

Fig. 8 Directivity Factor Q for Use in Fig. 6

Only at points more than 45 deg from the center line of an outlet will the beam effect produce a shadow zone in which the direct sound level is less than it would be for uniform radiation. It is, therefore, not justified to base calculations on a directivity of less than 2 or 4, depending upon outlet location.

The directivity factor for various source locations and sizes can be estimated from Fig. 8 as a function of frequency.

STEP 3—CALCULATION OF REQUIRED DUCT ATTENUATION

Noise is readily transmitted by ducts, unless they are acoustically treated. The attenuation required to reduce the duct noise below the power levels calculated in Step 2 depends on:

1. The amount of sound generated by the fan, and how it is divided among the various duct branches.⁴⁰

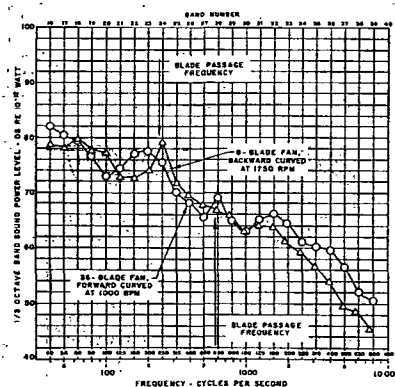


Fig. 9 Sound Power Spectra of Two Types of 12 1/2 in. Diameter Centrifugal Ventilating Fans Delivering 1120 cfm Against 1.4 in. Static

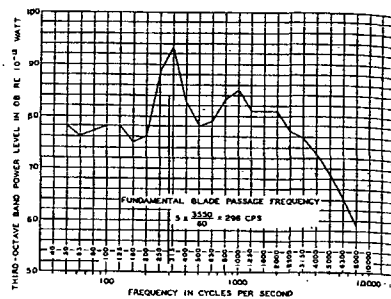


Fig. 10 Sound Power Spectrum of a Vaneaxial Fan with 5 blades at 3550 rpm

2. The natural attenuation provided even by untreated ducts.
3. Sound generated by other sources, such as air flow.
4. Cross transmission between rooms.

Since each of these items depends on frequency, separate calculations should be made for various octave bands.

Sound Generated by Centrifugal Fans

Selection of as quiet a fan as practicable will often reduce the required duct attenuation. When centrifugal fans for central systems are selected, the following items should be considered:

1. Sound level, as well as the usual selection factors should be considered in evaluating various fan types.
2. The fan should be selected to operate near its efficiency peak when handling the required air quantity and static pressure.
3. The system should be designed for smooth air flow, and resistance should be as low as economically feasible.⁴¹
4. Duct connections to the fan inlet should be designed to provide a smooth approach of the air.⁴²

To evaluate the effect of fan design, it is necessary to consider the entire sound spectrum.^{43,44} The sound power spectra⁴⁵ shown in Fig. 9 illustrate the following facts about ventilating fans of the centrifugal type:

1. When fans of different design are considered for a given application, neither the rpm nor the tip speed indicates which fan will be quieter. Backward-curved fans, if properly selected, are usually somewhat more efficient and a little quieter than forward-curved fans, although their tip speed is higher. On the other hand, forward-curved fans are more compact and lighter. Their lower speed may have other advantages, such as less bearing noise and more tolerance in regard to wheel unbalance.
2. The sound power spectra of centrifugal ventilating fans fall off from low to high frequency at an average rate of 4 to 6 db per octave. The overall power level, being a logarithmic sum, is primarily a measure of the noise at frequencies below 150 cps. Experience points to the 150-300 cps band as being the most critical one in silencing centrifugal central station fans, with the 75-150 and 300-600 cps bands being next. Noise comparisons of different fan types can therefore be based on the sound power level in these bands, but not on overall levels.
3. The sound spectra of centrifugal fans for air-conditioning systems should be relatively smooth, without prominent pure tone components. The spectrum for the backward-curved fan in Fig. 9 shows a peak at the blade passage frequency (number of blades times revolutions per second). This is typical for fans having a relatively small number of blades because of the distinct pressure field around each blade. The peak is more pronounced for high flow rates at relatively low static; it may be aggravated by a cut-off located too close to the wheel periphery. Because of the added annoyance of pure tones, the sound output at blade

Sound Control

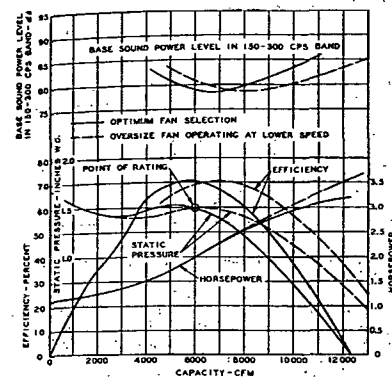


Fig. 11 Comparison of Two Similar Centrifugal Fans of Different Size and Speed, Selected to Deliver 6000 cfm Against 1.5 in. Static Pressure

frequency should be closely examined when selecting fans for critical applications.

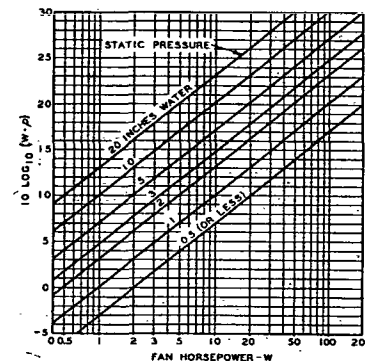
The sound power spectrum of a vaneaxial fan,⁴⁶ as illustrated in Fig. 10, is quite different from that of a centrifugal fan. Relatively little sound is generated at low frequencies. The spectrum usually has a very strong peak at the blade passage frequency and often has secondary peaks at multiples of this frequency.

Proper sizing of the fan is the most important factor in assuring a minimum of fan noise for any given type of fan. The noise will be lowest if the fan is sized to operate near the peak of its efficiency curve when delivering the required air volume (cfm) against a required static pressure.⁴⁷ Noise and efficiency of any fan are not related on an energy basis because of the exceedingly small amount of energy required to produce noise. However, the same factors which produce noise in a fan also tend to reduce the fan efficiency. As Fig. 11 shows, the noise energy may easily be doubled (increased by 3 db) for a drop in efficiency of only a few percent.

An undersized fan will operate under the right-hand part of the curve. Its efficiency will be lower and the noise higher than that of the optimum sized fan. The primary cause of both lower efficiency and higher noise appears to be the higher air flow velocities through the fan.⁴⁸ To avoid excessive noise, the fan should be large enough so that the velocity pressure corresponding to the fan outlet velocity is between 15 and 25 percent of the static pressure for forward-curved fans, and between 7 and 12 percent for backward-curved fans.

Oversized fans are not only uneconomical, but are also noisier than optimum sized fans. This is due to separation of air flow over the fan blades, which occurs when a fan operates to the left of the peak of the static efficiency curve shown in Fig. 11. Flow separation has less effect on efficiency than it has on noise. The efficiency of an oversized fan is, therefore, not a good measure of its quietness.

Since fan design and application details have such an important effect, fan sound ratings from the manufacturer should be consulted. It must be borne in mind, however, that the environment and technique used to obtain these rat-

Fig. 12 Horsepower and Pressure Factor, 10 log₁₀(W·p), for Use with Eq. 14 and Table 10

ings are of the utmost importance. These should always be clearly specified, and their significance in any selection or comparison clearly understood.⁴⁹

If actual test data are not available, the approximate fan sound power level for a centrifugal fan of the type used for central stations can be estimated for each octave band from Equation 14.⁵⁰

$$L_{w1} = L_{w2} + 10 \log_{10}(W \cdot p) \quad (14)$$

where

L_{w1} = approximate sound power level of the fan, decibels re 10⁻¹² watts

L_{w2} = approximate base sound power level for central station centrifugal fans, decibels re 10⁻¹² watts

Table 10 Approximate Base Sound Power Levels^a for Central Stations Fans of the Centrifugal Type,^{b,c,d} in db re 10⁻¹² watt

Static Efficiency ^a of Operating Fan, Percent	Octave Band Center, cps					
	104	212	425	850	1700	3400
	125	250	500	1000	2000	4000
Over 65	75-85	75-80	70-75	65-70	60-65	55-60
50 to 65	80-90	80-85	75-80	70-75	65-70	60-65
30 to 50	85-100	85-95	80-85	75-80	70-75	65-70
Under 30	Unpredictable					

^a Values of sound power level uncertain for 37.5 to 75 frequency.

^b Base sound power levels are based on reference quantities of 1 hp and 1 in. static pressure as defined by Equation 14.

^c Values are based on the gross sound power delivered by the fan to one duct system (supply or return). An equal amount is also delivered to the other system.

^d Poor air approach conditions at the fan inlet will add materially to the noise generated.

The efficiency parameters do not apply to oversized fans operating at an outlet velocity below the range recommended by the fan manufacturer for quiet operation.

If fan has less than 15 blades, add 5 db to level in band in which blade frequency occurs.