Practical Approaches to Engineering Noise Controls

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Mining Hearing Loss Prevention Workshop
June 21-22, 2005

Pittsburgh Research Laboratory

Topics

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

Basics of Sound

Sound Pressure (Pascals)

- Pressure fluctuation relative to atmospheric pressure
- Depends on sound power, distance from source, environment

Sound Power (watts)

- Sound energy generated by a source per unit time
- *Independent* of surroundings, a property of the sound source
- Used for rating/comparing sound sources, calculating sound pressure in a known environment

Sound Intensity (watts/m^2)

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

Basics of Sound

Three characteristics of sound

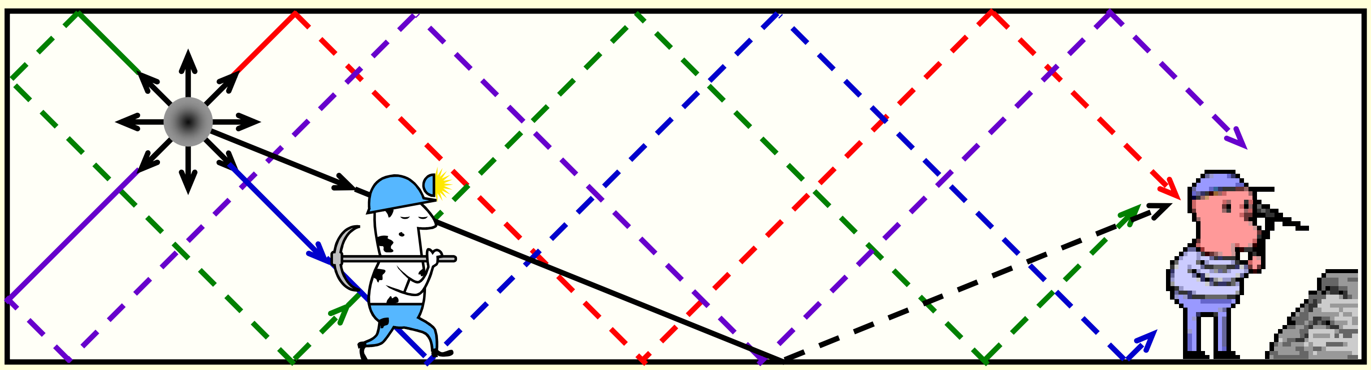
1. *Amplitude* – The amount of deviation of the pressure from atmospheric pressure (PSI or Pascals)
2. *Wavelength* – The distance from maximum to maximum or minimum to minimum (feet or meters)
3. *Frequency* – The number of pressure fluctuations per second (Hz or 1/s)

Basics of Sound

Sound Fields (acoustic environment)

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 the reverberant sound



Note: In general, the sound level measured underground will not be the same as the sound level measured above ground

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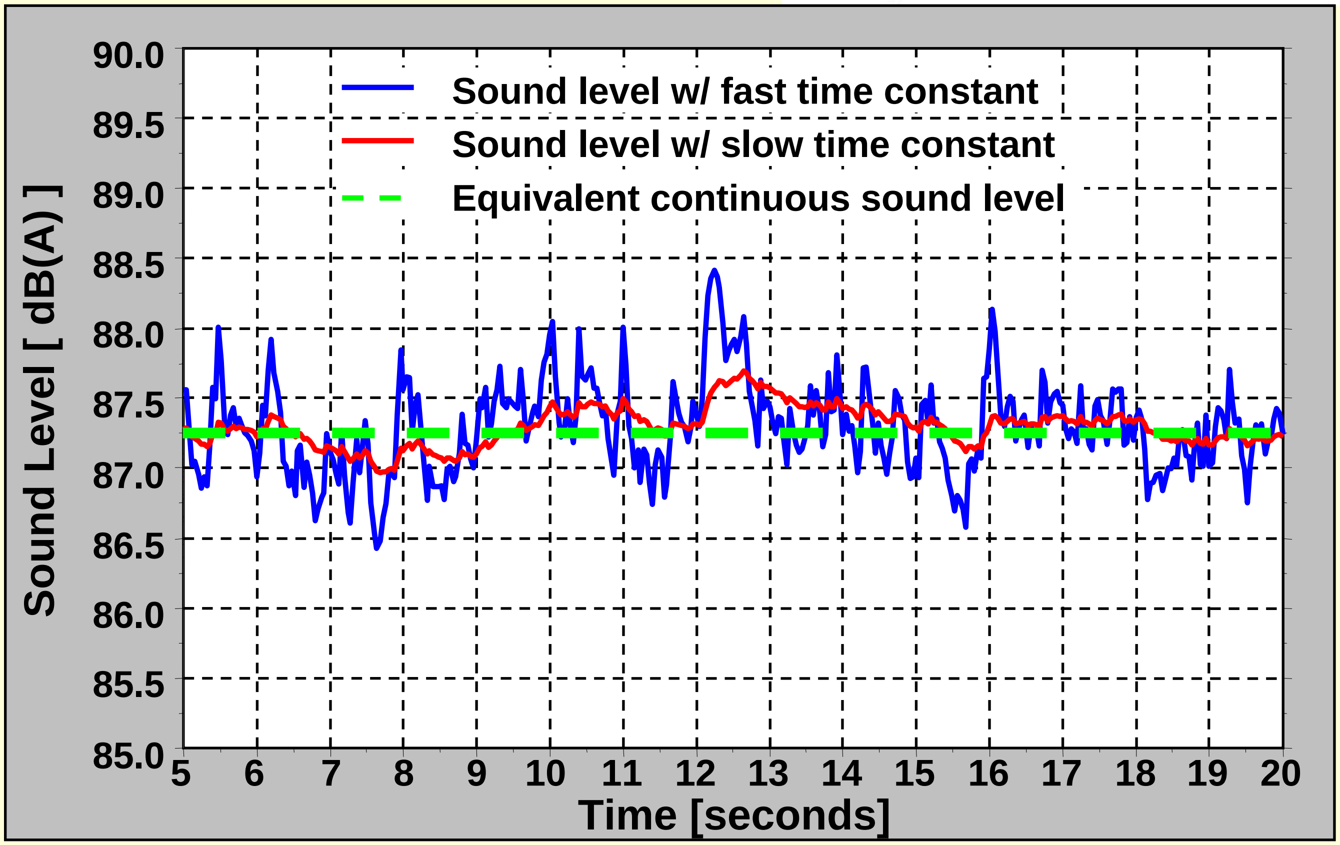
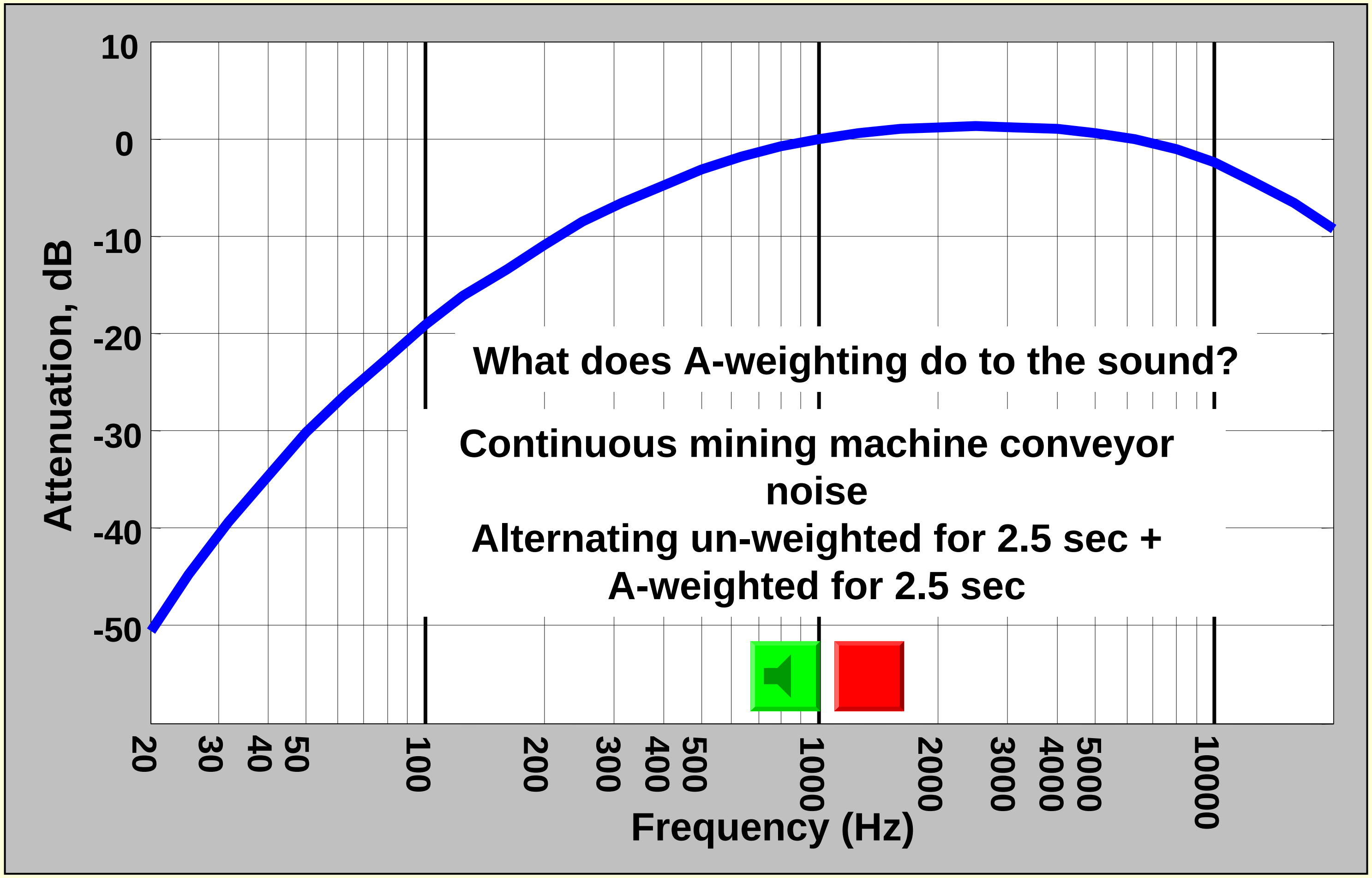
Measurement of Sound Pressure Level (SPL)

- Sound pressure level measurements are made using a sound level meter



A-Weighting Curve

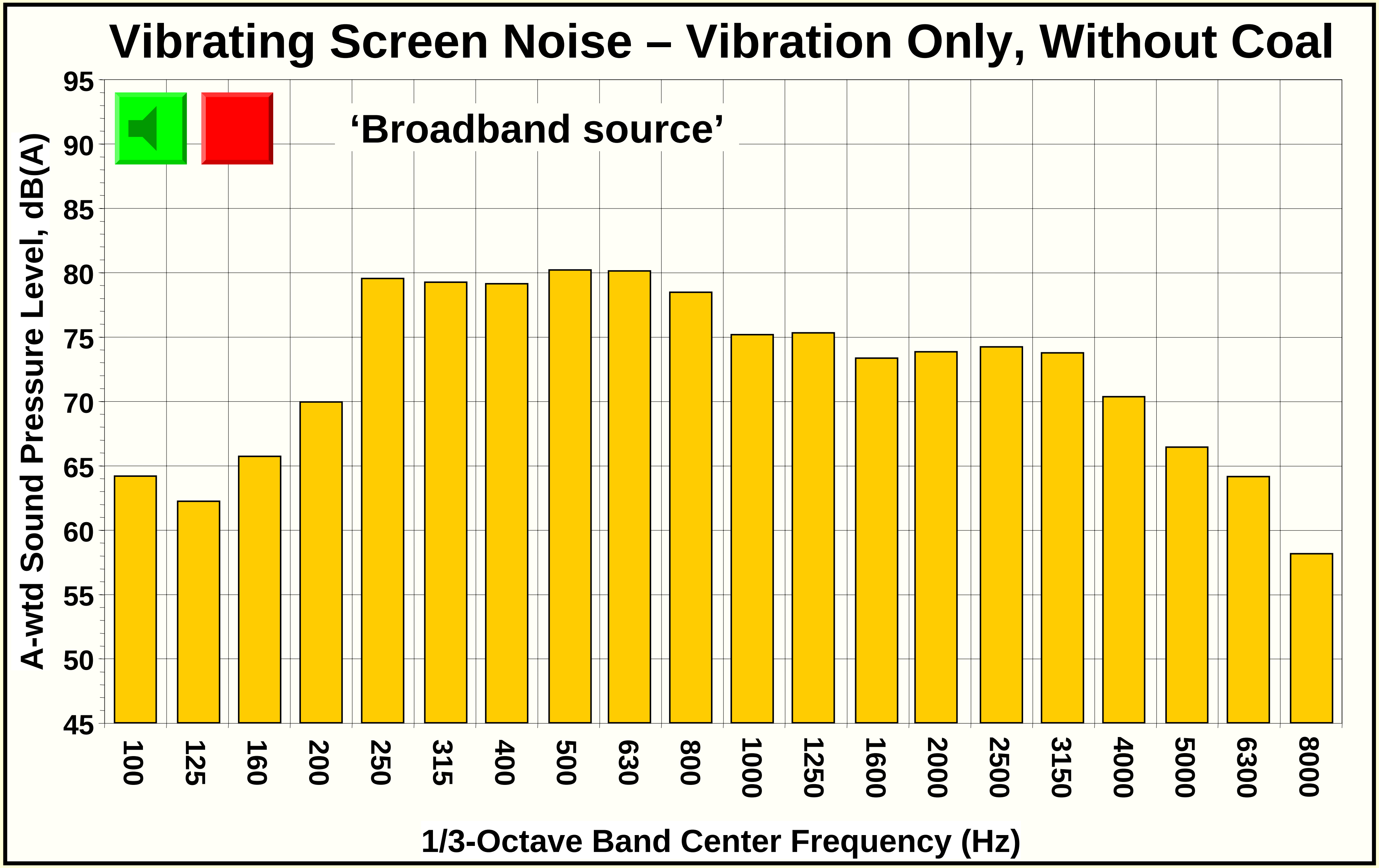
- The A-weighted sound level correlates reasonably well with hearing loss and is commonly-used in noise regulations and standards



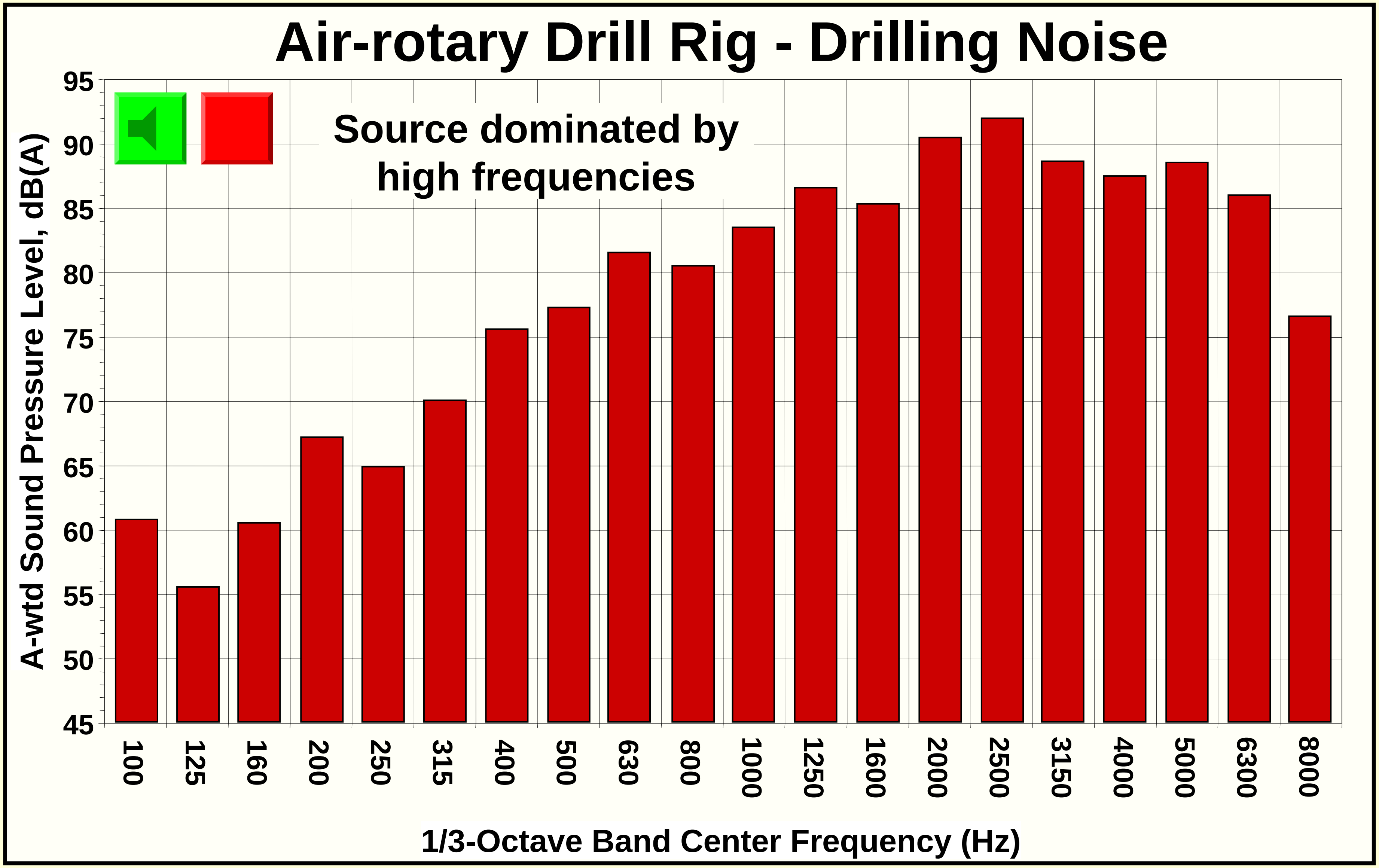
Measurement of Frequency Content

- 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

Measurement of Frequency Content



Measurement of Frequency Content



Adding, Subtracting, & Averaging Sound Levels

- Sound levels are logarithmic, not linear
- Cannot simply add, subtract, or average levels
- Two sources with equal sound level 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 Practices

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

Measurement Practices

Calibration & Instrumentation Set-up

- Calibrate instrumentation before and after testing
- Set the level of the calibrator to 114 dB when ambient SPL is high
- Make sure that A-weighting is selected prior to measurements
- 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 the effects of wind noise
- Lower BG noise when possible by turning off other machinery near the measurement area

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

- Generally, modern test equipment is insensitive to temperature, humidity, and barometric pressure
- Clear the area of large reflective surfaces
- Observers and even the person making the measurements can influence the data
  - Use a tripod and stand to the side and behind the sound level meter
  - Ask observers to stay away from the measurement area until measurements have been completed

Noise Sources

Sources of Mechanical Noise

Engine block vibration
Road-tire interaction
Drilling, cutting, grinding
Electric motors
Bearings
Gears
Conveyor systems

Sources of 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 significant source
- In terms of worker exposure, determine the machine and/or operation responsible for the highest amount of dose
- In terms of machinery sound levels, we must determine the source generating the highest sound level

Why is this important?

Rank Ordering of Noise Sources

<u>Example:</u> 3 sources of 90 dB, 88 dB & 85 dB

Overall Sound Level: 92.9 dB

<u>Case 1:</u> Reduce *85 dB* source to 75 dB
Overall Sound Level: 92.2 dB (0.7 dB reduction)

<u>Case 2:</u> Reduce *88 dB* source to 78 dB
Overall Sound Level: 91.4 dB (1.5 dB reduction)

<u>Case 3:</u> Reduce *90 dB* source to 80 dB
Overall Sound Level: 90.2 dB (2.7 dB reduction)

<u>Case 4:</u> Eliminate *88 dB* source
Overall Sound Level: 91.2 dB (1.7 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 probable noise sources on equipment
- Apply treatments to each source (turn source off or disconnect it if possible)
  - Treatments do not have to be practical or durable
  - Goal is to reduce the level of each 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 – Drill Rig Example

Intake	Intake silencer + long piping
Exhaust	Oversized muffler + long piping
Engine	Wrap with Lead / fiberglass 'blankets'
Fan	Disconnect belt or remove fan blade
Drilling	Turn Off

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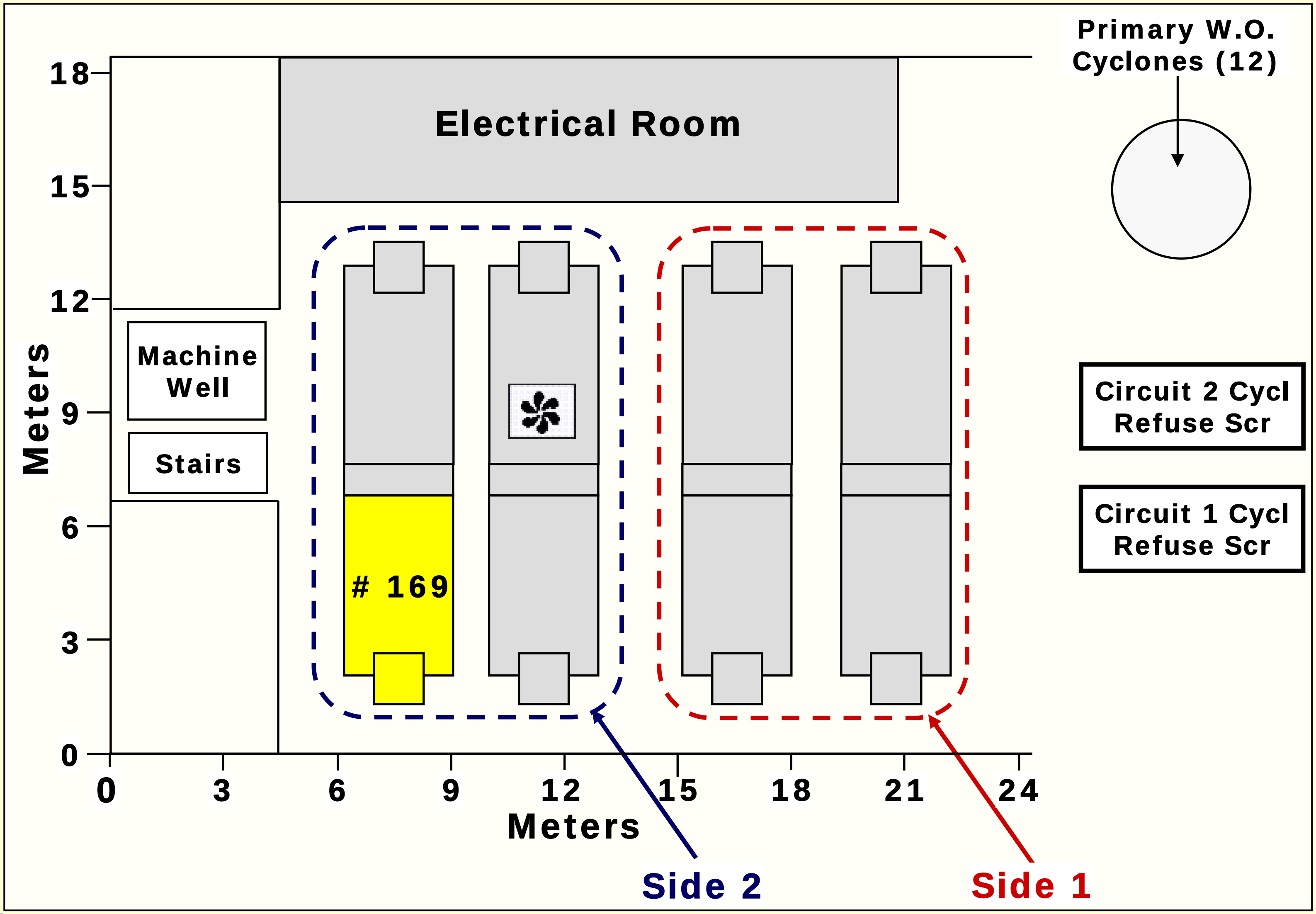
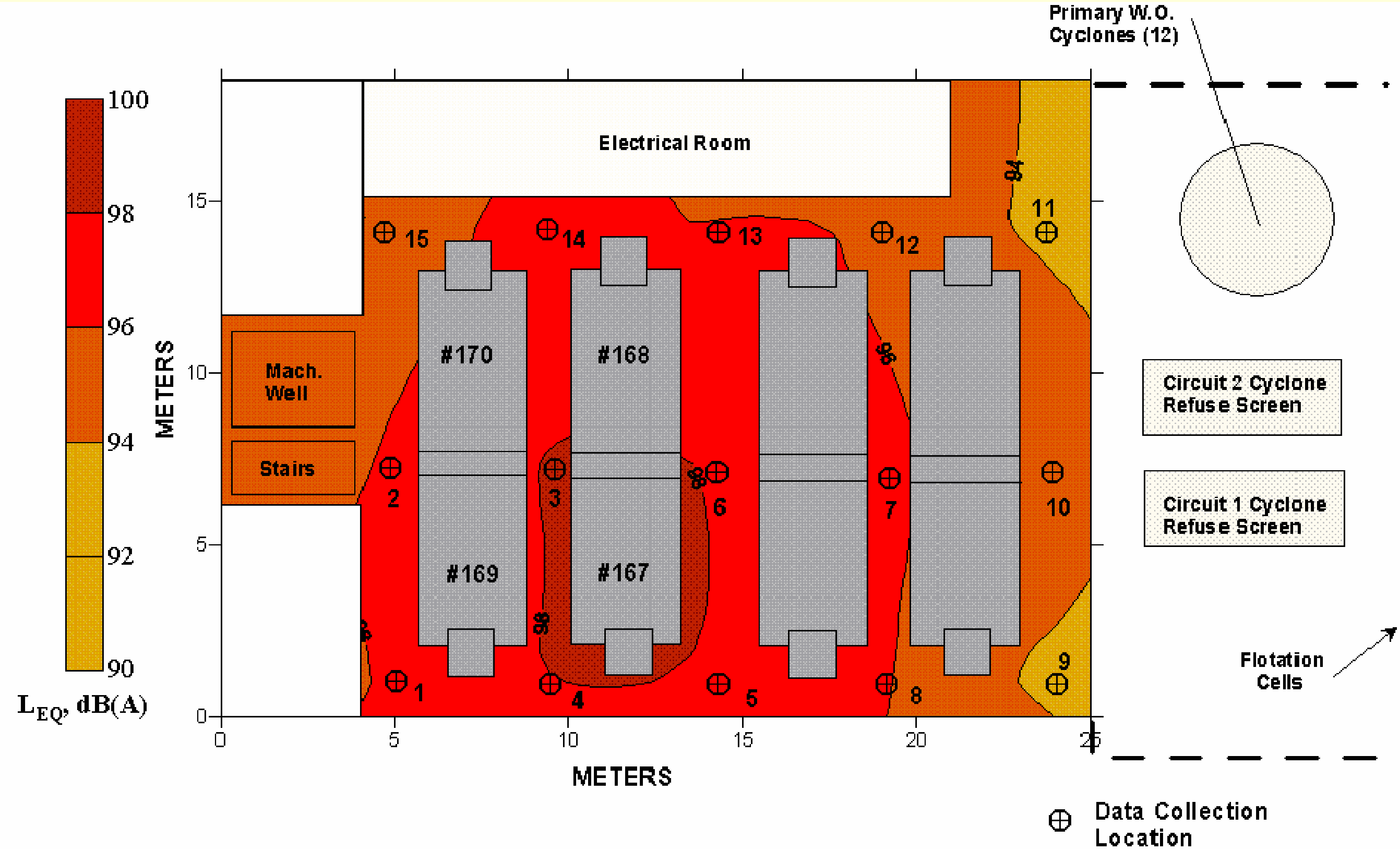
Multiple Noise Sources

Rank Ordering – Vibrating Screen Example



Multiple Noise Sources
Rank Ordering – Vibrating Screen Example



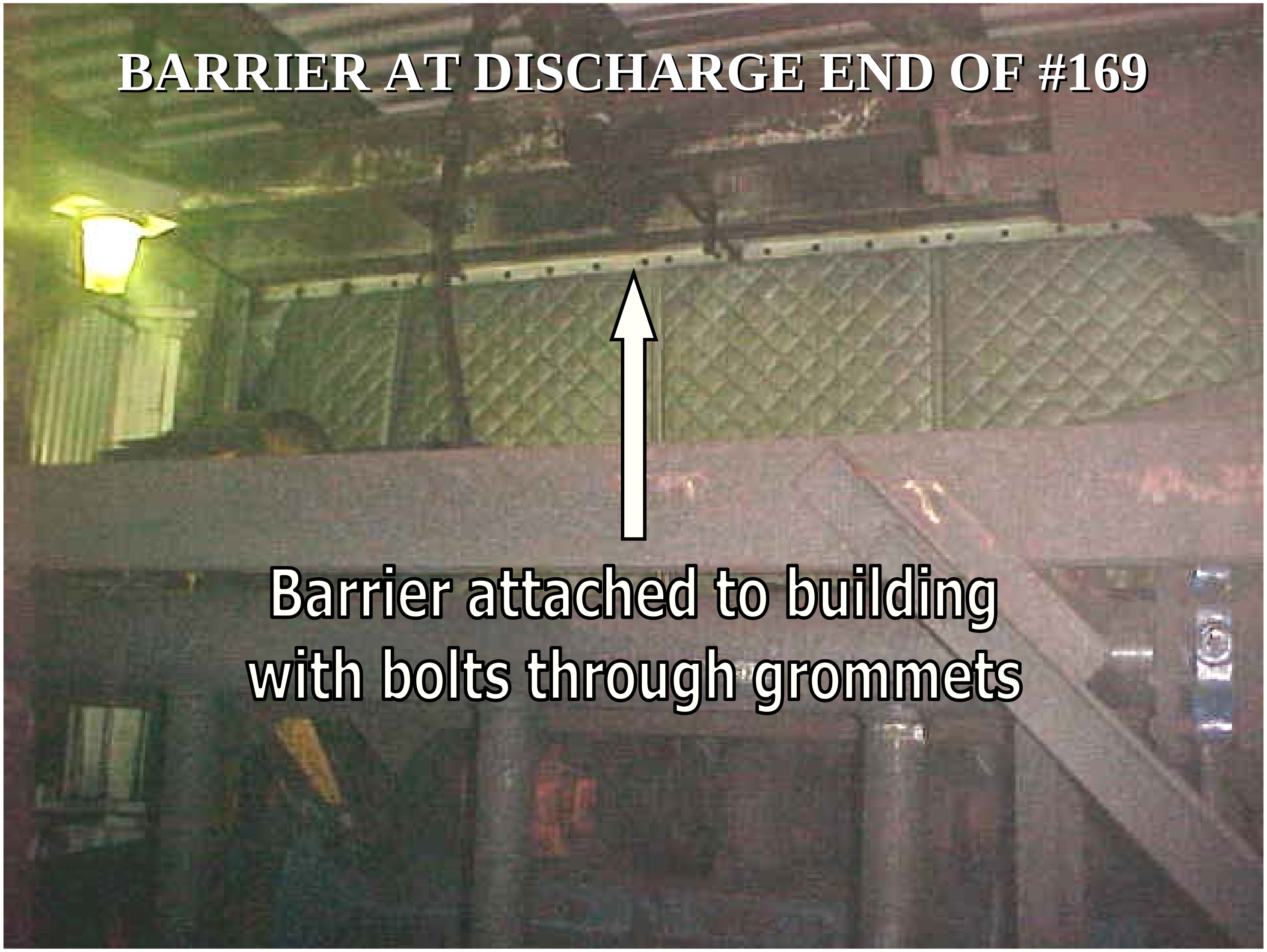
Multiple Noise Sources

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 the other screens off
- Even significant changes to the test screen will not result in a measurable sound level reduction
- Quilted fiberglass-vinyl-fiberglass barrier hung around test screen to reduce background noise from other equipment

Multiple Noise Sources

Rank Ordering – Vibrating Screen Example

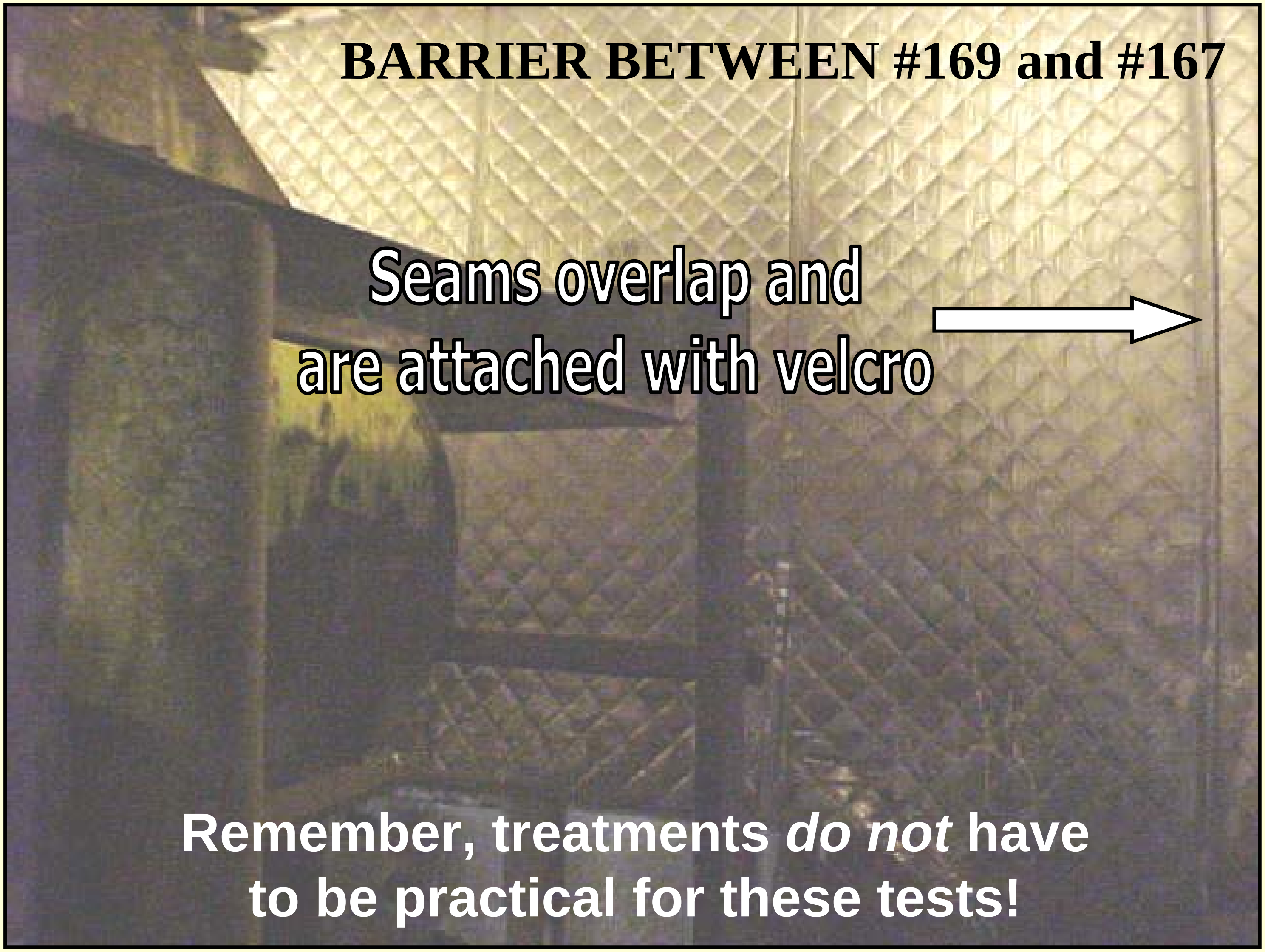


Multiple Noise Sources

Rank Ordering – Vibrating Screen Example

Multiple Noise Sources

Rank Ordering – Vibrating Screen Example



Remember, treatments *do not* have to be practical for these tests!

Multiple Noise Sources
Rank Ordering – Vibrating Screen Example

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

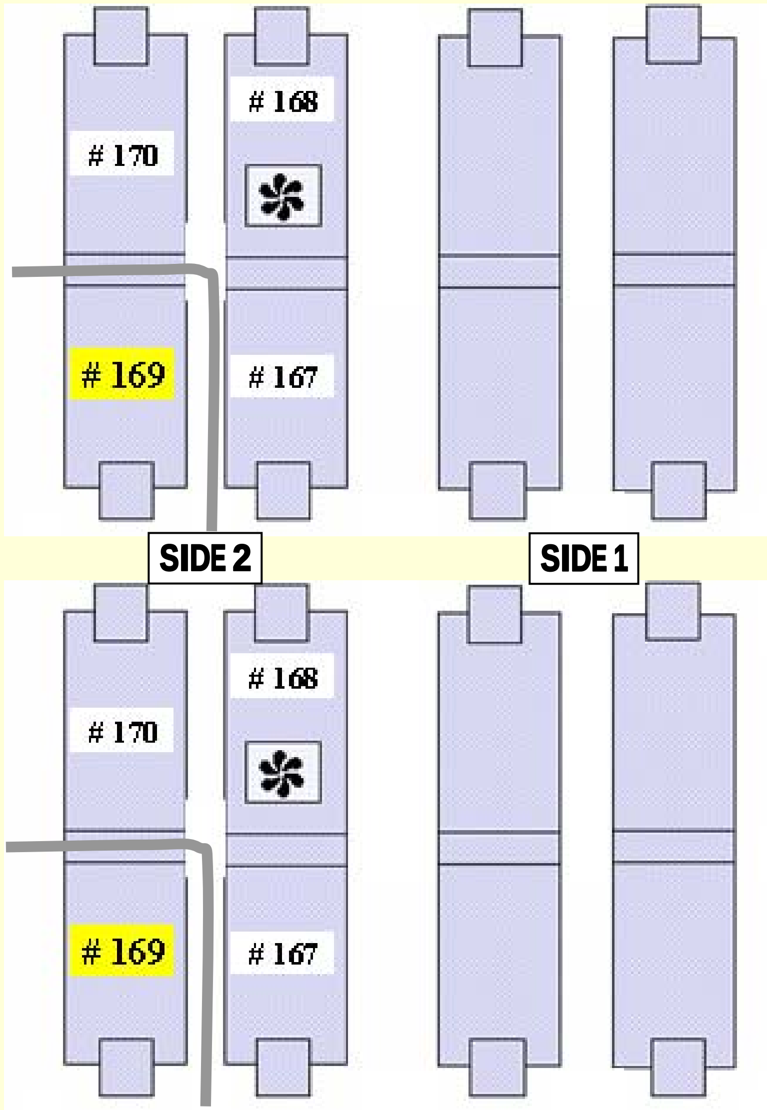
Multiple Noise Sources

Rank Ordering – Vibrating Screen Example

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

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)



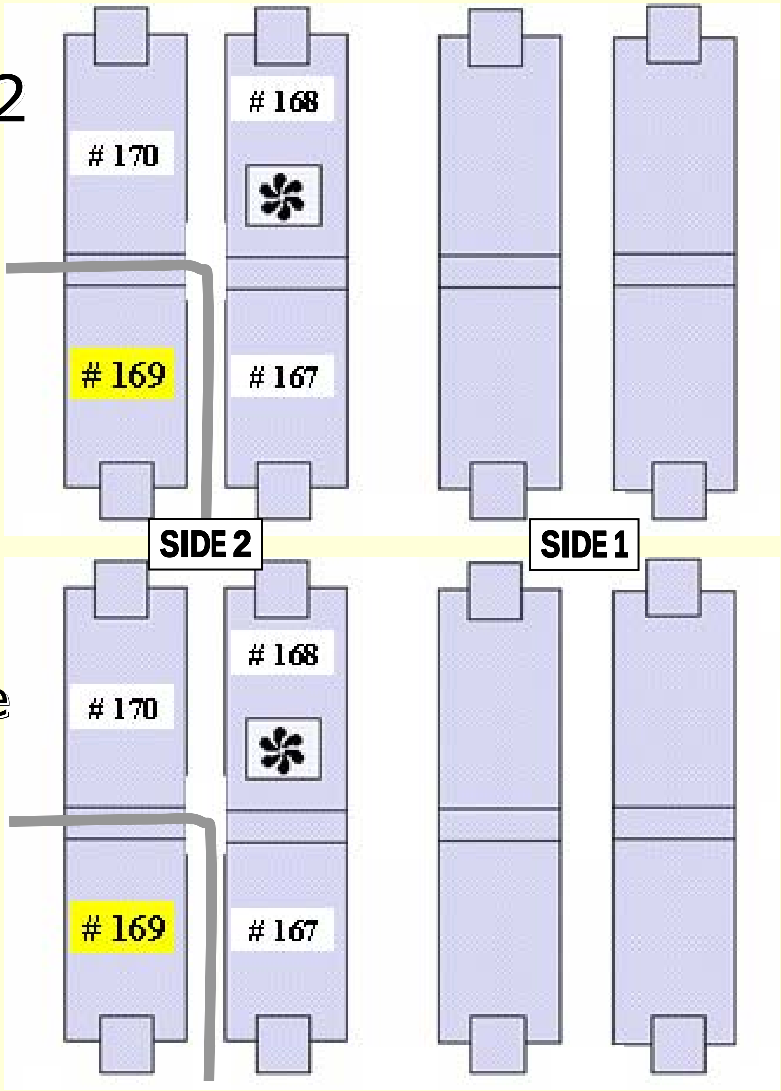
Multiple Noise Sources

Rank Ordering – Vibrating Screen Example

3. Side 1 processing coal, Side 2 off (BG noise for #169 VIBE only & #169 WATER only)

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

Yields sound level for drive noise

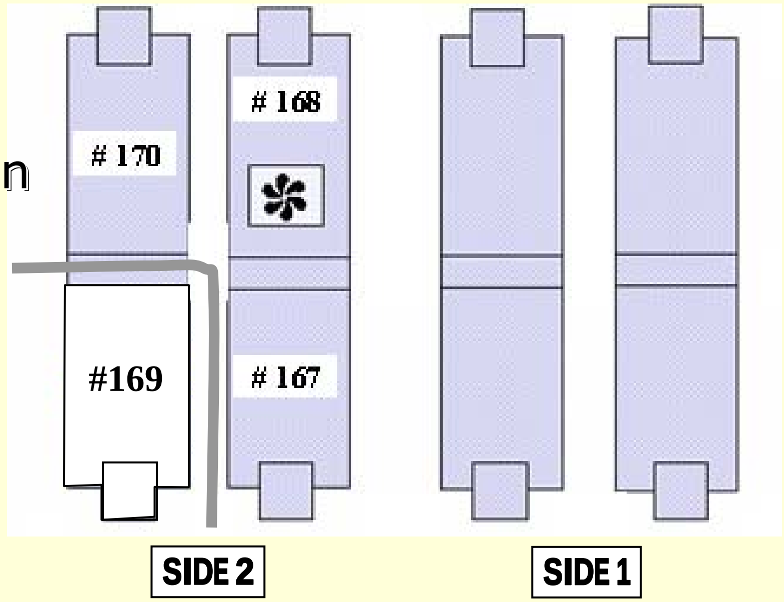


Multiple Noise Sources

Rank Ordering – Vibrating Screen Example

5. Side 1 processing coal, Side 2 off, #169 water spray only (Can calculate level of #169 WATER 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 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

- Noise can be reduced by applying 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

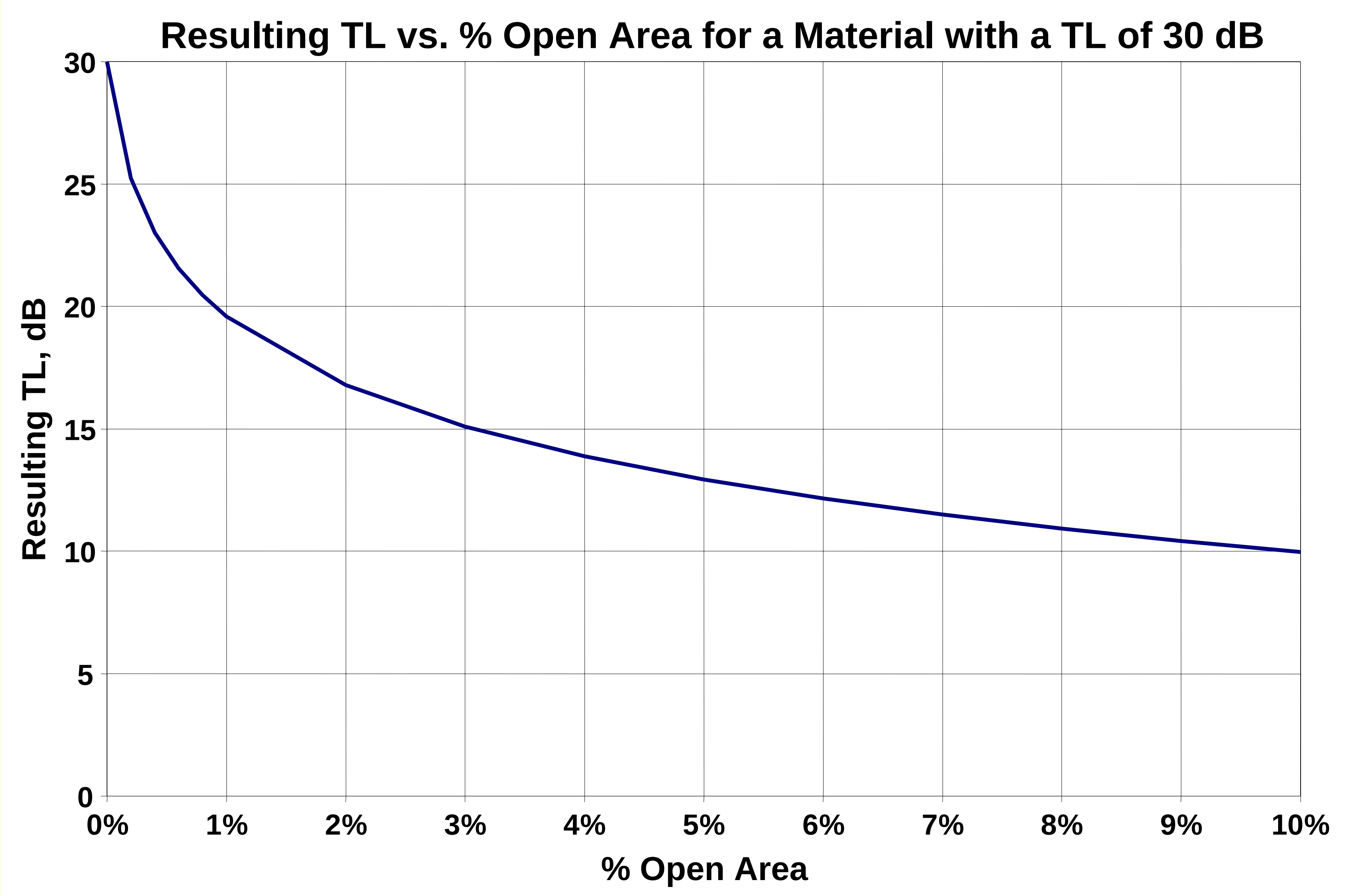
Noise Controls - Absorbers

- 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 gap will greatly reduce the overall TL

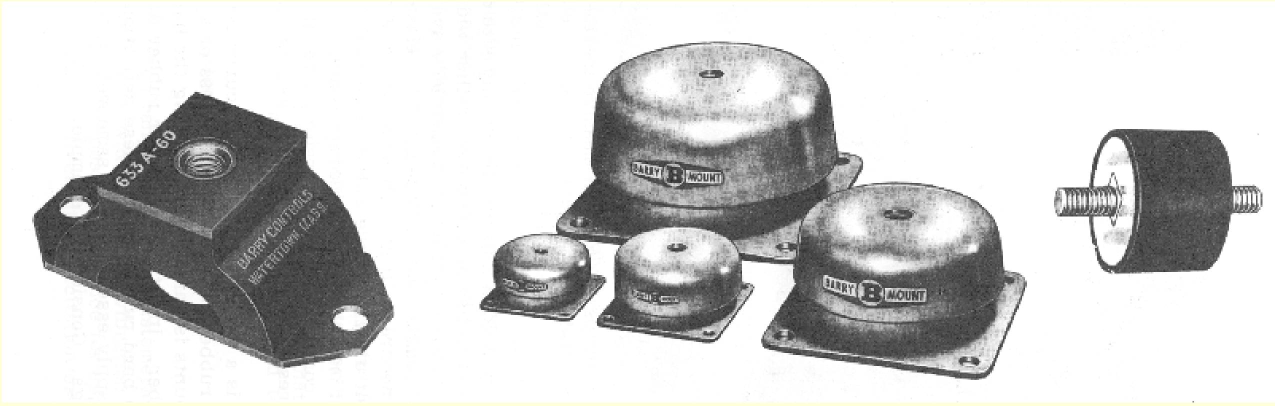
Noise Controls - Barriers



Noise Controls – Vibration Isolators

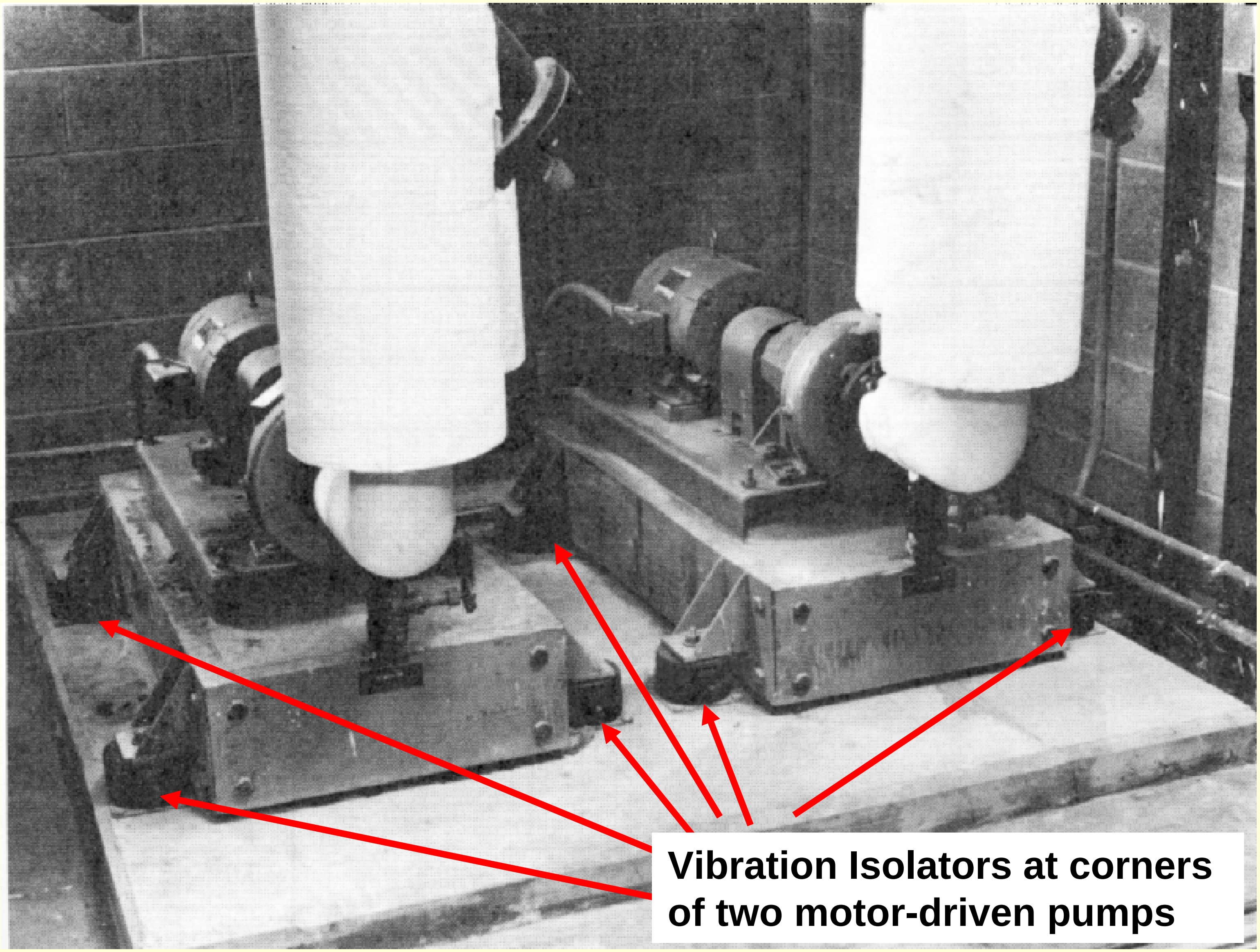
- Vibration isolators are flexible components typically made from rubber, cork, or even steel springs
- The source of vibration may not be the dominant source of radiated noise
- A large, flat surface set into vibration can act like a sounding board and radiate noise
- Properly applied isolators reduce transmission of vibration

Noise Controls – Vibration Isolators



- Selected based on equipment weight, required isolation frequency, and operating 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 like a bell' or 'buzz'
- Isolation pads made of rubber, cork, urethane and similar can be used to 'cushion' impacts

Examples:

Coated flight bars and composite tail rollers 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
- There are two types of damping treatments
  - Free-layer damping
  - Constrained-layer damping

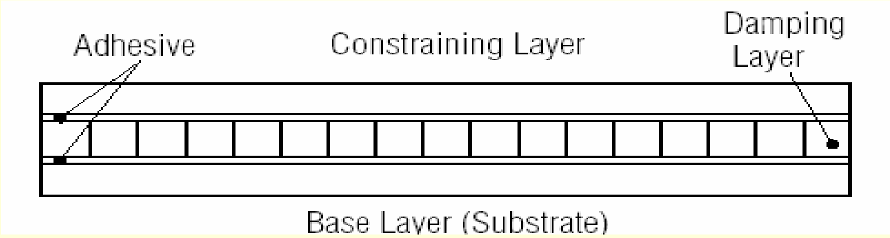
Noise Controls – Vibration Damping

Free-layer damping

- Applied to a surface via spray, roller, or brush
- Useful for relatively thin structures
- Applied damping material is often 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

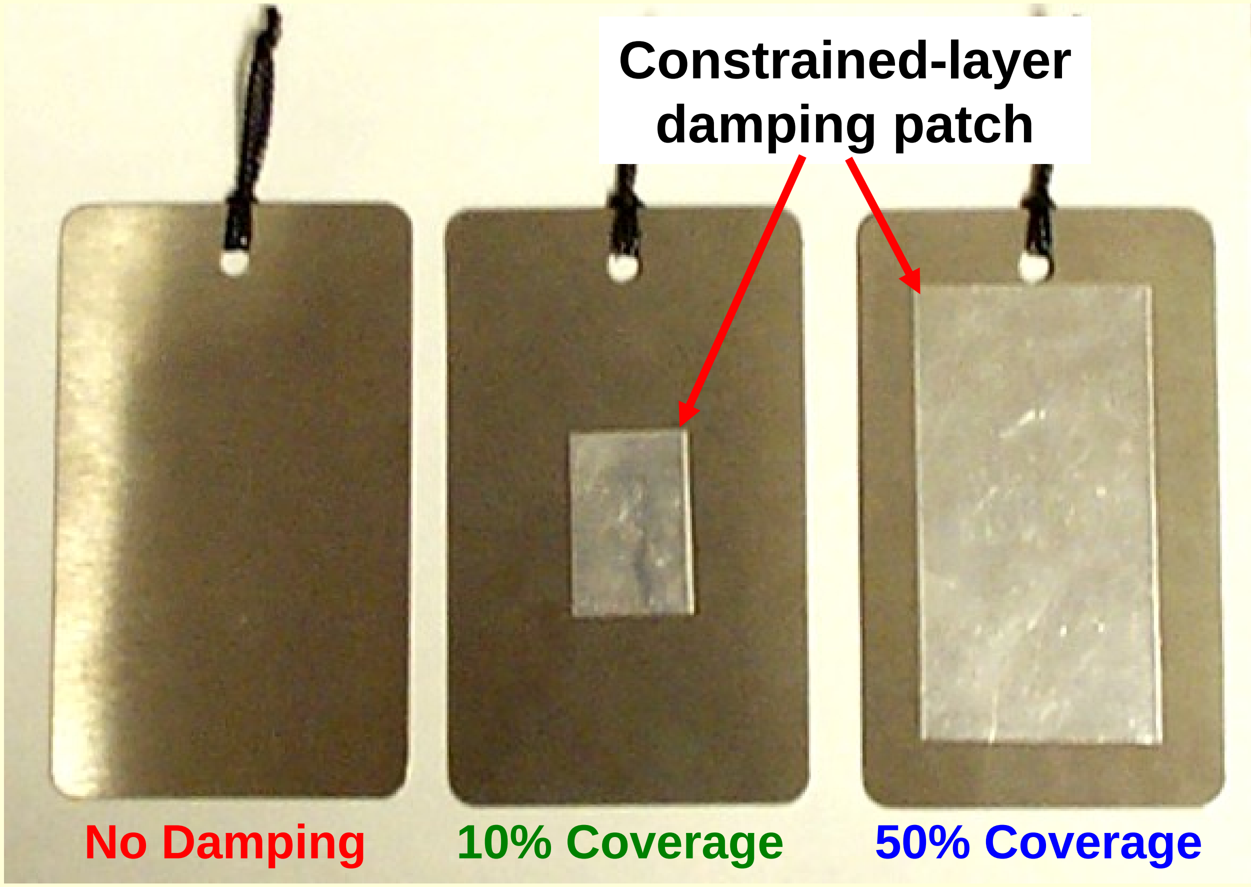


Example

Composite tail roller for a continuous mining machine

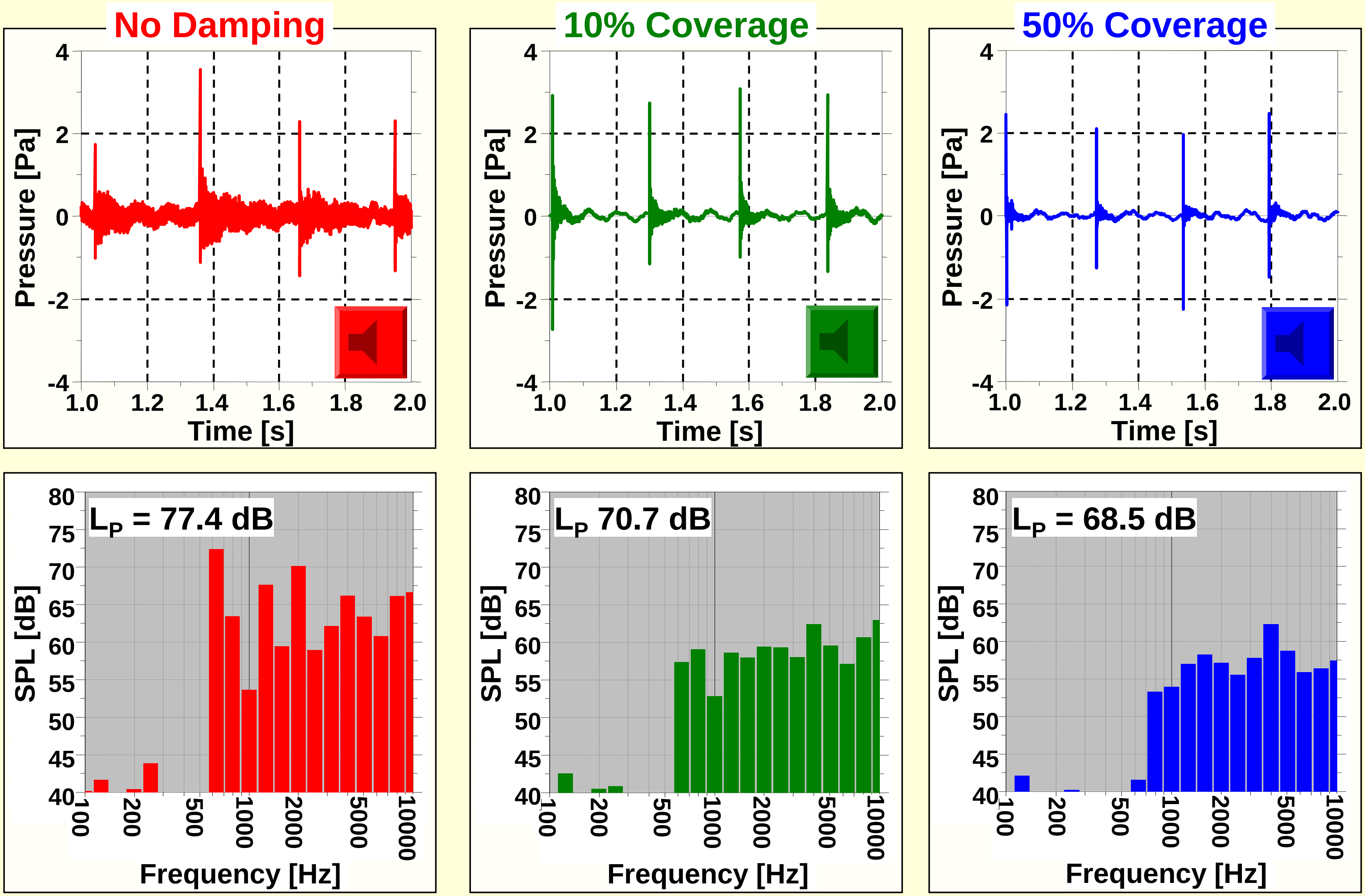
Noise Controls – Vibration Damping

Constrained-layer Damping Demonstration



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

Noise Controls – Vibration Damping



Cabs, Barriers, and Enclosures

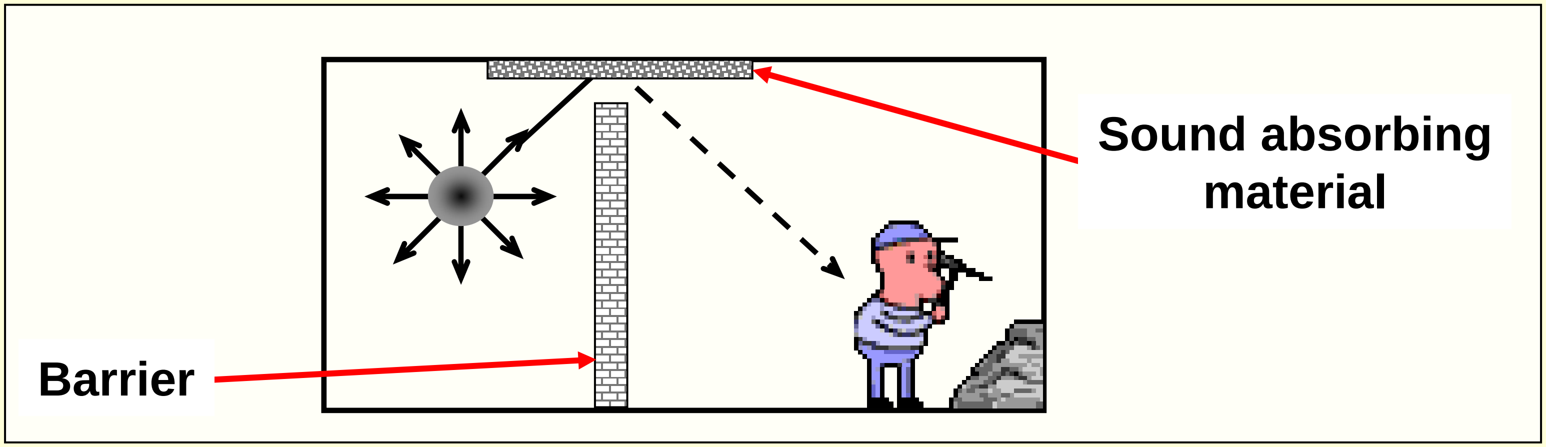
- Cabs, barriers, and enclosures can be very effective in reducing noise exposure if they are applied properly
- It is critical to limit gaps to a minimum
  - Pipe penetrations and openings around hydraulic lines or electrical wiring should be sealed as well as possible
  - Doors and windows should use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

Cabs

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

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



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 rubber gasket material
- Add damping treatments to the enclosure if vibration is a concern

For more information

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