

Fig. 9 .... Octave Band Spectrum of Ceiling Diffusers

overall sound power level (from 75 to 10,000 cps) can be found within ±2 db by the equation:

$$PWL_7 = 13 \log_{10} A_{min} + 60 \log_{10} V_{max} - 2 \text{ dbe} \qquad (21)$$

where

PWL_7 = overall sound power level in the seven octave bands from 75 to 10,000 cps, decibels re 10^{-13} watt.

A_{min} = minimum flow area for the air passing through the diffuser, square feet. For undamped flow the minimum area will normally occur in the diffuser neck, whereas for damped flow it will occur at the damper position (see Fig. 9).

V_{max} = maximum air velocity (q/A_{min}), feet per second.

q = quantity of air discharged, cubic feet per second.

For ceiling diffusers of cone-type construction used in conjunction with deflecting vanes and a damper, Fig. 9 presents the approximate octave band spectrum relative to the overall sound power level as given by Equation 21. The curves of Fig. 9 agree within approximately 3 db of the octave band data collected on 8-, 12-, and 18-in. neck diameter ceiling diffusers.

NOISE GENERATED BY OTHER SOURCES

Objectionable noise may be produced by fan motors, pumps, compressors, etc. The designer must give attention to these sources of noise. It is not possible to predict the noise, because units from different manufacturers differ greatly in the noise produced.

Objectionable noise is also generated in the duct system by excessive air velocity or poor duct fittings. No systematically taken data have been published from which conclusions can be drawn. The reader is referred to Chapter 21 Air Duct Design for good design practice.

Table 4 .... Approximate Attenuation in Straight Sheet-Metal Duct Runs in Decibels Per Foot

Duct	Size, Inches	All Frequencies
Small	6 x 6	0.1
Medium	24 x 24	0.05
Large	72 x 72	0.01

SOUND ATTENUATION IN DUCTS

Unlined Straight Sheet-Metal Ducts

The attenuation of sound in straight sheet-metal ducts is a function of the length, shape, and size of the duct. If a thermal insulating material is applied to the outside of the duct this will also affect the attenuation characteristics.[13] Attenuation values in common use are given in Table 4.[14]

A recent investigation conducted at the Massachusetts Institute of Technology indicates that the attenuation values given in Table 4 are probably satisfactory above a frequency of 500 cps, but are in most cases significantly lower than the observed values of attenuation below this frequency.[13] Only two sizes of ducts were tested, a 12 x 12 in. and a 12 x 24 in. However, these ducts were investigated not only bare, but also with two types of glass fiber thermal insulation applied to the outside of the duct. The first type used was a 1-in. thick glass fiber insulation with a density of 0.75 lb per cu ft. The second type was a glass fiber semirigid 1-in. board with a density of 6 lb per cu ft. Attenuation values were determined by plotting SPL readings made at 3-ft intervals over a total duct length of 40 ft. The results are presented in Table 5.

It should be noted from Table 5 that the addition of thermal insulation to the outer duct walls had little or no effect on the attenuation in the four octave bands above 600 cps for the ducts tested, and that the values are substantially in agreement with Table 4. In the lower octave bands, however, the effect of added thermal insulation on attenuation is indeed striking. More data on larger size ductwork is needed to confirm these results.

Branches

At a junction where a duct divides or has side branches or outlets, the sound power traveling down the duct divides.

The decibel reduction in sound power from the main duct to any branch may be calculated as 10 $\log_{10}$ of the ratio of the branch area to the total area of all branches leaving the junction. Generally the total area of the branches leaving a junction is greater than that of the duct entering a junction; therefore, the area of the branch should not be divided by the area of the supply duct. In a complicated branched system, errors incurred by such a practice may accumulate to several db. Table 6 gives the db reduction for various ratios of branch duct area to the total branch duct area.

Table 5 .... Octave Band Attenuation of Bare and Thermally Insulated Straight Sheet-Metal Ducts

Duct Size Inches	Type of Insulation	Density	Attenuation—db per ft							
			Frequency Band—Cycles per Second							
			20–75	75–150	150–300	300–600	600–1200	1200–2400	2400–4800	4800–10,000
12 x 12	1-in. Glass Fiber, blanket type	—	0.26	0.26	0.20	0.08	0.08	0.12	0.12	0.16
		0.75	0.40	0.40	0.32	0.16	0.08	0.24	0.12	0.16
		6.0	0.66	0.66	0.50	0.26	0.08	0.24	0.12	0.16
12 x 24	1-in. Glass Fiber, semirigid board type	—	0.30	0.36	0.16	0.06	0.12	0.12	0.12	0.16
		0.75	0.38	0.44	0.22	0.10	0.12	0.12	0.12	0.16
		6.0	1.04	0.56	0.28	0.16	0.12	0.12	0.12	0.16

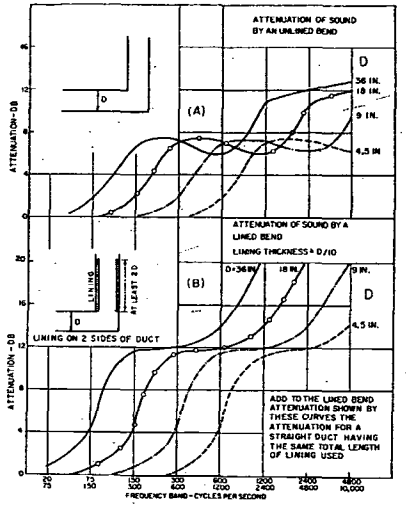
Table 6 .... Power Level Attenuation at Duct Branches or Outlets

Ratio Branch Duct Area / Sum of Branch Areas	Attenuation db	Ratio Branch Duct Area / Sum of Branch Areas	Attenuation db
1.0	0	0.25	6
0.8	1	0.2	7
0.63	2	0.16	8
0.5	3	0.13	9
0.4	4	0.1	10
0.32	5		

Square Corner Bends

Square corner bends can be quite effective in noise reduction provided they are widely separated in the system. The noise reduction for a single square corner bend with no turning vanes, unlined, is shown in Fig. 10 Part A. Turning vanes are usually employed in square corner ducts. When the width of the turning vanes is small, say less than one-fourth wavelength of the sound, they do not affect the noise reduction. At higher frequencies, they decrease the noise reduction substantially below that shown in Fig. 10 Part A.

When a square corner bend is lined with sound absorbing material, the lining should be extended several duct widths beyond the corner in the direction of sound transmission. For square bends lined in this manner the attenuation may be estimated from Fig. 10 Part B.



The attenuation is given for eight octave frequency bands with D in inches as the parameter.

Fig. 10 .... Attenuation in Decibels Provided by (A) Unlined Bend, and (B) Lined Bend in a Duct with the Lateral Dimension D

End Reflection Losses

All of the noise power that is produced in a duct by a fan (or by turbulence) does not radiate from the end of a duct into the room. Instead, part of the power is reflected back from the end toward the fan. The amount of noise power reflected is related to the product of the frequency of the sound and the length of a duct side L, assuming that the duct is square. If the duct is not square, the value of L is taken to be approximately equal to $\sqrt{L_x L_y}$. The end reflection loss is shown in Fig. 11 for two cases: (1) a duct ending in free space and (2) a duct ending flush with the wall.

Duct Lining Procedure

In the past, the most common method of obtaining sound absorption in ventilating systems has been to line the duct with absorbing material. It is usually more convenient to line all four sides of the duct, but a lining on one side over a longer length of the duct will, in general, give the same effect for the same area of applied acoustical material. Subject to certain restrictions, the attenuation of a fully lined duct to single-frequency sounds may be expressed by the approximate Equation 22.[15]

$$R = 12.6l \frac{P}{A} \alpha^{1.4} \text{ db} \qquad (22)$$

where

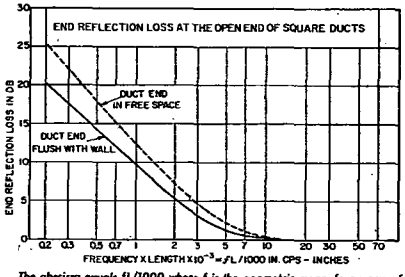
R = attenuation, decibels.

l = length of lined duct, feet.

P = perimeter of duct, inches.

A = cross-sectional area of duct, square inches.

α = absorption coefficient of lining (a function of frequency).[16]



The abscissa equals fL/1000 where f is the geometric mean frequency of an octave band in cps and L is the duct dimension in inches. Two cases are shown, with the duct end flush in the wall and with the duct end projecting into the room.

Fig. 11 .... End Reflection Losses in Decibels at the Open End of a Square Duct of Area L^2