Session 4

HVAC NOISE AND VIBRATION CONTROL BEST PRACTICES

Construction Trends

- Less mass in building
- Less space between floors
- Curb mounted equipment
- Drop ceilings
- Premium for rentable/usable space
- Heightened sensitivity of owners
- ANSI S12.60 (Standard for acoustic)
- GBI/PH

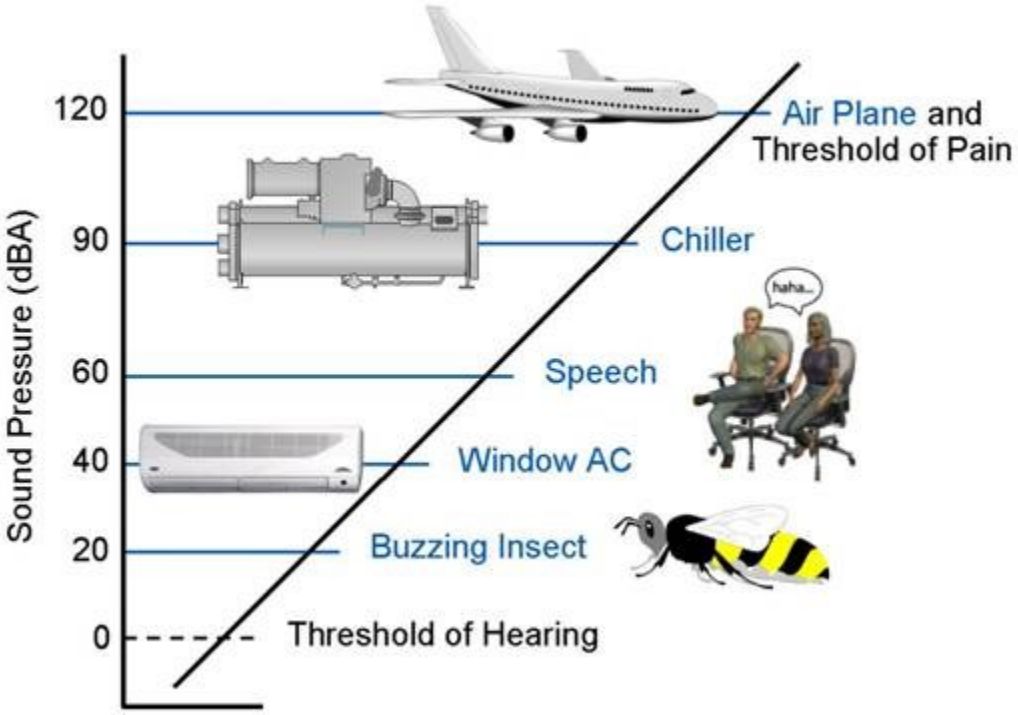
Important Acoustic Terminology

- Loudness vs. Pitch
- Tonal Content
- Decibels: Sound Power vs. Sound Pressure
- Decibel Weighting Networks

Loudness = Quantity of Sound

Pitch = Quality of Sound

What Is The Decibel Scale?



The decibel (dB) is a dimensionless unit calculated using the ratio of a measured value (p) to a reference value (ref). The values of sound pressure of most interest range from the threshold of hearing at about 20 μPa to a level of extreme danger at about 200 Pa. This range of variation translates to 7 orders of magnitude with the high level being 10,000,000 times that of the lower threshold. The use of a logarithmic scale compresses the unit of measure to a manageable range in order to simplify calculations, computations and quantitative manipulation of data.

What is Sound Pressure?

Decibels of sound pressure (Lp) have a universally accepted reference pressure of 2.0 x 10-5 Pascals (Pa).

$$Lp = 20 \log_{10} \left[\frac{\text{Root Mean Square (RMS) Sound Pressure}}{2.0 \times 10^{-5} \text{ Pa (Reference Pressure)}} \right]$$

What Is Sound Power?

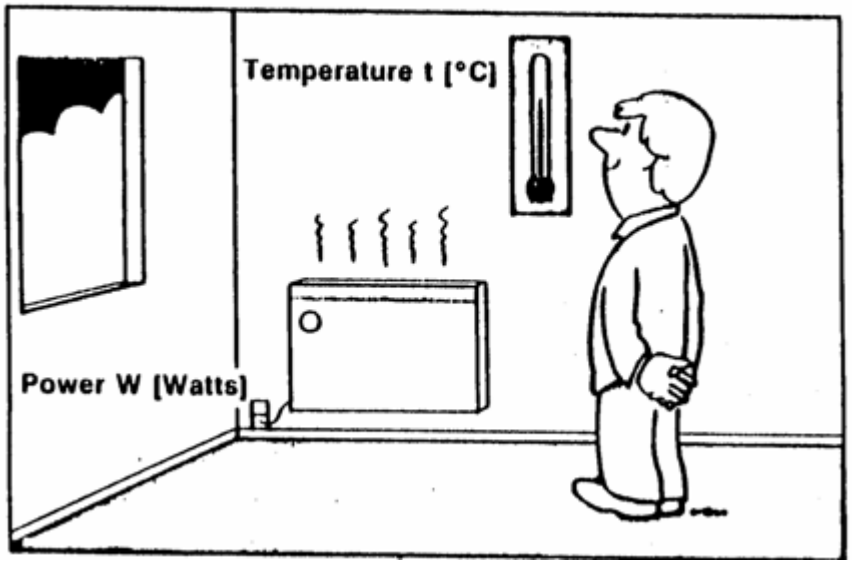
Decibels of sound power (Lw) have a universally accepted reference value of 10^{-12} watts (1 picowatt).

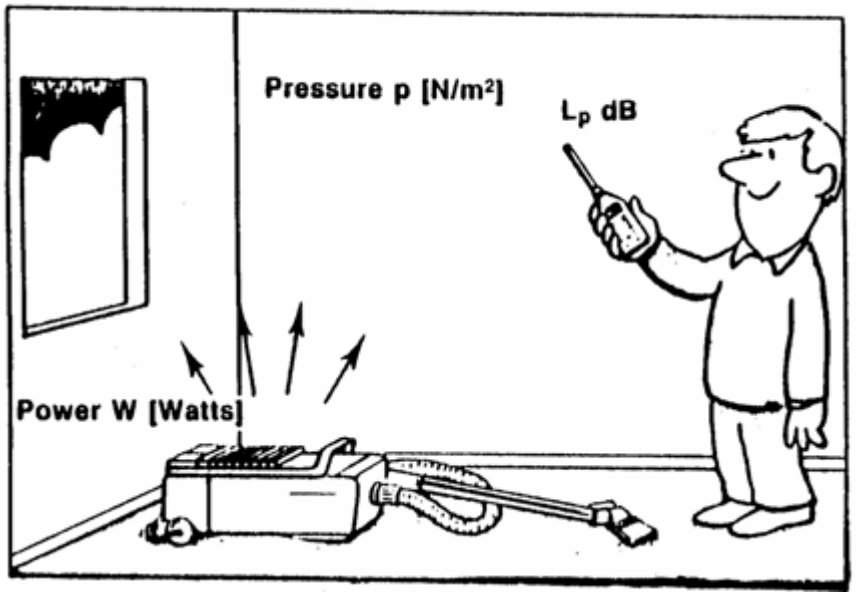
$$Lw = 10 \log_{10} \frac{\text{Watts Sound Power}}{10^{-12} \text{ Watts (Reference Value)}}$$

PWL vs. SPL

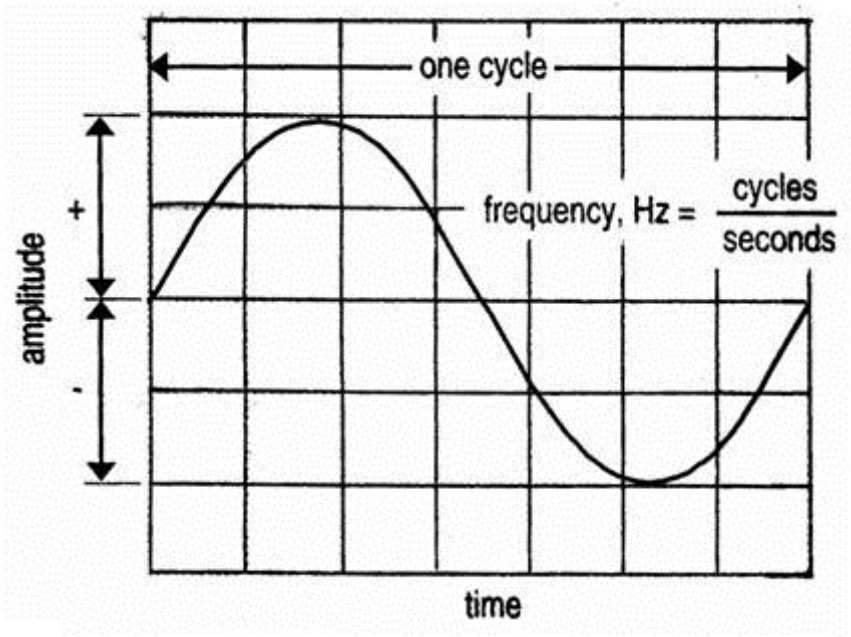
Power vs. Pressure

Cause vs. Effect





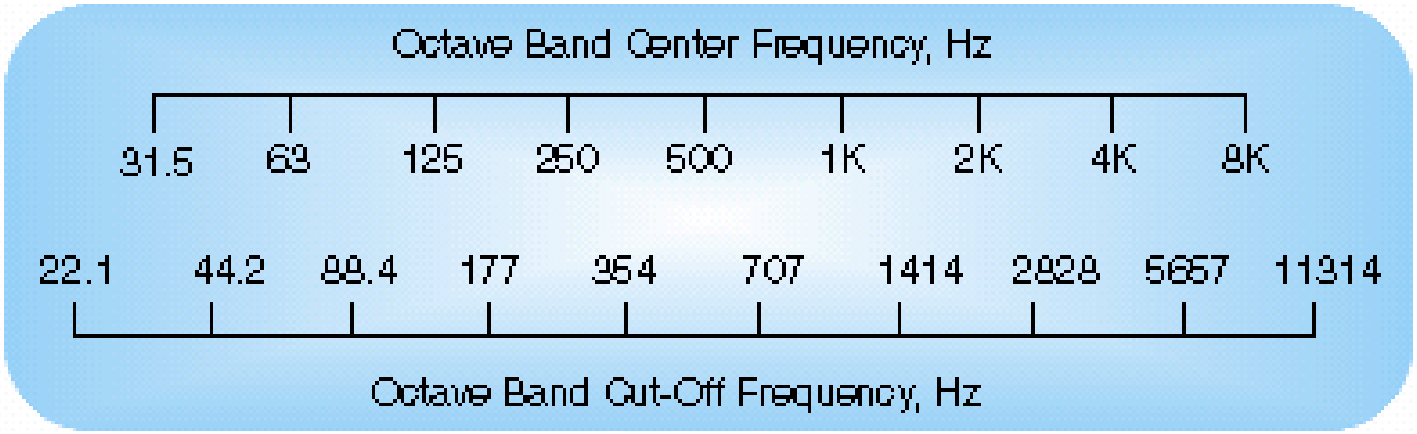
What Are Wavelengths?

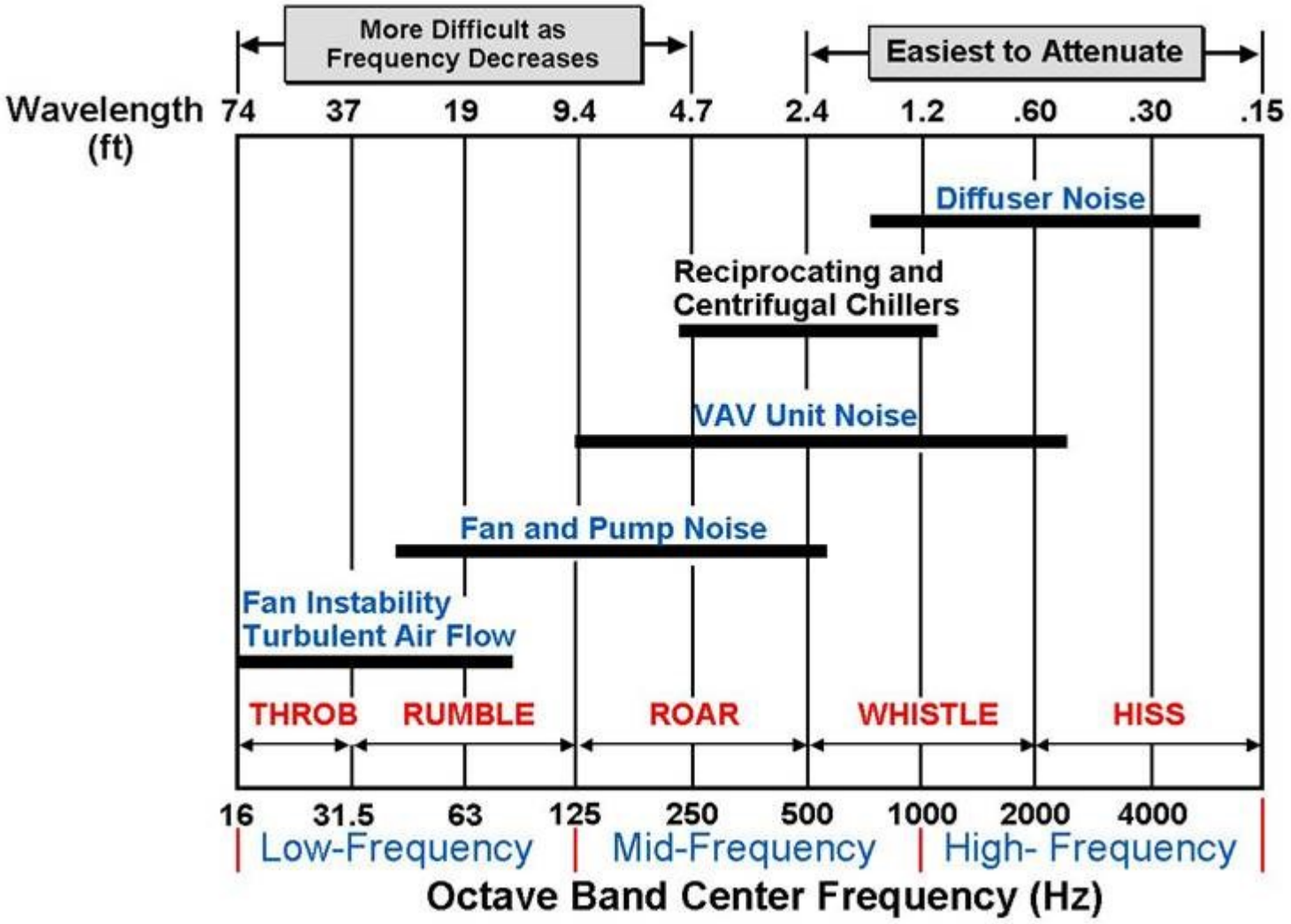


Sound wavelengths are the linear measurement of one full cycle of displacement where the motion of air molecules is first compressed and then rarefied or expanded. The wavelength is determined by the ratio of the speed of sound to the frequency.

$$\text{Wavelength} = \frac{\text{Speed of Sound}}{\text{Frequency}}$$

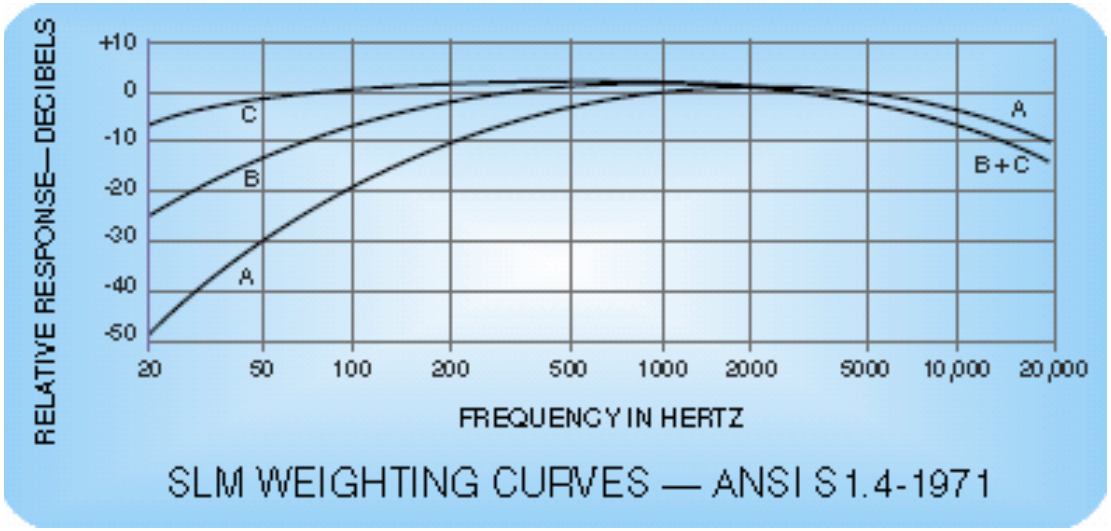
What Are Octave Bands?




More Difficult as Frequency Decreases
Easiest to Attenuate
Wavelength (ft)
74
37
19
9.4
4.7
2.4
1.2
.60
.30
.15
Diffuser Noise
Reciprocating and Centrifugal Chillers
VAV Unit Noise
Fan and Pump Noise
Fan Instability Turbulent Air Flow
THROB
RUMBLE
ROAR
WHISTLE
HISS
16
31.5
63
125
250
500
1000
2000
4000
Low-Frequency
Mid-Frequency
High- Frequency
Octave Band Center Frequency (Hz)

“A” Weighted Correction Factors Based on Human Frequency Response

	Octave Band Center Frequency, Hz								
	31.5	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Adjustment Factor	-39	-26	-16	-9	-3	0	+1	+1	-1



Common Spec Strategies on Noise Sensitive Projects

- Keep equipment away from noise sensitive areas
- Specify sound data for lowest rated model in equipment basis of design
- Specify all available OEM equipment low noise options
- Specify an equipment model that is not tonal
- Specify the same treatment used on the last noise sensitive project
- Retain an acoustical consultant to write the specification
- Specify base equipment and address any noise problems at start-up
- Boiler plate specification covers all jobs

Best Practices
Specifications

- Design specs preferred over performance specs
- Evaluate objective and subjective criteria
- Indoor criteria: NC, RC, NCB, RC Mark II
- Outdoor criteria: Zoning and ordinance criteria
- Place in Division 15 with equipment
- Specify single source
- Specify turnkey where installation critical
- Require submission for approval as “or equal” 10 days before bid date

Best Practices
Acoustic Design

- Answer the 4 questions
- Use 3 to 5 dBA safety factor
- Cursory review on every project; in depth review when warranted
- Assess site ambient noise levels
- Evaluate airborne and structure-borne transmission
- System problems require system solutions

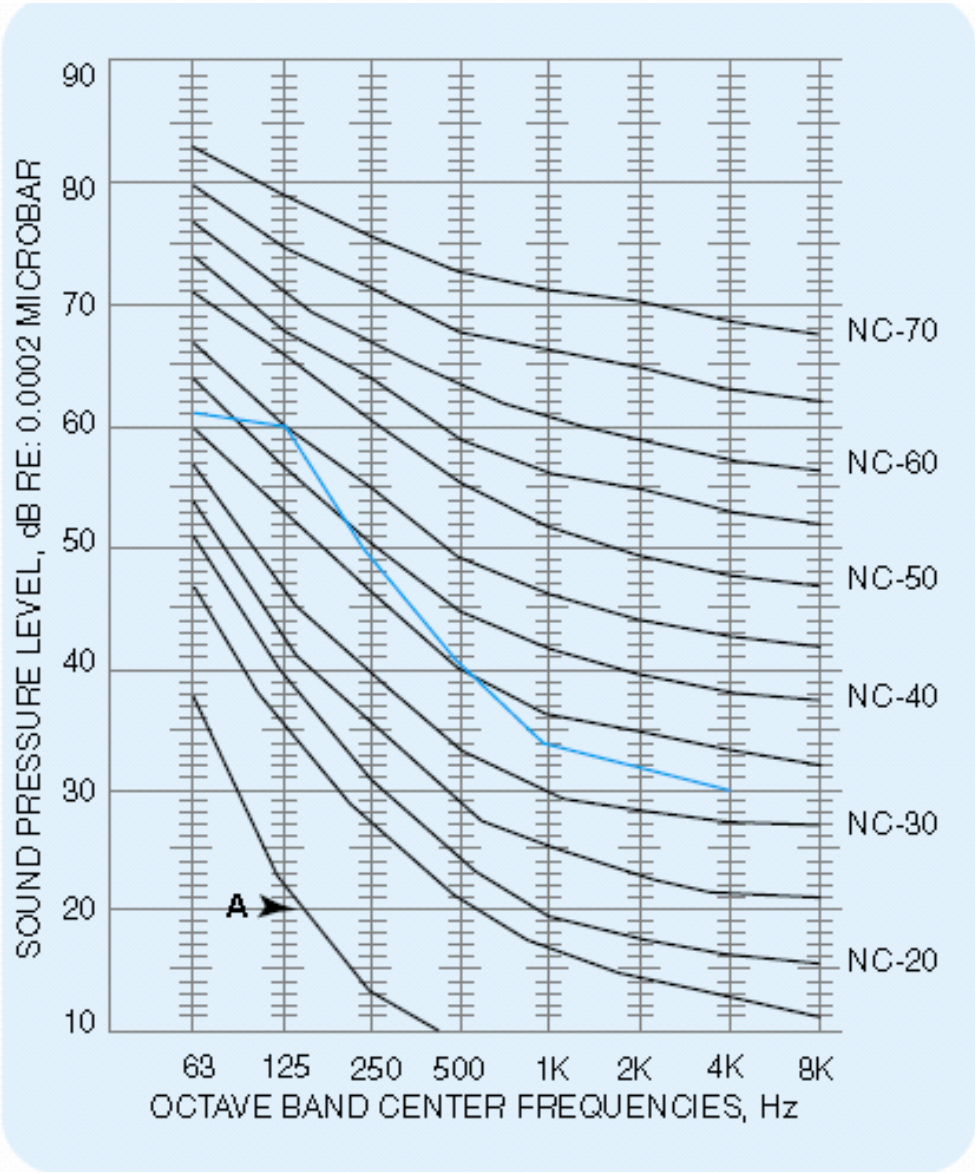
Simplified Acoustic Design (The four questions every design engineer wants to answer)

1. Where are we now?
2. Where do we need to be?
3. What needs to be done to get there?
4. How much will that cost?

Indoor Objective Criteria
Recommended NC Levels

Broadcast studios (distant microphone pickup used)	10
Concert halls, opera houses, and recital halls (listening to faint musical sounds)	15-18
Small auditoriums	25-30
Large auditoriums, large drama theatres, and large churches (for very good speech articulation)	20-25
TV and broadcast studios (close microphone pickup only)	15-20
Legitimate theatres	20-25
Private residences:	
Bedrooms	25-30
Apartments	30-40
Family rooms and living rooms	30-40
Schools:	
Lecture and classrooms	
with areas less than 70 sq. m.	35-40
with areas greater than 70 sq. m.	30-35
Open-plan classrooms	35-40
Hotels/motels:	
Individual rooms or suites	30-35
Meeting/banquet rooms	25-35
Service support areas	40-50
Churches, small	30-35
Office buildings:	
Offices	
executive	25-35
small, private	35-40
larger, with conference tables	30-35
Conference rooms	
large	25-30
small	30-35
General secretarial areas	40-45
Open-plan areas	35-40
Business machines/computers	40-45
Public circulation	40-50
Hospitals and clinics:	
Private rooms	25-30
Wards	30-35
Operating rooms	25-35
Laboratories	35-45
Corridors	35-45
Public areas	40-45
Movie theatres	30-40
Courtrooms	30-35
Libraries	35-40
Restaurants	40-45

Indoor Objective Criteria



NC

Curves

Outdoor Objective Criteria
State, City, Township Ordinances

ANNEX A
SCHEDULE OF PERMISSIBLE SOUND LEVELS

SCHEDULE 1

MAXIMUM PERMISSIBLE SOUND LEVEL (L_{Aeq}) BY RECEIVING LAND USE FOR PLANNING AND NEW DEVELOPMENT

Receiving Land Use Category	Day Time 7.00 am - 10.00 pm	Night Time 10.00 pm - 7.00 am
Noise Sensitive Areas, Low Density Residential, Institutional (School, Hospital), Worship Areas.	50 dBA	40 dBA
Suburban Residential (Medium Density) Areas, Public Spaces, Parks, Recreational Areas.	55dBA	45 dBA
Urban Residential (High Density) Areas, Designated Mixed Development Areas (Residential - Commercial).	60 dBA	50 dBA
Commercial Business Zones	65 dBA	55 dBA
Designated Industrial Zones	70 dBA	60 dBA

SCHEDULE 4

LIMITING SOUND LEVEL (L_{Aeq}) FROM ROAD TRAFFIC (FOR PROPOSED NEW ROADS AND/OR REDEVELOPMENT OF EXISTING ROADS)

Receiving Land Use Category	Day Time 7.00 am - 10.00 pm	Night Time 10.00 pm - 7.00 am
Noise Sensitive Areas Low Density Residential Areas	55 dBA	50 dBA
Suburban Residential (Medium Density)	60 dBA	55 dBA
Urban Residential (High Density)	65 dBA	60 dBA
Commercial, Business	70 dBA	60 dBA
Industrial	75 dBA	65 dBA

Best Practices
Outdoor Chillers

- Thickened slab for rooftop
- Evaluate loudness and tonal content
- Special consideration for remote evap piping
- Evaluate building and property line noise
- Optimize aerodynamic and acoustic performance
- Source and path acoustic treatment

Critical Design Factors

- Broadband Performance
- Tonal Performance
- Aerodynamic Performance
- Operating Efficiency
- Operating Costs

Compressor Source Treatments Sound Blankets

- Treat all accessible compressor circuit components
- 3 to 4 lb. surface density
- Fit/refit attachment features must be “user friendly”
- UL 764C Listed

Treating Compressor Circuits

Result of “generic” spec

Air Intake Source Treatments

Condenser Fan Source Treatments

- Acoustical plenums
- Plenum with baffles
- Plenum with silencer bank
- Individual stack silencers

Open Plenums

Plenum with Baffles

Plenum with Silencer Bank

Not Recommended by OEMs

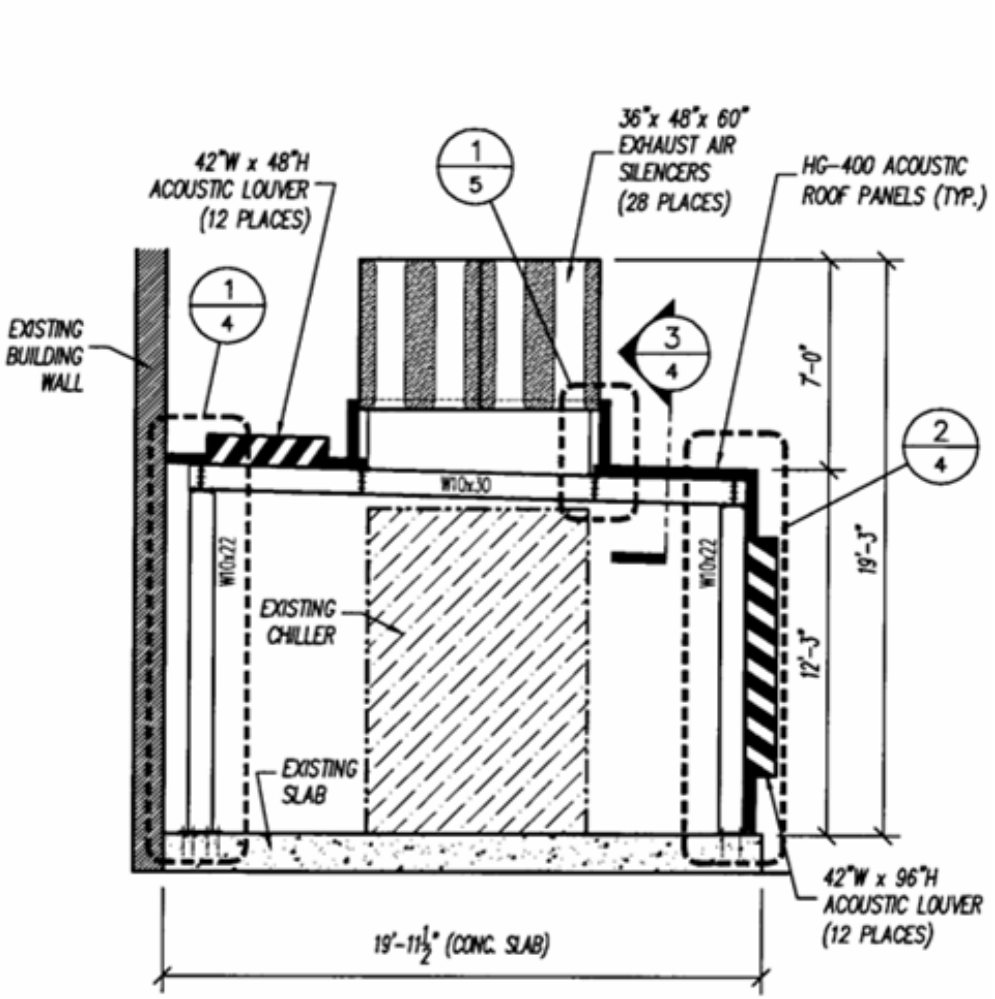
“Dedicated” Stack Silencers

Path Treatments
Wall and Fence Liners

Turnkey Acoustical Barrier Walls

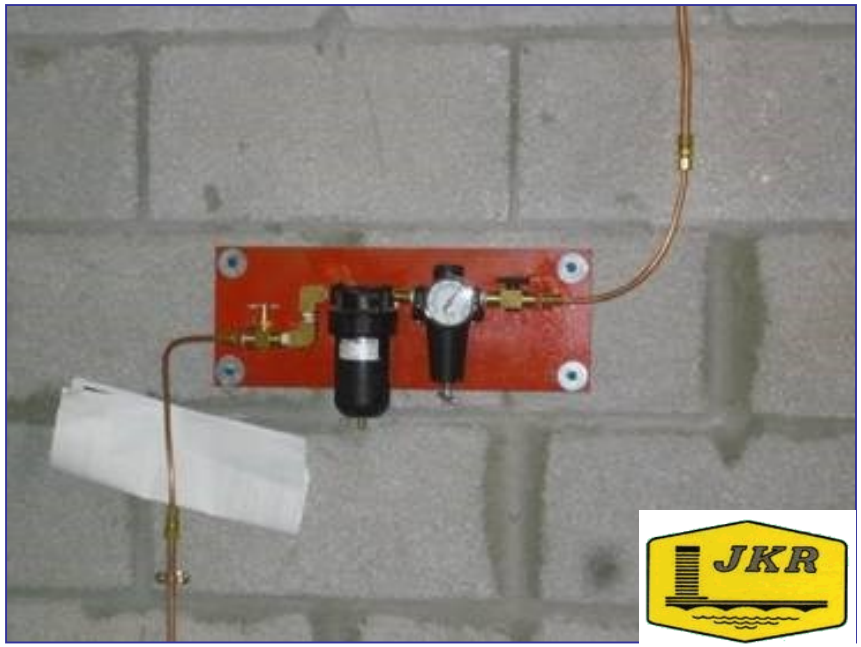
20+ dBA Attenuation Systems

HUSHCORE™ *Ultimate*™ System Solution



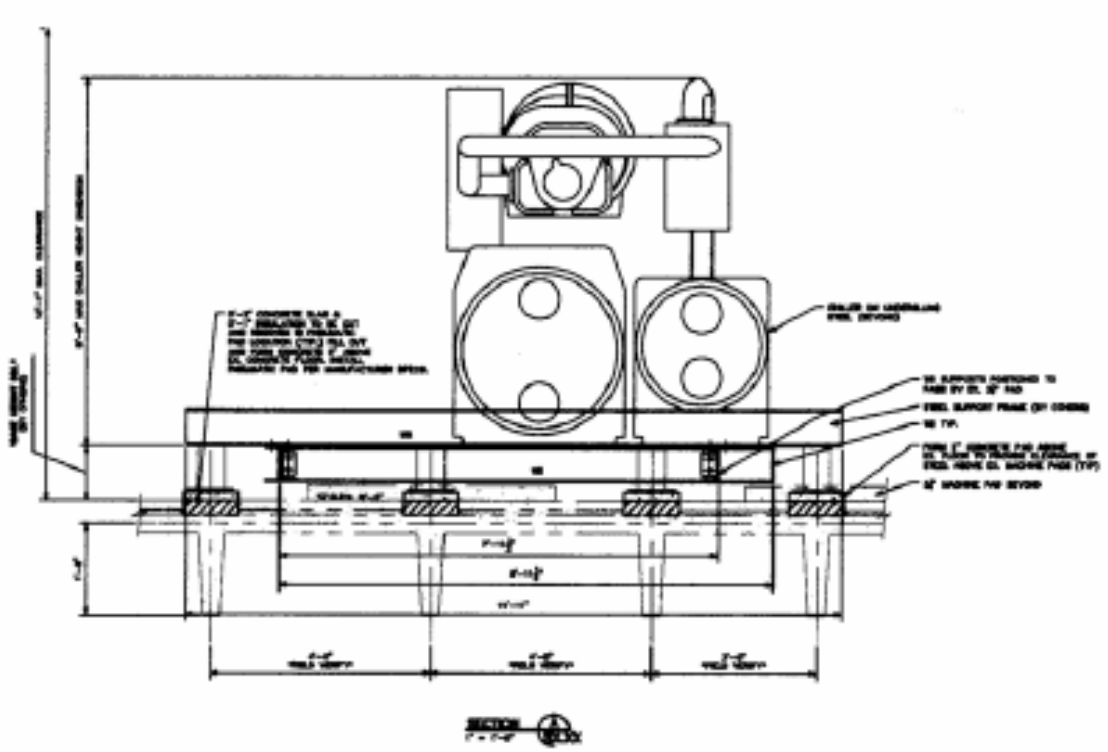
Best Practices
Indoor Chillers

- Thickened slab above and below
- Floating floors
- Pneumatic isolation systems
- 6 sided enclosures
- Stay away from midpoints of column spans
- Buffer from noise sensitive spaces
- Source & path acoustic treatments



Six-Sided Enclosures

- Mounted on inertia base
- Mounted on steel frame with panels

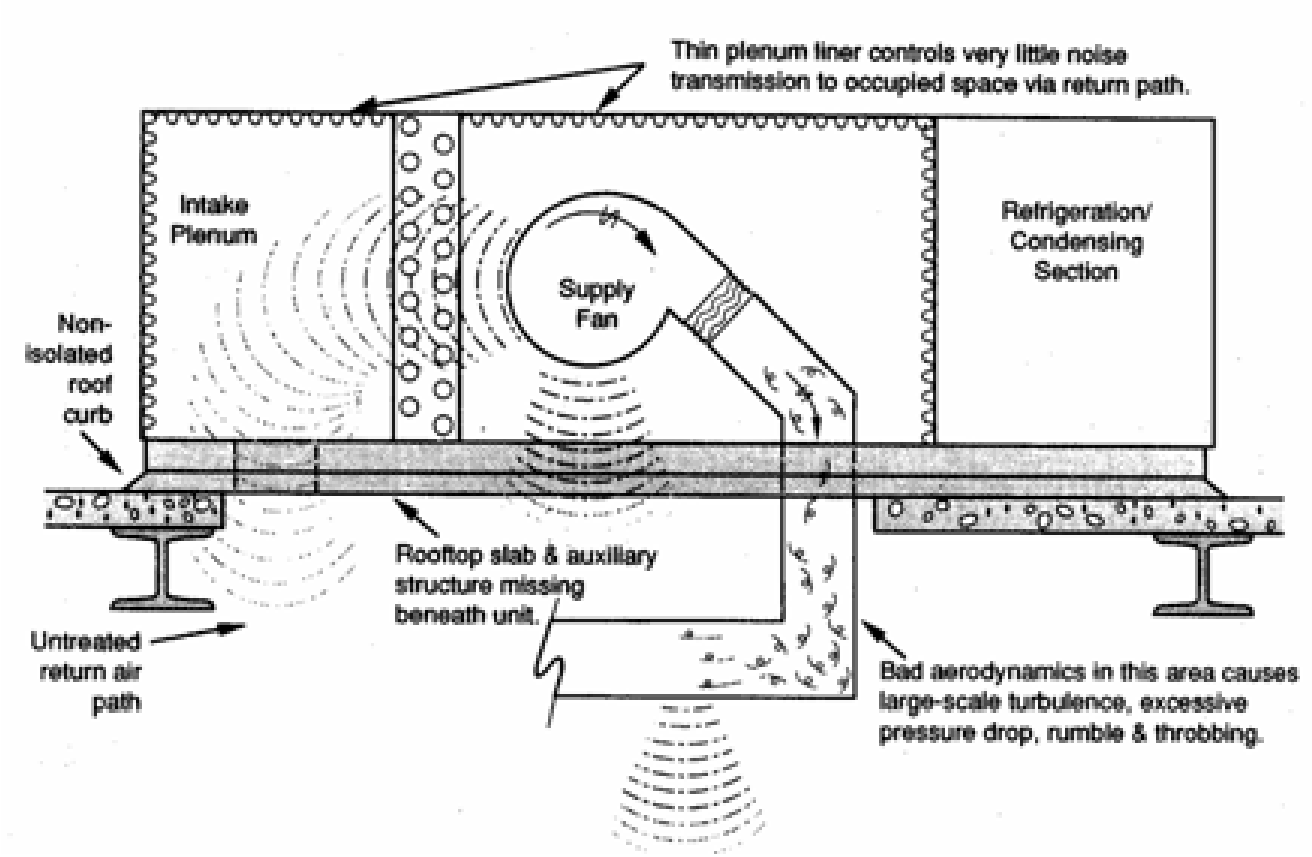


Source Treatments

“Soft” Enclosure Path Treatments

“Hard” Enclosure Path Treatments

Rooftop Unit System Problems



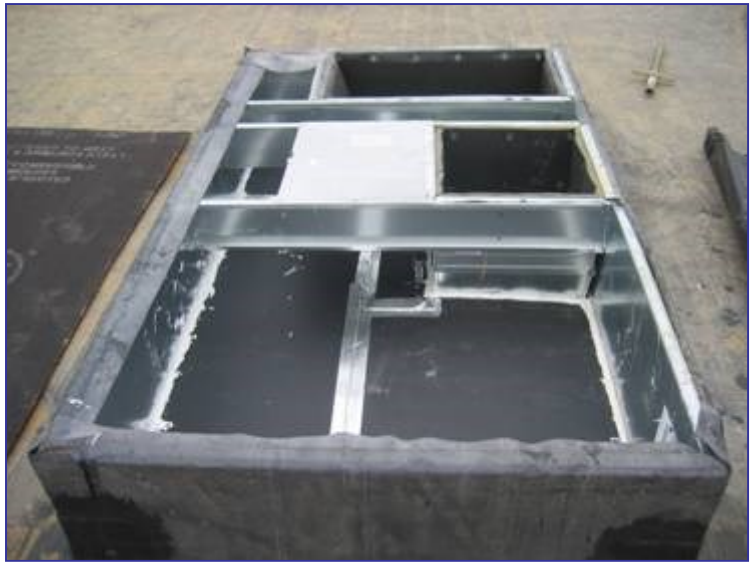
Best Practices
Roof Mounted Equipment on Dunnage Steel

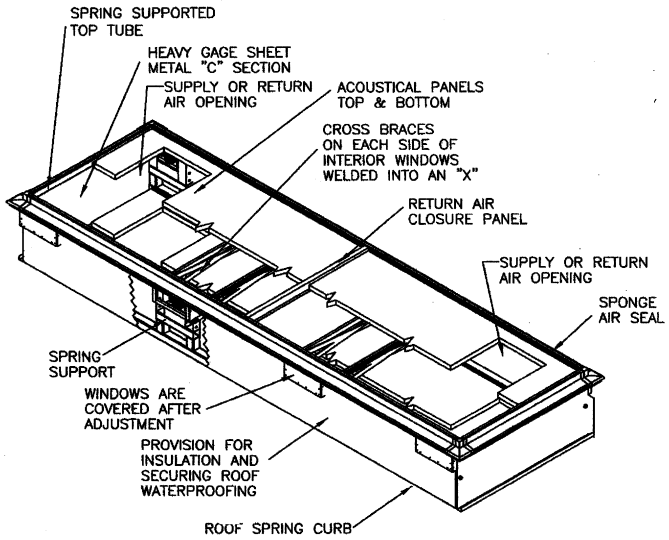
- Restrained isolators if spring
- UV compatible shear mounts
- 3” to 4” thickened slab 8’ to 10’ around unit perimeter
- Locate over utility space
- Keep away from skylights and operable windows

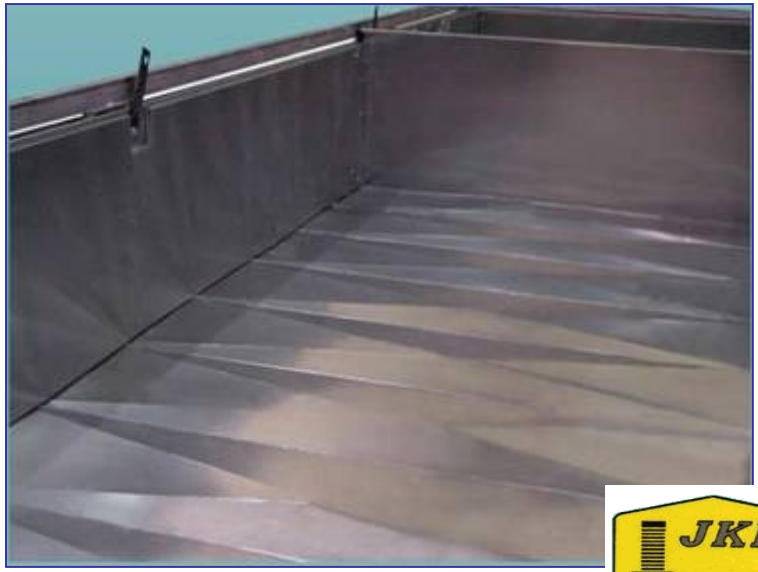
Best Practices
Rooftop Curb Mounted AHU

- Integral vibration/seismic curb
- Lock down internal isolation
- Add mass inside curbs
- Seal (acoustic) duct drops
- Dissipate supply breakout noise above deck
- Plenum style acoustic curbs
- Discharge plenums

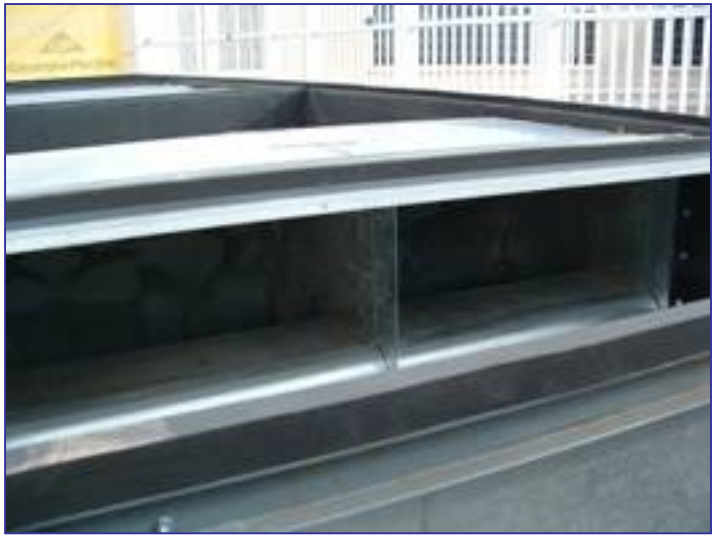
In-Curb Treatment

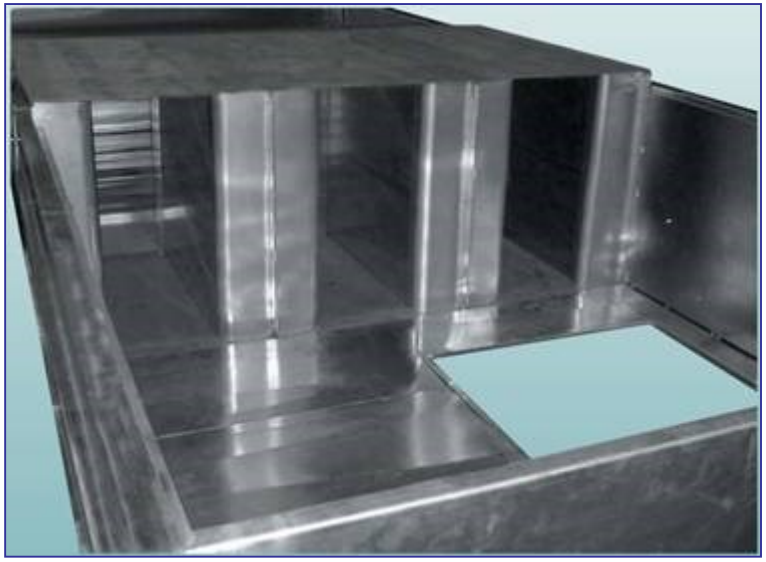


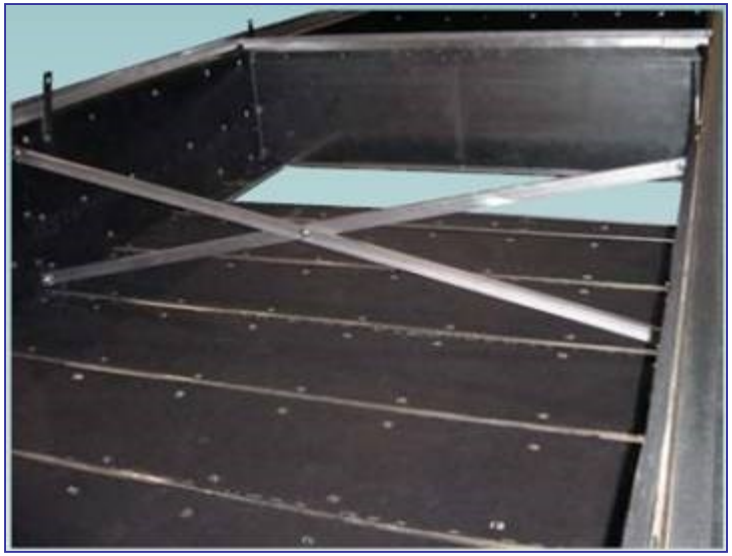




Integrated Sound Attenuators





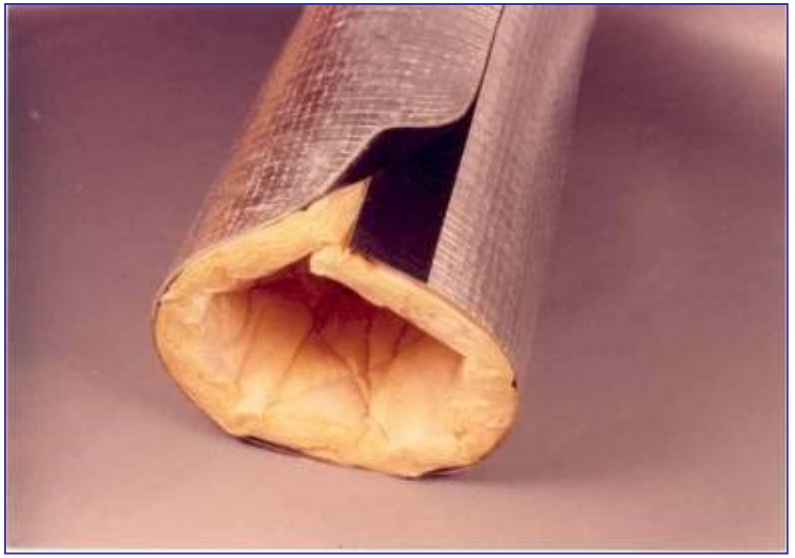


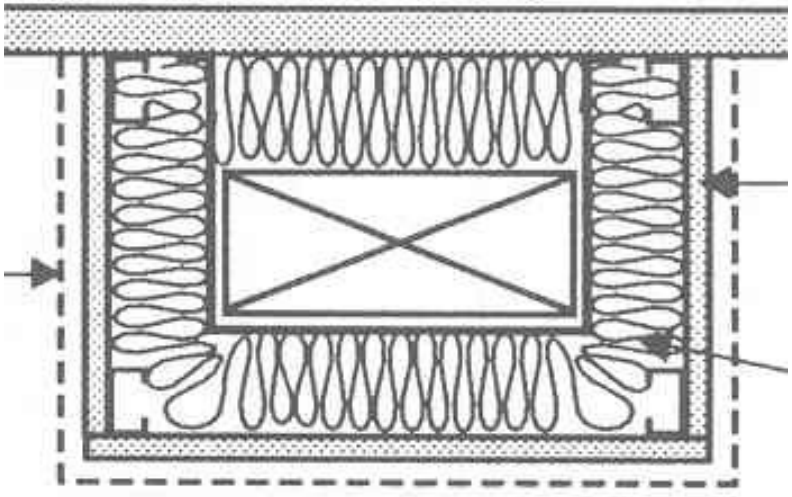
Best Practices

Roof Top Unit (RTU) Configurations

- Increase plenum liner thickness
- Utilize RTU discharge plenums on the supply side
- Avoid vane type flow modulation devices. VFD controllers are preferred
- Slower fan speeds = lower noise levels
- Evaluate fan wheel types. Backward inclined (BI) and aerofoil (AF) wheels are preferred over forward curved models (FC)

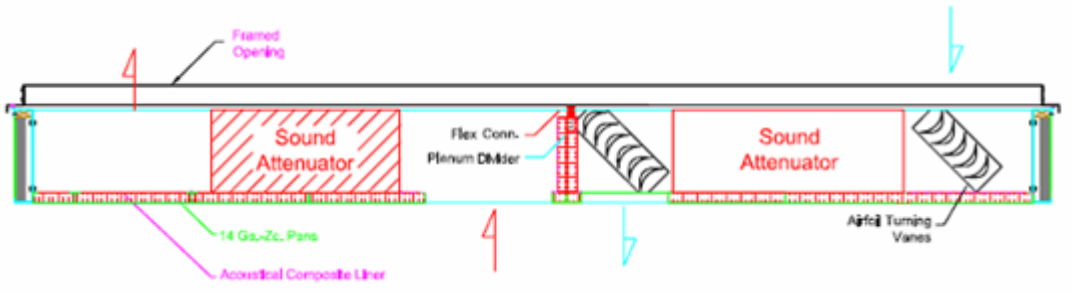
External Acoustic Duct Lagging

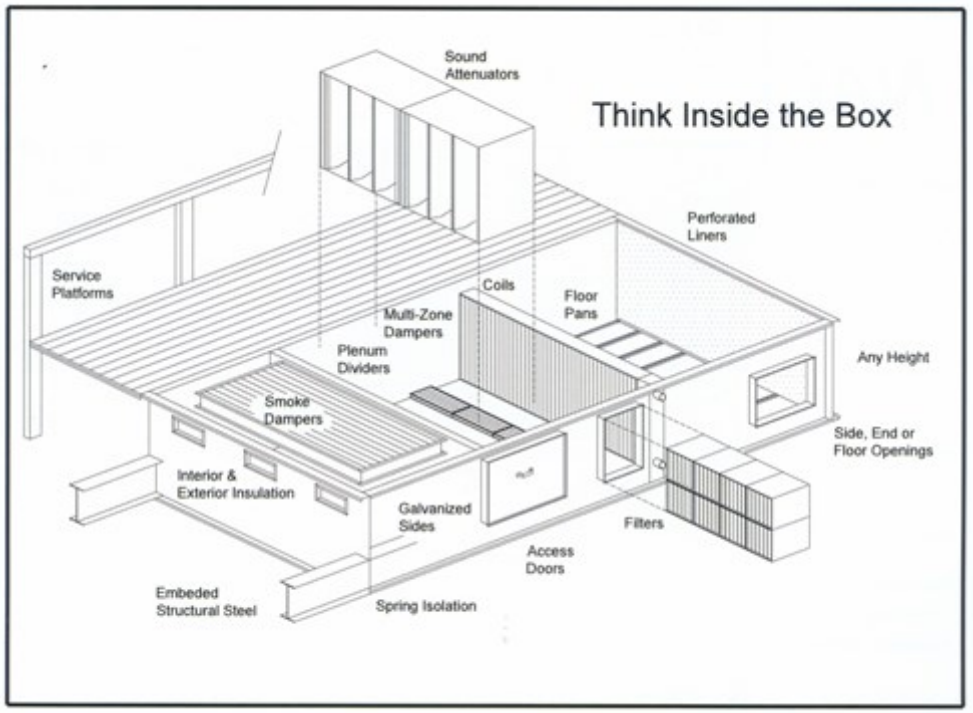


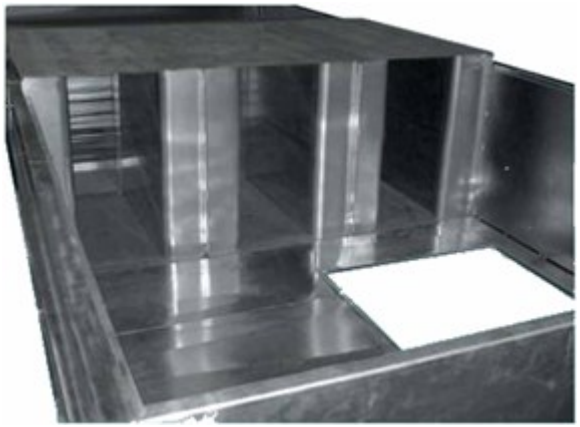


7 - 9 dB reduction in first 3 octave bands

Sample System Solution







Rooftop Unit Condenser Section Treatments

Have a noise-free day!