Table 11 .... Power Level Division at Branch Take-Offs

Area of Continuing Duct in Percent of the Total Area of all Ducts after Branch Take-Off	5	10	15	20	30	40	50	80
Decibels to be subtracted from power level before take-off in order to get power level in continuing duct	13	10	8	7	5	4	3	1

Table 12 .... Approximate Allotment of Fan Sound Power Level to Each Air Outlet

Cfm of Outlet in Percent of Total Fan Cfm	¼	½	1	2	5	10	20	50
Decibels to be subtracted from fan power level in order to get fan sound power level per outlet	27	23	20	17	13	10	7	3

W = horsepower input to the fan.
p_s = static pressure across fan, inches water gage.

The term $10 \log_{10} (Wp_s)$ can be read from Fig. 12.

The base sound power levels which can be estimated from Table 10, depend on how well the fan has been sized for the particular operating condition and also indicate the relative quietness of a particular type of fan.

Sound output of centrifugal fans should be estimated from Table 10 only when actual test data cannot be obtained, because this table is based on rather limited published data.[48,49] As more test data become available, Table 10 may need revision.

Note that the values derived in this manner represent ½ the total sound power output from the fan, or approximately the amount expected from either inlet or discharge.

Example 3: For the optimum size fan of Fig. 11, estimate the approximate octave band power levels of the noise delivered to the supply duct of an air-conditioning system.

Solution: From Fig. 11, the fan power input at 6000 cfm is approximately 2 hp. The base sound power levels can be expected to be close to the maximum values for an efficiency of over 65 percent in Table 10, say 1 db below the maximum. These values of base sound power level, together with the value of the term of $10 \log_{10} (Wp_s)$, found from Fig. 12 (for $W = 2$ hp and $p_s = 1.5$ in.) are tabulated in Lines 1 and 2 below. On Line 3, a 5 db allowance for the blade passage peak is added in the 150–300 cps band. The approximate sound power levels of the fan, obtained by adding Lines 1, 2, and 3 are entered in Line 4.

Item	Octave Band Center, cps						
	106	212	425	850	1700	3400	6900
1. L_{Wb}	84	79	74	69	64	59	54
2. $10 \log_{10} (Wp_s)$	5	5	5	5	5	5	5
3. Blade Passage Peak	—	5	—	—	—	—	—
4. L_{Wf}	89	89	79	74	69	64	59

Published data on axial flow fans at this time are insufficient to set up a general table covering not only the broad band part of the spectrum, but also the narrow band peaks. Axial flow fans are frequently used in self-contained air-conditioning units, which often provide considerable sound attenuation and contain sound sources other than the fans. Sound ratings of self-contained units, with either axial or centrifugal fans, should be based on tests of the complete unit.

Sound Distribution

At branch-off points, the sound power flow is divided in approximately the same ratio as the duct areas in the duct system (see Table 11). This power division is practically independent of frequency and therefore applies to all octave bands. While this area ratio method of calculation is reasonably accurate, it is also quite time consuming when there are many branches.

Assuming that all branch ducts are sized for approximately equal air flow velocities and that ducts and fittings are designed and sized so that air flow noise is insignificant, the fan power level for each outlet can be estimated in a single step, from Table 12. The error introduced by this simplified method is generally not greater than the tolerances of the present data on the power level of fans.

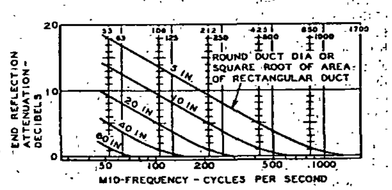
Attenuation of Untreated Ductwork

The total natural attenuation, in decibels, of duct work not acoustically treated is the sum of: (1) the transfer of acoustical energy to the duct walls, (2) the reflection of sound waves at the open end of the duct, and (3) the sound reflection by elbows.

Table 13 .... Approximate Natural Attenuation in Bare Rectangular Sheet Metal Ducts[6,a]

Duct	Size, in.	Octave Band Center, cps			
		53 63	106 125	212 250	Above 250
		Attenuation, db/ft			
Small	6×6	0.2	0.2	0.15	0.1
Medium	24×24	0.2	0.2	0.1	0.05
Large	72×72	0.1	0.1	0.05	0.01

[a] If duct is covered with thermal insulating material, attenuation will be approximately twice the listed values.



(a) *Above curves based on directivity factor, Q = 2, when opening is in a room surface several feet from other room boundaries.*
(b) *If opening is at the junction of two room surfaces, Q = 4, and reflection attenuation will be reduced to that of a duct with twice the area. (1.4 times the radius or square root of area.)*
(c) *For other values of Q, multiply actual area by Q/2 for equivalent area to be used in this figure.*

Fig. 13 .... Sound Reflection at Air Outlet

Table 14 .... Approximate Attenuation of Round Elbows

Diameter or dimensions in.	Octave Band Center, cps						
	106 125	212 250	425 500	850 1000	1700 2000	3400 4000	6900 8000
	Attenuation, db						
5–10	0	0	0	1	2	3	3
11–20	0	0	1	2	3	3	3
21–40	0	1	2	3	3	3	3
41–80	1	2	3	3	3	3	3

The walls of rectangular sheet metal ducts are readily set into vibration by sound waves, especially at low frequencies.[51] As a result, sound is radiated to the space surrounding the ducts at the expense of the sound within the duct.

The natural attenuation effect of bare ducts listed in Table 13 may seem small, but in long ducts, it may provide a very significant amount of low frequency attenuation.

If bare ductwork is located within the air-conditioned room, most of the sound will still remain in the room. Untreated ducts should be run only through non-critical areas.

When ducts are covered with thermal insulating material, wall vibrations are damped. This will not only lessen the sound radiation from the duct walls, but will also increase the attenuation effect[51] to about twice the values shown in Table 13.

The walls of round ducts used in high velocity systems are not set into vibration as readily as those of rectangular ducts. For diameters of 4 to 12 in., the natural attenuation with or without external thermal insulation is about 0.03 db per foot below 1000 cps, rising irregularly to 0.1 db per foot at high frequencies.[6]

Only a small percentage of the low frequency sound energy in a duct is radiated from the air outlet, because the sudden enlargement of the duct to the wide open room acts as an invisible sound reflecting barrier. For a 10 × 10 in. duct outlet, for example, 90 percent of the sound power in the 75–150 cps band is reflected back into the duct system, and only 10 percent is radiated into the room. In decible notation, this amounts to a 10 db reduction in sound power level in that band. Fig. 13 shows the end-reflection attenuation for various duct sizes as a function of frequency. The duct size to be used for calculating end-reflection attenuation is that which prevails for several wavelengths before the opening. No consideration need be given to the actual size of the opening itself or to the cross section of a very short length (up to several inches) preceding it.

Sound reflection is also responsible for the attenuation effect of elbows. In round elbows, much of the sound is reflected around the elbow rather than back to the fan. The attenuation of such elbows, as shown in Table 14,[6] is relatively small.

In square elbows,[6] however, the attenuation (Row A of Table 15) is considerable, especially at frequencies where the wavelength of the sound is in the same order of magnitude as the elbow width D (see Fig. 14).

Noise From Duct Fittings and Mixing Units

Air flow generates sound energy in elbows, vanes, sound traps, or any other element of the duct system which creates turbulence. Sound power levels for 90-deg elbows with turning vanes[52] are shown in Table 16 for a duct velocity of 2000 fpm. This table is also valid for 30, 45, and 60 deg elbows. Vane shape and size have little effect on the noise generated,

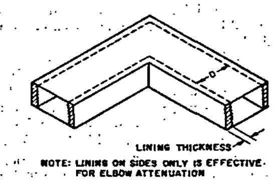


Fig. 14 .... Diagram of Square Elbow without Turning Vanes

Table 15 .... Attenuation of Square Elbows without Turning Vanes,[a] in Decibels

	Octave Band Center, cps															
	53	106	212	425	850	1700	3400	6900	63	125	250	500	1000	2000	4000	8000
(A) No Lining																
5" Duct width (D)	..	..	..	..	4	8	5	3	..	..	..	1	5	7	5	3
10" Duct width	..	..	..	4	8	5	3	3	..	..	1	5	7	5	3	3
20" Duct width	..	..	4	8	5	3	3	3	..	1	5	7	5	3	3	3
40" Duct width	..	4	8	5	3	3	3	3	1	5	7	5	3	3	3	3
(B) Lining* Ahead of Elbow																
5" Duct width	..	..	..	..	4	8	6	7	..	..	..	1	5	8	6	8
10" Duct width	..	..	..	4	8	6	7	11	..	..	1	5	8	6	8	11
20" Duct width	..	..	4	8	6	7	11	11	..	1	5	8	6	8	11	11
40" Duct width	..	4	8	6	7	11	11	11	1	5	8	6	8	11	11	11
(C) Lining* After Elbow																
5" Duct width	..	..	..	..	4	11	10	10	..	..	..	1	6	11	10	10
10" Duct width	..	..	..	4	11	10	10	10	..	..	1	6	11	10	10	10
20" Duct width	..	..	4	11	10	10	10	10	..	1	6	11	10	10	10	10
40" Duct width	..	4	11	10	10	10	10	10	1	6	11	10	10	10	10	10
(D) Lining* Ahead of and After Bend																
5" Duct width	..	..	..	..	4	11	13	15	..	..	..	1	6	12	14	16
10" Duct width	..	..	..	4	11	13	15	18	..	..	1	6	12	14	16	18
20" Duct width	..	..	4	11	13	15	18	18	..	1	6	12	14	16	18	18
40" Duct width	..	4	11	13	15	18	18	18	1	6	12	14	16	18	18	18

* Based on lining extending for a distance of at least two duct widths "D" and lining thickness of 10% of duct width "D." (See Fig. 14). For thinner lining, lined length must be proportionally longer.
[a] For square elbows with short turning vanes, use average between Tables 14 and 15.