FAN INSTALLATION EFFECTS –
A GUIDE TO INSTALLED FAN ACOUSTICS

GUIDANCE NOTE 2

This leaflet has been produced by the Fan Manufacturers' Association. It is intended to assist designers in the selection and use of fans for industrial and commercial installations, and it is applicable to all fans, from all manufacturers.

1. SOUND – THE BASICS

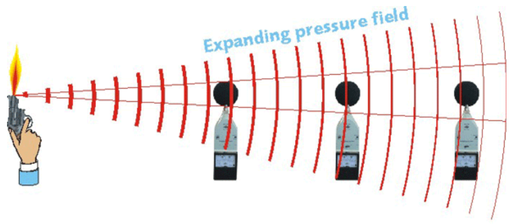
1.1 What do we mean by ……

Noise - Unwanted sound. All fans propagate sound as a consequence of the work that they do moving air. If the fan application contains bad design features, then noise can result.

Sound Level This is an ambiguous term and should be avoided. It gives no indication as to whether it is sound pressure, sound power, A, B or C weighting nor the distance from the sound source. Nor does it give any indication as to the environmental conditions around the fan such as fully reverberant, semi-reverberant or free field.

Sound Pressure Sound pressure is what we all feel (if the sound is loud enough). It is what can be measured. However, it is affected by what is around the sound source and the distance to the source. Sound pressure is denoted Lp expressed in decibels (dB) above a reference level of 20µPa.

Sound Power Sound power is a measure of the strength of a sound source. For example, if you fire a starting pistol, the sound power is always the same. How loud someone hears the sound (sound pressure) depends on how close they are and if the pistol was fired indoors or outdoors. Sound Power is denoted Lw and also expressed in decibels (dB) expressed above a different reference point of 1pW



Sound power is sound pressure multiplied by the area the sound pressure is measured over:

Sound Spectrum The sound is measured across a frequency range. Typically 44 to 22,500 Hz, Octave band centre frequencies 63Hz to 16 kHz. The actual measurement is broken up into small bandwidths of octave or 1/3rd octave segments.

A, B and C weighting People usually don't want a series of numbers, the sound at each octave, to assess a noise; they want one number. There are, therefore, weightings that approximate how the ear hears sound. These are added to the octaves and then the octaves are logarithmically added together. The main weightings are:

A weighting:- approximate hearing at 55dB.
B weighting:- approximate hearing at 70dB.
C weighting:- approximate hearing at 85dB.

Basically A weighting indicates how annoying a noise might be and C weighting indicates the potential for hearing damage. However, in practice, A weighting is invariably used

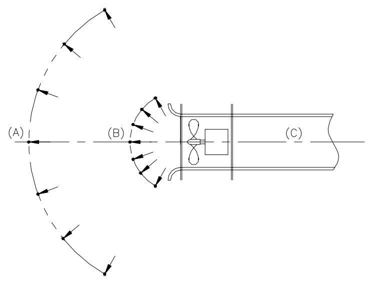
NC and NR curves Noise Criteria (NC) and Noise Rating (NR) curves are curves applied to the sound spectre octave measurements. Spectrum that fall under a particular curve are said to meet that curve. They cannot be applied to fan data as the ambient conditions, such as reflections have not been considered

1.2 What is the Noise Level?

There is no simple answer. In the past, certain manufacturers have given sound ratings in various ways such as –

Average Sound Pressure Level in free field at a distance of 3 impeller diameters (A) from the fan inlet or discharge.

Or average Sound Pressure Level in free field at a distance of 1 metre (B) from the fan inlet or discharge.



The resulting figure at (A) will be less than at (B), because sound decays with distance. Under these conditions the only common approach is to consider the Total Sound Power level emanating from the fan (C). This figure is not associated with any distance and is a measure of the Total Sound Energy leaving the fan unit.

Once you bring distance into consideration then the fan manufacturers have no choice generally than to quote values assuming free field conditions, as they are product suppliers and do not know details of its eventual installation.

Once true installation effects are taken into account, then actual levels will always exceed free field ones due to reflections off adjacent surfaces such as floors and walls. Actual installations will be somewhere between the free field and reverberant environments mentioned in section 2 of this guide.

As an example, let us consider a 1 metre fan with a quoted Sound Power level of **100**dB. This same fan will give the following Sound Pressure levels:-

a) **80** dB at a distance of 3 impeller dias. (ie. 3m in this particular case)

b) **89** dB at a distance of 1 metre

c) **102** dB within a 1 metre dia. duct

d) **96.5** dB within a reverberant room of approx. $100m^2$ surface area and an absorption co-efficient of 0.1

These differences vary with the size of the fan as a) and c) especially are size related.

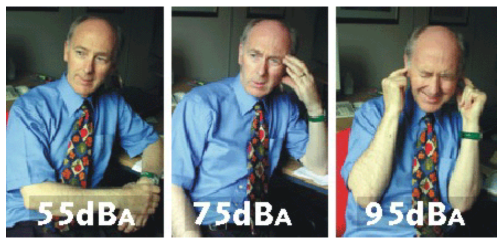
1.3 Human Perception of sound

Human speech is mainly in the 1kHz to 4kHz range, so human hearing is most sensitive in this range at lower sound levels. At higher sound levels, the ear has approximately the same sensitivity over the whole frequency range; a flat response.

The ear can hear over a very large range of sound pressure levels, from a quiet whisper to the roar of a jet engine. In order to accommodate this and partially mimic how we experience sound, a log scale is used. The type of log scale is called a decibel scale - $10\log_{10}$. This gives;

$$Lw = 10\log_{10} \text{(Sound Power Ratio)}$$
$$Lp = 10\log_{10} \text{(Sound Pressure Ratio)}$$
$$Lw = Lp + 10\log_{10} \text{(Area)}$$

Pure tones are seen as more damaging and more unacceptable, so there is sometimes a weighting added to them. Typically 5dB would be added to any octave band level that has a pure tone before adding the weighting and summing the octave bands.



1.4 Fan Manufacturers Data

Fan Manufacturers may quote Sound Power or Sound Pressure, at a distance of 1m or 3m from the inlet or the outlet, a linear figure or a weighted figure, a free field measurement or one taken in an exhaust duct.

Every method is different but they all quote a dB figure. It is important to understand which one is being quoted and understand that often there is no simple correlation between the different methods. Therefore they cannot always be compared.

2. APPLICATION AND INSTALLATION EFFECTS

Free-field Conditions –

Fan manufacturers normally measure their fans in free field conditions, i.e. those occurring in free space, in a room with sound absorbent surfaces (anechoic or semi-anechoic room), where the sound is effectively deadened by its rapid dispersion and absorption. Reflections do not occur (see figure 1, below). Applications of fans other than these will result in a change to the sound emission and therefore it will differ from the manufacturers data.

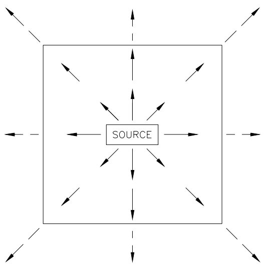


Figure 1

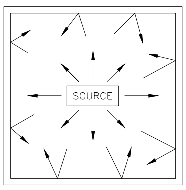


Figure 2

Sound transmission

The fan will emit sound that will transmit in the following manner,

- Radiates from the fan inlet
- Radiates from the fan outlet
- Sound will transfer to mechanical vibration in fan housing and transmit through to mounting and connected structures.
- Mechanical vibration in fan housing, mounting and connected structures will transmit as sound.
- Sound will break out of inlet and outlet ducts.

Increased Sound Levels

The above may well increase the sound level measured in free field conditions. The following will also add to the sound level as a result of the application of the fan.

- Using the fan away from peak operating efficiency.
- Poor fan inlet conditions.
- Poor fan outlet conditions.
- Poor design of duct work and associated equipment.
- High velocity airflow in application or installation.
- Reverberant conditions

Application and installation effects

Reverberant Conditions
Those conditions occurring in a room with hard reflecting surfaces e.g. a bathroom. Resulting in the sound reflecting, combing and mixing and taking a longer time to decay away (see figure 2, opposite). The result is a new higher noise level.

Mechanical Vibration
The sound transfers as mechanical vibration into housings and support member and structures. Added to this is the vibration due to the rotating imbalances of the impeller and motor. Mounting arrangements will transmit this to other parts of the system or building and could later return as sound into the environment.

Breakout noise
Sound from the fan will enter duct or application. Some of the sound can breakout of the duct or application. The breakout noise is a function of the internal sound power, internal area, wall material, thickness and length of the duct or application.

Peak operating conditions
The fan will have a peak operating condition where the efficiency is at its highest and noise is at its lowest level. Operation away from this point will lead to increased noise.

Poor inlet and outlet conditions
Fan manufacturers measure the sound with clean and free inlet and outlet conditions. Inlet obstructions cause turbulence that increases the broadband noise. Inlet obstructions can also lead to blade passing problems, where a relatively few blades pass a fixed object causing fluctuating pressure waves that produce an annoying tonal effect. This also applies to outlet conditions.

Poor Ductwork of application
Noise is also generated by the airflow as it is obstructed or turned along ducts or within applications. Sharp bends, sudden changes in area, inlet/outlet grilles, louvers and filters, and high velocity air can all add to the overall noise level

3. Methods of Control

There are a number of ways to control unwanted sound that utilise acoustic enclosures and attenuators. These expensive solutions may not be necessary if the source of the sound is considered prior to installation.

Noise is unwanted sound and sound is pressure waves propagating from the source. Sound is the result of fluctuating forces, variations in pressure such as turbulent airflow within a duct. A fan is a moving machine which generates a pressure difference from inlet to outlet and in doing so causes many fluctuating forces due to the turbulent flow on the inlet, through the fan and at the outlet.

One way of reducing the sound source is therefore to reduce the turbulence produced by the fan. This accounts for the difference in noise between different types and makes of fan.

Another source of noise is high turbulent flow. This noise source is not generated by the fan but rather by the velocity of the air within the application or within the ducts.

There are other effects and components within the fan assembly that can create noise issues. These typically cause peaks in the sound spectrum that the human ear can register as an annoying noise.

With most fans, there can be a noise effect related to its blade passage frequency. This being a function of the number of blades in the impeller and its rotational speed. Sometimes it is caused by fixed objects being placed too close to the rotating impeller whether at its inlet or discharge, whilst it can also be caused by the disturbed flow coming off the preceding blade, as it rotates. The resulting discrete noise peak can easily be noticed above the otherwise general broadband levels. If fan manufacturers are supplying complete fan units, then there is less likelihood that this will occur, however every endeavour should be made to present the fan impeller with uniform, turbulent-free conditions within the installation.

Mechanical vibration of elements of the fan can also breakout as noise. The electric motor generates noise and could be higher than the sound level produced by the fan. There are also noise effects resulting from poor application of the motor. If the motor is used significantly away from its peak efficiency then electromagnetic imbalances result in mechanical vibrations at certain frequencies. This is particularly true for single phase motors.

The electric motors and fans are mechanically balanced, but rotating electrical machines cannot be perfectly balanced, there is always a residual imbalance. Depending on the degree of balance selected by the manufacturer, this can create a vibration at a particular frequency which can break out and become a peak in the noise spectrum above the broadband noise.

Various methods of speed control can cause undue noise. Mechanical dampers used to restrict the amount of airflow can also create turbulence and air turbulence can result in undue noise.

Variable voltage motor controllers generally work by chopping the current wave form into the motor. This can create mechanical vibrations in the motor at particular frequencies.

Variable frequency drives provide a variable supply frequency to the motor by the use of pulse width modulation (PWM). This PWM wave form is typically at a high frequency and can cause motor and fan vibrations.

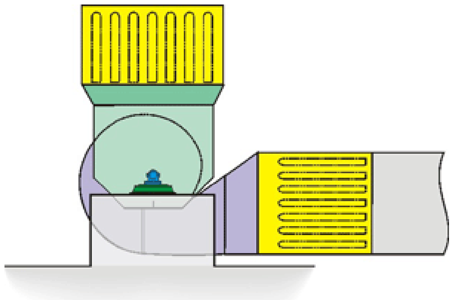
Electronically commutated DC motors work by electrically switching the current direction within the motor winding. This can cause motor and fan vibrations.

Methods of control should therefore consider the possible affects discussed above and could include some or all of the following.

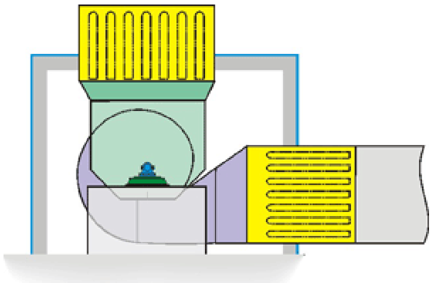
- A fan chosen to operated at peak efficiency at the particular duty requirement.
- Reduce the speed of the fan as much as possible to reduce the sound generated by the fan.
- Keep air velocities as low as possible to minimise turbulence.
- Ensure smooth transitions and generous bends in duct work to minimise turbulence.
- Avoid obstructions in front of and after the fan.
- Ensure the motor has been selected to operate at its peak efficiency.
- Consider the imbalance of the electric motor and impeller and if necessary isolate the motor and impeller from the installation.
- Use output filters on speed control devices or consider isolating motor and fan from the installation.

Noise attenuation can come in a number of formats. It could be an acoustic enclosure around the fan and this enclosure could even be a plant room. Sound attenuators can be used on the inlet and outlet of the fan and sound attenuation cladding can be used on the application or duct work. The selection of attenuators and attenuation material depends on the frequency of the sound that needs to be attenuated and the amount of attenuation required.

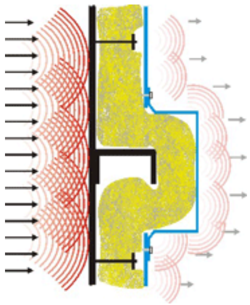
3.1 Mounting and connection



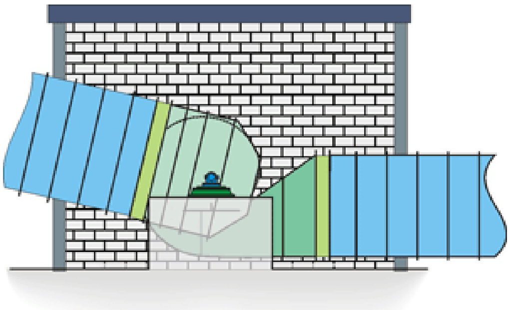
Inlet/Discharge silencer - prone to blockage. Consume power through flow resistance.



Acoustic Enclosure - This is essentially cladding remote from the machine. It is more expensive than cladding. The lower reliability is due to doors not being kept closed and panels being removed but not replaced.



Duct Cladding - very expensive installation cost. Thermal lagging on hot fans can sometimes be an effective acoustic cladding.



Plant Room - This is basically a brick built acoustic enclosure. It gives more restricted access and, due to the hard walls, much higher internal noise.

FOR FURTHER INFORMATION REFER TO CIBSE GUIDE B

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