Noise Control Engineering Basics

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Topics

- Basics of sound
- Measurement of sound
- Measurement practices
- Noise source identification
- Noise controls

Basics of Sound

Physical Parameters

Sound Power (watts)

- Sound energy generated by a source per unit time
- *Independent* of surroundings, property of a source
- Used for comparing sound sources, calculating sound pressures

Sound Intensity (watts/m^2)

- Measure of the sound power per unit area
- Vector quantity (magnitude and direction)

Sound Pressure (Pascal)

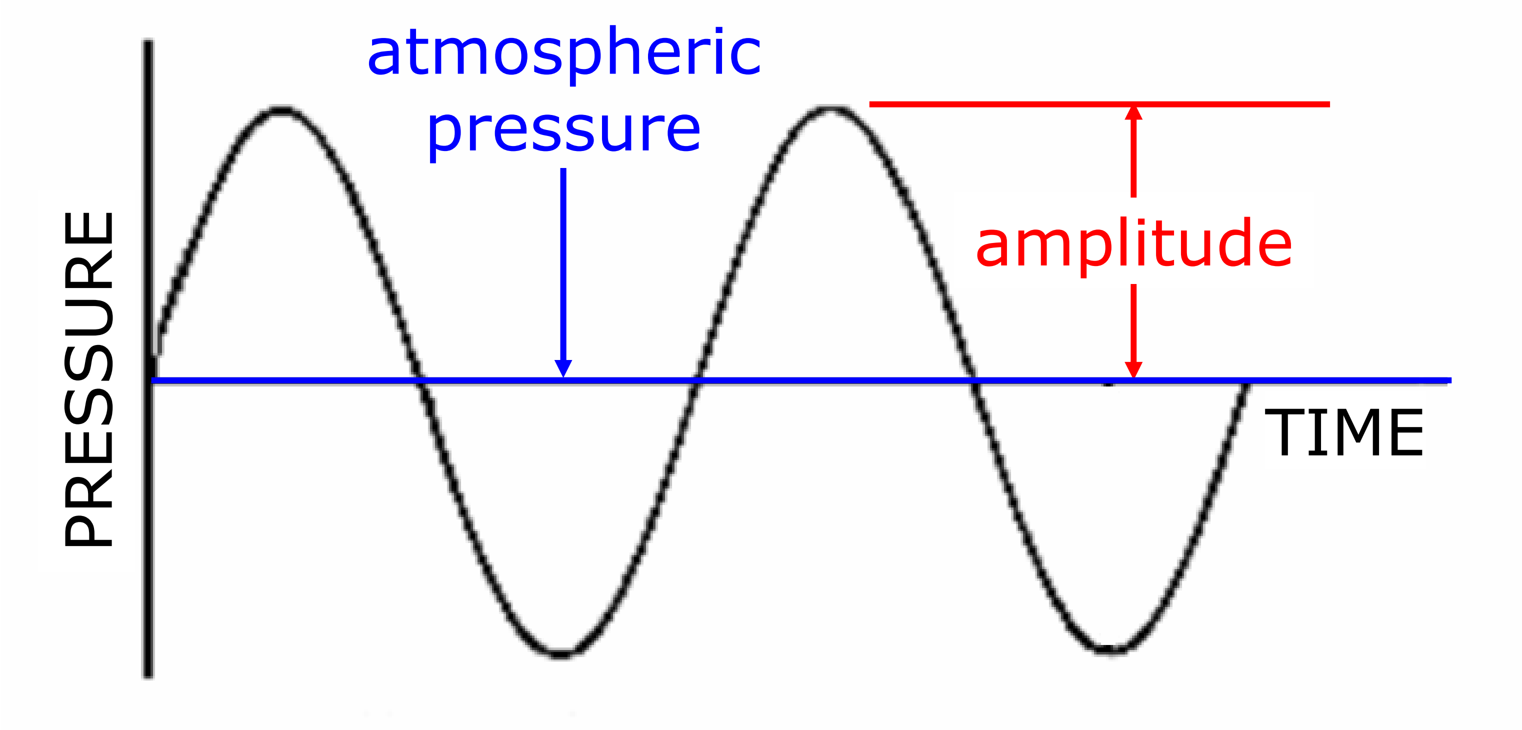
- Pressure fluctuation from atmospheric pressure
- Depends on *sound power* of source, *distance* from source, *environment*

Note: 1 PSI = 6,900 Pascal

Basics of Sound

Characteristics of Sound: Amplitude

Deviation of the pressure from atmospheric pressure

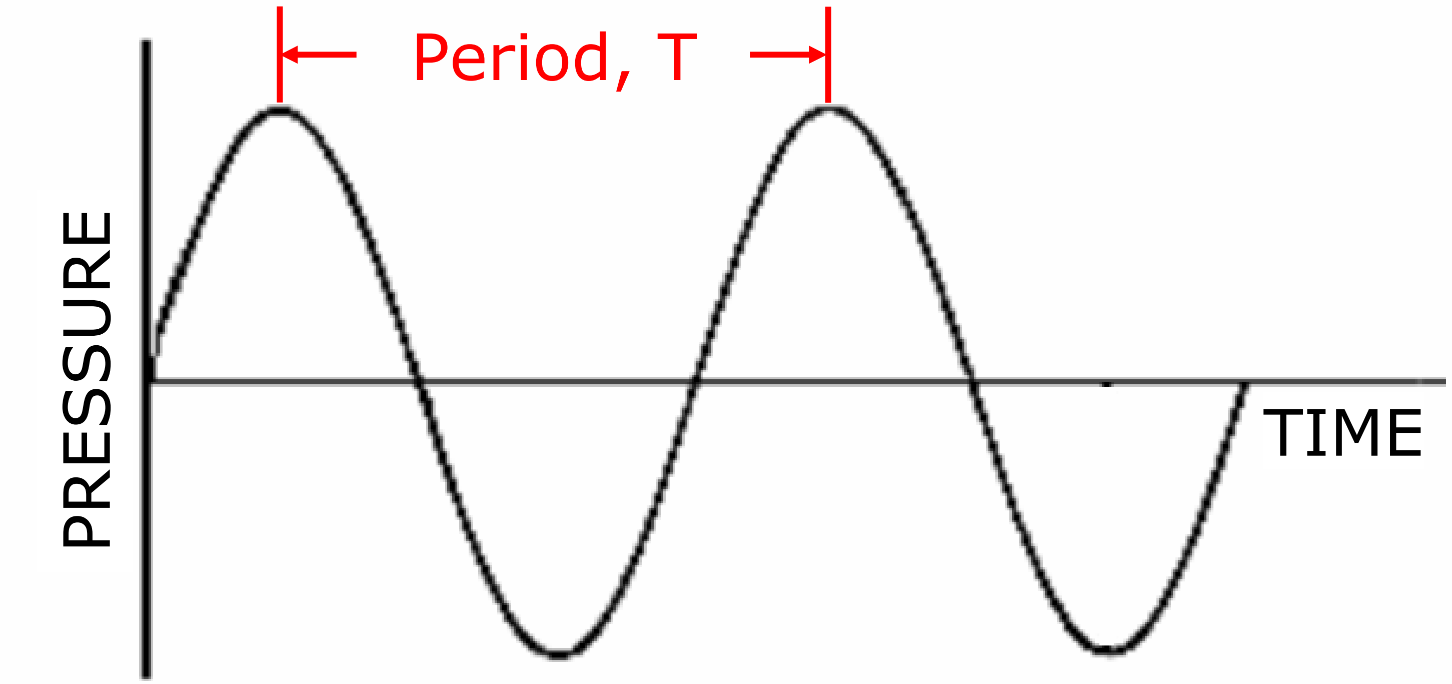


The higher the amplitude, the higher the sound pressure level

Basics of Sound

Characteristics of Sound: Frequency

The number of pressure fluctuations per second



Frequency is related to the period: f = 1/T

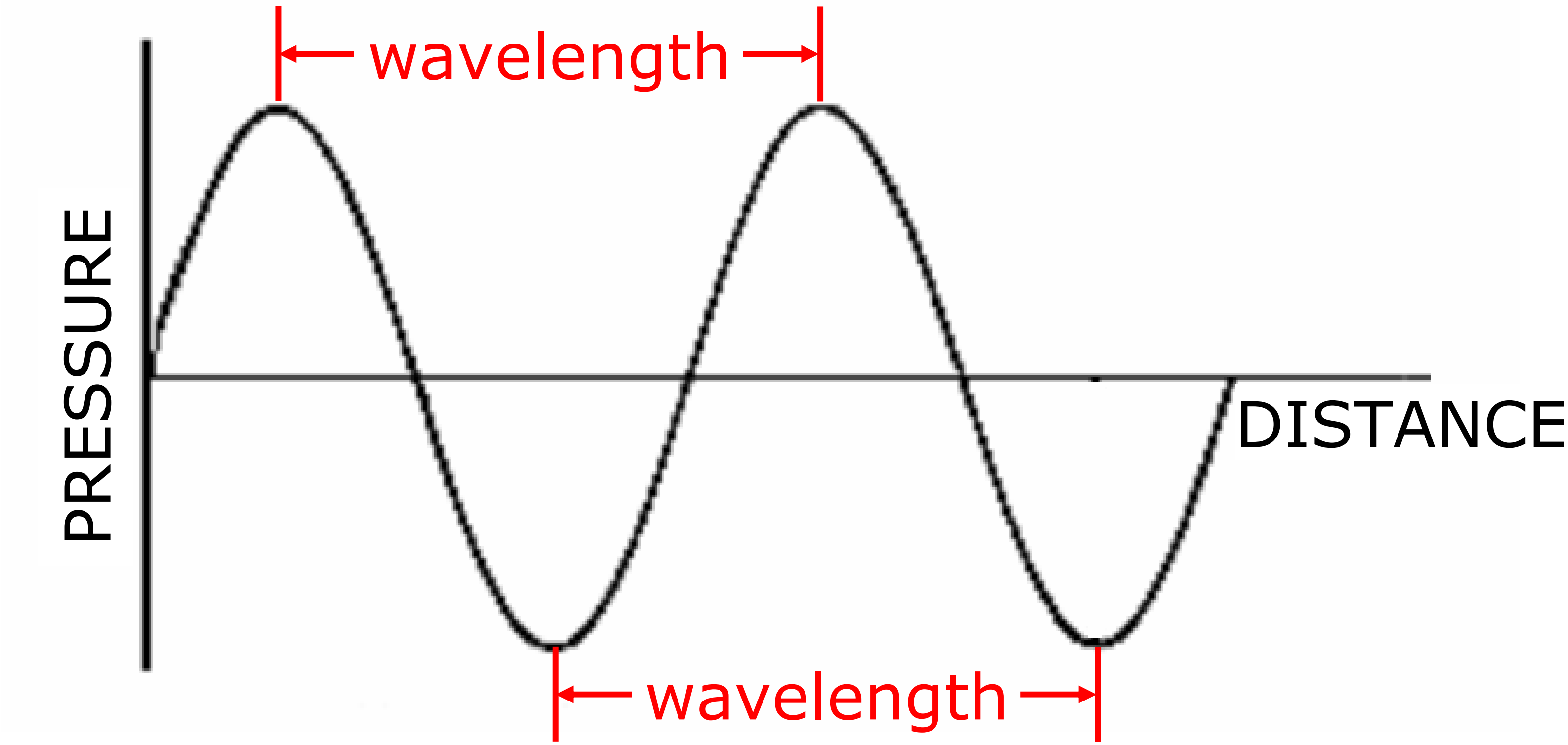
Frequency is measured in Hertz (Hz)

1 Hz = 1 cycle per second

Basics of Sound

Characteristics of Sound: *Wavelength*

The distance required for the wave to repeat itself



Wavelength is related to frequency by the speed of sound: $\lambda = c/f$

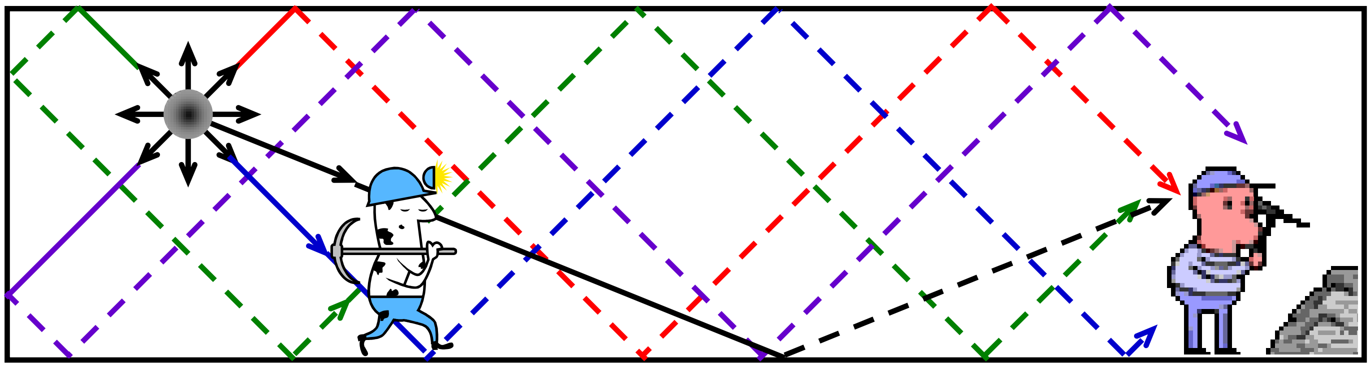
low frequency – long wavelength   high frequency – short wavelength

Basics of Sound

Sound Fields (acoustic environments)

In typical indoor environments (including mines)

- A region close to the source is dominated by ***direct sound***
- A region far from the source is dominated by ***reverberant sound***

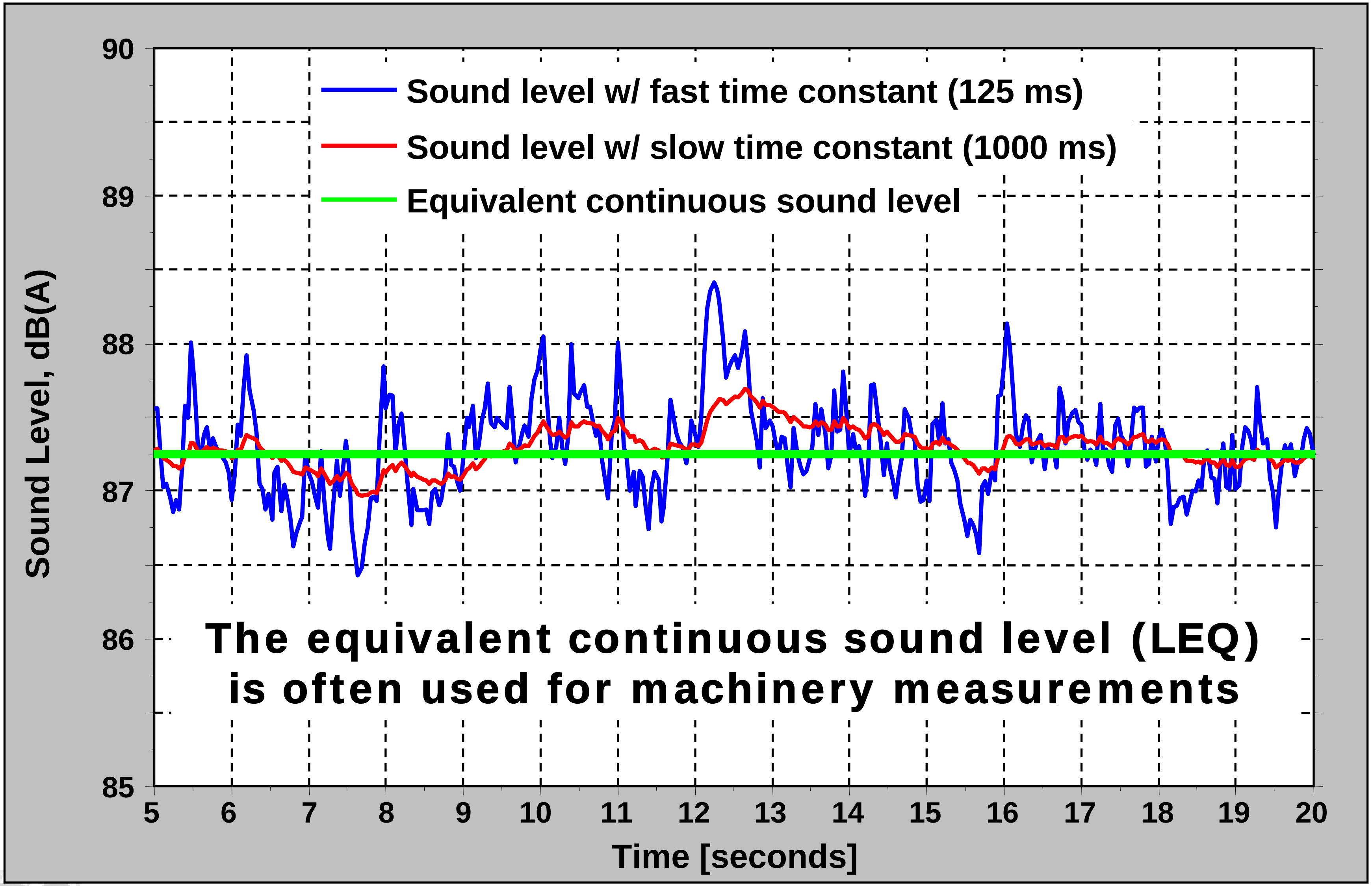


- For a given source, the sound level measured indoors (underground) will usually be higher than the sound level measured outdoors (above ground)

Measurement of Sound

A *sound level meter* (SLM) or a microphone & data acquisition system is used to measure sound pressure levels

Measurement of Sound



Measurement of Sound

Examples of Sound Pressures and SPLs

Sound Source	Sound Pressure	SPL (dB)
Military jet takeoff with afterburner from aircraft carrier at 50 feet	89 Pascal (0.013 PSI)	130
Leaf blower at 25 feet	0.51 Pascal (0.000074 PSI)	85
Conversation at 3 feet	0.020 Pascal (0.0000041 PSI)	60

NOTE: Atmospheric pressure is 101,325 Pascal (14.7 PSI)

Source: Noise and Vibration Control, Edited by Leo L. Beranek, Revised Edition. 1998.
Published by the Institute of Noise Control Engineering, Washington, DC.

Measurement of Sound

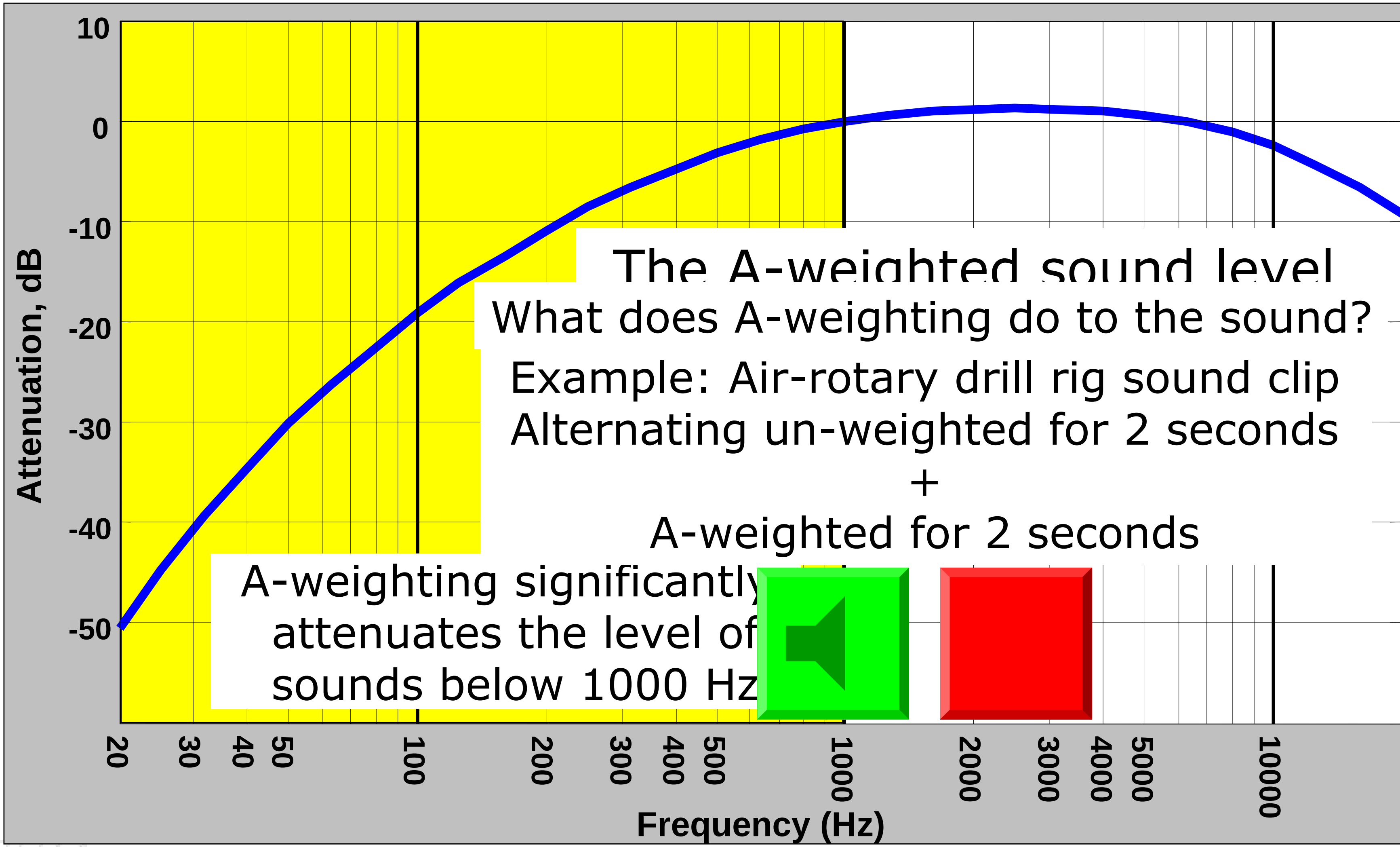
Examples of Sound Pressures and SPLs

Sound Source	% of Atmospheric Pressure	SPL (dB)
Military jet takeoff with afterburner from aircraft carrier at 50 feet	0.088%	130
Leaf blower at 25 feet	0.00050%	85
Conversation at 3 feet	0.000028%	60

NOTE: Atmospheric pressure is 101,325 Pascal (14.7 PSI)

Measurement of Sound

A-weighting



What does A-weighting do to the sound?

Example: Air-rotary drill rig sound clip
Alternating un-weighted for 2 seconds
+
A-weighted for 2 seconds

A-weighting significantly attenuates the level of sounds below 1000 Hz

Measurement of Sound

Mathematics of Decibels

- Decibels are logarithmic, not linear
- Cannot simply add, subtract, or average sound levels
- Two sources with equal sound levels increase sound level by 3 dB

<u>Example</u>

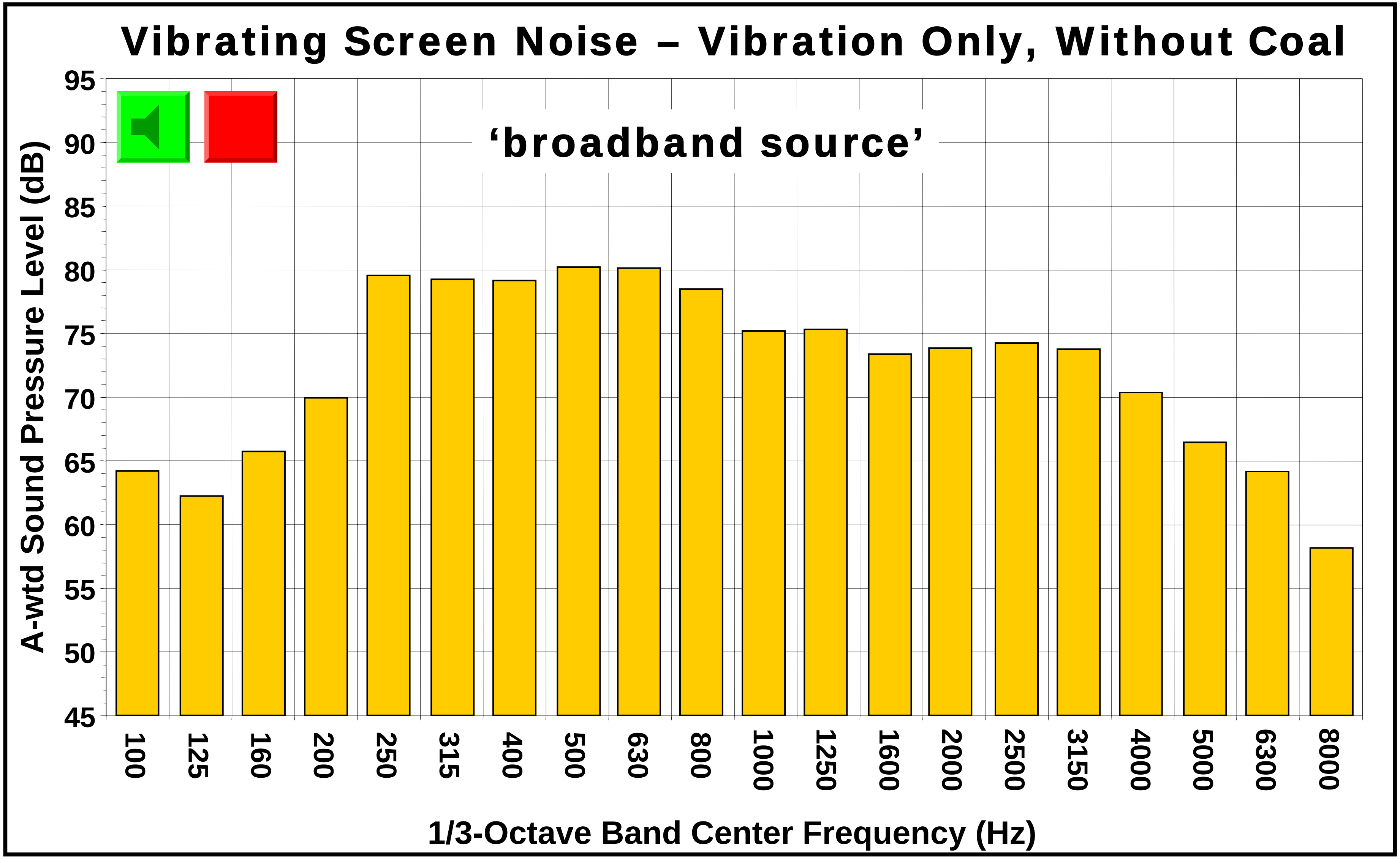
$$90 \text{ dB} + 90 \text{ dB} \neq 180 \text{ dB}$$

$$90 \text{ dB} + 90 \text{ dB} = 93 \text{ dB}$$

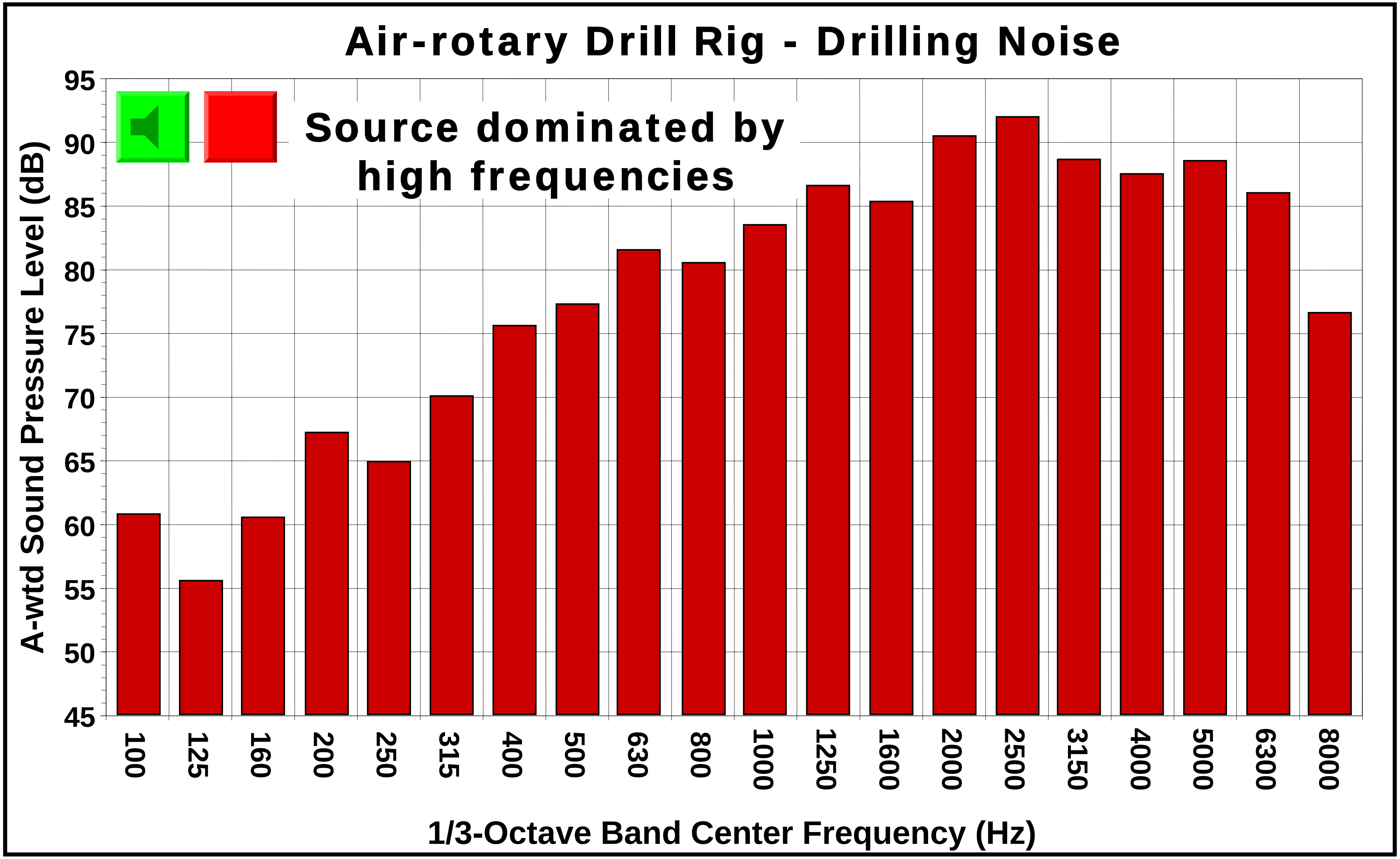
Measurement of Sound
Frequency Content

- The frequency range for human hearing is 20 Hz to 20 kHz
- The frequency content of sound helps to identify noise sources
- Octave-band or 1/3-octave-band filters are used to examine frequency content
- We may think of these filters as a frequency ‘bin’ where the energy in a small frequency band is counted

Example: 1/3-Octave-Band Spectrum



Example: 1/3-Octave-Band Spectrum



Measurement Practices

- Several factors may influence measured sound levels
  - Instrumentation calibration & set-up
  - Background noise
  - Measurement locations
  - Machinery operation
  - Measurement environment

Measurement Practices

Calibration & Set-up

- Calibrate before and after testing
- Set the level of the calibrator to 114 dB when ambient SPL is high
- Select the desired weighting prior to testing
- Measure the LEQ with a 15 to 30 second measurement duration

Measurement Practices

Background Noise

- Measure ambient sound levels (aka background noise) before and after machinery sound level measurements
- Wind (or airflow from ventilation fans) can be a source of background noise
- Use a windscreen to reduce wind noise
- Turn off other machinery near the measurement area to reduce BG noise

Measurement Practices

Background Noise

- BG SPL must be *at least 3 dB* below SPL of machinery
- If BG SPL is 10 dB lower than the SPL of machinery, it has little effect on the measured SPL

  (in practice the effect is considered to be negligible)
- Must correct for BG noise when the BG SPL is 3 to 10 dB lower than the machinery SPL

Measurement Practices

Measurement Locations

- Make operator ear SPL measurements as close to the ear as possible
- If we are examining noise radiated to the environment
  - Measurements should not be made close to the machine or reflective surfaces, if possible
  - A measurement distance of 3 feet (1 m) is commonly used
  - Measurements close to the machine or boundaries will be significantly affected, particularly at low frequencies

Measurement Practices

Equipment Operation

- Warm-up machinery prior to testing
- Operate machinery in a ‘typical’ manner (RPM, load, equipment functions, etc.) when measuring operating sound levels
- Perform tests with well-defined parameters to limit test-to-test variability when evaluating noise controls

Measurement Practices
Measurement Environment

- Modern test equipment is *relatively* insensitive to atmospheric conditions
- Clear the area of large reflective surfaces
- Observers and the person making the measurements can influence the data
  - Use a tripod and stand to the side and behind the sound level meter
  - If a tripod is not used, hold the SLM away from the body
  - Ask observers to stay away from the measurement area

Noise Source Identification

Examples of Noise Sources

Mechanical Noise

Engine block vibration

Road-tire interaction

Drilling, cutting, grinding

Electric motors

Bearings

Gears

Conveyor systems

Flow Noise

Ventilation systems

Engine cooling systems

Water sprays

Dust scrubbers

Engine intake & exhaust systems

Noise Source Identification

- The first step in controlling noise is to determine the most *dominant source*
- In terms of worker exposure, determine the machine and/or operation responsible for the *highest percent dose*
- In terms of machinery sound levels, we must determine the source generating the *highest sound level*

Why is this important?

Noise Source Identification

Multiple Noise Source Example

Three Noise Sources: 90 dB, 88 dB, & 85 dB

Overall Sound Level: 92.9 dB

Case 1: Reduce *85 dB* source to 75 dB

Overall Sound Level: 92.2 dB (0.7 dB reduction)

Case 2: Reduce *88 dB* source to 78 dB

Overall Sound Level: 91.4 dB (1.5 dB reduction)

Case 3: Reduce *90 dB* source to 80 dB

Overall Sound Level: 90.2 dB (2.7 dB reduction)

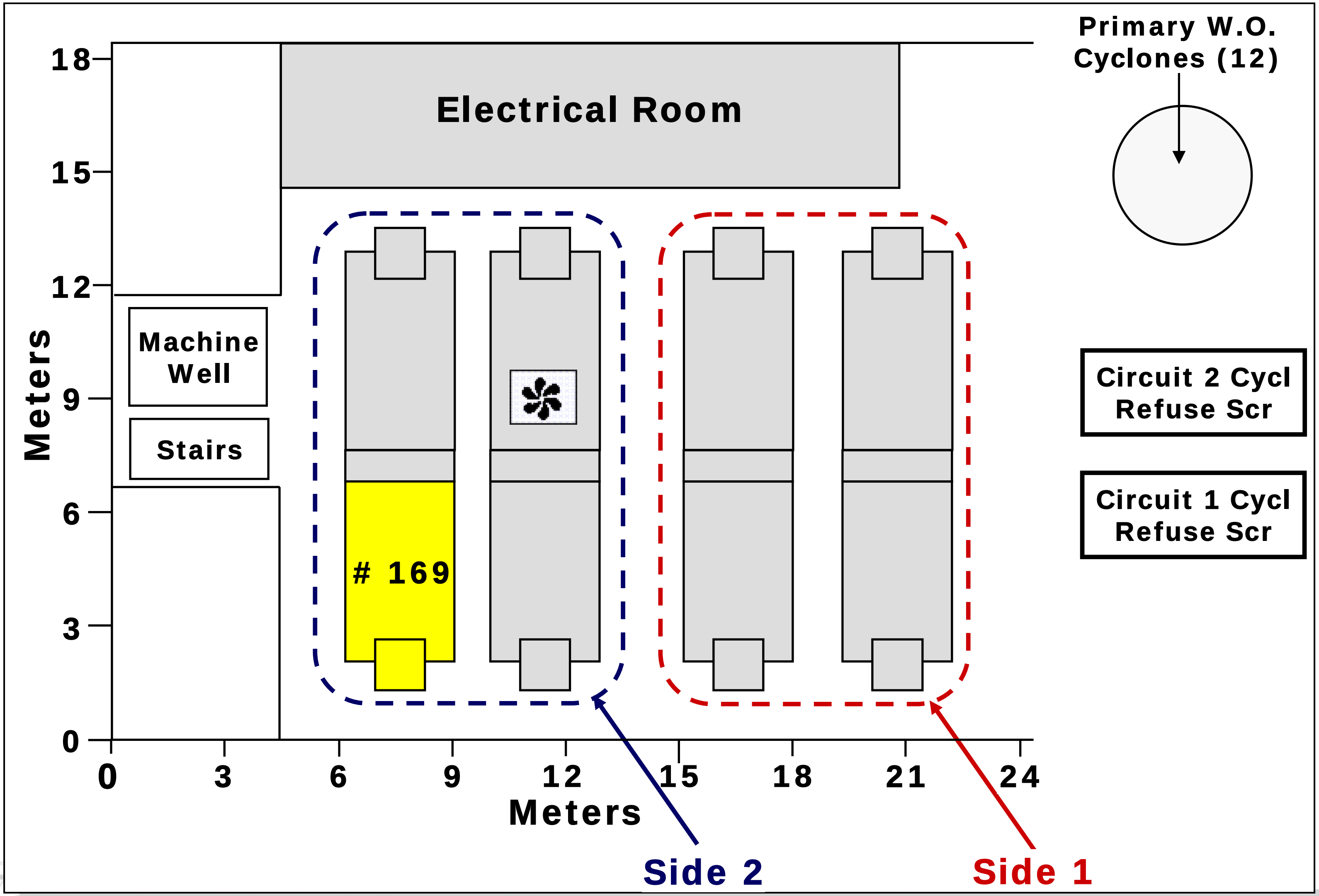
We must identify and treat the dominant noise source(s) to get the most sound level reduction for the least cost!

Multiple Noise Sources
Procedure to Rank Order Sources

- List noise sources on equipment
- Apply treatments to *all sources* (turn off or disconnect when possible)
  - Treatments do not have to be practical or durable
  - Goal is to reduce the level of each individual source by *10 dB or more*
- Remove treatment from 1st source, measure sound levels, reinstall treatment
- Remove treatment from 2nd source, measure sound levels, reinstall treatment
- Continue for all sources

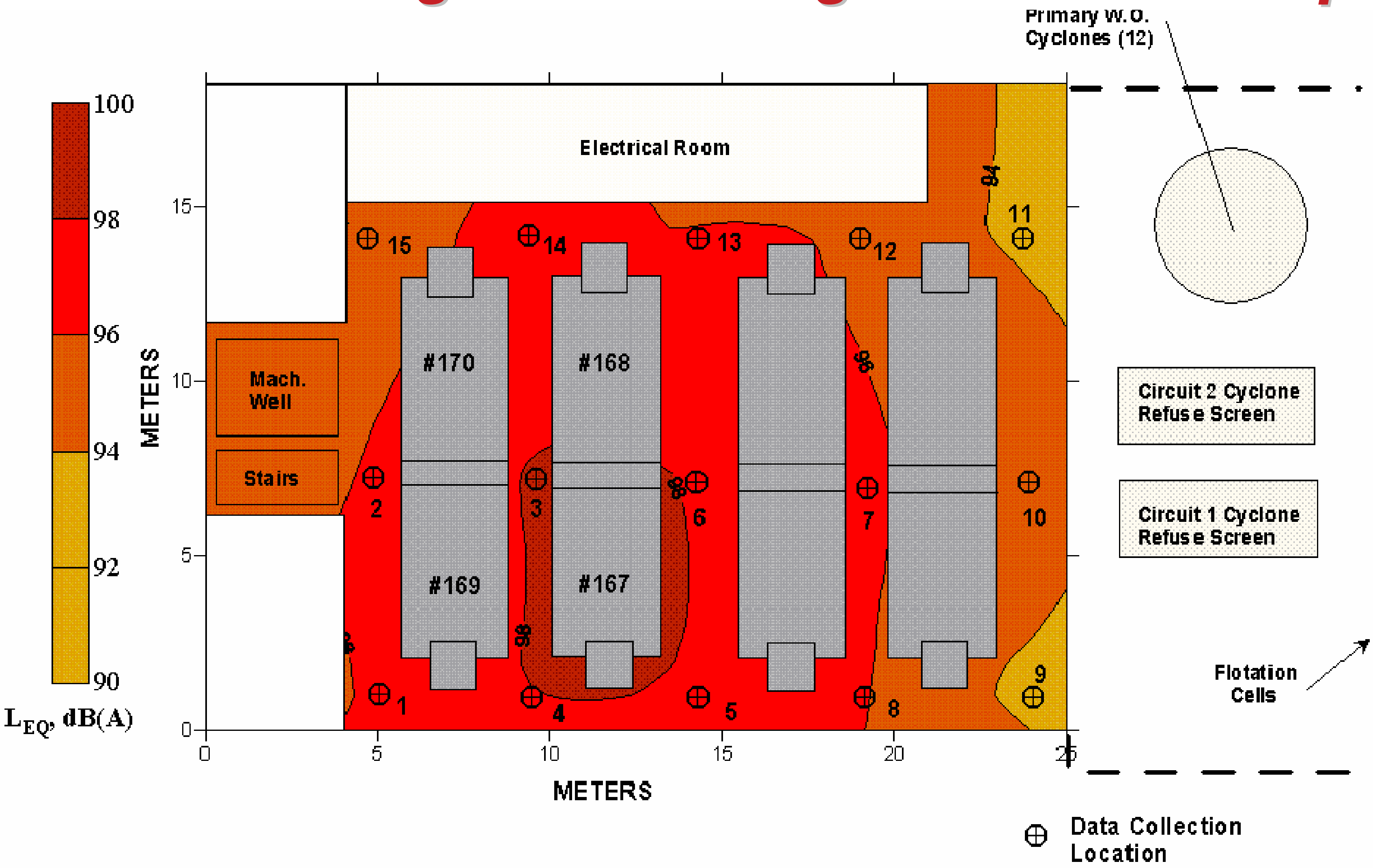
Multiple Noise Sources

Rank Ordering – Vibrating Screen Example



Multiple Noise Sources

Rank Ordering – Vibrating Screen Example



Multiple Noise Sources

Rank Ordering – Vibrating Screen Example

- The sound level at any location is the result of all surrounding screens
- Cannot process coal on the test screen with all of the other screens off
- Large changes to the sound level from the test screen would result in only a small (insignificant) change in the measured sound level
- Quilted fiberglass-vinyl-fiberglass barrier hung around test screen to reduce background noise from other equipment

Multiple Noise Sources
Rank Ordering – Vibrating Screen Example

Vibrating Screen Noise Sources:

Screening noise:

Noise generated by the flow of material due to coal-coal, coal-chute, and coal-screen impacts

Drive noise:

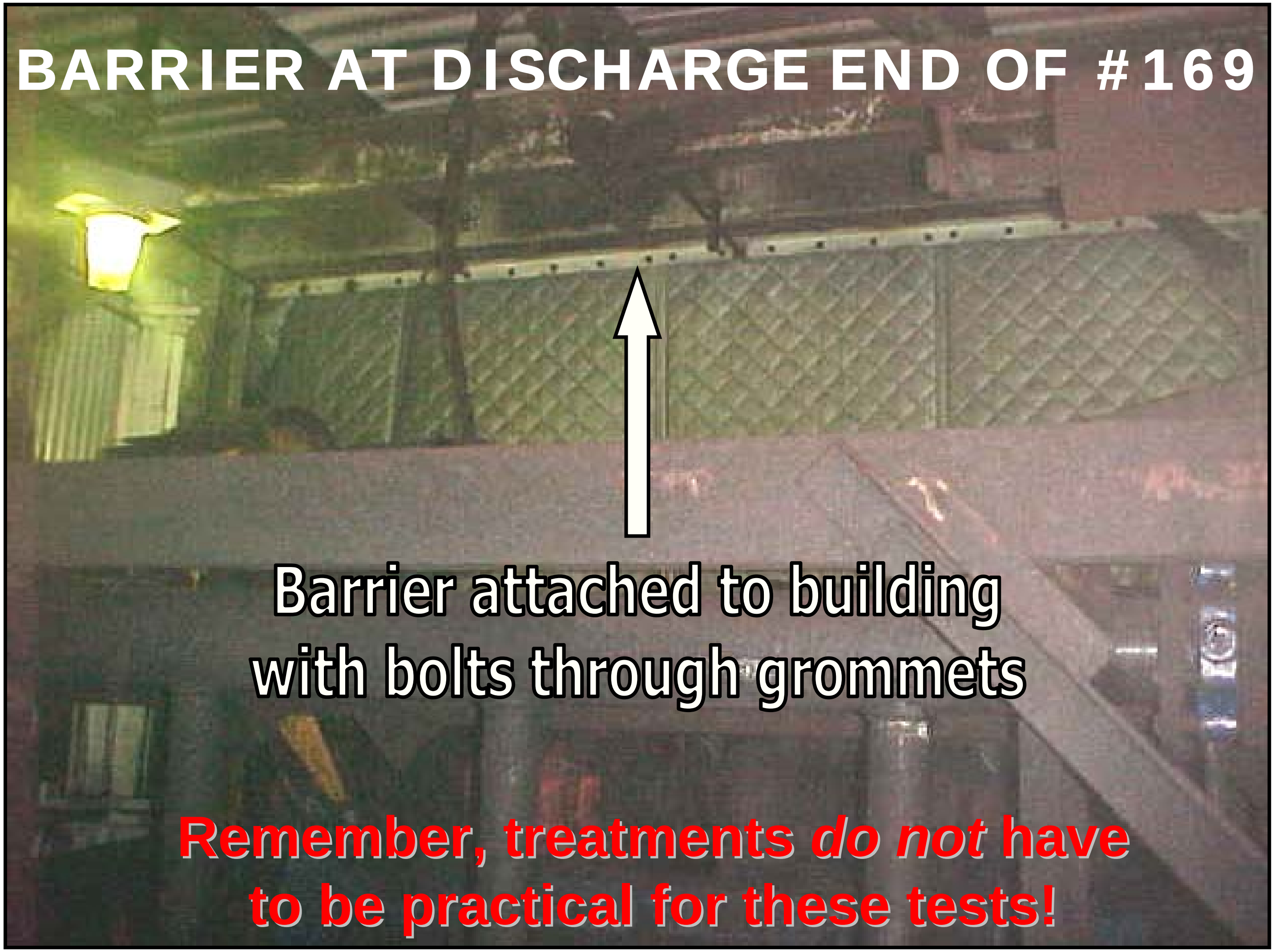
Noise radiated by the vibration mechanism housings, screen sides, and the building due to excitation by the gears, bearings, and eccentric weights of the mechanisms

Rinse water spray noise:

Noise due to spraying water onto coal

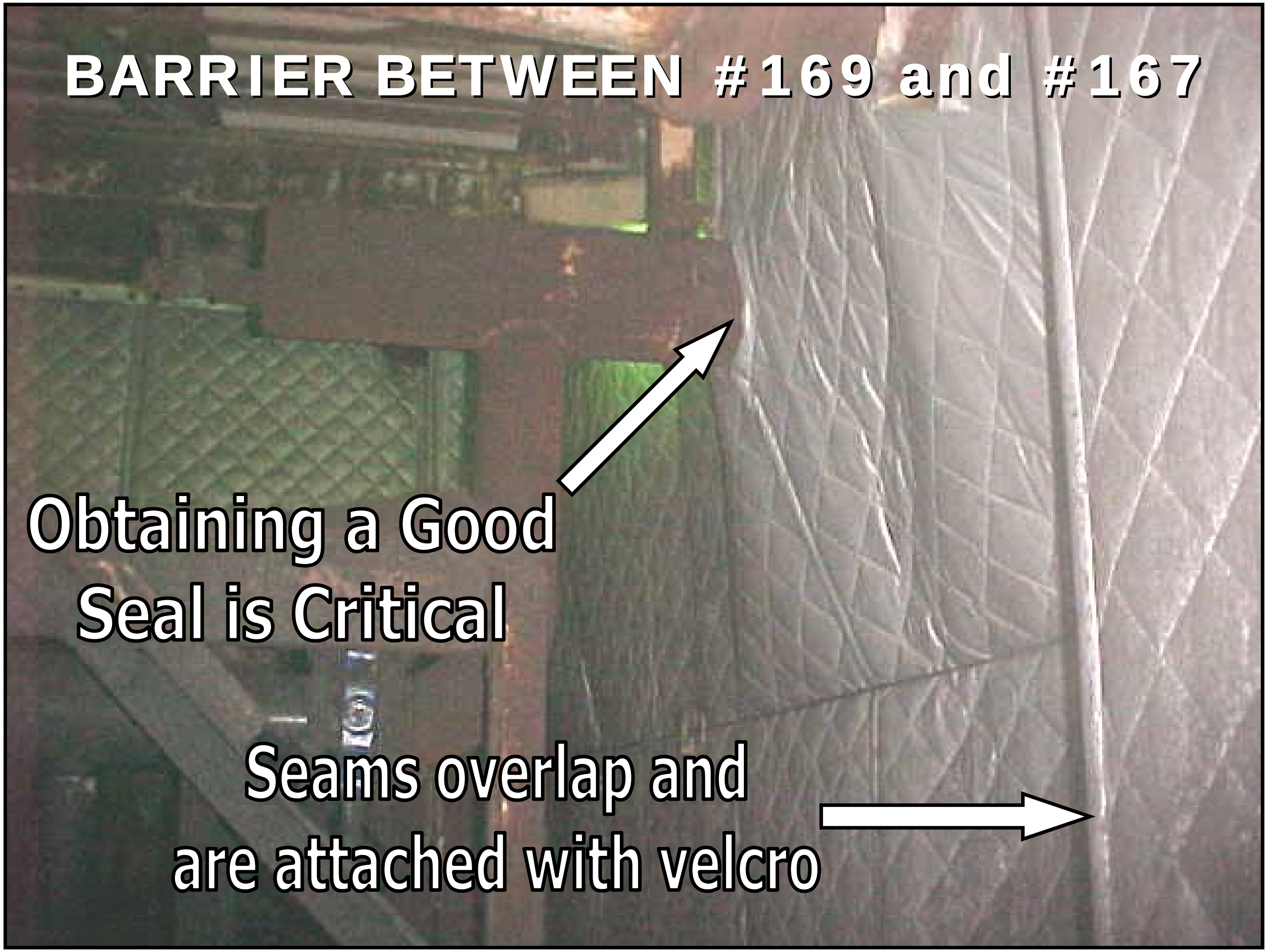
Multiple Noise Sources

Rank Ordering – Vibrating Screen Example



Multiple Noise Sources

Rank Ordering – Vibrating Screen Example



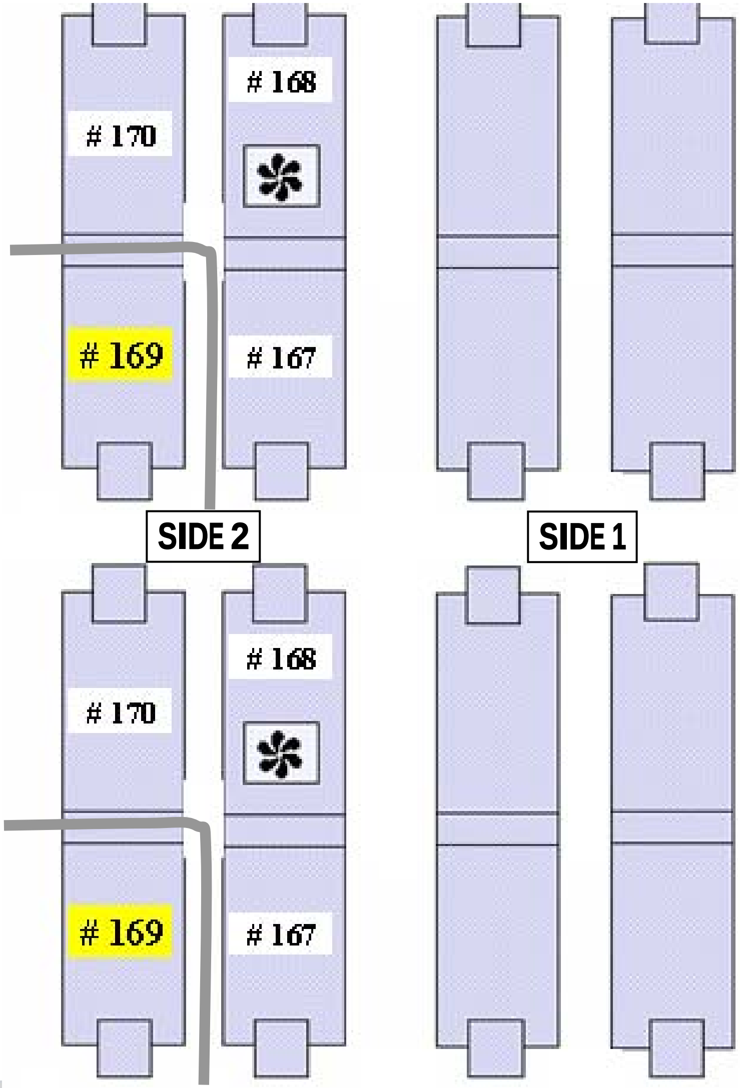
Multiple Noise Sources

Rank Ordering – Vibrating Screen Example

1. Side 1 and Side 2 processing coal, #169 OFF (BG noise for #169 overall level)

2. Side 1 and Side 2 processing coal, #169 processing coal (Can calculate level due to #169 by subtracting levels of test 1)

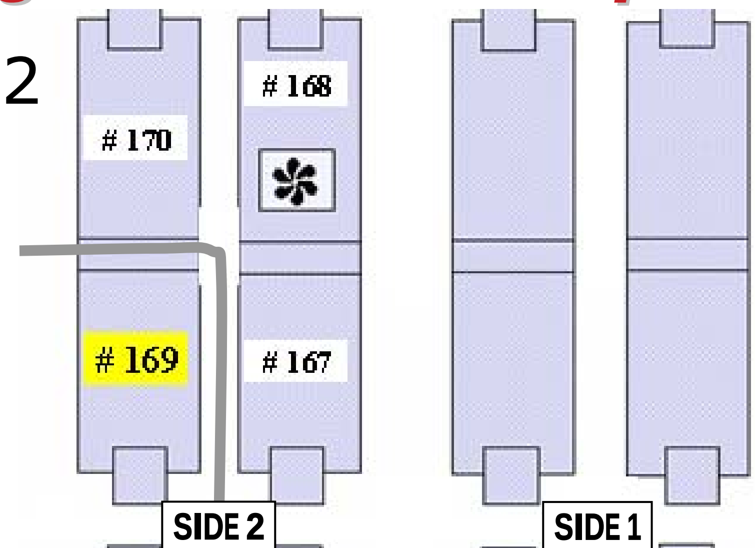
Yields total sound level for test screen (drive noise + screening noise + water spray noise)



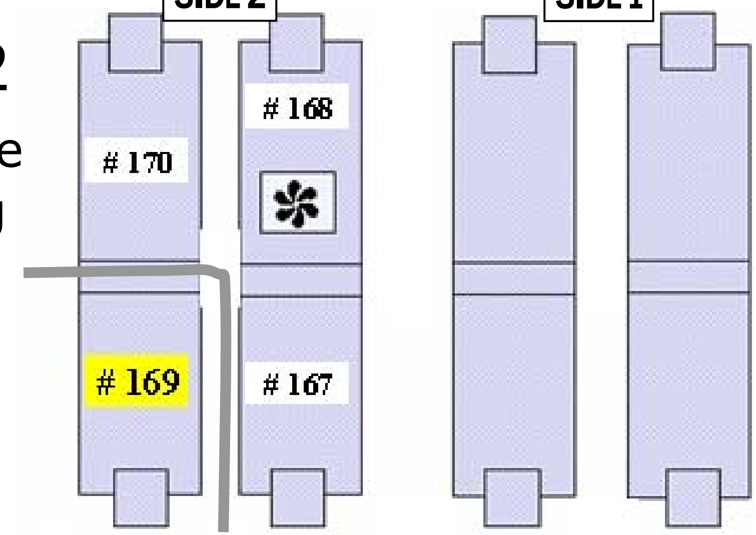
Multiple Noise Sources

Rank Ordering – Vibrating Screen Example

3. Side 1 processing coal, Side 2 off (BG noise for #169 *drive noise* & #169 *water spray noise*)



4. Side 1 processing coal, Side 2 off, #169 vibe only (Can calculate level of #169 *drive noise* by subtracting levels of test 3)



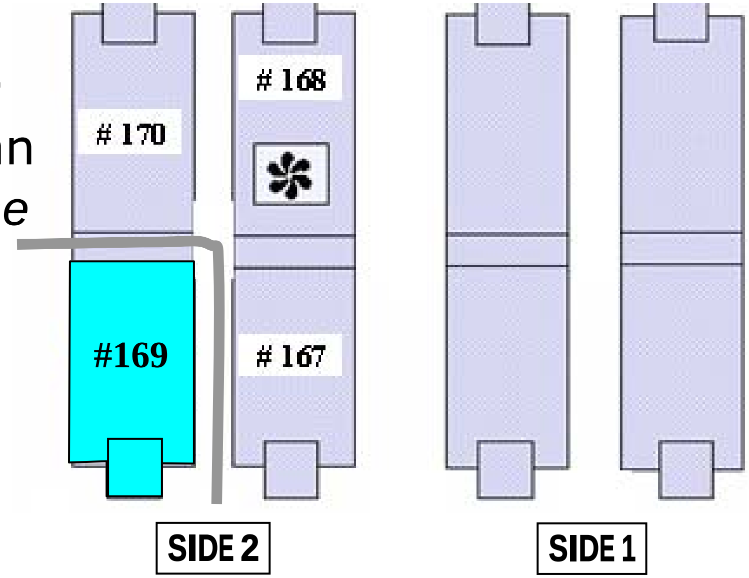
Yields sound level for drive noise

Multiple Noise Sources

Rank Ordering – Vibrating Screen Example

5. Side 1 processing coal, Side 2 off, #169 water spray only (Can calculate level of #169 *water spray noise* by subtracting levels of test 3)

Yields sound level due to water spray noise



6. Subtract sound levels due to *drive noise* and *water spray noise* from total sound level due to all three sources

Yields sound level due to screening noise

Multiple Noise Sources

Rank Ordering – Vibrating Screen Example

Test Condition or Noise Source	Overall Sound Level
Total, processing coal (measured)	92 dB(A)
Drive noise (measured)	91 dB(A)
Screening noise (calculated)	87 dB(A)
Rinse water spray (measured)	80 dB(A)

Noise Controls

- Four basic types of treatments (often used together)
  - Absorbers
  - Barriers
  - Vibration Isolators
  - Vibration Damping

Noise Controls
Absorbers

- Applied at a reflective surface to absorb energy and reduce reflection of sound
- Typically made of porous materials (open cell foam, fiberglass, mineral wool)
- The sound absorption coefficient is used to describe the ability of a material to absorb sound
- Most effective at higher frequencies
- Absorber thickness influences absorption

Noise Controls

Absorbers

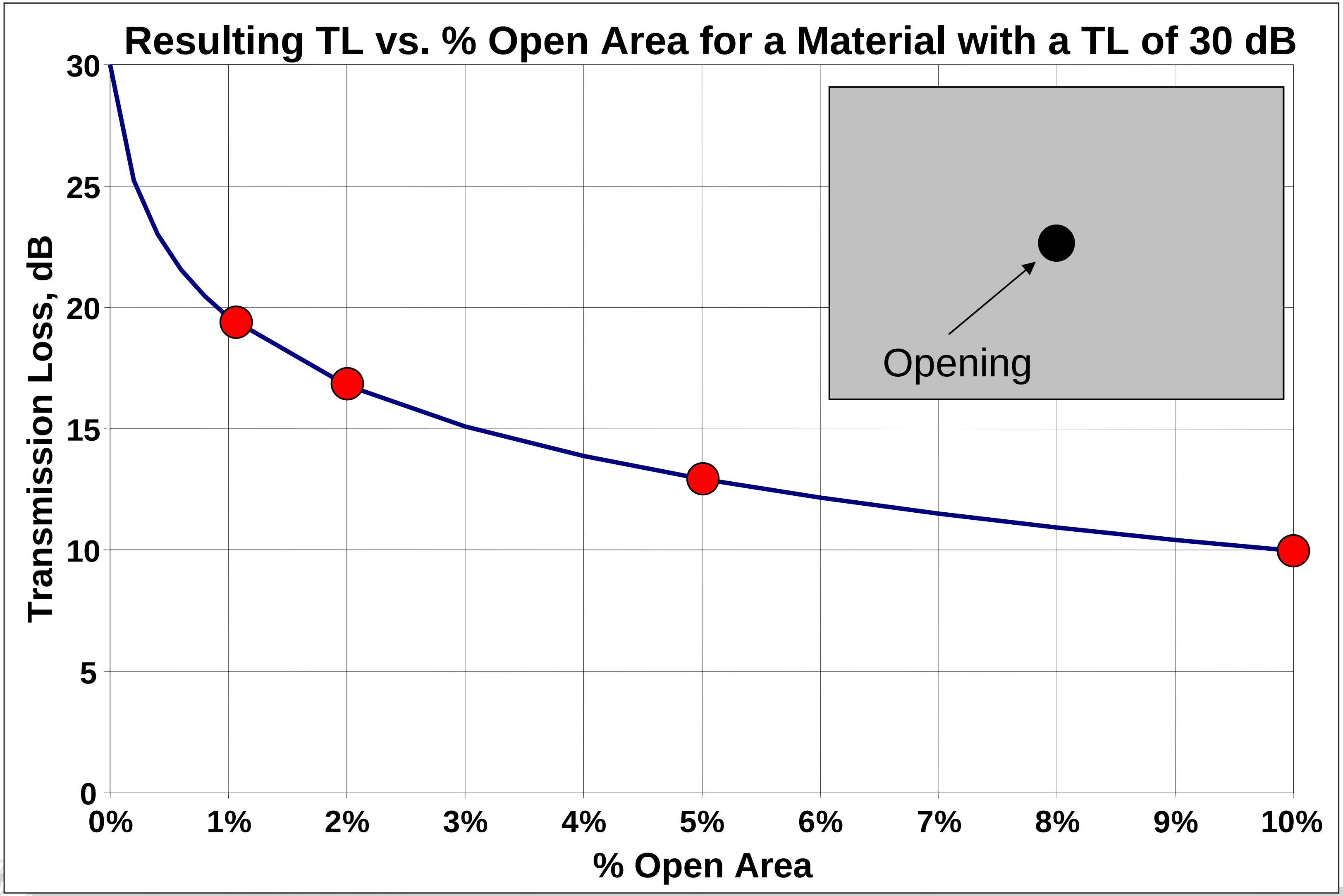
- Flammability may be a concern with some sound absorbing materials or their facings
- Lining cabs, enclosures, engine compartments, overhead guards, and ducts may reduce noise
- Good sound absorbing materials are *NOT* usually good sound barriers

Noise Controls
Barriers

- Barriers are materials that block transmission of sound
- Good barrier materials are *dense*, limp materials
- The *transmission loss* (TL) is used to describe the performance of barrier materials
- In general, TL increases with frequency
- Even a small opening will greatly reduce the overall TL

Noise Controls

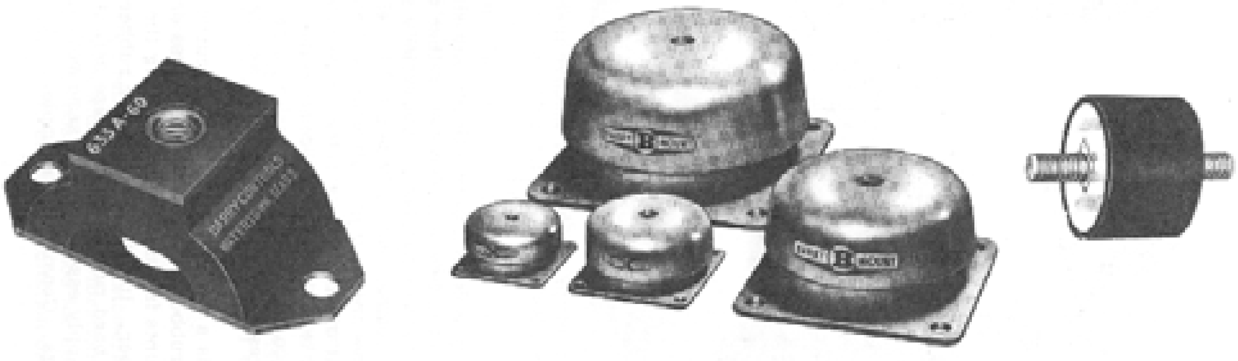
Barriers



Noise Controls
Vibration Isolators

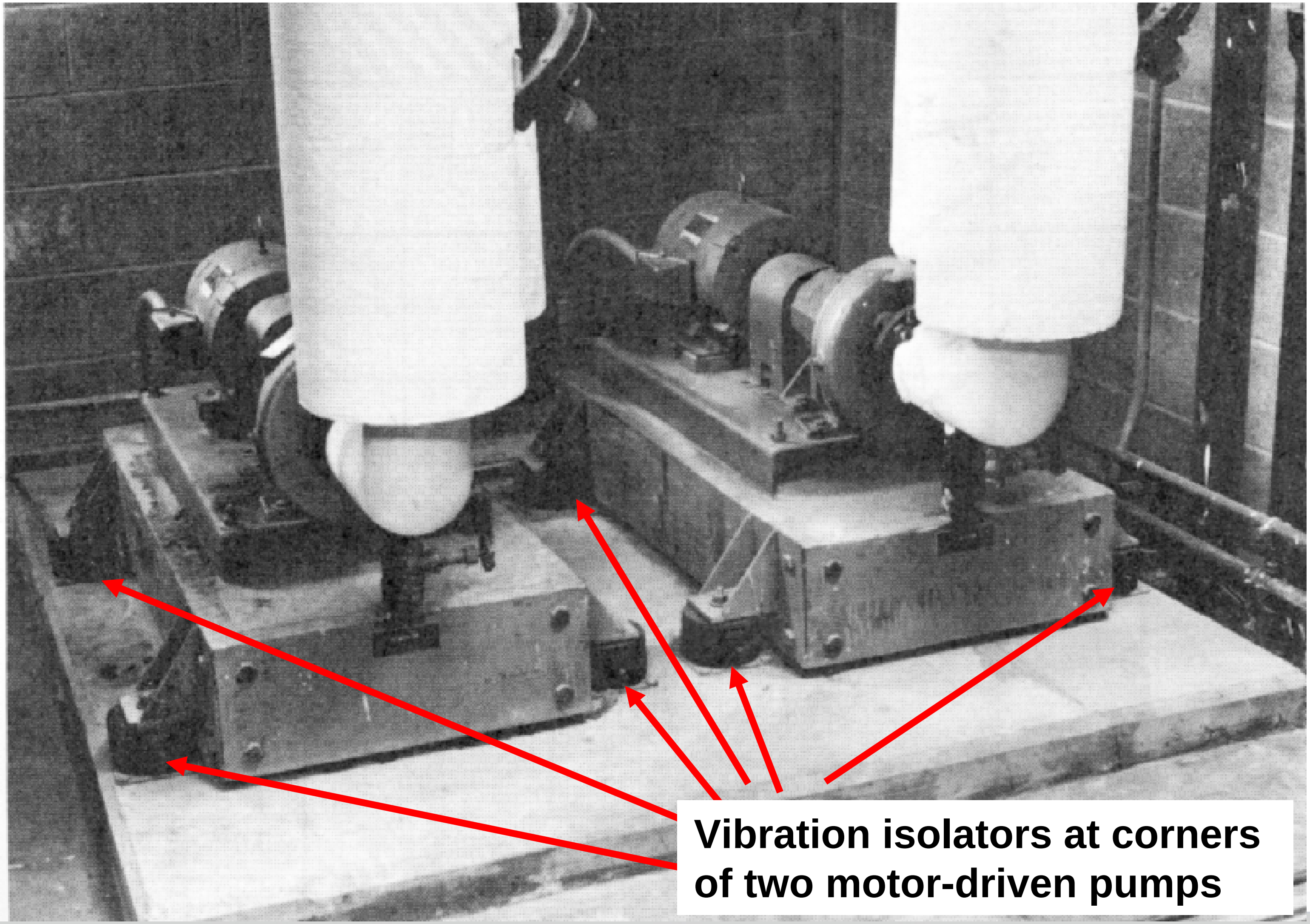
- Vibration isolators are flexible components used to reduce transmitted vibration
- The source of vibration energy may not be the dominant source of radiated noise
- A large, flat surface set into vibration can act like a sounding board and radiate noise

Noise Controls
Vibration Isolators



- Select based on equipment weight, operating speed, and environment
- A rigid mounting location is needed on both the source and the support structure
- It is critical to make sure that no 'shunt paths' exist

Noise Controls
Vibration Isolators



Noise Controls

Vibration Isolators - Impact Isolation

- Impacts can create noise
- Impacts can cause surfaces to ‘ring’ or ‘buzz’
- Isolation pads made of rubber, cork, urethane and similar can be used to ‘cushion’ impacts

Example:

Coated flight bars for a continuous mining machine

Noise Controls
Vibration Damping

- Damping material can be applied to vibrating surfaces to convert mechanical motion into a small amount of heat
- Two types of commonly-used damping treatments
  - Free-layer damping
  - Constrained-layer damping

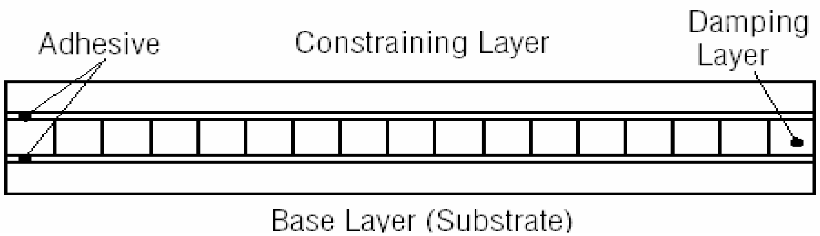
Noise Controls
Vibration Damping

Free-layer damping

- Applied to a surface via spray, roller, or brush
- Useful for relatively thin structures
- Applied damping material is thicker than the structure itself

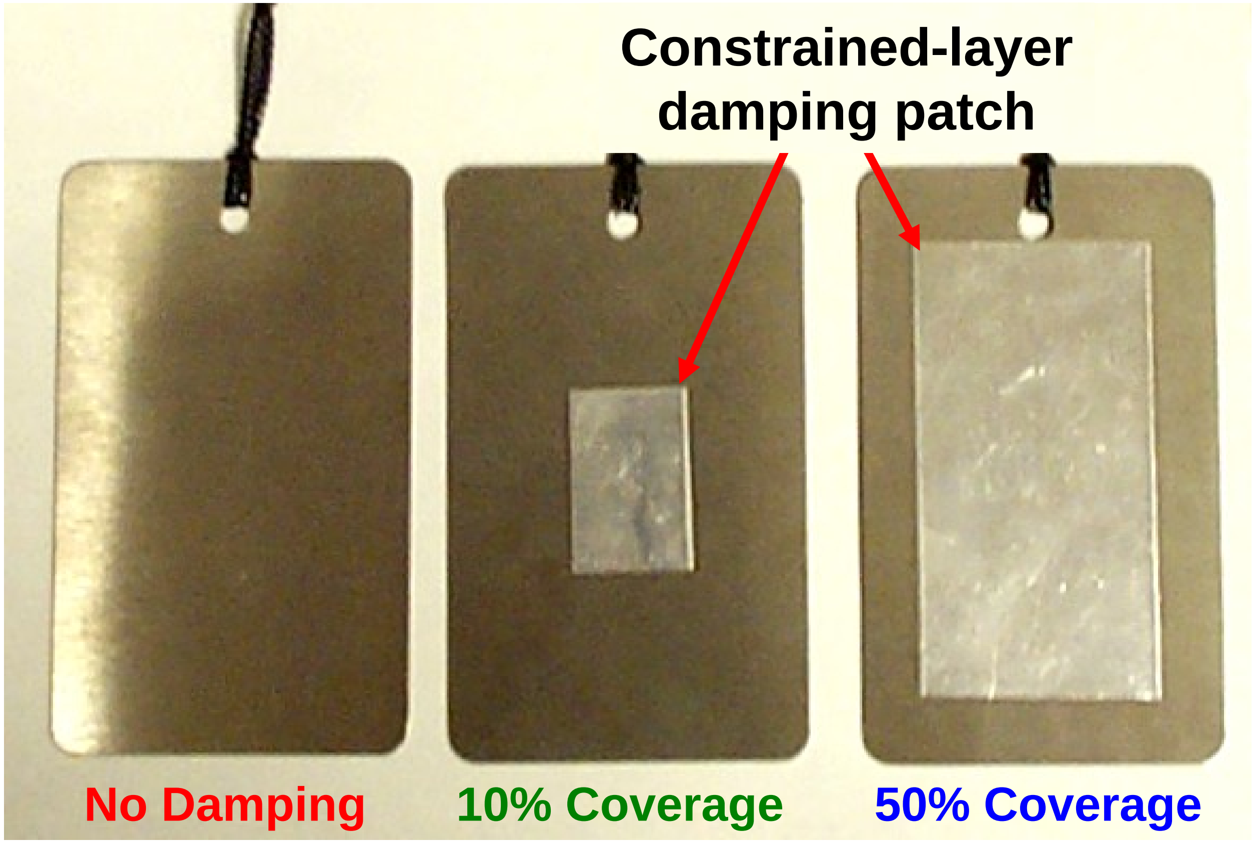
Constrained-layer damping

- Damping material is bonded to the structure
- Stiff constraining layer is bonded to the damping material
- Must use a stiff adhesive
- Surfaces must be clean



Noise Controls

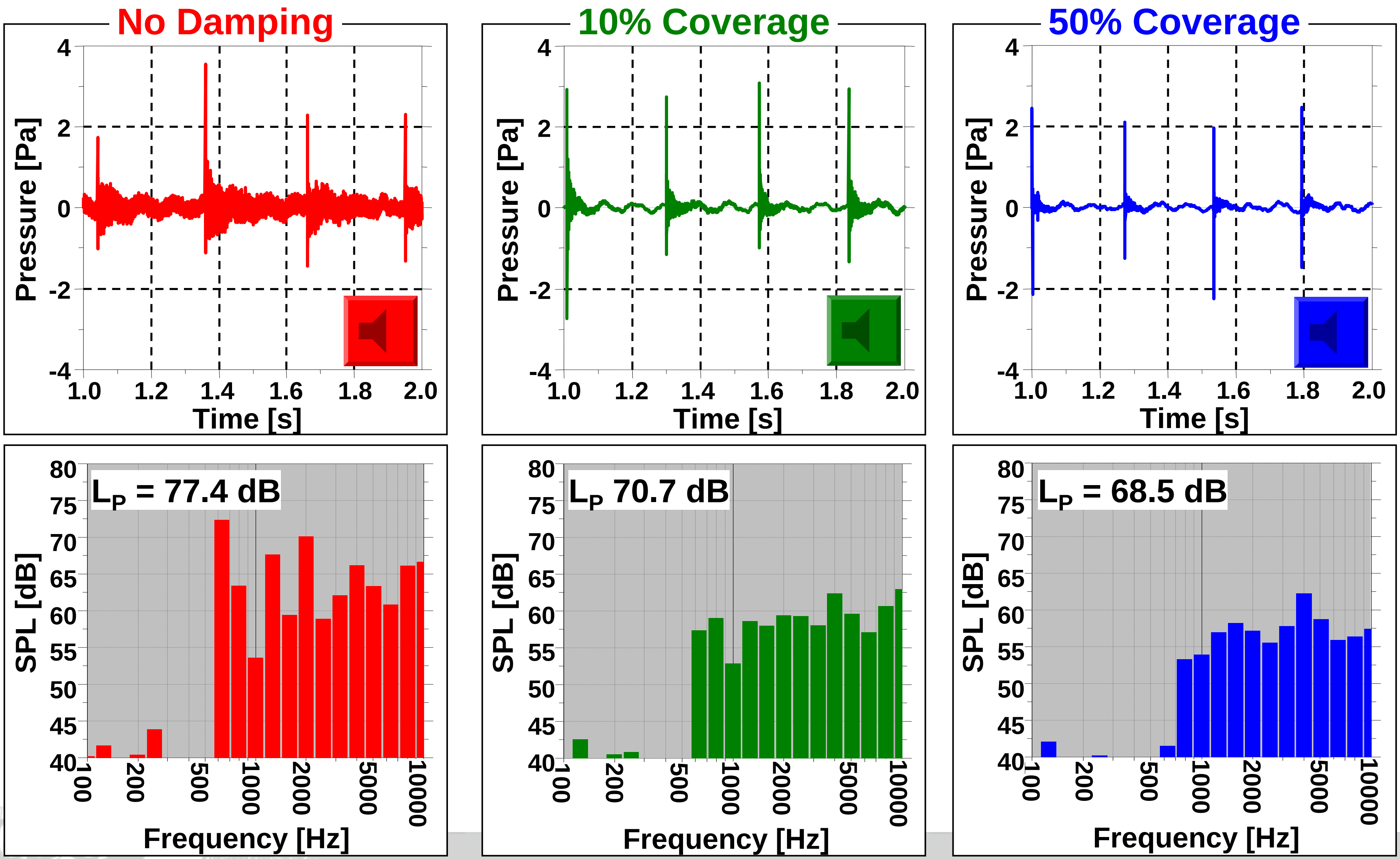
Constrained-layer Damping Demonstration



- 3-inch wide x 5-inch high aluminum plates
- Samples were suspended and struck with a small metal object

Noise Controls

Constrained-layer Damping Demonstration



Noise Controls
Cabs, Barriers, and Enclosures

- Cabs, barriers, and enclosures can be very effective at reducing noise
- It is critical to limit gaps to a minimum
  - Pipe penetrations and openings around hydraulic lines or electrical wiring should be sealed as well as possible
  - Doors and windows should use a flexible seal

Noise Controls

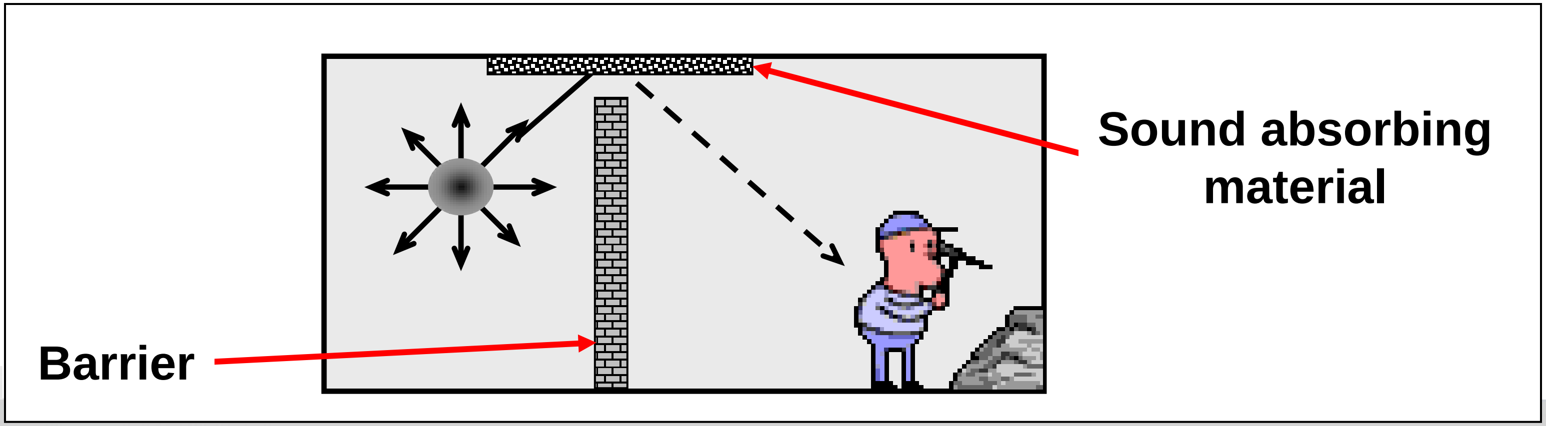
Cabs

- Hydraulic lines resting on cab surfaces can increase noise
- Rattling doors and windows can increase noise
- Use laminated glass for windows because it has higher damping (higher TL)
- Use *barrier material* with a closed cell foam backing on the floor and/or firewall
- Install *vibration isolators* to reduce structure-born noise (watch out for shunt paths!)
- Line with *sound absorbing material* to reduce build up of reverberant sound
- Treat vibrating surfaces with *damping material*

Noise Controls

Barriers

- Should be installed either close to the noise source or close to the worker
- Must be high enough to create an 'acoustic shadow'
- Place sound absorbing material on reflective surfaces above the barrier to increase noise reduction



Noise Controls

Enclosures

- Use materials with high transmission loss
- If airflow is required, the worker should not have 'line of site' to the enclosed noise source
- Line with sound absorbing material to reduce build-up of reverberant noise
- Use barrier-absorber materials to increase noise reduction
- Vibration isolate enclosure from structure with compliant materials
- Add damping treatments to the enclosure to reduce vibration of the enclosure

For more information

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