as well as Equation 6, show that the attenuation in decibels is directly proportional to the length of duct lined, and that the larger the duct the greater will be the length which must be lined in order to obtain a given noise reduction.

If the length of duct from the main duct to a grille is shorter than the length of lining indicated by the calculations, this duct may be subdivided into smaller ducts, as shown in Fig. 4. The increase in noise reduction thus obtained may be calculated from Equation 7, provided the splitters are installed parallel to the long side of the duct:

$$R_s = R_o \frac{a + bn}{a + b} \qquad (7)$$

where

R_s = reduction with splitters, decibels.
R_o = reduction in same length of duct, without splitters, decibels.
a = dimension of short side of duct, inches or feet.
b = dimension of long side of duct, inches or feet.
n = number of channels formed by splitters.

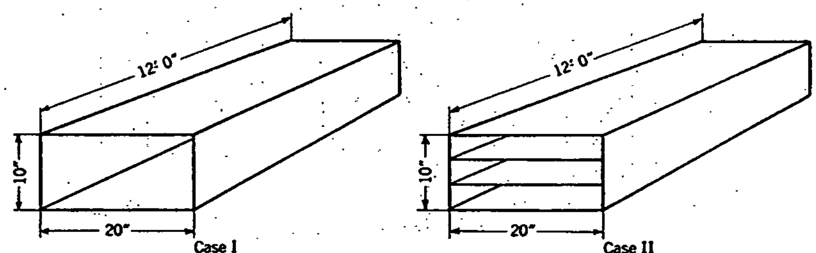

Fig. 4. Diagram of Branch Duct Treatment Where Length is Insufficient for Adequate Absorption

Example 1. An air conditioning installation is to be installed in a small theater. Determine the necessary sound treatment for the air distribution system to provide a satisfactory noise level in the theater utilizing these conditions:

Fan tip speed 4000 fpm, total pressure 1.25 in.	77 db
Acceptable room noise level (Table 1)	40 db
Required attenuation	37 db

Solution: Natural attenuation of supply duct.

Sheet metal duct 50 ft long 48 in. x 36 in. (Table 2) 50 x 0.01	0.5 db
Elbows, two size 48 in. x 36 in. (Table 3) 2 x 1	2.0 db
Attenuation grilles to theater air change 10 min (Table 5) outlet velocity 1000 fpm	22.0 db
Total natural attenuation	24.5 db

Difference between required and natural attenuation, 37 minus 24.5, is 12.5 db. This attenuation must be supplied by sound treatment in the duct, either in the form of duct lining or plate cells.

A similar analysis of the return duct system shows that 15 db attenuation is to be furnished by absorptive material. An inspection of the installation shows that the lining of the plenum on the suction side of the fan would prove the most economical, where it would secure the dual function of heat insulation and sound absorption.

Example 2. A 10 x 20 in. duct is connected to a private office space in a quiet location. Determine the length of lining necessary to attenuate average fan noise satisfactorily, using a lining material of a type to which Equation 6 applies, and having an absorption coefficient of 0.40 at 256 cycles. Assume that the duct is only 12 ft long as shown in Fig. 4, and that a 30 db reduction is required in this length.

Solution:

Case 1. (No splitters), From Equation 6,

$$R_o = 12.6 \times 12 \times \frac{60}{200} \times 0.40^{1.4} = 12.6 \text{ db}$$

Case 2. (Two splitters, three channels), From Equation 7,

$$R_s = 12.6 \times \frac{10 + (20 \times 3)}{10 + 20} = 29.6 \text{ db}$$

AIR SUPPLY OPENING NOISES

When air is introduced into a room through a grille or register at a constant velocity, sound energy is being introduced into the enclosure at a constant rate [12]. Due to partial reflection at the boundaries of the enclosure, the intensity of sound at any point in the space builds up to some maximum value. In a large room at a point remote from the source of sound (the supply opening) the intensity can be shown to be substantially

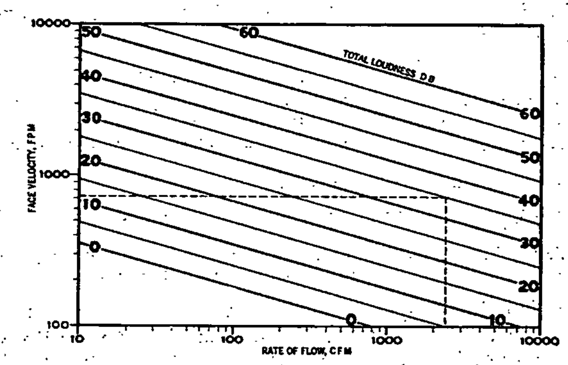

Fig. 5. Air Flow and Loudness Chart

proportional to the rate at which sound energy is generated and inversely proportional to the number of sound absorption units (sabines) in the room. It would thus appear that doubling the sound absorption of the room would halve the intensity and result in a noise level decrease of 3 db.

Grille noise is similar in character to fan vortex noise. Knowing the noise level at the face of a grille for a given grille blade setting, the noise will vary as given in Equation 8 where V is the velocity of the air through the grille.

$$db \text{ (change)} = 55 \log_{10} \left(\frac{V_2}{V}\right) \qquad (8)$$

For a change in blade setting Equation 9 applies and in this case the total pressure is measured directly behind the face of the grille. For a typical air conditioning grille the noise level at the grille face may be approximately 48 db with a total pressure behind the grille of 0.1 in.

$$db \text{ (change)} = 27.5 \log_{10} \left[\frac{(\text{Total Pressure})_2}{(\text{Total Pressure})_1}\right] \qquad (9)$$

The resultant room noise level can be approximated by Equation 10.

$$\text{Room Level} = \left[\begin{matrix}\text{Noise Level at Face}\\ \text{of Grille}\end{matrix}\right] - 10 \log_{10} \frac{\text{Total Room Absorption in Sabines}}{\text{Total Grille Area}} \qquad (10)$$