Acoustic Noise: Causes, Rating Systems, & Design Guidelines

Acoustic Noise

Noise is, to a great extent, a purely subjective personal phenomena. Perhaps the best definition of it is as an unwanted sound. Noise does, however, have two basic characteristics. The first is the physical phenomenon which can be measured and thus used in technical specification. The second is the psycho acoustical characteristic which attempts to judge the effect of noise on human beings. In industries that use small cooling fans, fan noise simply interferes with the ability of the people working nearby to concentrate on their work. The factors of greatest importance to the system designer are the psychological influences on the person rather than the physical influences of sound on the human ear.

Sound is perceived and measured as minute pressure fluctuations above and below the ambient pressure. The pressure variations of interest for their psycho acoustical effect vary as much as 13 orders of magnitude. Because of this large range of hearing capability, it is convenient to express these values in decibels. Sound Pressure Level (SPL) which is environmentally dependent, is defined as:

$$\mathbf{SPL = 20 \log (P/P_{Ref})}$$

where:

P = pressure
P_{Ref} = a reference pressure

In defining the noise generated by a fan, it is best to define the noise emanating from the source. This is called the Sound Power Level and is independent of the environment. Sound Power Level is defined similarly to sound pressure on a logarithmic scale as:

$$\mathbf{PWL = 10 \log (W/W_{Ref})}$$

where:

W = acoustic power of the source
W_{Ref} = an acoustic reference power

Sound Power Level cannot be measured directly and must be calculated from sound pressure measurements. Sound Power Level, since it is a measurement of noise unaffected by such factors as the fan's distance from the hearer, is used as the basic measurement for comparing noise levels of fans, as well as noise levels at different operating points of the same fan. In practice, another property of noise, its frequency, is also considered. For fans, two types of noise related to frequency are important: wide band noise, in which acoustic energy is continuously distributed over a frequency spectrum; and pure tones, in which the acoustic energy is concentrated over narrow bands in the frequency spectrum.

Since fan noise is predominantly wide band in nature with some pure tones, it is convenient to divide the audible frequency range into bands and to plot the average Sound Power Level in each band. For specification and rating purposes, it is generally acceptable to divide the audible frequency spectrum into eight octave bands, each with an upper limit twice that of the lower limit. These bands are usually designated by their center frequency. Fan noise data is usually plotted as Sound Power level against the octave frequency bands.

Noise Rating Systems

Comair Rotron uses four rating methods for describing the noise levels in the fans it manufactures:

PSIL

The first system used is Preferred Speech Interference Level. The PSIL is determined as the arithmetic average of the sound pressure level in the three octave bans with center frequencies of 500, 1000 and 2000 Hz. This rating is a good guide to the effect of noise on spoken communications.

dBA
A second rating system is the "A" weighted sound pressure level (dBA) often used by government agencies in determining compliance with such regulations as the Occupational Safety and Health Act (OSHA). The dBA rating is determined directly by a sound level meter equipped with a filtering system which de-emphasizes both the low and high frequency portions of the audible spectrum. This measurement is recorded at a distance of 3 feet from the source.

NPEL
A third rating system is the "A" weighted sound power level reference to a 1 picowatt and expressed in Bels. This is also referred to as the Noise Power Emission Level (NEPL). NEPL was adopted by the Institute of Noise Control Engineering (INCE) as the preferred unit of measure. The INCE "Recommended Practice for Measurement of Noise Emitted by Air Moving Devices (AMDs) for Computer and Business Equipment" is a guideline for the description and control of noise emitted by components. ANSI S12.11 now includes the procedures called for in the INCE Practice. This is the latest and most technically thorough acoustic test procedure available. Comair Rotron does all acoustical testing per INCE and ANSI S12.11-1987.

Freely Suspended
The fourth rating system used is a method known as Freely Suspended. In this method a fan is suspended from springs in the middle of a Calibrated Reverberate Room. The fan is run at nominal voltage, free delivery, and at a distance of 1 meter. The sound pressure level (dBA) is recorded. (For comparison dBA @ 1 meter + .7778 = dBA @ 3 feet).

Causes of Fan Noise

Since noise in most measuring systems is specified in decibels (dB), it is useful to see how dB changes relate to perceived loudness:

dB Change Apparent Change in Loudness

- 3dB Just noticeable
- 5dB Clearly noticeable
- 10dB Twice (or half) as loud

Noise emanating from axial fans is a function of many variables and causes:

Vortex Shedding
This is a broad band noise source generated by air separation from the blade surface and trailing edge. It can be controlled somewhat by good blade profile design, proper pitch angle and notched or serrated trailing blade edges.

Turbulence
Turbulence is created in the airflow stream itself. It contributes to broad band noise. Inlet and Outlet disturbances, sharp edges and bends will cause increased turbulence and noise.

Speed
The effect of speed on noise can best be seen through one of the fan laws:

$$\mathbf{dB_1 = dB_2 + 50 \log_{10} (RPM_1 / RPM_2)}$$

Speed is a major contributor to fan noise. For instance, if the speed of a fan is reduced by 20%, the dB level will be reduced by 5 dB.

Fan Load
Noise varies as the system load varies. This variation is unpredictable and fan dependent. However, fans are generally quieter when operated near their peak efficiency.

Structure Vibration
This can be caused by the components and mechanism within the fan, such as residual unbalance, bearings, rotor to stator eccentricity and motor mounting. Motor mounting noise is difficult to define. It should be remembered that cooling fans are basically motors and should be treated as such when mounted.

System Effects on Fan Noise

System disturbances are the biggest cause of fan noise. When a fan is designed for low noise operation, it can be very sensitive to inlet and outlet disturbances caused by card guides, brackets, capacitors, transformers, cables, finger guards, filter assemblies, walls or panels, etc.

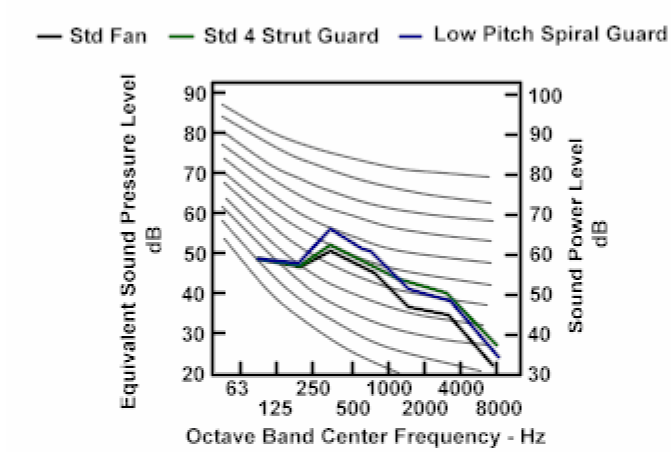

Figure 1: Impact of Finger Guard on Noise

When placing a fan in an electronic package, great care should be taken in locating components. Trial and error will be needed to determine the system's effect on noise. Different fan types will react differently in the same system. Common sense and intuition play a large role in the fan/system design.

For instance, if it is necessary to place card guides against the face of the fan for card cooling, the fan may develop a large pure tone if it is done on the inlet side; on the discharge side, the effect may be much less.

Figure 1 illustrates how one system component, finger guards, can effect noise.

Guidelines for Low Noise

The following guidelines will aid the fan user in minimizing fan noise.

System Impedance
This should be reduced to the lowest possible level so that the least noise for the most airflow is obtained. The inlet and outlet ports of a cabinet can make up to between 60 and 80% of the total system impedance, which is much too high for a low-noise result. And, if a large part of the fan's flow potential is used up by the impedance of the inlet and outlet, a larger, faster and noisier fan will be required to provide the necessary cooling.

Flow Disturbance
Obstructions to the airflow must be avoided whenever possible, especially in the critical inlet and outlet areas. When turbulent air enters the fan, noise is generated, usually in discrete tone form, that can be as mush as 10 dB higher and thus cause considerable annoyance.

Fan Speed and Size
Most Comair Rotron fans have several low speed versions. These should be tried and used whenever possible. Various fan sizes should also be explored; quite often a larger, slower fan will be quieter than a smaller, faster fan delivering the same airflow.

Temperature Rise
Airflow is inversely proportional to allowable temperature rise with the system. Therefore, the rT limit placed on a piece of equipment will dictate to a large extent the required flow, and therefore, noise. If the temperature limit can be relaxed even a small amount, a noise reduction may result.

Vibration Isolation
In certain instances, the fan must be isolated from the cabinet to avoid vibration transmission. Because fans operate at a low frequency, and are light in weight, vibration isolators must be soft and flexible. Since the transmission is dependent on the system, trial and error is the best approach to a quiet system/fan interaction. In systems that require 20 CFM or less, noise radiated by the cabinet is the predominant noise. Isolation of the fan is the only practical solution to this type of system noise problem.