ASHRAE Qatar Oryx Chapter

Fundamentals of Acoustics
&
Practical HVAC Design Considerations

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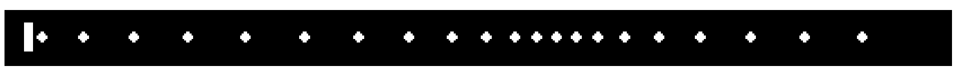
What is sound?

Sound is a mechanical wave that is an oscillation of pressure transmitted through some medium (like air or water), composed of frequencies which are within the range of hearing.

In 20 ° C (68 ° F) air at sea level, the speed of sound is approximately 343 m/s (1,230 km/h; 767 mph)

Propagation of sound

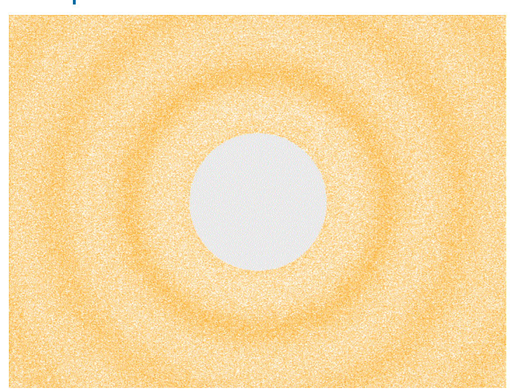
Source | Medium - Air | Receiver



moving membrane

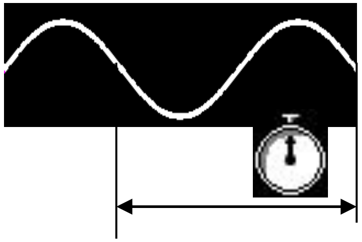
air particles, transfer of energy to next particles

pressure at receiver oscillates with source freq.



What is frequency?

- The term Frequency applies to periodic events - such as sound waves.
- The time for one event to take place is T. T is measured in seconds.
- The Frequency is the number of times the event happens per second.
- The unit of measurement for Frequency is Hertz or Hz.
- 1 Hz means that the event takes place once per second.
- 100 Hz means that the event takes place 100 times per second.



$$\boxed{T}$$

$$f = \frac{1}{T}$$

$$[Hz] = \frac{1}{[s]}$$

Frequency range of speech and music

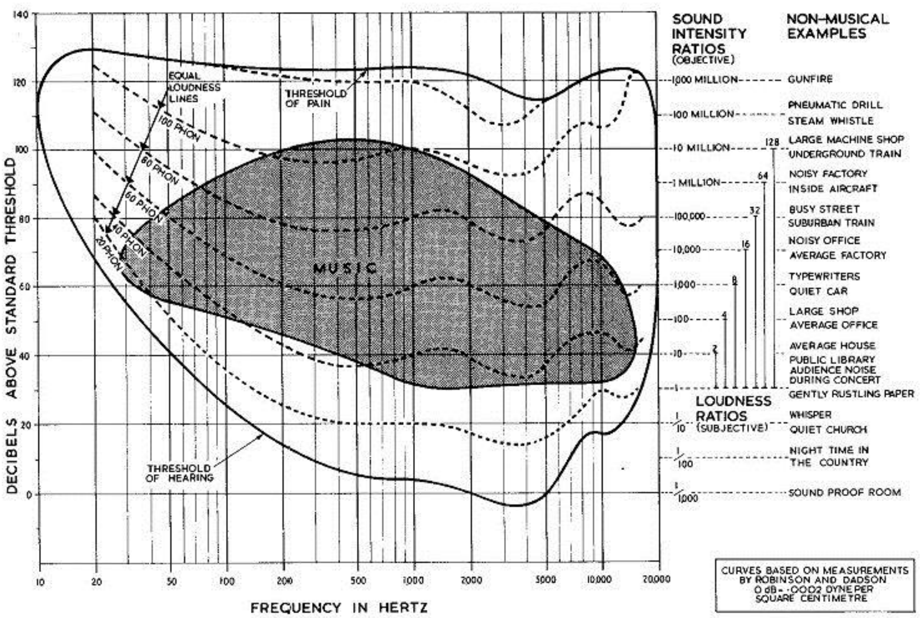
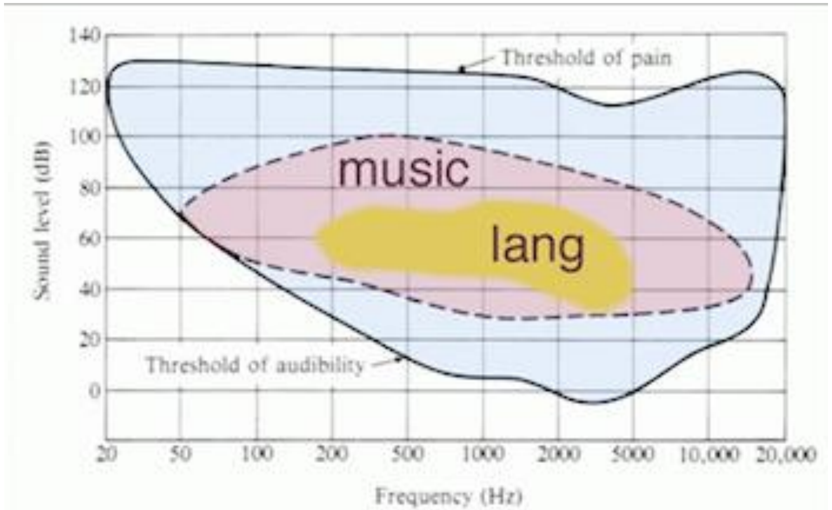


Fig. 7 Place of music within the sensitivity range of human hearing. All limits are approximate and statistically determined.



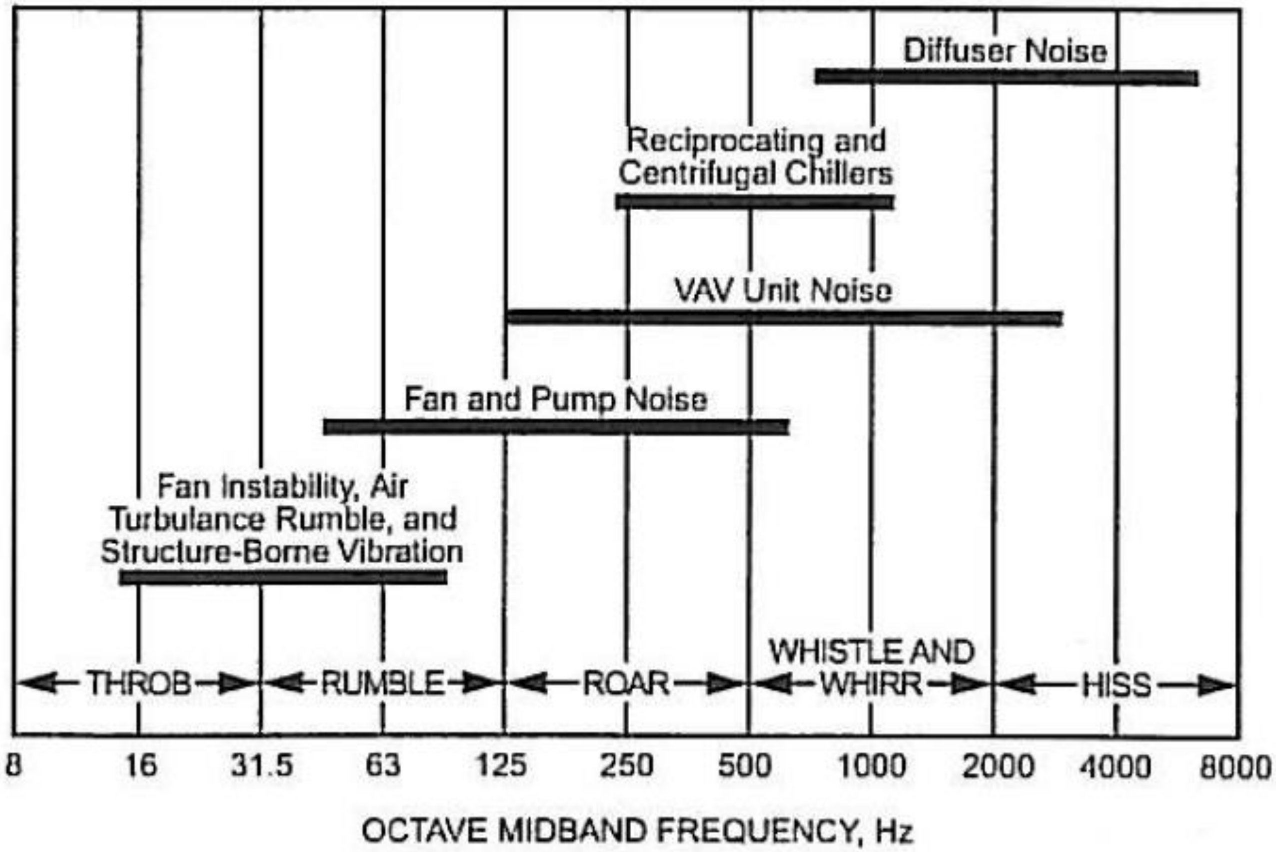
Frequency bands

- The most common frequency bands have their centers at octave or 1/3 octave intervals.

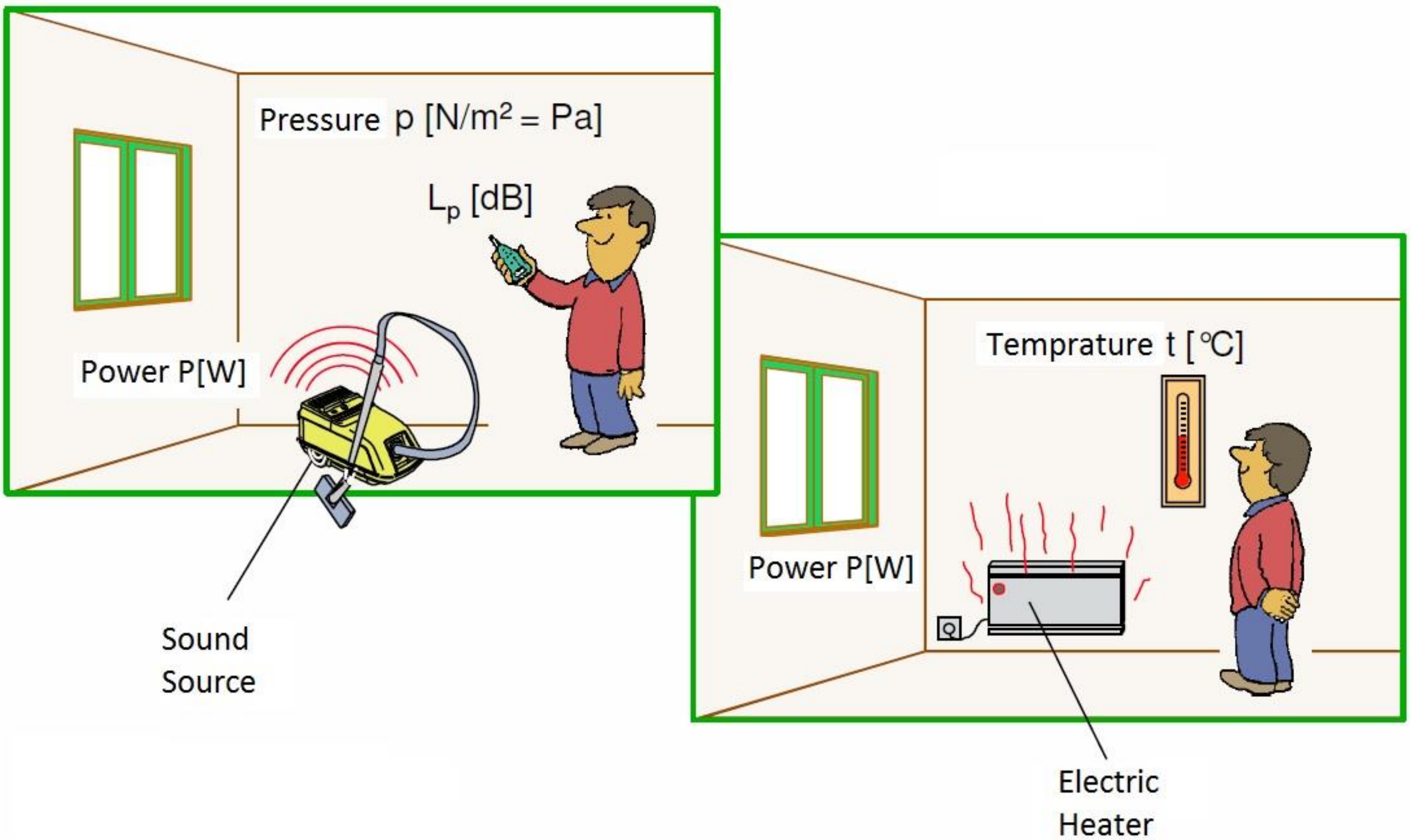
Octave Bands

63	125	250	500	1k	2k	4k	8k

Frequency Characteristics of HVAC Eq.

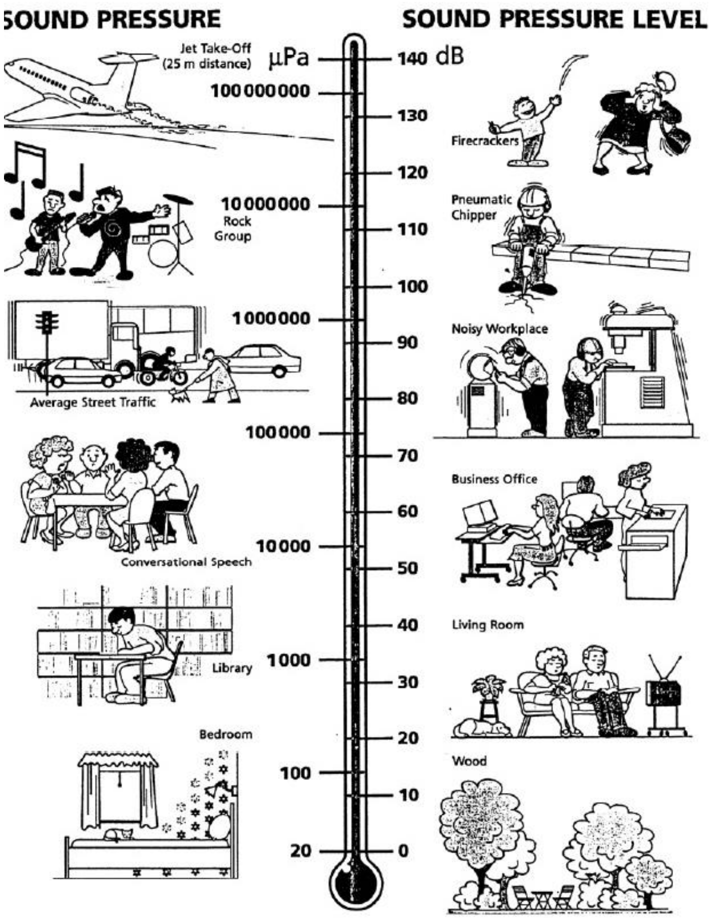


Sound Power & Sound pressure



Sound pressure level

- Sound pressure level of everyday noise sources



$$L_p = 20\ \log_{10}\left(\frac{p}{p_0}\right)\ \text{in dB} = L_I = 10\ \log_{10}\left(\frac{I}{I_0}\right)\ \text{in dB}$$

$$L_p\ (\text{dBSPL}) = 20 \cdot \log_{(10)} \frac{p}{p_0}$$

$$p_0 = 0.00002\ \text{Pa}$$

$$p\ (\text{Pa}) = p_0 \cdot 10^{\frac{L_p(\text{dBSPL})}{20}}$$

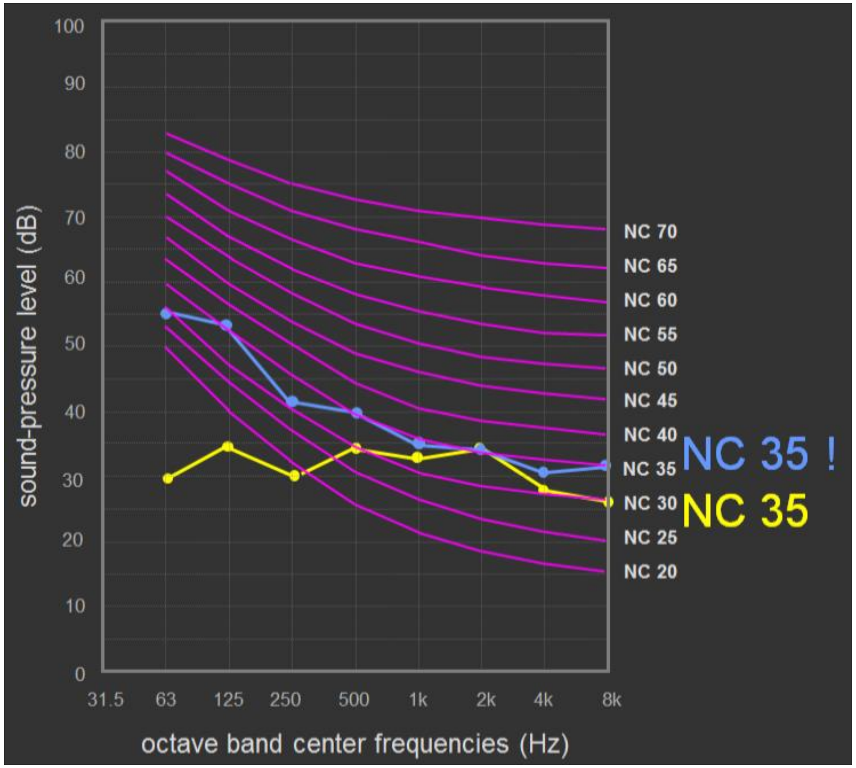
$$L_I\ (\text{dBSIL}) = 10 \cdot \log_{(10)} \frac{I}{I_0}$$

$$I_0 = 10^{-12}\ \frac{\text{W}}{\text{m}^2}$$

$$I\ \left(\frac{\text{W}}{\text{m}^2}\right) = I_0 \cdot 10^{\frac{L_I(\text{dBSIL})}{10}}$$

Noise Criteria Curves (NC)

- One of the most commonly used single-number readings is the Noise Criteria (NC) standard.
- NC is defined as single number noise rating system commonly used to rate the steady-state noise levels in a room. They consist of a family of curves which defines the maximum allowable sound pressure levels in octave bands.



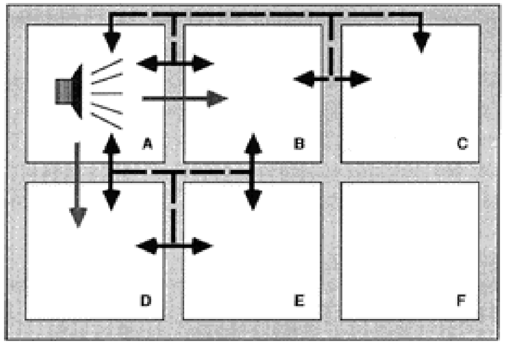
Conditions	NC level
Sleeping	25-35
Living	35-45
Office	30-45
Audio Studio	15-20
Restaurant	35-50
Laboratory	40-45
Computer room	45-60

Types of Sound Transmission

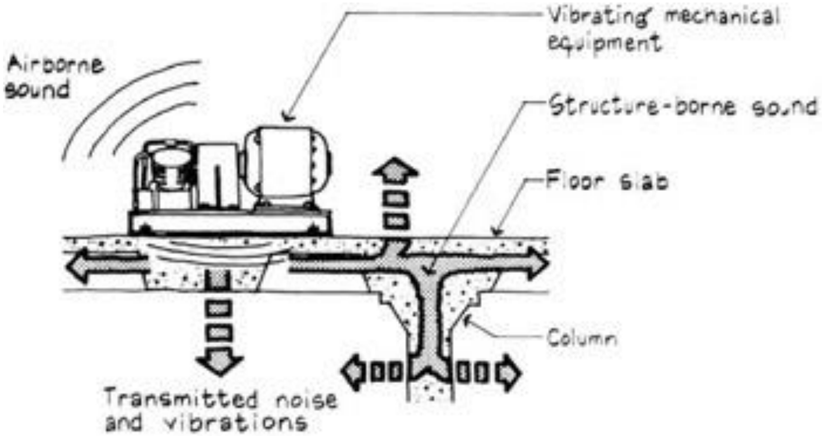
- Airborne Sound: Airborne sound refers to sources which produce sound by directly setting the air around them into vibration.

- Impact Sound : Impact sound refers to sources which produce sound by impulsive mechanical excitation of part of a building (e.g. by footsteps, electric light switches, slamming doors). Many sources of impact sound also produce significant levels of airborne sound.

- Structure-borne Sound: Structure-borne sound is often used to refer to sound that travels for long distances via the structure, especially in connection with vibrating machinery linked directly to the structure



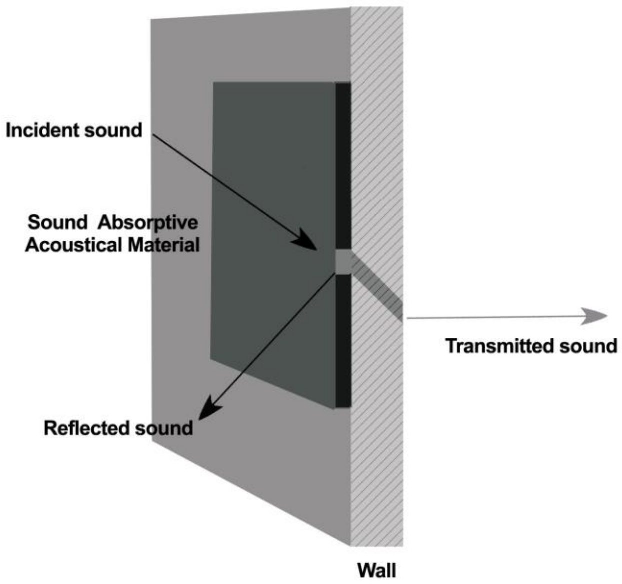
AIRBORNE AND STRUCTURE-BORNE SOUND



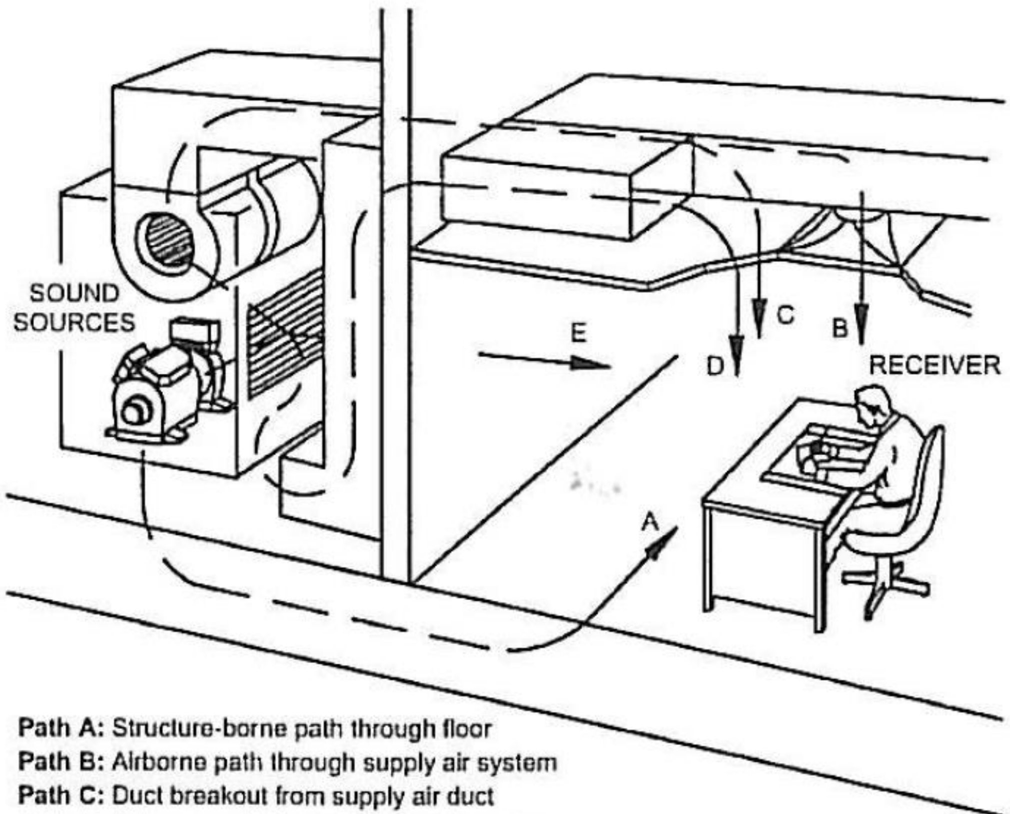
Sound Absorption VS Sound Insulation

- Sound Insulation: Sound insulation refers to the act of impeding the transmission of sound from one area to another or from a source to a receiver. Typical examples include the sound insulation between adjacent apartment units or between a busy highway and one's bedroom. The best way to improve the insulation between two areas typically involves the use of heavy materials such as concrete or gypsum board.

- Sound Absorption: Sound absorption refers to the phenomenon whereby some or all of the sound energy incident on a surface is either converted into heat or passes through the absorber.



Noise Paths for HVAC Equipment



Path A: Structure-borne path through floor
Path B: Airborne path through supply air system
Path C: Duct breakout from supply air duct
Path D: Airborne path through return air system
Path E: Airborne path through mechanical equipment room wall

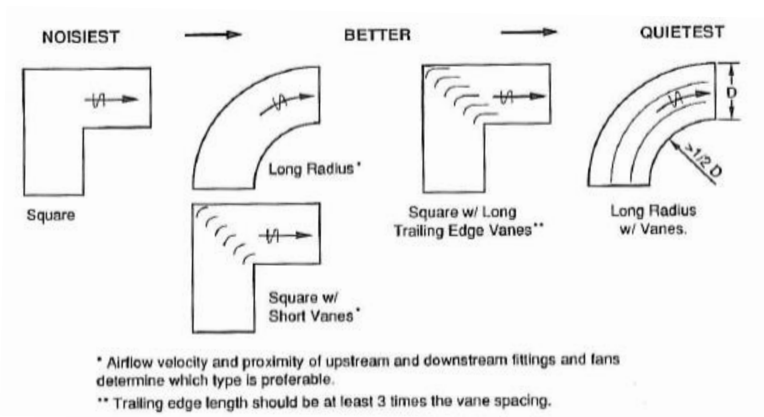
HVAC Noise Control

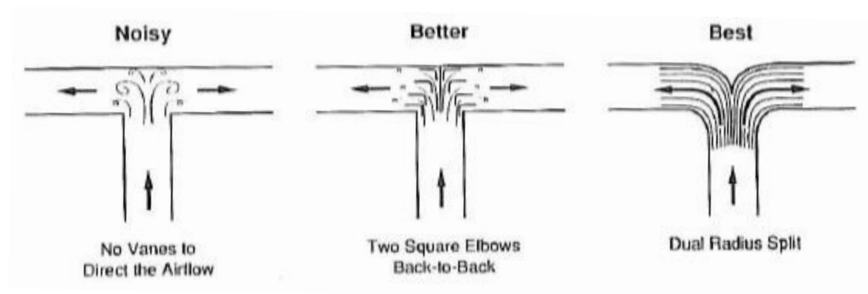
- Duct Velocities
  Air velocity within a duct system influences the noise levels significantly. Regenerated noise can be created by transition pieces, bends, dampers, grilles and diffusers. Regenerated noise can be avoided by limiting the air velocities within the duct system.

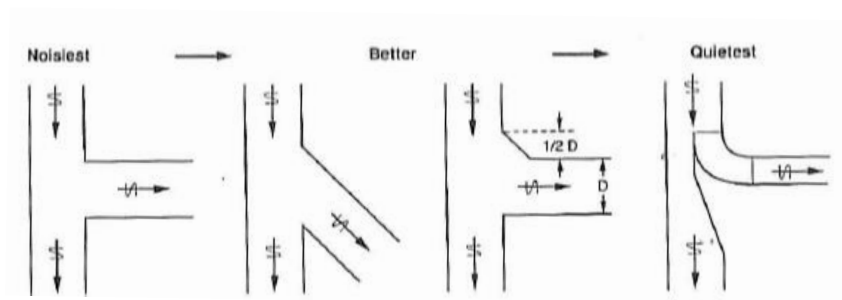
NR or NC design requirement	In-duct air velocity (m/s)		
	Main	Branch	Final run-outs
20	4.5	3.5	2.0
25	5.0	4.5	2.5
30	6.5	5.5	3.25
35	7.5	6.0	4.0
40	9.0	7.0	5.0

HVAC Noise Control

- Regenerated Noise From Duct Elements

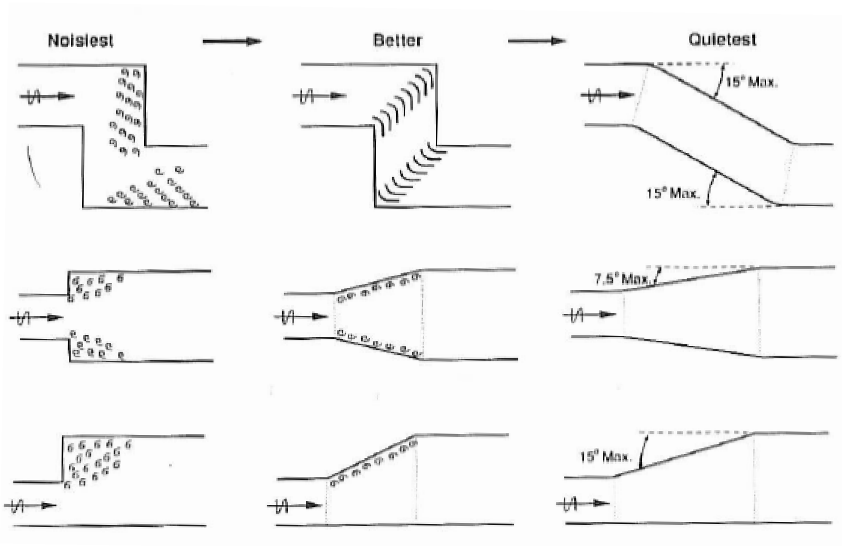


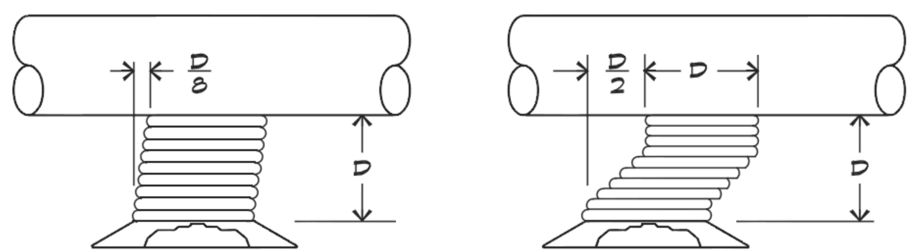




HVAC Noise Control

- Regenerated Noise From Duct Elements



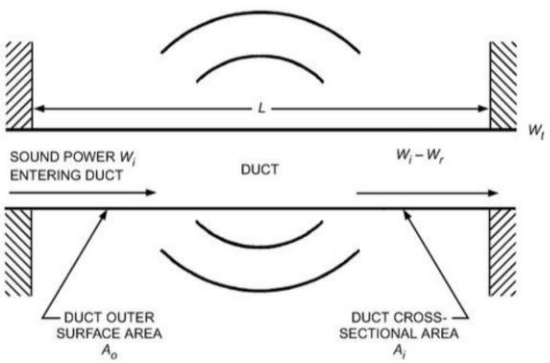


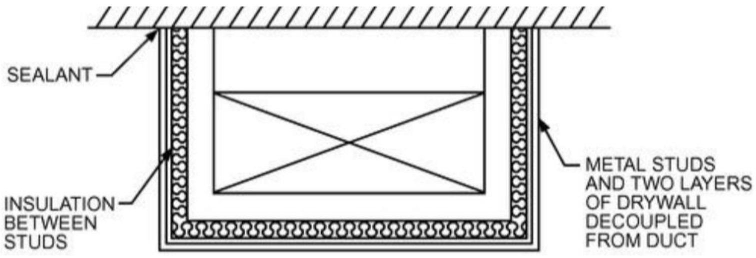
Sound levels same as manufacturer's ratings

Sound levels 12 to 15 dB higher than manufacturer's ratings

HVAC Noise Control

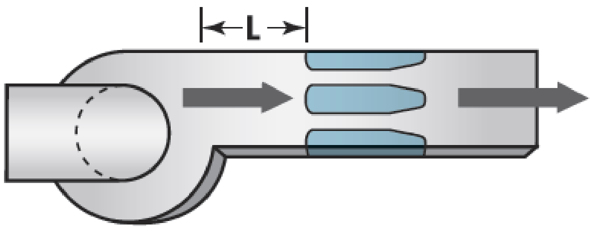
- Sound Breakout from the Ducts
- Breakout is the sound associated with fan or airflow noise inside a duct that radiates through duct walls in to the surrounding area.





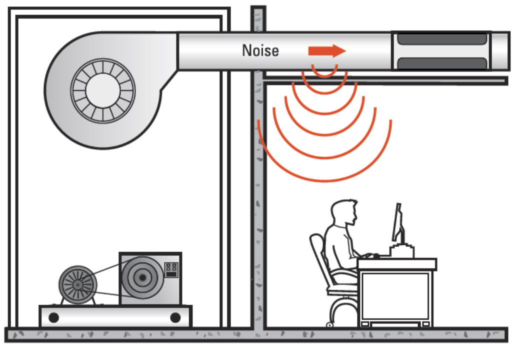
HVAC Noise Control

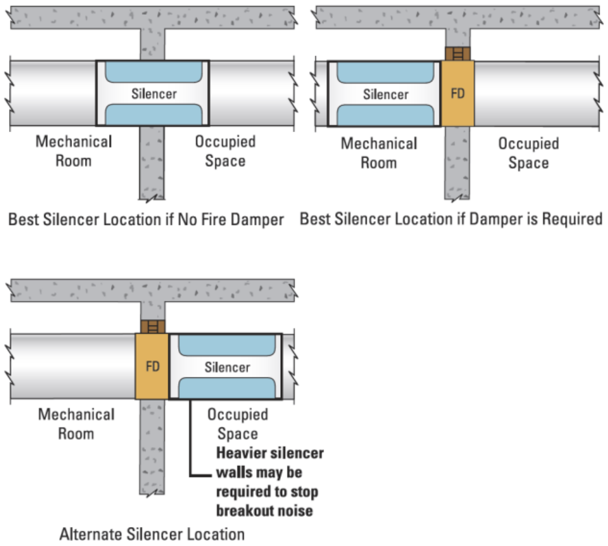
- Silencer positioning for low regenerated noise and low pressure drop



L > 3 to 4 duct diameters

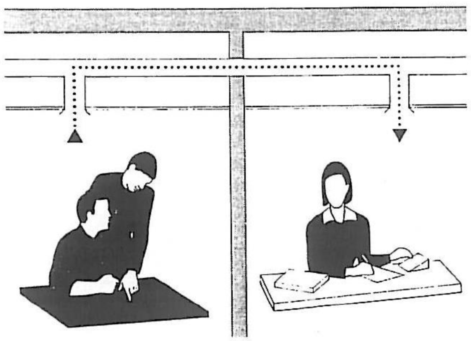
- Silencers positioning for minimizing breakout noise

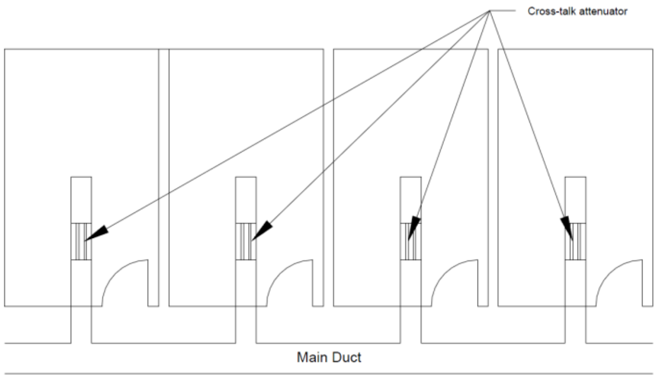




HVAC Noise Control

- Cross-talk
  When two adjacent or closely positioned rooms are sharing the same ductwork, sound travels within ducts and decrease the sound insulation dramatically.

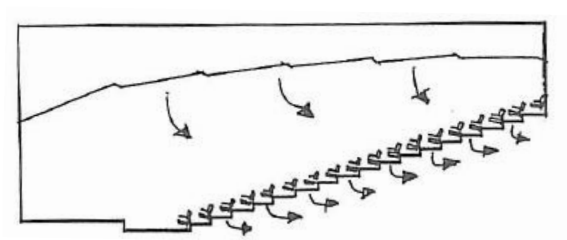
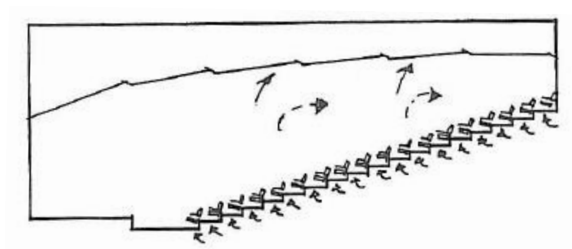
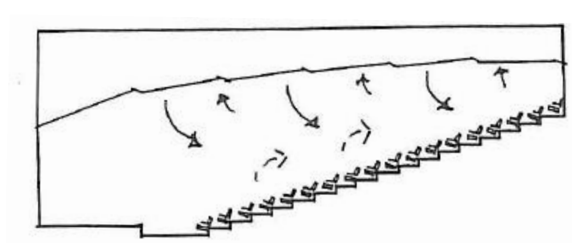




Requirement in receiver room	Attenuator Length (mm)	Noise reduction at 500 Hz (dB)
NR - NC 40	750	25
NR - NC 35	1000	30
NR - NC 30	1250	35
NR - NC 25	1500	40

Practical Design Recommendations

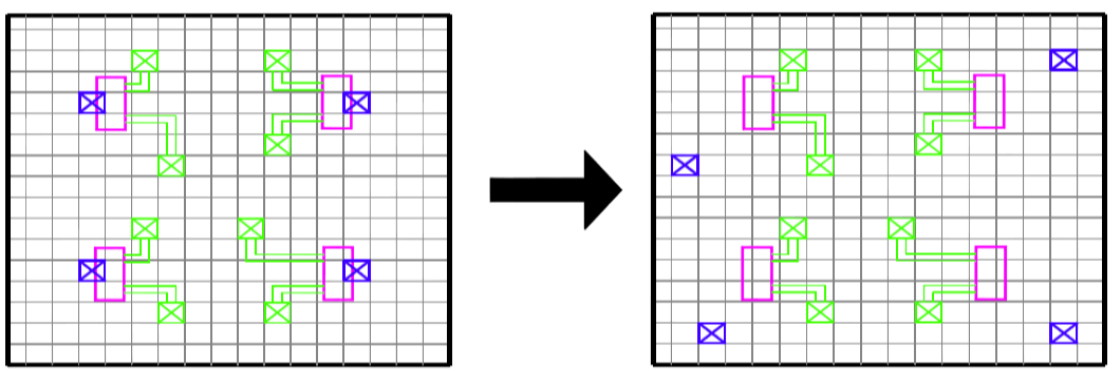
- HVAC design for Auditoriums

	Advantages	Disadvantages
Overhead supply under seat to extract to plenum 	-Lower cost	- Fights natural convection - Underseat noise break in weakness - diffucult to avoid draughts - throw and noise produced too great for concert halls
Underseat Supply, High level extract 	-Standart practice in quality halls, best for concert halls and low noise auditoria - High degree of control on airflow	- Higher cost - Suits fixed seating only
Overhead supply, high level extract 	-Suitable for flexible seating halls	- Cluttured ceiling void with both supply and extract duct runs clashing with lighting bridges - Underseat noise break in weakness - diffucult to achieve <NR25 criteria -Greater running costs/energy need

Practical Design Recommendations

- FCU Design

- Do not expect very low NR levels from a fan coil unit installation; levels lower than NR30 are generally unrealistic unless special measures are taken.
- For ceiling void units, noise from the inlet is more of an issue.
- For floor standing units, noise from the discharge of a fan coil is more of an issue.
- Use maximum number of discharge outlets possible on the unit to reduce air resistance hence the fan noise
- For ceiling void installations don't position the return grilles directly under or near the unit inlet. Badly placed return grilles can increase overall noise levels 3-4 dB.



Badly Placed (SPL 1)

Better Located (SPL 2)

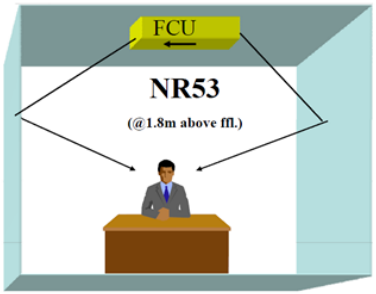
Practical Design Recommendations

- FCU Design

- False ceiling with good acoustic grade is necessary
- Filters of the units needs to be cleaned before acoustic commissioning checks on site. Fan coil units are often used for drying the building and dust in site conditions blocks the filters hence increase the noise levels.
- Beware of fresh air ducted directly to the inlet of a fan coil unit with no air break as this can impose a significant air resistance across some units.
- Minimize the air leakage from ducts since higher fan speeds is required to produce the specified duty.

Practical Design Recommendations

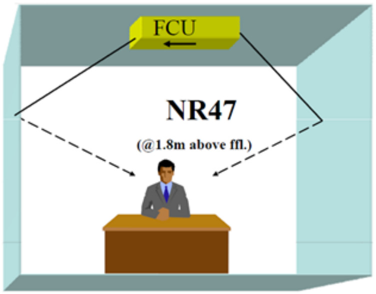
- FCU Design



Chassis unit fixed to slab

(hard room 6m x 6m x 3.2m h) FCU @ 240 l/s 30 pa

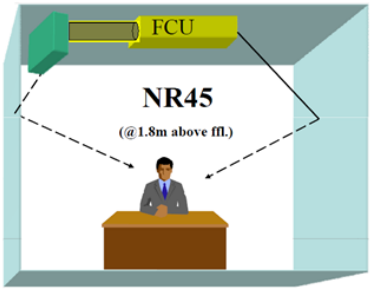
No Room absorption, No Ductwork, No Ceiling



Chassis unit fixed to slab

(Furnished room 6m x 6m x 3.2m h) FCU @ 240 l/s 30 pa

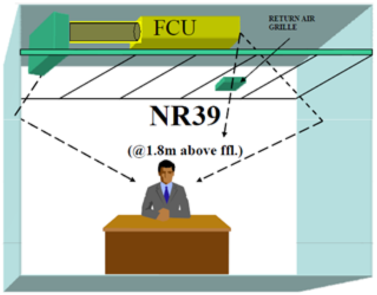
With room absorption, No Ductwork, No Ceiling



Chassis fixed to slab with acoustic discharge ductwork

(Furnished room 6m x 6m x 3.2m h) FCU @ 240 l/s 30 pa

With Room absorption, 1 m of **Acoustic** Ductwork, Plenum & Grille



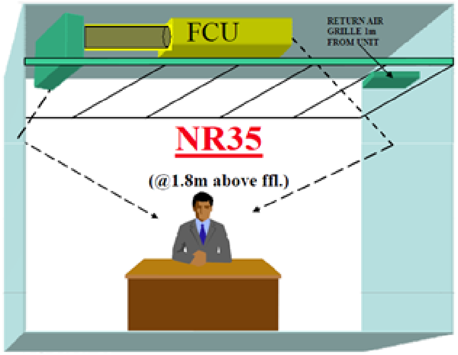
Chassis unit mounted above a false ceiling with acoustic flex discharge ductwork (poor return air position)

(Furnished room 6m x 6m x 3.2m h) FCU @ 240 l/s 30 pa

With Room absorption, 1 m of Acoustic Ductwork, Plenum & Grille, false ceiling, poor return air position just under the unit

Practical Design Recommendations

- FCU Design



Chassis unit mounted above a false ceiling with acoustic flex discharge ductwork (good return air position)

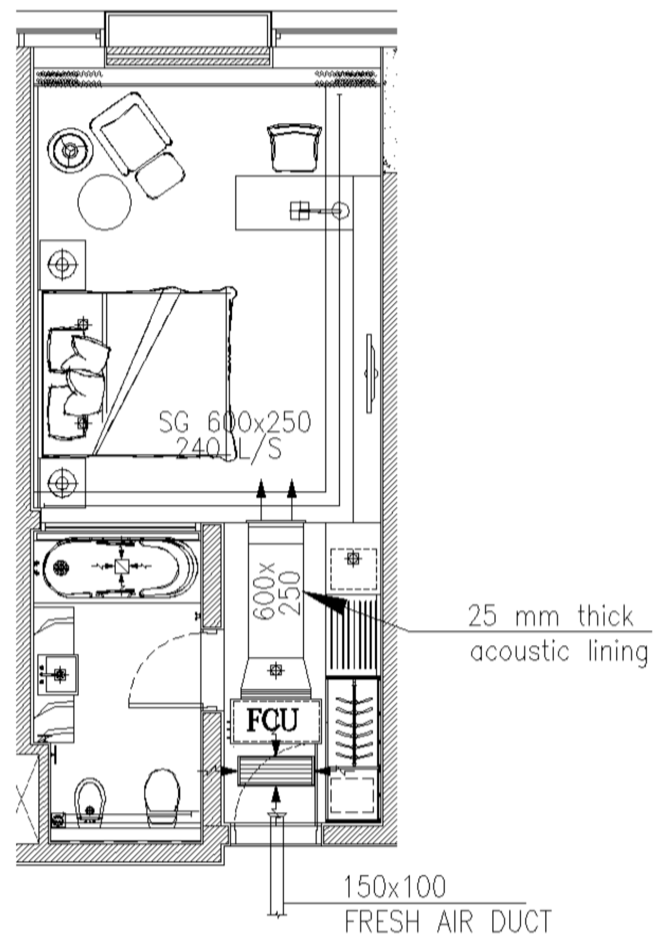
(Furnished room 6m x 6m x 3.2m h) FCU @ 240 l/s 30 pa

With Room absorption, 1 m of Acoustic Ductwork, Plenum & Grille, false ceiling, good return air position just under the unit

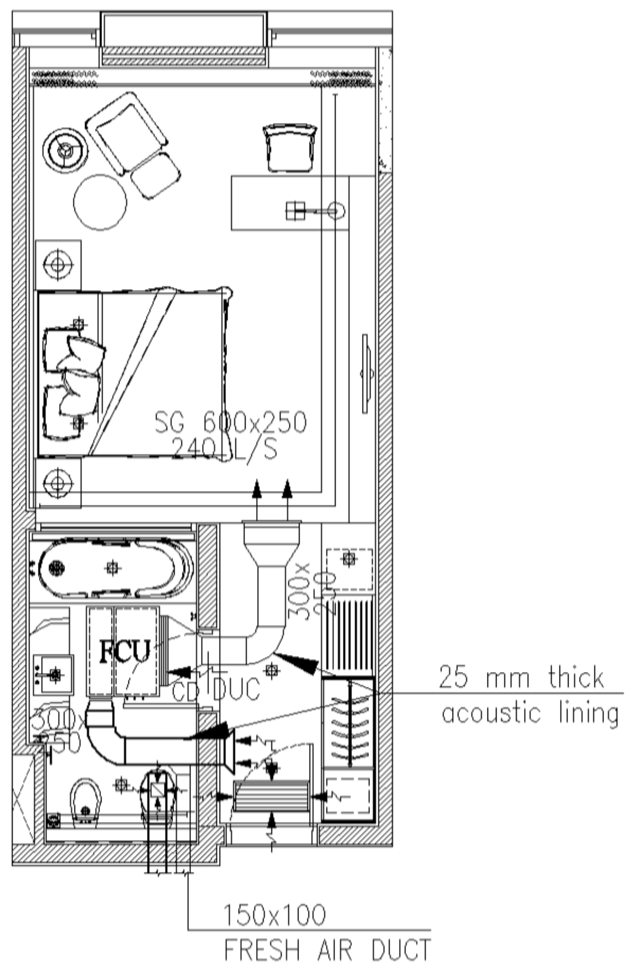
Practical Design Recommendations

- FCU Design examples for a hotel guestroom

Resultant noise ≥ NC 35



Resultant noise ≤ NC 30



Thank You, Any Questions?