Noise Control Demystified

A Quick View of Industrial Noise Control

Oregon GOSH 2025
Wednesday, March 5

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Colorado Analytics

- Fort Collins, Colorado
- Consultants in acoustics, noise, and vibration
- Specialize in industrial and manufacturing noise control
- Active in environmental and community noise
- Sometimes architectural acoustics
- Merged with Associates in Acoustics in 2019
- Have worked on 5 continents, all 50 U.S. states, and a few US territories

Who Is This Guy?

Joshua Leasure, P.E.

- Taylor Elementary Citizen of the Year, 1983
- Studied mechanical engineering
- Doing acoustics since 2002
- Focused on manufacturing / industrial noise since 2012
- Independent since 2016
- Acoustics and vibration measurement
- Environmental / community noise
- Architectural acoustics
- Mechanical / industrial noise and vibration control

Topics

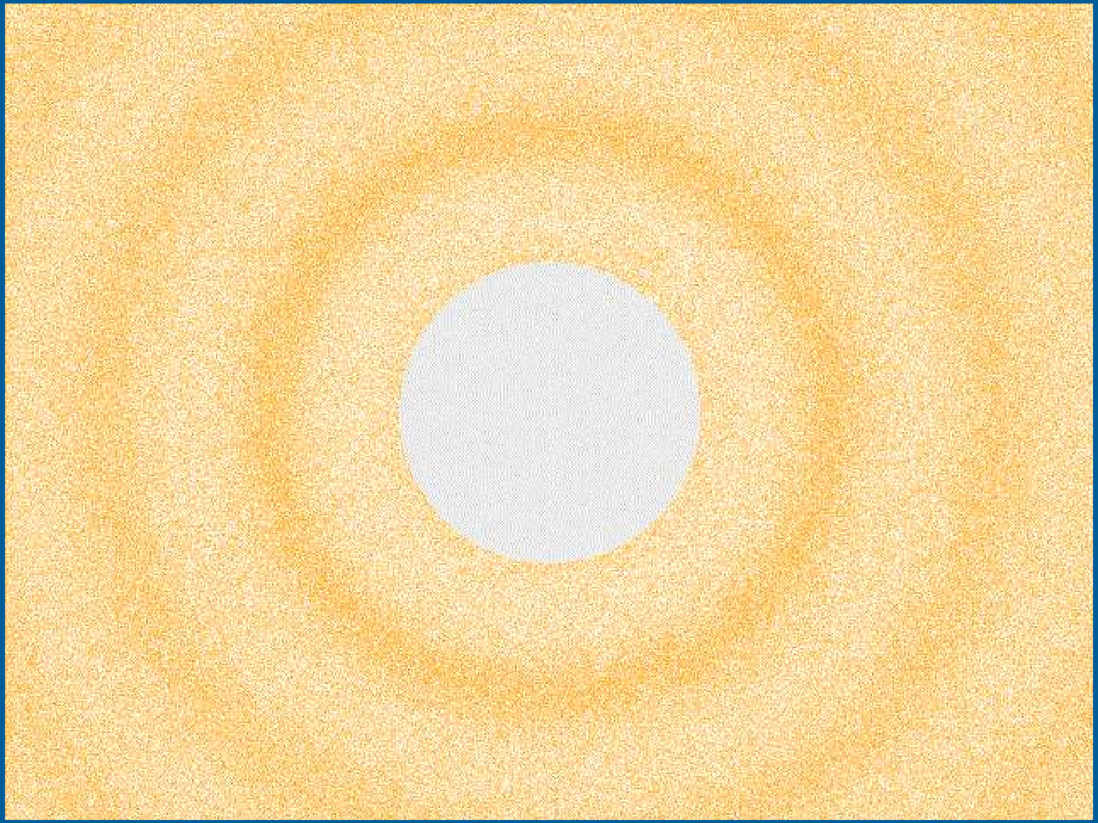
- Fundamentals of Acoustics
- Principles of Noise Control
- Noise Control Applications
- Case Studies

Fundamentals of Acoustics

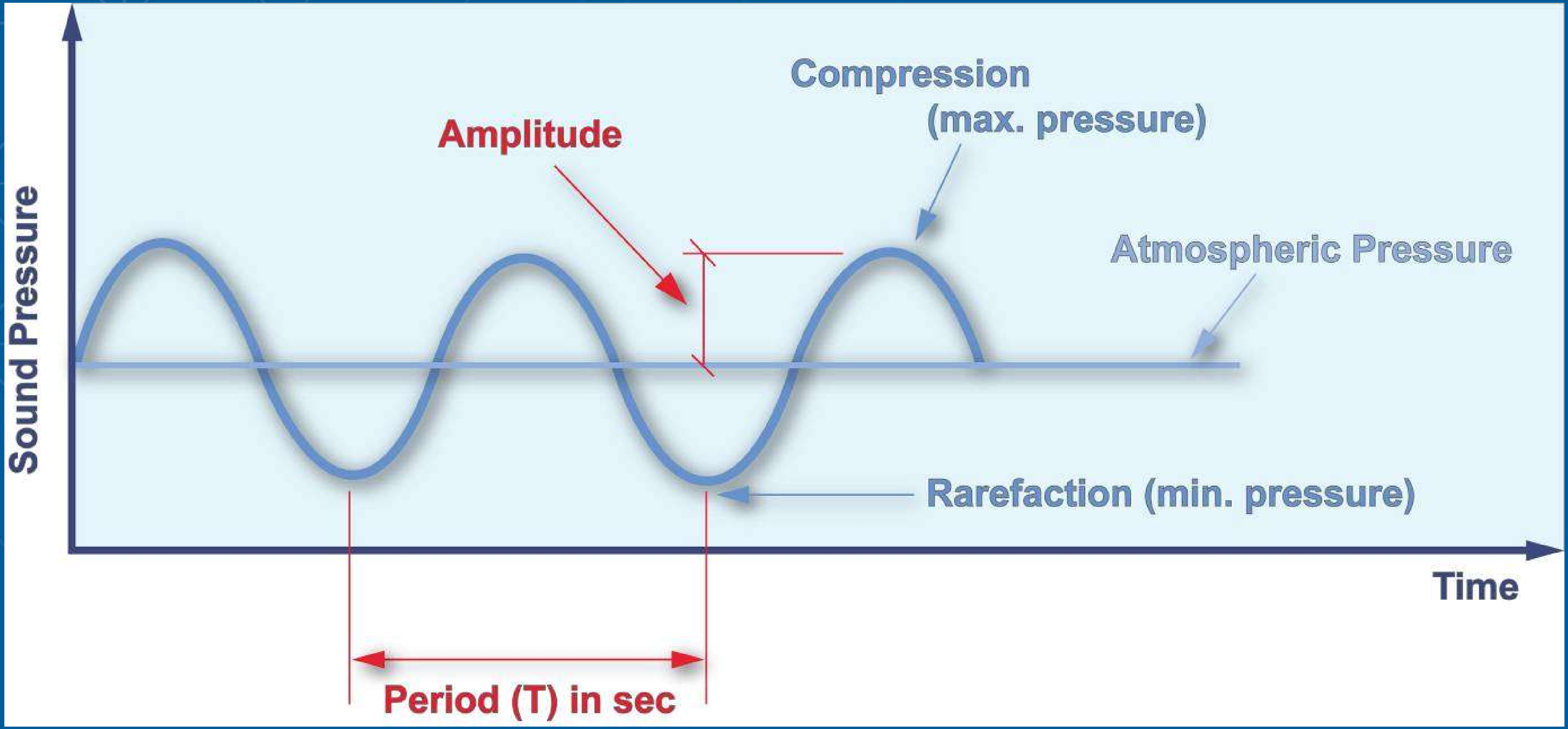
You can't spell fundamentals without fun

What is Sound?

- A longitudinal pressure wave that travels through a solid, liquid, or gas
- Created by a vibrating object or by turbulence in a fluid
- Alternating regions of high pressure (compression) and low pressure (rarefaction)
- Molecules move from high pressure points towards low pressure points, forwards and then backwards (and then forwards, and then backwards…).
- Pressure regions move forward while molecules move back and forth.



Properties of Sound Waves



Decibel Is Not a Unit (not really)

- Mathematical trick to make big numbers easier to deal with and to make consistent comparisons between numbers that scale logarithmically
- Used for many quantities in acoustics
  - Sound pressure (Pascals)
  - Sound intensity (Watts / sq m)
  - Sound power (Watts)
  - And a number of quantities derived from these
- Used for many other quantities in signal processing

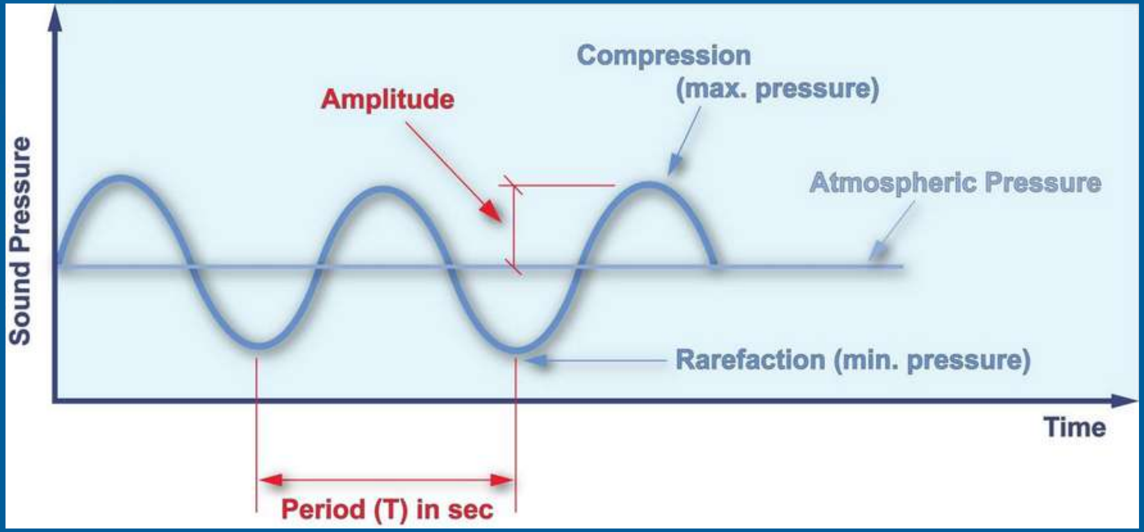
Sound Pressure Level (SPL)

- A "level" is a decibel representation
- Sound Pressure Level is a level of… sound pressure (Pascals)

- Reference quantity = 20µPa (threshold of human hearing)
- Differences in dB are a meaningful comparison at any level
  - represents the same percent change at any point on the scale
  - Rules of thumb for human perception of changes in SPL:
    - = not usually noticeable
    - = just perceptible
    - = clear difference
    - = twice / half as loud

Frequency

- Cycles per second - Hertz (Hz)
- I.e. number of times per second the wave repeats
- Ultra-healthy human hearing is sensitive from 20 Hz to 20 kHz
- Later in life sensitivity to high frequencies drops
- Sensitivity is highest 1-4 kHz (speech consonants)

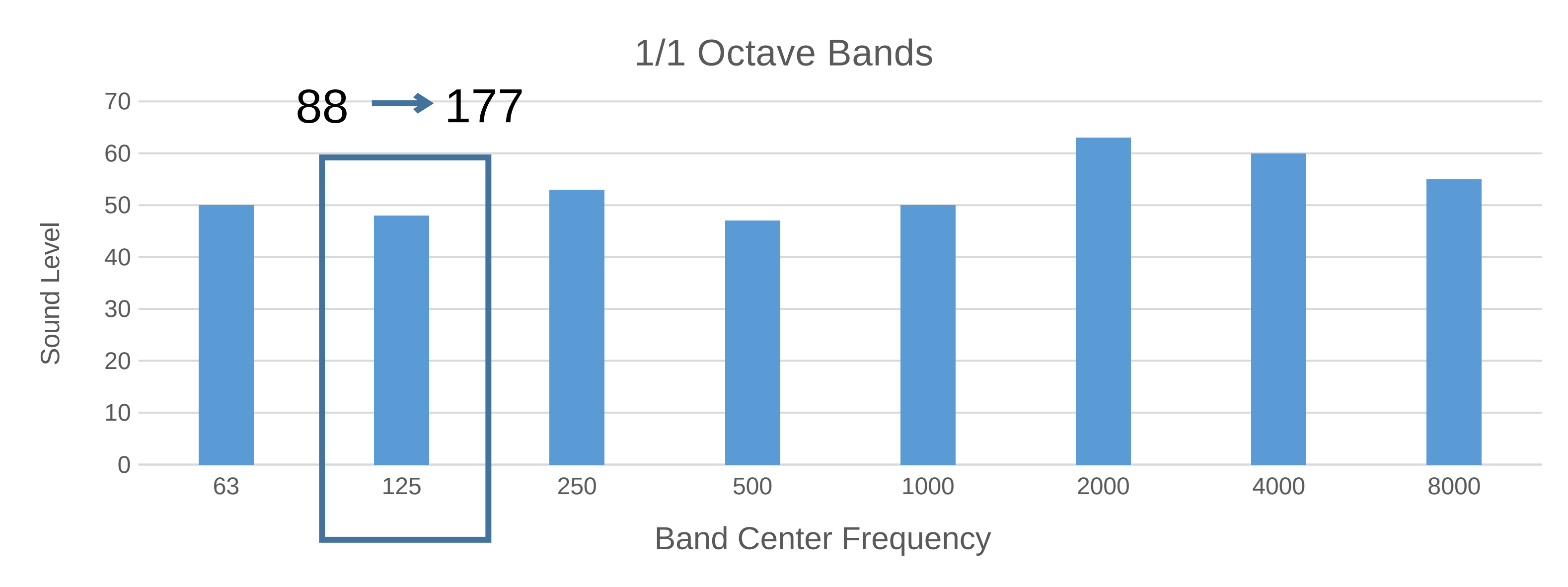


Frequency Bands

- A Frequency Band is a specific range of frequencies
- “Broadband” is one band that covers all (or most) frequencies
- Sounds that are not pure tones exist across many frequencies
- Frequency bands quantify the distribution of sound energy across different frequencies for a single sound

Octave Bands

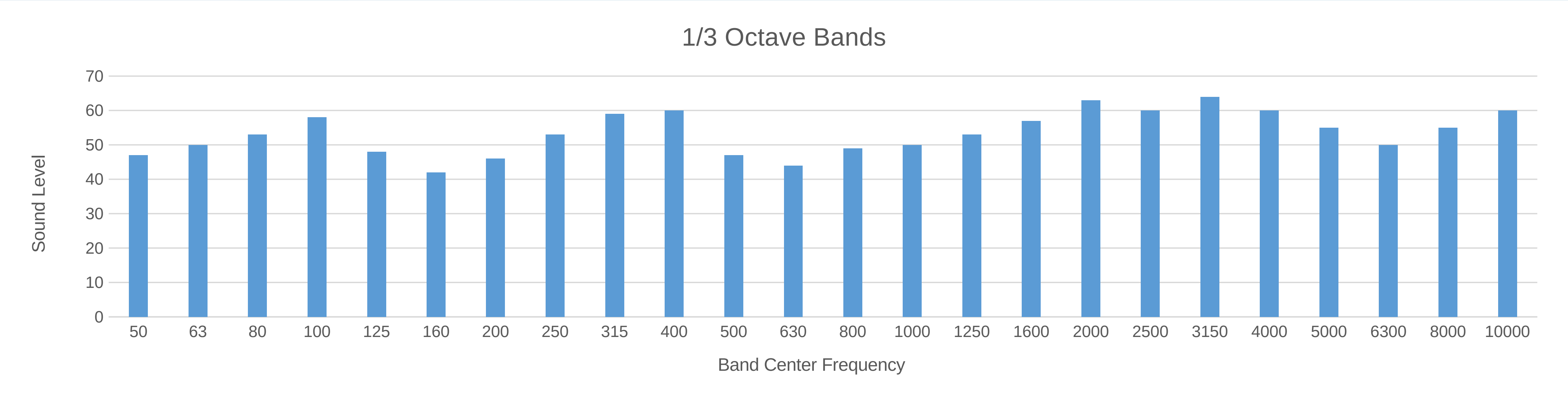
- For workplace sound, the most common bandwidth is the octave band
- Octave bands are an example of Constant Percentage Bandwidth (CPB) bands
- An octave band is defined as a range of frequencies where the upper end (f2) frequency is twice the lower end (f1): $f2 = 2f1$, Hz



Lower	Center	Upper
44	63	88
88	125	177
177	250	355
355	500	710
710	1000	1420
1420	2000	2840
2840	4000	5680
5680	8000	11360

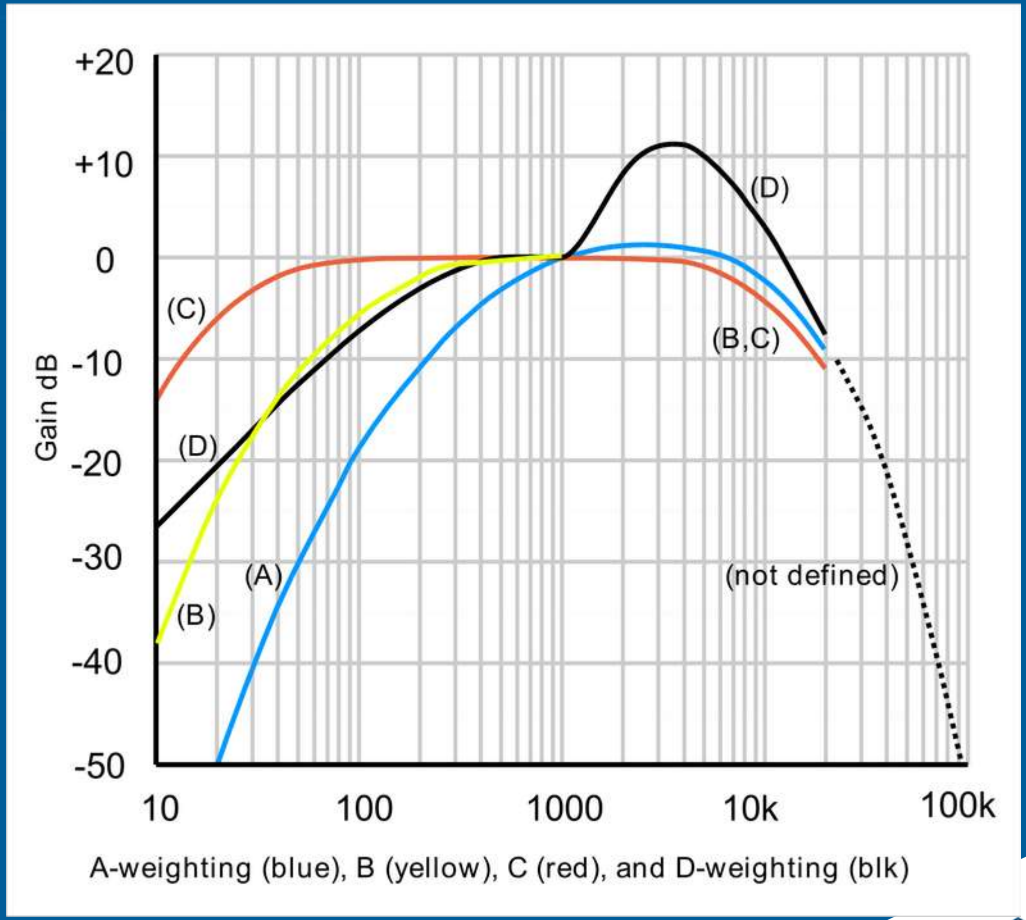
1/3 Octave Bands

- Each octave is divided into 3 narrower bands



Frequency Weighting

- A) Approximates human ear response at low levels.
  - Discounts low frequencies, emphasizes high frequencies
  - Used extensively in regulation and in hearing conservation
  - Assume A if not otherwise specified
- C) Approximates ear response at higher levels.
  - Greater emphasis in lower frequencies
  - Comparing C to A can give an idea of low-frequency content
- B and D are rarely used



Weighting Octave Bands

- Weights are applied to each band individually
- Adding up all weighted bands logarithmically gives the (overall) broadband weighted level

example	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**Overall**	
Unweighted Level	90	90	90	90	90	90	90	90	99.0	dB
A-weighting correction	-26.2	-16.1	-8.6	-3.2	0	1.2	1.0	-1.1		
A-weighted levels	63.8	73.9	81.4	86.8	90	91.2	91	88.9	97.0	dBA

Time Domain

- SPL – Sound Pressure Level
  - An instantaneous value that is often a running exponential average that looks at the most recent 1 second or 1/8 second:
    - “Fast” = 1/8 second
    - “Slow = 1 second
  - Lmax is the highest single SPL measured during a given period of time
- Leq - Continuous Equivalent Sound Level
  - Logarithmic average of a sound over a given period of time
  - Most useful for most applications
  - Good assumption to make when a time setting is not specified

Sound Pressure vs Sound Power

- Sound Pressure
  - The propagating, slight change in atmospheric pressure caused by a sound wave
  - What can be heard and measured
  - Pascals (Pa)
- Sound Power
  - The energy per second converted by a sound source into a sound wave
  - Cannot be heard or directly measured, only inferred
  - Watts (W)
- Sound Power Levels
  - Sound power in decibel form
  - Referenced to 1 pico-Watt (

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Decibel Math

- To add or subtract decibels, levels must first be converted back to their original quantities, added or subtracted, then converted back to decibels
- Sound pressure levels do not need to be converted all the way back to Pascals, it is OK to add or subtract the squared quantities before converting back to decibels

Formula to add decibels in cells A1 and A2 of a spreadsheet:

=10*log10(power(10,A1/10)+(power(10,A2/10))

Decibel Addition with The Table

1. Find the adjustment amount in the table corresponding to the difference in the two decibel values being added
2. The total value is the higher of your two values plus the adjustment amount

63 dB + 66 dB:

66 – 63 = 3 => 1.8

66 + 1.8 = 67.8

Difference between L_1 and L_2 (dB)	Amount to be added to the higher of L_1 or L_2 (dB)
0	3.0
1	2.5
2	2.1
3	1.8
4	1.5
5	1.2
6	1.0
7	0.8
8	0.6
9	0.5
10	0.4
>10	0.0 for all practical purposes

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Principles of Noise Control

Principles of Noise Control

- Measuring Sound
- Noise Generating Mechanisms
- Source Identification
- Transmission Paths
- Acoustic Materials
- Noise Control Options

Sound Measuring Equipment

Sound Level Meter

How loud is it in this specific spot at this specific time?

Noise Dosimeter

What is the time-weighted average noise exposure of a worker over an entire workday?

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Selecting a Sound Level Meter

For noise control, choose a meter that has:

- Leq (continuous equivalent level, or “average”)
- 1/3-octave bands (octaves OK if 1/3-octaves not available)
- Logging or time history, if available
- Type 1 is nice, but Type 2 is perfectly appropriate

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SLM Settings: Time Response

- “Fast” and “Slow” time Constants (τ) for RMS (root mean square) measurements
  - **Slow** = 1-second time constant, common for regulatory measurements
  - Fast = 1/8-second time constant
  - Affects SPL, Lmin, Lmax, Ln
- “Peak” – instantaneous highest level seen by the instrument, regardless of other time settings
- “Impulse” – exotic τ used for special types of measurements
- Continuous Equivalent Sound Pressure Level – **Leq**, LAeq
  - Integration of sound energy over time
  - Conceptually (and often called) the “average”
  - **Most useful for most types of measurements**

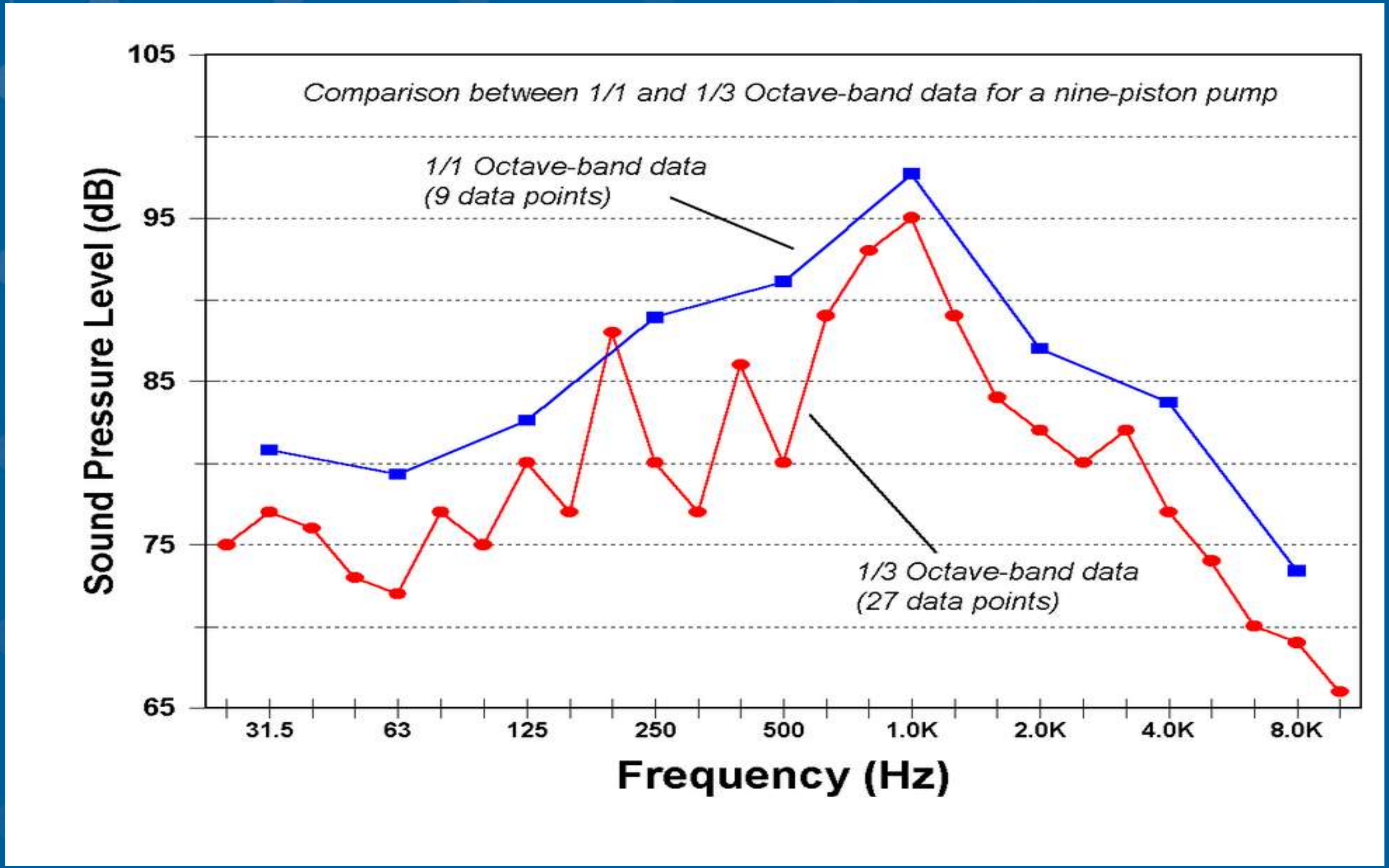
SLM Settings: Frequency

Level in each frequency band is weighted according to the chosen frequency weighting setting

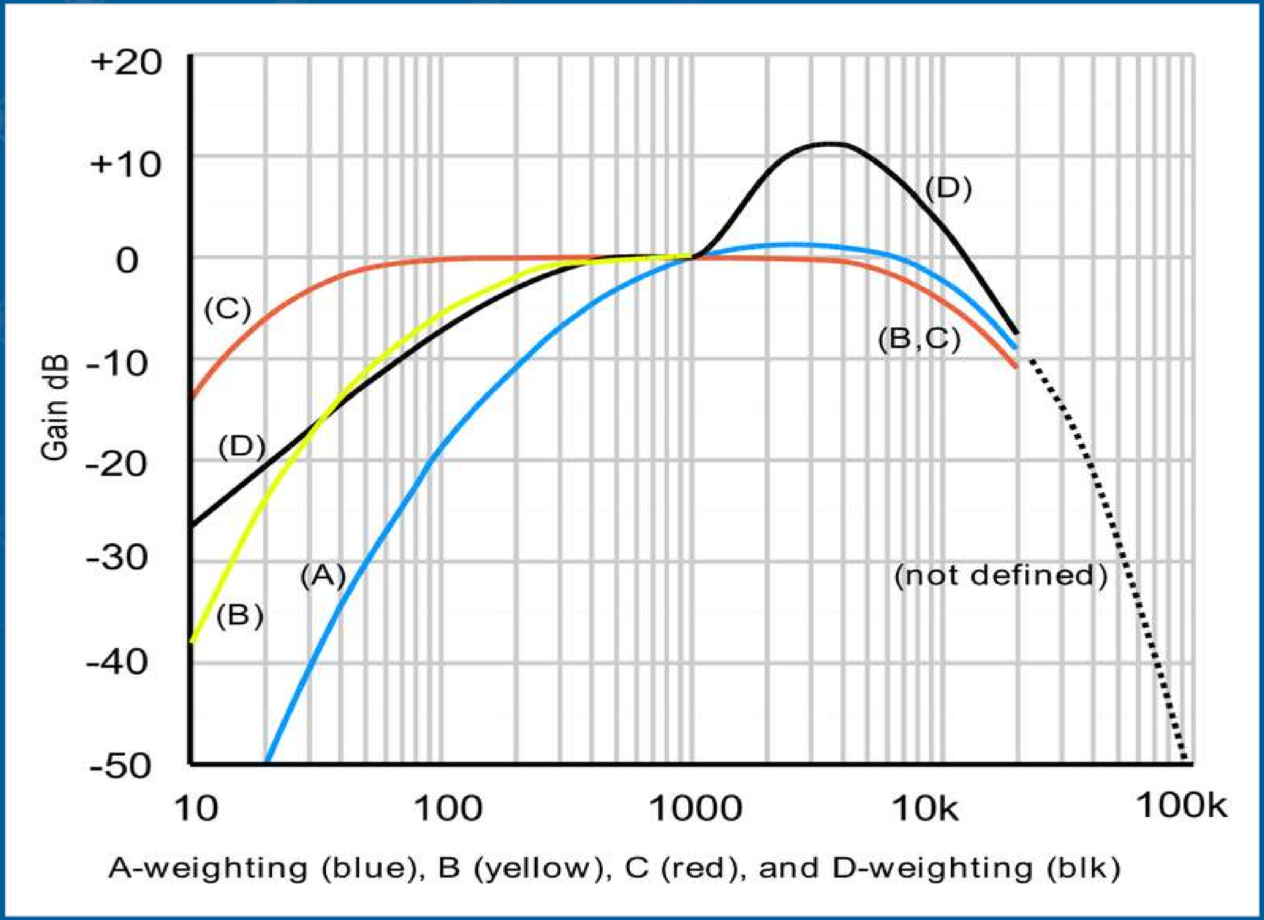
- Linear / Unweighted / Z-weighted – detailed analysis, noise control engineering, room acoustics, peaks
- **A-Weighting** – regulatory compliance, worker noise exposure, basic noise control evaluation
- C-Weighting – used for hearing protector noise reduction ratings and some low-frequency noise analysis

If no weighting is specified, that usually means "A"

Frequency Bands



Frequency Weighting



Noise Exposure

- The accumulation of exposure to noise throughout a workday
- A product of time and level. Both are important and the calculation differs per standard
- Expressed as a percent of the daily maximum
- …or as a time-weighted average value in decibels

Sound Generation

Understanding the mechanisms of sound generation increases your chances of identifying a primary noise source and developing an effective mitigation strategy

- Vibrating Surfaces
- Impacts
- Fluid Turbulence
- Rotating Equipment

Sound Generation: Vibrating Surfaces

Microscopic vibrations in solid surfaces radiate sound energy

- Panels
- Pipes
- Conduit
- Floors
- Walls

Large, flat surfaces are the most efficient radiators

Sound Generation: Mechanical Impacts

Whenever an impact occurs, sound is generated

- Material processing
- Actuators
- Product conveyance

Impacts are not always obvious

Sound Generation: Turbulent Fluid Flow

Any turbulent fluid flow will generate noise. Gas flows are most common.

- Exhausts
- Nozzles
- Flow Through Orifices
- Flow Over Objects or Edges

Sound energy created by a gas jet is proportional to or (that’s a lot!!!)

Sound Generation: Rotating Equipment

Continuously cycling equipment creates noise that can travel through mechanical connections and/or through fluid pathways

- Vibration
- Gears Meshing
- Blade Passage

1 RPM = 1/60 Hz

Primary Noise Source Identification

- Isolating and identifying primary noise sources is necessary for developing a mitigation strategy
- Primary sources are not always obvious
  - The most audible sources are not always the highest contributors to worker noise exposure
- Primary sources are often hidden in busy industrial environments

Source Identification Strategies

- Toggling Sources
- Spectral Comparison
- Temporary Controls
- Time History for Intermittent Sources

Source Identification: Starting at the Receiver

Measure noise levels in locations where noise is *received*

- Control Panels / HMIs
- Walkways
- Access Points

Noise exposure is a product of both level and time, so identify locations where people spend time in elevated noise levels

- Measure the 1/3-octave spectrum as well as the overall, broadband levels

Source Identification: Toggling

- Turning individual noise sources off and on to determine which has the most impact on the receiver
- The most reliable method of identifying primary noise sources
- Not always available

Source Identification: Spectral Analysis

- Compare the spectral shape of measurements taken near potential sources to measurements taken at the receiver
- Our most common technique

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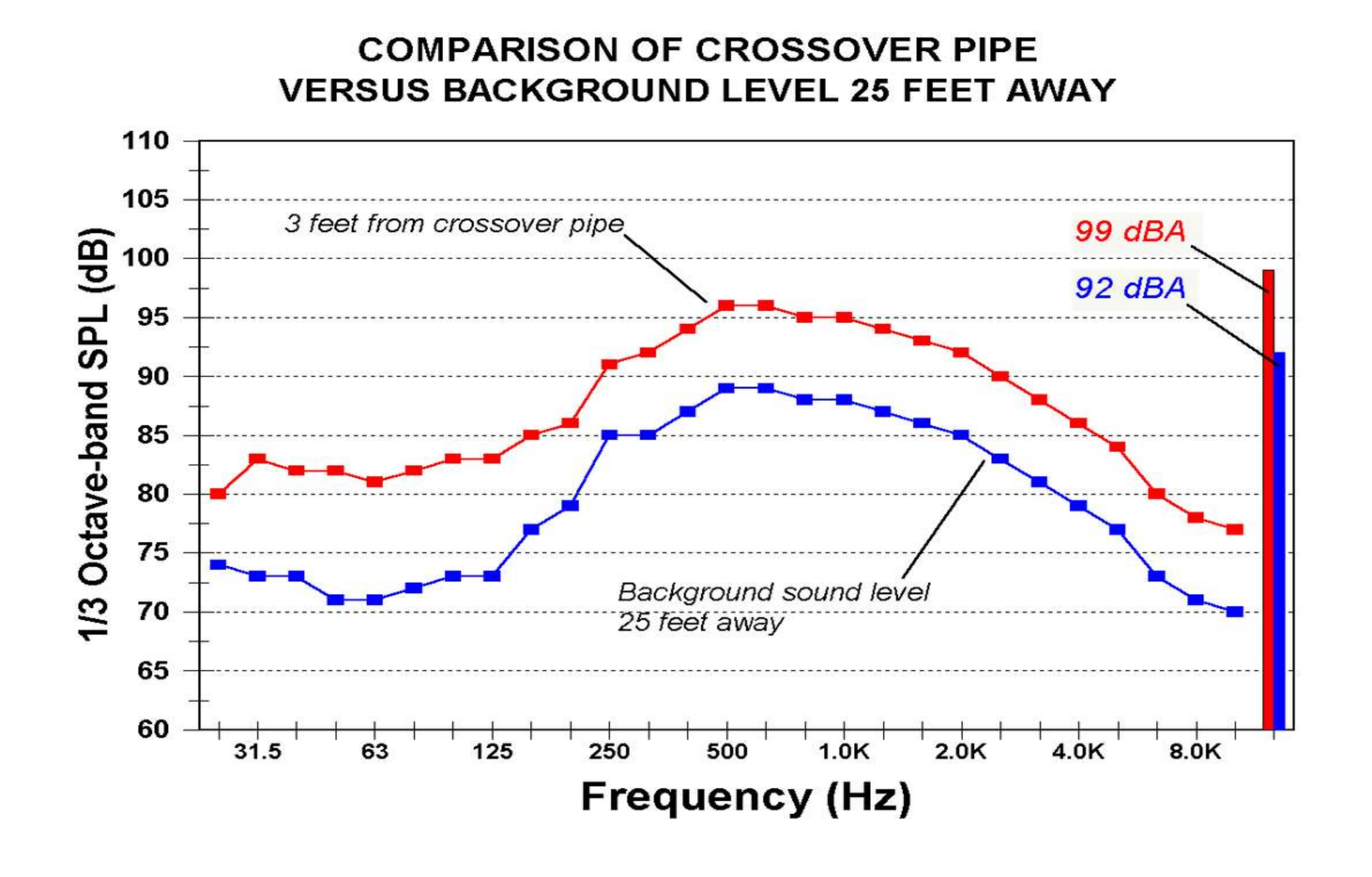
Spectral Shape Comparison



Source Identification: Temporary Controls

Use temporary noise controls to isolate potential noise sources

- Shielding
- Mufflers

Typical approach is to place shielding between components and the microphone while looking for the most significant drop in measured noise level

Temporary Controls

With Cardboard: 84 dBA @ 1m

Without: 94 dBA @ 1m

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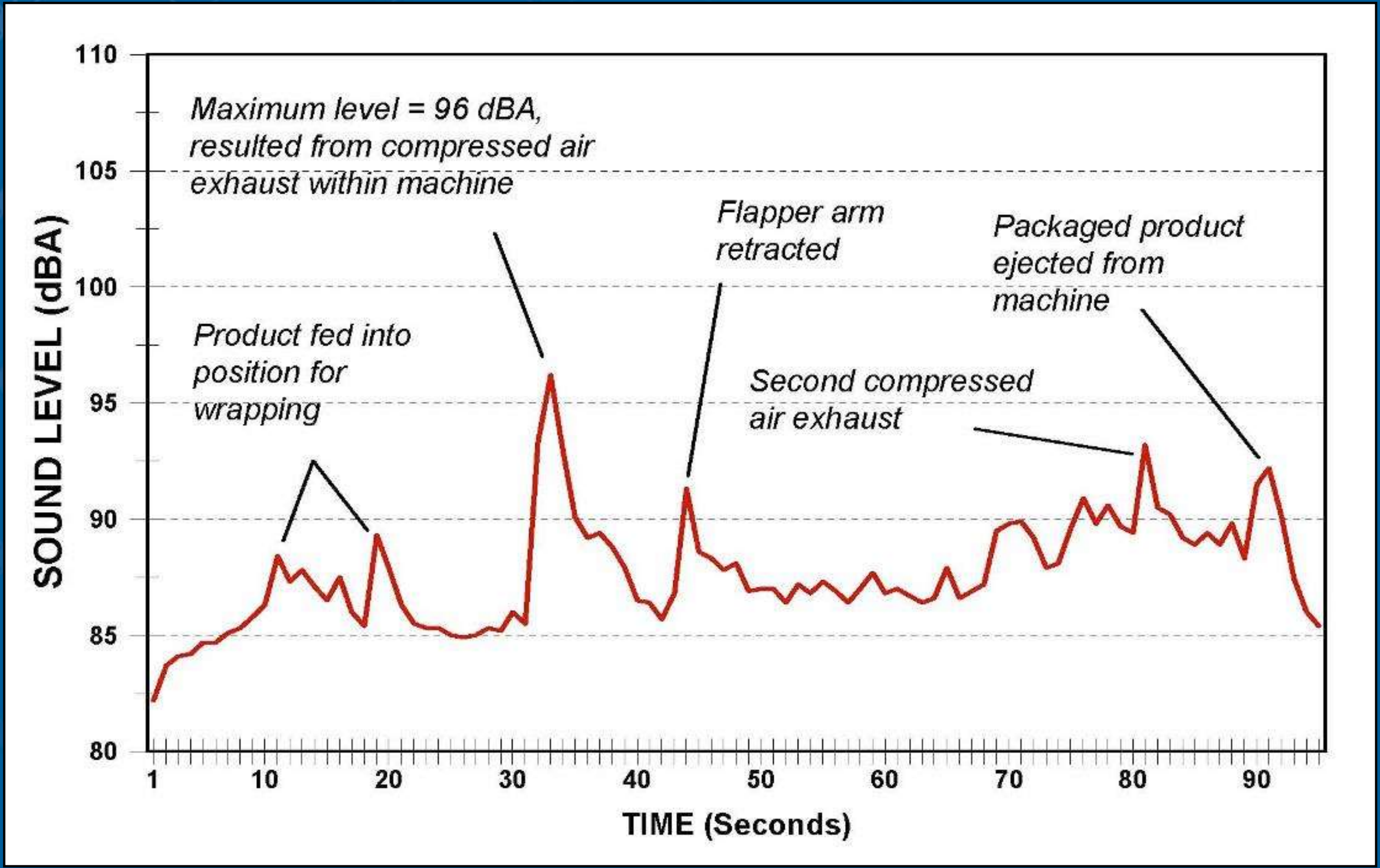
Source Identification: Time History for Intermittent Sources

- Useful when machines have multiple events that each produce noise
- Record time history (logging) to compare the individual contribution of each event
- Both level and duration are important

Time History for Intermittent Sources

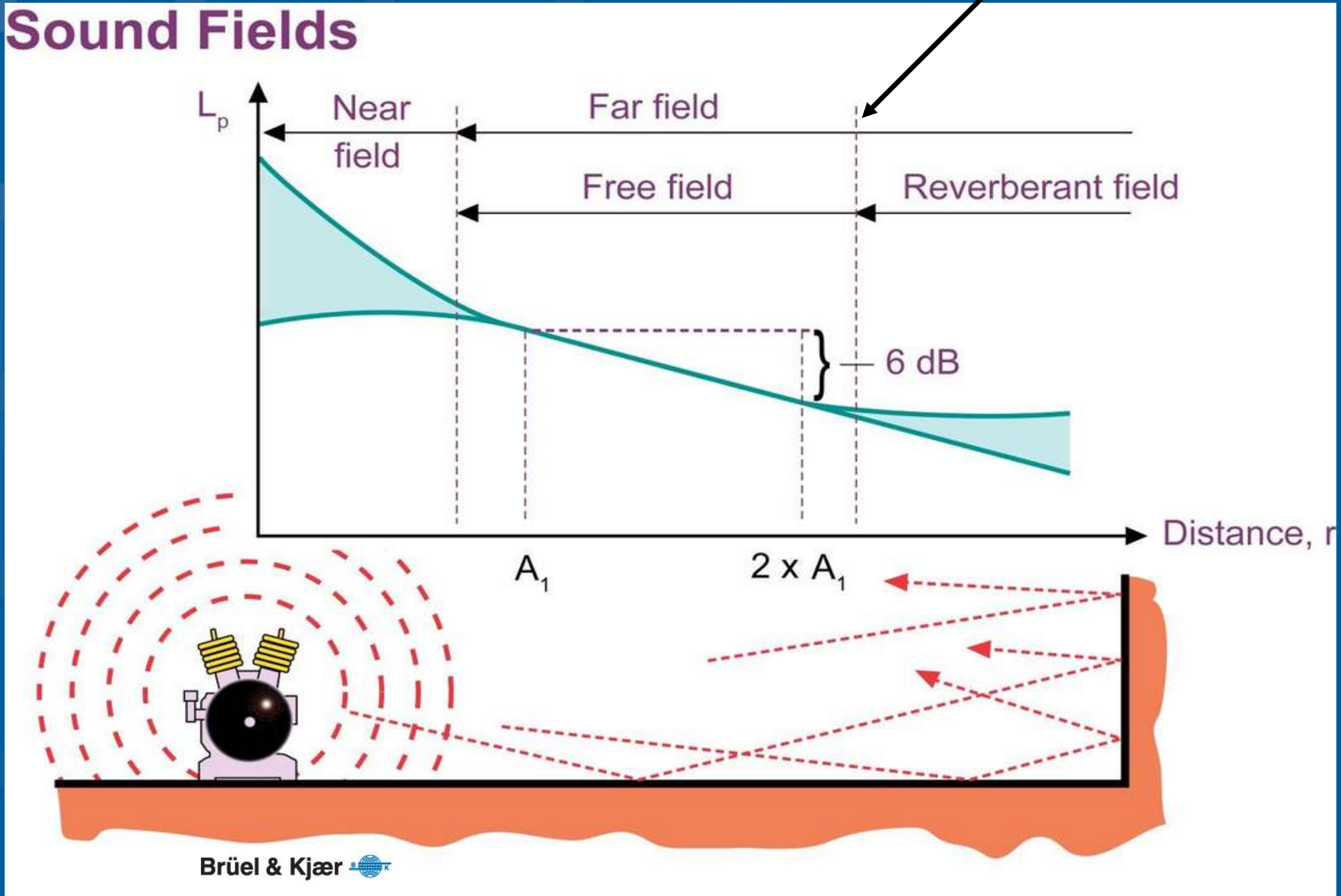


Sound Transmission Pathways

- Direct Sound
- Reverberant field
- Vibration through structures

Direct and Reverberant Sound

Transition zone



Vibration

- Surfaces with vibration energy radiate airborne noise
- Transmits through any solid connection
- Transmits through any solid object
- Commonly transmits through building structures

Material Selection

Different materials for different tasks:

- Sound Absorption
- Sound Isolation
- Vibration Isolation
- Vibration Damping

Materials For Sound Absorption

Placed on our near surfaces to capture sound energy as it reflects.

- Fiberglass
- Mineral wool
- Open-cell foam

Should not be used as a sound barrier

Materials for Sound Isolation

Solid materials that prevent sound energy from passing between spaces

Anything solid can be used. More mass and more complete enclosure is more effective.

- Enclosures
- Walls
- Barriers

Materials for Vibration Isolation

Materials that interrupt vibration pathways

- Springs
- Rubber (usually neoprene or nitrile)
- Open trenches
- Sudden dimension changes

Materials for Vibration Damping

Materials that attach to a surface and absorb vibration energy

- Visco-elastic treatments
- Mass

Noise Control Options

- At the Source
  - Modify the Source
  - Redesign the Source
  - Relocate the Source
- In the Path
  - Enclosure
  - Absorption
  - Barrier
- At the Receiver
  - Enclosure
  - Administrative Controls

Source Controls: Modification

Add products to the noise source or make changes so that it operates more quietly

- Handle fluid flow
  - Silencers and quiet nozzles
- Damp impacts
- Break vibration transmission paths
  - Flexible couplers
- Vibration isolation mounts

Source Modification

Curved fans are quieter and more efficient

Source Control: Redesign

Alter the design and operation of a source to something that produces less noise

- Better control of material flow
  - Reduce fall heights
  - Change impact materials
- Different energy sources
  - Electric vs pneumatic
- Eliminate vibration pathways
  - Inertia pads, isolators, flexible couplers
- Change process

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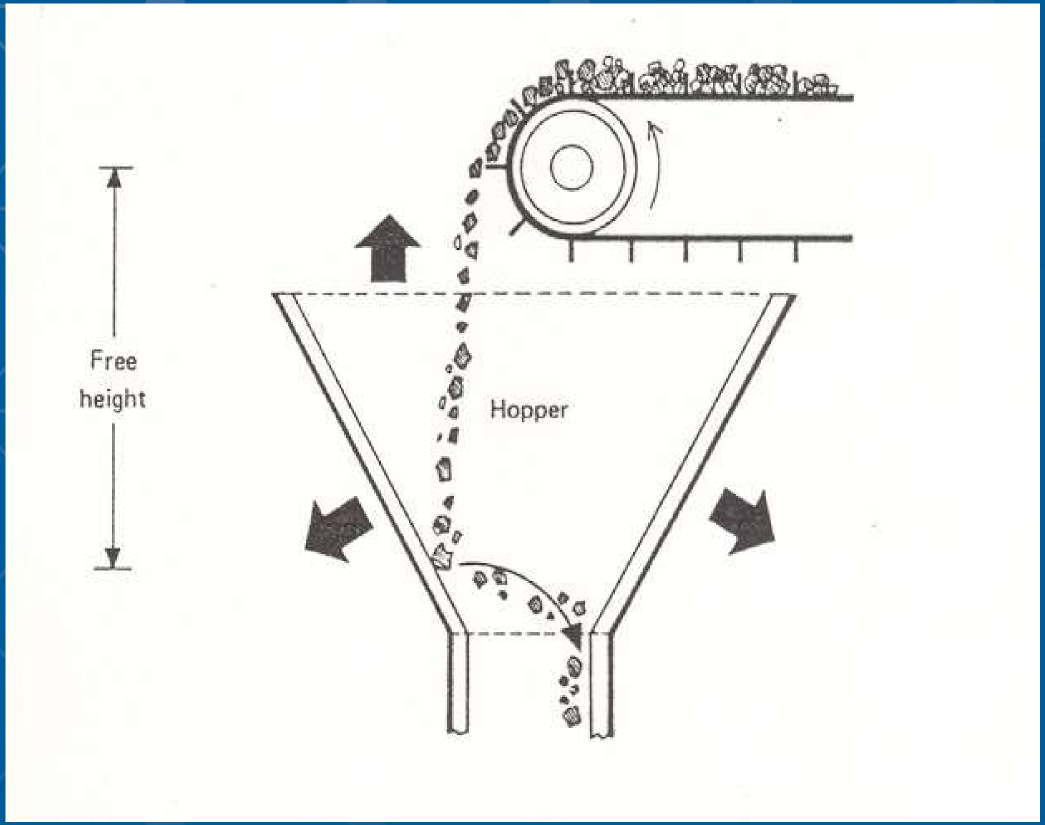
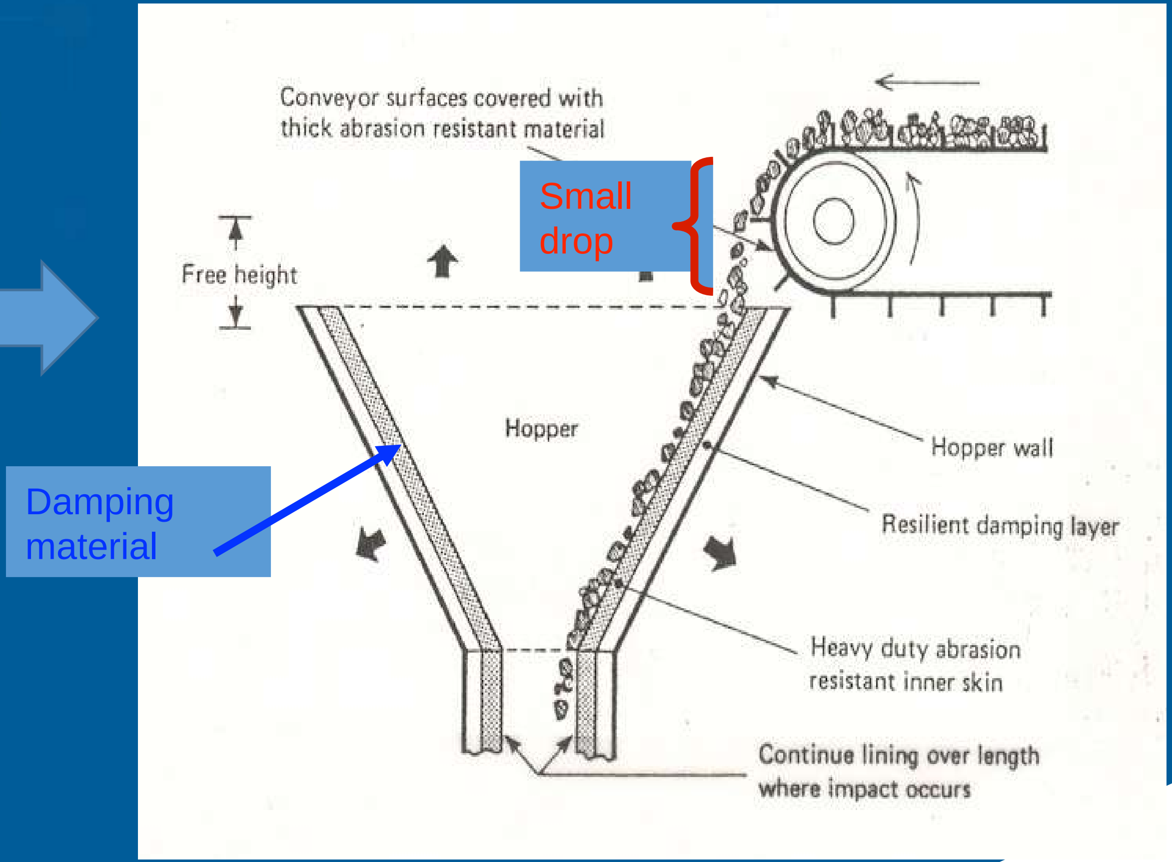
Source Redesign





Source Control: Relocation

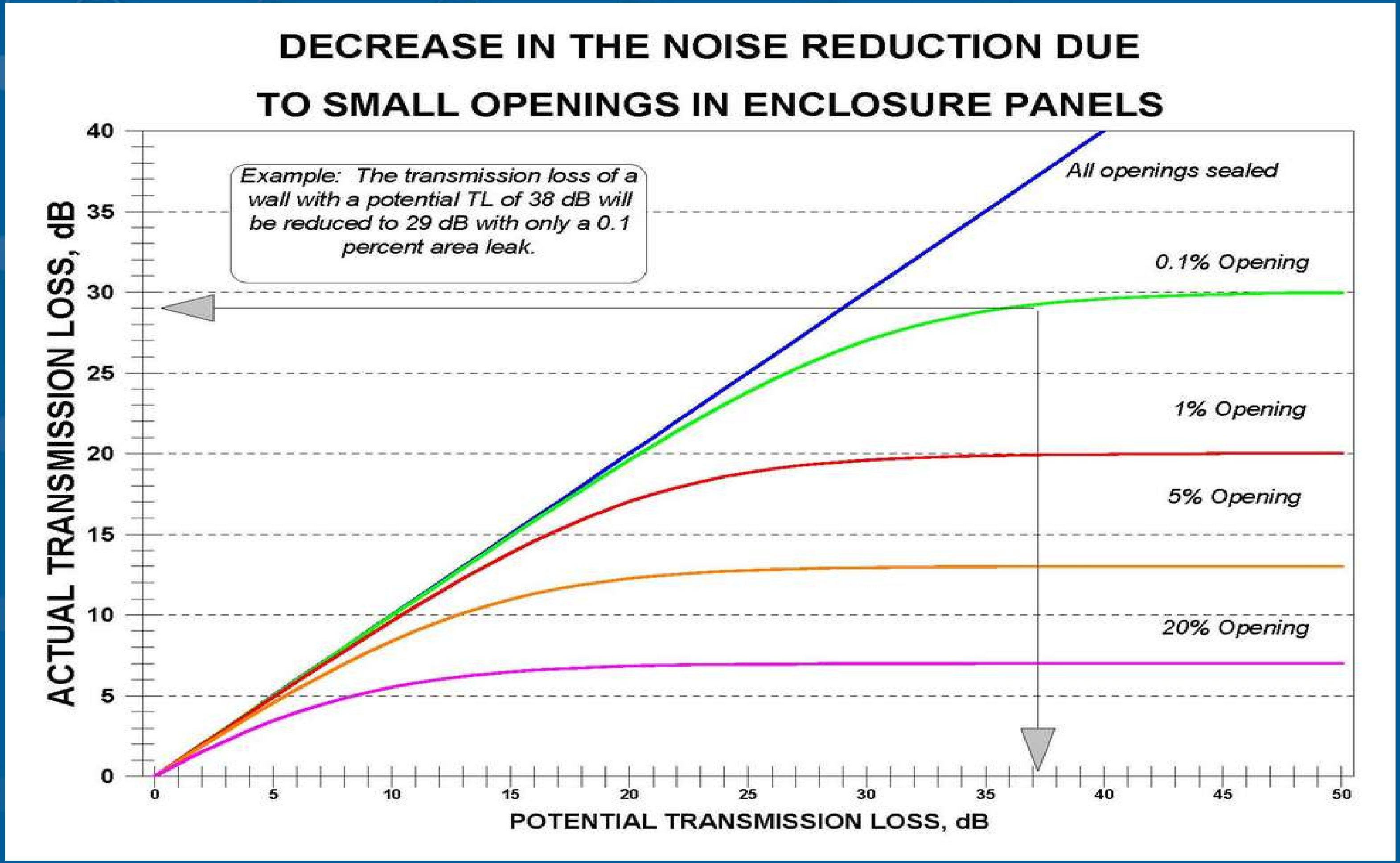
Simply move the noise source away from receivers

- To an unoccupied space
- To a greater distance from occupied areas

Path Control: Enclosure

- Sometimes these are the most effective noise controls, but they are not always preferred
- Expensive
- Often impractical
  - Access
  - Product flow
- Can be defeated by workers
  - Left open or off
- Degrade over time

Enclosures Vulnerable to Gaps



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Effect of Gap Example

Path Control: Barriers

Interrupt sound transmission by forcing diffraction over top or around edges.

Must be:

- Physically large compared to source
- Close to source or receiver
- Solid and with sufficient mass

More useful outdoors

Path Control: Absorption

- Reduces noise build-up in the room
- Effective if the reverberant field dominates
- Completely ineffective against direct sound

Receiver Controls

Sometimes the only option
Sometimes the most effective option

- Enclosure of receiver
  - Enclosed control rooms
  - Modular offices

- Administrative controls
  - Schedule adjustment
  - Job rotation

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Noise Control Applications

Using Sound Absorption

- Sound absorption can reduce reverberant sound build up inside a room
- Sound absorption materials may also be used to attenuate noise traveling through an enclosed pathway
- Effective at mid and high frequencies, but not low

Sound Absorption in Rooms

- Only useful when the reverberant field has more impact than the direct field
- Small rooms with reflective surfaces
- Rooms where workers aren’t typically close in to noise sources, instead spending time in reverberant field
- Absorption applied to walls and ceilings, coverage of 50% or more usually required to make a substantial difference

Sound Absorption in a Feed Chute

- The operator typically stands at the slot opening in the wall opposite the grinder and manually feeds in scrap material.
- 95 to 116 dBA measured at the opening, where the operator stands.
- Chute is constructed of stainless-steel panels

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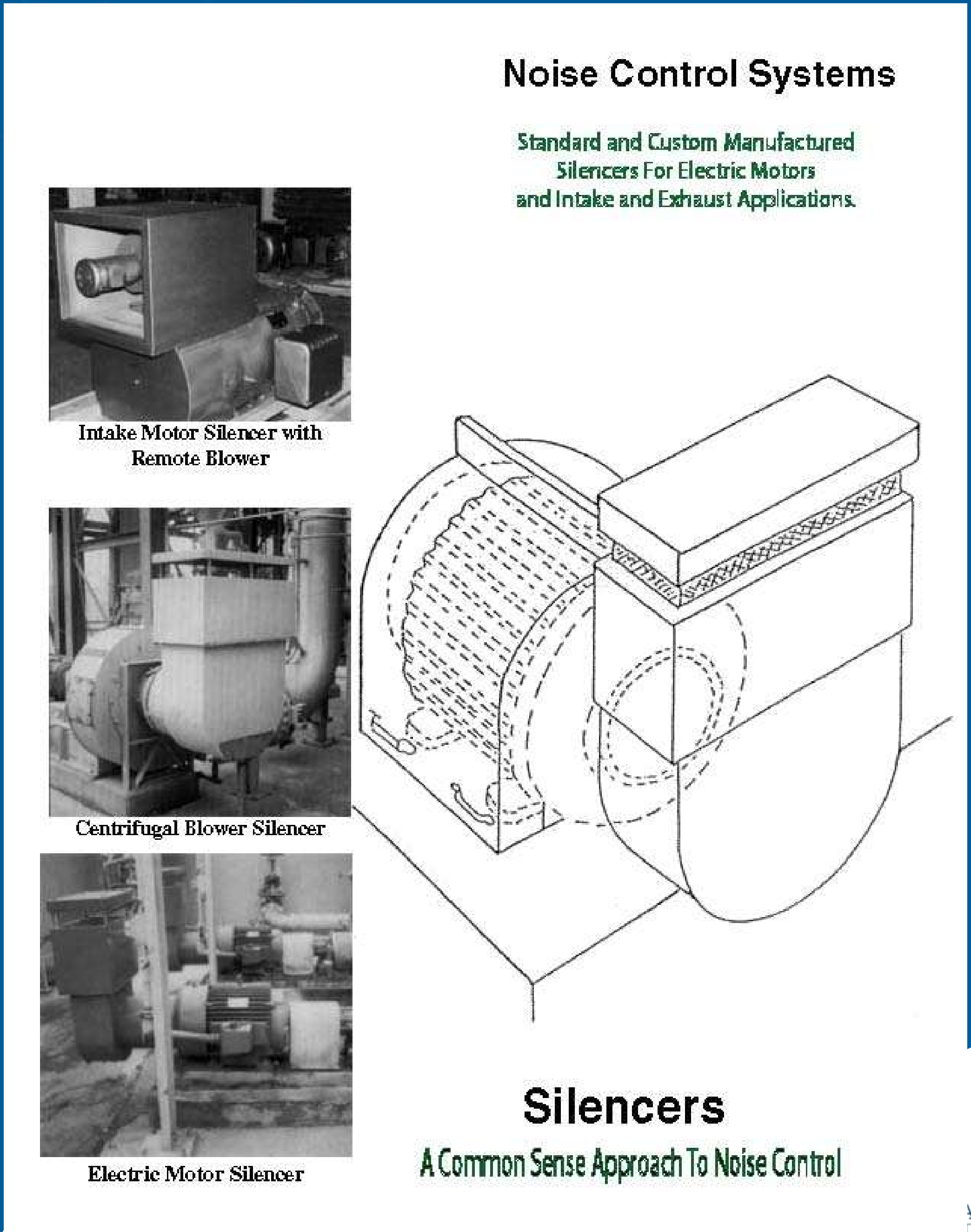
Sound Absorption in a Feed Chute

- Material was fed through an added lined chute
- Interior surfaces of chute lined with acoustical absorption to catch sound exiting the grinder
- The fiberglass was protected with perforated sheet metal
- For perforation to be acoustically transparent, it must have at least 25% open area
- TWA of operator reduced by 11 dBA

Electric Motors

- Primary noise source: Cooling fan (especially in TEFC motors)
- Control options:
  - Air intake silencer (10-15 dBA reduction)
  - Unidirectional fan replacement (5-6 dBA reduction)
  - Vibration isolation for structure-borne noise



Compressed Air

- Most common and most impactful noise source we see
- Operate or motivate equipment, using devices such as air cylinders
- Air jets and nozzles, including hand-held air guns, are used to move parts/product, blow-off debris, close flaps on corrugated containers (boxes/cases), or similar service-type actions.

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Compressed Air

- Often a plant-wide noise issue in manufacturing plants.
- Can easily be responsible for most or all of a plant's noise problems.
- Often the easiest noise source to control.
- Getting a handle on compressed air usage and noise can have significant financial and energy savings over time.

Controlling Compressed Air

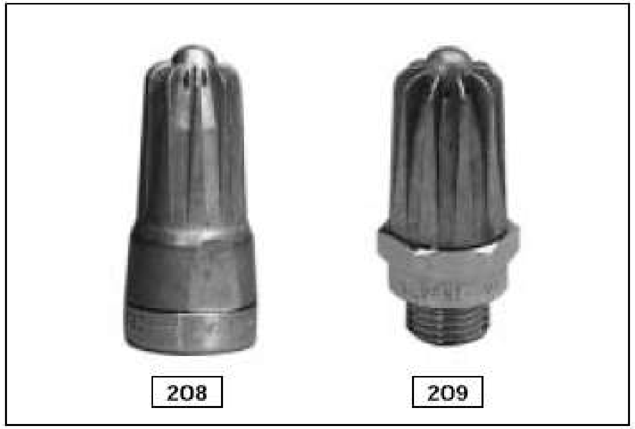
- **Step 1 is always to reduce pressure** as low as you can while maintaining reliable performance.
- The next step is to treat all open-ended discharge lines and exhaust ports, including standard air jets and nozzles with commercially-available quiet-design nozzles or pneumatic silencers.
- Compressed air should *never* be exhausted directly to atmosphere.
- Care must be exercised to ensure the type of device used meets the service needs of the plant.

Controlling Compressed Air Noise

- Reduce Noise From Exhausts

- Reduce Noise From Air Streams

Controlling Compressed Air Noise



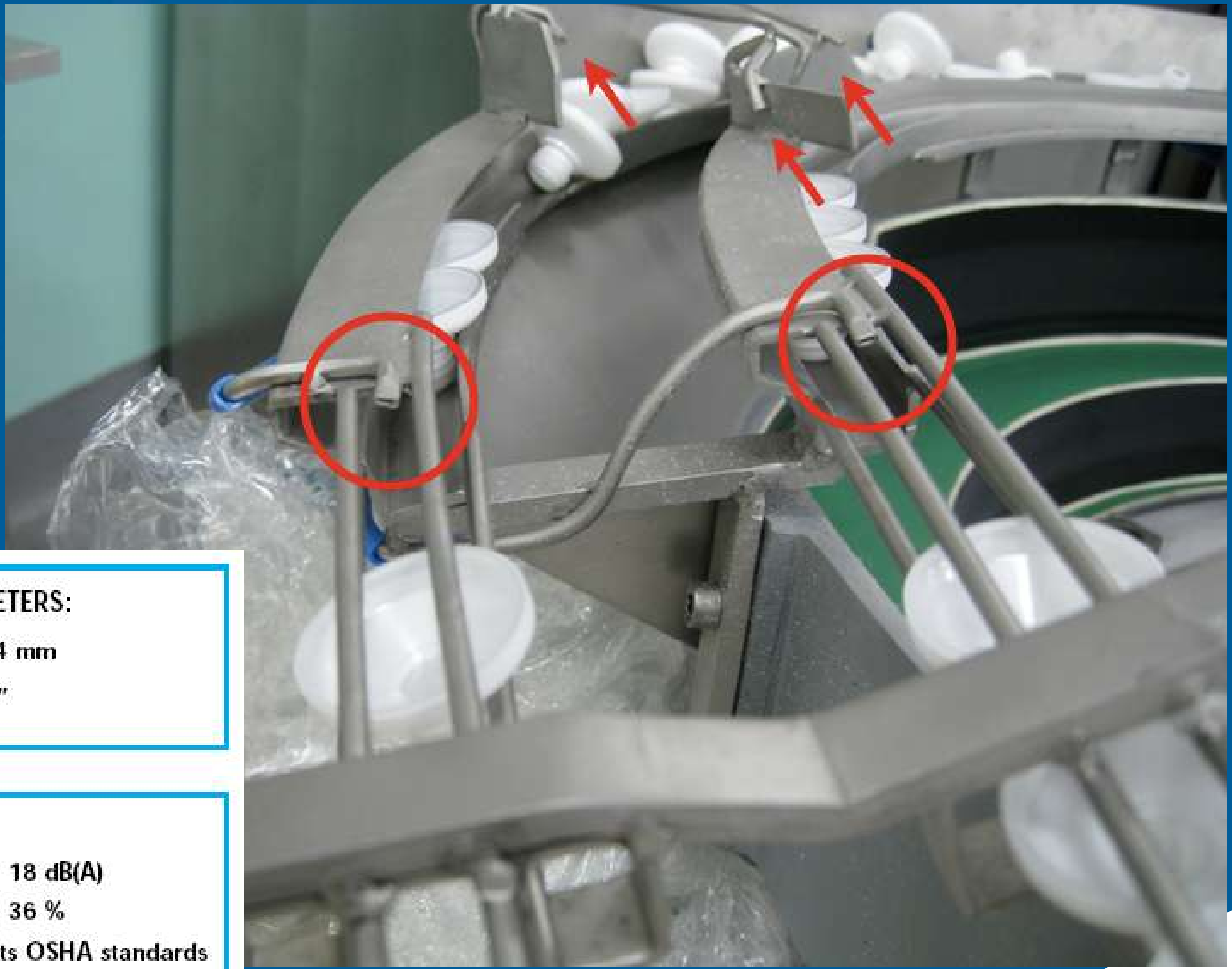
REPLACE OPEN PIPE OF DIAMETERS:

3 - 4 mm

1/8"

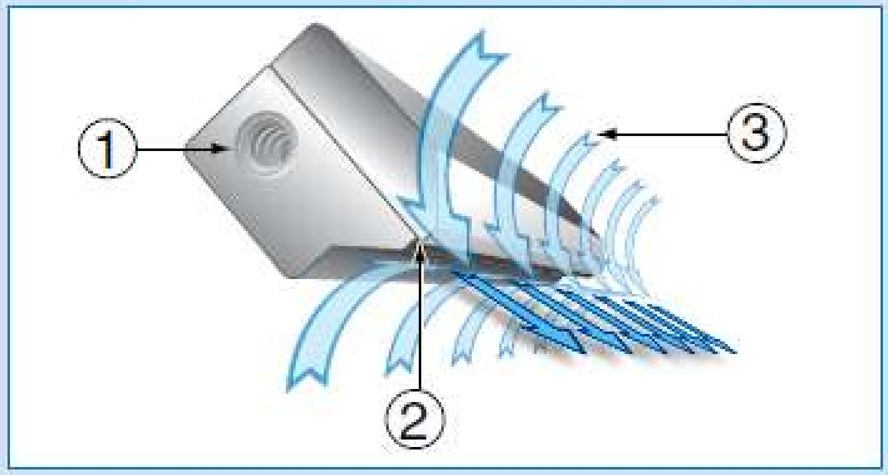
BENEFITS

Reduces the noise level	14 - 18 dB(A)
Decreases air consumption	23 - 36 %
Safety nozzle	Meets OSHA standards



Controlling Compressed Air Noise

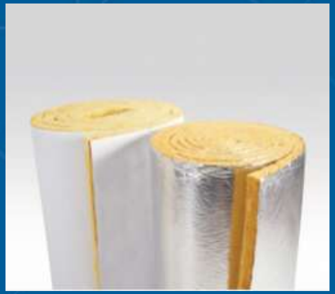
How The Super Air Knife Works



Compressed air flows through an inlet (1) into the plenum chamber of the Super Air Knife. The flow is directed to a precise, slotted orifice. As the primary airflow exits the thin slotted nozzle (2), it follows a flat surface that directs the airflow in a perfectly straight line. This creates a uniform sheet of air across the entire length of the Super Air Knife. Velocity loss is minimized and force is maximized as the room air (3) is entrained into the primary airstream at a ratio of 40:1. The result is a well defined sheet of laminar airflow with hard-hitting force and minimal wind shear.

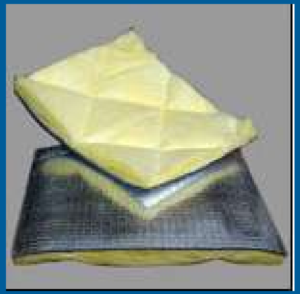
Acoustical Lagging

- Lagging consists of encapsulating or covering the source with a treatment that provides both *sound absorption* and *sound transmission loss* properties.
- Sold as individual materials or with both layers as a composite



Fiberglass Absorption

Metal Jacketing



Composite

Acoustical Lagging

Common sound absorption materials are typically:

- fiberglass
- mineral wool (Rockwool)
- calcium silicate, or
- any comparable acoustically-porous material.

Common transmission loss materials are typically:

- aluminum (greater than1.4 mm thick),
- steel (greater than 0.5 mm thick), or
- mass-loaded vinyl

Vibration Damping

- When excessive vibration is transferred to light, flat surfaces, primarily equipment with metal panels like bin or hopper chutes, airborne noise will often result.
- There will almost always be a resonant tone resulting from this form of vibration.

Vibration Damping

- Assuming the transmission of vibratory energy cannot be treated, then the most effective noise control option would be to treat the vibrating surface area.
- This treatment is called *Vibration Damping*

Constrained Layer Damping

- We can apply “composite” layers of material, which have significantly different properties.
- This technique is referred to as *Constrained-layer Damping* (CLD).

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Industrial Fans

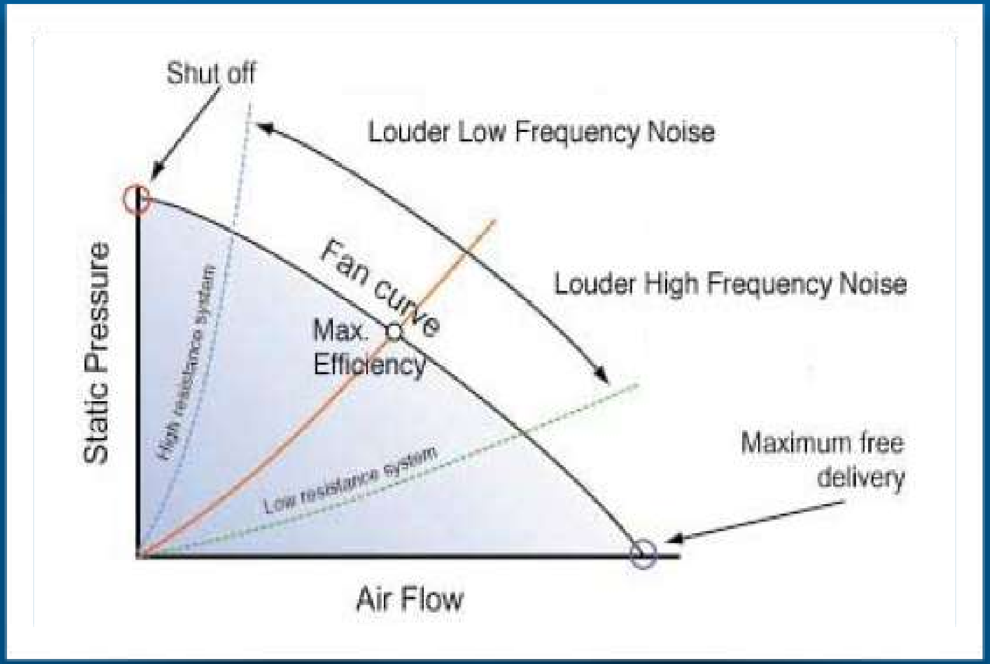
Fan noise usually results from:

- Improper selection or design
- Air turbulence around the blades
- Blade passage frequency
- Mechanical vibration of the fan housing, or the drive system
- Poor maintenance

Industrial Fans: Selection and Design

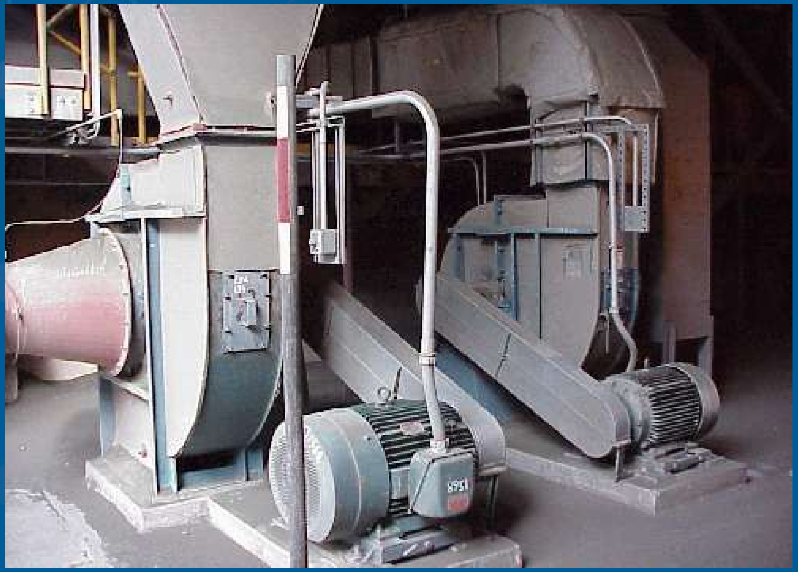
Fan Selection and Design Considerations:

- Controlling fan noise is best accomplished in the selection and design stage.
- Fan efficiency is critical. **Efficient fans are often quiet fans.**
- The lowest noise levels result when a fan operates at, or near, the optimum static efficiency.



Inertia Bases

- Fan and drive motors are typically mounted on a common base called an inertia base.
- Some very large fans with high-torque drive motors must be rigidly mounted to maintain their position.



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Fan Silencers

- Fan silencers are effective in reducing noise at open inlets and discharge points.
- Silencers introduce restrictions to the system and reduce efficiency.
- Review all aspects of fan and duct design before simply adding a silencer to reduce noise.

Noise Barriers

The performance of a barrier is a function of:

- Distance between the source and barrier
- Distance between the barrier and the receiver
- Effective height and width of the barrier

To be effective:

- The receiver is not in the reverberant sound field
- The barrier is a solid partition with high sound transmission loss properties
- Locate the barrier as close as to the source or to the receiver as possible

Enclosures

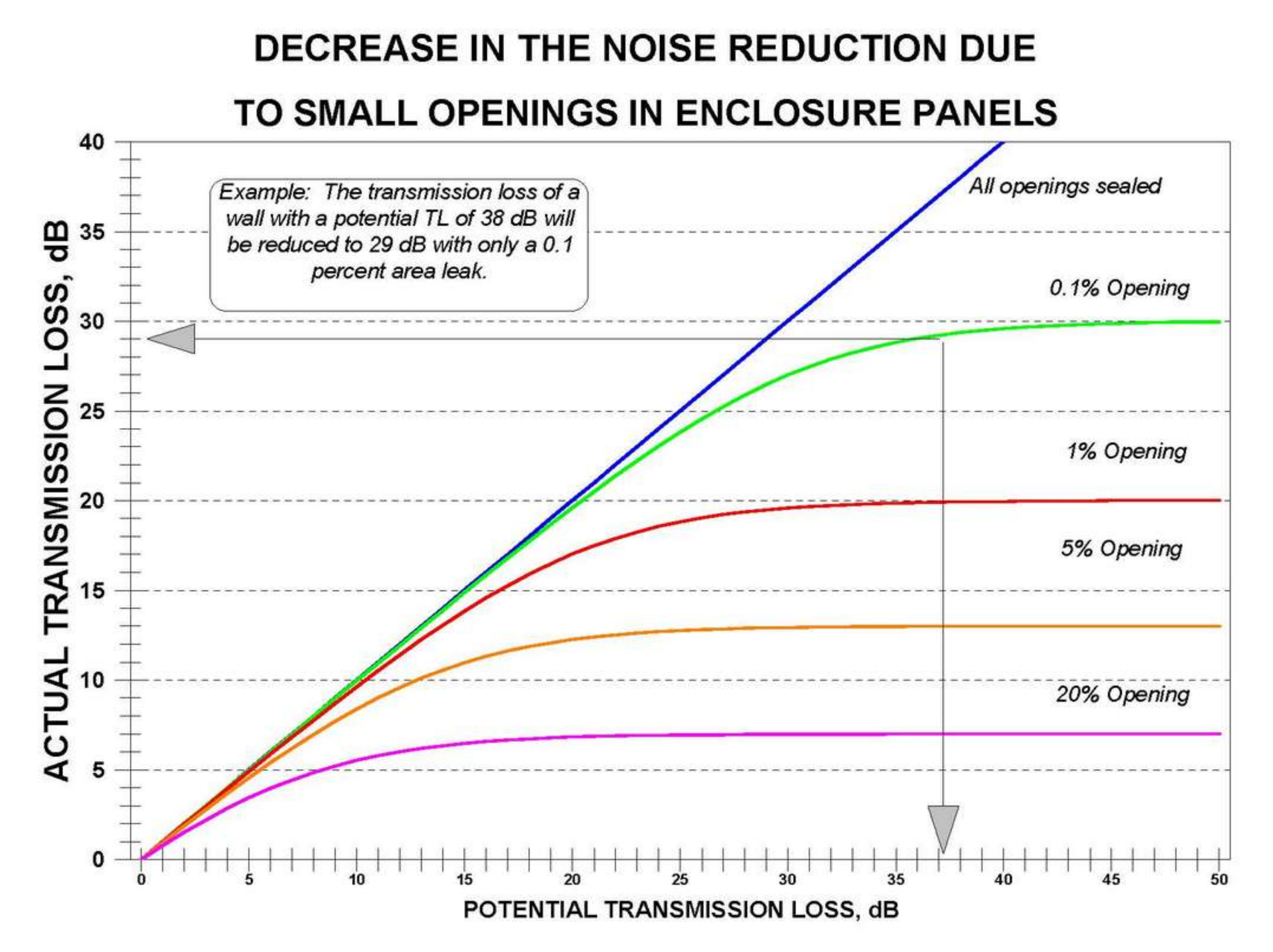
- The most common path treatments
- Does not require identification of the source(s)
- Octave-band data is all you need
- A tightly sealed enclosure can provide 20-40 dBA of noise reduction

Enclosures

Downside to enclosures:

- Restrict visual and physical access to equipment
- Potential for internal heat build-up
- Potential surface and/or product contamination
- Will lose effectiveness over time due to wear and tear
- Employee acceptance can be difficult.

Enclosures Are Sensitive to Gaps

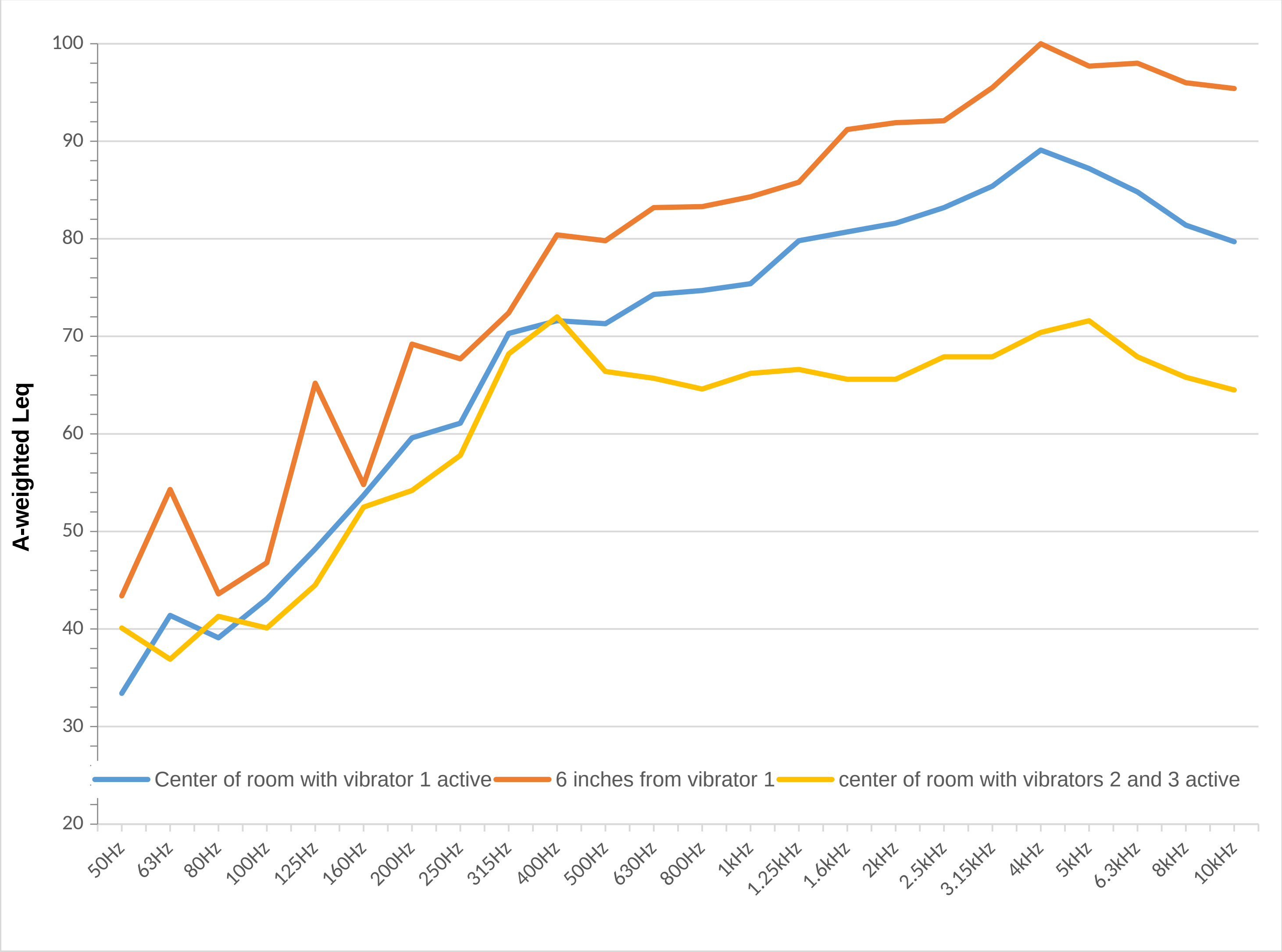


Machine Guarding Can Be An Acoustical Enclosure

- For all existing polycarbonate guards, tightly seal, or at least minimize, all gaps or openings between the panel edges and their frame, and between all adjacent metal frame sections.
- For sealing polycarbonate enclosures with large openings, such as gaps between the floor and bottom edge of the machine cabinet, use a dense but flexible barrier material.

Discussion 1

Dicussion 2



COLORADO ANALYTICS

Discussion 3

Installing tall noise walls did not reduce noise at neighboring houses a meaningful amount. The site has 2 compressors (red circles) and their associated pipes and nothing else. What is the next step?