Fan Coil Unit Acoustics & Room Noise Levels

1. Introduction

The selection of fan coil units is governed not only by thermal or air volume flow rate requirements, but also by any constraints on the level of noise permitted in the room. Frequently, the manufacturer is required to select fan coil units based on the predicted noise levels in the room as a result of the fan coil unit application, however these are influenced not only by the fan coil unit but also by the room itself. During the preliminary design stages, not all the room conditions may be known but certain assumptions allow the room noise levels to be approximated.

2. Sound Pressure Level

The human ear reacts to fluctuations in air pressure caused by sound. The level of sound heard by the human ear (and measured by an acoustic meter) is known as the sound pressure level (SPL). The ear reacts logarithmically over a very broad range of sound levels and therefore sound pressure levels are quantified on a logarithmic scale relative to a reference sound pressure. They are measured in decibels (dB) above the pressure corresponding to the threshold of hearing for a typical human ear.

Sound pressure level (SPL) is given by.. $SPL = 20 \log_{10} P / Pr$

where P = sound pressure being measured (Pa)

Pr = sound pressure reference i.e. limit of hearing (2×10^{-5} Pa)

3. Sound Power Level

In generating sound, the source will expend energy. The rate of transfer of acoustic energy from the source to the medium though which the sound is transmitted is known as the sound power level (SWL). In a similar manner to sound pressure levels, sound power levels are measured on a logarithmic scale, in dB above the power corresponding to the threshold of hearing for a typical human ear.

Sound power level (SWL) is given by.. $SWL = 10 \log_{10} W / Wr$

where W = sound power of source (W)

Wr = sound power reference (1×10^{-12} W)

4. Frequency & Octave Band Spectra

Sound is oscillatory in nature and the speed of oscillation is measured as a frequency in Hertz (Hz). In practice, virtually all sound consists of components at different frequencies; each component has a sound power level at its relevant frequency. The human ear is sensitive to sound with a frequency between 30Hz and 20kHz. Since frequency is a continuous variable, sound levels (both SPL and SWL) are grouped in frequency bands for convenience. These are referred to as octave bands (since their width is typically one octave) and the mid band frequency is used to identify them.

Octave band - mid-frequencies (Hz)

32 63 125 250 500 1000 2000 4000 8000 16000

For fan coil unit applications, octave bands 125Hz, 250Hz, 500Hz, 1kHz, 2kHz and 4kHz are critical.

Each octave band, for a piece of equipment such as a fan coil unit, has a corresponding sound power level, from which an equivalent sound pressure level at the same frequency may be derived.

5. The Relationship Between SWL & SPL

In simple terms, the SWL is the rate at which acoustic energy is transferred to a room and the SPL is a measure of the effect of the SWL at a given point within the room. A useful analogy is to consider a heater; the output of a heater is measured as power in Watts (W) and the effect of the output of the heater is measured as temperature in degrees Celsius (°C).

6. Sound Path

It is important to consider that sound can be emitted from different sources to the listener.

1) Inlet and case radiated sound is transmitted through the ceiling into the room space.
2) In duct sound is carried along the duct and through the supply air diffusers to the room space.

It is also important to consider that sound is transmitted via more than one route.

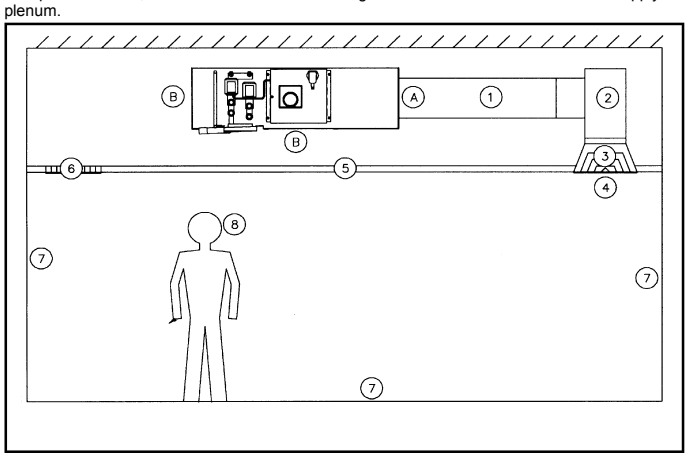
1) The direct sound path is a straight uninterrupted path between the source and the listener.
2) Reverberant sound paths are any path, beginning at the source, along which sound is reflected off one or more surfaces prior to reaching the listener.

7. Factors Affecting Room Sound Pressure Levels

Figure 1 represents a typical ceiling void fan coil unit installation. Certain criteria must be known In order to determine room sound pressure levels.

1) Sound power levels of the fan coil unit - Sound power levels are specified as two separate sets of acoustic data, namely: discharge in duct sound power levels, and; inlet and case radiated sound power levels.

2) Outlet ductwork - The size, length and type of ductwork, together with the quantity of bends incorporated into it, all affect the level of discharge in duct sound that reaches the supply air plenum.



A In-duct discharge sound power levels
B Inlet and case radiated sound power levels

3) Supply air plenum - The acoustic characteristics of the supply air plenum are affected by its size, the number of duct connections and whether or not it is acoustically lined.

4) Supply air grille - The type and size of the supply air grille affect the level of the discharge in duct sound radiated into the room. High air velocities through the grille may result in noise regeneration.

5) Position of supply air grille - The position of the supply air grille, i.e. its proximity to one or more major room surfaces, affects the level of discharge in duct sound radiated into the room that is transmitted via the direct sound path to the listener.

6) Ceiling construction - The level of inlet and case radiated sound transmitted into the room space is dependent upon the acoustic characteristics of the ceiling.

7) Return air grille - The position of the return air grille affects the inlet and case radiated sound emitted into the room. Return air grilles should be installed as far as possible from the inlet to the fan coil unit.

8) Room conditions - The sound pressure levels resulting from the component of sound transmitted from the ceiling and the grilles via the reverberant sound path is affected by both the surface area of the room space and the quality of the room surfaces.

9) Position of the listener - As sound travels further from the source, both acoustic energy and hence sound pressure levels reduce.

8. Noise Assessment

Noise rating (NR) curves are the most commonly used method for assessing noise level. Each curve connects predefined sound pressure levels, which consider the response of the human ear at each of the octave bands.

The noise level at a particular point in space is represented by the value of the NR curve whose constituent sound pressure levels are either greater than or equal to those calculated or measured. Figure 2 shows a set of sound pressure levels with a noise level of NR35.

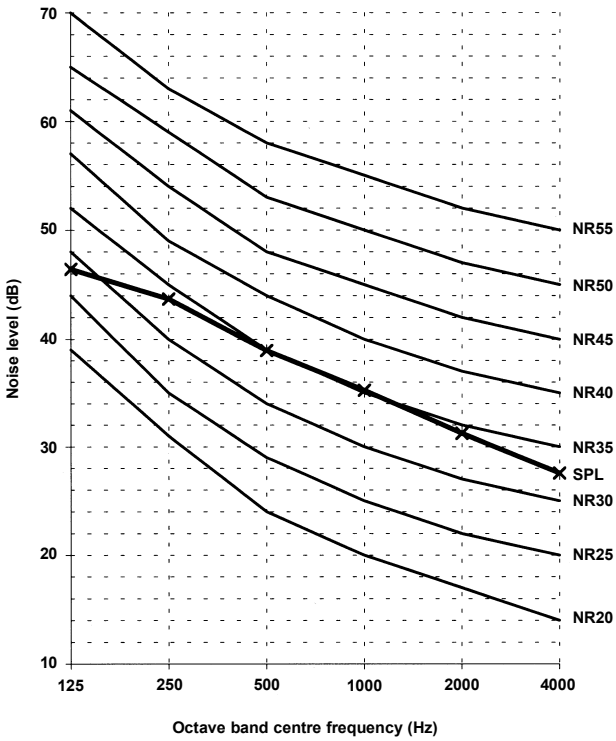


Figure 2: Noise Rating (NR) curves with typical SPL data plotted
The noise level in this case is said to be NR35

9. Common Problems with Fan Coil Unit Installations

1) Undersized outlet ductwork - Undersized outlet ductwork leads to high air velocities and external static pressures, and noise regeneration in the duct. As a guide, the maximum air velocities should be limited to 3m/s in typical office environments and to a lower figure in noise critical areas. Recommended air volume flow rates for duct sizes of Ø250mm, Ø200mm and Ø150mm are 145l/s, 95l/s and 55l/s respectively.

2) Excessive quantities of flexible ducting - For a given air volume flow rate, flexible ducting produces a higher pressure drop than an equivalent length of rigid ducting. Higher pressure drops may lead to noise regeneration.

3) Position of return air grilles - The installation of return air grilles too close to the inlet of the fan coil unit results in more of the inlet and case radiated sound reaching the room via the grille. The length of the air path between the inlet of the fan coil unit and the return air grille should be maximised to minimise the level of inlet and case radiated sound that is transmitted through the return air grille into the room space.

4) Hard acoustic conditions - Predominantly hard surfaces in the room space results in higher sound pressure levels. The addition of decorations and furnishings yields lower noise levels.

5) Poor ceiling attenuation - Some of the inlet and case radiated sound will reach the room space via the ceiling. The use of acoustic ceiling tiles with low sound transmission and good absorption properties reduces the level of inlet and case radiated sound transmitted in this manner.

6) Listener too close to supply air outlet - Sound pressure levels reduce with increasing distance between the listener and the supply air outlet.

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