Environmental Noise Due to Fans and Equipment

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- Actively involved in several AMCA committees including: Acoustic Attenuation Engineering, Louver Engineering and North American Region Marketing.

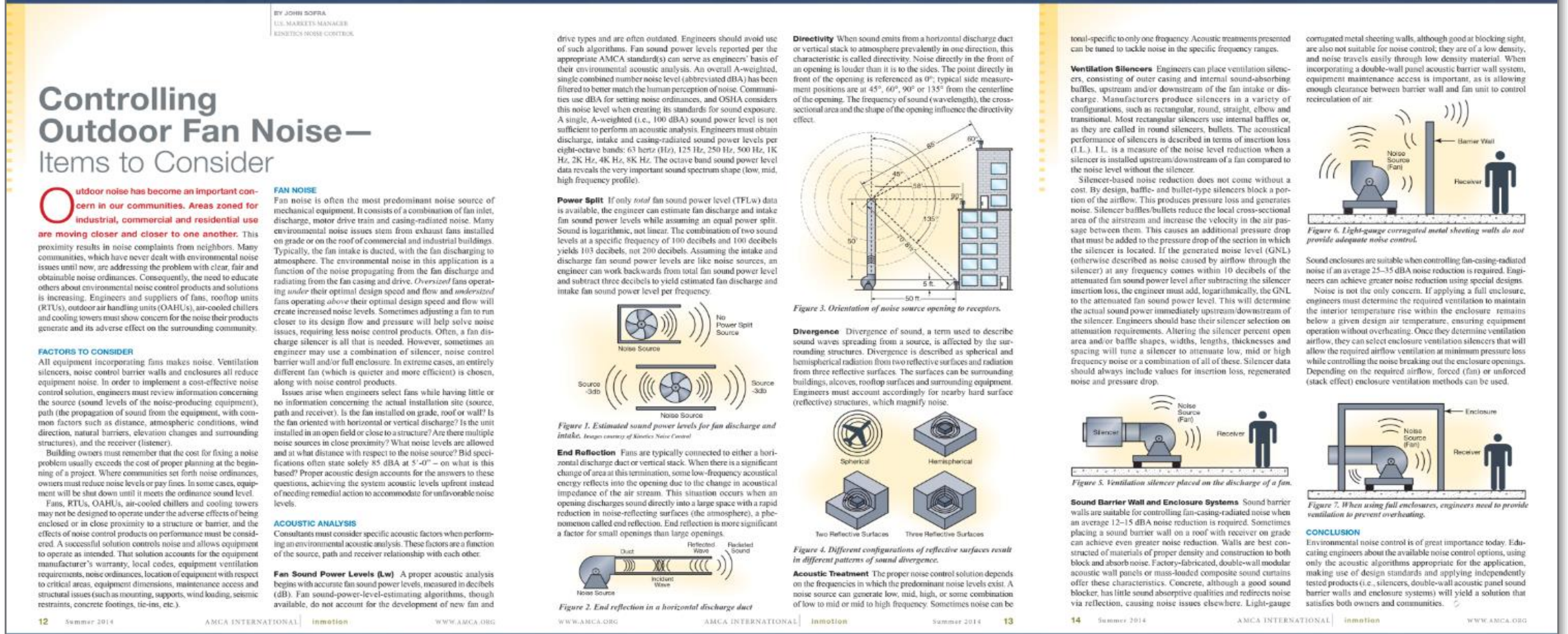
Environmental Noise Due to Fans and Equipment

Purpose and Learning Objectives

The purpose of this presentation is to review the need for engineered controls to address environmental, “outdoor” sound propagation as it affects neighboring communities.

At the end of this presentation you will be able to:

1. Identify the characteristics of, and need for, a well written noise ordinance.
2. Explain why the sound spectrum and spectrum shape of a noise source is important, not all noise is the same.
3. Describe the factors affecting an outdoor sound propagation path.
4. Compare the different products used for controlling noise in an outdoor setting.


BY JOHN SOFRA
U.S. MARKETS MANAGER
KINETICS NOISE CONTROL

Controlling Outdoor Fan Noise— Items to Consider

Outdoor noise has become an important concern in our communities. Areas zoned for industrial, commercial and residential use are moving closer and closer to one another. This proximity results in noise complaints from neighbors. Many communities, which have never dealt with environmental noise issues until now, are addressing the problem with clear, fair and obtainable noise ordinances. Consequently, the need to educate others about environmental noise control products and solutions is increasing. Engineers and suppliers of fans, rooftop units (RTUs), outdoor air handling units (OAHUs), air-cooled chillers and cooling towers must show concern for the noise their products generate and its adverse effect on the surrounding community.

FACTORS TO CONSIDER

All equipment incorporating fans makes noise. Ventilation silencers, noise control barrier walls and enclosures all reduce equipment noise. In order to implement a cost-effective noise control solution, engineers must review information concerning …

FAN NOISE

Fan noise is often the most predominant noise source of mechanical equipment. It consists of a combination of fan inlet, discharge, motor drive train and casing-radiated noise. Many environmental noise issues stem from exhaust fans installed on grade or on the roof of commercial and industrial buildings. Typically, the fan intake is ducted, with the fan discharging to atmosphere. The environmental noise in this application is a function of the noise propagating from the fan discharge and radiating from the fan casing and drive. *Oversized* fans operating *under* their optimal design speed and flow and *undersized* fans operating *above* their optimal design speed and flow will create increased noise levels. Sometimes adjusting a fan to run closer to its design flow and pressure will help solve noise issues, requiring less noise control products. Often, a fan discharge silencer is all that is needed. However, sometimes an engineer may use a combination of silencer, noise control barrier wall and/or full enclosure. In extreme cases, an entirely different fan (which is quieter and more efficient) is chosen, along with noise control products.

ACOUSTIC ANALYSIS

Fan Sound Power Levels (Lw)

Power Split

Figure 1. Estimated sound power levels for fan discharge and intake.

End Reflection

Figure 2. End reflection in a horizontal discharge duct

Directivity

Figure 3. Orientation of noise source opening to receptors.

Divergence

Figure 4. Different configurations of reflective surfaces result in different patterns of sound divergence.

Acoustic Treatment

Ventilation Silencers

Figure 5. Ventilation silencer placed on the discharge of a fan.

Sound Barrier Wall and Enclosure Systems

Figure 6. Light-gauge corrugated metal sheeting walls do not provide adequate noise control.

Figure 7. When using full enclosures, engineers need to provide ventilation to prevent overheating.

CONCLUSION

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Overview

- Introduction
- Sample outdoor noise ordinance
- Fan noise generating components
- Components of acoustical modeling of fan noise and environmental surroundings. Determining if a noise problem exists.
- Noise control products and solutions – fan silencers, acoustic barrier wall systems, acoustic enclosures

Outdoor Noise Ordinance

- Outdoor noise = community noise
- Areas zoned industrial, commercial & residential moving closer together.
- Need to educate the community, city officials, building owners; many have never had to deal with environmental noise issues.
- Develop a fair and obtainable noise ordinance.

Outdoor Noise Ordinance

“Too Subjective” of Noise Ordinance

“Noise levels in the city limits shall not exceed those that bother surrounding neighbors.”

“Too Stringent” of Noise Ordinance

“Any noise level that exceeds ambient noise by three (3) decibels or more in any octave band is declared excessive or unreasonable.”

------- (3) dB increase is barely discernable

Outdoor Noise Ordinance

Sample – Well Written Noise Ordinance

At Property Line:

Ambient noise quality zone	Day-time standards (7am - 10pm)	Night-time standards (10pm - 7am)
Noise quality zone N-1 (Low density residential RL; land-use zones R-1 to R-3	Leq=60 dB(A) measured for any one hour	Leq=50 dB(A) measured for any one hour
Noise quality zone N-2 (High density residential RH; land-use zones R-4 to R-10)	Leq=65 dB(A) measured for any one hour	Leq=55 dB(A) measured for any one hour
Noise quality zone N-3 (All Commercial and manufacturing land-use zones)	Leq=70 dB(A) measured for any one hour	Leq=70 dB(A) measured for any one hour

Outdoor Noise Ordinance

Common Sound	Noise / Sound Level
Rocket Launch Pad	180 dBA
Pile Driver	110 dBA
Garbage Truck	100 dBA
City Traffic	90 dBA
OSHA Permissible 8 hrs. Exposure	**85 dBA**
Noisy Restaurant	70 dBA
Conversational Speech	60 dBA
Light Auto Traffic at 100 ft.	55 dBA
Rural Ambient Noise Level	**45 dBA**
Library	30 dBA

Outdoor Noise Ordinance

- Where clear noise ordinances are set forth in a community, the owner may be forced to reduce noise levels or be fined.
- Citations can consist of monetary fines or the shutting down a business until the sound level dictated by the noise ordinance is met.
- Where clear noise ordinances are not set forth in a community, the owner may elect to take it upon themselves to reduce the noise levels.
- Good Neighbor" in the eyes of the community.

Factors to Consider

Implementing a cost-effective noise control solution:

- Obtain as much technical data on the mechanical equipment (source) as possible
- Analyze all sound propagation (paths)
- Clearly define the location of neighbor (receiver)

Factors to Consider - Source

- Pertinent Technical Data of (source):
  - Airflow (cfm)
  - Operating Temperature of Airstream
  - Allowable External Static Pressure
  - Horsepower (HP)
  - Heat Generation (BTU/hr.)
  - Equipment Configuration & Installation Guidelines

Factors to Consider - Path

- Items affecting sound propagation (path)
  - Distance (source – receiver)
  - Atmospheric conditions
  - Downwind/upwind directions
  - Terrain (natural barriers)
  - Wooded areas
  - Surrounding buildings
  - Other noise sources

Factors to Consider - Receiver

- Location of Community / Noise Sensitive Area (receiver)
  - Is there a published noise ordinance?
  - Requirements of the noise source
  - Who was there first, the “noise maker” or the neighbor?
  - Topography of the source, neighbor and property line

Factors to Consider

- Cost for remedial work usually exceeds that which is properly planned and anticipated from the beginning of the project.

Factors to Consider

- Most important factor is to know how the noise source works.
- It is not good enough to only know and address acoustics.
- Most mechanical equipment is not designed to operate under the adverse effects of being enclosed or in close proximity to a structure or barrier.

Factors to Consider

- Maintenance access must be designed into any noise control solution.
- Access must be designed to be “easy”.
- Doors and hatches left open will short circuit any noise control solution.
- Allowance for removal of portions or entire equipment system in case of catastrophic failure.

Factors to Consider

- A Successful Noise Control Solution factors in:
  - Equipment Manufacture's Warranty & Installation Guidelines
  - Local Codes (i.e., electric, etc.)
  - Proper Equipment Ventilation
  - Local Noise Ordinance
  - Location of Equipment
  - Equipment Dimensions
  - Maintenance Access
  - Structural Supports (i.e., snow, wind and seismic loads, etc.)

Acoustic Terminology

- **Sound Power Level** - the total acoustic energy output of a noise source independent of the environment.

- **Sound Pressure Level** - dependent on environmental factors such as distance from the source, reflective surfaces, and other conditions of the room/building/ area hosting the source.

Acoustic Terminology

Logarithmic Addition

Difference between levels to be combined, dB	0 to 1	2 to 4	5 to 9	10 & more
Number of dB to add to highest level	3	2	1	0

86 dB + 86 dB = **89** dB	86 dB + 80 dB = **87** dB
86 dB + 85 dB = **89** dB	86dB + 79 dB = **87** dB
86 dB + 84 dB = **88** dB	86 dB + 78 dB = **87** dB
86 dB + 83 dB = **88** dB	86 dB + 77 dB = **87** dB
86 dB + 82 dB = **88** dB	86 dB + 76 dB = **86** dB
86 dB + 81 dB = **87** dB	86 dB + 75 dB = **86** dB

$$10\log(10^{\frac{100}{10}} + 10^{\frac{100}{10}}) = 103dB$$

Acoustic Terminology

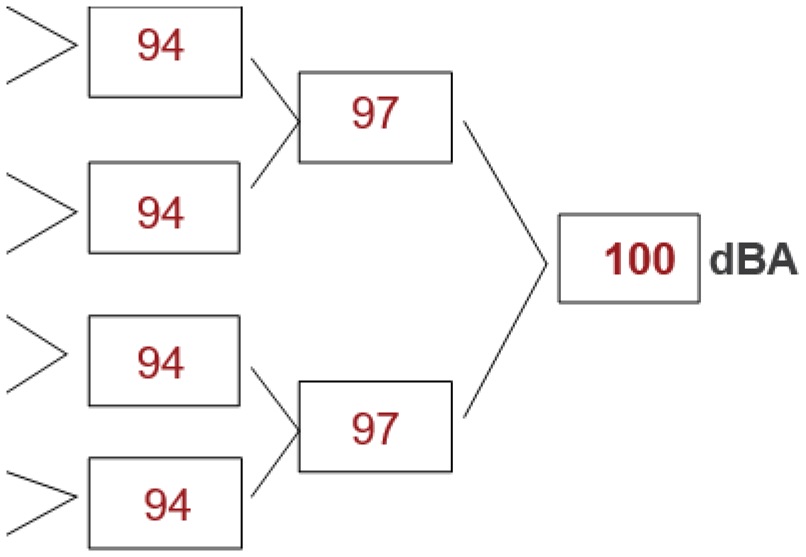
"A-Weighting" (dBA):

- Filters the spectrum to simulate the frequency response to sound by the human ear.
- Deemphasizes the low frequencies, compensating for the lower sensitivity of the human ear to low frequency.
- Add the 8 filtered bands to arrive at a single dBA level.
- Typically used for environmental / outdoor noise design criteria. But also in an "in-plant", factory setting.

Mid-band Frequency (Hz)	A-weighted Correction (dB)
63	-26.2
125	-16.1
250	-8.6
500	-3.2
1000	0
2000	+1.2
4000	+1.0
8000	-1.1

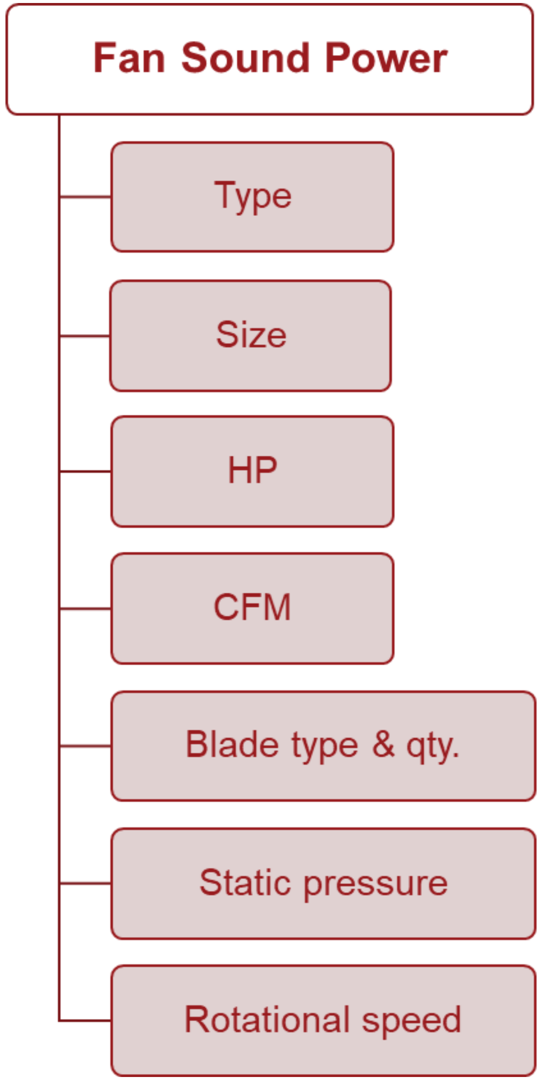
Acoustic Terminology

Center Frequency (Hz)	Sound Pressure Level (dB)	"A" Filter	Resultant
63	117	-26	91
125	107	-16	91
250	100	-9	91
500	94	-3	91
1k	91	0	91
2k	90	(+1)	91
4k	90	(+1)	91
8k	92	-1	91



Fan Noise

- Most predominant noise source of any industrial or commercial air system.
- Function of fan inlet, discharge, motor drive train and casing radiated noise.
- Magnitude and intensity of noise will vary per …………..
- The rotating action of vanes produce a broad band sound spectrum consisting of low, mid to high frequencies.



Common Mechanical Equipment

- **Process/Vent Fans**
  - Inlet, discharge, motor drive train & casing radiated noise
- **Air-Cooled Chillers**
  - Screw Compressors & up-blast fans
- **Induced/Forced Draft Cooling Towers**
  - Intake and up-blast fans

Common Mechanical Equipment

FANS

Common Mechanical Equipment

AIR-COOLED CHILLERS

Common Mechanical Equipment

INDUCED DRAFT COOLING TOWERS

Fan Noise

- A proper acoustic analysis begins with accurate FAN SOUND POWER LEVELS (dB), Lw, PWL

- It is important to obtain **discharge, intake** and **casing radiated** sound power levels per 8-octave bands: 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1K Hz, 2K Hz, 4K Hz, 8K Hz.

- Field sound level measurements via a hand-held sound level meter may be required for **retrofit applications**.

Fan Noise

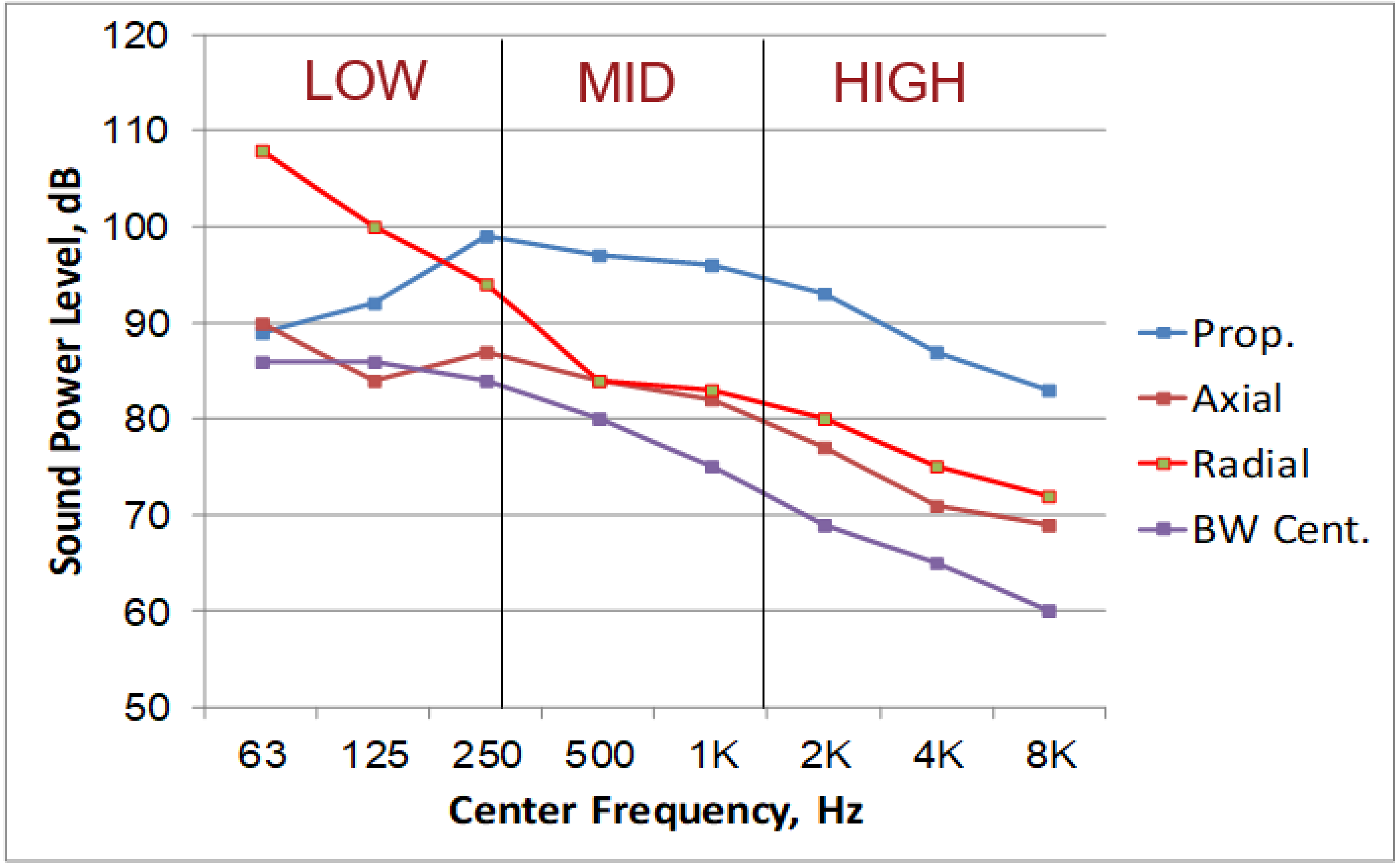
- Some fan data is presented only as **inlet** and **outlet** FAN SOUND POWER LEVELS (dB)

RPM	SP	Condition	SOUND POWER re 10^{-12} WATTS OCTAVE BANDS 1	2	3	4	5	6	7	8	Lw_iA
1000	1	Inlet	72	77	76	71	70	66	59	52	75
		Outlet	80	89	79	74	74	69	59	51	79
1240	1	Inlet	78	81	82	77	75	73	67	60	81
		Outlet	85	88	87	80	78	75	68	59	84
	2	Inlet	74	76	77	71	71	69	63	58	76
		Outlet	81	84	82	75	73	70	63	56	79
1360	1	Inlet	82	83	87	80	79	78	74	66	85
		Outlet	90	87	91	84	82	80	75	65	88
	2	Inlet	80	80	84	78	76	74	68	61	82
		Outlet	87	86	91	83	80	77	70	60	86
1540	1	Inlet	86	84	90	83	82	82	79	72	88
		Outlet	94	88	93	88	86	83	81	71	91
	2	Inlet	85	82	88	81	80	79	74	67	86
		Outlet	92	87	93	87	84	81	76	67	90
	3	Inlet	84	80	86	78	77	77	70	65	83
		Outlet	90	85	91	84	82	79	72	64	88
	1	Inlet	88	88	92	87	85	84	82	76	92
		Outlet	96	92	95	91	89	86	84	76	94

1540	2	Inlet	85	82	88	81	80	79	74	67
		Outlet	92	87	93	87	84	81	76	67

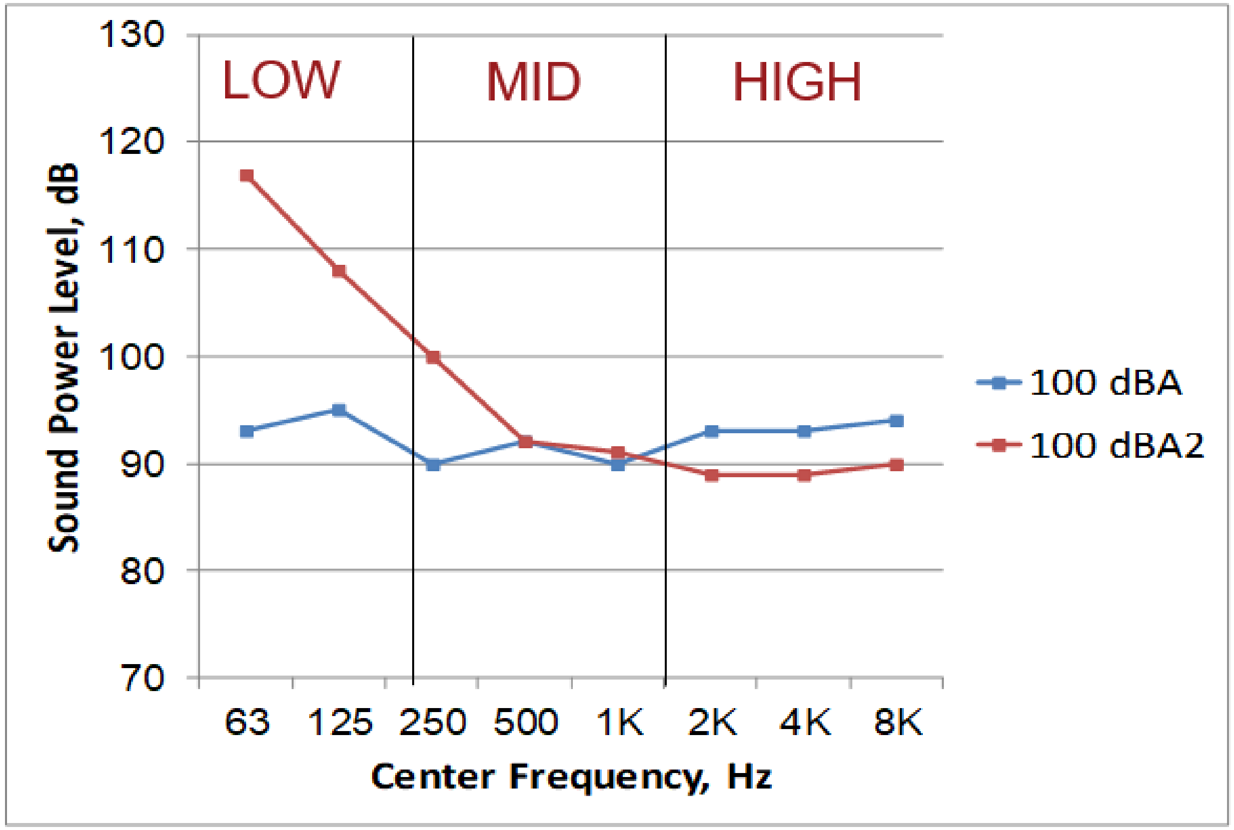
Fan Noise

- The sound spectrum shape (low, mid, high frequency) is very important and is revealed by the octave band sound power level data.



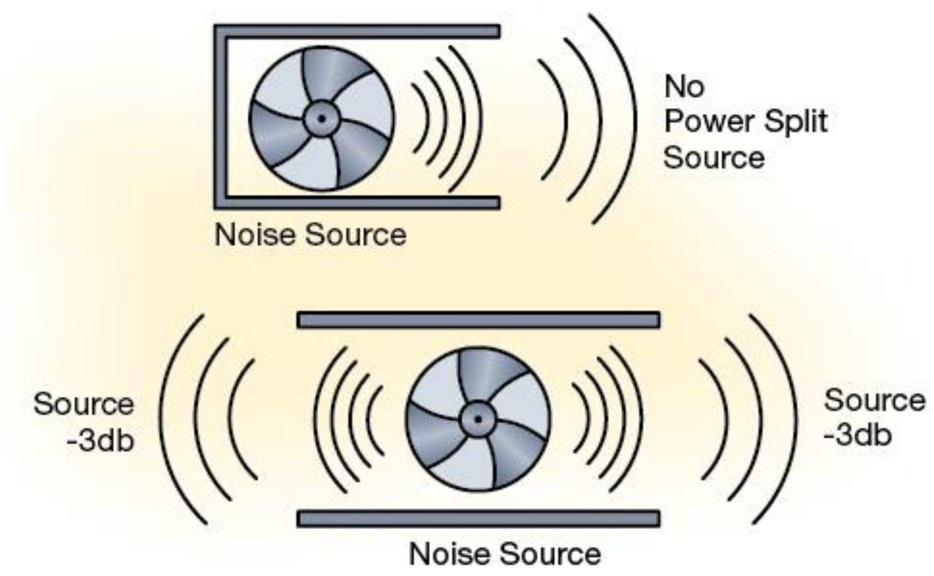
Fan Noise

- The following **two sound spectrums** are **both 100 dBA**. But one has predominantly low frequency noise requiring an entirely different noise control solution than the other. (Target 85 dBA @ 3 ft.)



Acoustic Analysis – Power Split

If only **TOTAL Fan Sound Power Levels (TFLw)** are **available,** the **INTAKE** and **DISCHARGE Sound Power Levels (Lw)** can be calculated assuming an equal power split.



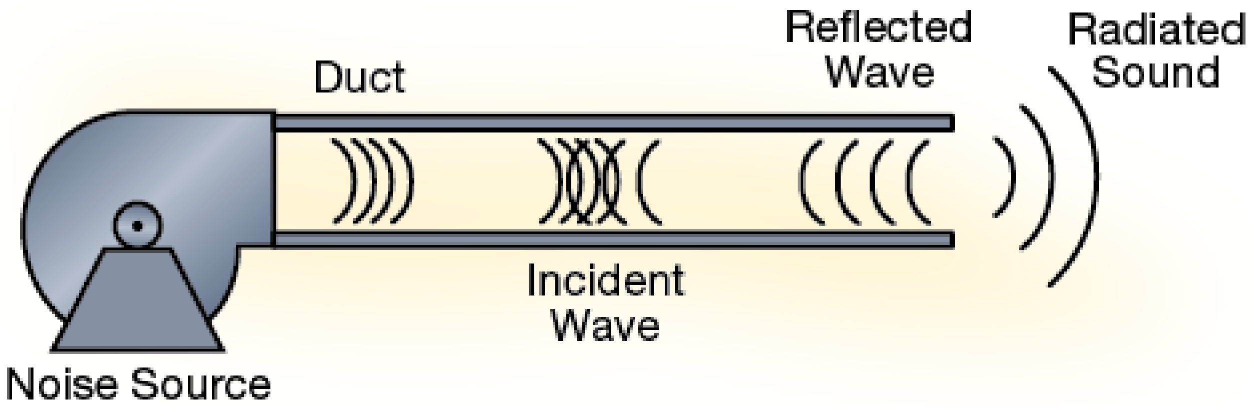
$$10\log(10^{\frac{100}{10}} + 10^{\frac{100}{10}}) = 103dB$$

Acoustic Analysis – Power Split

	Octave Band / Center Frequency, Hz								
	1	2	3	4	5	6	7	8	dBA
	63	125	250	500	1K	2K	4K	8K	
TFLw, dB	108	105	100	95	86	81	78	73	96
Adj., dB	-3	-3	-3	-3	-3	-3	-3	-3	
Inlet Lw, dB	105	102	97	92	83	78	75	70	93
outlet Lw, dB	105	102	97	92	83	78	75	70	93

Acoustic Analysis – End Reflection

- **Exhaust Fans** are typically **connected to** either a **horizontal** discharge duct or **vertical** discharge stack.
- **Low frequency (most predominant)** acoustic energy reflects back into the duct or discharge stack offering low frequency acoustic attenuation.



Acoustic Analysis – End Reflection

More significant a factor for small **non-flanged openings** than large openings.
Value to be subtracted from fan sound power level.

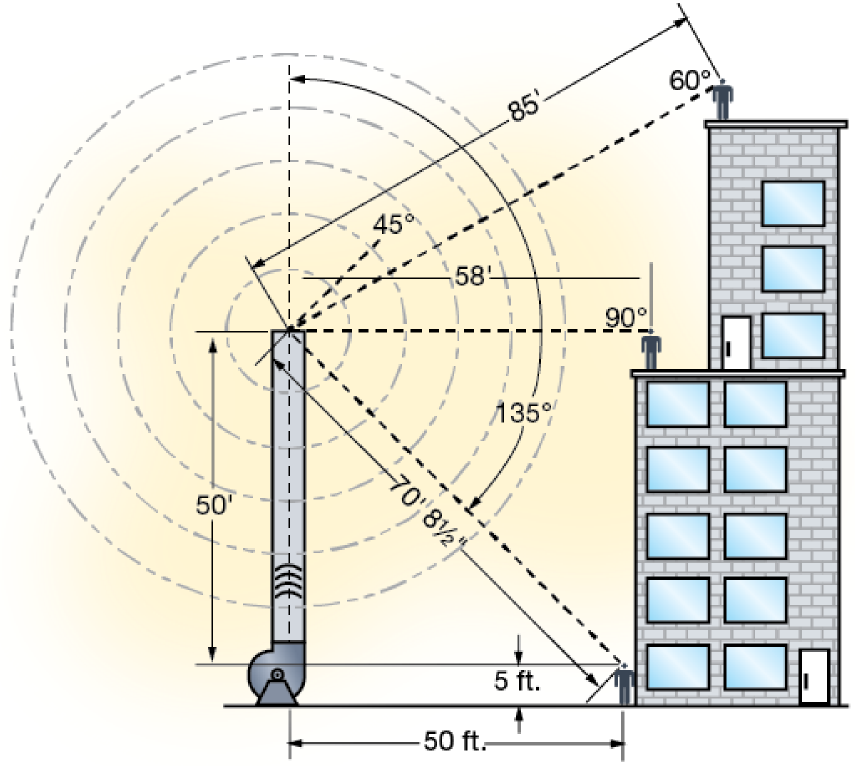
Equivalent Diameter, inches	Octave Band / Center Frequency, Hz							
	1	2	3	4	5	6	7	8
	63	125	250	500	1K	2K	4K	8K
4	25	19	13	8	3	1	0	0
12	15	10	5	2	0	0	0	0
18	12	7	3	1	0	0	0	0
36	7	3	1	0	0	0	0	0
48	5	2	0	0	0	0	0	0

Acoustic Analysis – Directivity

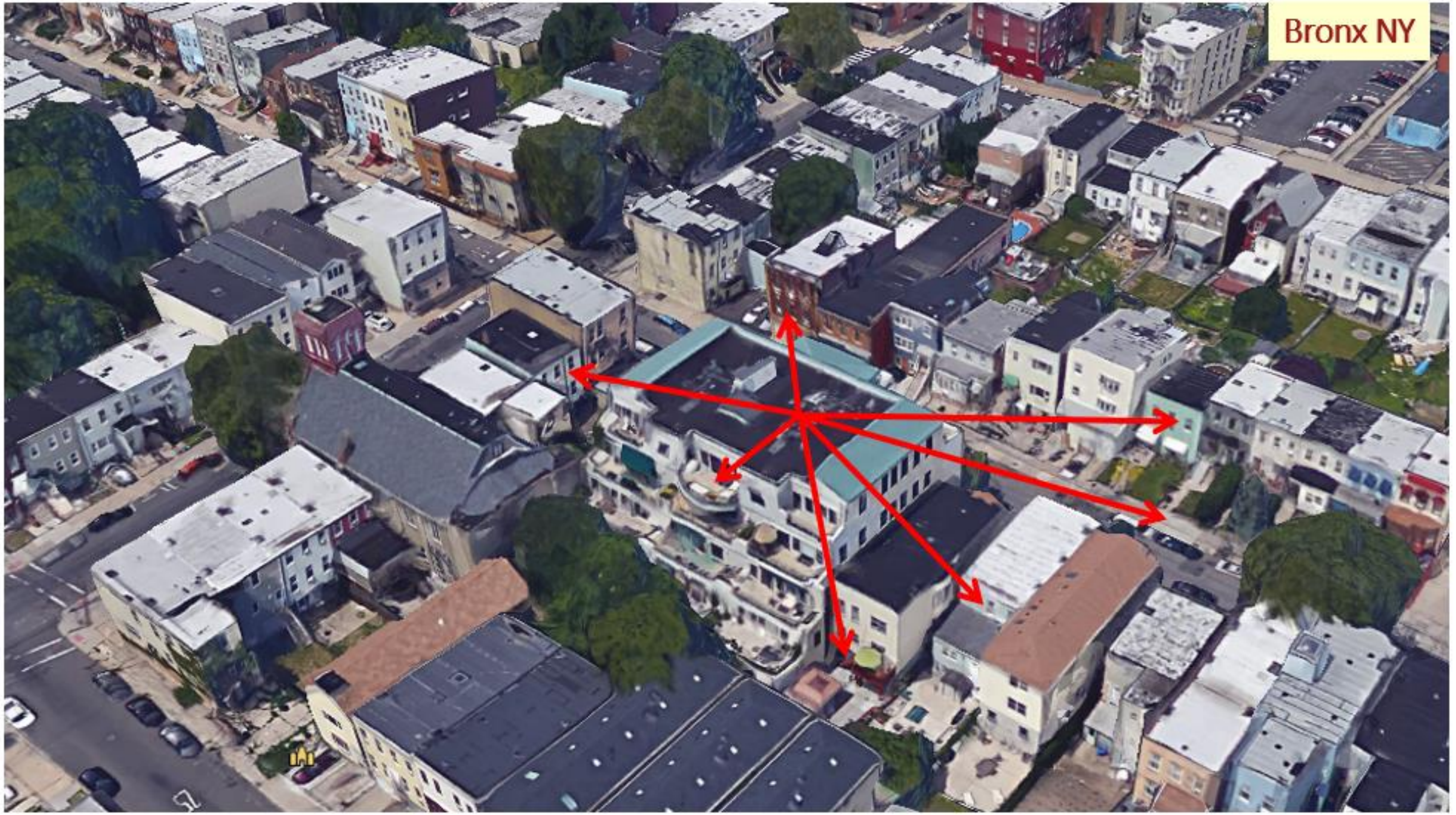
Sound from a horizontal discharge duct or vertical discharge stack is more prominent in one direction. Sound directly in front of an opening is louder than to the sides.

Elevation between sound source and receiver is important.

>> Prize question…. What does "SOHCAHTOA" refer to?



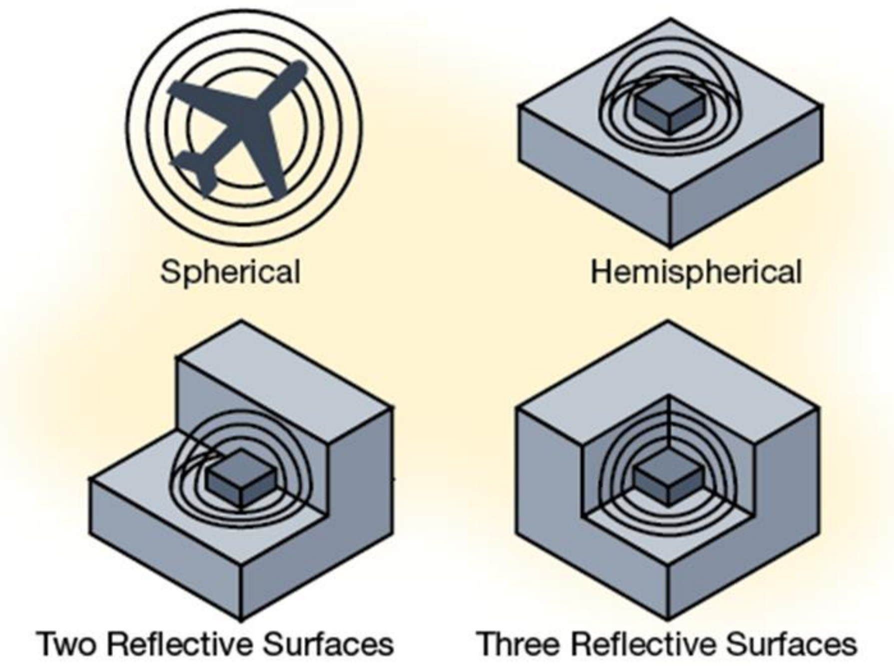
Acoustic Analysis – Directivity



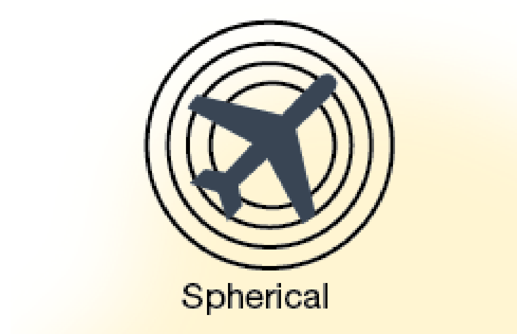
Acoustic Analysis – Directivity

Acoustic Analysis – Divergence

- Sound propagation is affected by surrounding structures (i.e., buildings, alcoves, roof top surfaces, surrounding equipment).
- Nearby hard surfaces magnify noise.
- Function of type and distance



Acoustic Analysis – Divergence



Acoustics Analysis – Sample – Fan Discharge

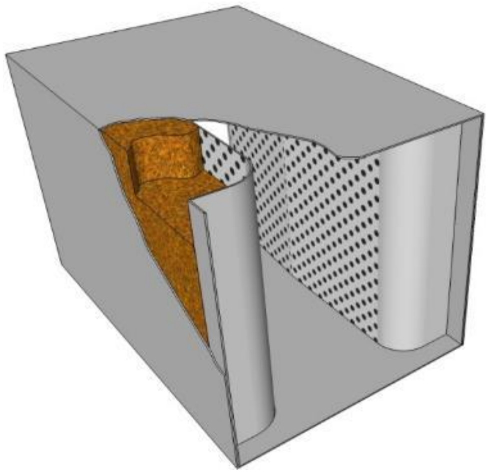
Factor	Octave Band / Center Frequency, Hz								dBA
	1	2	3	4	5	6	7	8	
	63	125	250	500	1K	2K	4K	8K	
TFLw, dB	108	105	100	95	86	81	78	73	**96**
Power Split, dB	-3	-3	-3	-3	-3	-3	-3	-3	
End Reflection, dB	-8	-4	-1	0	0	0	0	0	
Directivity, dB	+1	0	0	-1	-1	-1	-2	-2	
Divergence, dB	-7	-7	-7	-7	-7	-7	-7	-7	
Resultant, dB	91	91	89	84	75	70	66	61	**85**

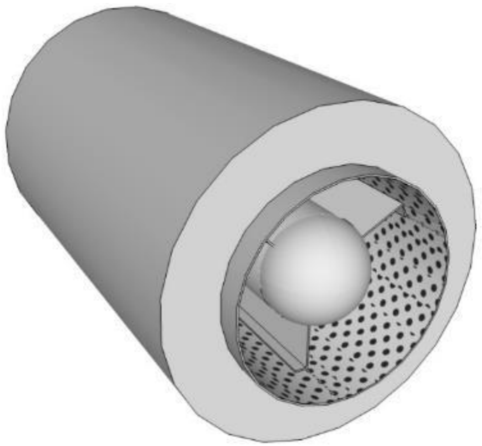
Acoustic Treatment - Products

- Ventilation silencers
- Fixed-blade acoustic louvers
- Sound Barrier Walls
- Sound Enclosures

Noise Control Products

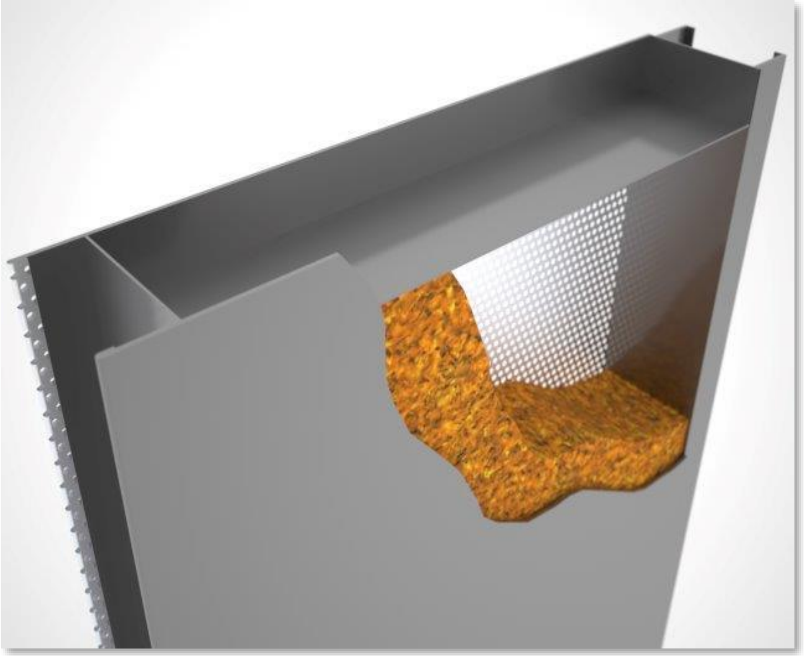
- Ventilation silencers
  - Industrial Grade
  - Commercial Grade
- Fixed-blade acoustic louvers





Noise Control Products

- Double-walled, acoustic barrier & enclosure panels



Noise Control Products

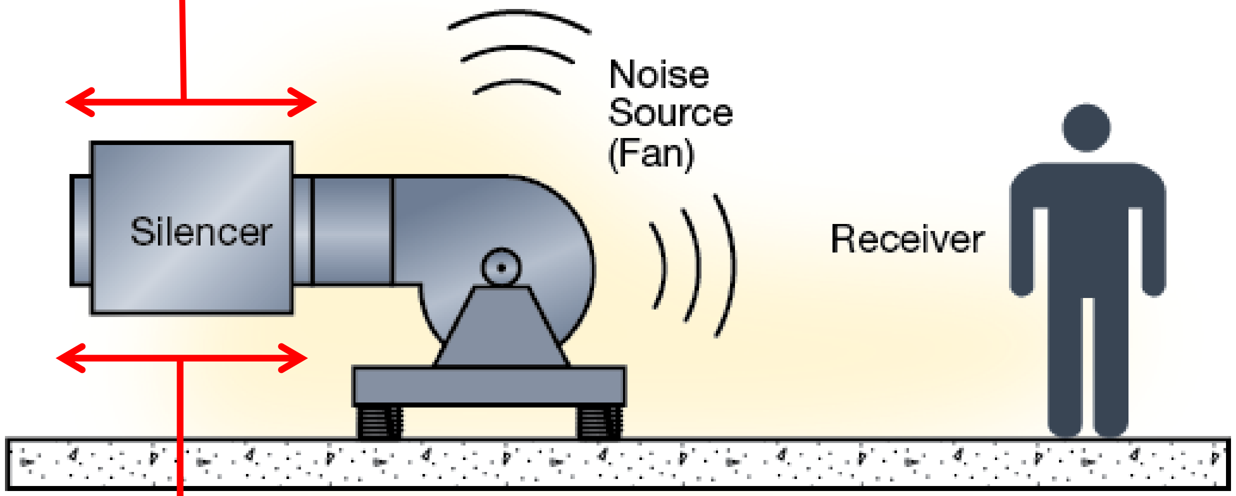
- Independently Tested Products:
  - **ASTM E477**, Standard test method for measuring **acoustical and airflow performance** of duct liner materials and prefabricated silencers.
  - **AMCA 1011-03 (R2010)**, Certified Ratings Program- Product rating manual for acoustical duct silencers.
  - **ASTM 423**, Standard test method for sound absorption and sound **absorption coefficients** by the reverberation room method.
  - **ASTM E90**, Standard test method for laboratory measurement of airborne sound **transmission loss** of building partitions and elements.

Expected Performance - Realistic

Mechanical Equipment	Applied Products	Noise Reduction & Pressure Loss
Fan	Silencers	25 dBA 85 Pa (0.35 inches of water)
Air-cooled chiller	Acoustical Louvers, Acoustic Barrier Walls, Silencers	Walls: 18-23 dBA @ 10’-0” Top: 8-10 dBA @ 10’-0” 25 Pa (0.10 inches of water)
Induced-draft cooling tower	Silencers – Intake & Discharge	10-20 dBA @10’-0” 25 Pa (0.10 inches of water)

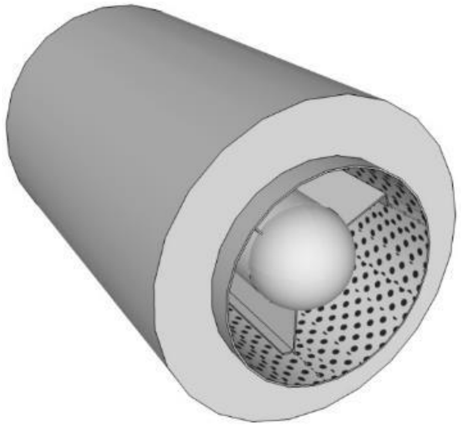
Acoustic Treatment – Ventilation Silencers

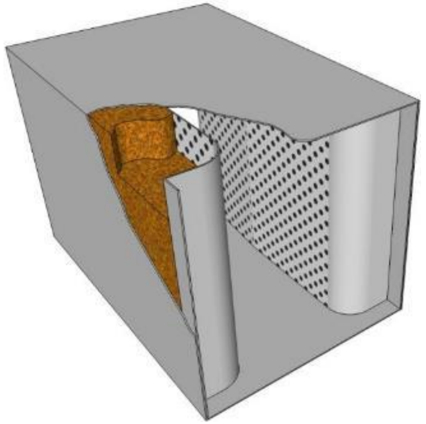
Allowable Pressure Loss + Required Attenuation

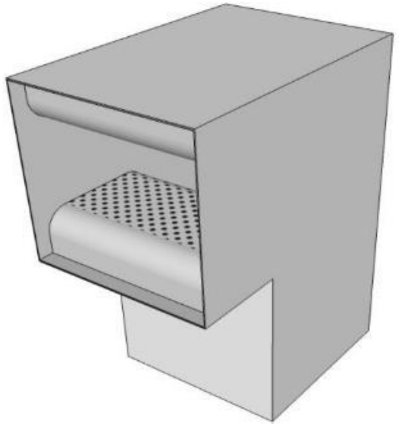


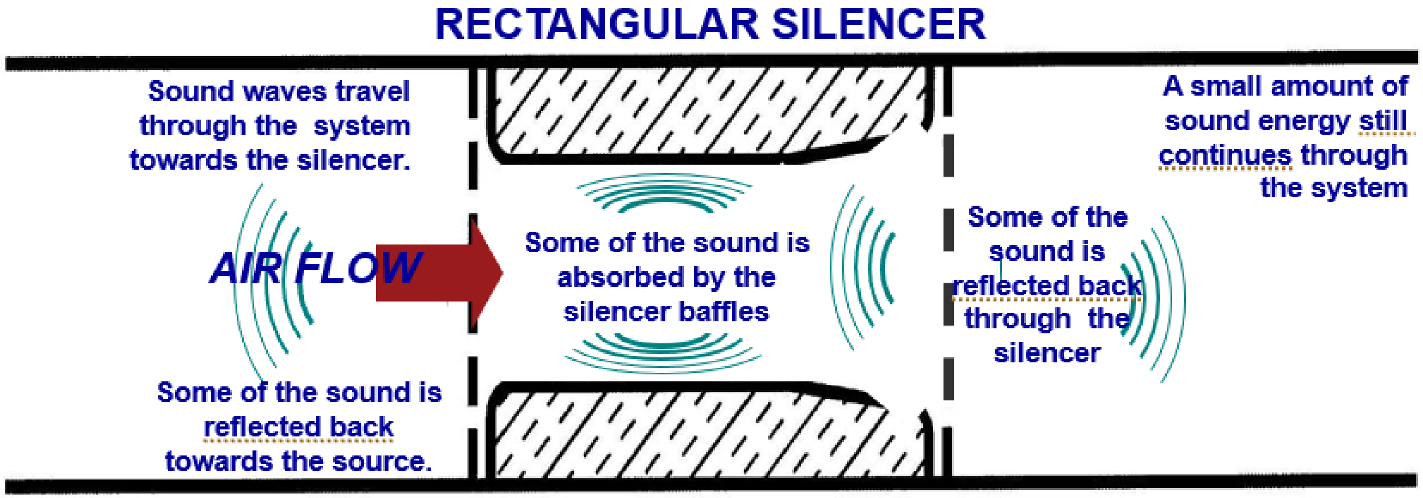
Silencer Length

Acoustic Treatment – Ventilation Silencers









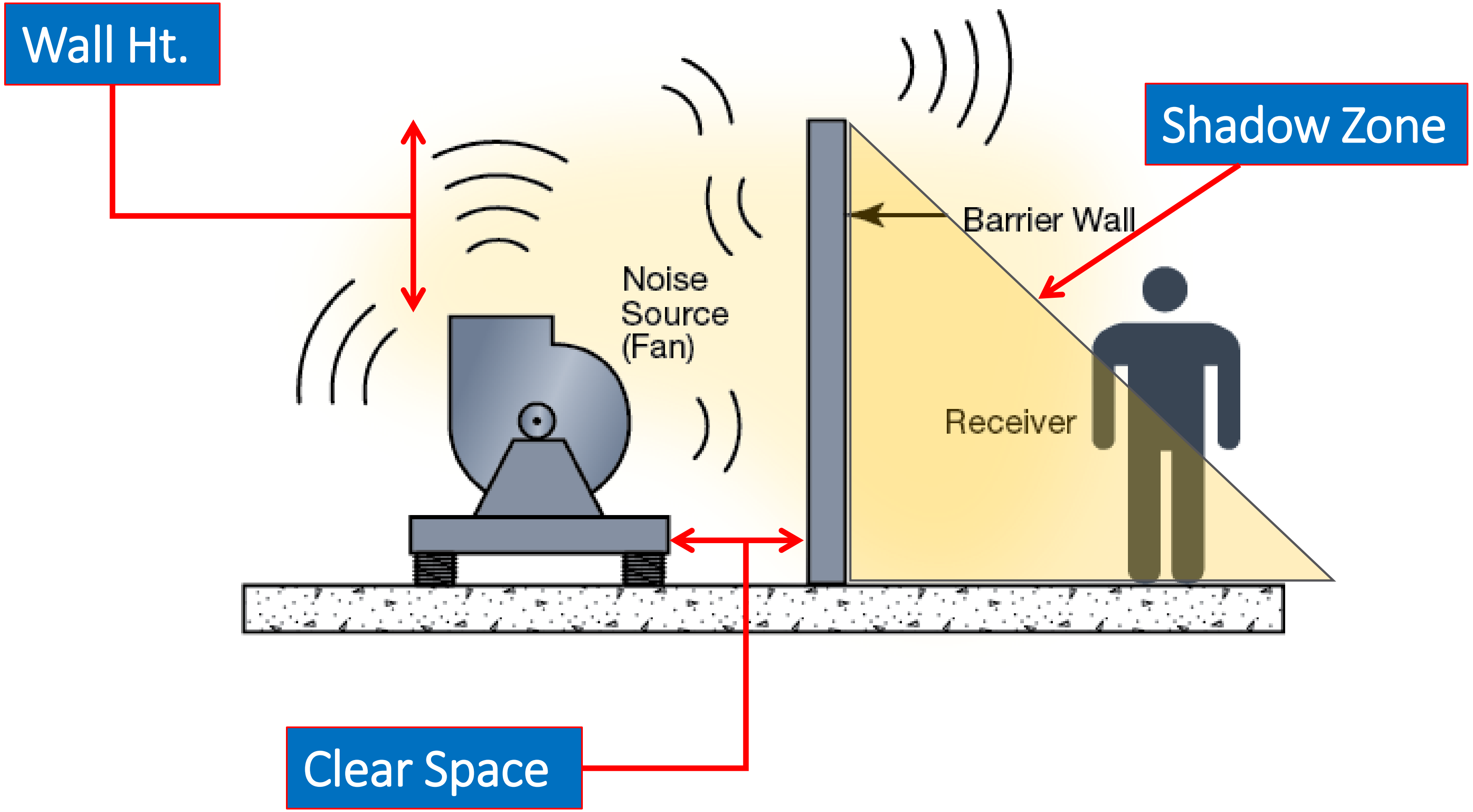
Acoustic Treatment – Ventilation Silencers

Dynamic Insertion Loss: The attenuation or reduction of sound power after the silencer is inserted. IL is stated in dB in octave bands from (63 Hz - 8000 Hz).

Pressure Loss (drop, PD): The differential pressure across the silencer at a given flow velocity. PD is stated in inches WG or Pa.

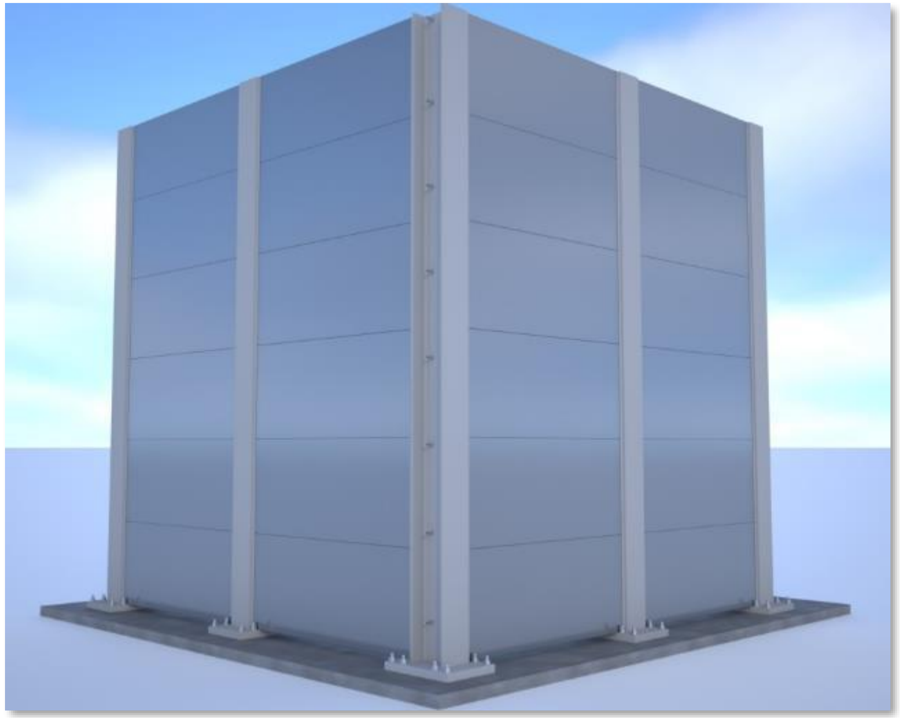
Flow-Generated Noise: Also called regenerated noise. The sound power generated by air flow through the silencer. GN is also stated in dB in octave bands from (63 Hz - 8000 Hz). (CFM) or liters per second (L/s)

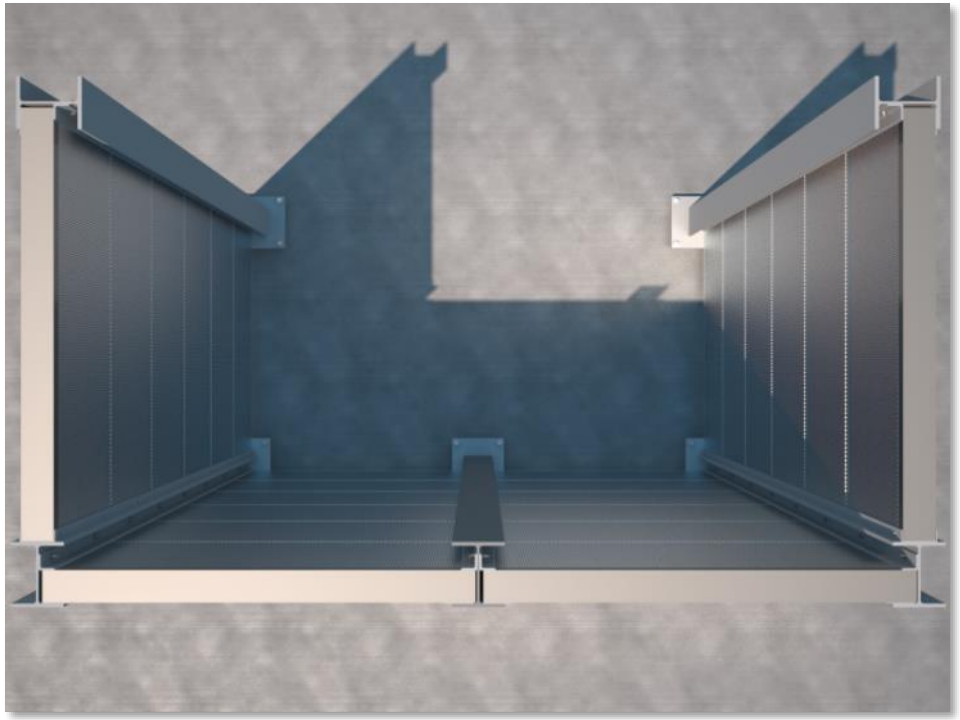
Acoustic Treatment – Sound Barrier Wall



Acoustic Treatment – Sound Barrier Wall

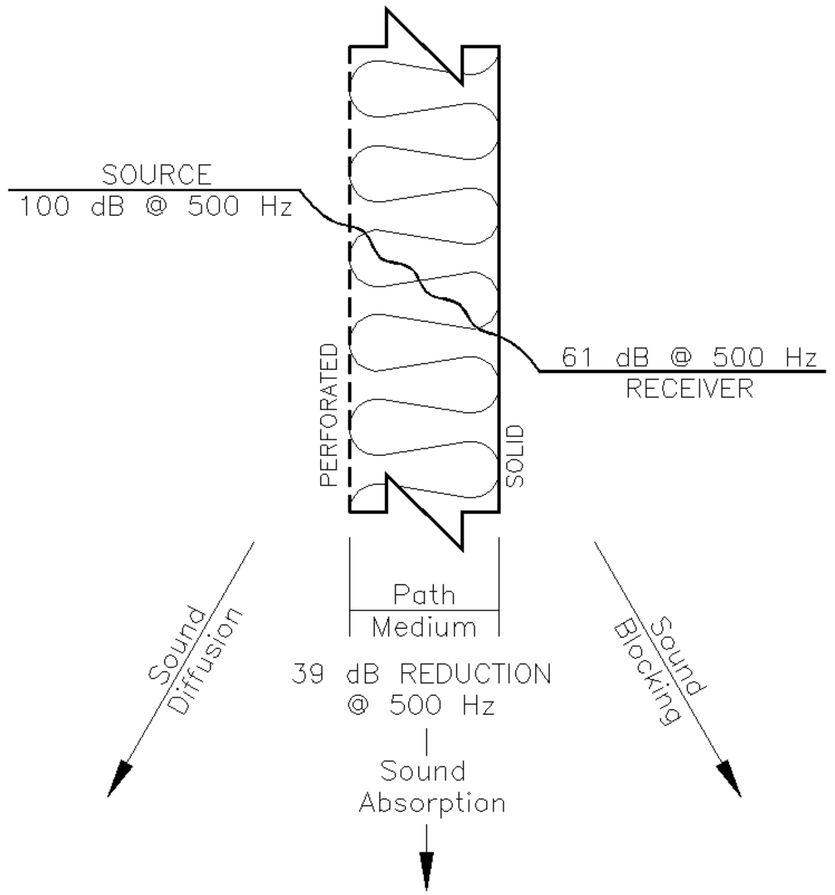
Key Components: types, spacing & height determination



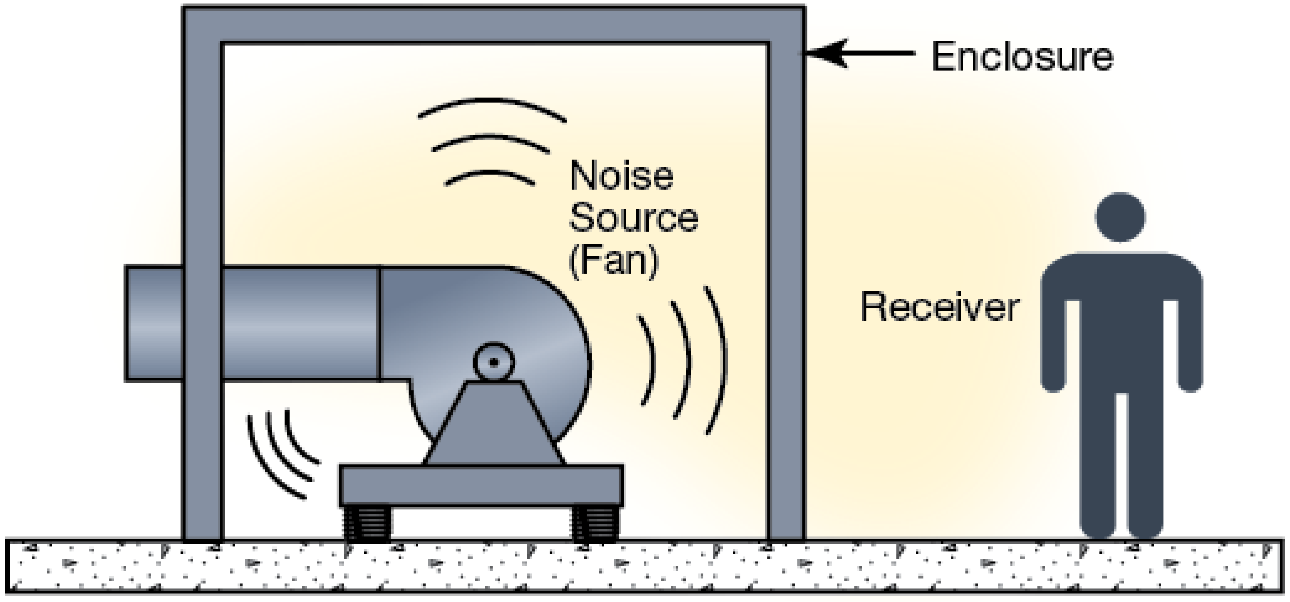


Acoustic Treatment – Sound Barrier Wall

- **Sound absorbing material is used on the sound source side** of the barrier to reduce the build-up of sound pressure level.
- **Absorbing material prevents sound reflection** from barrier surface.
- **Improves** overall **acoustic performance** of barrier system.
- **Solid** outer **skin blocks sound**.



Acoustic Treatment – Sound Enclosure



Acoustic Treatment – Sound Enclosure

- **Proper access** for routine maintenance must be designed into the sound enclosure.
- **Proper silenced ventilation** must be designed into the system to maintain a not to exceed operation temperature.
- **Improve**s overall **acoustic performance** of barrier system.
- **Structurally designed** to withstand, snow, wind and seismic loads.

Conclusion

Environmental “outdoor” noise control is of great importance today.

Educating owners and communities on the available noise control options, using the most up-to-date acoustic algorithms and design standards and applying independently tested products (i.e., ventilation silencers, fixed-blade acoustic louvers, acoustic barrier wall and enclosure panel systems, and rigid perforated absorption panels) will yield a solution which makes the owner and community one “happy family.”

Resources

- **AMCA International**: *www.amca.org*

- **AMCA Publication 1011-03 (R2010)** (Free PDF Download): *www.amca.org/store*

  > Certified Ratings Program- Product Rating Manual for Acoustical Duct Silencers

- **2014 AMCA *inmotion* Magazine:** *https://www.amca.org/educate/inmotion/amca-inmotion-magazine-2014-issue.html*

  > Controlling Outdoor Fan Noise – Items to Consider

Thank you for your time!

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Questions?

NEXT PROGRAM

Join us for our next AMCA *insite*™ Webinar:

- Wednesday, October 14
- 1:00-2:00pm CT
- ***TOPIC: Basics of Fan Noise***
- Presenter: Rad Ganesh, Director, Product Applications, AMCA Member Company

>> For additional webinar dates go to: *www.amca.org/webinar*