuously

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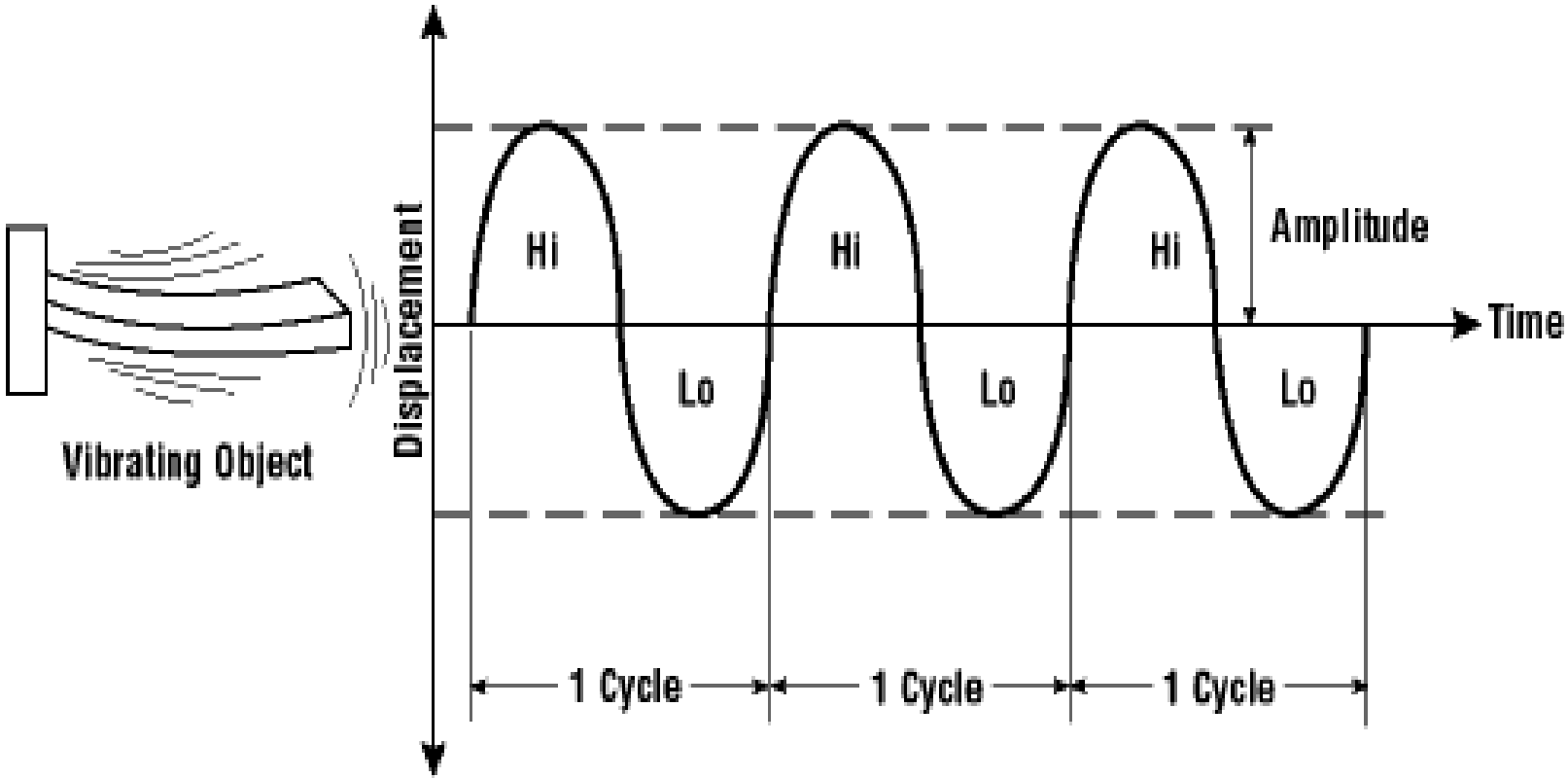
Vibration Basics



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Measures of Vibration Exposure

Magnitude: Acceleration meters per second squared (m/s^2)

Frequency: Hz

Direction: x, y, z

Exposure duration: Years

Posture: Awkward. Static

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Quantifying Vibration Exposure

- Measure vibration exposures by task, tool, trade, operation
- Determine worker exposure
- Identify problematic equipment
- Recommend appropriate control strategies
- Assess potential of worker self-reporting

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Types of Vibration Exposure

- Whole Body Vibration: Vibration transmitted through a supporting area to whole body: sitting in a chair, standing on vibrating ground
  0.5 - 80 Hz; ISO 2631-2
  Sea sickness 0.1- 0.5 Hz, ISO 2631-1
- Hand Arm Vibration: Vibration transmitted through hand: holding a vibrating tool, 5 - 1500 Hz, ISO 5349-1

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Occupational Exposures

- Whole Body Vibration
- Agriculture
- Construction
- Forestry
- Transportation etc
- Hand-Arm Vibration
- Boiler Making
- Forestry
- Furniture Making
- Road Construction etc

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Why Worry About Vibration?

- Regular and frequent exposure to vibration can lead to permanent health effects
- This is most likely when contact with a vibrating tool or work process is a regular part of a person's job

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Vibration Adversely Affects the Body

- Mechanical Effects
- Psychological Effects
- Very difficult to assess
- Contributes to WMSDs

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Risk Assessment of Vibration Exposure

- Magnitude, type and duration of exposure
- Health effects of exposure to vibration
- Effects of vibration on the workplace and work equipment
- Information provided by the manufacturers

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Risk Assessment of Vibration Exposure

- Availability of replacement equipment designed to reduce vibration exposure
- Exposure beyond normal working hours
- Working conditions such as low temperatures

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Hand-Arm Vibration Exposure

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Examples - Tools That Can Cause Hand-Arm Vibration Injuries

Chipping Hammers	Grinders	Cutters
Pedestal Grinders	Nut Runners	Sanders
Road Breakers	Power Hammers	Chainsaw
Hammer Drills	Trimmers	Lawnmowers

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Health Effects

- Vascular (Vibration White Finger)
- Sensory Nerve Damage
- Musculoskeletal

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When is it Hazardous

- Regular and frequent exposure to high levels
- Prolonged Contact with vibrating tools
- Occasional exposure is unlikely to cause injury
- People with medical conditions such as Reynaud's disease are at high risk

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Hand Arm vibration Can Affect Routine Activities

- It can limit the work we can do
- It can affect what we do in our leisure time
- We may have difficulties carrying out tasks that require fine movement or manipulation

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Signs and Symptoms

Sensory Nerve Damage

- Loss of sense of touch or temperature
- Numbness or tingling in the fingers (possibly constantly)

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Signs and Symptoms

Musculoskeletal

- Loss of grip strength in the hands
- Pain in your hands and fingers
- Painful wrists

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White Finger

www.whitefinger.co.uk/images/hand.jpg

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Hand Arm Vibration Syndrome 2

Rare case of gangrene in hands of vibrating pneumatic hand-tool operator at terminal stage of irreversible Hand Arm Vibration Syndrome2

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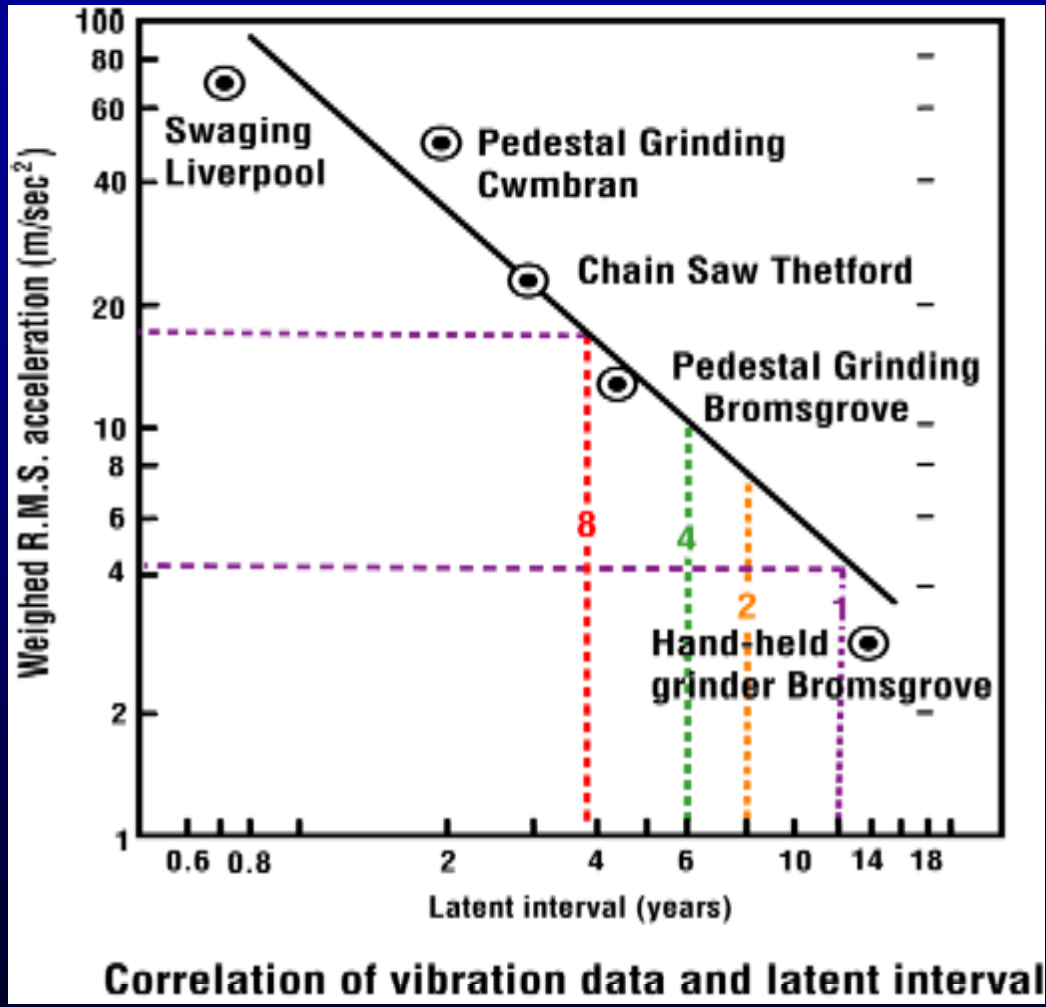
Correlation of Vibration Data



Correlation of vibration data and latent interval

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Table 4: Average Latent Periods for Vibration-induced Diseases in Different Occupations

Occupation	Stage of VWF	Latency (years)
Foundry worker	Tingling Numbness Blanching	1.8 2.2 2.0
Shipyard worker	Tingling Numbness Blanching	9.1 12.0 16.8
Chainsaw operator	Numbness	4
Grinder	Blanching	13.7

Source: Vibration effects on the hand and arm in industry. Edited by A.J. Brammer et al. New York: John Wiley and Sons, 1982

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Vibration Induced Disorders of the Hand

- Hand-Arm Vibration Syndrome (HAVS)
- Vascular Disorders- Raynaud's Syndrome (white-finger); complex reduction of blood flow
- Bone and Joint
- Neurological and Muscular disorders
- Sensory loss
- Muscle atrophy: voluntary & involuntary contractions contributing to fatigue

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Stockholm (Revised) Hand-arm Vibration Syndrome Classification System (Vascular)

Stage	Symptom
0	No Attacks
1	Occasional, 1 or More Finger Tips
2	Occasional, Distal & Middle Finger
3	Frequent Attacks All / Most Fingers
4	Same as 3 With Skin Change in Finger Tips

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Stockholm (Revised) Hand-arm Vibration Syndrome Classification System (Sensory Neural)

Stage	Symptom
0SN	No Attacks
1SN	Intermittent Numbness
2SN	Same as 0SN + Reduced Sensory Perception
3SN	Same as 2SN with Reduced Tactile & Discrimination & Manipulative Dexterity

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Objective Tests

- Cold Provocation Test
- Plethysmography
- Two Point and Depth Sense
- Vibro-Tactile Threshold
- Moberg Pick-up and Object Recognition
- Nerve Conduction Velocity

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Effect of Smoking Railway Track Maintenance

	#	Age (y) Mean(sd)	Work (y) Duration (sd)	VWF %
Nonsmoker	53	37.6 (13)	11.7 (9.6)	8.0
Ex-smoker	70	46.8 (10.4)	17.1 (10.2)	16.9
Smoker	127	39.0 (10.3)	12.2 (7.2)	18.4

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What increases the risk?

- How high the vibration levels are
- How long the equipment is in use
- How awkward it is to use the equipment
- How tightly the equipment is gripped
- How cold and wet the individual is during use
- Social & medical factors

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Hand Arm Vibration Measurement

- Instrumentation
- Measurement methodology

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Measurement of Hand Arm Vibration Exposure

- Triaxial accelerometer is typically used
- Standards (ISO 5349; ACGIH) provide detailed guidelines on measuring vibration.
- Acceleration levels are weighted according to frequency to determine if vibration level is "acceptable" for a certain exposure.

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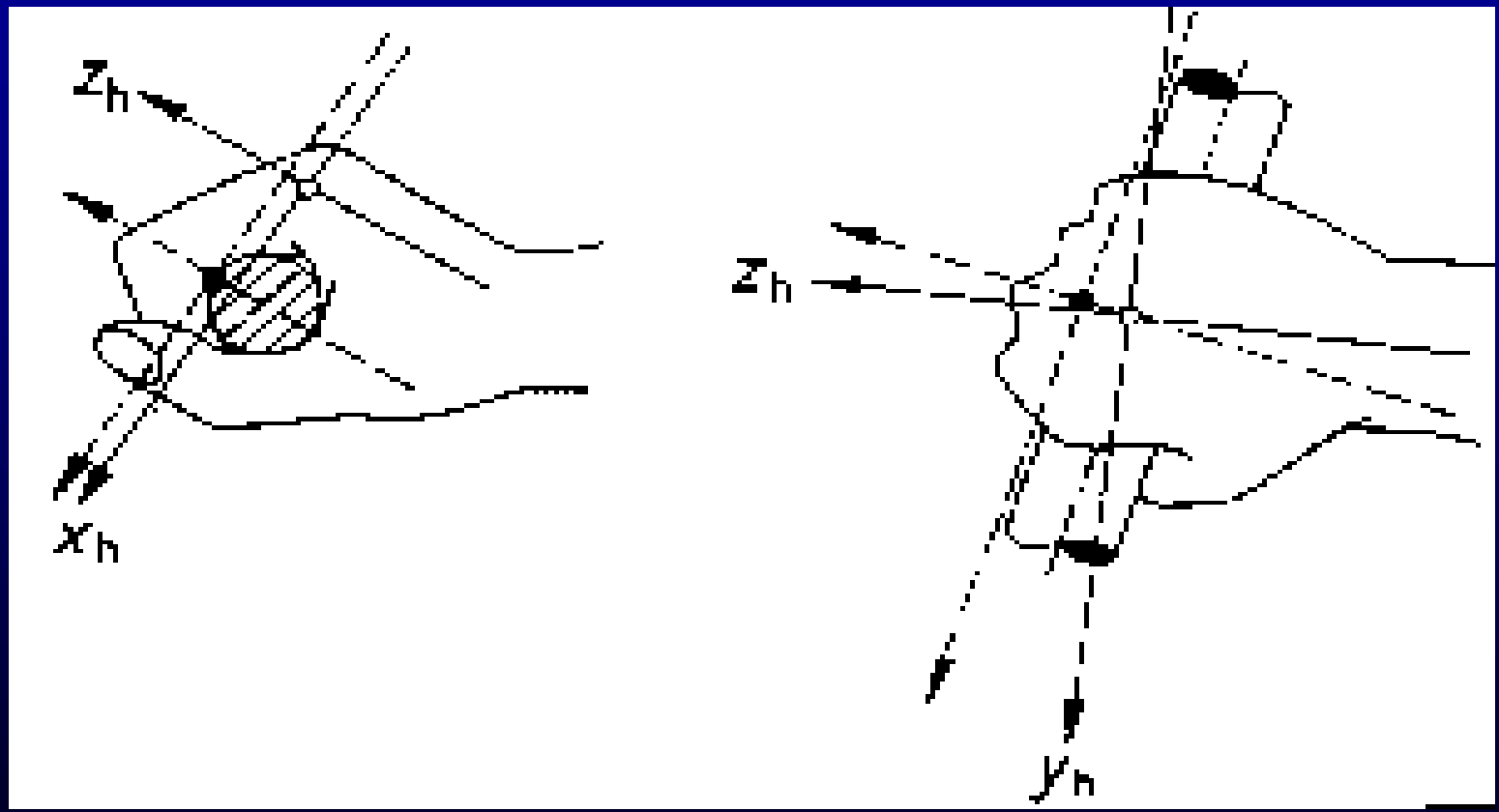
Measuring Hand Arm Vibration



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Measuring Hand Arm Vibration

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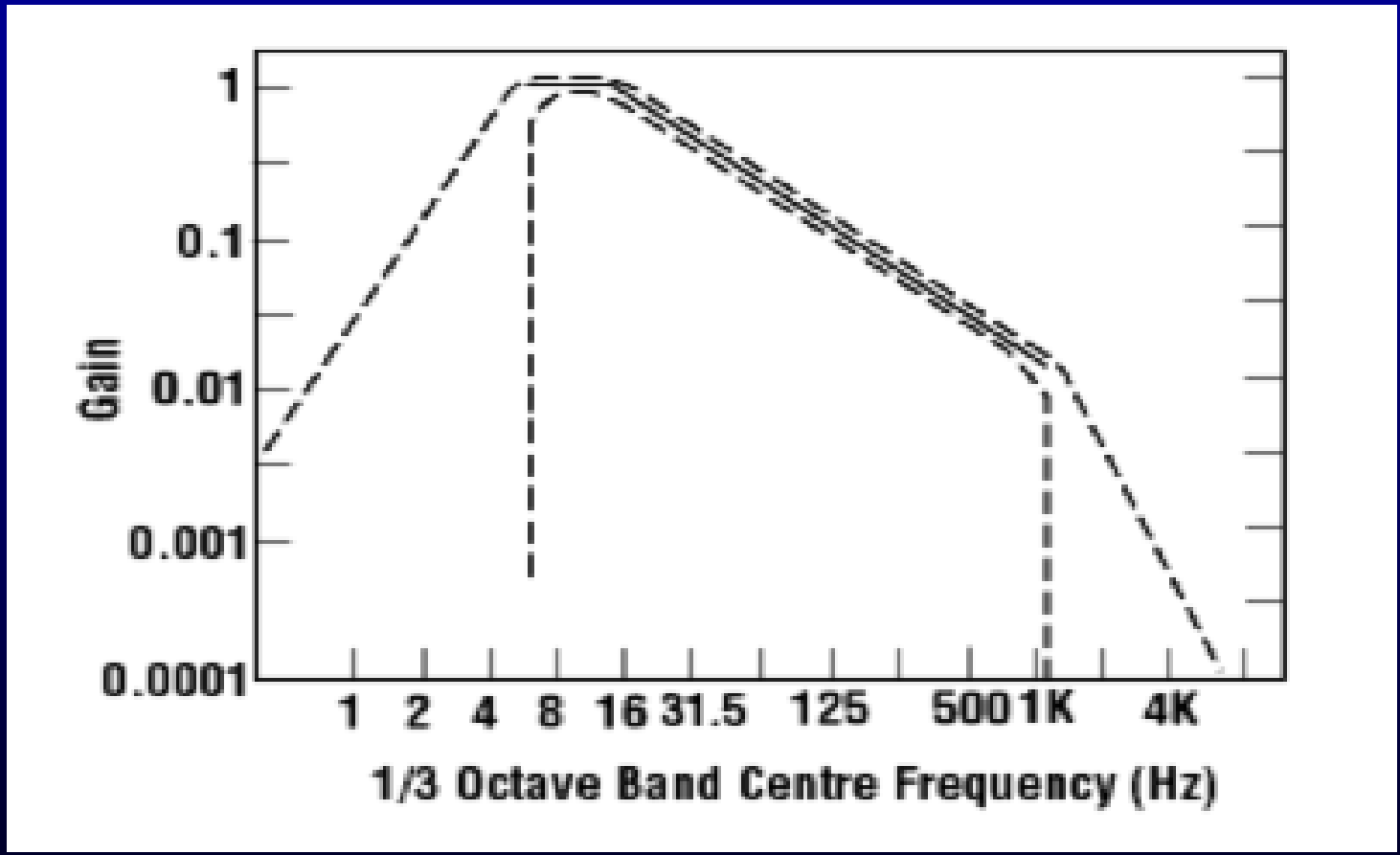
Hand Arm Vibration Weighting Curve



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Typical Vibration Levels

http://www.hse.gov.uk/vibration/index.htm

- Pneumatic stone-working hammers
  Vibration-reduced hammers & sleeved chisels 8-12 m/s2
  Older tools, conventional chisels 30 m/s2
- Chainsaws Typical 6 m/s2
- Brush cutters Typical 4 m/s2, Best 2 m/s2
- Sanders (random orbital)
  Typical 7-10 m/s2

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Examples of Hand Arm Vibration Exposure Levels

Notching Stumps: $A_{EQ}x$ 23.36 m/s^2

- TLV less than 1 hr/day

Felling Trees: $A_{EQ}x > 8$ m/s^2

- TLV: 1-2 hrs/day

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Vibration Dose

- Combines vibration magnitude and time
- "Normalised" over standard 8-hour working day, expressed as the value,
  A(8) in m/sec²
- The A(8) aids comparison between exposure patterns and assessment of health risk
- A programme of actions is recommended where the A(8) regularly exceeds
  2.5 m/sec²

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Minimizing Exposure

- Make sure your tools are maintained
- Use the right tool for the job
- Do not use any more force than necessary
- Avoid long periods of use without a break
- Keep yourself warm
- Report any symptoms

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Exposure Limits

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Table 1: TLVs for Exposure of the Hand to Vibration in Either of the X, Y, or Z direction*

Total Daily Exposure Duration (hours)	Maximum value of frequency weighted acceleration (m/s^2) in any direction*
4 to less than 8 hours	4
2 to less than 4 hours	6
1 to less than 2 hours	8
less than 1hour	12

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EU Vibration Exposure and Action Limits, A(8)

Hand Arm Vibration

- Exposure Limit 2.5 m/s2
- Exposure Action Value 5.0 m/s2

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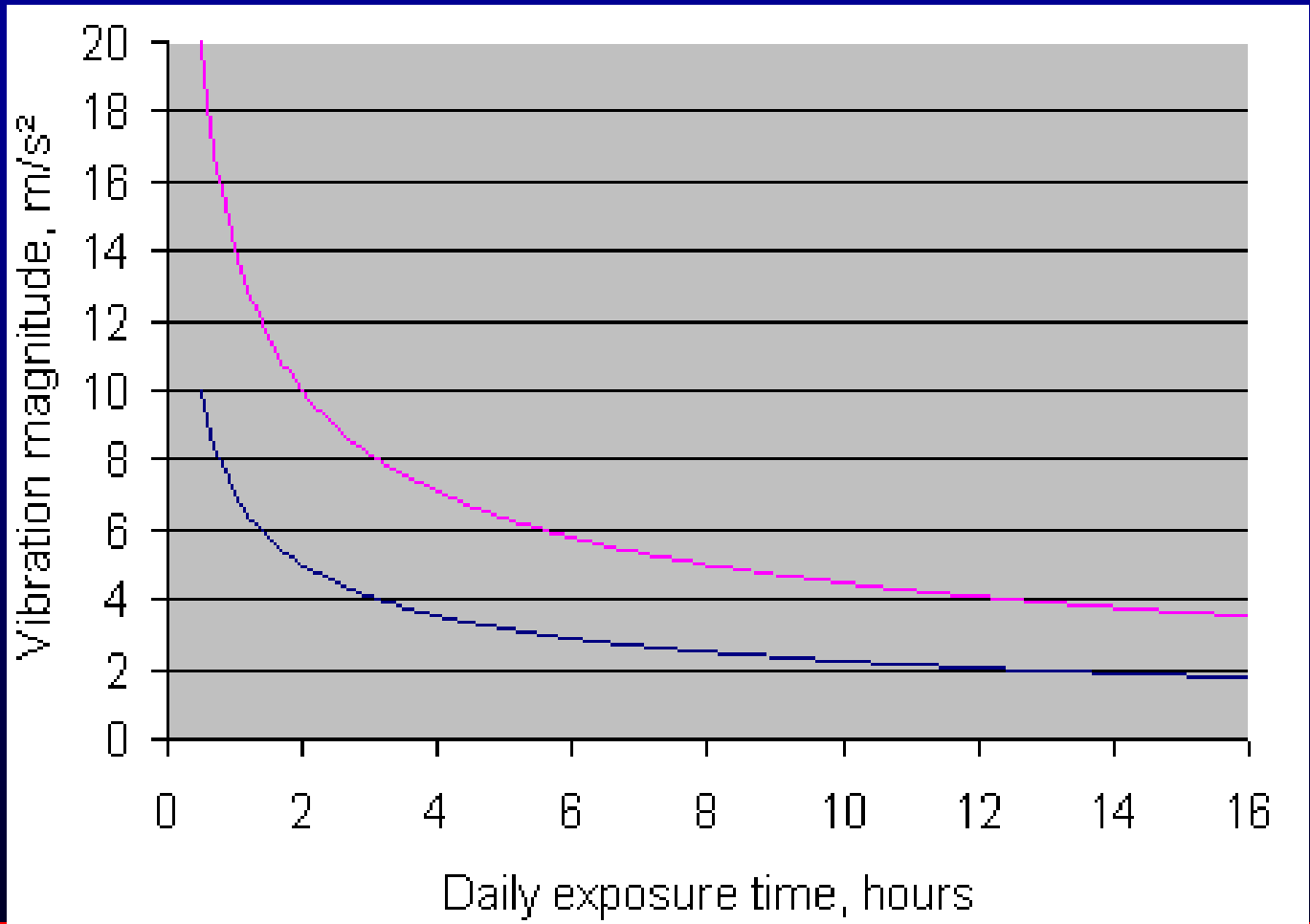
Exposures Equivalent to the Daily Action and Limit Values



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Recap

- Potential sources of Hand-Arm vibration
- Risk factors
- Signs & symptoms
- Use tools correctly
- Protect yourself
- Report problems

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Whole Body Vibration

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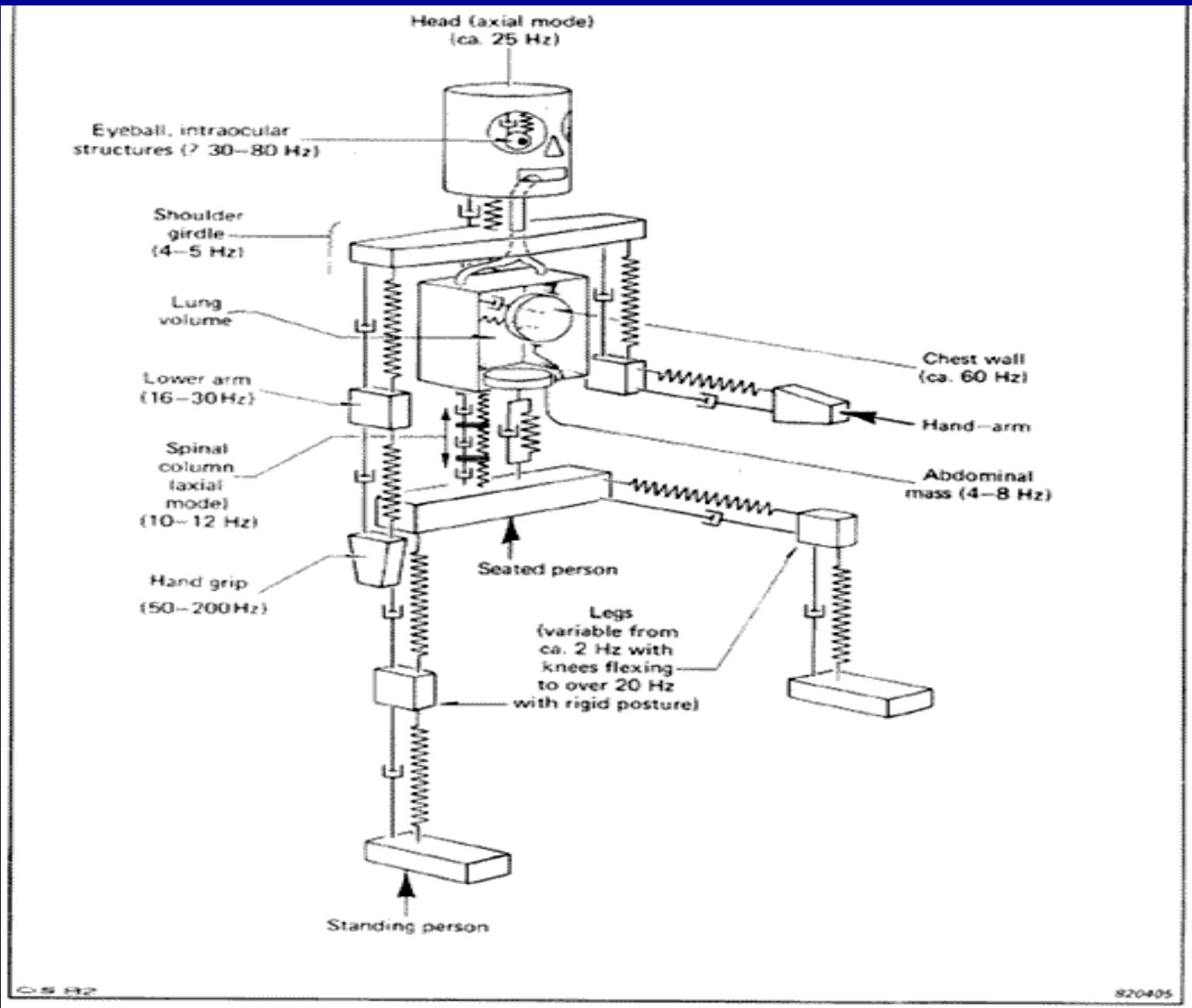

Fig. 1. Simplified mechanical system representing the human body standing on a vertically vibrating platform

Health Effects of Prolonged Exposure to Whole Body Vibration

- Lumbar spinal disorders
- Hemorrhoids
- Hernias
- Digestive problems
- Urinary problems

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Effect of Vibration on Spine

- Increased risk in low-back pain for drivers of trucks, buses, and
- Three Frequency Ranges
- Low Frequencies 0-2 Hz
- Middle Frequencies 2-20 Hz
- High Frequencies >20 Hz Cranes Vehicles, Aircraft Power Tools

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Vibration Measurement

- Triaxial accelerometer is typically used
- Standards (ISO 5349; ACGIH) provide detailed guidelines on measuring vibration
- Acceleration levels are weighted according to frequency to determine if vibration level is "acceptable" for a certain exposure

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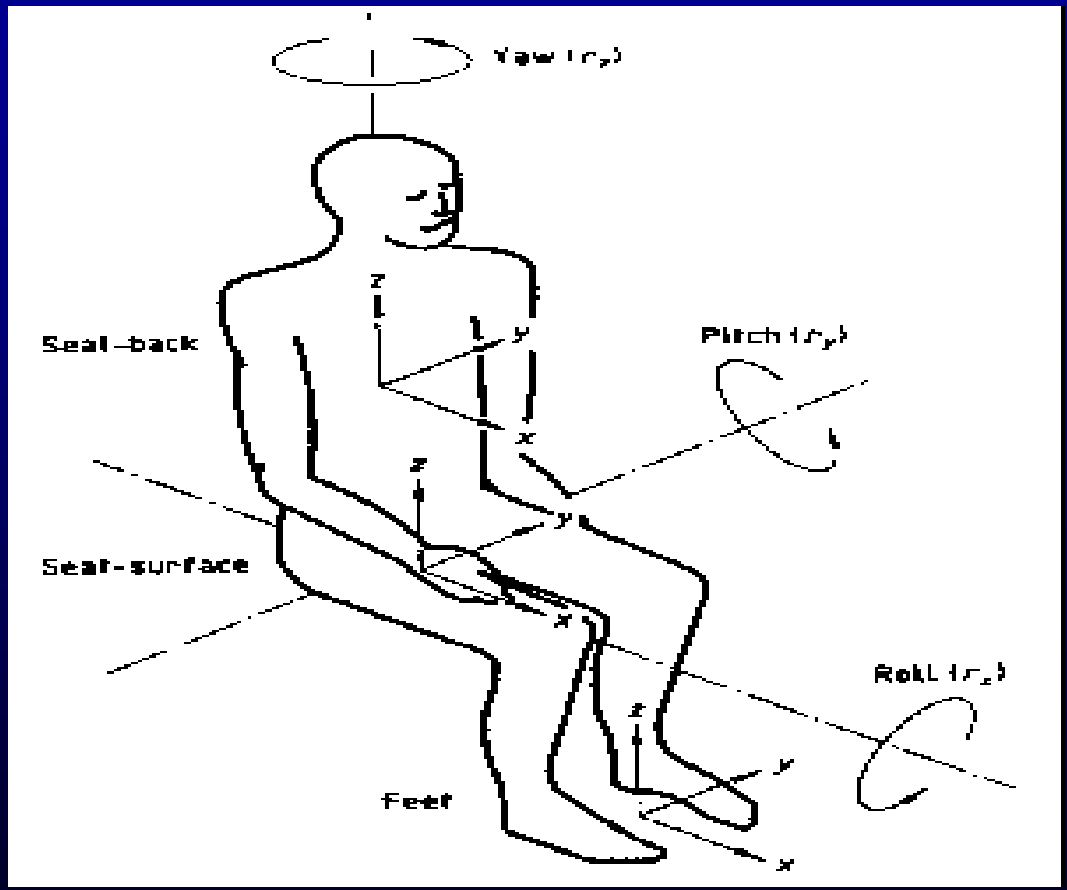
Exposure Standards - Vibration

H-A and W-B vibration measured in 3 axes



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Methods

- Workers participate voluntarily
- Participation incentives
- Exposures Measurement at various sites and for various tasks :
  - Workers fill out self-report task data cards listing timing of daily tasks/tools
  - Workers observed periodically to assess self-report accuracy

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Instrumentation

- Commercially available
- Log continuously throughout vibration event
- PC download yields event runtime, overall A_{EQ}, and L_{max}, L_{min}, L_{peak}, and A_{EQ} for three channels
- Triaxial measurements using three piezoelectric accelerometers

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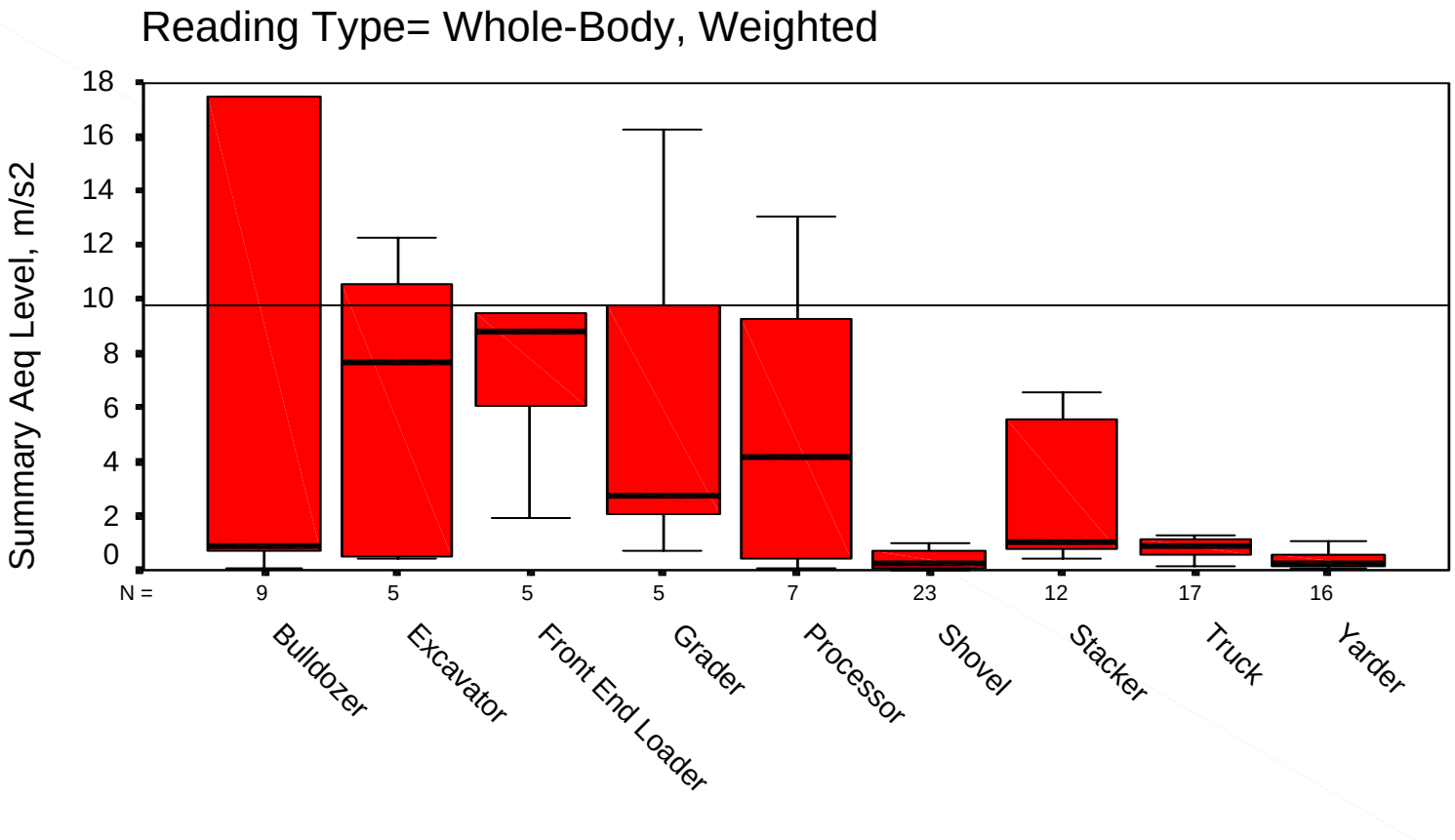
Example of Results



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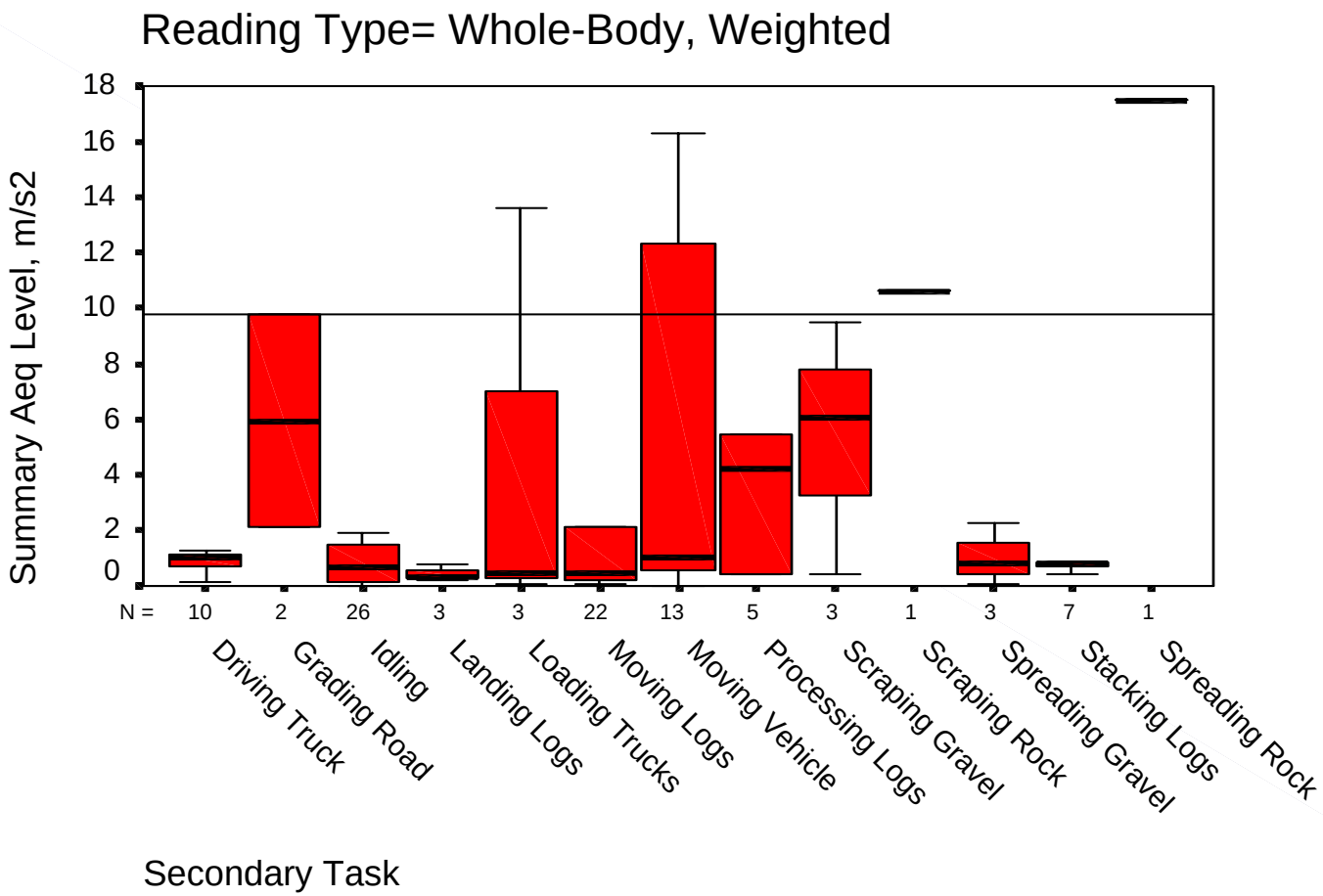
Examples of Vibration data



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ACGIH WBV TLV Exposure Values

Total Daily Exposure Duration, hrs	Value of Dominant RMS Acceleration Component, m/s^2
8 to less than 16	2.2
4 to less than 8	3.4
2.5 to less than 4	4.8
1 to less than 2.5	8.1
25 min to less than 1	12.1
16 min to less than 25 min	14.4
1 min to less than 16 min	19.2

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Daily (8 hour) Exposure Limit (UK)

- Daily exposure limit value 1.15 m/s2
- Action value 0.5 m/s2

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Whole Body Vibration Exposure ACGIH TLV

- Same as ISO 2631
- Presented a set of graphs
- Frequency Weighting
- Axis weighting
- Exposure time weighting

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Vibration Exposure During Pregnancy: Prevention

It is advised that pregnant workers and those that have recently given birth avoid work that is likely to involve uncomfortable, whole body vibrations, especially at low frequencies, or where the abdomen is exposed to shocks or jolts.

South Africa 1998/reg98-1441

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Directive 2000/14/ EC (Almost all equipment for use outdoors)

- Daily exposure action value: 0,5 m/s2
- Daily exposure limit value: 1,1 m/s2

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Whole-body Vibration Exposure Limits in x, y, or z Directions

(Work Safe BC Canada)

Daily Exposure Duration	Values of the dominant, frequency-weighted (rms), component acceleration, ms^{-2}		
	No clear effects	Caution	Health risks likely
4 hours	Less than 0.6	0.6 to 1.1	Greater than 1.1
8 hours	Less than 0.5	0.5 to 0.9	Greater than 0.9

(rms = root mean square, ms^{-2} = metres per second squared)

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Whole Body Vibration Case Study

What are the risk factors?

Source: University of Queensland

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Examples of Vibration Exposure Levels

Whole Body Vibration

- Bulldozer, FEL, Grader: $A_{EQ}z$ >4.84 m/s^2
  - 2.5-4 hrs/day recommended by TLV, but operated 8 hrs
  - Overall $A_{EQ}z$ for Operating Vehicle: 2.39 m/s^2 = 4-8 hrs/day

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Examples of Vibration Exposure Levels

Hand-Arm Vibration

- Notching Stumps: $A_{EQ}x$ 23.36 m/s^2
  - >12 m/s^2 ;TLV less than 1 hr/day
  - Chainsaw, Felling Trees: $A_{EQ}x$ > 8 m/s^2
  - TLV: 1-2 hrs/day but done for 4-5 hrs

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EU Vibration Exposure and Action Limits, A(8)

Whole Body Vibration

- Exposure Limit 1.15 m/s2
- Exposure Action Value 0.5 m/s2

Hand Arm Vibration

- Exposure Limit 2.5 m/s2
- Exposure Action Value 5.0 m/s2

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Vibration Control

Reducing **vibration** produced and emitted by the source;

Preventing the propagation, and amplification of **vibration**;

Isolating the workers from **vibrating** tools and equipment.

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Whole-body Vibration (WBV) Control

- Suspended adjustable seat with vibration-damping mechanism
- Balanced vehicle wheels
- Tires with a low vibration tread pattern
- Reduced speed over bumpy surfaces
- Avoid sudden load changes (pick up, drop off)

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Whole-body Vibration (WBV) Control

- Avoid bumping into obstacles while driving
- Fit vibration-damping mechanisms
- Maintain shock absorbers on vehicles
- Isolate booths/cabs, etc.
- Train workers

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Hand-arm Vibration (HAV) Control

- Properly maintained tools, anti-vibration mounts and suspended handles
- Grinders with effective, balanced, grinding discs
- Dynamically balanced. Rotary tools
- Grip on the tool handle with the least hand strength practicable
- Handles with a resilient wrapping layer cover

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Hand-arm Vibration (HAV) Control

- “Antivibration" gloves meeting the requirements of *ISO standard 10819-1996*
- Tools with lower vibration level
- Substitution by a process to eliminate or reduce the need for vibrating tools
- Shorter daily exposure time by job rotation

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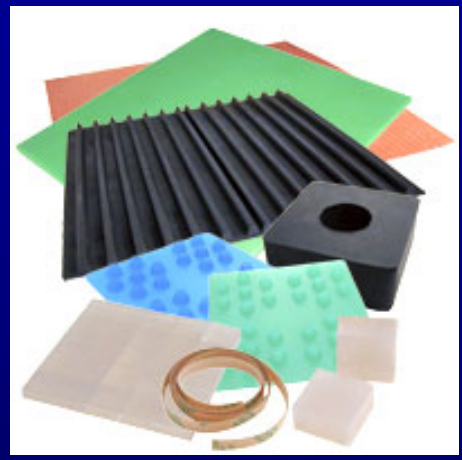
Vibration Isolators



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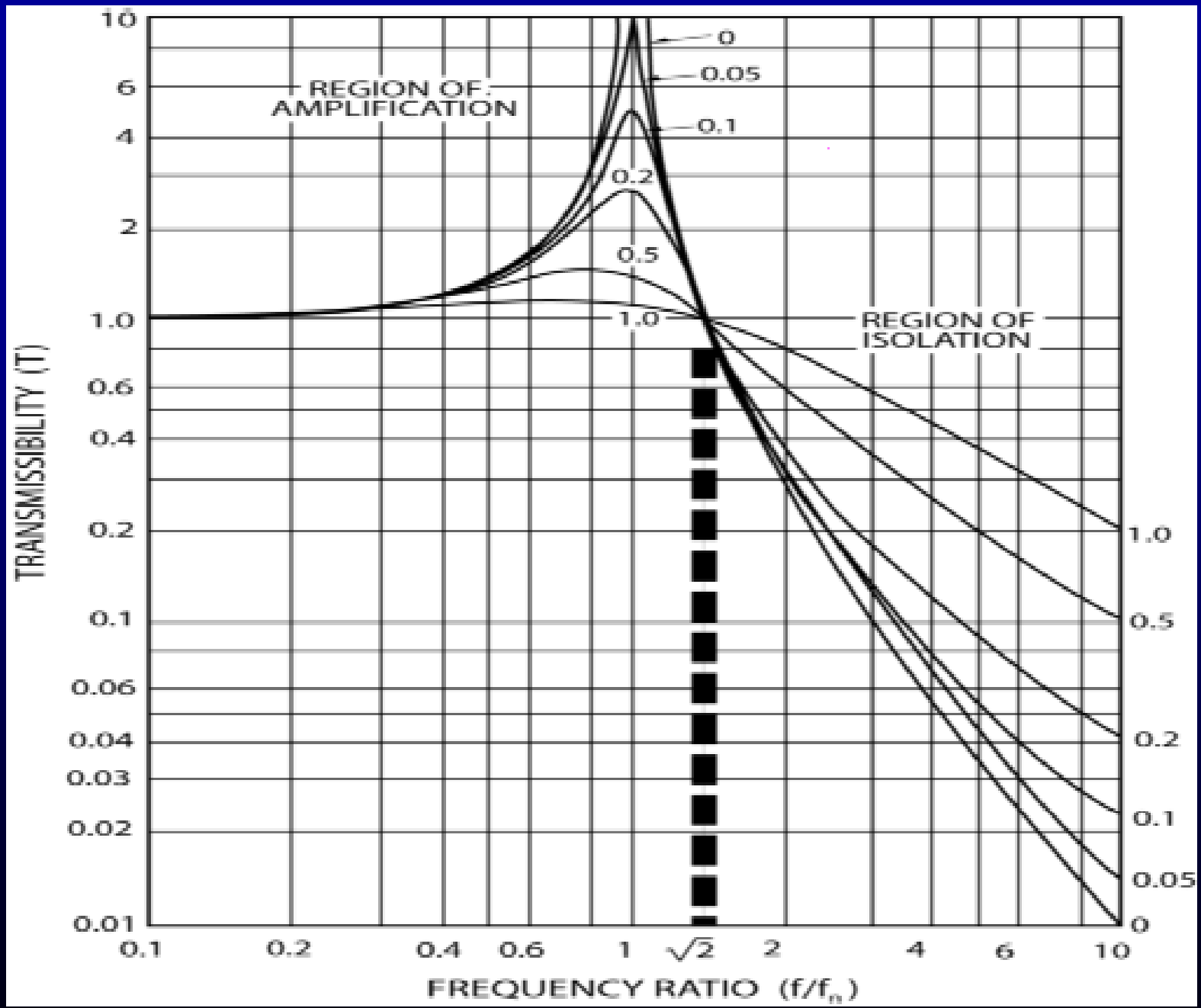
TRANSMISSIBILITY (T)
10
6
4
2
1.0
0.6
0.4
0.2
0.1
0.06
0.04
0.03
0.02
0.01
REGION OF AMPLIFICATION
0
0.05
0.1
0.2
0.5
1.0
REGION OF ISOLATION
1.0
0.5
0.2
0.1
0.05
0
0.1
0.2
0.4
0.6
1
√2
2
4
6
10
FREQUENCY RATIO (f/fn)

Selection a Vibration Isolator

- Establish the total weight and forcing frequency of the equipment to be isolated
- Determine the Static defection required to provide the degree of isolation desired
- Select appropriate spring mounts from the listed spring constants of the mounts supplied by the manufacturer

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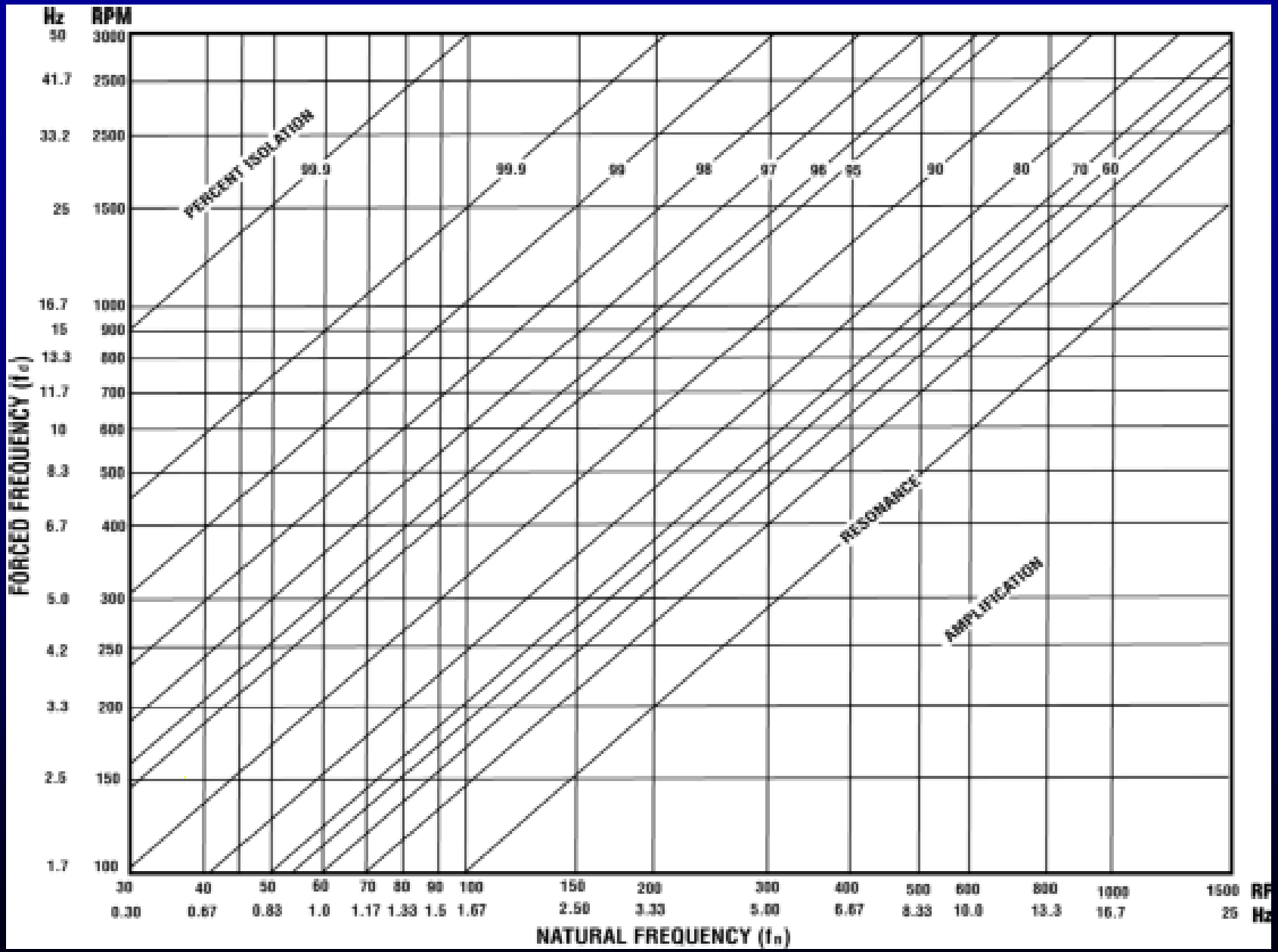
Hz
RPM
50
3000
41.7
2500
33.2
2500
25
1500
16.7
1000
15
900
13.3
800
11.7
700
10
600
8.3
500
6.7
400
5.0
300
4.2
250
3.3
200
2.5
150
1.7
100
PERCENT ISOLATION
99.9
99.9
99
98
97
96
95
90
80
70
60
RESONANCE
AMPLIFICATION
FORCED FREQUENCY (fd)
30
0.30
40
0.67
50
0.83
60
1.0
70
1.17
80
1.33
90
1.5
100
1.67
150
2.50
200
3.33
300
5.00
400
6.67
500
8.33
600
10.0
800
13.3
1000
16.7
1500
25
RF
Hz
NATURAL FREQUENCY (fn)

Natural Frequency (Fn) of a Vibration Isolator

- Fn (Hz) = 4.98 [1/static deflection, cm]$^{1/2}$
- Fn (Hz) = 3.13 [1/static deflection, inch]$^{1/2}$

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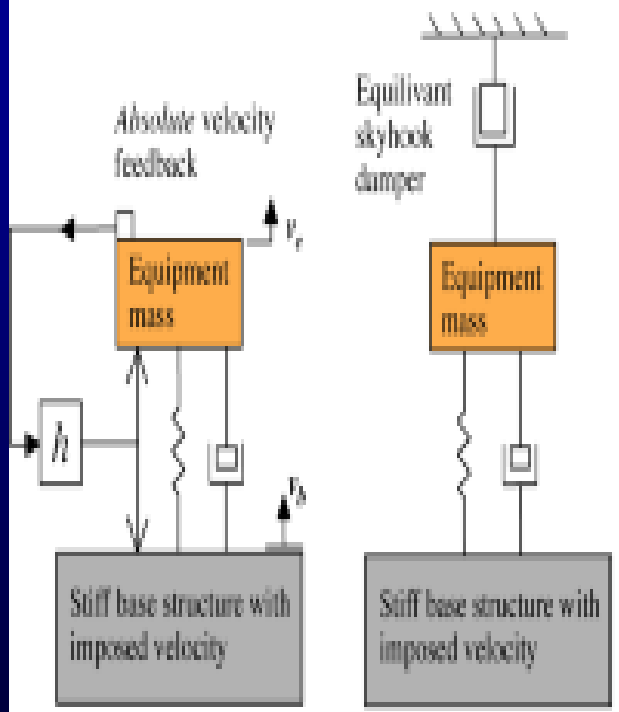
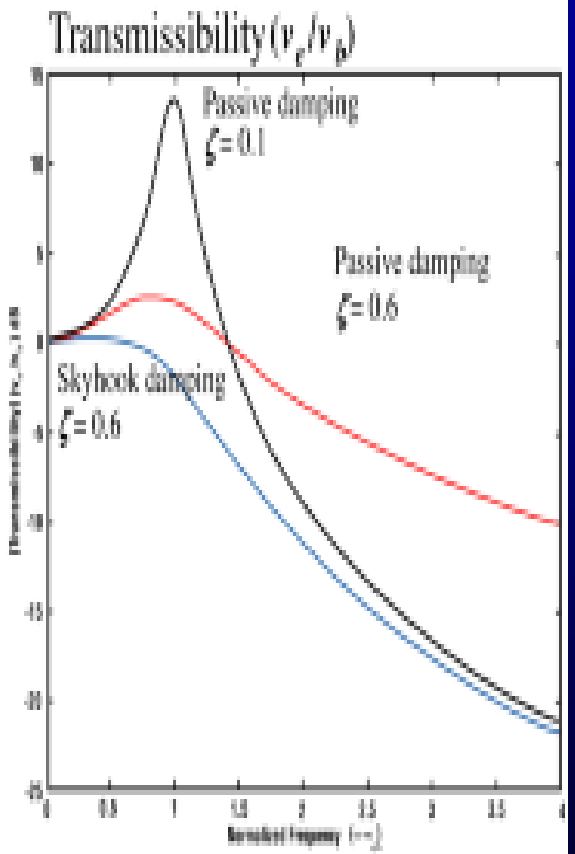
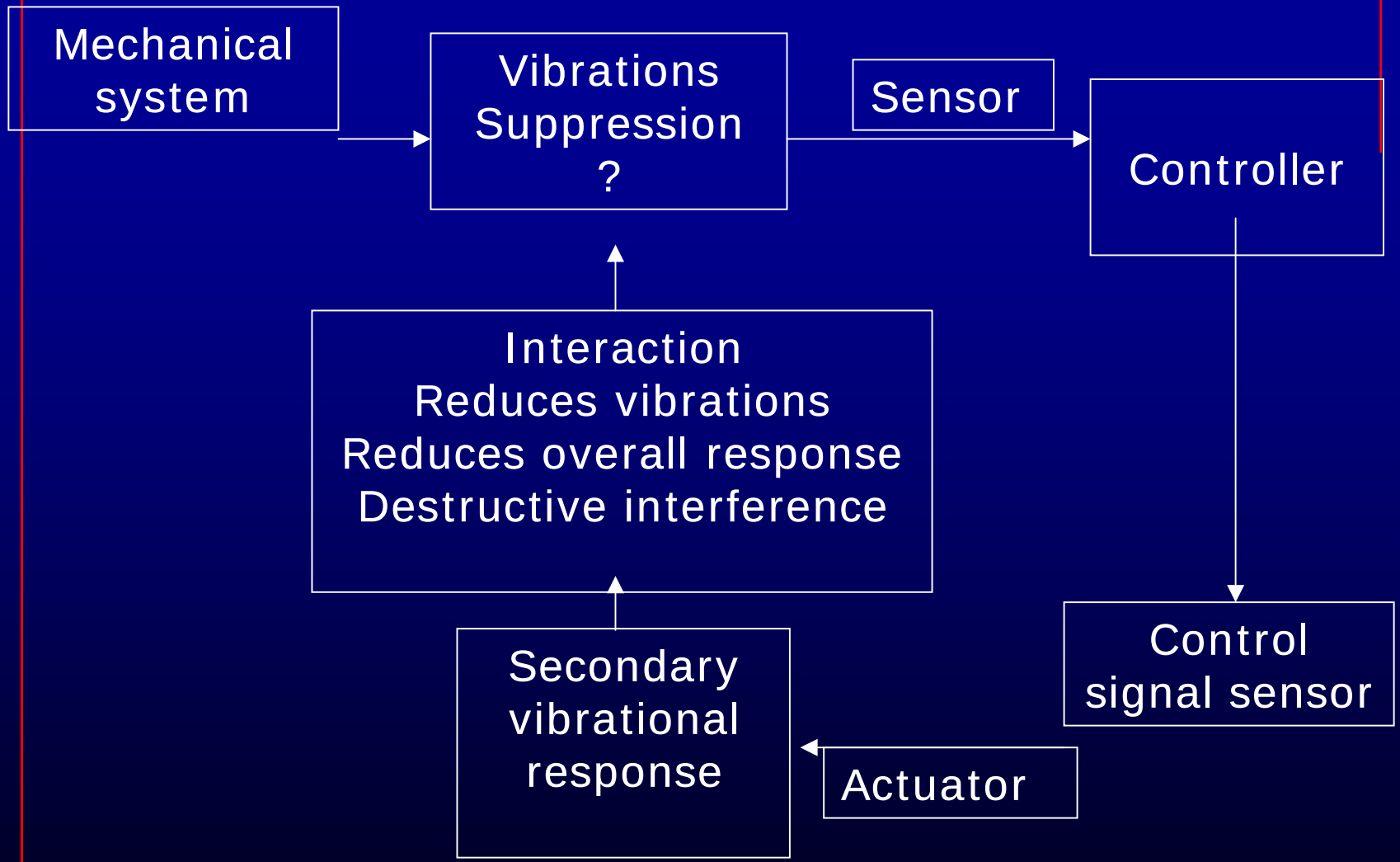
Active "skyhook" of inertial damping (Karnopp 1975)



Ramdom base disturbance





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Example

A motor- generator unit weighing 700 lbs and 500 lbs, respectively, is to be installed in a vibration sensitive area. The motor turns 3600 rpm and the generator at 1800 rpm. Select four spring mounts which will provide a transmissibility of no more than 5%.

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Whole Body Vibration Data Base

http://umetech.niwl.se/Vibration/WBVHome.html

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Hand Arm Vibration Data Base

http://umetech.niwl.se/Vibration/HAVHome.html

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Thank you for your attention

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