Fan Coil Acoustics

Best Practice

HEVAC

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Fan Coil Acoustics - Introduction

Fan coil manufacturers manufacture fan coils, they do not make or install ductwork, grilles, diffusers or ceilings – the other components that are critical to system noise.

However, in selling fan coils, it has become common practice for fan coil manufacturers to specify acoustic installation requirements, and base installation noise predictions on that specification.

It is therefore important that the key aspects of a complete system are widely understood and correctly applied on site.

The purpose of this document is to highlight those system components, the effect they can have, and the associated pitfalls that can occur, especially in relation to small scale projects.

Key points to note are:

There is no industry standard for NR predictions.
Acoustic assumptions have to be made which affect the specification of other equipment / subcontract work.
The spacing of the units affects the resulting noise level.
Ceiling attenuation is crucial.
Discharge duct attenuation is more important than inlet attenuation.
The fabric of the served environment affects the resulting noise level.

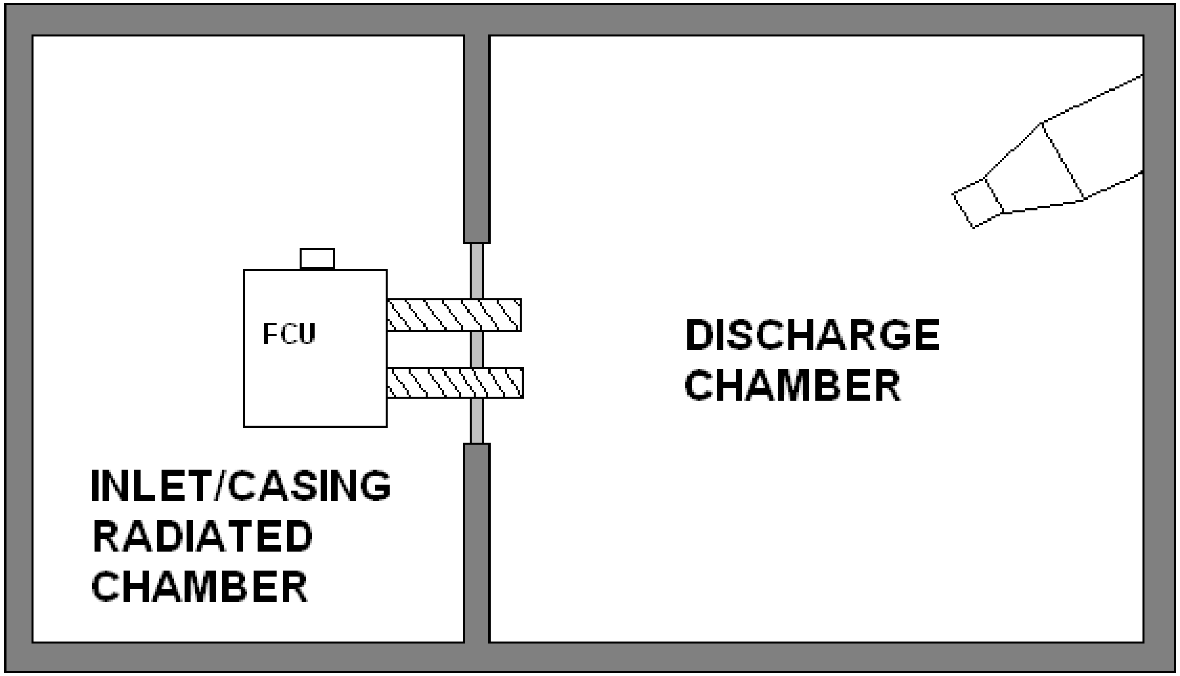
Fan Coil Testing

Factory 'type' testing is carried out in accordance with :

BS EN 16583:2015 Heat exchangers – Hydronic room fan coil units – Determination of the sound power level.

- The FCU is mounted within a reverberant chamber and ducted via spiral ducting into another chamber.
- The room Background and Reverberant time is measured across the octave centre frequencies (usually 63Hz, 125Hz, 250Hz, 500Hz, 1KHz, 2KHz, 4KHz and 8KHz).
- The unit is switched on and the voltage to the fan is controlled remotely. The air velocity is measured using a pitot tube traverse in each duct to determine the total air volume.
- The external pressure is regulated via dampers on the air inlet or discharge of the reverberant chamber.
- The voltage and dampers are varied to achieve the desired air volume against design external pressure.
- The sound pressure levels (SPL) are measured at the above frequencies. The Inlet/Casing Radiated Sound Power Level (SWL) in one chamber and Discharge SWL in the other can then be calculated.

Layout of Reverberant Test Chambers



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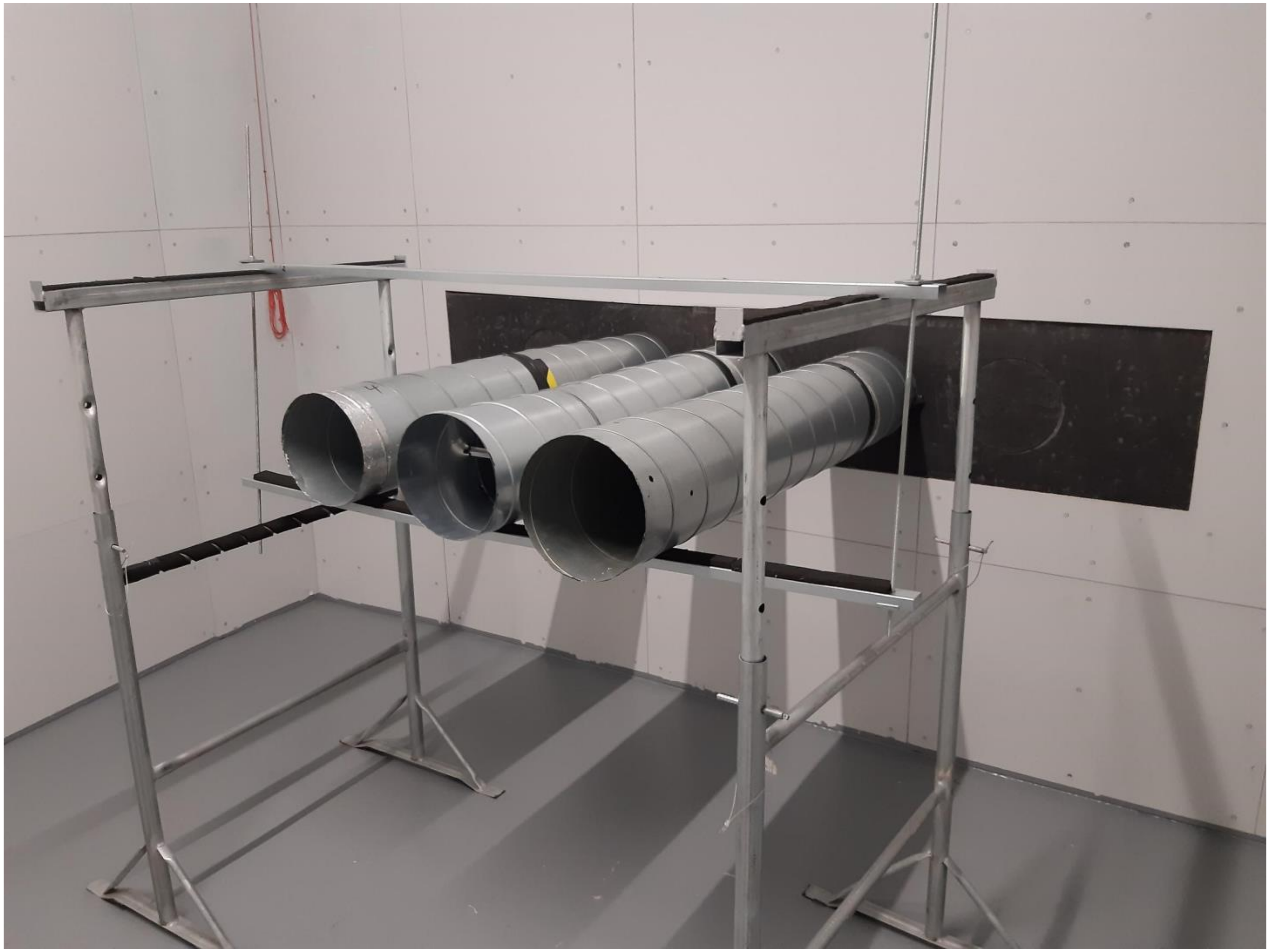
Fan Coil Noise Test Installation – Inlet and Casing Radiated sound measurement

Fan Coil Noise Test Installation – Discharge sound measurement



Installation features and the effect on resultant noise.

The installation built up over the next few pages is a horizontal ceiling slab suspended fan coil unit in a cellular office. The unit is installed with circular discharge duct, rectangular plenum and linear slot diffuser. The office walls and floor are initially hard surfaces, and subsequently carpets and other softening items are introduced. The suspended ceiling system is a 600mm square grid with fibre or insulated metal pan tiles. Correct and incorrect return air path design is indicated. Along the way, common pitfalls are identified in the panel on the right of the page.

The stated NR noise levels are for comparison before and after the addition of system components, and actual NR values will vary depending on other variables such as the design and selection of the fan coil and the size/shape of the room.

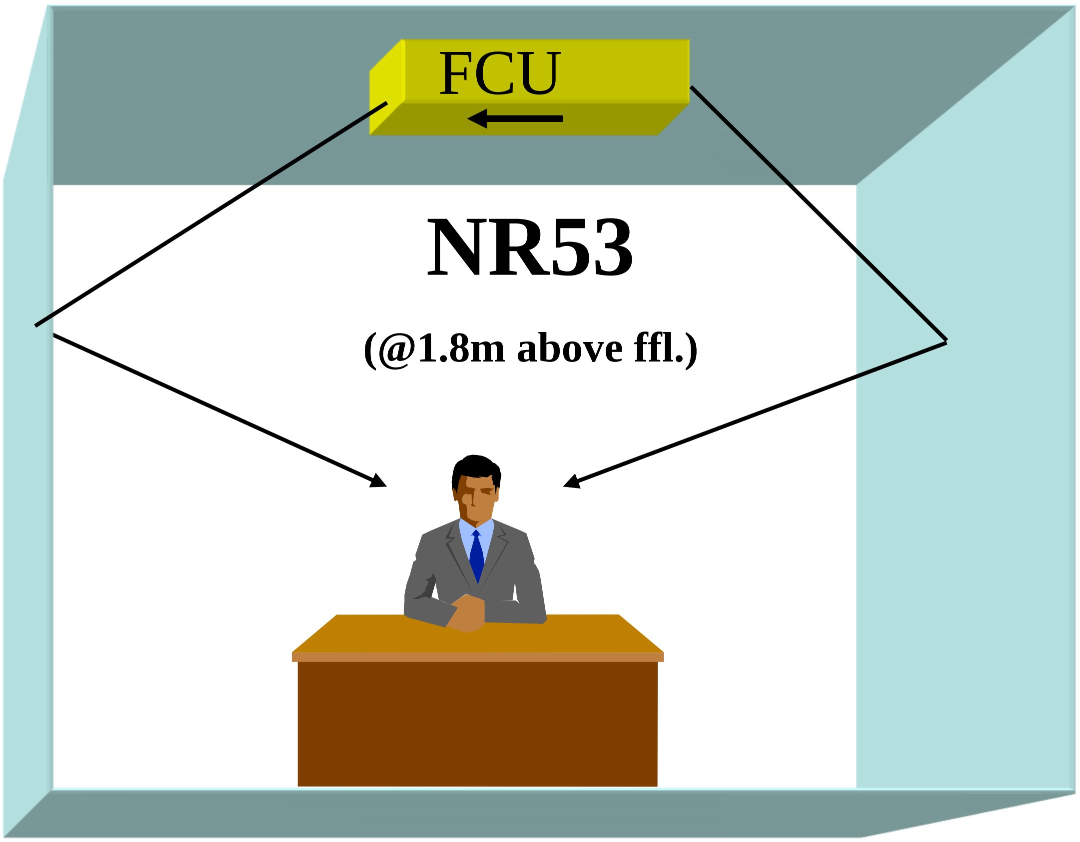
Multiple Sound Sources

The more dominant noise sources are indicated in each view. As a rule of thumb, two noise sources of the same magnitude and frequency characteristic, experienced very near to each other, will add together to produce a resultant level 3db higher than the greater of the two noises. This is true for two fan coils very close together, and to a lesser extent for two sources – inlet and outlet - from one fan coil.

For two noises which differ by 5db, the resultant is 1db greater than the loudest original source.

For two noises which differ by 10db, only the greater noise source is experienced.

NR Prediction 1 - Chassis unit fixed to slab (Hard room 6m x 6m x 3.2m h)



Watch out for :-

Hard faced walls and floors, large areas of glazing.

Adjacent similar noise sources add together.

All FCU in a common space should be a similar noise selection, or the loudest might annoy, even if within specification.

FCU @ 240 l/s & 30 Pa
No Room absorption
No Ductwork
No Ceiling

To demonstrate how the different components affect the finished NR level , we have built a room, and then add attenuating items one at a time.

When we calculate what the NR level will be without room absorption, ductwork or ceiling, the result is a very high NR53 when measured at head height

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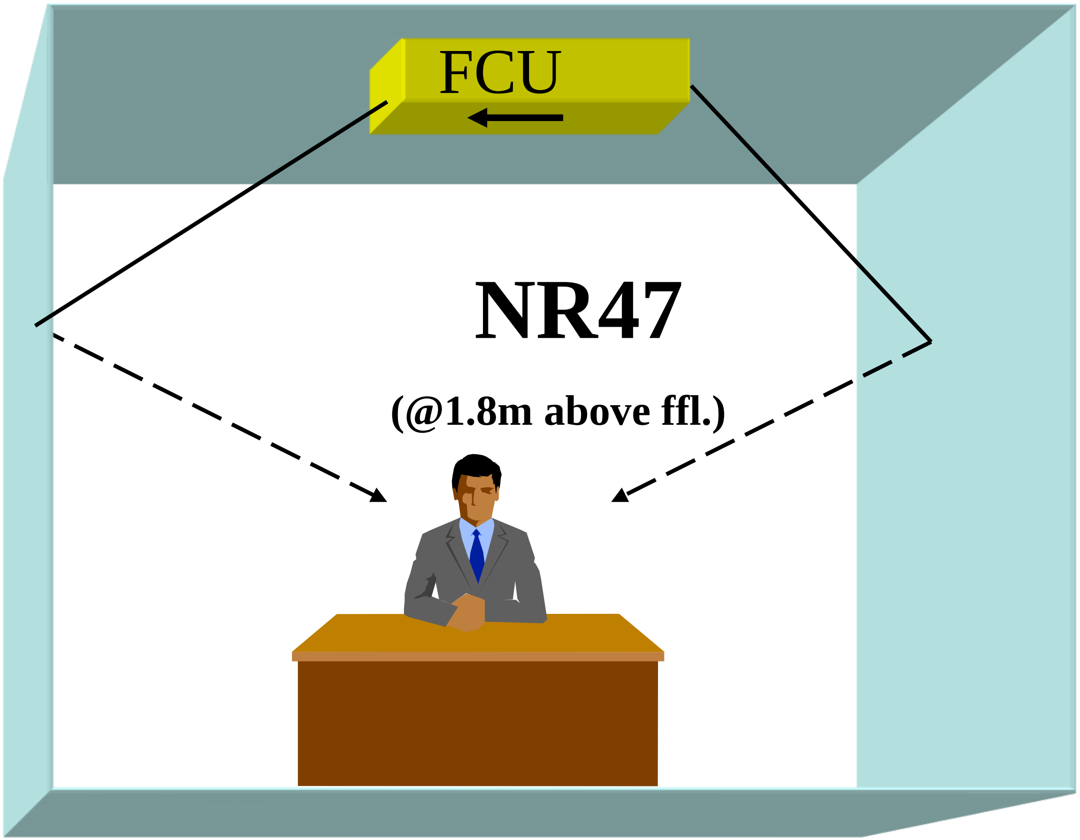
NR Prediction 2 - Chassis unit fixed to slab (Furnished room 6m x 6m x 3.2m h)



Watch out for :-

Dirty filters at time of commissioning.

Higher fan voltage = higher noise.

Other sound sources – fresh air duct, external noise and other plant generated noise.

FCU @ 240 l/s & 30 Pa
With Room absorption
No Ductwork
No Ceiling

Room Absorption (or room effect) resulting from softer surfaces such as carpet, blinds, fixtures and fittings, can reduce the noise level experienced by 6NR

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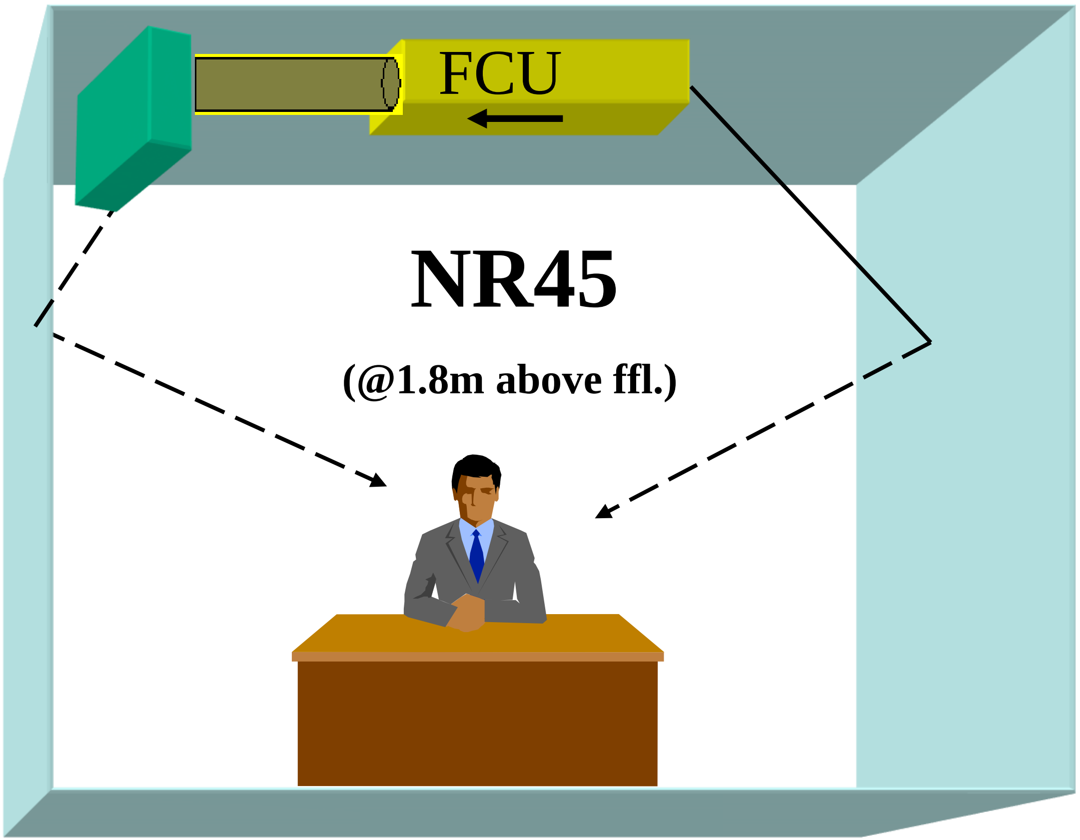
NR Prediction 3 - Chassis unit fixed to slab with acoustic discharge ductwork



FCU @ 240 l/s & 30 Pa
With Room absorption
1 m of Acoustic Ductwork,
Plenum & Grille
No Ceiling

If 1m of acoustic flex and a diffuser is added then a further 2NR comes off the noise level. However all this is doing is attenuating the discharge side of the unit, the dominant noise level is coming from the open casing and inlet of the FCU.

Watch out for :-

Duct leaks and poor air measurement technique, resulting in fans moving more air than is apparent.

Duct leaks also allow noise to bypass attenuating components, and generate high frequency noise.

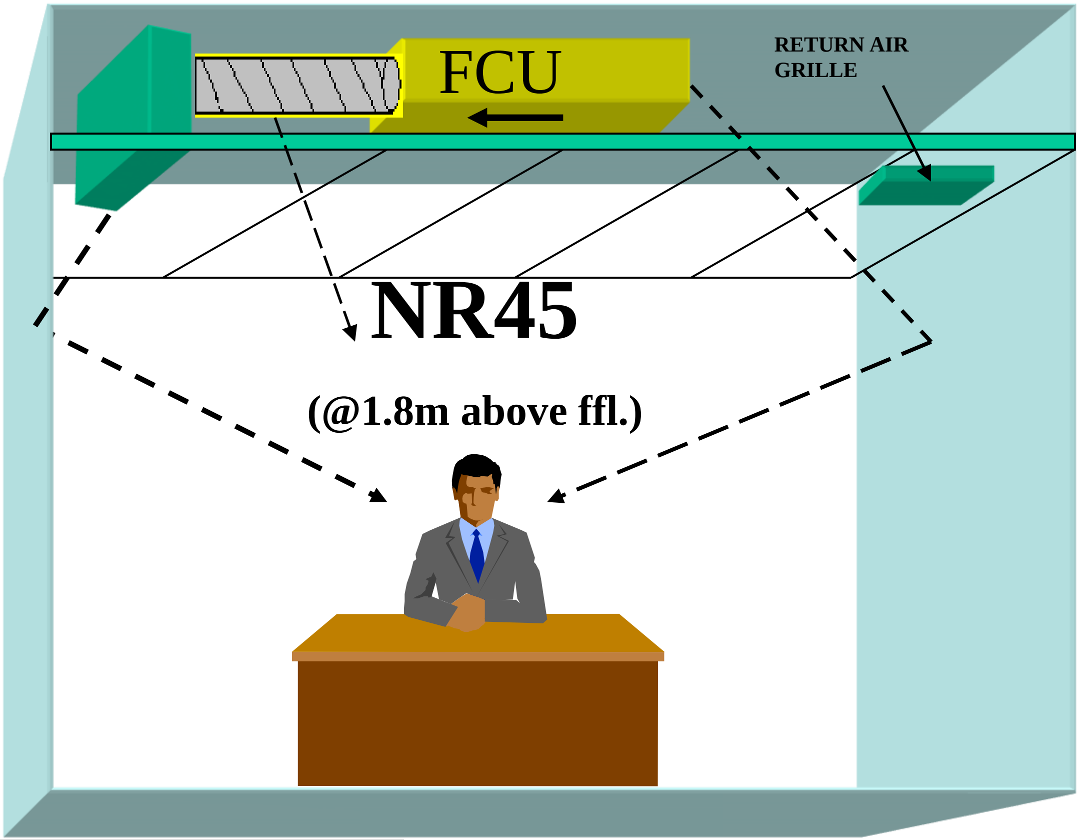
Quantity of duct connections sufficient for total air volume, recommended duct velocity of 3 m/s.

Duct length causing excessive pressure drop.

Volume commissioning should be achieved with fan speed voltage, not with discharge dampers

Higher fan voltage = higher noise.

NR Prediction 4 – Chassis unit mounted above a false ceiling with spiral discharge ductwork



Watch Out For:-

Noise breakout through duct wall.

Poor plenum air entry design generating noise.

Un-insulated plenums installed, where design is based on insulated ones.

FCU @ 240 l/s & 30 Pa
With room absorption
1 m of spiral ductwork, plenum & grille
With 10mm insulated pan tile ceiling.

To demonstrate that both ends of the fan coil need attenuating, we have now installed a false ceiling with insulated pads above each tile, this provides a good level of attenuation to the Casing / Inlet of the FCU.

However we have swapped the acoustic flex for spiral, this has little or no attenuation properties and allows noise transmission through the duct wall. The result is a still unacceptable NR45.

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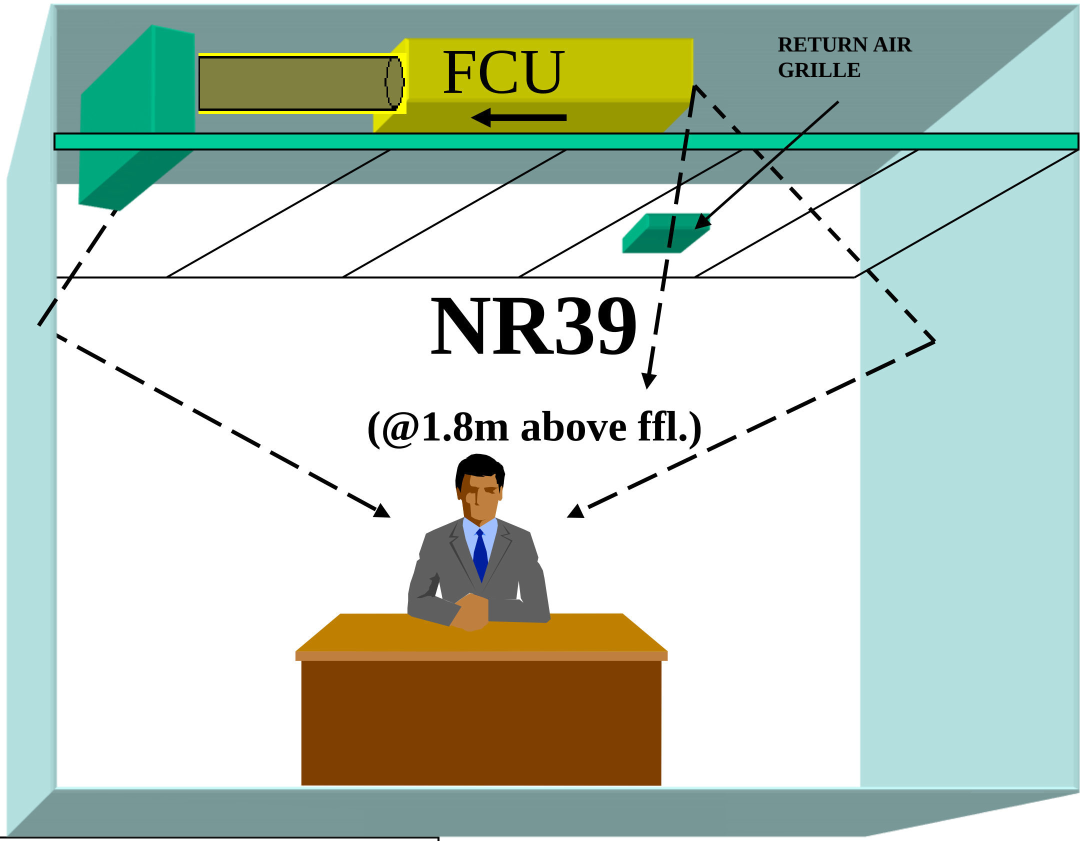
NR Prediction 5 – Chassis unit mounted above a false ceiling with acoustic flex discharge ductwork (Poor return air position)



Watch Out For :-

Return air grille too close to fan coil inlet, allowing direct transmission of casing/inlet noise.

Inadequate return air path area / grille size causing extra fan effort.

FCU @ 240 l/s & 30 Pa
With room absorption
1 m of acoustic ductwork, plenum & grille.
With insulated metal pan ceiling.

An inadequate return air grille (causing increased fan effort) placed immediately under the unit inlet allowing direct transmission of noise also returns the room to unacceptable NR levels.

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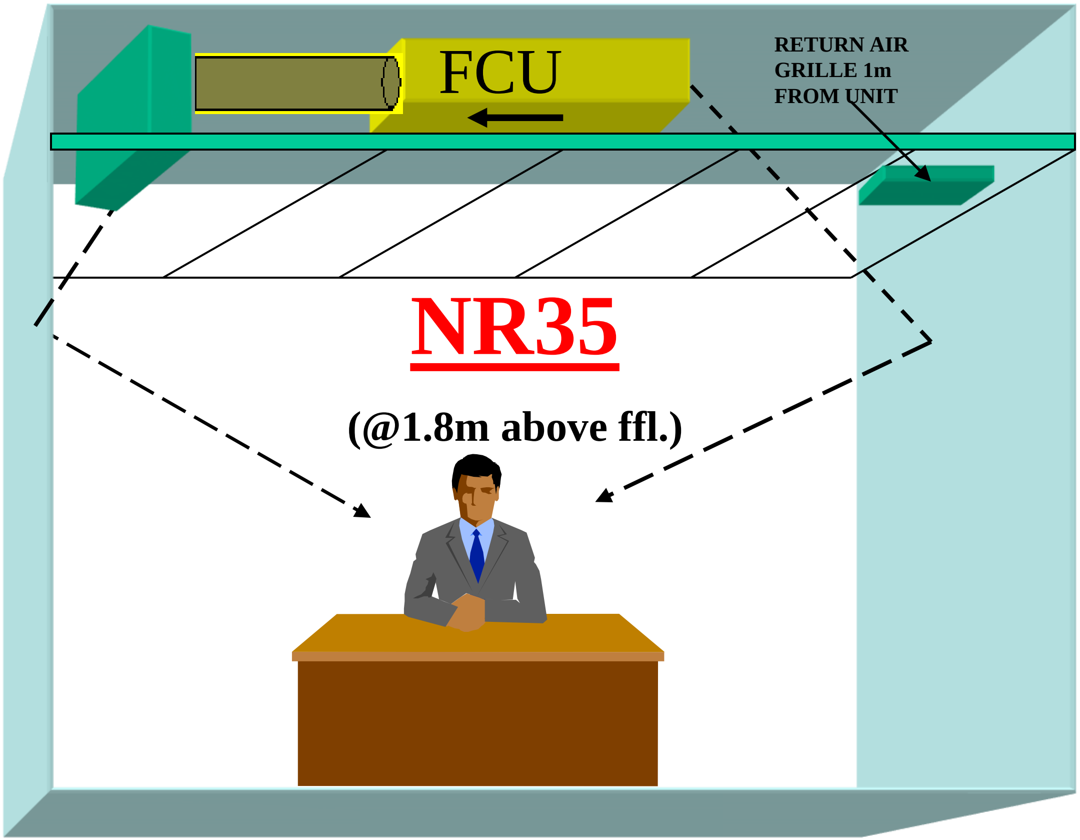
NR Prediction 6 – Chassis unit mounted above a false ceiling with acoustic discharge ductwork – Recommended Installation



Watch Out For :-

Poor ceiling fit and finish, missing tiles, poor ceiling tile specification.

Bends or collapse in flexible connections restrict air flow causing unnecessary fan effort and noise.

If ductwork has to route through or under beams, ensure sufficient duct area is used to reduce duct velocity to below 3m/s.

FCU @ 240 l/s & 30 Pa
With room absorption
1 m of acoustic ductwork, plenum & grille.
With 10mm insulated pan tile ceiling.

Once the inlet and casing of the unit is attenuated by the ceiling, the measured NR comes down to an acceptable level. This is because both sides of the unit are now acoustically treated.

The example ceiling has an insulated metal pan tile ceiling, but the same figures can be used for fibre board tiles

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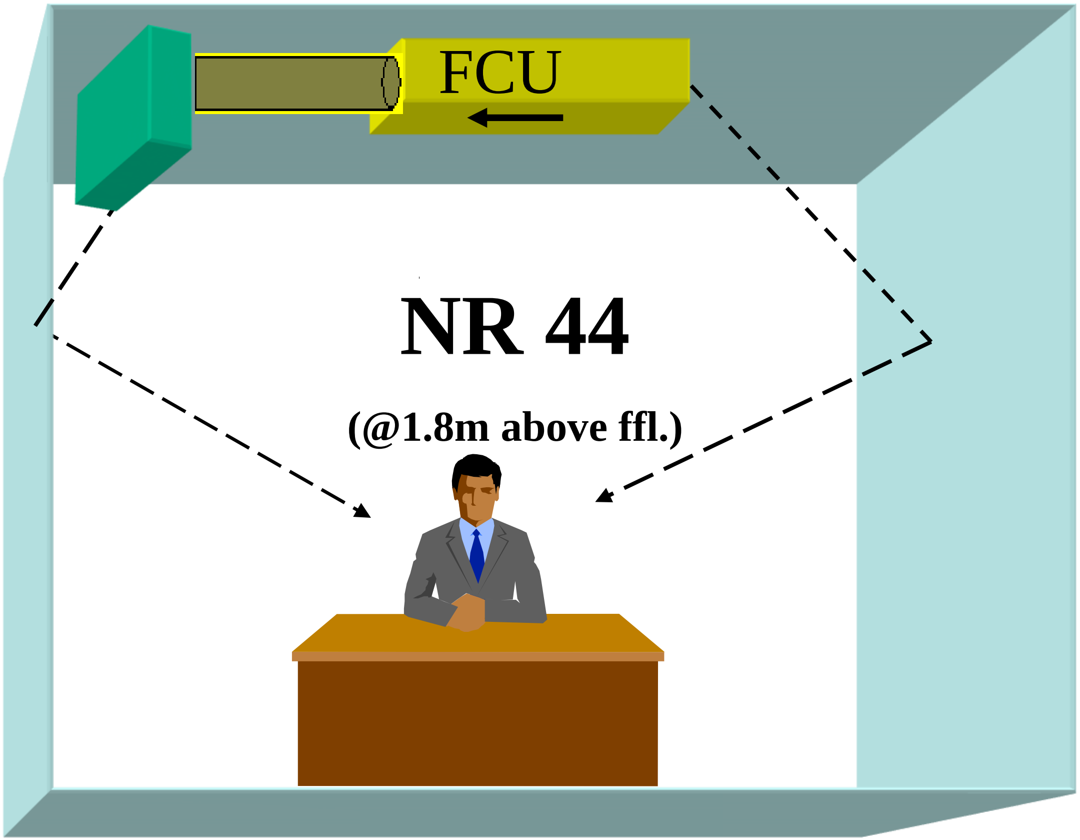
NR Prediction 7 – Chassis unit "exposed" with acoustic discharge ductwork



Watch Out For :-

The inlet noise will be dominant, followed by the case radiated.

Placing an acoustic raft underneath the fan coil footprint will have minimal effect.

FCU @ 240 l/s & 30 Pa
With room absorption
1 m of acoustic ductwork, plenum & grille.
With No ceiling.

The inlet and casing of the unit is not attenuated by the ceiling, the measured NR level increases to an unacceptable level. This is because the inlet side is not acoustically treated.

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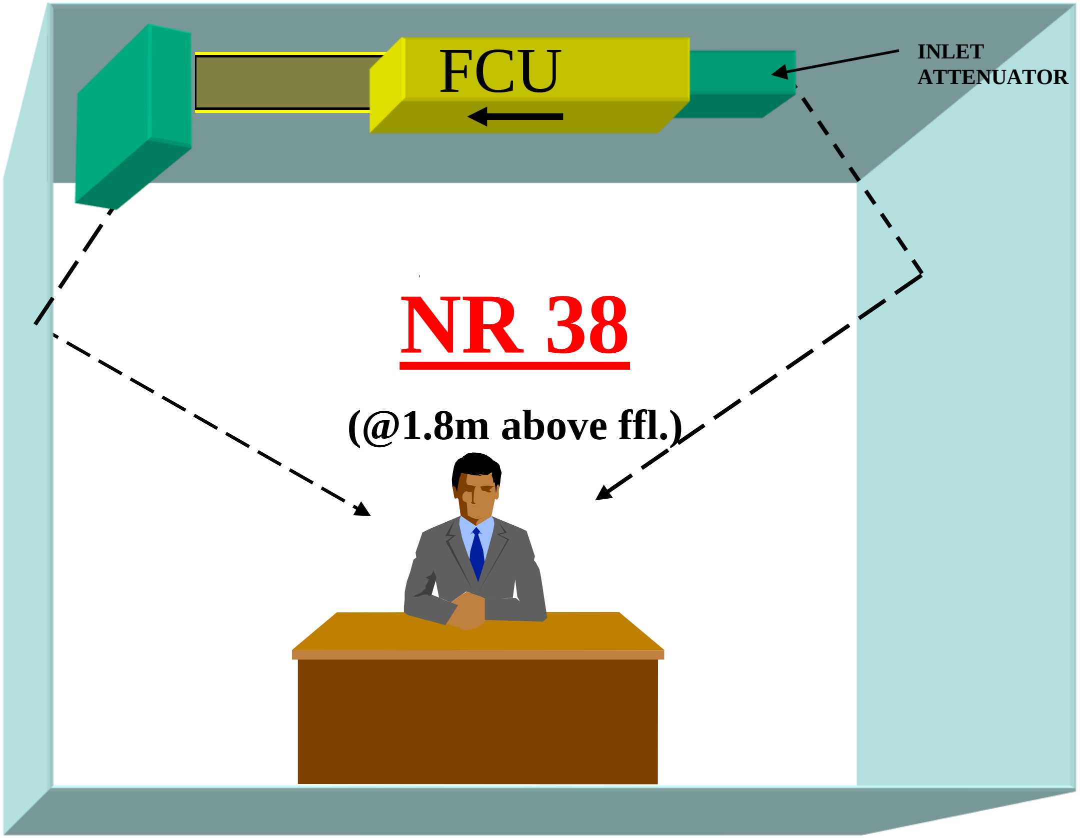
NR Prediction 8 – Chassis unit "exposed" with acoustic discharge ductwork and an inlet attenuator



Watch Out For :-

Bends or collapse in flexible connections restrict air flow causing unnecessary fan effort and noise.

If ductwork has to route through or under beams, ensure sufficient duct area is used to reduce duct velocity to below 3m/s.

FCU @ 240 l/s & 30 Pa
With room absorption
1 m of acoustic ductwork, plenum & grille.
With inlet attenuator.

Once the inlet of the unit is attenuated by the attenuator, the measured NR comes down to a more acceptable level. This is because both sides of the unit are now acoustically treated.

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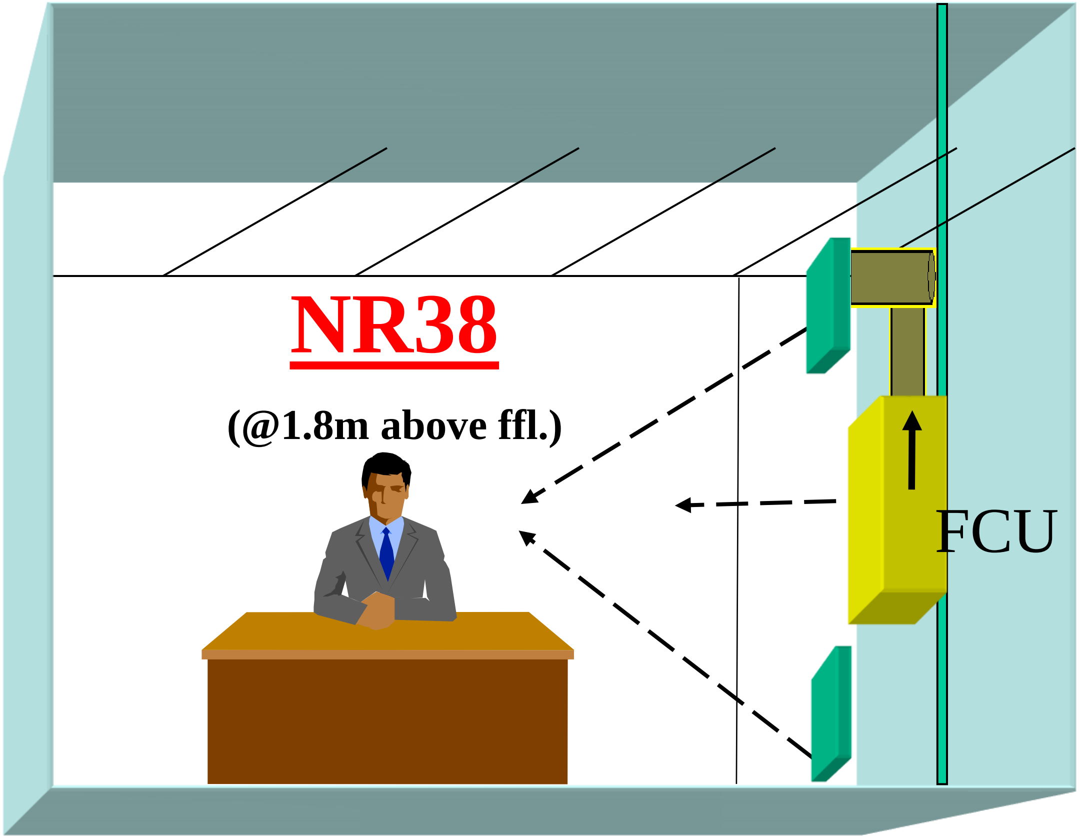
NR Prediction 9 – Vertical unit mounted behind a partition wall with acoustic discharge ductwork



Watch Out For :-

Restrictions in ductwork, attenuators, sharp bends, limited grille area which will increase external static pressure.

Bends or collapse in flexible connections restrict air flow causing unnecessary fan effort and noise.

Partition wall sound reduction index will need to be evaluated.

If ductwork has to route through or under beams, ensure sufficient duct area is used to reduce duct velocity to below 3m/s.

Access for maintenance

FCU @ 210 l/s & 30 Pa
With room absorption, ductwork, plenum & grille.

Note, lower air volume due to lower on coil temp. Generally lower cooling performance if vertical FCU are compared with horizontal ceiling mounted FCU.

Potentially both sides of the unit will require acoustic treatment.

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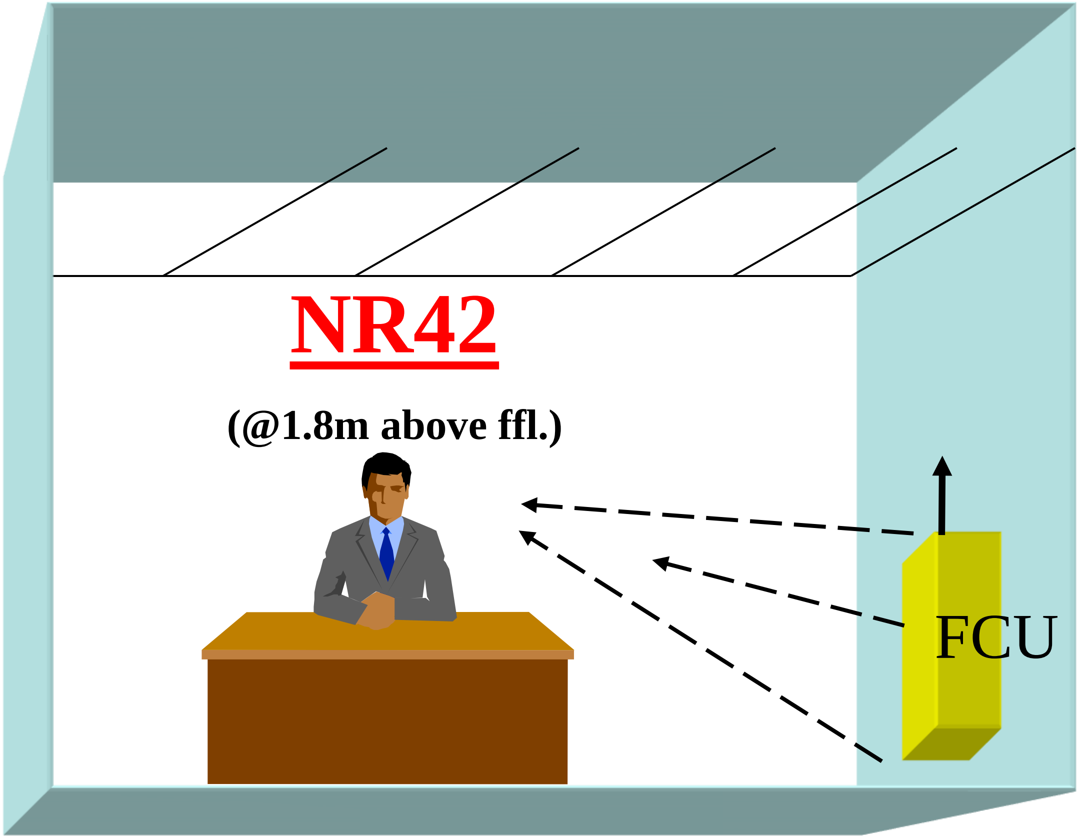
NR Prediction 10 – Cased Vertical unit in a room



Watch Out For :-

Location, especially that there is sufficient return air path.

Position of ChW, LTHW valves, pipes & condensate routes.

Access for maintenance

FCU @ 210 l/s & 0 Pa
With room absorption.

Note, lower duties due to the lack of acoustic attenuation. Applications where acoustics is not important such as server rooms, back of house & receptions areas.

Also commonly used in hotels and under window applications in offices (refurbishments) where acoustics can be an issue.

Can be installed at high level.

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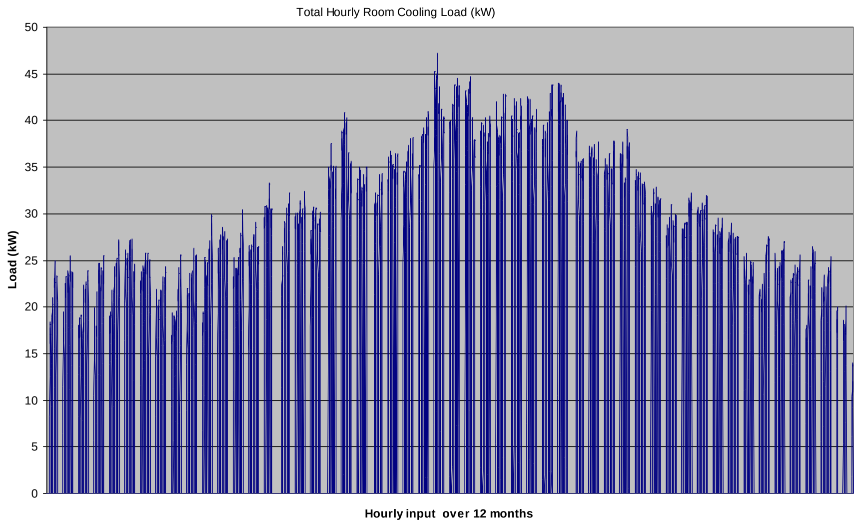
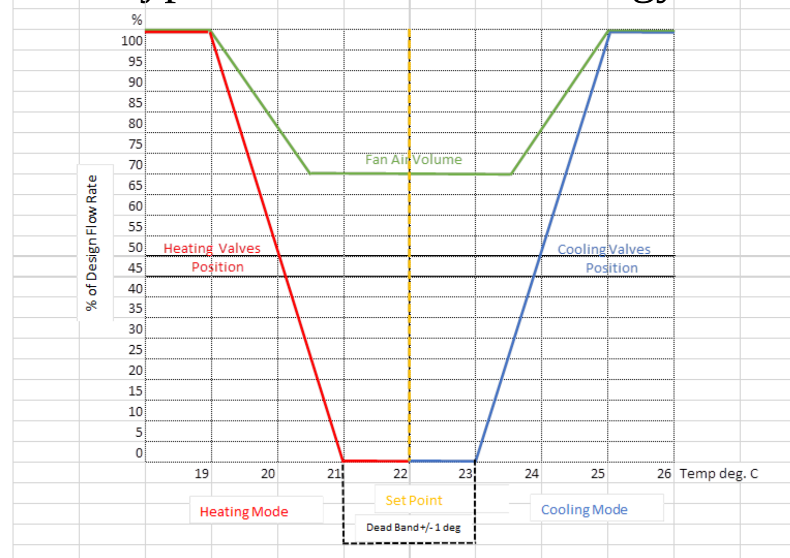
Variable Air Volume Operation

Typical Base building cooling load



Typical VAV fan coil strategy



EC motors enable a form of 'variable air volume' (VAV) control, where a BMS system, or similar, can modulate the airflow rate, as well as water flow rate, between a present maximum and minimum air volume flow rate to meet the actual heating or cooling demand thus saving energy, reducing noise and increasing life expectancy.

For variable speed FCU's, some relaxation may be appropriate for worst case conditions (up to +5dB relaxation at maximum design duty) to avoid overdesign, provided the criteria are achieved under normal conditions.

Watch Out For :-
Air dumping from the air terminal device at Vmin.
Building services noise levels are critically important in providing masking of transferred noise and hence privacy.
If the proposed building systems cannot provide reliable background levels, the use of electronic sound masking systems should be considered.

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Quoted Sound Power Levels

It is normal to quote Octave band sound power levels in the octaves 63Hz to 8KHz for "Discharge" and combined "Inlet + case radiated" levels.

Discharge sound power levels

It is important to clarify the status of the quoted levels as they can be numerically different . These can either be;

1. **In duct** (Radiated + Duct end correction E).
2. **Radiated**

Here there are two possibilities;

2.1. Flush which gives a hemispherical radiation (2π)

2.2. Free field which gives spherical radiation (4 π)

When comparing quoted sound power levels, it is normal to use the in-duct value as this is independent of the discharge configuration

Inlet + case radiate sound power levels

Measurement of these levels can be undertaken as described in BS EN 16583:2015 using Figure 12 - Typical installation for measurement of discharge sound level on the right side and free inlet + sound radiated by the case on the left side

Duct end correction.

As the sound level is conveyed by one or several ducts, the sudden acoustic impedance change at the free end of the duct creates a reflection of the sound in the duct, the sound transferred to the measurement space being reduced. The duct end correction shall then be applied to take into account this reflection effect, giving the sound power level travelling in the duct.

Quoted Sound Power Levels

BS EN 16583:2015 Heat exchangers - Hydronic room fan coils units - Determination of the sound power level Paragraph 6.3.2.5 Duct end correction gives full details of the correction process. The calculation is based on

$$E = 10\lg\left[1 + \left(\frac{c}{4\pi f}\right)^2 \frac{\Omega}{S}\right]$$

Where

c the speed of sound (m/s);

f octave band centre frequency (Hz);

S section of duct opening in the measurement space (m^2);

Ω solid angle of the radiation field;

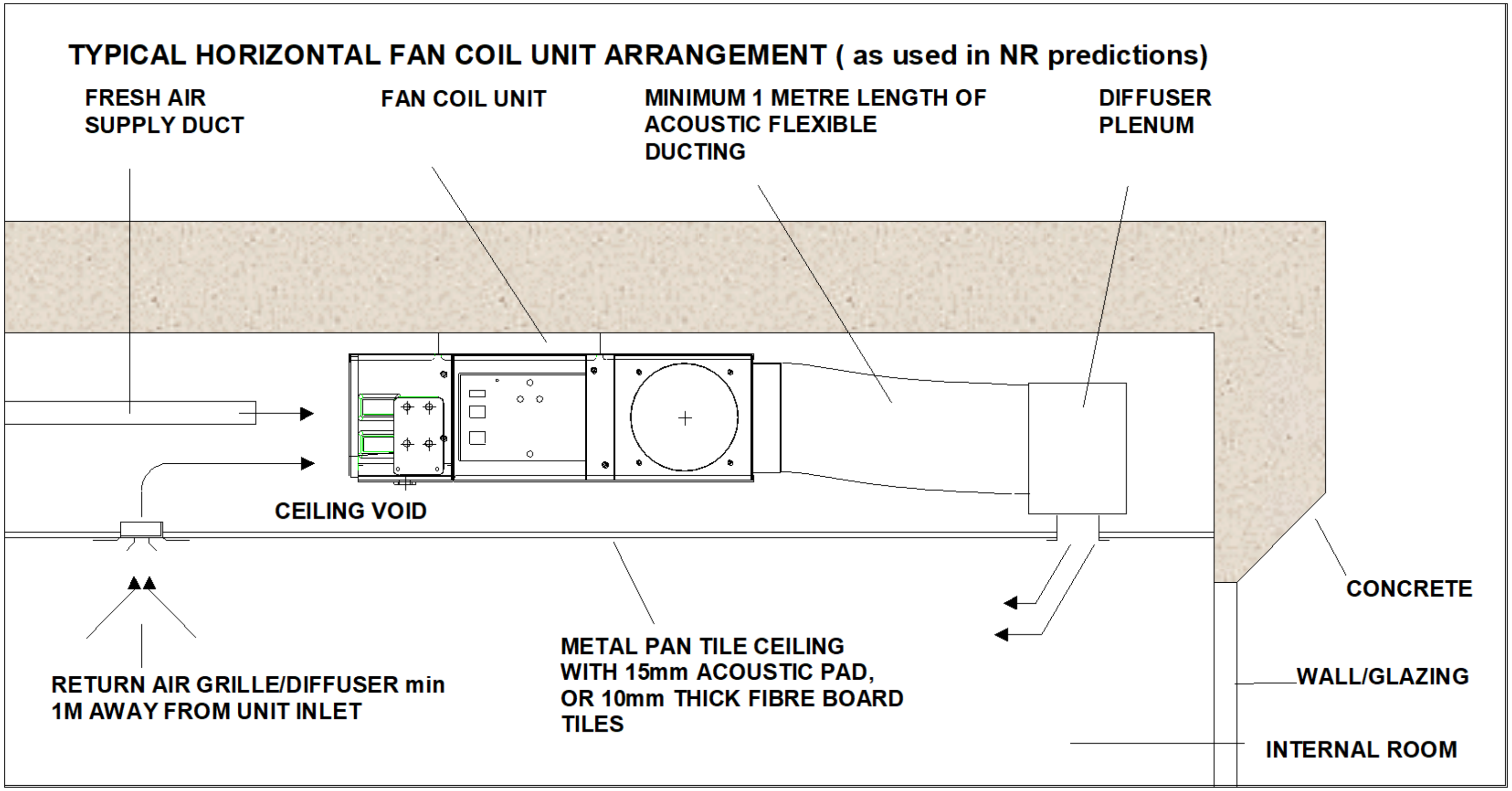
2π for flush termination (hemi spherical);

4π for free termination (spherical).

SPIGOT SIZE		*E* – Corrections to be added to radiated levels to obtain in-duct sound power levels.							
	OCTAVE BANDS	63	125	250	500	1K	2K	4K	8K
200mm Dia	HEMI SPHERICAL RADIATION	16	10	5	2	1	0	0	0
	SPHERICAL RADIATION	19	13	8	3	1	0	0	0
250mm Dia	HEMI SPHERICAL RADIATION	14	9	4	1	0	0	0	0
	SPHERICAL RADIATION	17	11	6	2	1	0	0	0
WxH 800x200mm	HEMI SPHERICAL RADIATION	9	5	2	0	0	0	0	0
	SPHERICAL RADIATION	12	7	3	1	0	0	0	0
WxH 1400x200mm	HEMI SPHERICAL RADIATION	7	3	1	0	0	0	0	0
	SPHERICAL RADIATION	10	5	2	1	0	0	0	0

Final Sound power level *Lw* in-duct = *Lw* measured outside + *E*

Acoustic Installation Summary



To ensure that the installed noise levels achieve the suppliers quotations, many manufacturers include an installation specification like this, to ensure that the units are not installed into non-standard applications. Follow best practice and the final system will achieve the specified noise performance.

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Conclusion

For Economic Fan Coil Selection

- Use acoustic flex on the discharge of unit.
- An Insulated ceiling is part of the system.
- Fan speed = Fan voltage = Unit noise. Minimise duct resistance and use speed control to match performance by varying demand.
- Reduce FCU oversizing by using Best Acoustic Practice

Glossary

- **FCU** - Fan Coil Unit – A packaged air conditioning unit consisting of an inlet filter, chilled water and hot water heat exchange coil, fan and discharge plenum
- **SWL**- Sound Power Level –Expressed a relation to the threshold of hearing –*10^{-12}Watts or 0.000000000001Watts* in a logarithmic scale named sound power level

  $L_{w,} = 10 \log (N/N_0)$expressed as

  L_w = *Sound Power Level in Decibels (dB)*

  N = sound power (W)

  $N_0 = 10^{-12}$ *- reference sound power (W).*

  i.e A quiet office has a SWL of = 10log $(10^{-7}/10^{-12}) = 50\ L_w$

- **SPL** – Sound Pressure Level is the force (*N*) of sound on a surface area (*m^2*) perpendicular to the direction of the sound. The SI-unit for the Sound Pressure is *N/m^2* or *Pa*.

  Sound is usually measured with microphones responding proportionally to the sound pressure - *p*. The power in a sound wave goes as the square of the pressure.

  The log of the square of x is just 2 log x, so this introduces a factor of 2 when we convert to decibels for pressures.

  The lowest sound pressure possible to hear is approximately *$2\ 10^{-5}$ Pa (20 micro Pascal, 0.02 mPa)*, 2 ten billionths of a an atmosphere.

  It therefore convenient to express the sound pressure as a logarithmic decibel scale related to this lowest human hearable sound - *$2\ 10^{-5}$ Pa, 0 dB.*

  The Sound Pressure Level:

  $L_p = 10 \log(p^2 / p_{ref}^2) = 10 \log(p / p_{ref})^2 = 20 \log (p / p_{ref})$

  where

  L_p = *sound pressure level (dB)*

  p = sound pressure (Pa)

  $p_{ref} = 2\ 10^{-5}$ *- reference sound pressure (Pa)*

- **dB** – Decibel is a logarithmic unit used to describe the ratio of the signal level - power, sound pressure, voltage or intensity or several other things.

  The decibel can be expressed as:

  decibel $= 10 \log(P / P_{ref})$

  where

  P = signal power (W)

  P_{ref} *= reference power (W*

- **Hz** – The **hertz** (symbol: **Hz**) is the (SI) unit of frequency. It is defined as the number of complete cycles per second.

Optional Reading

- Noise Control in Building Services – Sound Research Laboratories Ltd
- CIBSE Guide TM43 - Fan Coil Units
- British Council of Offices (BCO) guide
- CIBSE Guide F
- BSRIA TG 20/2021 Noise in the Built Environment