Noise effects of cooling fans and its measurement

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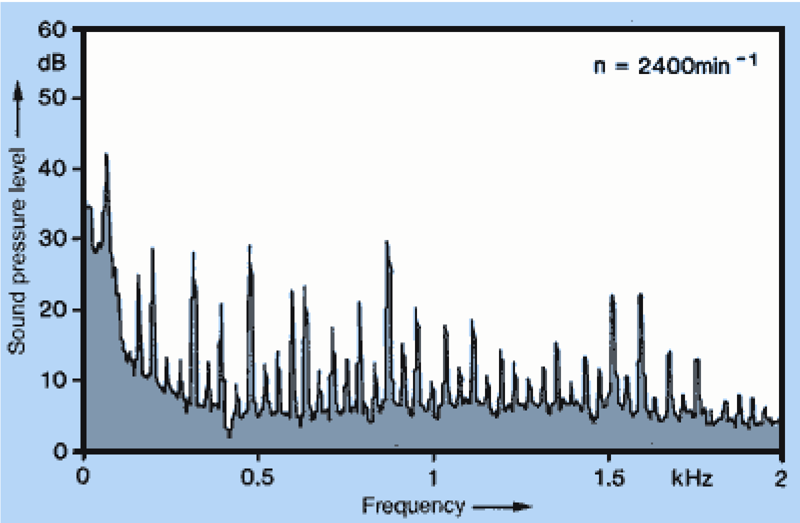
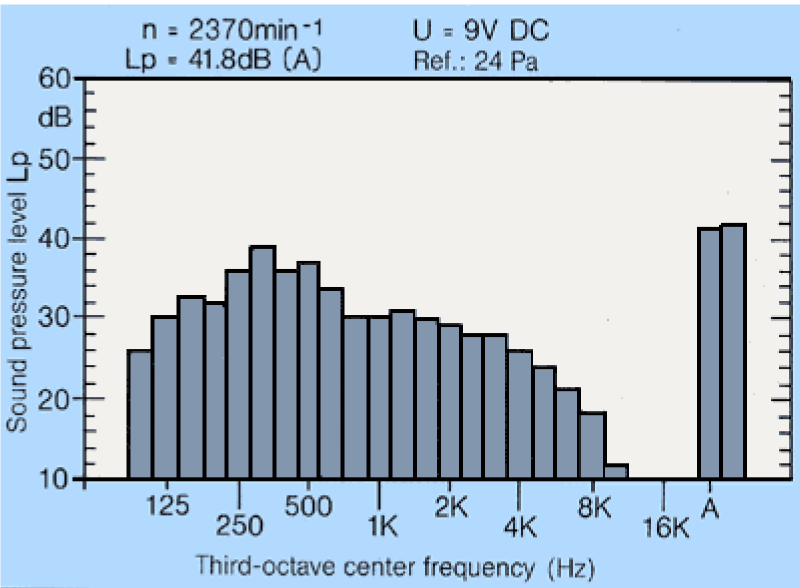
Noise from fans becomes disturbing when it rises above a certain auditory level. Since many electronic systems are located close to users, fan noise emissions must therefore be as low as possible. Consequently, any fan designed into a product must be optimised to keep noise within acceptable bounds. Therefore, noise performance of fans is a decisive criterion relative to design-in selection.

Sound pressure and power

Sound consists of vibrations in the range of human hearing that operates at frequencies from 16 to 16,000 Hz. It is propagated by air pressure waves. The value of the pressure changes is termed sound pressure, which is determined with microphones and instruments and expressed as sound pressure levels in decibels (dB). In practice, an overall sound power increase of 3dB is just perceptible to the human ear, 5dB is clearly louder and 10dB sounds twice as loud.



The measured sound pressure is dependent on frequency, as indicated by the noise spectrum of Figure 1 above (narrow band analysis of fan noise). The frequency range is usually divided into sections or bands, for which measurement and detection instruments are used to obtain time-averaged values (see Fig 2 below) and the perceived total level is obtained by weighting the measurement values with the sensitivity curve of the human ear.



The resulting so-called A weighting curve is commonly employed and the sound pressure level obtained is expressed in dB (A). Its suitability as tool to measure the perceived effect of noise is limited because, by definition, sound pressure levels are equal throughout the diffused sound field, but perceived noise levels are not. Sound power measurements are therefore more meaningful.

Measuring sound

Definite sound measurement is normally undertaken under controlled conditions, there are two distinct methods, the selection of which depends on whether sound power or sound pressure is to be measured.

A different measuring environment is required for each method. Noise can be measured in either an Anechoic or a Reverberation chamber.

Anechoic Chamber

This is designed to make measurements in a free-field and is constructed such that all surfaces are lined with sound absorbing materials. This ensures that the only sound being measured is attributed to the noise source. An Anechoic chamber allows the sound pressure level in any given direction, away from the source, to be measured without interference from reflected sound.

Reverberation Chamber

This chamber is built from non-absorbing hard materials and is designed to reflect all the sound back from the walls to produce a diffuse field where the total 'sound power' can be measured. The noise energy produced is distributed throughout the chamber.

In practice, many sound measurements are made in locations which are neither Anechoic nor Reverberate, but a mix of both. In many ways, these measurements only give an indicative or perceived level of noise. It is also difficult to select the particular point from which the measurement is to be taken due to the partial reflecting of noise off the hard surfaces.

Actual in-situ noise measurements

Most measurements of noise tend to be made in imperfect locations. This means that the readings taken must be considered in conjunction with the total background noise. However, strict criteria must be adhered to if errors in the methodology of noise measurement are to be avoided.

Possible errors

Firstly, Near Field measurement. If measurements are taken too close to the source the sound pressure levels will vary significantly with even a small change in microphone position.

The Near Field is specified as being a distance less than the wave length of the lowest frequency of noise emitted from the source or twice the largest dimension of the machine, whichever is greater. Measurements can be taken as close as 0.25 metres for frequencies down to 10Hz.

The next issue is Far Field Measurement. Here, errors will occur if the measurements are made too far away from the source. The reflected sound from walls and other objects could be as strong as the direct source and meaningful measurements are impossible. This is called the Reverberant Field.

Moving on to Free Field Measurements, this area can be found by observing that in the area between the Near Field and Reverberation Field the noise level will drop by 6dB for a doubling of distance from the source. It is here that measurements should be taken. This sensitivity to positional errors means that, when making any measurements, the distance and location of the microphone in relation to the source must be recorded.

Specific noise measurement of fans

Fan measurements are made in an Anechoic chamber.

Most fan measurements are carried out in accordance with DIN 45635. The fans are measured under two operating conditions.

1. Suspended on flexible mountings and running in free air
2. In their optimum operating range by means of a throttle mechanism

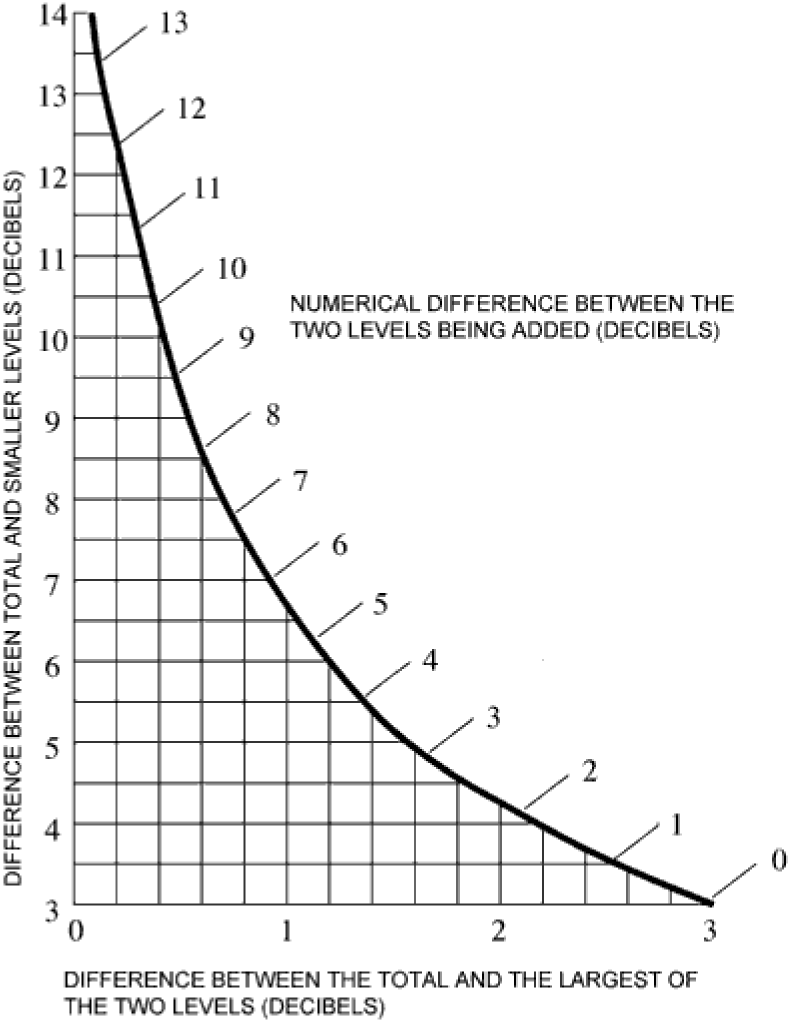


Figure 3 (above) shows that a difference of 0dB between the fans, gives an additional 3dB over the individual level.

This can be proved in the following ways:

Assume two fans each generate 30dB(A).
Using the formulae:

$$SPL = 10\log_{10}(P1^2 \div P0^2)$$

where P1 is the source to be measured and P0 is the reference source.

To calculate the total SPL for two similar fans:

$$SPL = 10\log_{10}\{2(P1^2 \div P0^2)\}$$

$$= 10\log_{10}(P1^2 \div P0^2) + 10\log_{10}2$$

$$= 10\log_{10}(P1^2 \div P0^2) + 3$$

New SPL = Old SPL + 3

Assuming that each fan produces 30dBs:

New SPL = 30 + 3=33dB

Using the above formula for the addition of identical fans:

3 fans add 4.7dB(A) 6 fans add 7.8dB(A)
4 fans add 6.0dB(A) 7 fans add 8.5dB(A)
5 fans add 6.9dB(A) 8 fans add 9.0dB(A)

To calculate the increase in Noise Level when fitting additional fans of differing noise levels.

METHOD 1
Fan A has a noise level of 30dB(A).
Fan B has a noise level of 36dB(A).

Therefore 36dB-30dB = 6dB difference.

Enter 6dB on curved scale of the graph (Fig 3).

Read down to the bottom scale and it shows 1dB(A).
i.e. 1dB(A) is the difference between the total and the largest individual SPL.

Therefore, to find the total, take highest noise level 36dB(A) and add 1dB(A) (from bottom scale).

Therefore total = 36 +1 = 37dB(A).

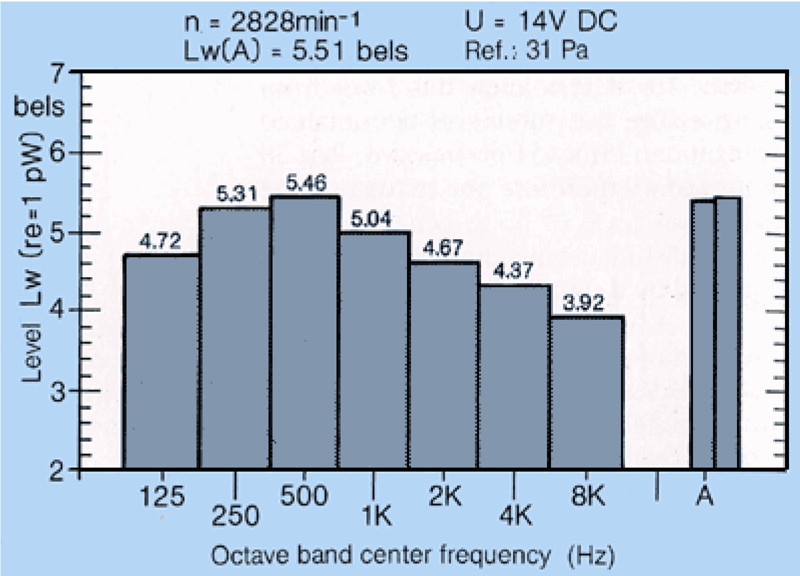
METHOD 2
Enter 6dB(A) (difference) onto curved scale then read off on the vertical scale - again the answer is 7dB(A). Therefore 7dB(A) is the difference between the total and the smallest individual SPL.

Therefore total noise level = 30+7 = 37dB(A).

Sound power level emissions are also referred to in the German DIN 45635 Standard. In Appendix A of Part 38, the total sound power level of small fans measured at nominal speed at optimum efficiency is the figure used for comparing noise emissions. Other standards include BS848-1966 part 2 and ISO R266-1975.

To determine this figure, a pressure chamber is used in an acoustic chamber, which is acoustically transparent and fitted with a sliding panel. The measurement of sound power requires a number of microphones arranged to approximate an enclosing surface. The sound pressure level responses must then be measured and evaluated.

Figure 4 (below) shows sound power level in frequency bands of an octave wide and the total, A-weighted sound power level of a typical axial fan. To help interpret the results, the sound power level is often expressed in units of bels (1 bel = 10 decibels).

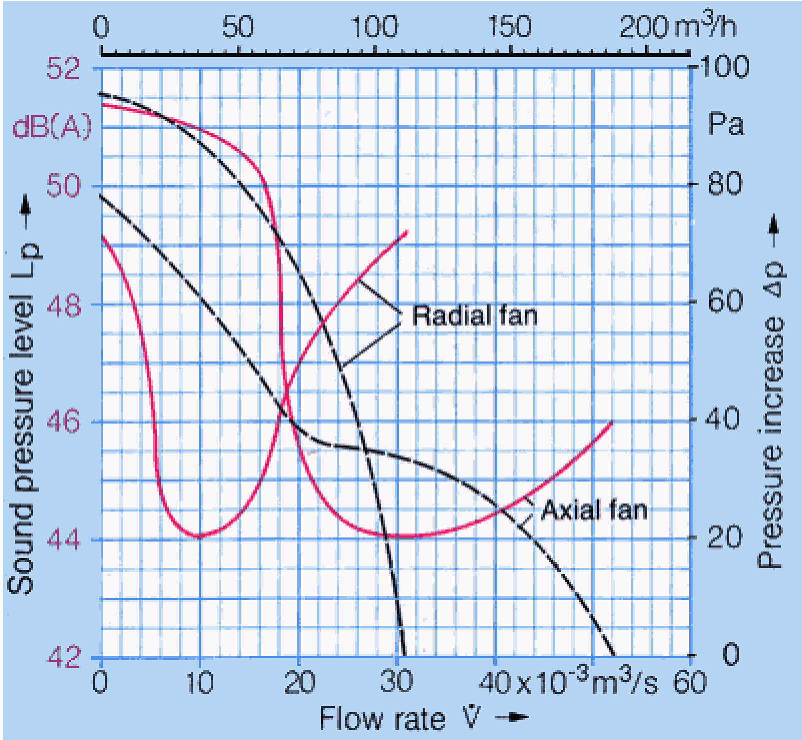


Characteristic acoustical curve

The sound radiation of a fan changes with its operating state, so that the DIN sound power level is only conditionally indicative for applications in which the fan does not operate under optimum conditions. The pressure chamber contains a servomotor that adjusts the sliding. This enables the sound pressure level to be determined in relation to the pressure increase or the flow rate.

Noise levels with respect to flow rate

Figure 5 (below) shows this characteristic for an axial fan and a radial fan, where the sound pressure level measured at a distance of 1 meter from the intake side of the fan is depicted as a function of the flow rate.



For axial designs, a sharp increase in noise is noticeable when the flow rate is excessively restricted. The axial fan enters an operating range in which the air currents no longer follow the contour of the impeller hub, resulting in additional noise.
The discontinuous currents frequently produce alternating air forces on the blades. This portion of the characteristic curve must not be used with larger fans, since the blade oscillations could cause breakage. With low-energy small fans this danger does not exist. Noise emission not only depends upon the operating state, but also on the installation conditions.

Tonal content

The noise level peaks in Fig 1 are produced by dominant natural frequencies that may be perceived as disturbing even when the total level is low. For office equipment, procedures exist for identifying prominent individual tones (ISO 7779). These are produced with fans by interference occurring between the rotating components and the stationary housing environment.

Pure tones are produced by fans due to interference effects that can occur between the rotating components. While these cannot be entirely eliminated they may be minimised by careful engineering.