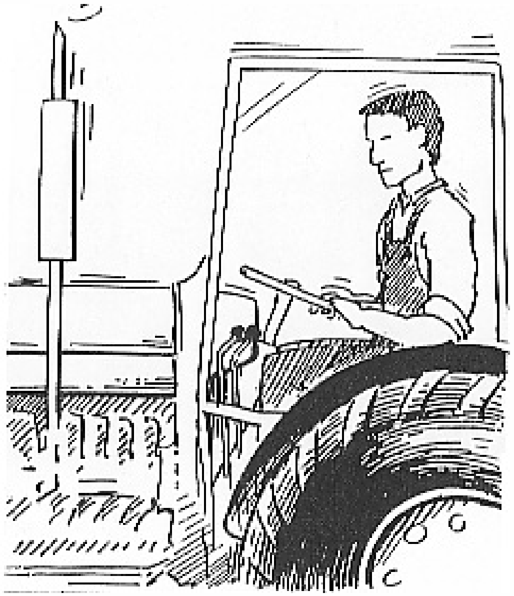
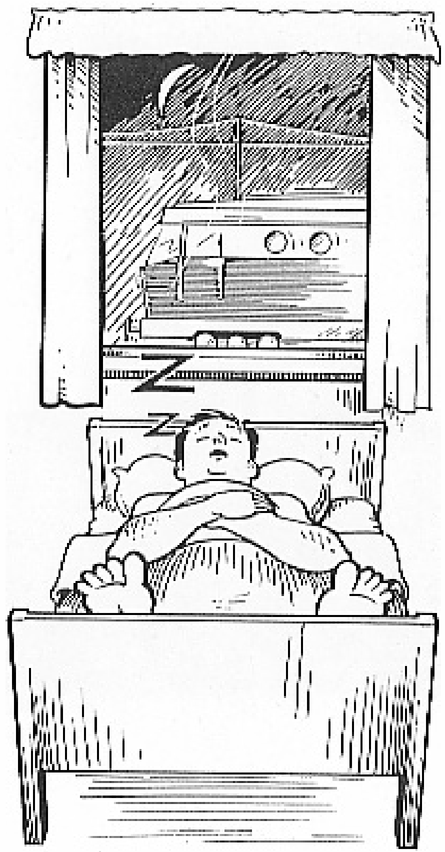
Human Vibration





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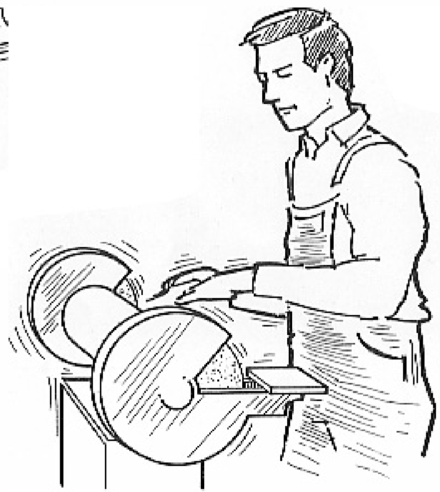
Hand-arm Vibration

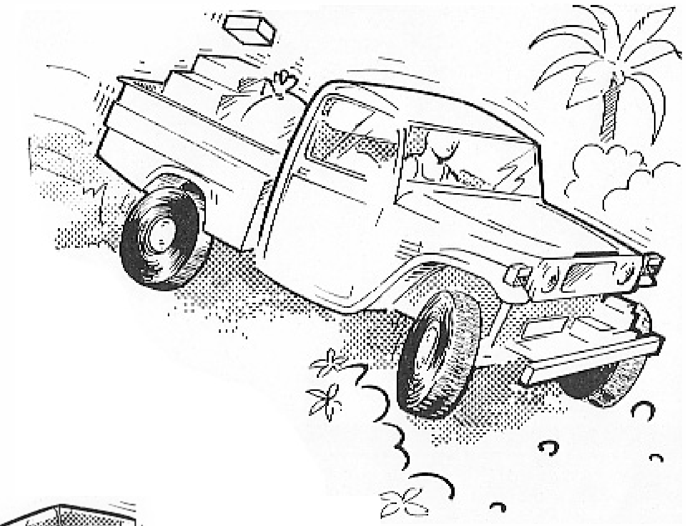


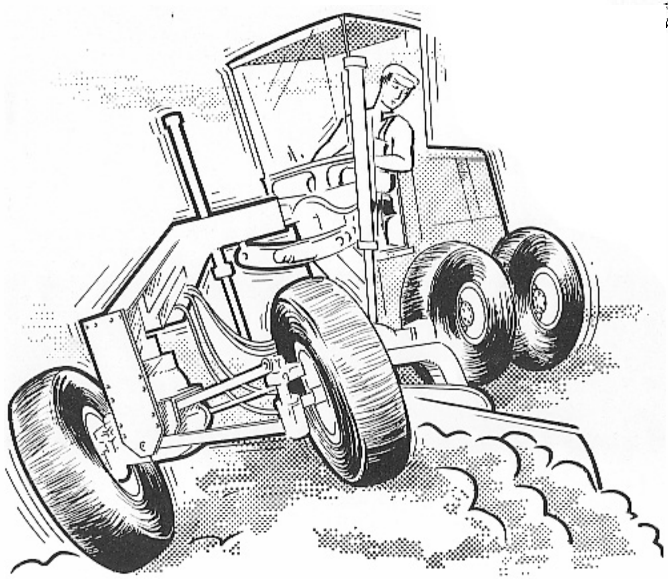
Long-term exposure can cause white-finger or dead-finger syndrome

Symptoms:

- Tingling
- Numbness
- Blanching
- Over-reaction to coldness

Whole-body Vibration





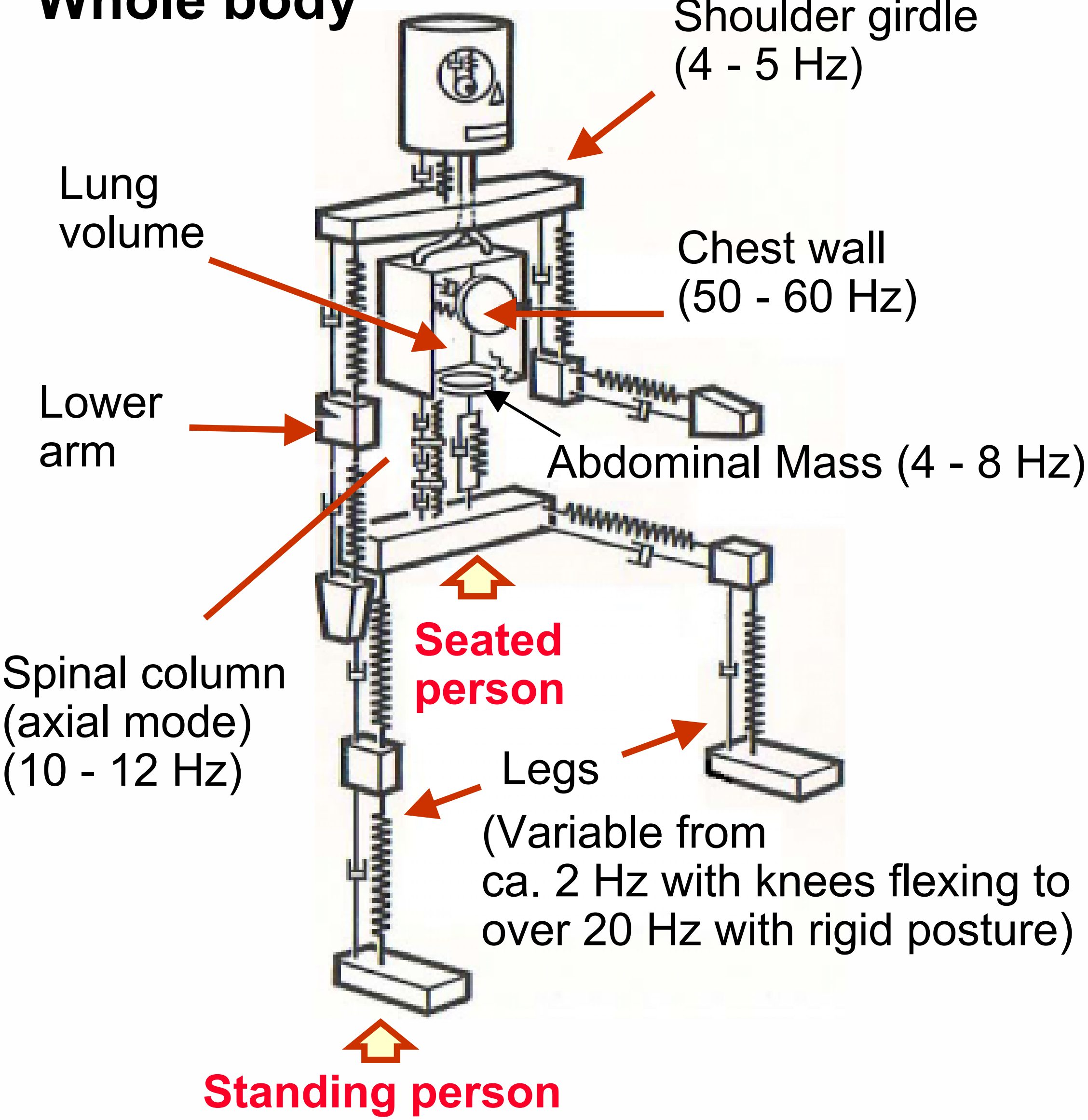
Long-term exposure can cause severe damage especially to the lumbar region of the spine

Short-term symptoms:

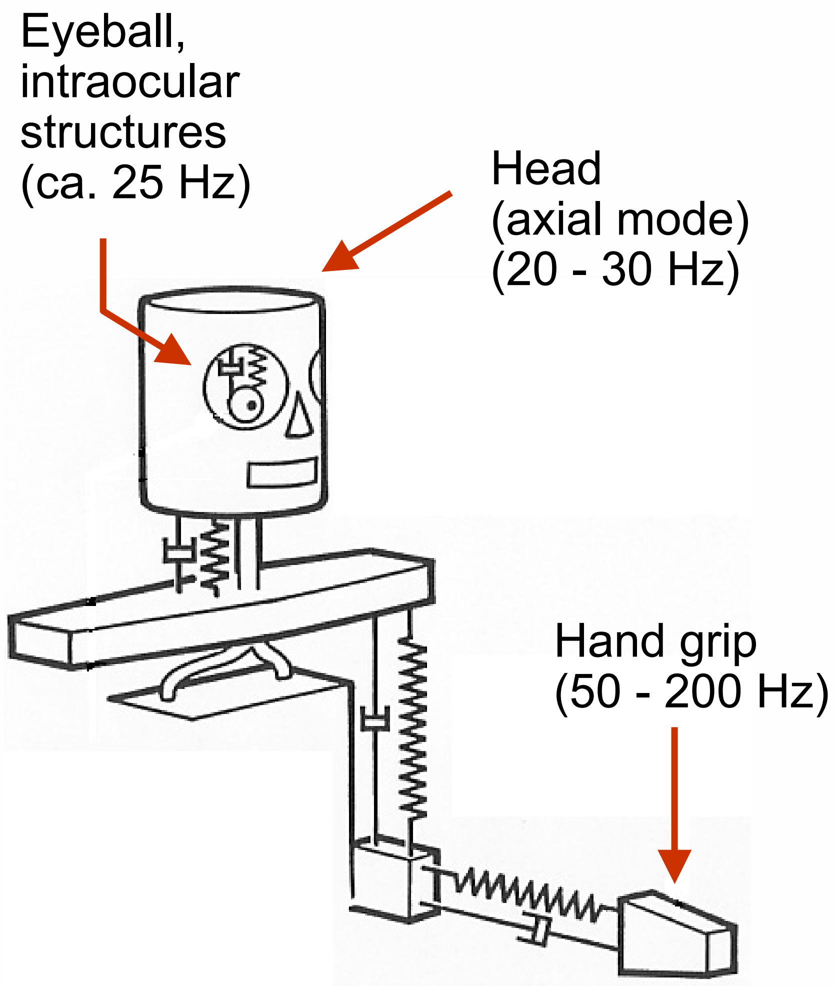
- Fatigue
- Headache
- Slower reactions
- Nausea
- Insomnia

Mechanical Models of the Human Body

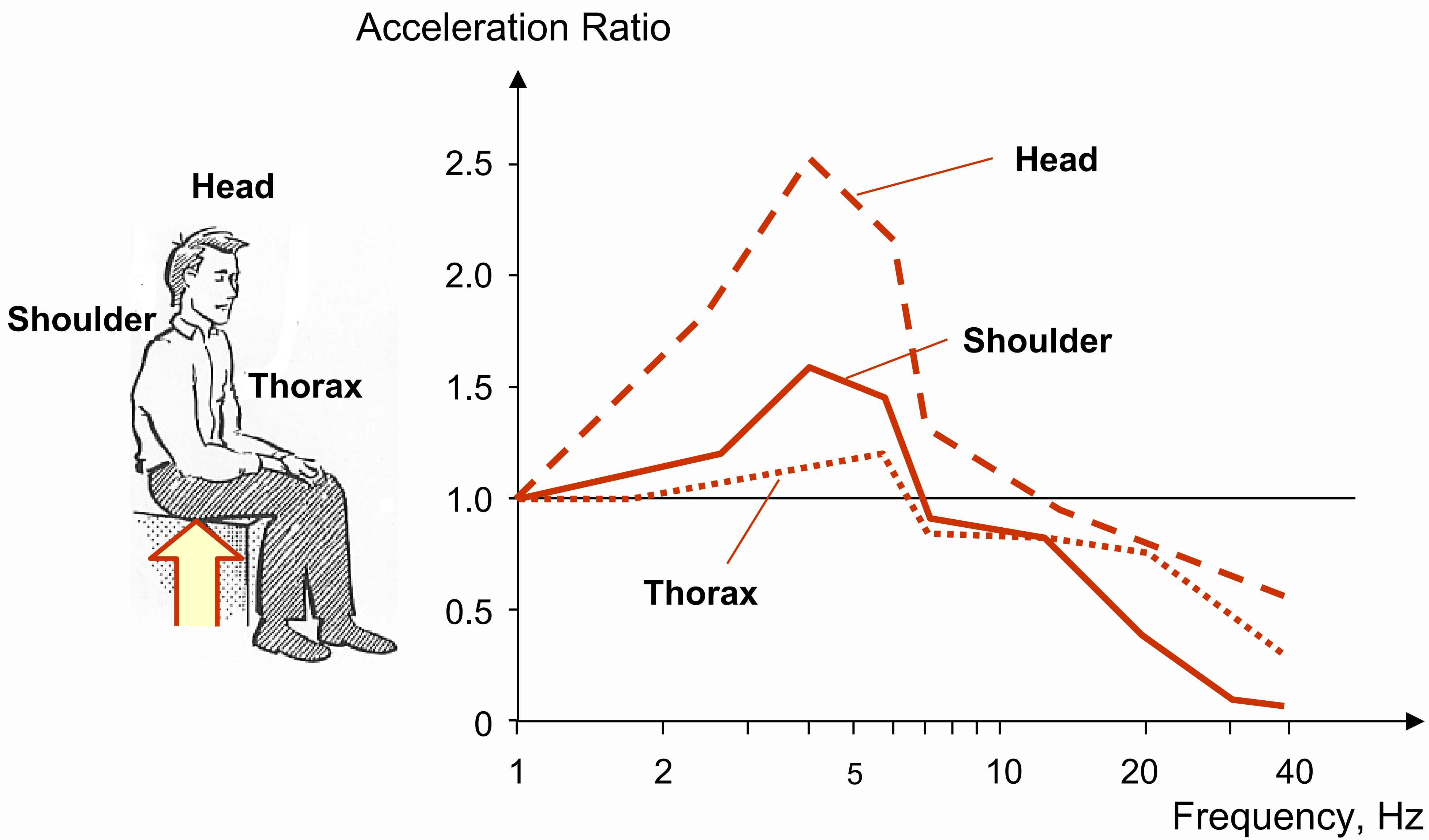
Whole body



Hand-arm



Transmission of Vibration through the Body



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Standards for Human Vibration

INTERNATIONAL STANDARD ISO 2631

ISO 2631-1:1997

“Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration,

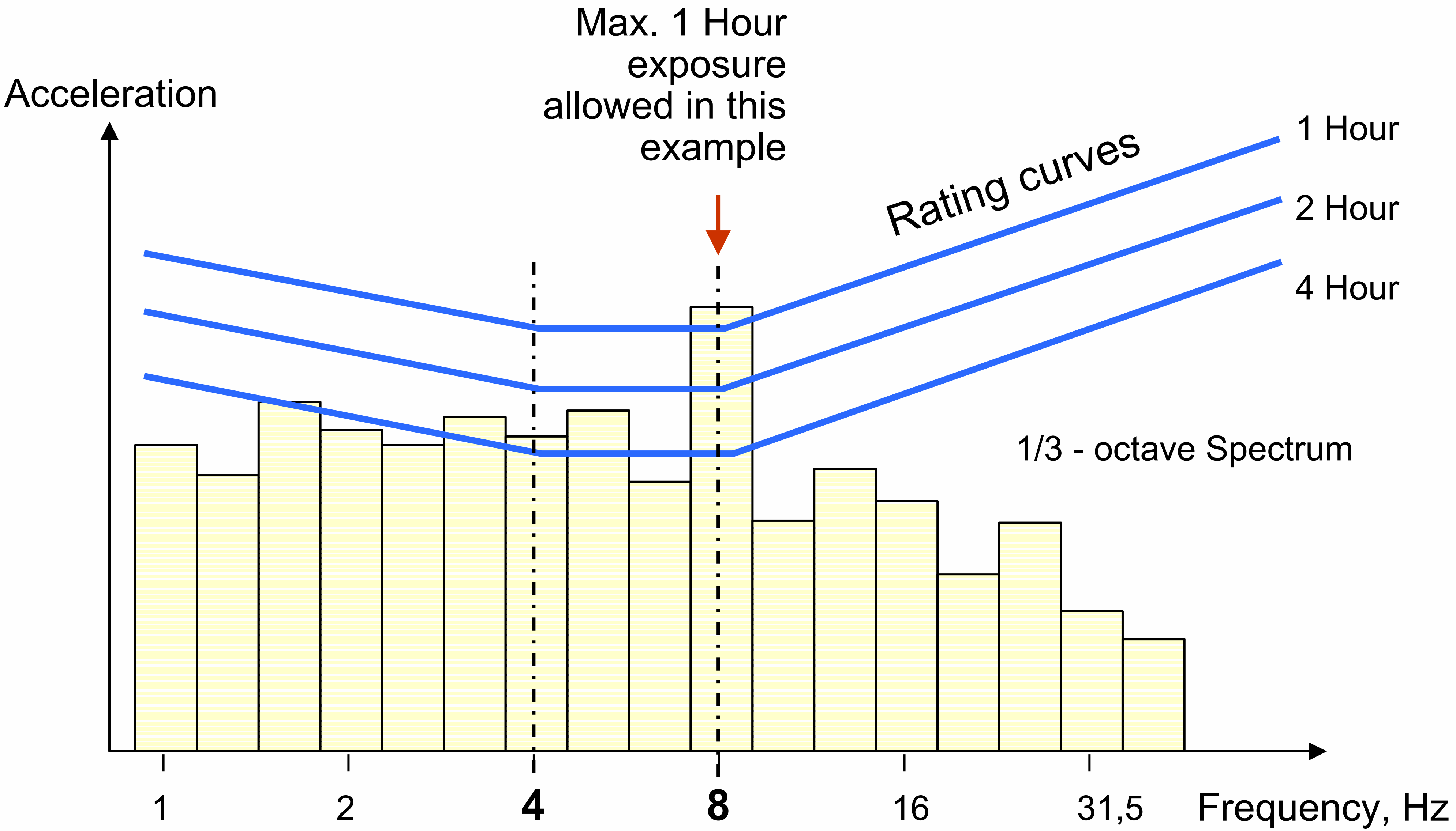
Part 1, General Requirements”.

INTERNATIONAL STANDARD ISO 5349

ISO 5349-1986

“Mechanical vibration - Guidelines for the measurement and the assessment of human exposure to hand-transmitted vibration.”

Evaluation Method: Rating



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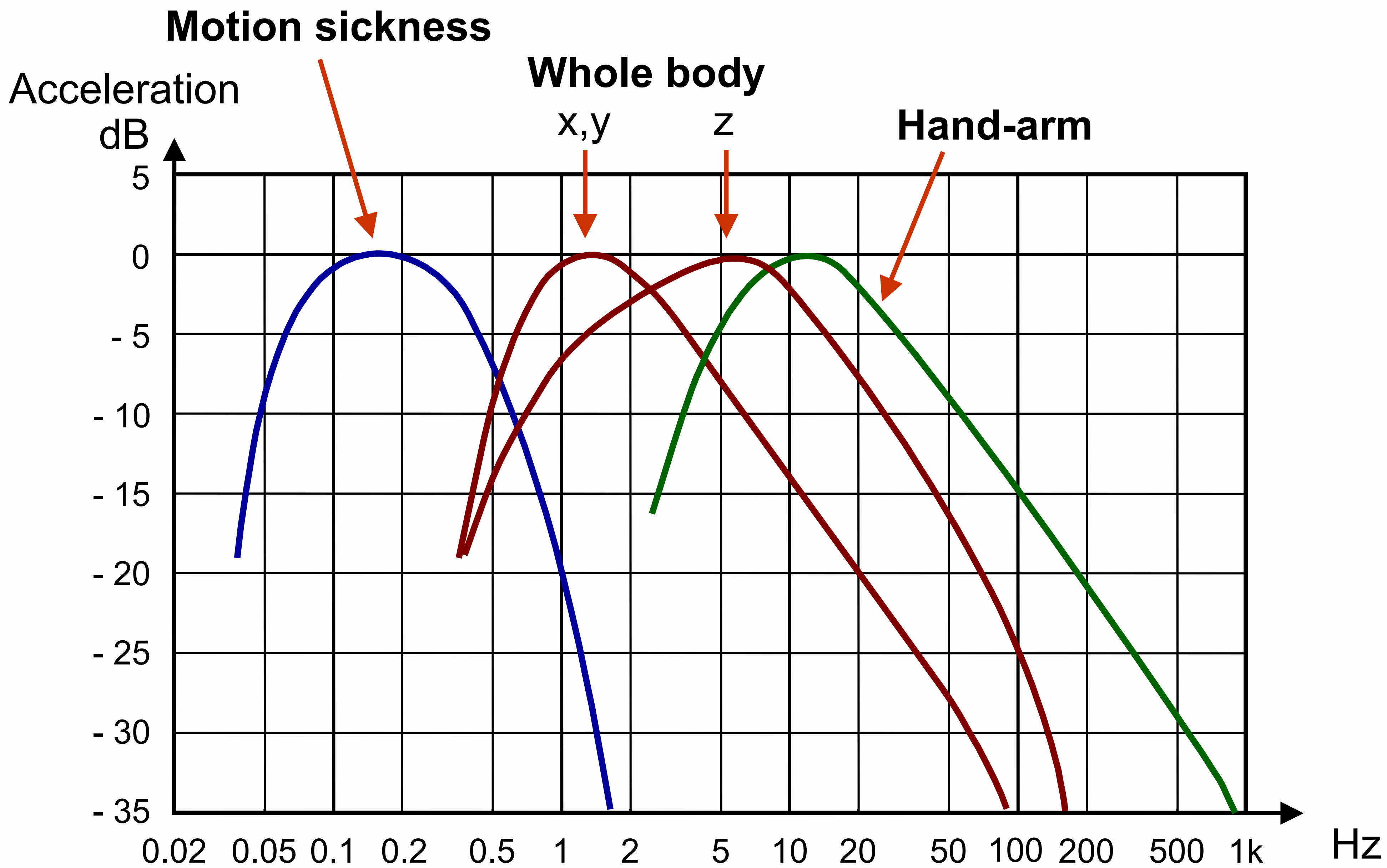
Evaluation Method: Weighting



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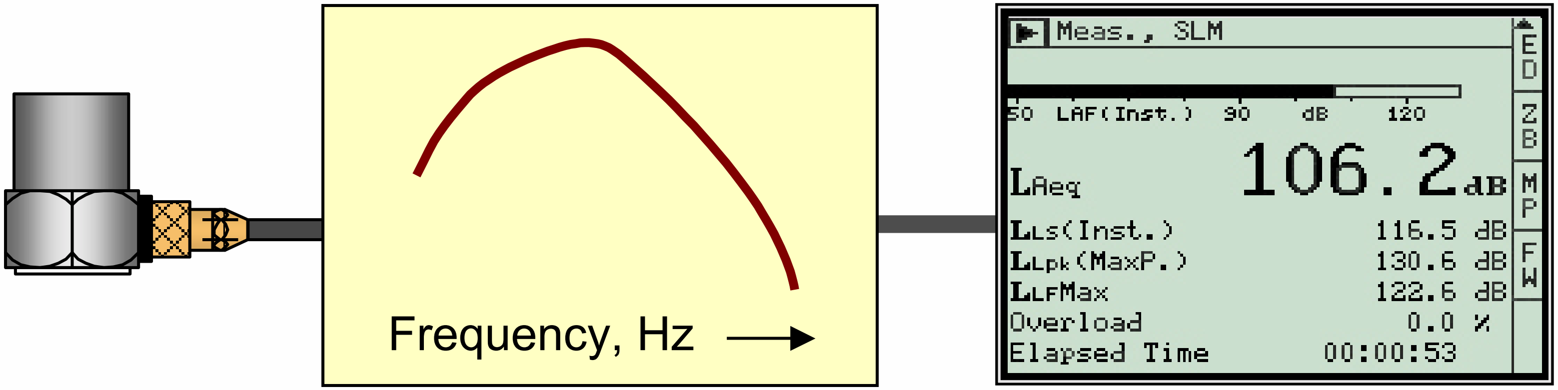
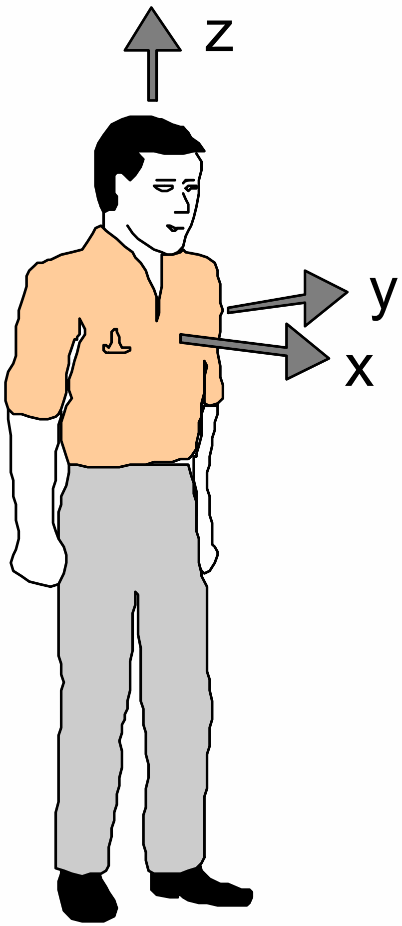
Using the Weighing Method in Practice

Measurement | Weighting | Display

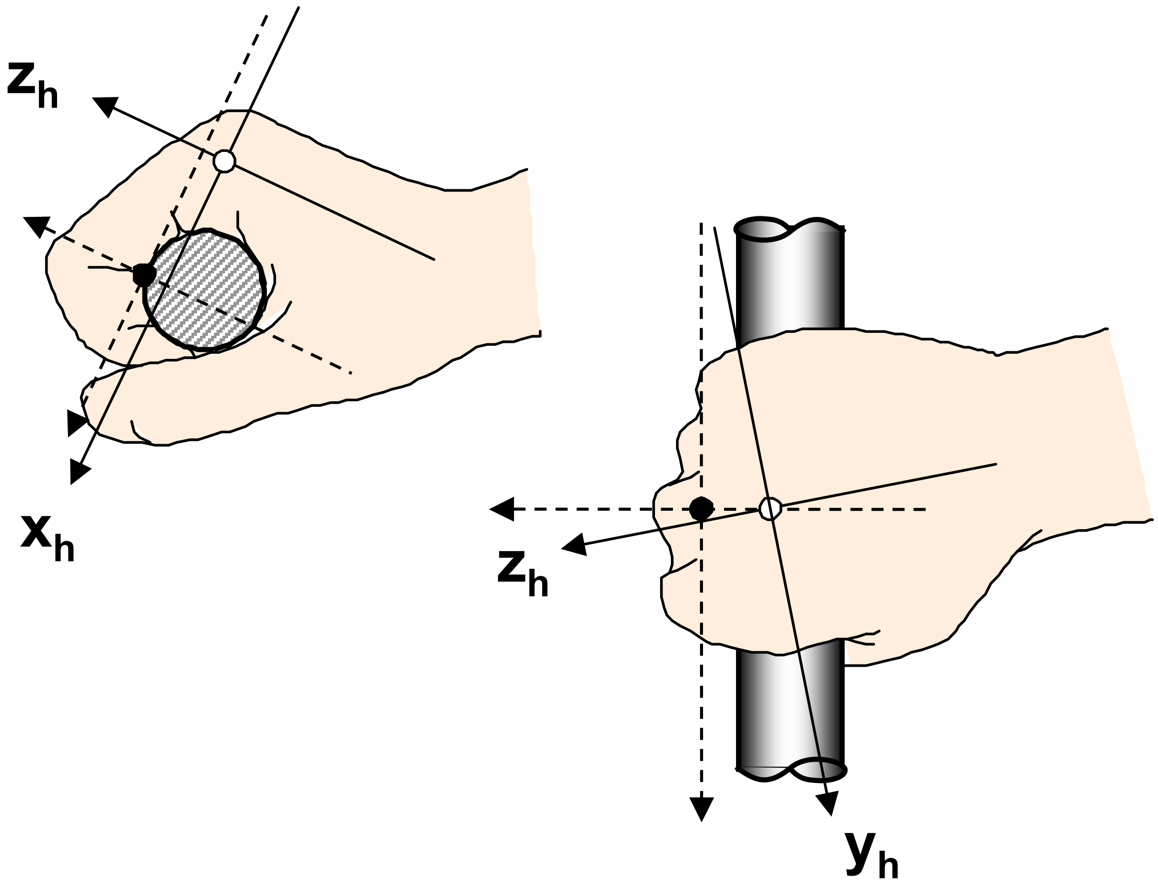


Measurement Directions

Whole-Body



"Handgrip" position



- - - - Basicentric coordinate system

——— Biodynamic coordinate system

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Categories of Whole-Body Vibration

Motion sickness, in ships or vehicles with very soft suspension systems

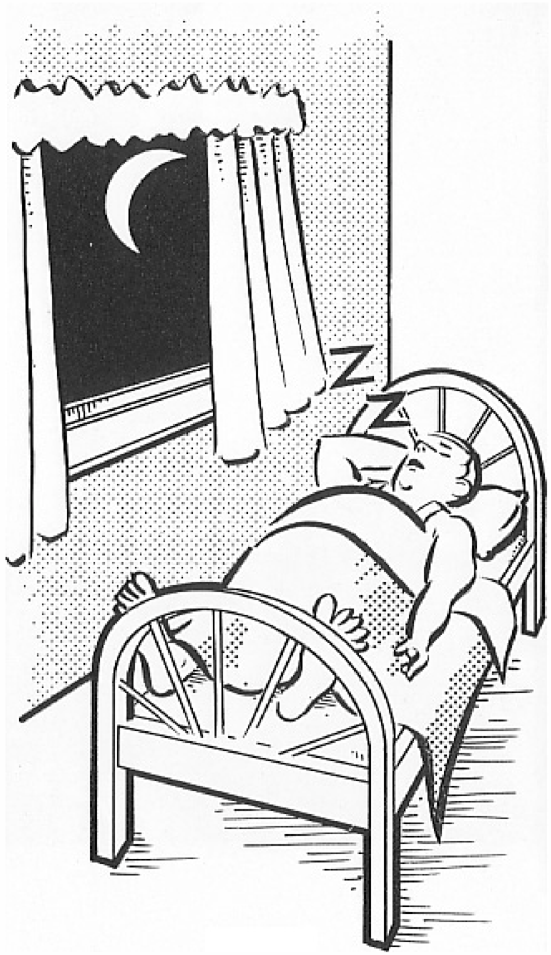
– 0.1 to 0.63Hz

Whole-body vibration in vehicles or on platforms

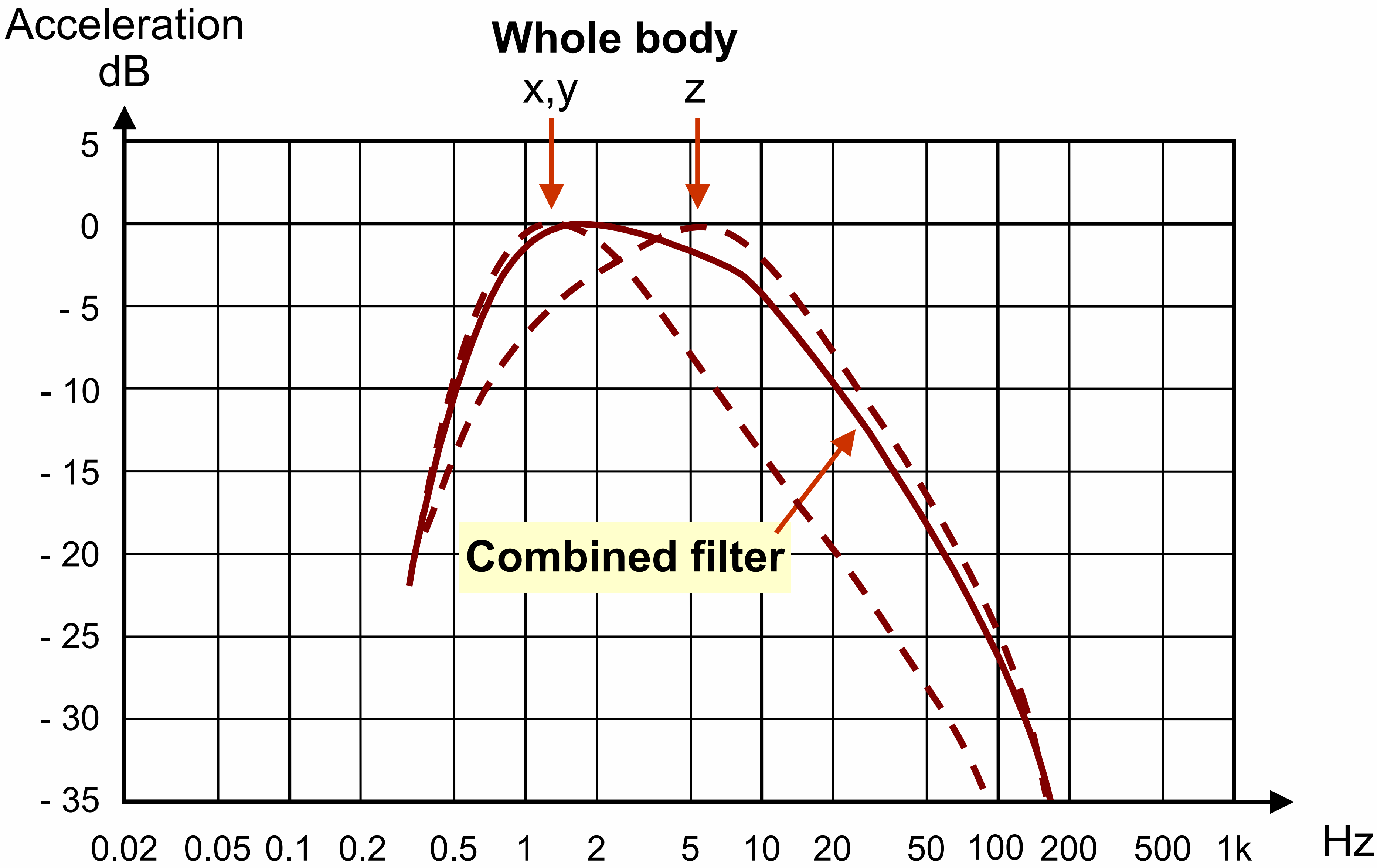
– 1 to 80Hz

Whole-body vibration in buildings

– 1 to 80Hz



Whole-Body Vibration Weighting



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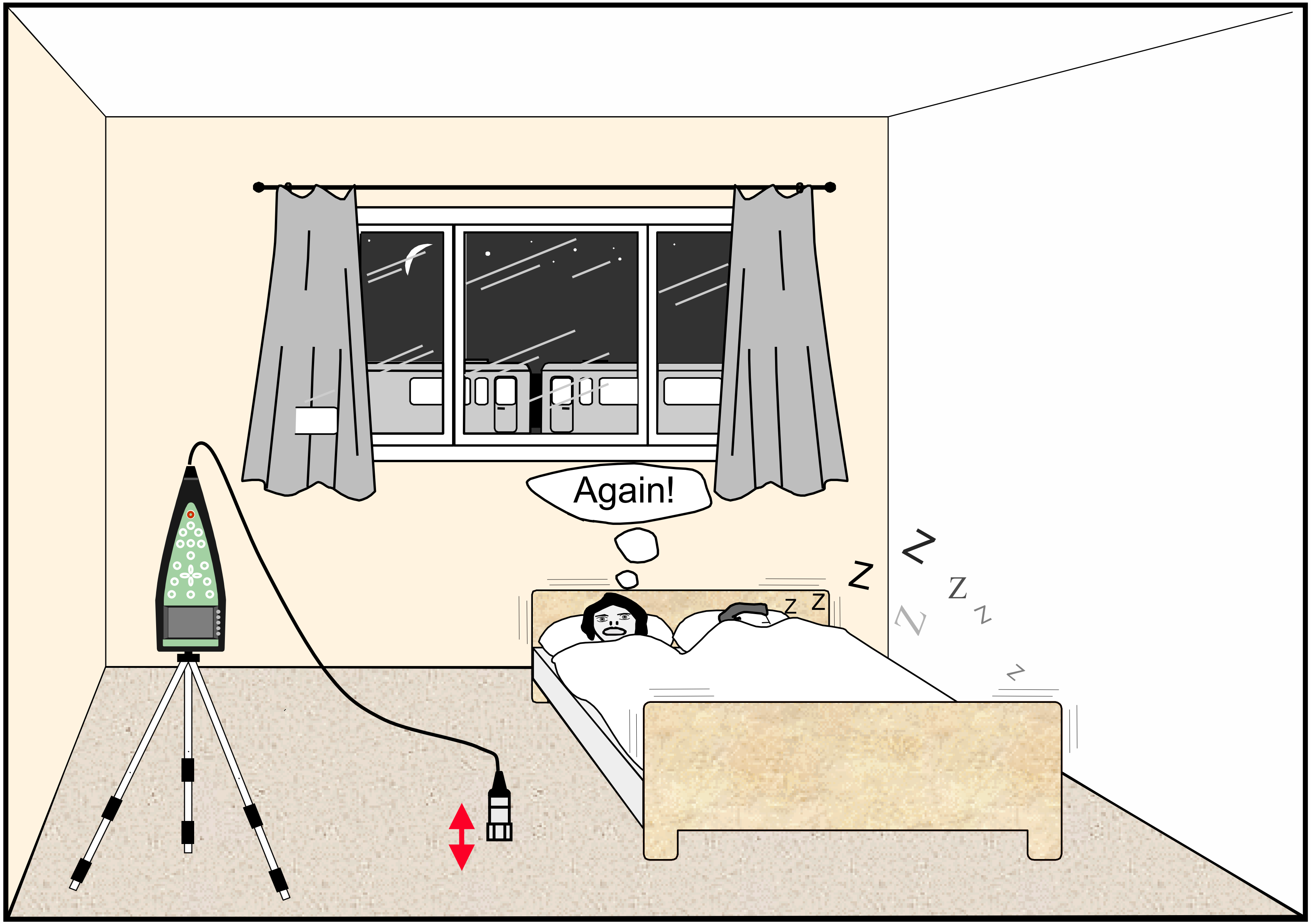
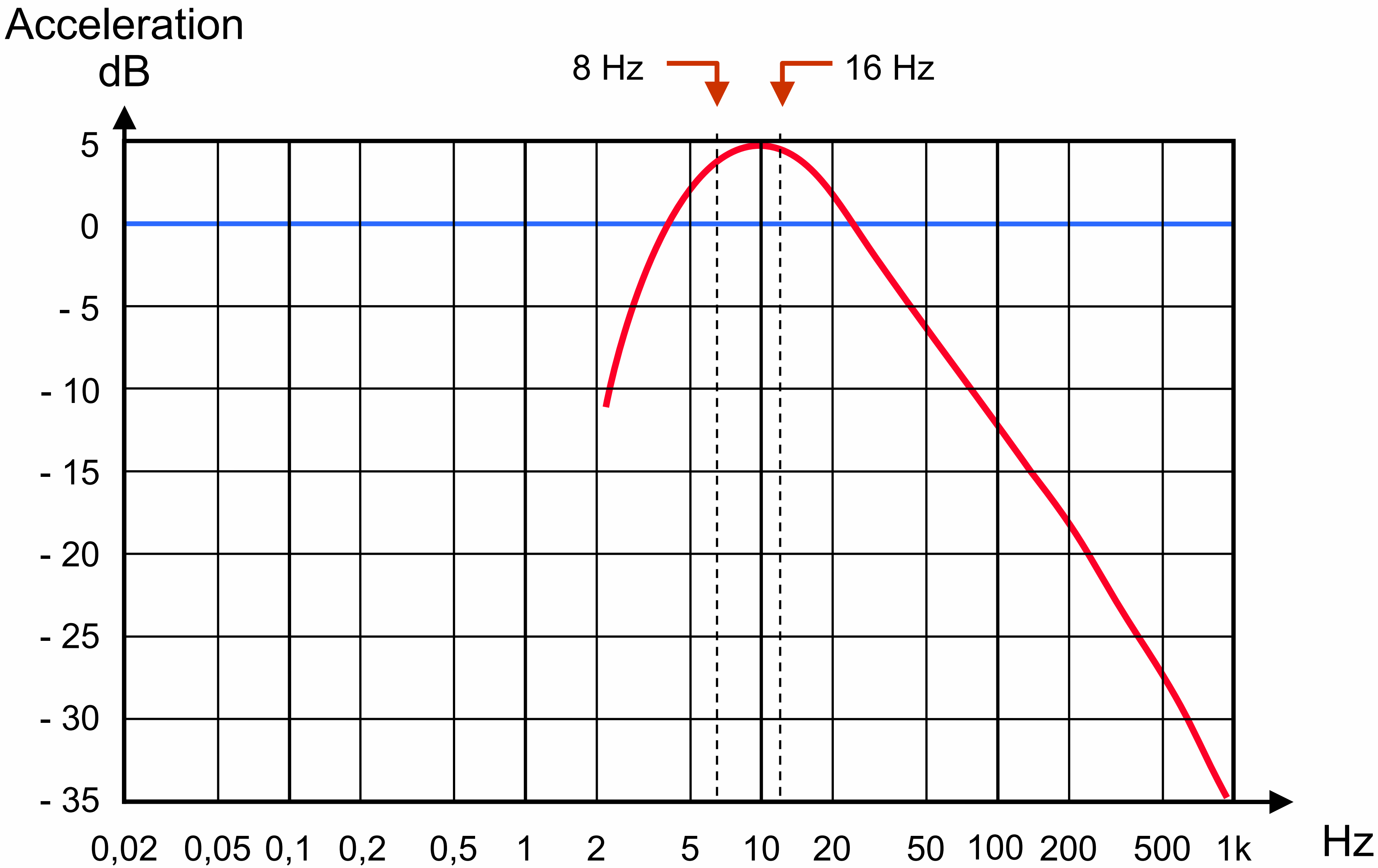
Measure in the Vertical Direction In Buildings



Hand-Arm Vibration Weighting



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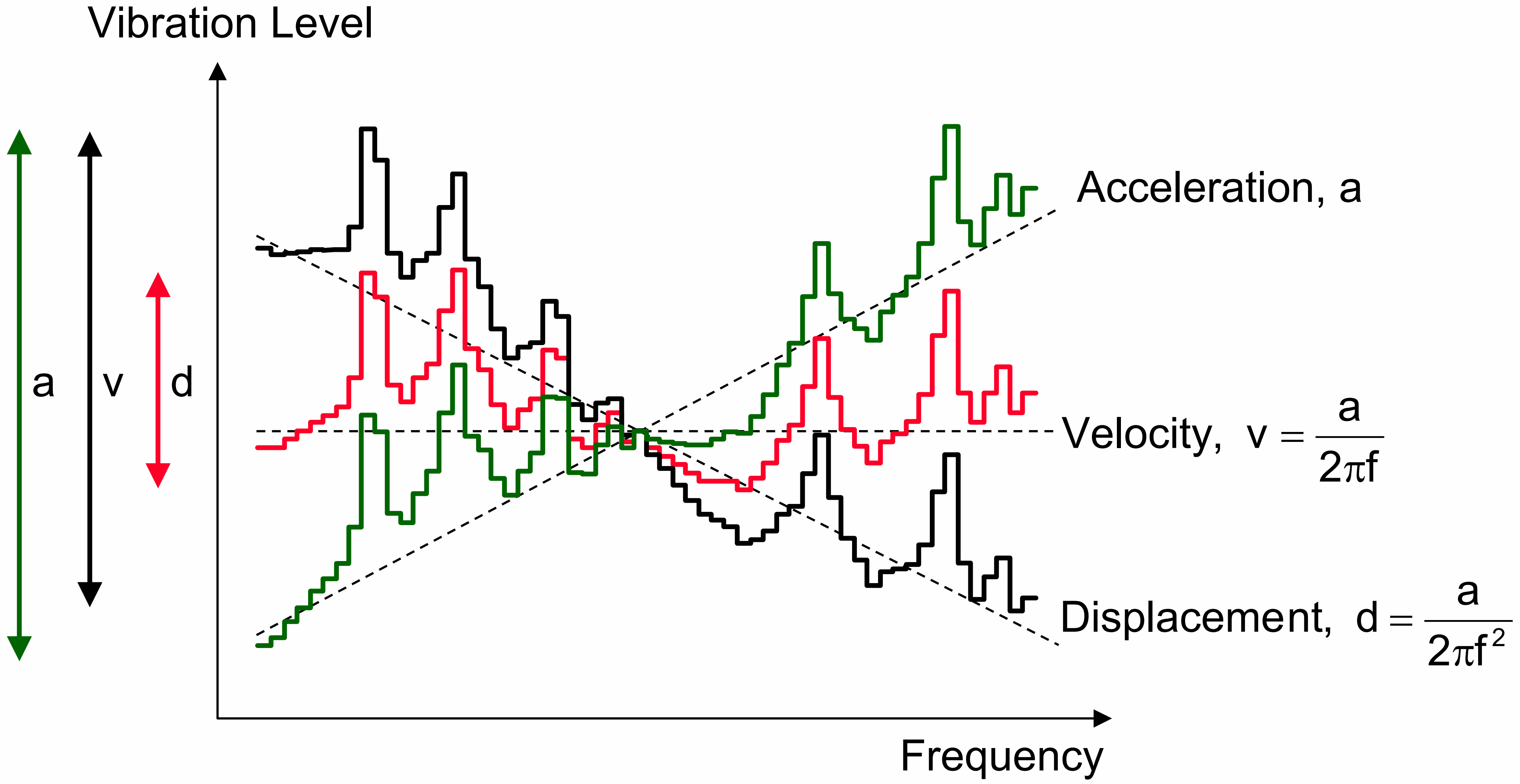
Vibration Amplitude



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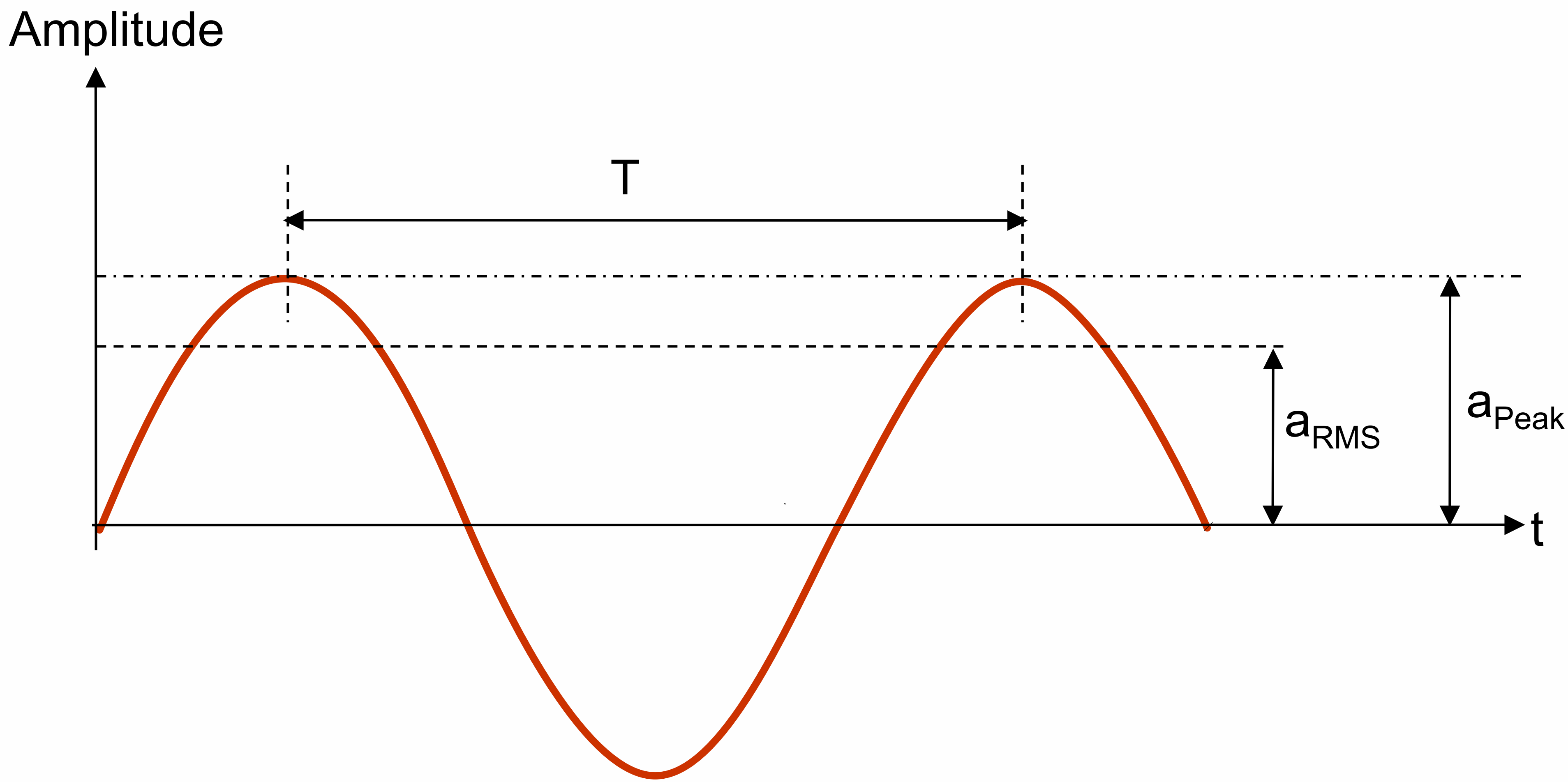
Descriptive Parameters



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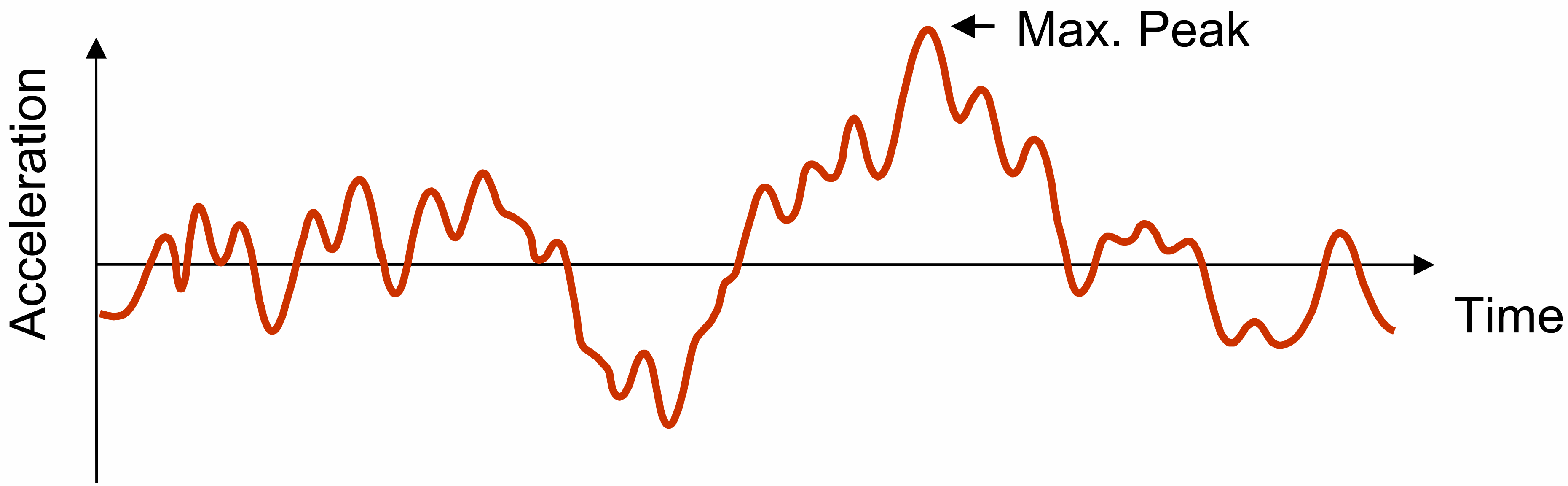
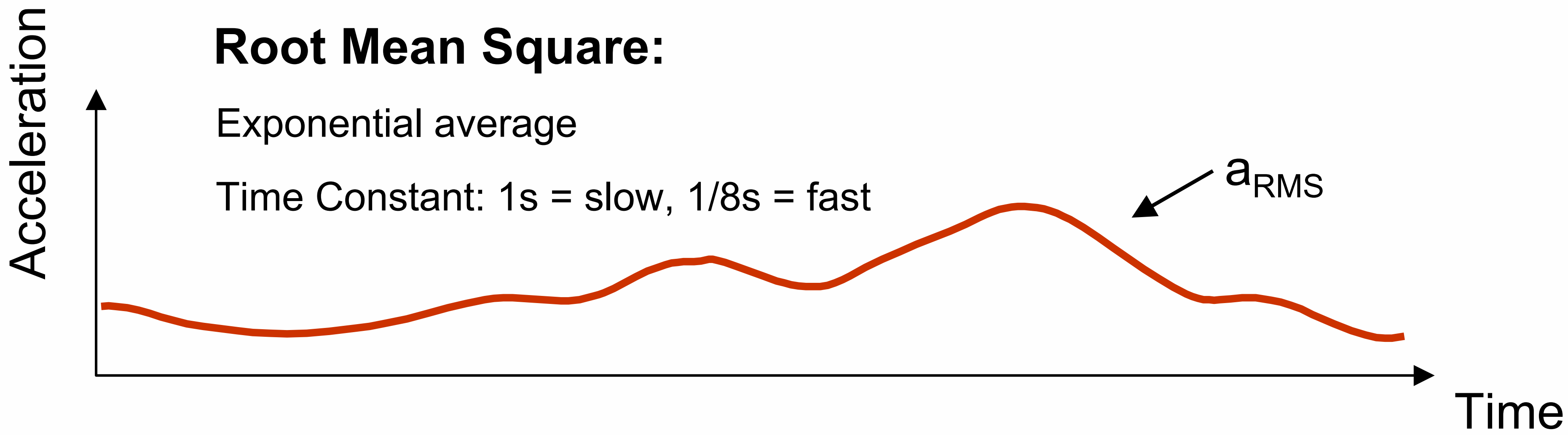
Characteristics of Vibration – RMS



Root Mean Square:

Exponential average

Time Constant: 1s = slow, 1/8s = fast



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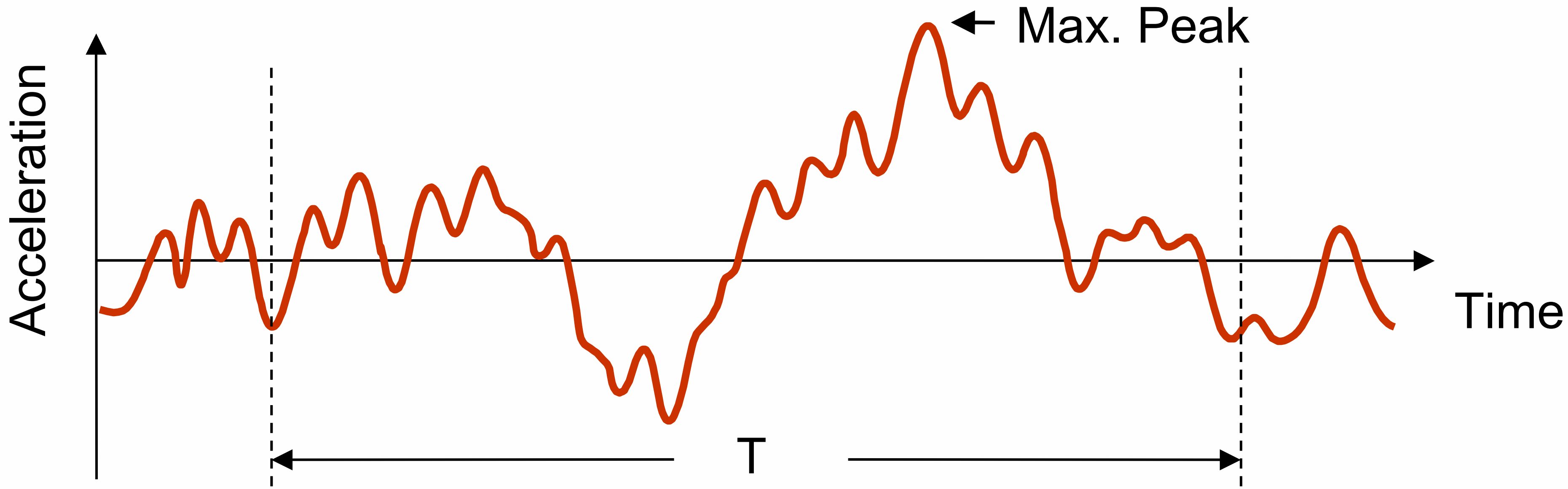
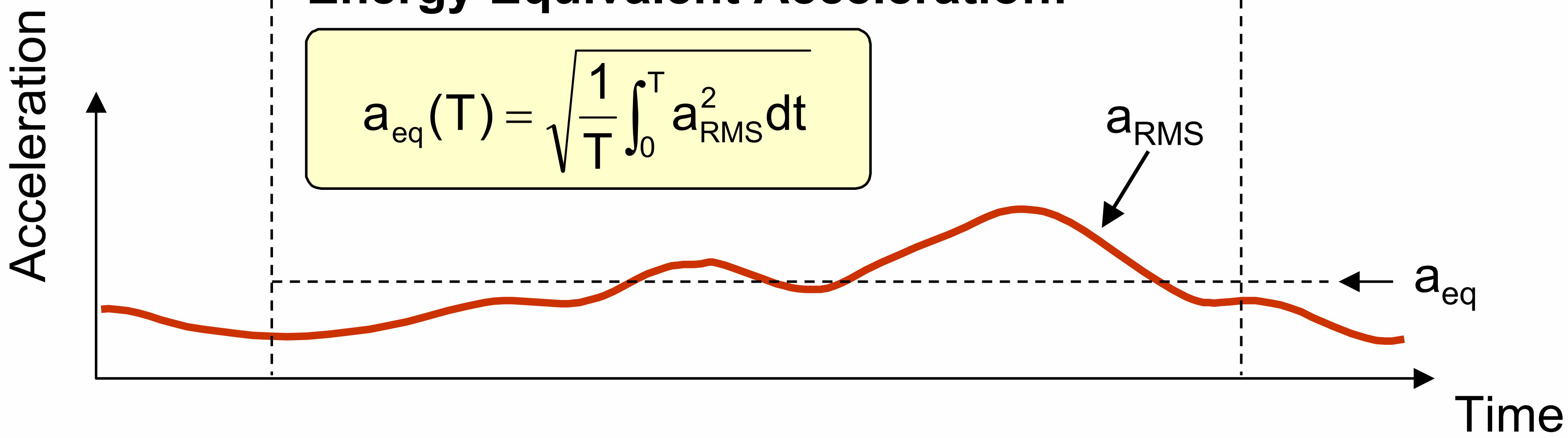
The “Energy Equivalent” Acceleration, a_{eq}



Energy Equivalent Acceleration:

$$a_{eq}(T) = \sqrt{\frac{1}{T}\int_0^T a_{RMS}^2 dt}$$



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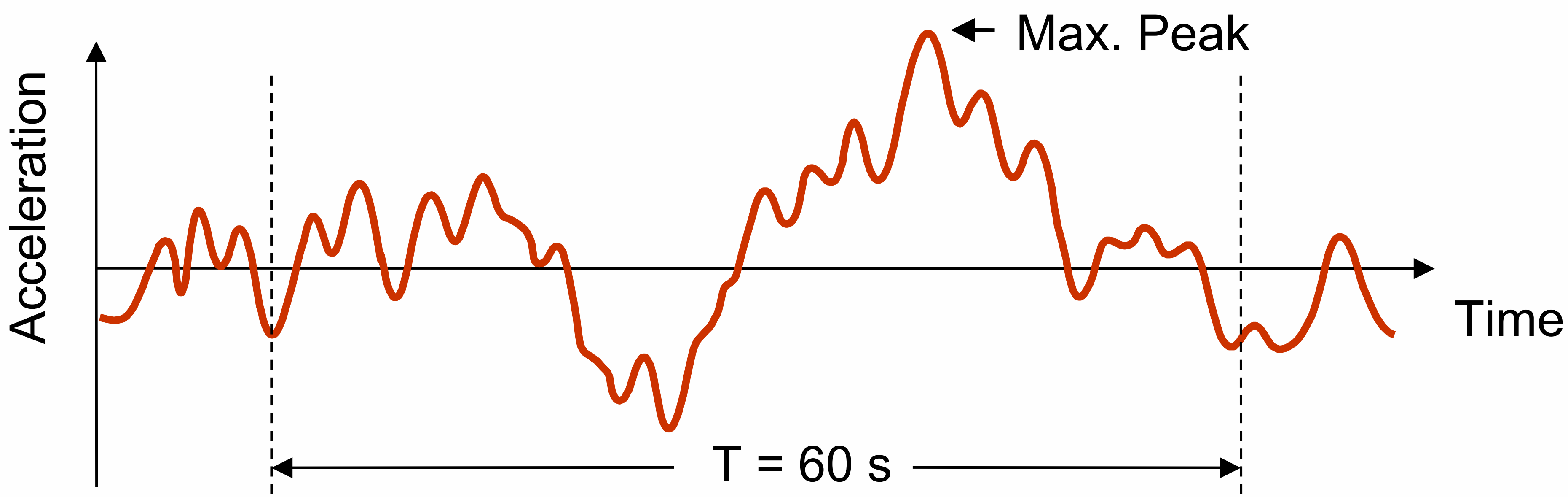
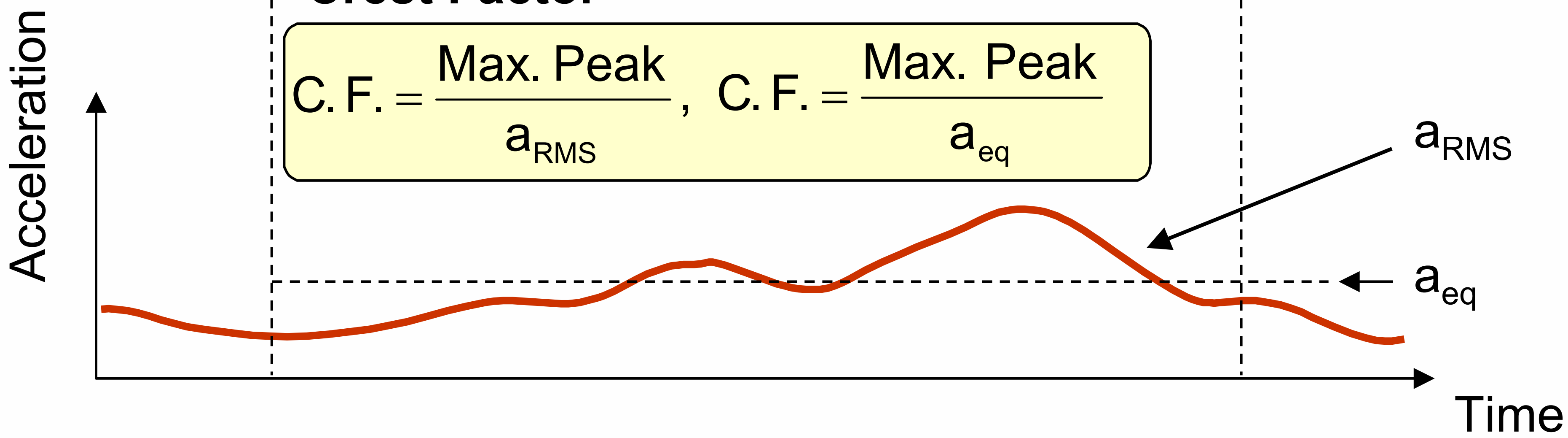
Max. Peak and Crest Factor



Crest Factor

$$C.F. = \frac{\text{Max. Peak}}{a_{RMS}}, \quad C.F. = \frac{\text{Max. Peak}}{a_{eq}}$$



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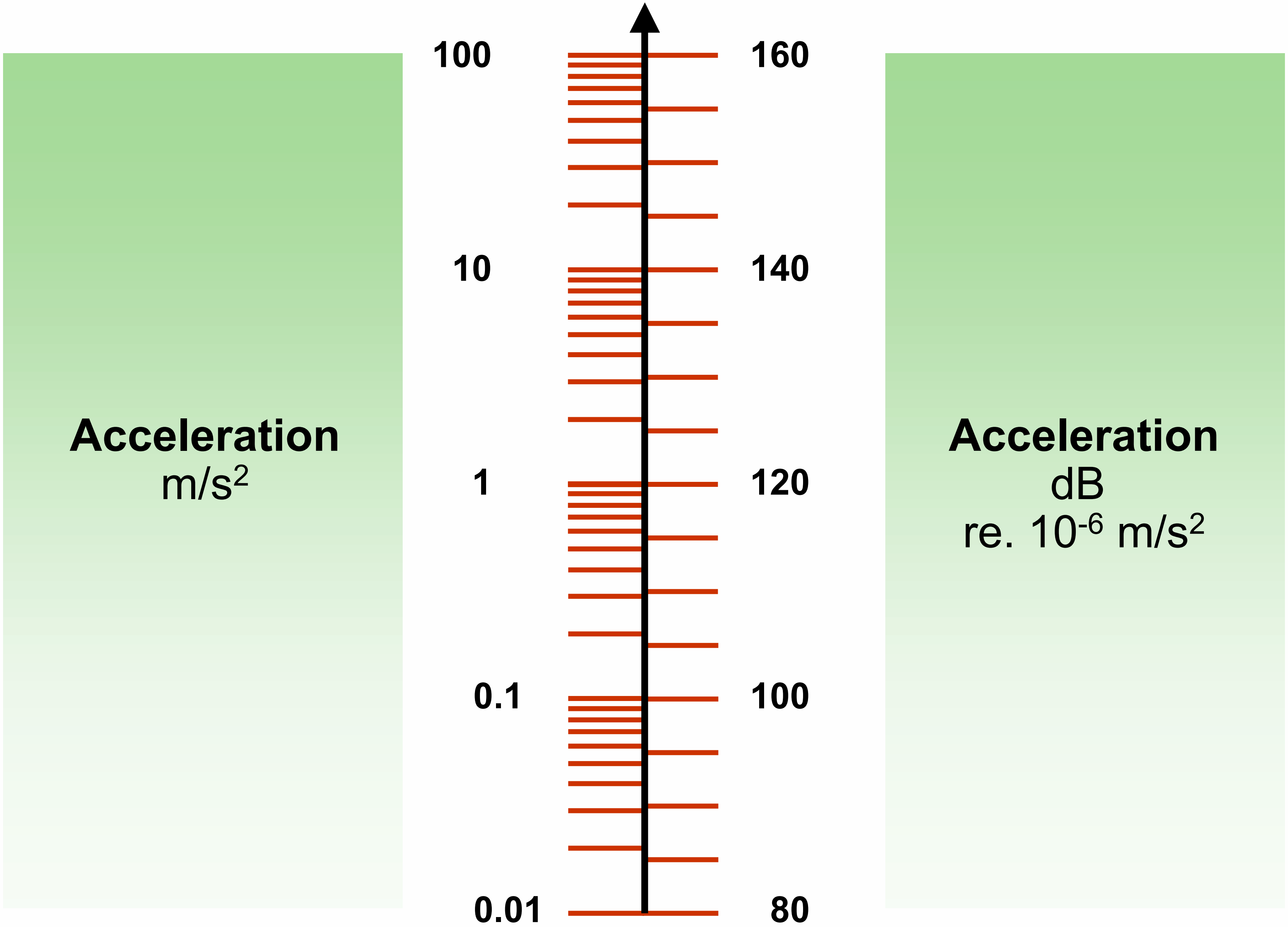
m/s^2 or Decibels?



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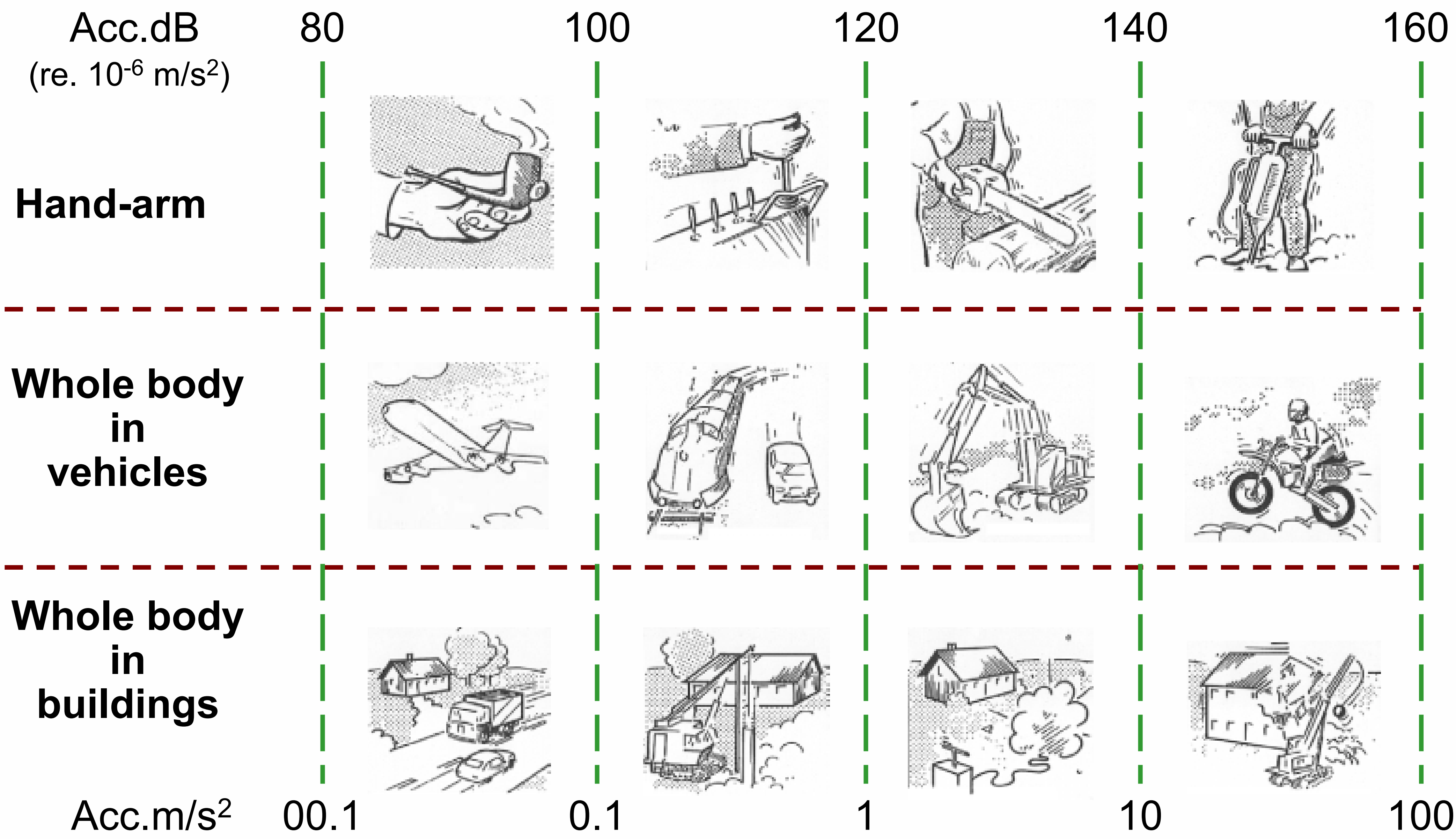
m/s² or Decibels?



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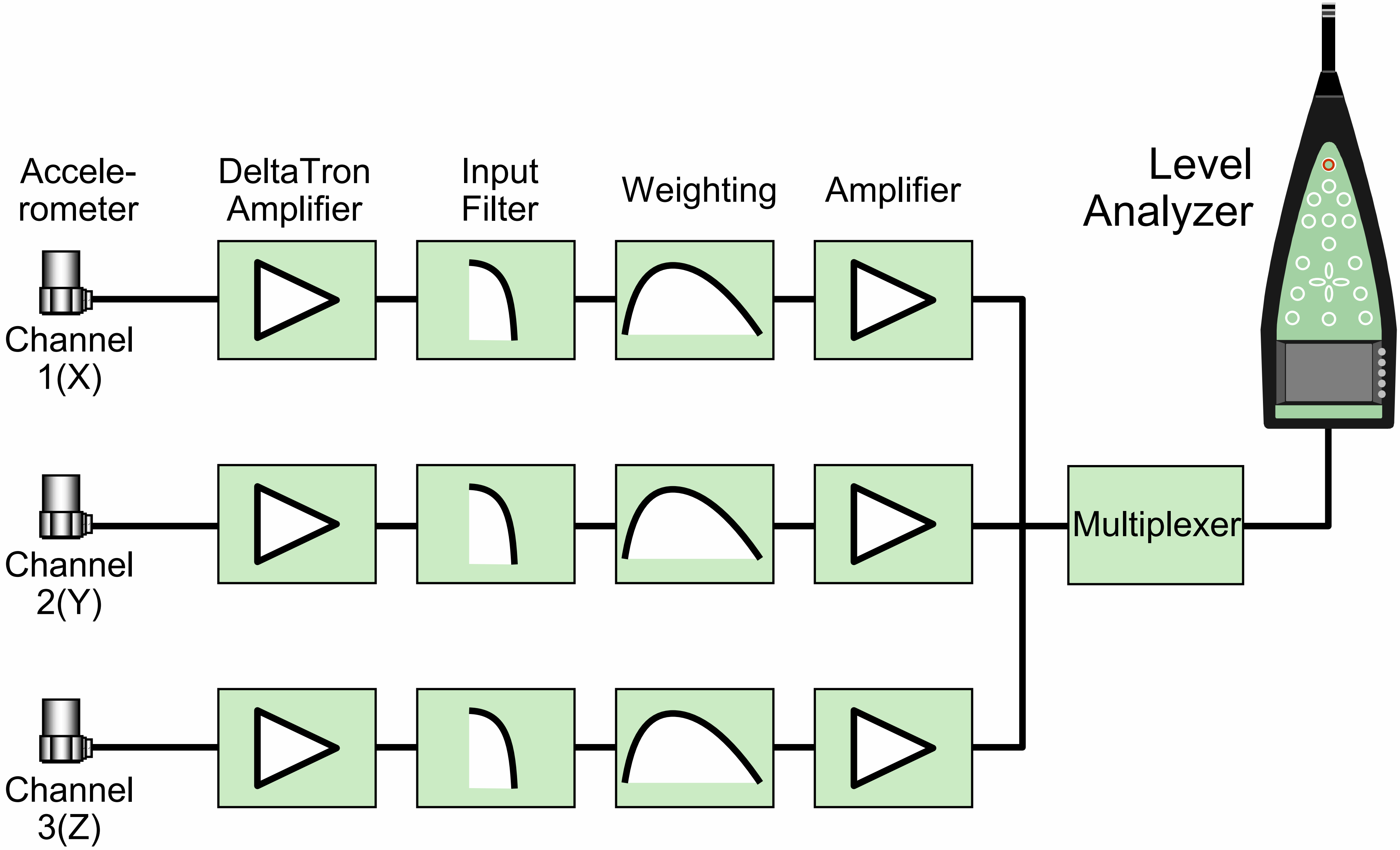
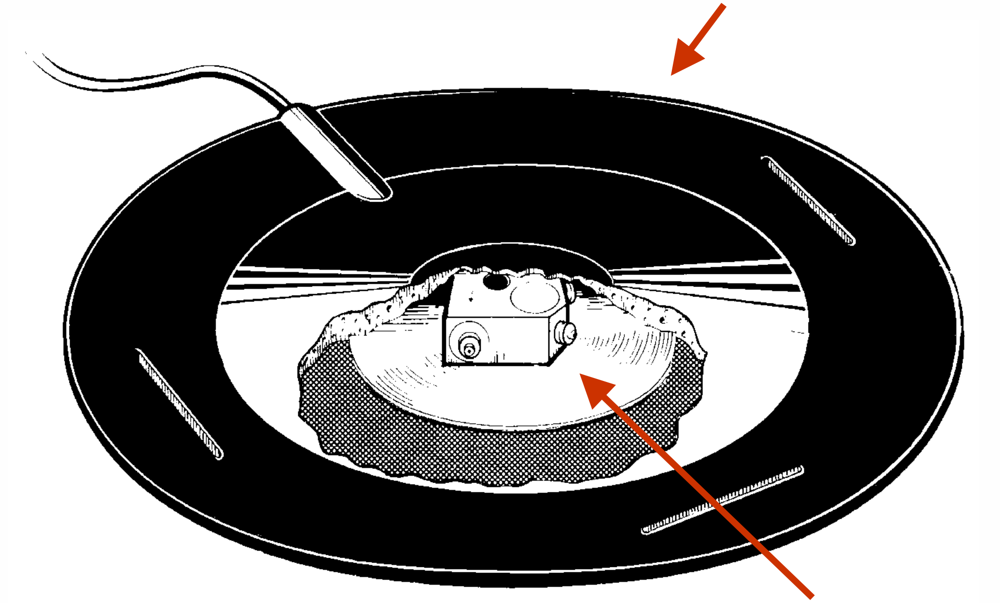
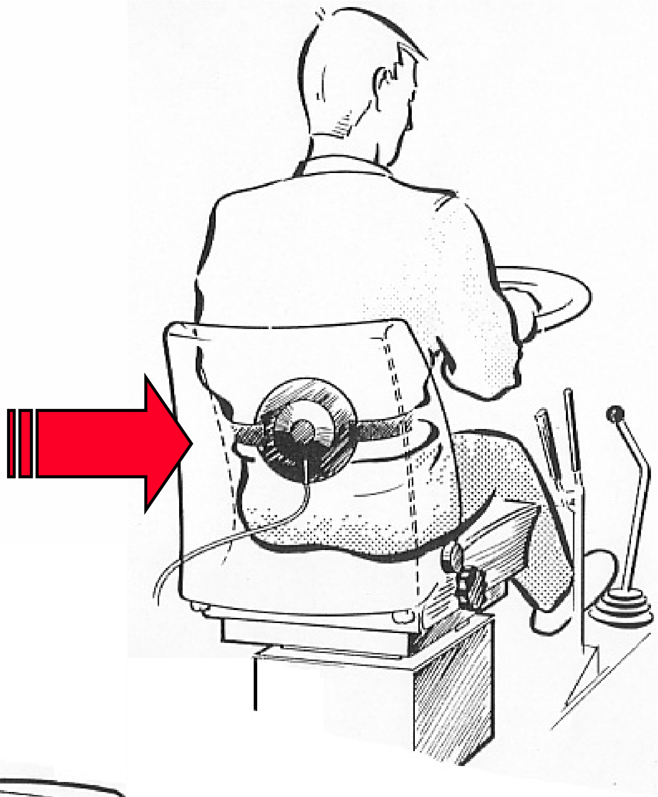
Basic Instrumentation for Weighted Measurements

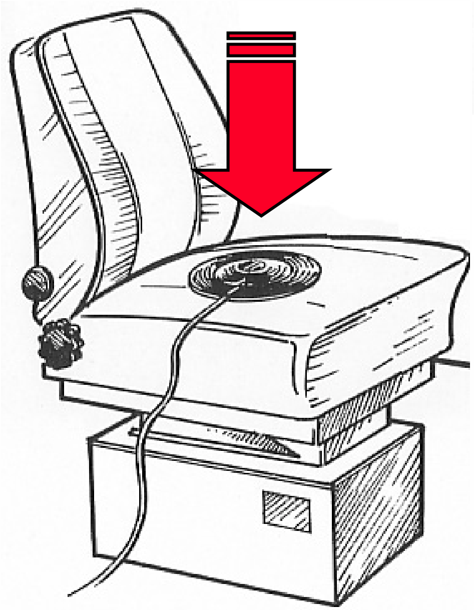


Transducer for Whole-body Vibration



Mounting the Transducer – Whole Body





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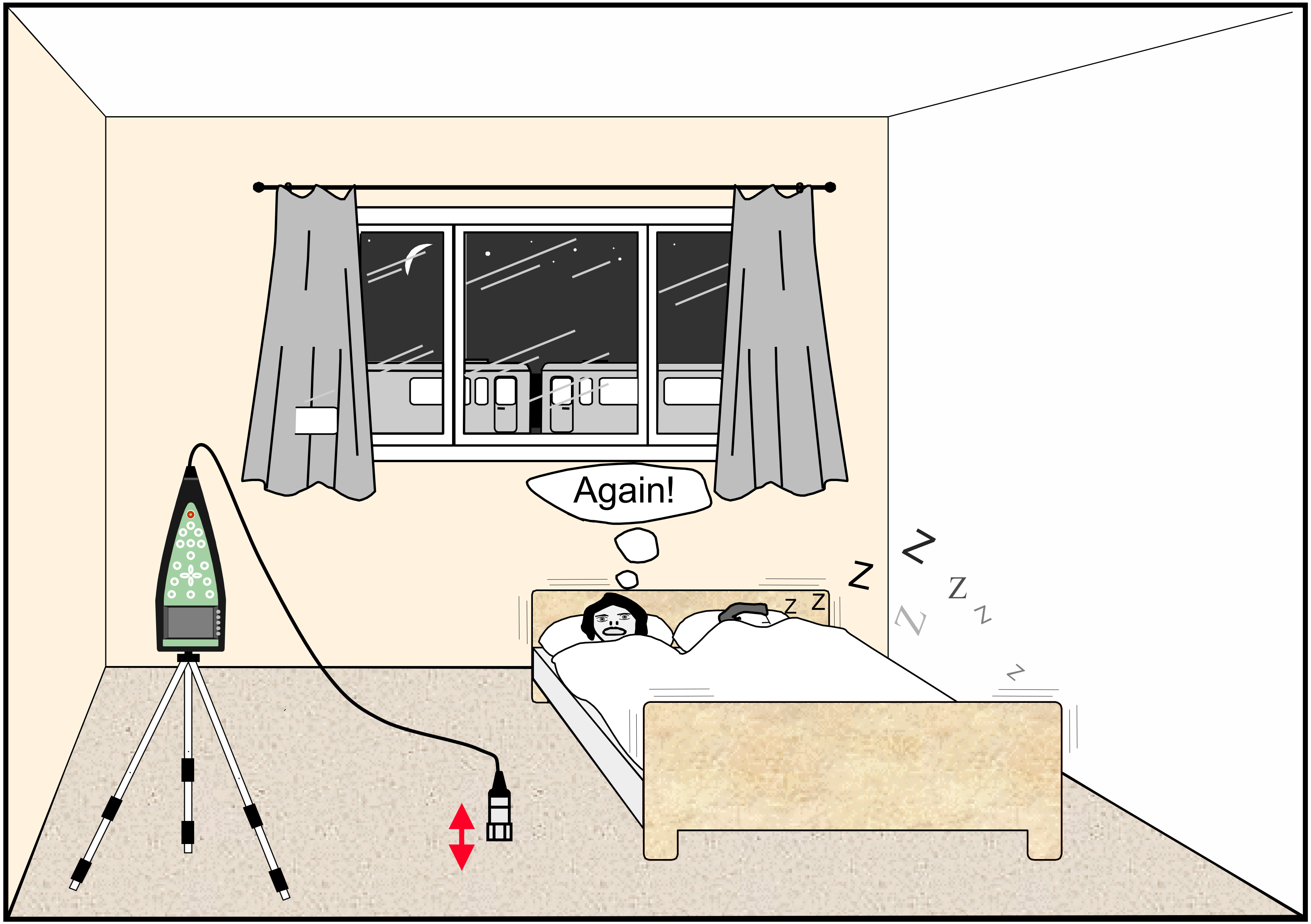
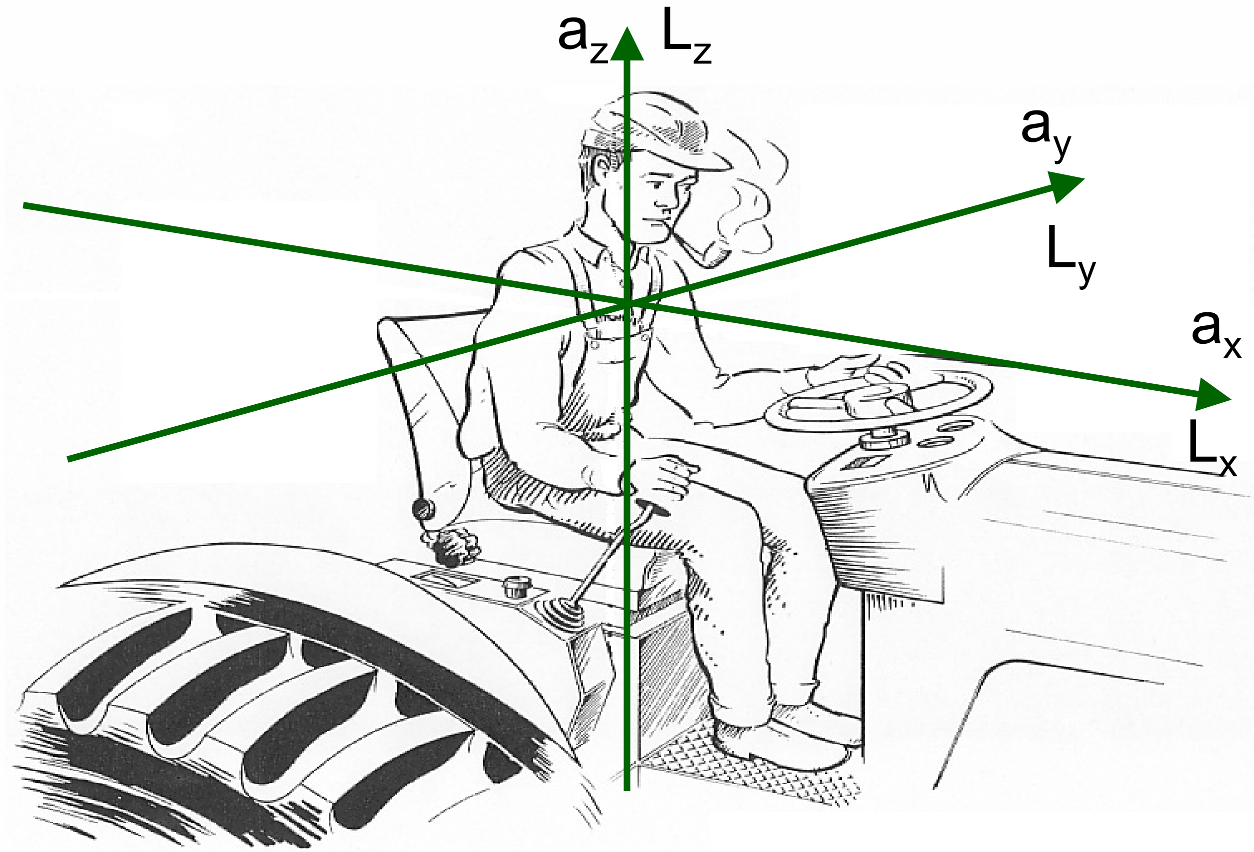
Whole-body Vibration in Buildings



Directional Considerations



Weighted Acceleration Sum:

$$WAS = \sqrt{(1.4a_x)^2 + (1.4a_y)^2 + a_z^2}$$

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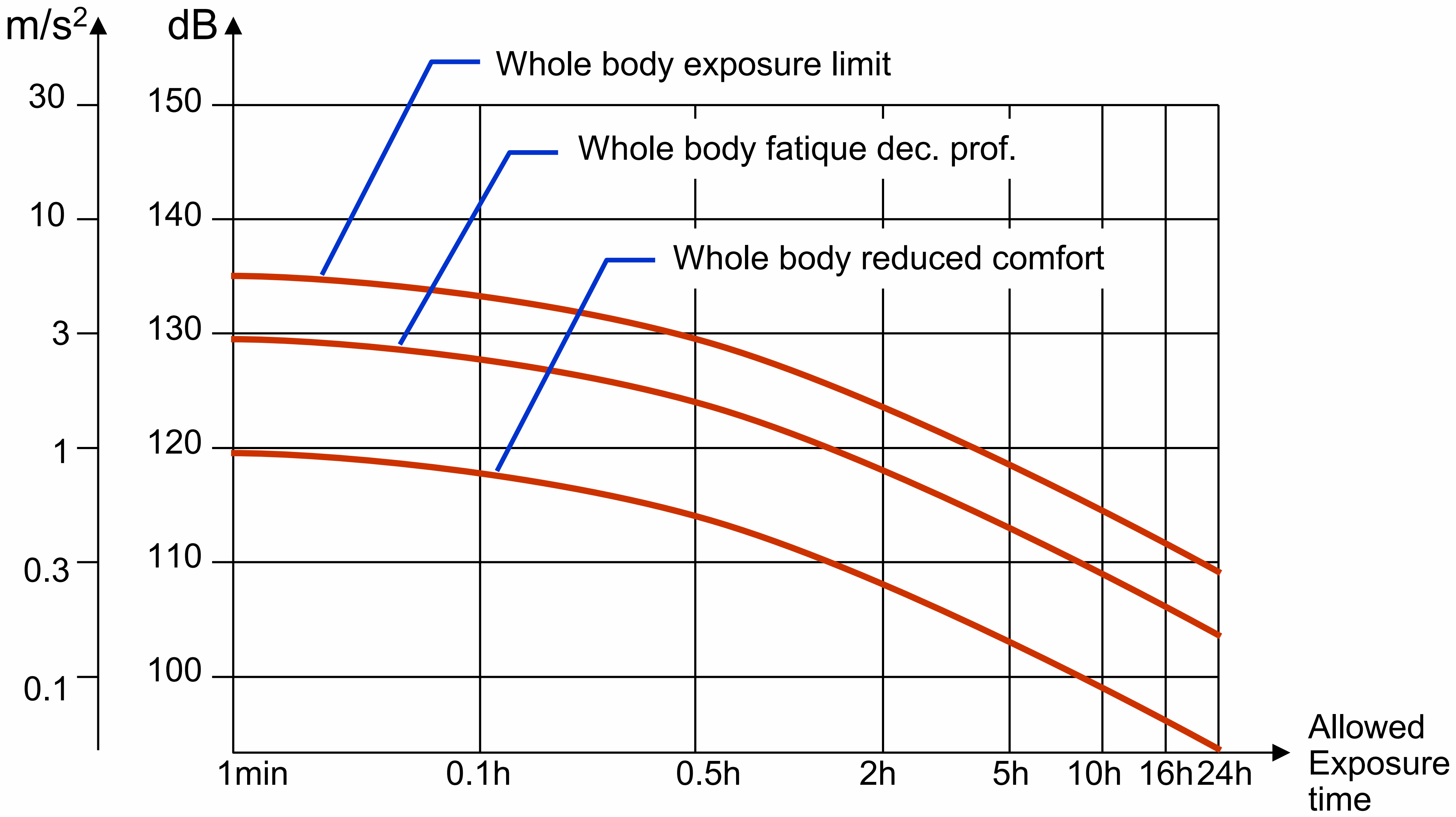
Exposure Evaluation



Calculation of the Working Day Dose

t_1 t_2 t_3

WAS_1 WAS_2 WAS_3

or a_{1eq} or a_{2eq} or a_{3eq}

or τ_1 or τ_2 or τ_3

$$\text{Dose} = \left(\frac{t_1}{\tau_1} + \frac{t_2}{\tau_2} + \frac{t_3}{\tau_3} \right) \times 100\%$$

t = Elapsed time

τ = Allowed time

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Example of Dose Calculation:

Work Type	Elapsed Time t(hours)	a_{eq} m/s^2	Allowed Time τ (hours)
1	2	0.7	2.5
2	0.5	1.3	0.9
3	1	0.3	8

$$\text{Dose} = \left(\frac{2}{2.5} + \frac{0.5}{0.9} + \frac{1}{8} \right) \times 100\% = 148\%$$

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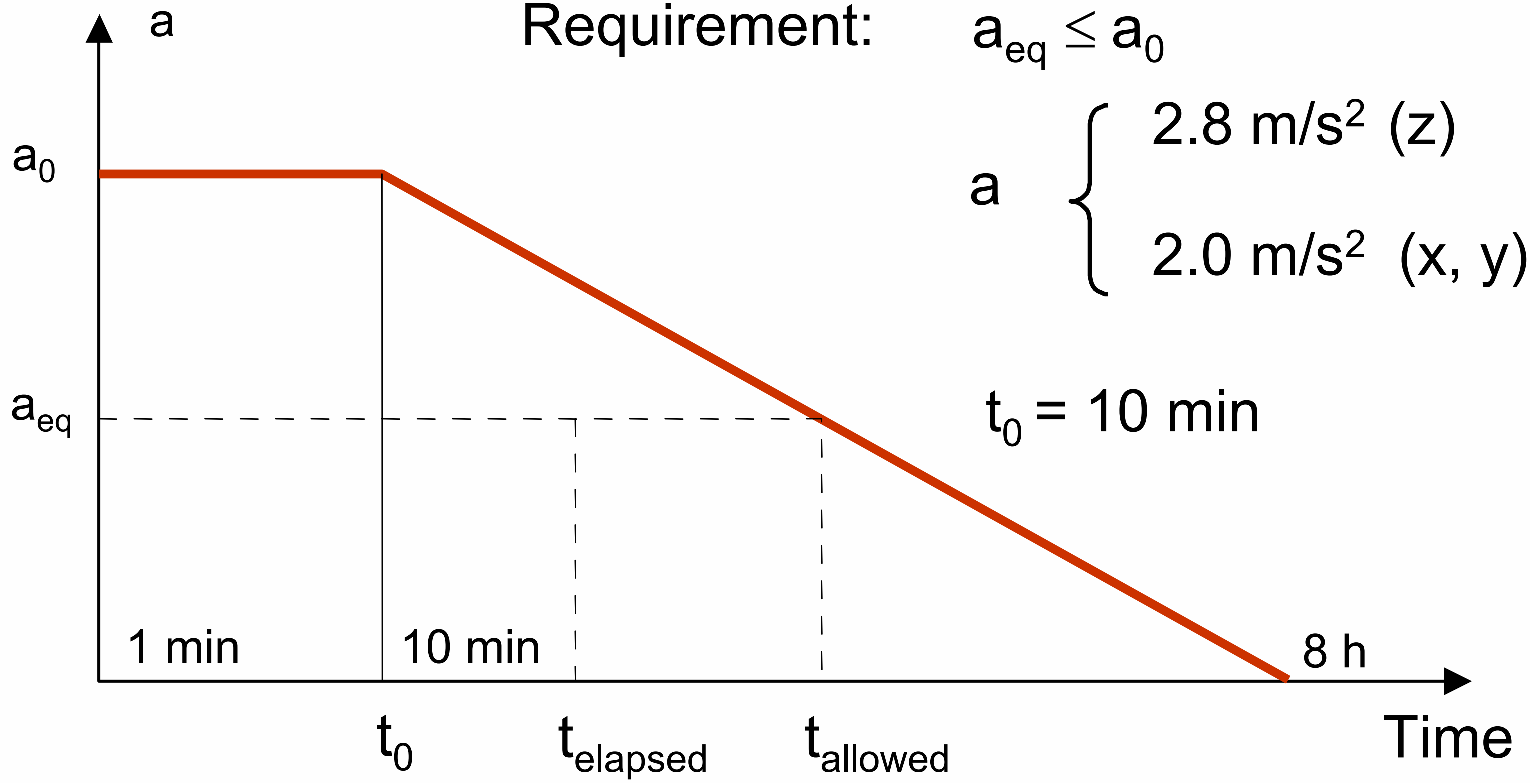
Approximated Exposure Evaluation



Requirement: $a_{eq} \le a_0$

$$a \begin{cases} 2.8\ \text{m/s}^2\ (z) \\ 2.0\ \text{m/s}^2\ (x, y) \end{cases}$$

$t_0 = 10$ min

$$t_{allowed} = \left(\frac{a_0}{a_{eq}}\right)^2 \times t_0 \qquad (1)$$

$$\text{Dose} = \frac{t_{elapsed}}{t_{allowed}} \times 100\% \qquad (2)$$

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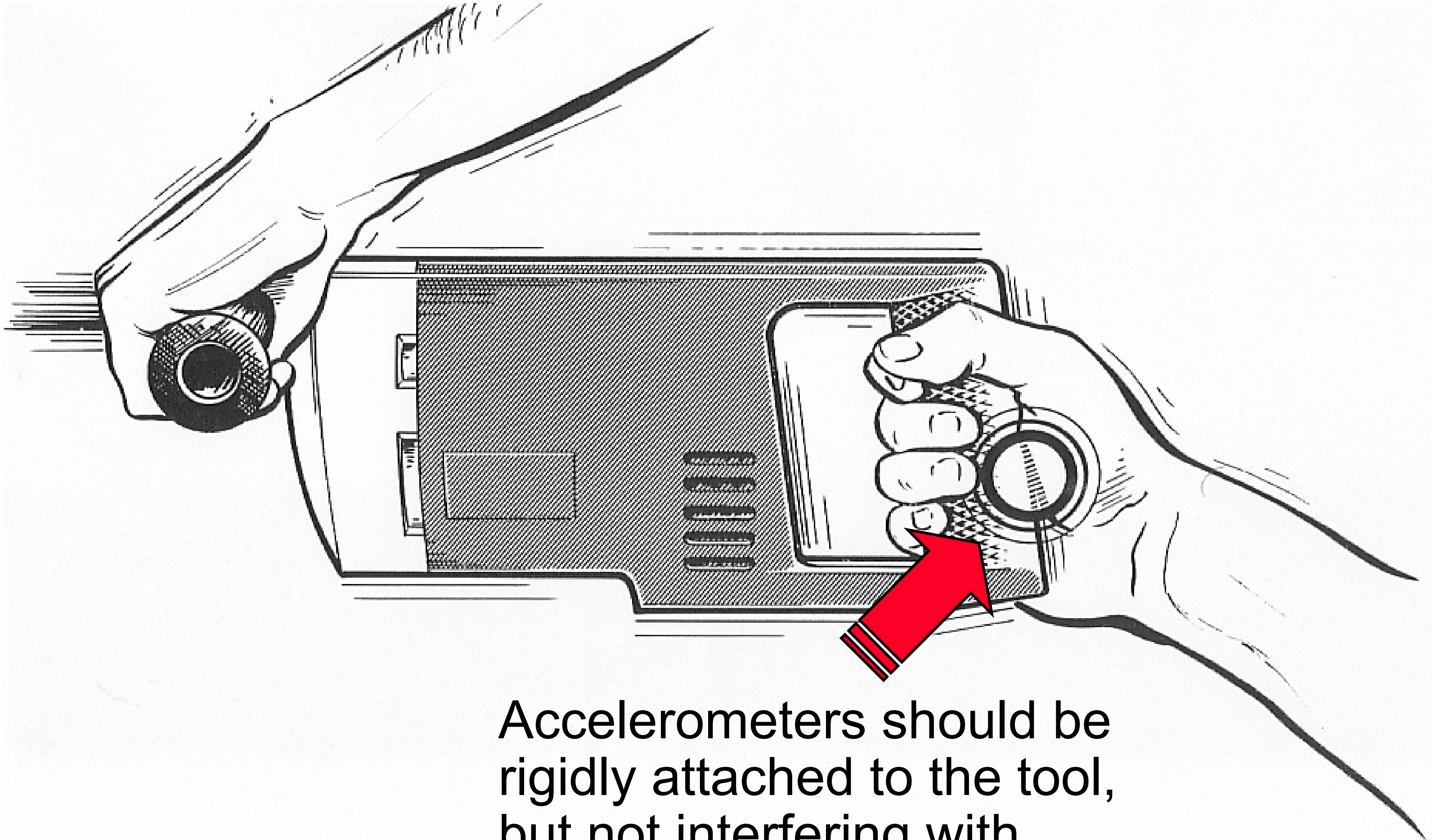
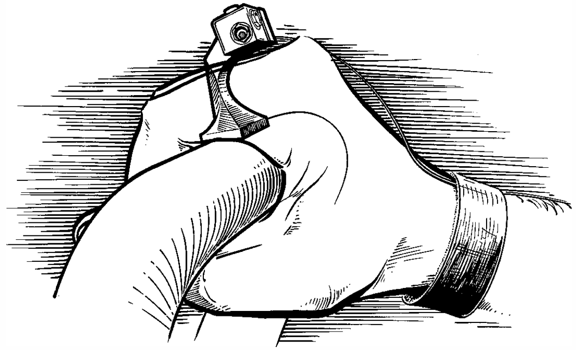
Mounting the Transducer – Hand Arm



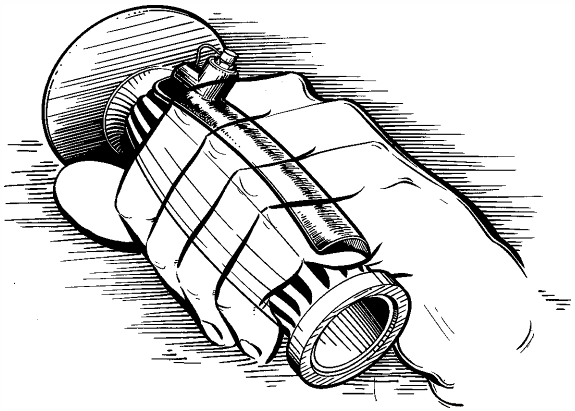
Accelerometers should be rigidly attached to the tool, but not interfering with normal operation

Mounting Adaptors – Hand Arm

Hand-adaptor

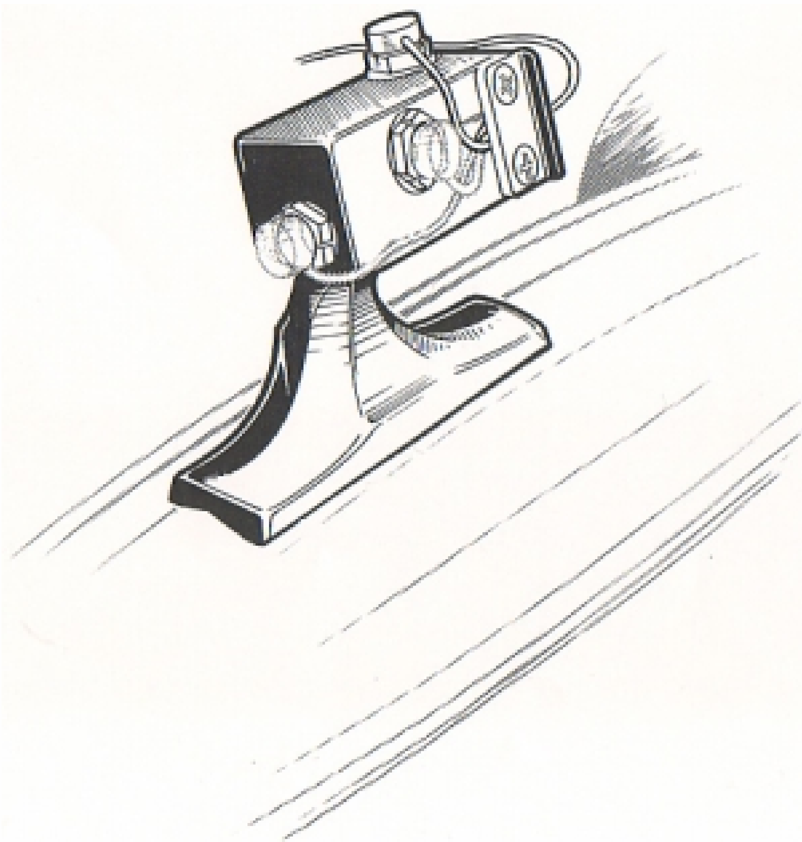


Handle adaptor

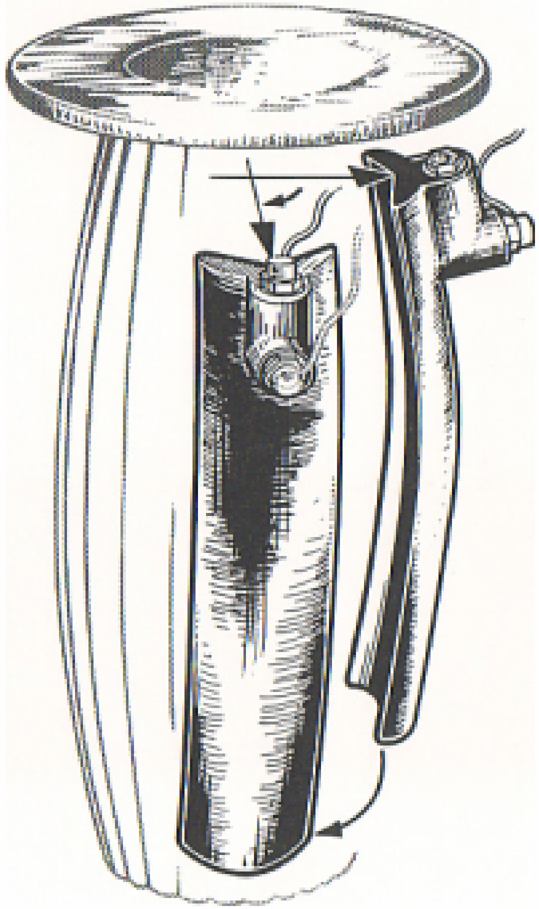


Handle adaptors and hand-adaptors are used when rigid mounting to the tool is not possible

Coordinate Systems



The hand adaptor measures in the biodynamic coordinate system



The handle adaptor measures in the basicentric coordinate system

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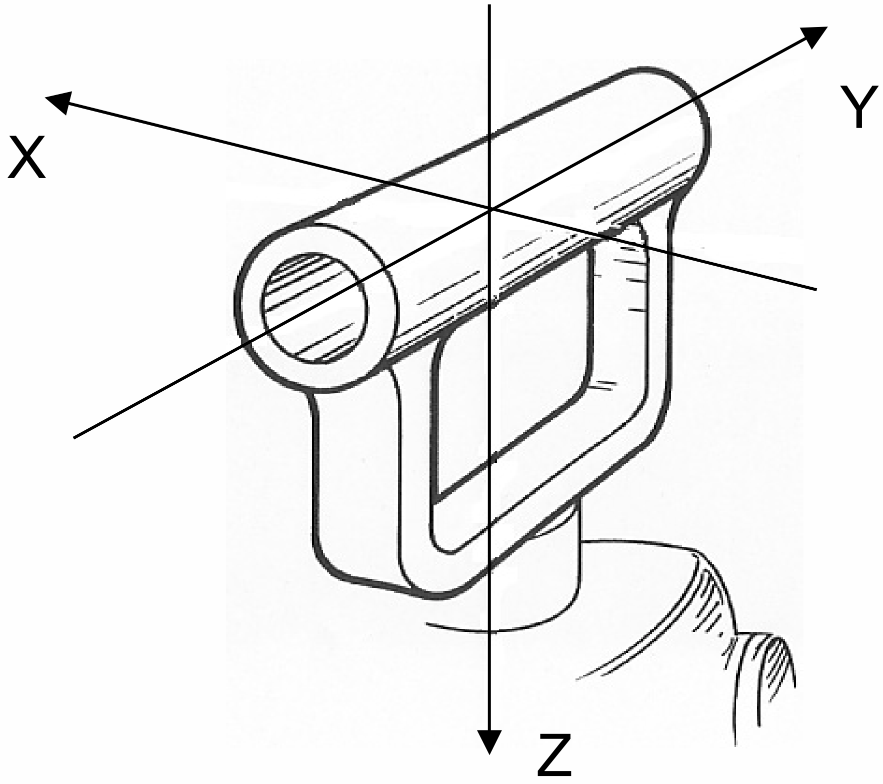
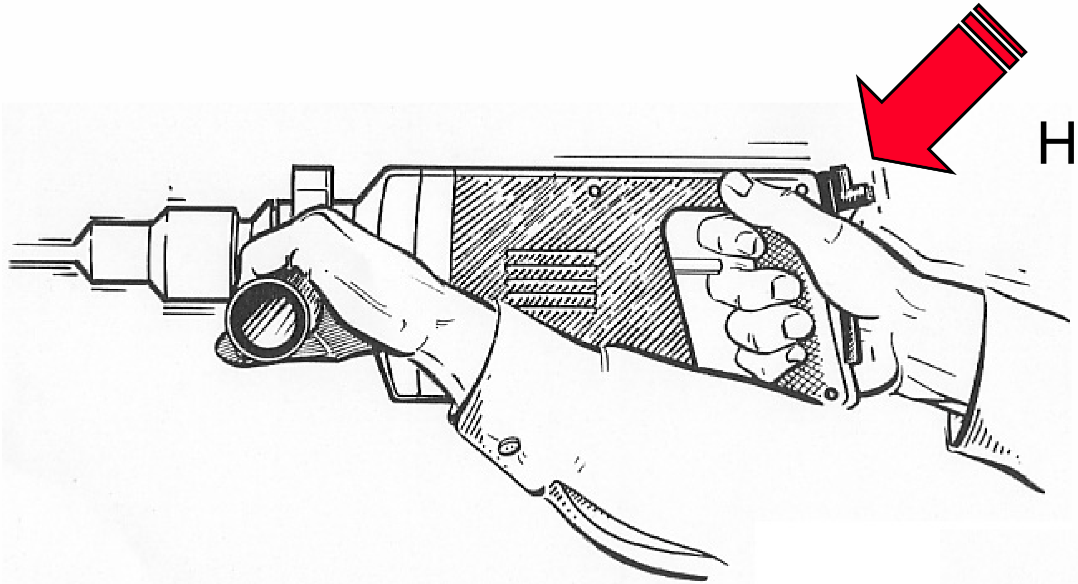
Directional Considerations for Hand-Arm



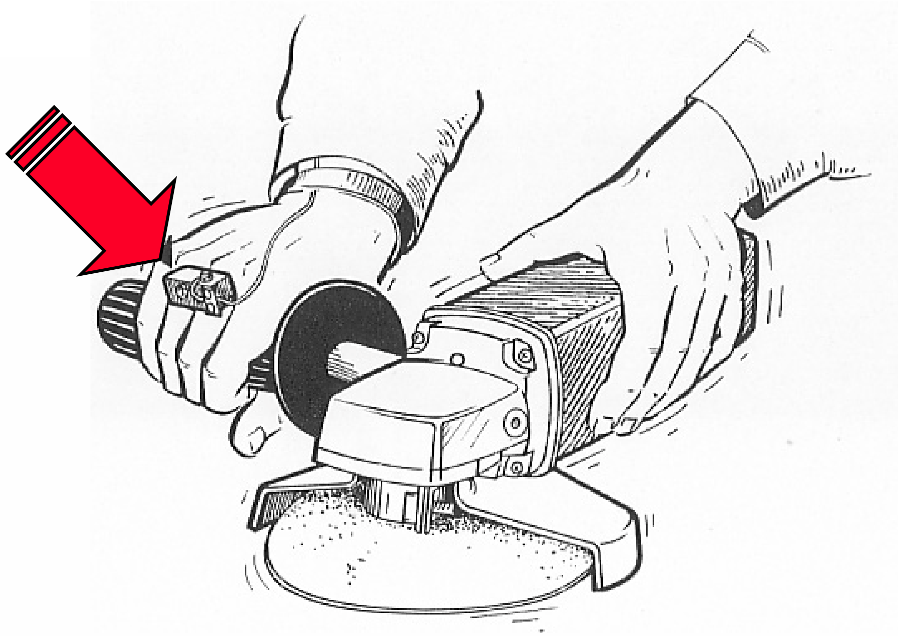
For hand-arm vibration it is often necessary to measure in all three directions to find the worst one

Type of Adaptor

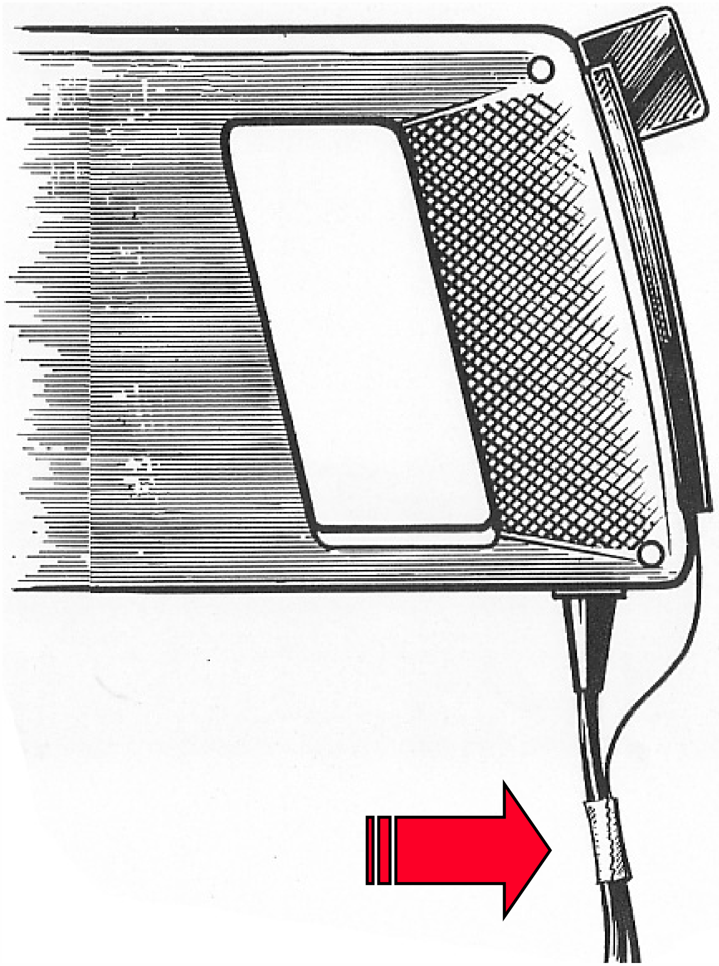


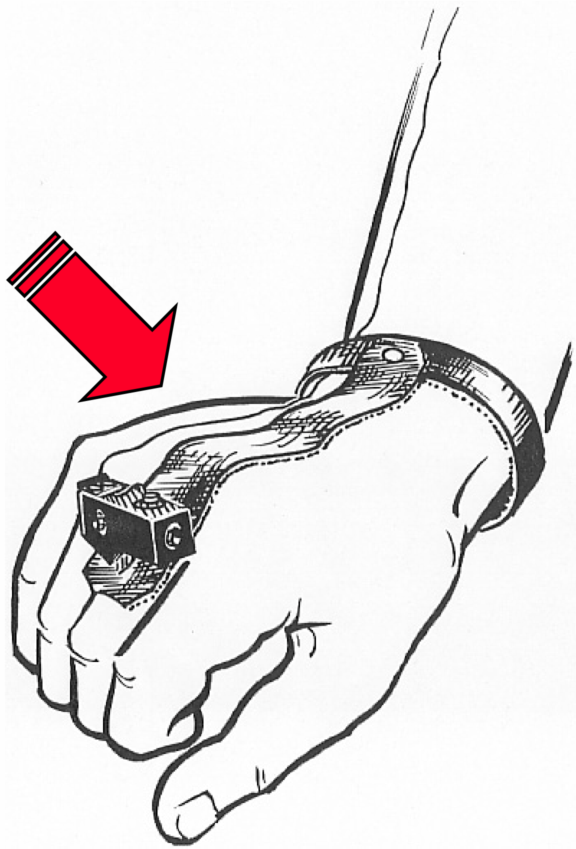
Handle adaptor

Hand-adaptor



Accelerometers Cables





Cables are fixed down, often with tape, so that there is minimal cable-induced vibration in the measurement system

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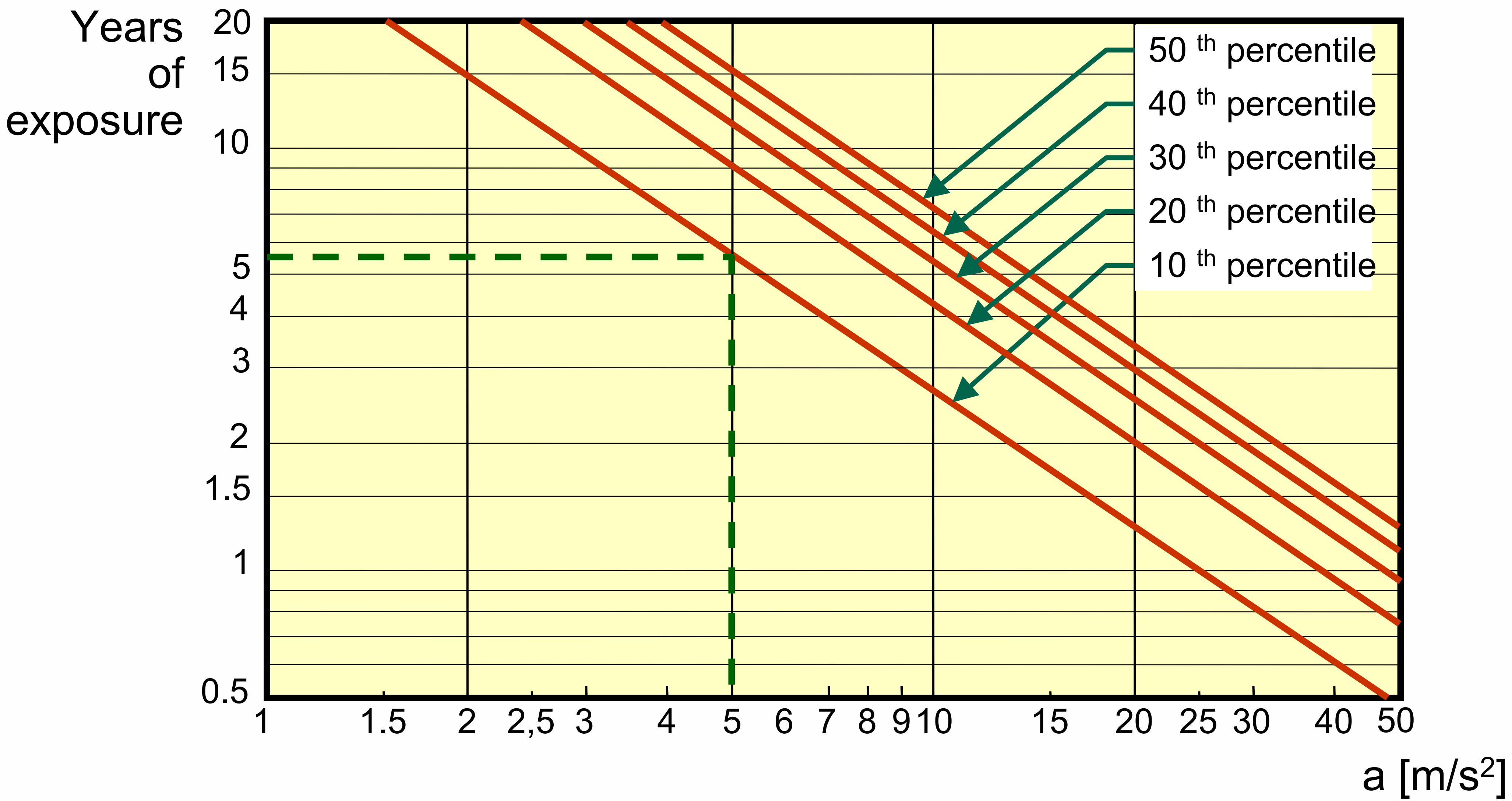
Exposure Evaluation

Risk of getting vascular disorders (White finger syndrome)



The 4-hour Energy Equivalent Acceleration, $a_{eq\ (4)}$

m/s²

$$a_{eq}(4) = a_{eq}(t)\sqrt{\frac{T}{4}}$$

dB

$$L_{eq}(4) = L_{eq(T)} + 10\log\frac{T}{4}$$

Exposure from Several Events

m/s²

$$a_{eq}(T) = \sqrt{\frac{a_1^2 T_1 + a_2^2 T_2 + a_3^2 T_3 + \ldots\ldots\ldots\ldots\ldots}{T_1 + T_2 + T_3 + \ldots\ldots\ldots}}$$

dB

$$L_{eq}(T) = 10 \log \frac{T_1 \,\mathrm{inv.log}\, \frac{L_1}{10} + T_2 \,\mathrm{inv.log}\, \frac{L_2}{10} + \ldots\ldots\ldots}{T_1 + T_2 + \ldots\ldots}$$

Example of Exposure Calculations

Work Type	a_n m/s²	Effective time Hours
1	5.6	0.7
2	10.3	0.5
3	2.5	1.0

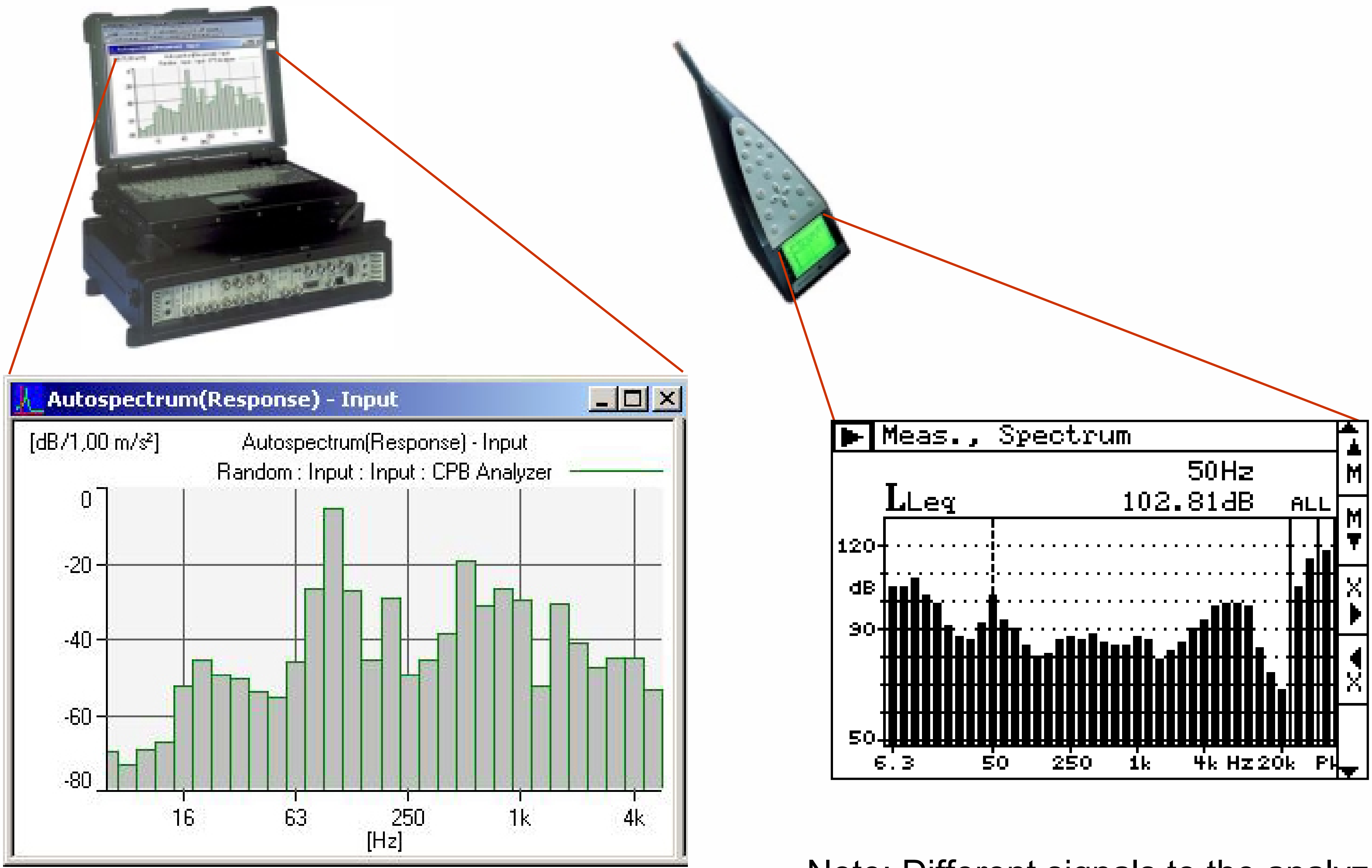
= 2.2

$$a_{eq}(T) = \sqrt{\frac{5.6^2 \times 0.7 + 10.3^2 \times 0.5 + 2.5^2 \times 1.0}{0.7 + 0.5 + 1.0}} = 6.1\,m/s^2$$

$$a_{eq}(4) = 6.1 \times \sqrt{\frac{2.2}{4}} = 4.5\,m/s^2$$

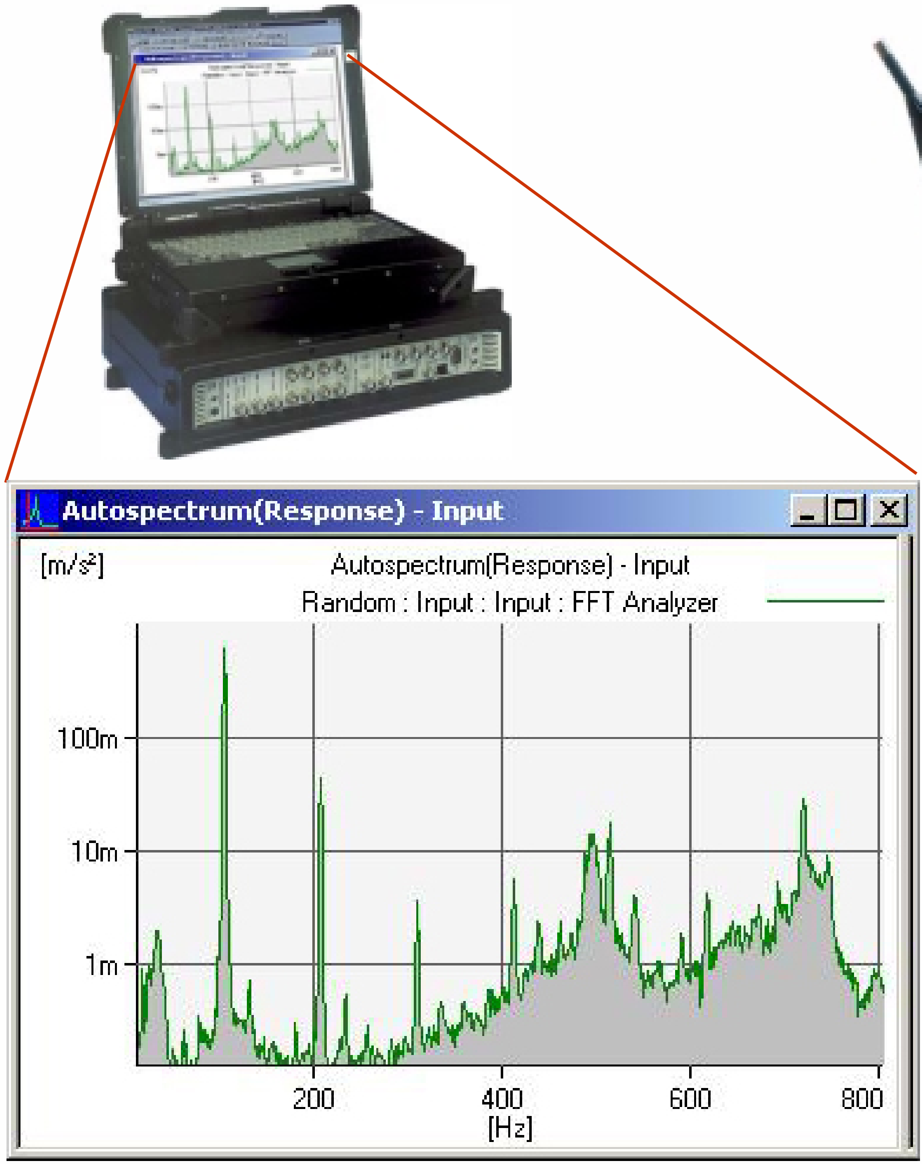
$$a_{eq}(8) = 6.1 \times \sqrt{\frac{2.2}{8}} = 3.2\,m/s^2$$

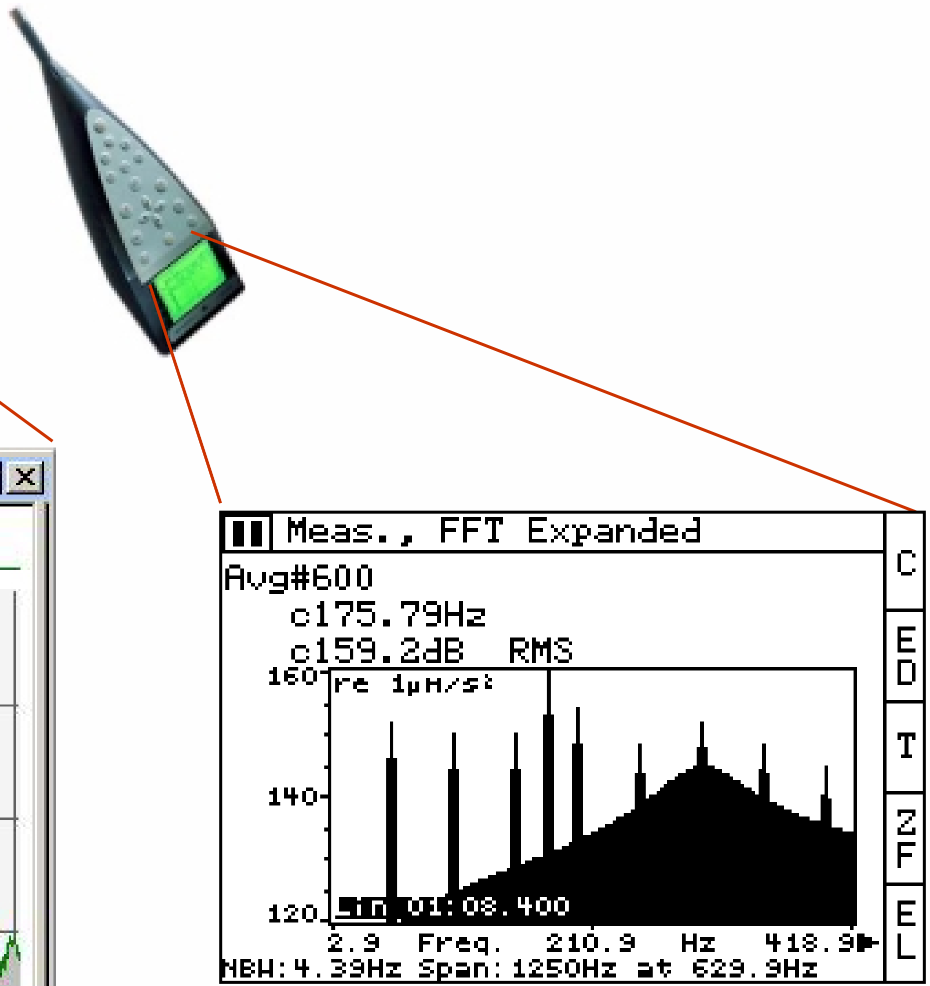
Frequency Analysis – 1/3 Octave



Note: Different signals to the analyzers

Frequency Analysis – FFT





Note: Different signals to the analyzers

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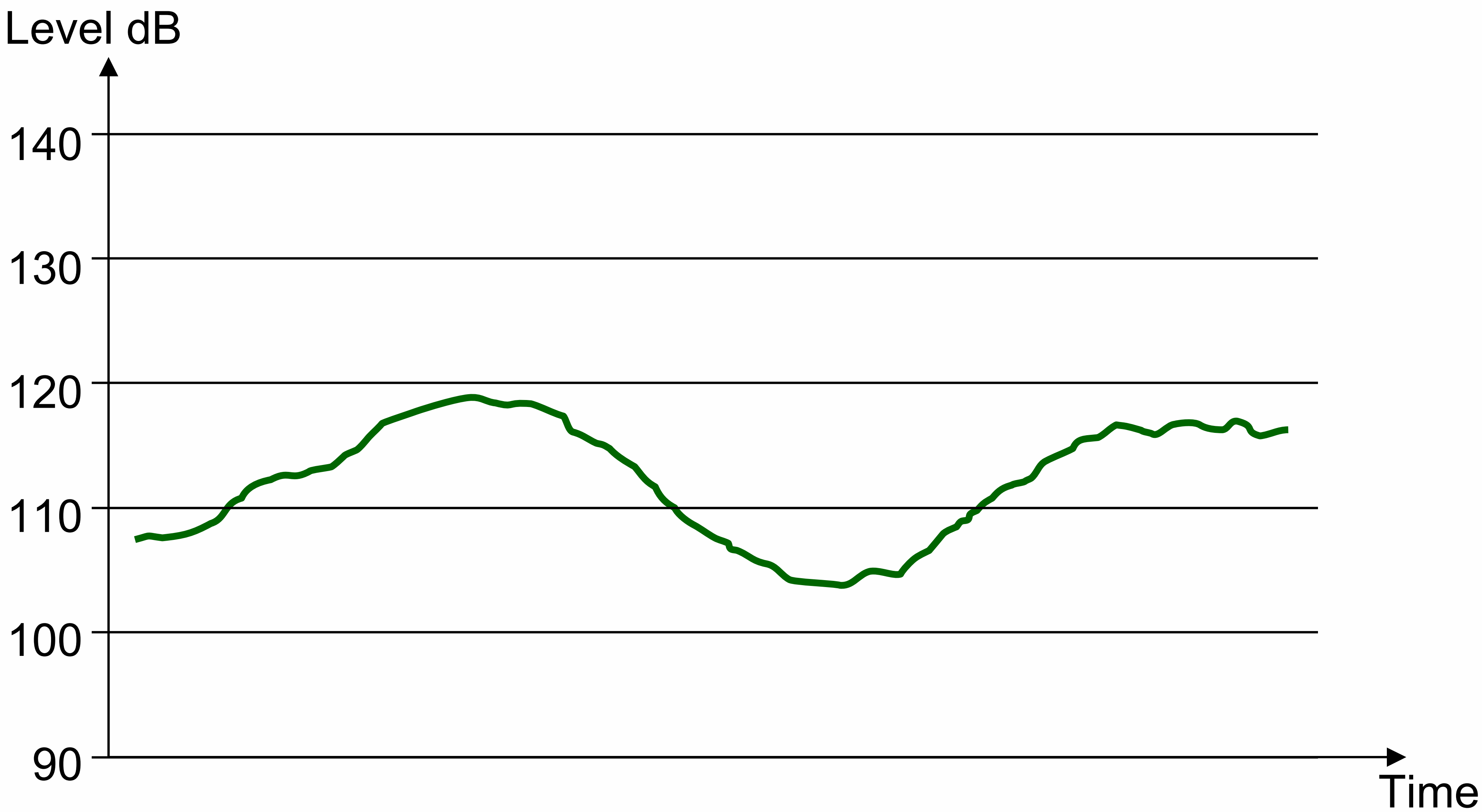
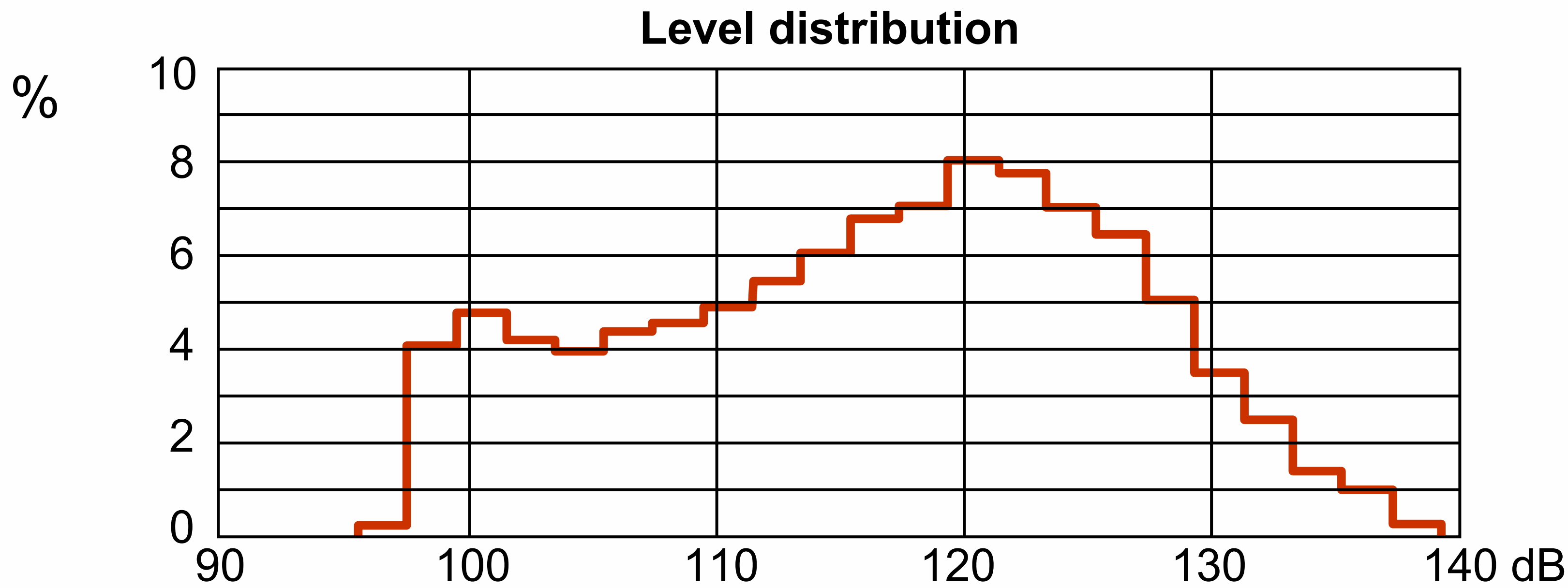
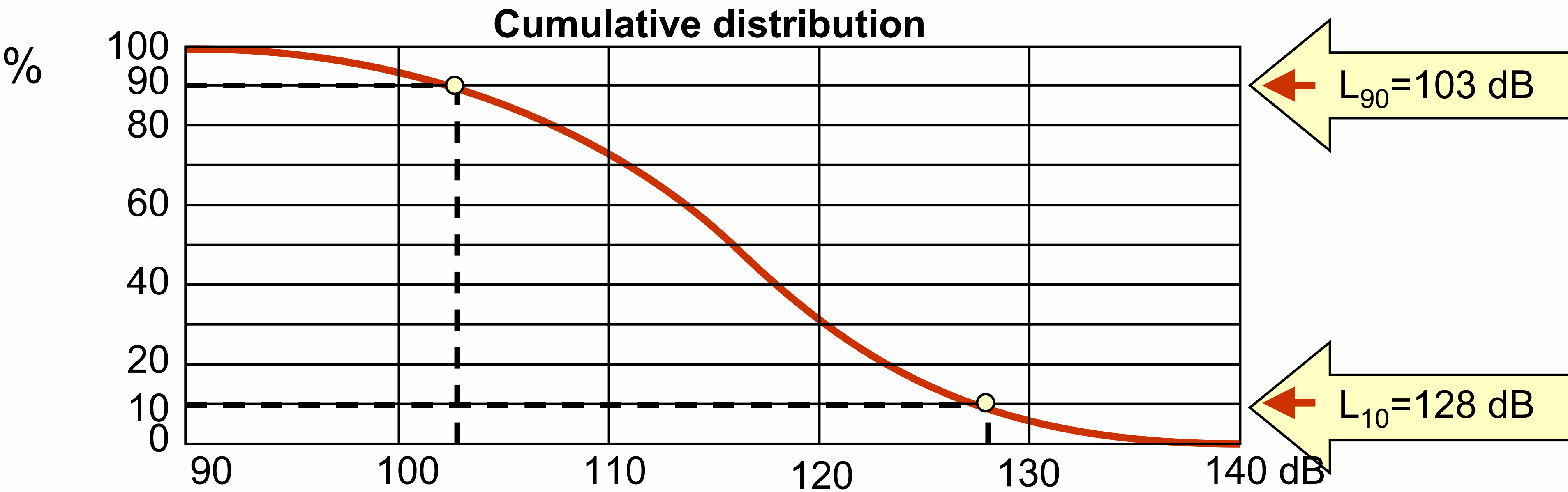
Level Analysis

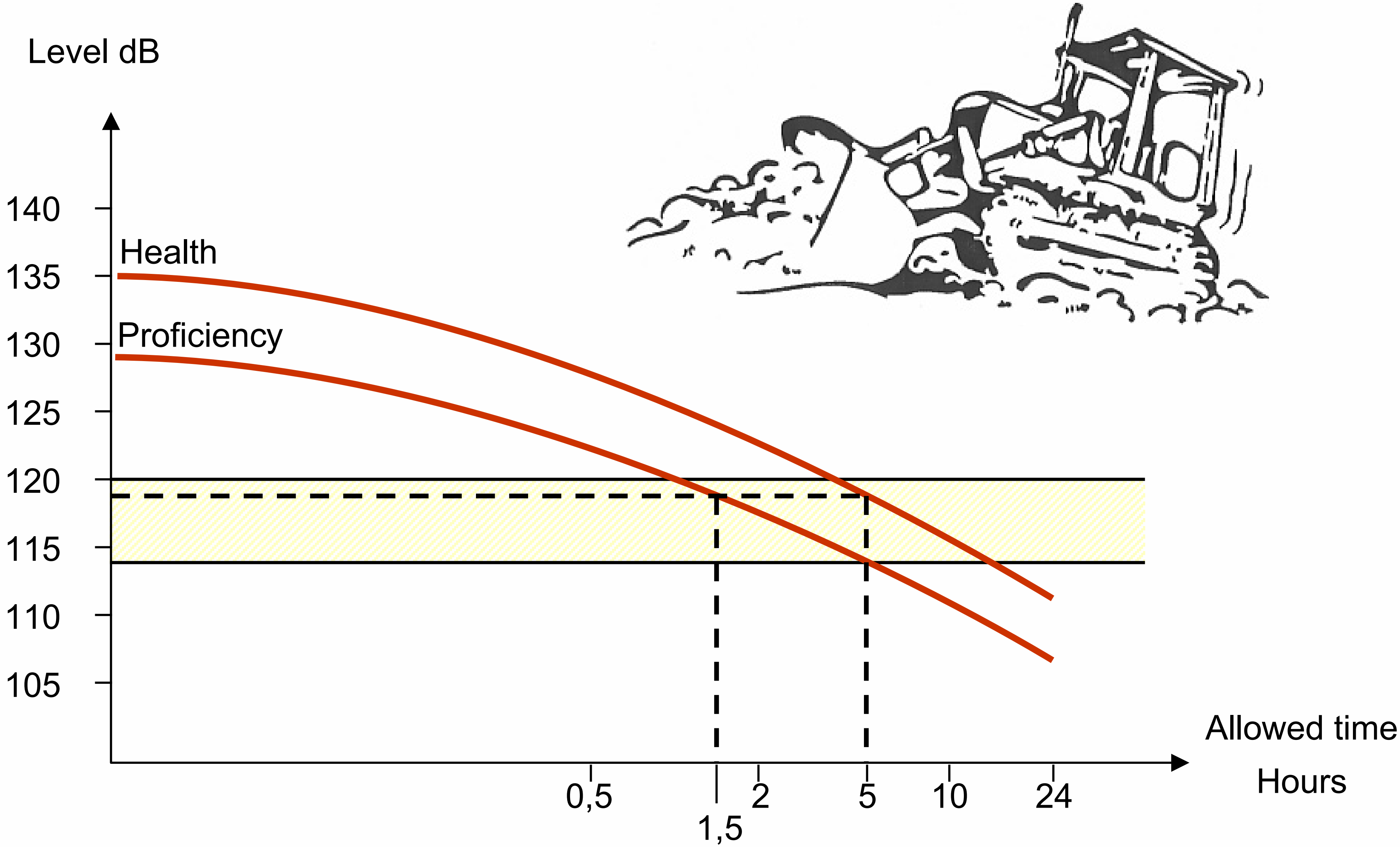


Statistical Analysis



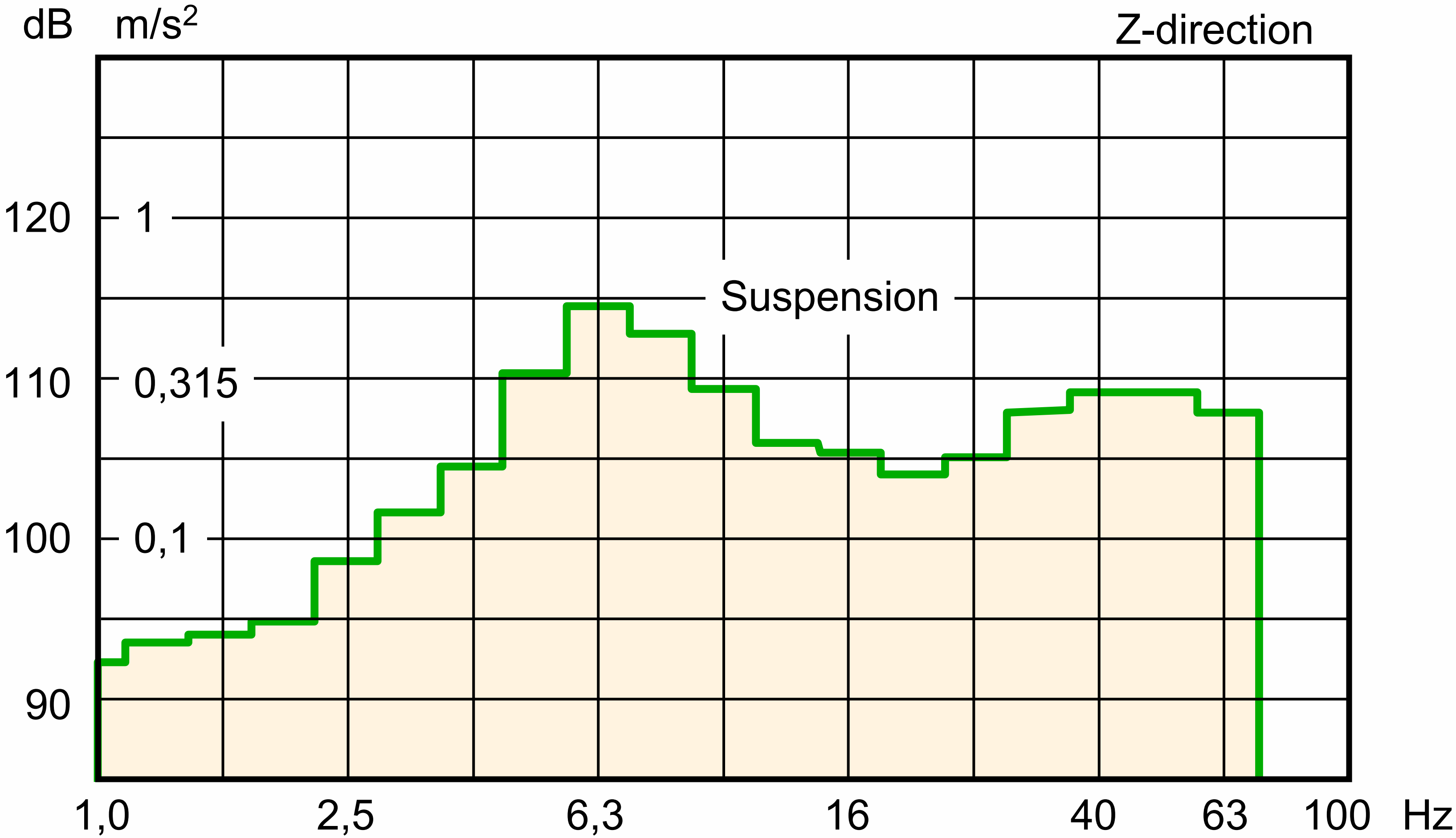


Example: Wheel-loader



Example: Wheel-loader

1/3 Octave Spectrum



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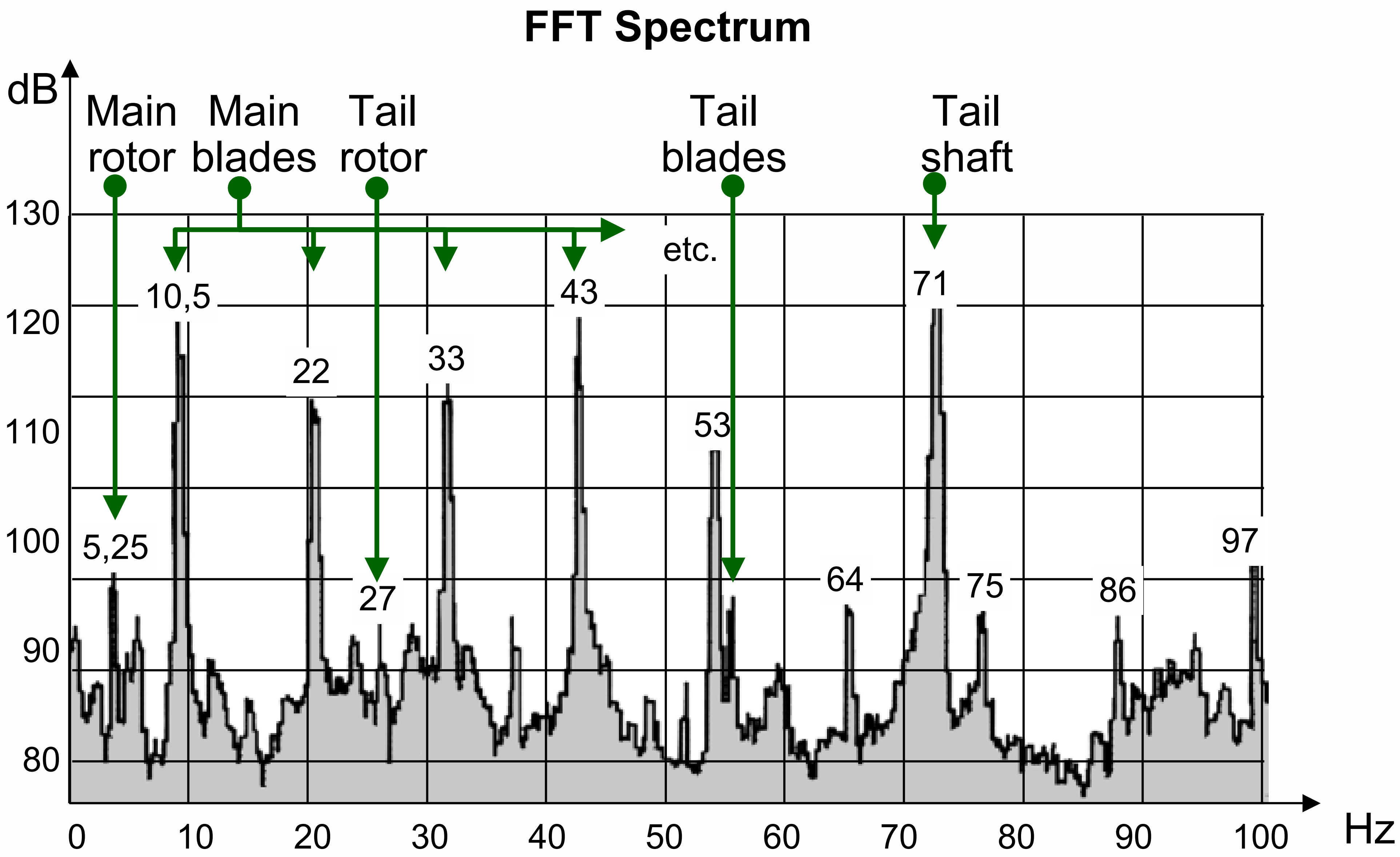
Example: Helicopter



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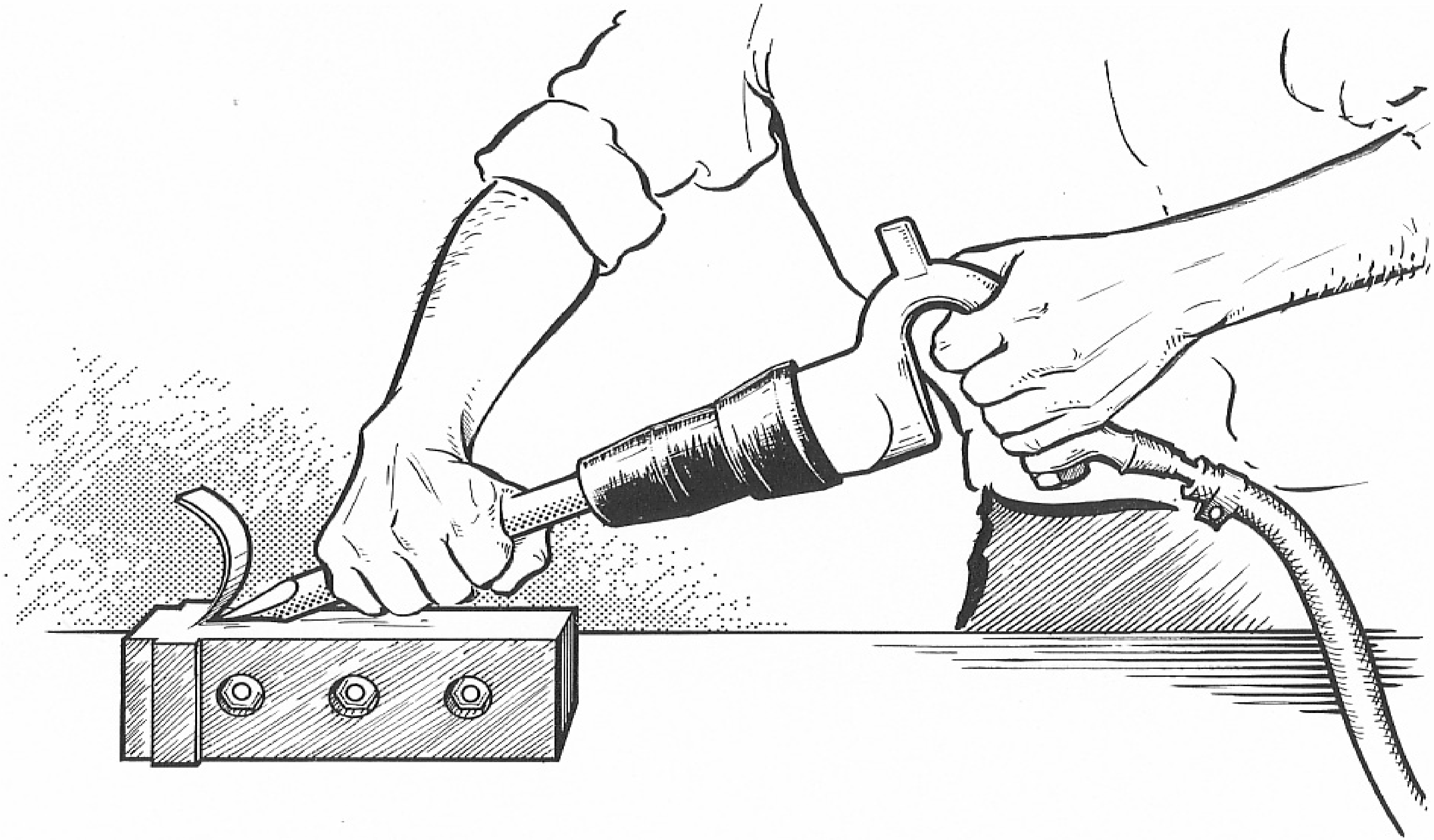
Example: Chipping Hammer



Very high peak acceleration levels are found at the handle of the chipping hammer. Even higher levels are found at the chisel (and the operator often uses his other hand to control the chisel)

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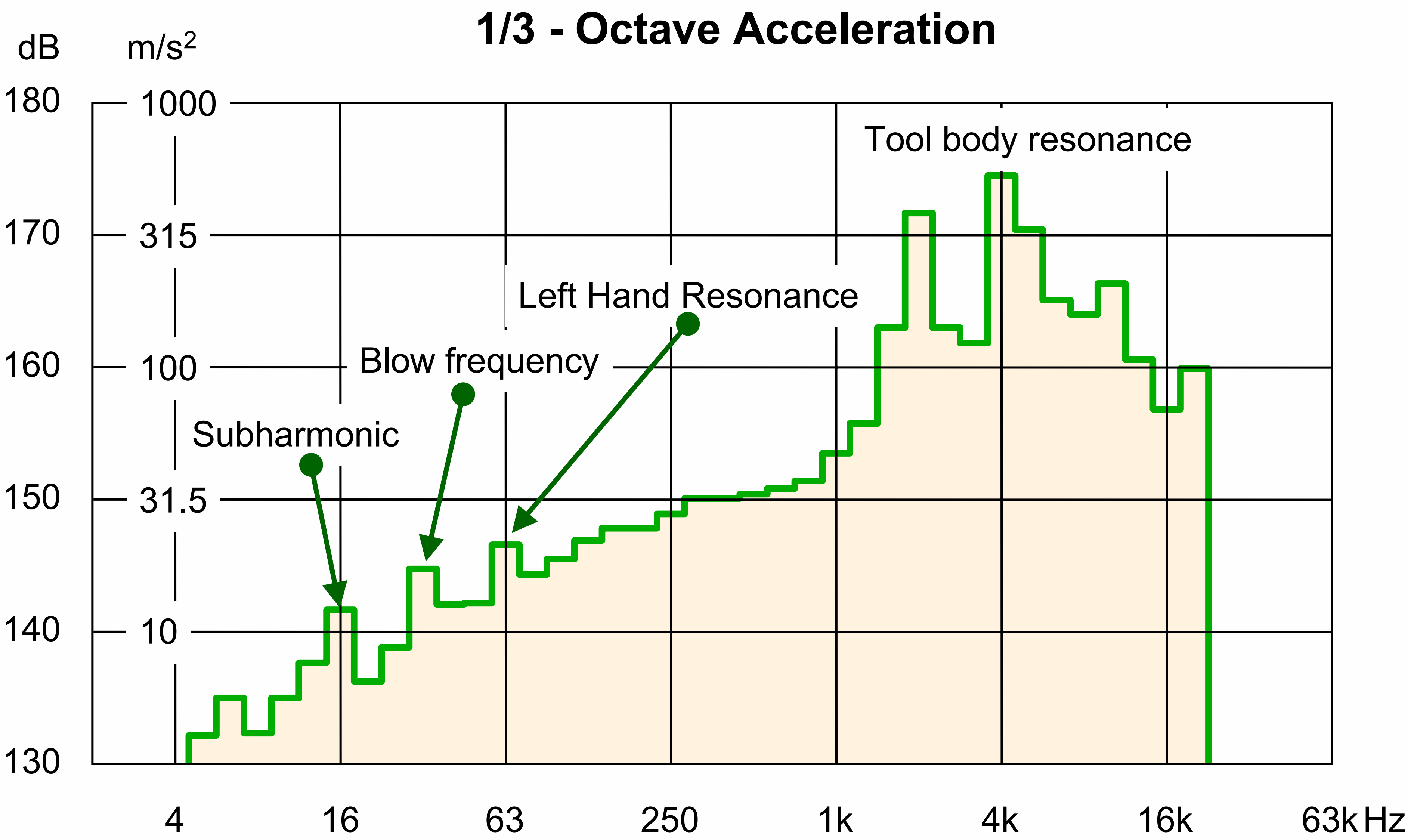
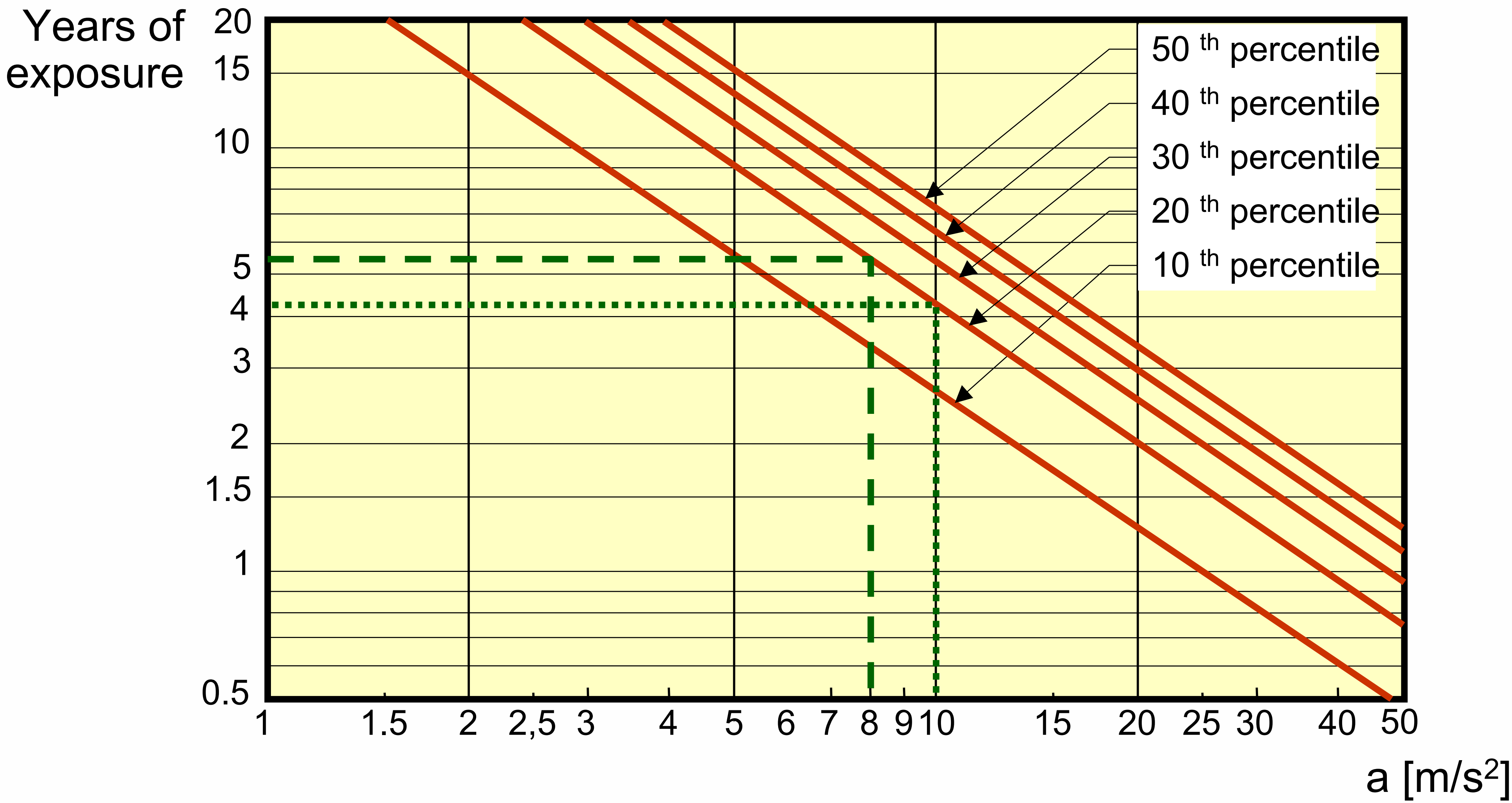
Chipping Hammer Vibration

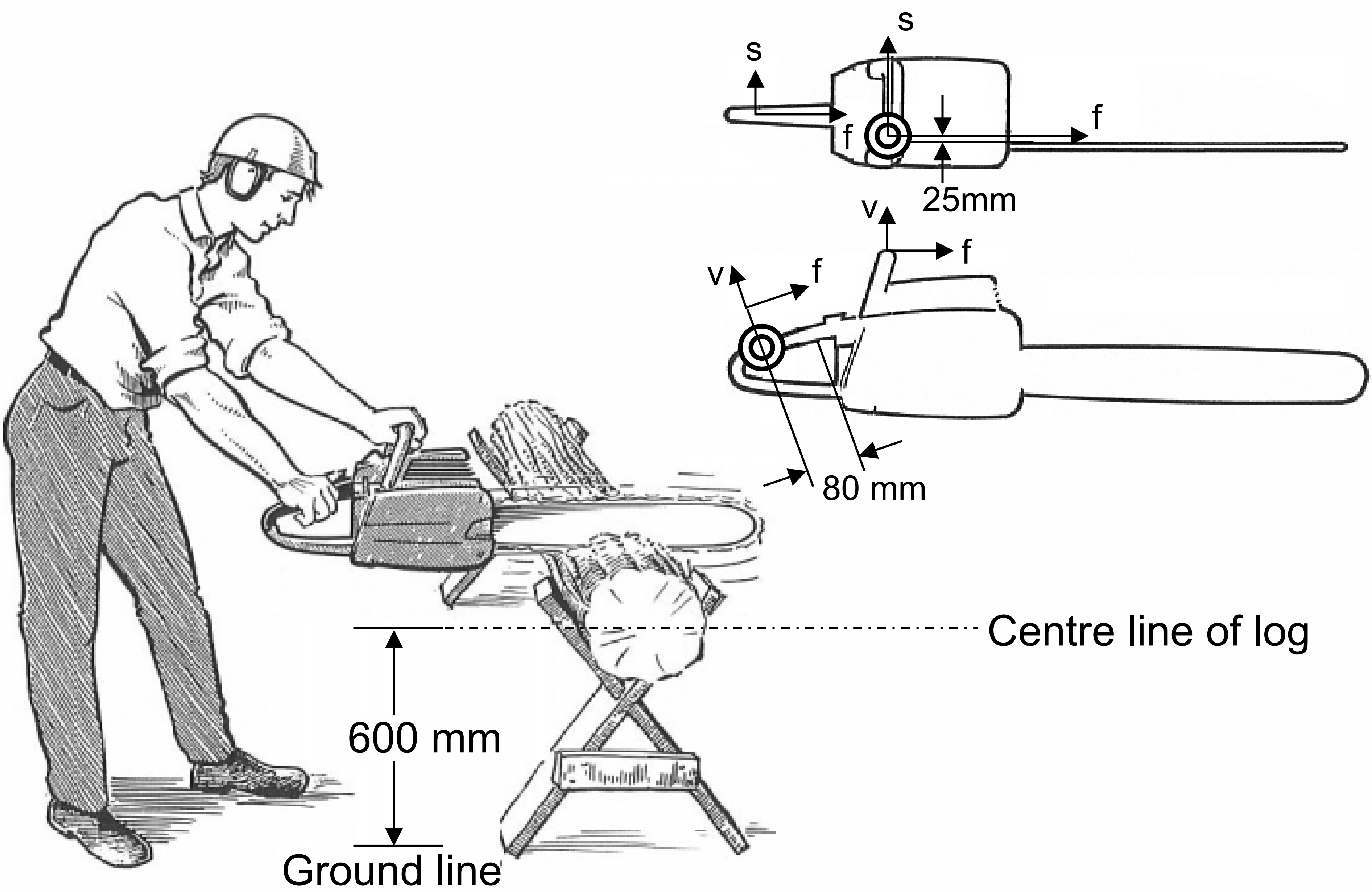


Chipping Hammer Risk Evaluation

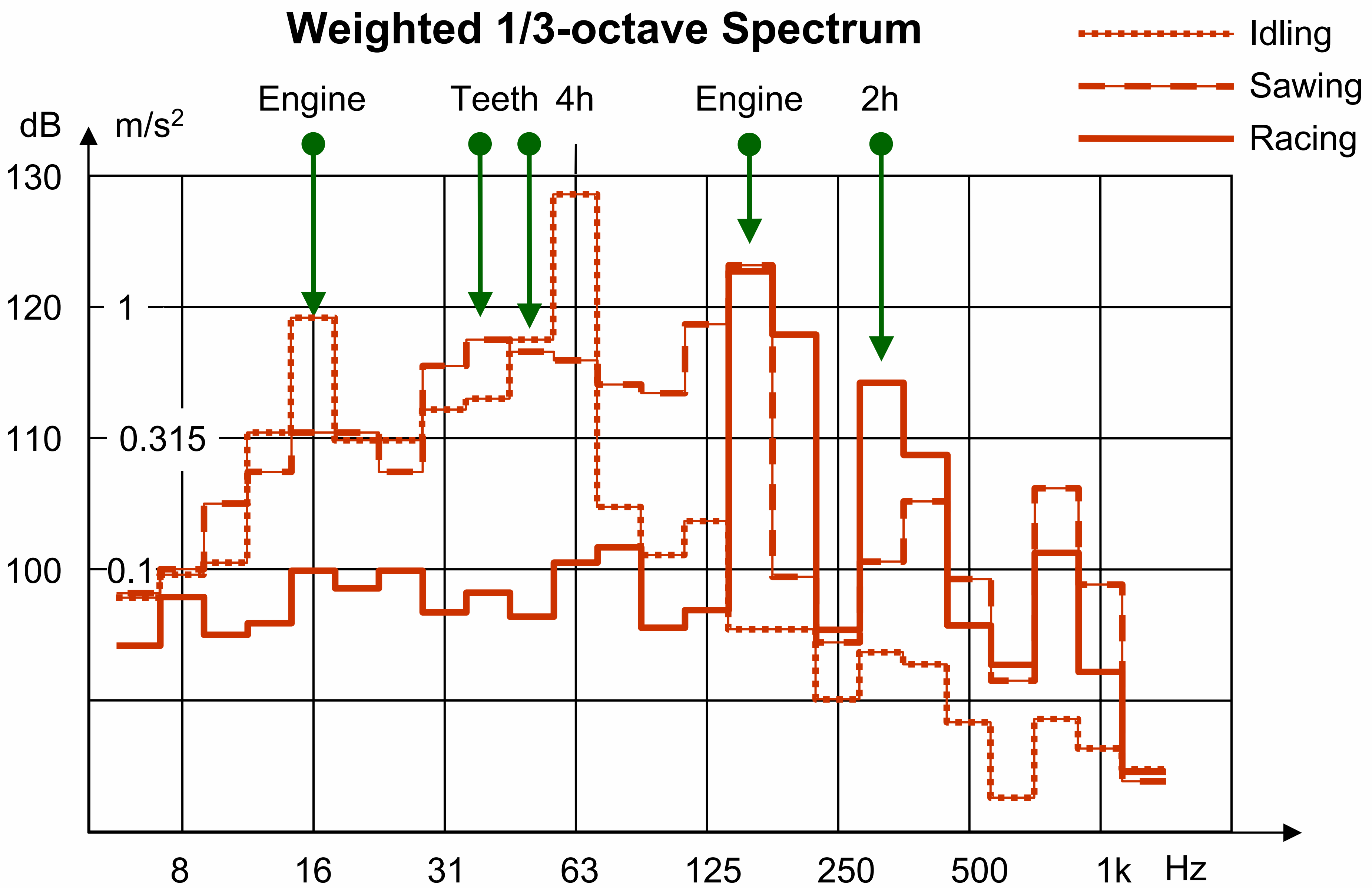


Brüel & Kjær

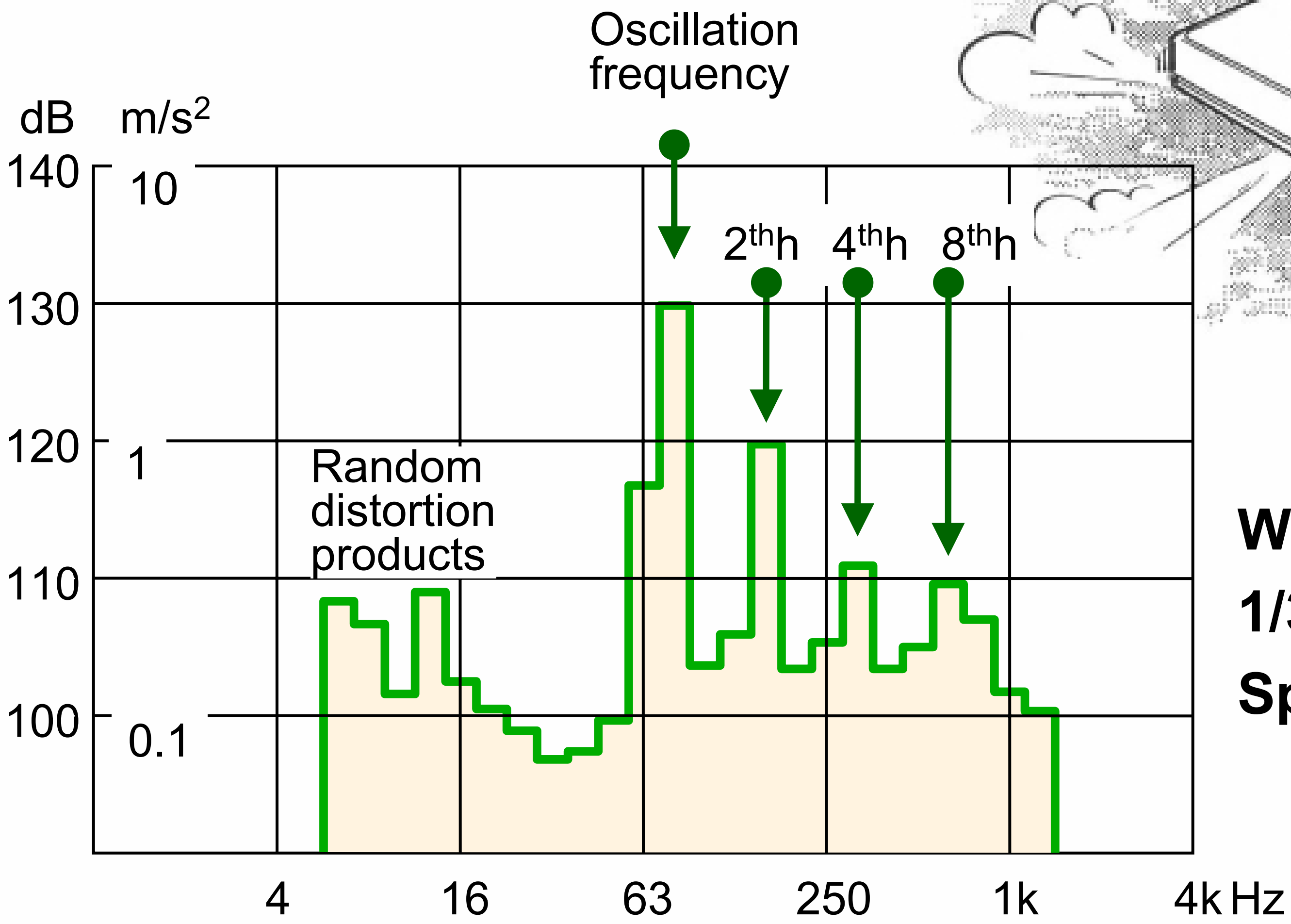
Example: Chain Saw

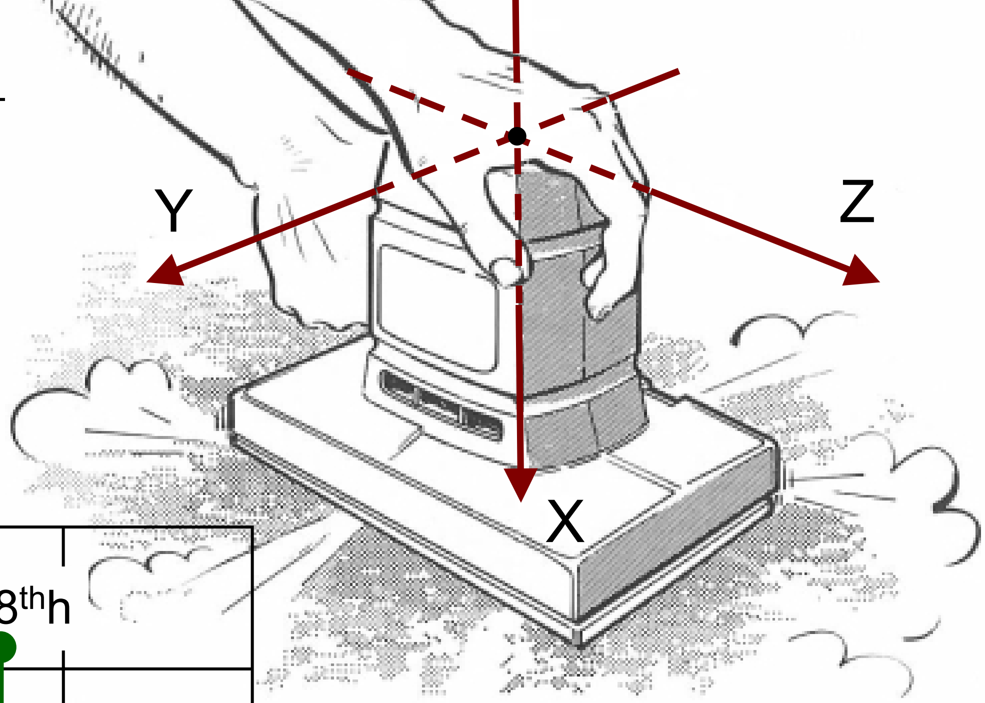


Chain Saw


Weighted 1/3-octave Spectrum
Idling
Sawing
Racing
Engine
Teeth 4h
Engine
2h
dB
m/s²
130
120
110
100
1
0.315
0.1
8
16
31
63
125
250
500
1k
Hz

Example: Grinders





Weighted 1/3-octave Spectrum

Conclusion

Central Issue:

Avoid breaking occupational health legislation at lowest cost

Monitoring and Risk assessment checklist:

- Is there a problem?
- How big is the problem?
- What causes the problem?
- How do we reduce the problem?
- How do we prevent the problem?

Vibration + Time = Vibration Exposure

Vibration Exposure + Time = **Tissue Damage**

Vibration exposure is measured according to national and international standards for Hand-Arm Vibration and Whole-Body Vibration.