The following text will present data and discussion of methods whereby solutions of the noise problem can be obtained when the allowable room noise level, and the path through which the noise reaches the room, are known.

NOISE GENERATED BY FANS

Aerodynamic noise from all types of fans may be broadly divided into a rotational component and a vortex component. The rotational component is associated with the impulse given to the air each time a blade passes a given point and is hence a series of discrete tones at the fundamental blade passing frequency and harmonics thereof. The vortex component of noise is largely due to the shedding of vortices from the fan blades. It is random in character and has a continuous spectrum over a wide range of frequencies determined by the fan geometry and operation. It may also have many non-harmonic single frequency components determined by blade geometry and local air velocity. Since the laws of generation of these two types of noise are different, they will vary in importance for different types of fans and operating conditions.[6, 7]

In addition to aerodynamic noise, there are usually several non-aerodynamic sources of noise in equipment involving fans. Such sources include noise resulting from unbalance, bearing noise, brush noise, magnetic noise, and belt noise.

The number of blades of a centrifugal fan generally is governed by optimum air flow design. The noise generation decreases but slightly for more than the optimum number of blades.

A shroud around a propeller fan may serve to reduce noise considerably if it is working properly. Such reduction is generally most effective at the higher harmonics. However, if the flow breaks down over part of the shroud, the noise may become considerably worse than for an unshrouded case.

As the operating pressure across axial fans is increased the maximum sound intensity is shifted from the fundamental to higher harmonics. This effect is not observed for centrifugal fans.

Effect of Fan Parameters on Noise vs Performance

Fan Laws. The principal laws governing the mechanical performance of a fan, whether centrifugal or axial, are fairly well established and are given in Chapter 32 of this Guide.

Fixed Point of Rating. A fixed point of rating of a given size fan at a given speed is one for which the capacity (volume flow) is chosen as a given fraction of the free delivery capacity. Having chosen this capacity ratio, the ratio of pressure to the static no-delivery pressure is determined. This fixed point of rating will have a fixed efficiency within the limitation of certain manufacturing details. The fan laws serve to relate the performance of two members of a symmetrical series of fans operating at the same fixed point of rating whether at the same or different speeds.

Correlation of Fan Noise with Size, Static Pressure, Speed and Capacity. The empirical relations between the noise generated by a fan and its size, static pressure, speed and capacity are as follows:

Change in overall sound power level varies as:

$$70 \log_{10}(\text{size}_2/\text{size}_1) + 50 \log_{10}(\text{speed}_2/\text{speed}_1) \tag{12}$$

$$20 \log_{10}(\text{size}_2/\text{size}_1) + 25 \log_{10}(\text{pressure}_2/\text{pressure}_1) \tag{13}$$

$$10 \log_{10}(\text{capacity}_2/\text{capacity}_1) + 20 \log_{10}(\text{pressure}_2/\text{pressure}_1) \tag{14}$$

These relations also apply only for a fixed point of rating.

A double width fan is essentially two fans of the same size, speed and sound pressure level and therefore its sound power level will be 10 $\log_{10} 2$ or 3 db greater than for the single one.

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

Solution: From Equation 12,

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

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

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.

Specific Plots

Curves which describe the characteristics of an entire series of similar fans can be plotted by using dimensionless coordinates.[7] To describe the pressure characteristics the pressure coefficient ψ can be plotted against the flow coefficient ϕ as shown in Fig. 5, where

$$\psi_t = \frac{p_t}{\left[\dfrac{(\pi)(D)(\text{RPM})}{4005}\right]} = \frac{\text{total pressure}}{\text{wheel peripheral velocity pressure}} \tag{15}$$

$$\psi_s = \frac{p_s}{\left[\dfrac{(\pi)(D)(\text{RPM})}{4005}\right]^2} = \frac{\text{static pressure}}{\text{wheel peripheral velocity pressure}} \tag{16}$$

$$\phi = \frac{(\text{CFM})/(\text{Outlet Area})}{(\pi)(D)(\text{RPM})} = \frac{\text{outlet velocity}}{\text{wheel peripheral velocity}} \tag{17}$$

where

D = wheel diameter, feet.

p_s = static pressure.

p_t = total pressure.

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.

An overall specific sound power level PWL_s in dbe as shown in Fig. 5 can also be defined that will be applicable to all fans in a family.[7] It is obtained by means of Equation 18 which follows: