lined duct. It decreases as the cross-sectional area increases, and increases as the aspect ratio is increased.

The noise reduction varies to a considerable extent with the frequency of the sound. In calculating noise reduction, consideration should be given both to the comparative efficiency of the duct lining material at different frequencies, and to the frequency distribution of the noise to be quieted. In the case of fan noise, it is recommended that calculations be based upon the predominant frequency component in the fan sound level spectrum. Normally, most of the sound energy is in the region of this frequency, which generally corresponds to the blade frequency and is equal to rpm $\times$ no. of blades $\div$ 60.

Where the noise reduction is calculated upon the basis of the fundamental frequency component, the treatment indicated as required should be ample for the harmonics which are more easily absorbed than the fundamental. In quieting noise due to air turbulence and eddy currents where high frequencies predominate, the frequency 1024 should be used.

Since ventilating system noise contains many frequencies, an exception should be noted to the previous statement that attenuation in decibels is directly proportional to length of duct. Most sound absorbent materials are more efficient at high frequencies than at low frequencies. In consequence, the attenuation in the first five or ten feet of lined duct will be greater because the high frequencies are being absorbed. Thereafter, since low frequencies will be predominant, the overall noise attenuation per foot will gradually be less.

Duct Lining

By far the most commonly used method of obtaining sound absorption in ventilating systems is 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 6:[7]

$$R = 12.6L\frac{P}{A}a^{1.4} \qquad (6)$$

where

R = attenuation, decibels.
L = length of lined duct, feet.
P = perimeter of duct, inches.
A = cross-sectional area of duct, square inches.
a = absorption coefficient of lining.

This formula was empirically developed for a set of duct sizes ranging from 9 x 9 in. to 18 x 18 in., for cross-sectional dimension ratios of 1:1 to 2:1, for frequencies between 256 and 2048 cycles, and for absorption coefficients between 0.20 and 0.80. The duct lining material used was 1 in. rock wool sheet. In Table 8 are listed the absorption coefficients of a material of this type in one-half and one inch thickness.

It is also possible to calculate the absorption by a very complicated mathematical theory.[8,9] Such calculations are in substantial agreement with Equation 6. This equation may be in error when applied to other

Table 8. Attenuation Data for Typical 1 in. and ½ in. Thick Duct Lining Board

Frequency cycles per second	1-Inch Thickness			½-Inch Thickness		
	Absorption Coefficient a	$a^{1.4}$	Attenuation db	Absorption Coefficient a	$a^{1.4}$	Attenuation db
128	0.29	0.17	$2.1\ L\frac{P}{A}$	0.13	0.06	$0.8\ L\frac{P}{A}$
256	0.51	0.39	$4.9\ L\frac{P}{A}$	0.25	0.15	$1.9\ L\frac{P}{A}$
512	0.70	0.60	$7.6\ L\frac{P}{A}$	0.40	0.28	$3.5\ L\frac{P}{A}$
1024	0.80	0.73	$9.2\ L\frac{P}{A}$	0.72	0.63	$7.9\ L\frac{P}{A}$
2048	0.79	0.72	$9.1\ L\frac{P}{A}$	0.78	0.71	$8.9\ L\frac{P}{A}$

types of duct lining and to duct sizes and shapes greater than those specified. An empirically-derived chart[10] representing the average experimental data on a number of different types of materials, is shown in Fig. 5. Since individual materials vary, the curves of Fig. 5 are given only as representing the best available averages for duct sizes of cross-sections from 6 x 6 in. to 48 x 48 in. The dotted lines are plotted from Equation 6 and show that the slope is materially different from the average values.

Rectangular Cells (Plate or Cell Absorbers)

If the length of duct from the main duct to the grille is shorter than the length of lining indicated by Equation 6, the duct may be subdivided into smaller ducts as shown in Fig. 6, or it can also be even more subdivided by an egg-crate construction. In such a construction in which all the subdivided ducts are the same size, sound will be equally absorbed down each channel. It is, therefore, only necessary to calculate the sound attenuation of an individual channel. For this, Equation 6 is adequate.

When the number of splitter plates or cell partitions is large, the percentage free area of the gross duct size may be materially reduced. This leads to a further sound attenuation. Values of the attenuation possible, due to this cause, are given in Table 9.

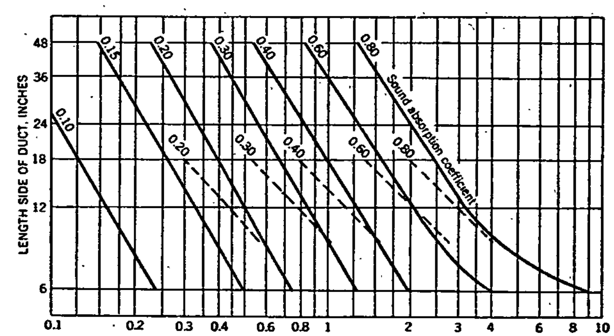

Fig. 5. Sound Attenuation for Various Absorbing Duct Liners