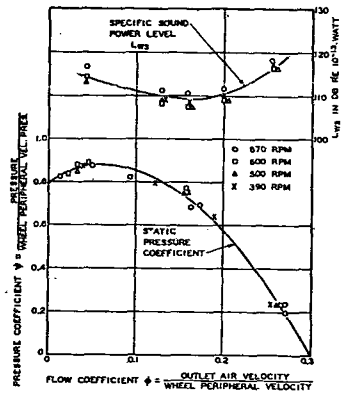


These data are for a particular fan. The quantities ψ_s, ϕ, and L_{WS} are discussed in the text. Such curves apply to all fans in a similar series.

Fig. 5 . . . . Typical Specific Fan Characteristic Curves, Including Specific Sound Power Level

Example 1: Consider a 36½-in. diameter fan operating at 700 rpm. If it produces a noise level of 70 db what will be the level if a 49-in. diameter fan operating at 1000 rpm is substituted for it?

Solution: From Equation 12,

$$\text{Change in level} = 70 \log_{10} \frac{49}{36.5} + 50 \log_{10} \frac{1000}{700} = 16.8 \text{ db}$$

$$\text{Noise level of second fan} = 70 + 16.8 = 86.8 \text{ db}$$

Fan noise does not follow equations exactly. The radiated sound power of a centrifugal fan, for example, is not all concentrated on the blade frequency. While the overall sound power level seems to follow these equations fairly closely, the various components in the different frequency bands may show greater deviation. In the case of axial flow fans there is a wider range in characteristics of the vortex noise, so it would be expected that a slightly greater deviation from these equations exists than for centrifugal fans. This is particularly true as speed is increased. The fundamental or blade frequency exists over a wider range of pressure in the case of the centrifugal fan. In the axial fan, the harmonics are more easily excited and often the second and third harmonics exceed the level of the fundamental.[9]

Specific Plots

Curves which describe the characteristics of an entire series of similar fans can be plotted by using dimensionless coordinates.[8] To describe the pressure characteristics the pressure coefficient ψ can be plotted against the flow coefficient ϕ as shown in Fig. 5, where

$$\psi_t = \frac{p_t}{\left[\frac{(\pi)(D_w)(\text{rpm})}{4005}\right]^2} = \frac{\text{total pressure}}{\left(\begin{matrix}\text{wheel peripheral}\\ \text{velocity pressure}\end{matrix}\right)} \quad (15)$$

$$\psi_s = \frac{p_s}{\left[\frac{(\pi)(D_w)(\text{rpm})}{4005}\right]^2} = \frac{\text{static pressure}}{\left(\begin{matrix}\text{wheel peripheral}\\ \text{velocity pressure}\end{matrix}\right)} \quad (16)$$

$$\phi = \frac{q/A_o}{(\pi)(D_w)(\text{rpm})} = \frac{\text{outlet velocity}}{\text{wheel peripheral velocity}} \quad (17)$$

where

D_w = wheel diameter, feet.
p_s = static pressure, inches of water.
p_t = total pressure, inches of water.
q = quantity of air discharged, cubic feet per minute.
A_o = outlet area, square feet.

Such curves apply to all fans in a similar series, i.e., a series of fans differing in size only while preserving complete similarity in shape by having all linear dimensions changed in the same proportions.

The overall specific sound power level L_{WS} in decibels, as shown in Fig. 5, is defined as follows:[8]

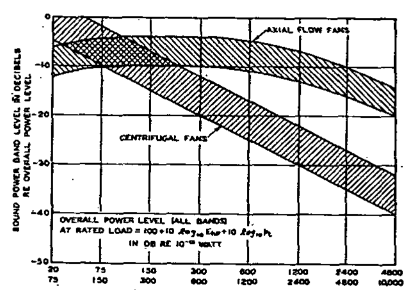
$$L_{WS} = L_W - 10 \log_{10}[q \cdot p_t^2] \quad (18)$$

where

q = quantity of air discharged, cubic feet per minute.
p_t = total pressure, inches of water.
L_W = sound power level actually measured at equivalent point of rating, decibels *re* 10^{-12} watt.

Since static pressure p_s is more frequently measured for fans than total pressure p_t, p_s may be used under most normal operating conditions. When the difference between p_s and p_t is less than 20 percent, the error will then be less than 1 db. Near free discharge, p_s is near zero and p_t must be used. In other words, L_{WS} is the sound power level that a similar hypothetical fan would produce when operating at 10,000 cfm and a total pressure of 1 in. of water at an equivalent point of rating.

Although few data are available to confirm the conclusion, it is indicated that such a plot also holds throughout a series of fans for all eight of the frequency bands provided rotor or blade passage frequencies are not predominant.



The overall power level is first determined from Equation 19 and is added algebraically to the ordinate in Fig. 6. From Reference 22. Used by permission.

Fig. 6 . . . . Chart for Determining the Sound Power Band Levels for Ventilating Fans of Two Types

Approximate Overall Sound Power Level

In practice, data of the type shown in Fig. 5 are usually not available. Hence, in design an estimate has to be made of the overall sound power level and of the shape of the noise spectrum. Tests on centrifugal fans ranging in size from 0.01 hp to 100 hp show that the sound power level in a duct *either* upstream or downstream from the fan can be found within ±4 db from the simple relation:[10]

$$L_W = 100 + 10 \log_{10} E_{hp} + 10 \log_{10} p_t \quad (19)$$

where

E_{hp} = rated horsepower of the fan motor.

(Note: Static pressure p_s may be substituted for total pressure p_t if the difference between p_t and p_s is less than 20 percent.)

The assumption is made that the fan is being operated near the *knee* on its operating characteristics, i.e., near maximum efficiency or near the minimum in the curve of specific sound power (upper curve on Fig. 5).

It is interesting to note that if the formula for fan mechanical, or total, efficiency is substituted in Equation 19, it may be brought into the same form as Equation 18. Assuming actual horsepower = E_{hp} and 50 percent mechanical efficiency, L_{WS} is 105. The example illustrated in Fig. 5 demonstrates the fact that all fans of the same power input are not equally noisy, since the minimum value of L_{WS} for this particular fan is 109 db, 4 db higher than the value calculated in the above manner from Equation 19. It is on the edge of the stated limit of approximation of ±4 db.

It should be emphasized that Equation 19 is intended to be used only when actual noise data are not available.

Approximate Octave Band Spectrum

Within about ±4 db approximation, and assuming no turbulence in the duct or the coupling between it and the fan, the octave band spectrum for a centrifugal fan, relative to the overall sound power level, is given in Fig. 6.

Limited data on vane-axial fans,[11] where sound pressure level measurements were made in the discharge duct, indicate that the overall sound power level is about the same as that for centrifugal fans. However, the spectrum shape of the vane-axial fan noise is similar to that shown in Fig. 6.

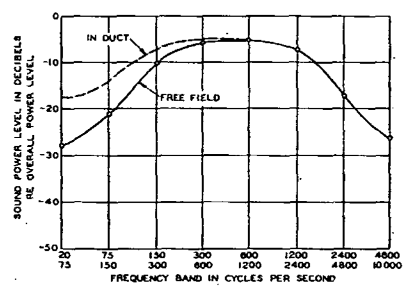


Fig. 7 . . . . Sound Power Spectrum for Single-stage Axial Fan[9]

More recent free field measurements on axial fans indicate that perhaps the drop in level at the high and low ends of the spectrum are more pronounced.[9] The solid line in Fig. 7 is typical of the sound power spectrum for the axial fans reported, as taken directly from the free field measurements. Application of a correction for the end reflection losses from the discharge opening (see Fig. 15) gives the dashed curve in Fig. 7, which corresponds to the relative sound power level in the duct. This spectrum shape for the axial fan appears to be based on more extensive data than those of Fig. 6.

NOISE GENERATED BY GRILLES AND DIFFUSERS

Grille Noise

The subject of grille noise has not been covered thoroughly in the literature. The information given in this chapter has been taken from the advertising literature of several grille manufacturers and from recent experiments at the Massachusetts Institute of Technology.

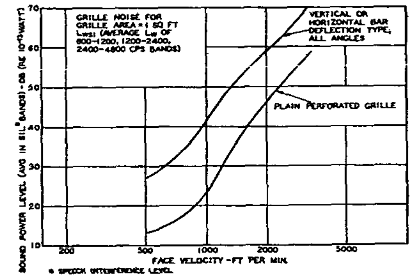
In general, grille noise at the lower frequencies is dependent primarily on the size and shape of the grille opening, on the mass flow per minute, and on the temperature of the air. At the higher frequencies, the noise is determined primarily by the area of the grille, the velocity of air through the free (open) areas (not the core or nominal area), and the pressure drop across the grille.

For two simple types of grille, stamped and deflector vane, power levels are given in Fig. 8. These power levels are given in terms of the speech interference level, L_{WSI}. Conversion to the speech interference level in db in the room at a listener's position is described in the section on Determination of Room Levels. In the absence of more complete information, it may be assumed that the power levels of the noise produced by the grilles themselves at low frequencies are inconsequential.

Fig. 8 is for a grille core area of 1 sq ft. Correction to other areas of grille is made by the relation:

$$\text{Decibel addition} = 10 \log_{10} A$$

where A = core area, square feet.



The noise is expressed as the sound power level in db in each of the three speech interference bands (L_{WSI}).

Fig. 8 . . . . Grille Noise for a Grille Area of One Square Foot