tion[22] from a direct measurement of the reverberation time. Another method of measuring R is to use a standardized sound source of known sound power level L_W and apply Equation 23 backwards. Such a standard sound source is commercially available.[23] It should be pointed out that the value of R found from Equation 24 should be augmented by the natural air absorption before use in Equation 23. It should also be pointed out that Equation 23 is not accurate for a room of unusual shape, such as a long room with a low ceiling.

For estimating purposes, approximate values of the room constant R may be obtained from Fig. 18 as a function of room size for five classes of rooms.

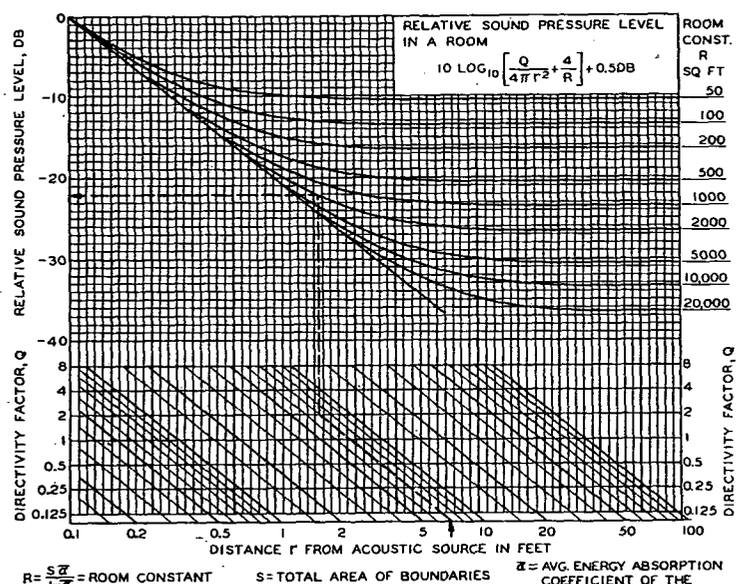
The value of the second and third terms of Equation 23 (including 0.5 db) is plotted in Fig. 19 with distance r from the source as the abscissa, with the sound pressure level in decibels as the ordinate and the room constant R in sq ft as the parameter.

The directivity factor Q is given at the bottom left-hand side of the graph. The procedure for using the graph is:

Determine the room constant R and the directivity factor Q for the particular direction θ of interest. Enter Fig. 19 at the bottom at the distance r. Then move diagonally to the left until the value of Q is reached. Then move vertically until the value R is reached. Then read the relative sound pressure level from the ordinate. An example is shown by the dotted line in Fig. 19 for $r = 7$ ft, $Q = 2$, and $R = 2000$ sq ft. The relative sound pressure level is added algebraically to the sound power level to yield the sound pressure level at the distance r and the angle θ in the room (see Equation 23).

It is seen from Fig. 19 that the noise from a ventilating duct is less at distances far from it than nearby. Moreover, at large distances, the levels produced in the room depend only on the power level of the source and the room constant and not on the directivity factor and the distance r.

Example 3: To illustrate the application of the noise criteria and control procedures outlined in this chapter, calculation will be made for the required treatment for the ventilation system supplying the library reading room of Fig. 20. This room has a total volume of 80,000 cu ft and may be considered as an *average room* for acoustic properties (see Fig. 18). The total air



$R = \frac{S\bar{\alpha}}{1-\bar{\alpha}}$ = ROOM CONSTANT IN SQ FT S = TOTAL AREA OF BOUNDARIES OF ROOM IN SQ FT $\bar{\alpha}$ = AVG. ENERGY ABSORPTION COEFFICIENT OF THE SURFACE OF THE ROOM

THE ABSOLUTE SPL (DB RE 0.0002 MICROBAR) EQUALS THE SUM OF THE ORDINATE AND THE PWL (DB RE 10^{-13} WATT) OF THE NOISE SOURCE AT NORMAL ROOM TEMPERATURE AND PRESSURE CONDITIONS.

The listener's position is at a distance r and an angle θ with respect to the duct opening. Q is determined from θ and from the duct dimensions (see Fig. 18). To use the graph proceed as for the example shown by the dotted line for r = 7 ft, Q = 2, and R = 2000 sq ft. The sound pressure level in the room equals the sum of the ordinate and the sound power level. Normal room temperature and pressure conditions are assumed.

Fig. 19 .... Curves for Determining the Sound Pressure Level in the Room Relative to the Sound Power Level

Table 10 .... Summary of Calculations for *Example 3* on Ventilating Noise Levels in Libary Reading Room

Item	Octave Frequency Bands							
	20–75 cps	75–150 cps	150–300 cps	300–600 cps	600–1200 cps	1200–2400 cps	2400–4800 cps	4800–10,000 cps
1. L_W (duct DH)	101	96	91	86	81	76	71	66
2. Attenuation (straight duct)	5	5	5	5	5	5	5	5
3. Attenuation (bend B)	—	—	2	7	7	6	11	12
4. Attenuation (bend H)	—	—	1	4	7	7	8	10
5. Attenuation (end loss)	13	7	4	1	—	—	—	—
6. Total duct attenuation	18	12	12	17	19	18	24	27
7. L_W (grille outlet)	83	84	79	69	62	58	47	39
8. fL/1000 cps-in	0.5	1.3	2.5	5.1	10.2	20.4	40.8	81.6
9. Q	2	2	2.2	2.7	3.2	3.6	3.9	4.1
10. Rel. L_p at 7 ft	−22	−22	−22	−21	−20	−20	−20	−20
11. L_p at 7 ft	61	62	57	48	42	38	27	19
12. L_W (all grilles)	89	90	85	75	71	67	56	48
13. Rel. L_p far field	−26	−26	−26	−26	−26	−26	−26	−26
14. Reverberant L_p	63	64	59	49	45	41	30	22
15. Criterion L_p	60	51	43	37	32	30	28	27
16. Required attenuation	3	13	16	12	13	11	2	—
17. Attenuation 4 ft pkg. unit	7	11	14	30	40	40	38	33

supply to the reading room is 6000 cfm which is equally divided between four 12 x 18 in. supply grilles located along one wall. The supply of outdoor air is from a central fan system which handles a total of 25,000 cfm at 2-in. water static pressure and requires a 15 hp motor.

Solution: It is necessary to determine the noise level in the reading room as a result of the ventilating system, both for the position of the nearest listener to a grille, and for a position remote from the supply grilles since it is impossible to tell beforehand which will be greater. The required attenuation for acceptable octave band noise levels will then be determined.

Analysis of Fan and Duct System

The acoustic power level of the fan should be computed from Equation 18 when the specific power level is available. In this example it is assumed that the specific sound power level is not known. Therefore, employ the approximate Equation 19

For duct AB:

$$L_W = 100 + 10 \log 15 + 10 \log 2 = 114.7 \text{ db}$$

Of this total acoustic power generated by the fan the main interest is in the part that reaches the reading room. At each duct branch the power will divide approximately as the ratio of the branch duct area to the total duct area after the branch. Thus at Station B (Fig. 20) the acoustic power delivered to the 18 x 48 in. duct, neglecting any attenuation in the system, will be:

For duct BC:

$$L_W = L_W \text{ from duct AB} + 10 \log (A_{branch}/A_{total})$$

$$= 115 + 10 \log \left[\frac{18 \times 48}{(24 \times 48) + (18 \times 48)}\right] = 111 \text{ db}$$

At Station C the power division gives:

For duct CD:

$$L_W = 111 + 10 \log \left[\frac{12 \times 48}{(18 \times 24) + (12 \times 48)}\right] = 108 \text{ db}$$

Thus neglecting, at first, the attenuation in the connecting duct system, the total acoustic power delivered to the room by the fan will be 108 db. Assuming that the branch fittings at D, E and F are similar to that at C in Fig. 20, the unattenuated fan acoustic power delivered to each of the four 12 x 18 in. grilles will be approximately

For duct DH:

$$L_W = 108 - 10 \log 4 = 102 \text{ db}$$

The octave band spectrum of the centrifugal fan noise is given by Fig. 6. This chart indicates that the power level in

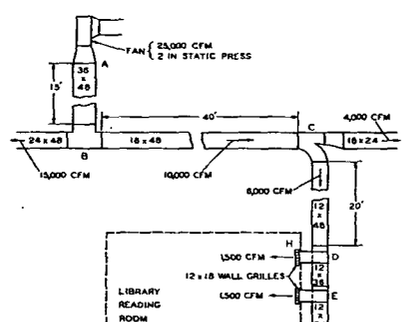


Fig. 20 .... Assumed Ventilating System for *Example 3*