Table 9 . . . . Power Level Attenuation at Duct Branches or Outlets

Ratio $\frac{\text{Branch Duct Area}}{\text{Sum of Branch Areas}}$	Attenuation db	Ratio $\frac{\text{Branch Duct Area}}{\text{Sum of Branch Areas}}$	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		

tion. 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 9 gives the db reduction for various ratios of branch duct area to the total branch duct area.

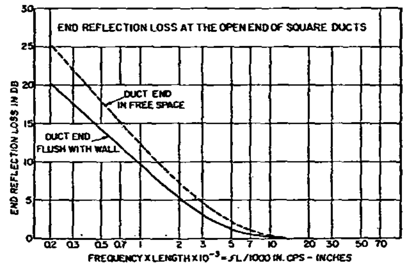
Outlet Sound Absorbers

Outlet sound absorbers are rectangular or plate cells installed directly behind an outlet or they may be the lining of a pan or plaque outlet. They are particularly effective in the elimination of high frequency whistles which are generated by air flow in the ducts. They are also employed in large system with long runs where only a few outlets near the fan require treatment. Frequently outlet cells are the only means of correcting existing noisy installations, as the duct sections directly behind the outlets may be the only sections accessible for treatment. (See Fig. 14.)

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 $\sqrt{L_1L_2}$. The end reflection loss is shown in Fig. 15 for two cases: (1) a duct ending in free space and (2) a duct ending flush with the wall.

In Fig. 15 the re-reflection from within the duct is assumed to be negligible.



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

DETERMINATION OF ROOM LEVELS

In the previous sections on fan and grille noise, sound power levels were given in dbe referred to 10^{-13} watt. These quantities as they appear at the duct termination (grille) must be converted to sound pressure levels in the room, because it is sound pressure to which the ear and the sound level meter respond. The sound pressure level at a distance r from the grille opening and at an angle θ with respect to an axis perpendicular to its surface is given by the equation[22]

$$L_p = L_W + 10 \log_{10}\left(\frac{Q}{4\pi r^2} + \frac{4}{R}\right) + 0.5 \qquad (23)$$

where

L_W = sound power level emitted at the duct termination and is the power summation of the attenuated fan noise and the grille noise, decibels.

Q = directivity factor and is a dimensionless function of θ.

r = distance from the duct opening, feet.

R = the room constant, square feet. (R increases with the amount of acoustical absorption in the room and generally depends somewhat upon frequency.)

In Fig. 16 four methods are shown for terminating a ventilating duct in a room. In each of these cases, the noise power

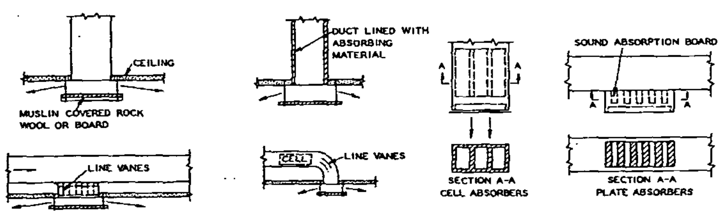


Fig. 14 . . . . Outlet Cells for Pan Outlets or Grilles

radiates into the room. Low-frequency sounds radiate equally in all directions. High-frequency sounds tend to beam in the direction the duct opening is facing. The magnitude of this beaming effect is described mathematically by the directivity factor Q. After the sound at any frequency has reflected from a wall, it generally travels around the room many times to produce reverberant sound. This fact appears in Equation 23, wherein the first term in the parenthesis described the *direct* sound (prior to reflection) and the second term described the *reverberant* sound (the result of many reflections).

The directivity factor Q is of importance only when the listener is near the duct termination, i.e., when r is small. At large distances, i.e., when the first term becomes negligible compared to the second, the listener hears only the reverberant sound.

For the four duct positions of Fig. 16, approximate values of Q are given in Fig. 17 for θ = 0 deg and for θ = 45 deg. The abscissa is the product of frequency times L assuming that the duct is approximately square with an area of L^2 sq in. If the duct is rectangular, the value of Q should be computed for L equal to the smaller dimension.

The room constant R is defined by the equation

$$R = \bar{a}S/(1 - \bar{a}) \qquad (24)$$

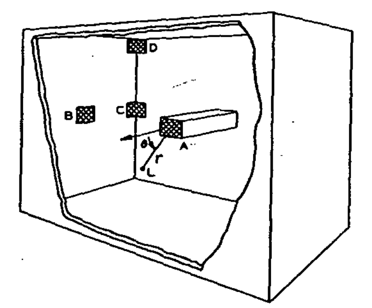
where

$\bar{a}$ = average sound absorption coefficient (dimensionless) for the room at the mid-frequency of the band of noise being considered.

S = total area of the boundary surfaces of the room, sq ft.

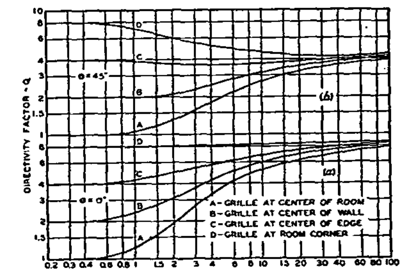
Where a room contains several surfaces, each with different absorption coefficients, the average absorption coefficient may be determined by the equation

$$\bar{a} = \frac{S_1\alpha_1 + S_2\alpha_2 + \cdots}{S_1 + S_2 + \cdots} \qquad (25)$$



A. Duct projecting in the room
B. Duct in the center of and flush with the wall
C. Duct in the center of one edge
D. Duct in the corner
The listener L is at distance r and angle θ from the duct opening.

Fig. 16 . . . . Four Typical Means for Terminating a Ventilating Duct in a Room



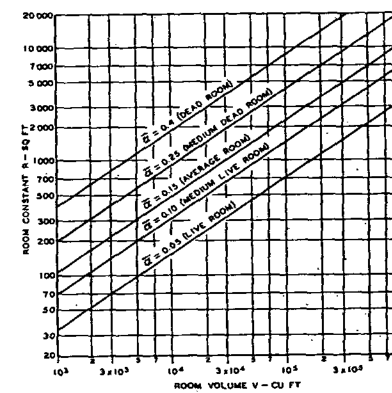
A. The value of Q is given for θ = 0; i.e., directly in front of the duct opening
B. Same as for (A) except the value of Q is given for θ = 45 deg.
The frequency of f is in cps and the duct is assumed to be square with an area L^2 in square inches.

Fig. 17 . . . . Directivity Factor Q for the Four Duct Configurations of Fig. 16

where

S_1, S_2 = the areas of each type of absorbing material. α_1, α_2 etc., = the absorption coefficients of each type of material at the mid-frequency of the band of noise being considered. (Values of α for many materials are published by the Acoustical Materials Association.[16])

The room constant R may also be determined by calcula-



These proportions give S = $6.25V^{2/3}$. The parameter is the average sound-absorption coefficient for the room. The subjective ratings dead, live, etc., are the author's[22] and are not necessarily in standard use.
From Reference 22. Used by permission.

Fig. 18 . . . . Value of the Room Constant *R* as a Function of Room Volume for Rooms with Proportions of About 1:1.5:2