metal ducts of *medium size* is 0.05 db per ft. All of the ducts of this system may be assumed to fall within this medium category. The total length of the duct run from the fan to the grille at station H (Fig. 19) is 90 ft. The straight duct attenuation is, therefore, 0.05(90) = 5 db, which is entered in line 2 of Table 7. The divided flow fitting at B may be considered equivalent in attenuation to an 18-in. square bend. Values are read from Fig. 8, Part A and entered as line 3 in the calculation table. The rounded corners of the branch flow fittings at C, D, E, F, and G are assumed to have no attenuation. The 12 × 15-in. risers serving each of the wall grilles have a square bend (see Fig. 20), and attenuation values are read from Fig. 8, Part A and entered as line 4 of Table 7. The attenuation due to the end reflection loss at the grille face is given by Fig. 9. For the 12 x 18-in. grilles used here $L = \sqrt{12 \times 18} = 14.7$ in. Thus, for the first octave band (20–75 cps), which has a geometric mean frequency of 40 cps; $fL/1000 = (40 \times 14.7)/1000 = 0.58$ and the end loss is 13 db.

The attenuation in the other octave bands is similarly determined and entered in line 5 of Table 7. The total natural duct attenuation is now found by summing lines

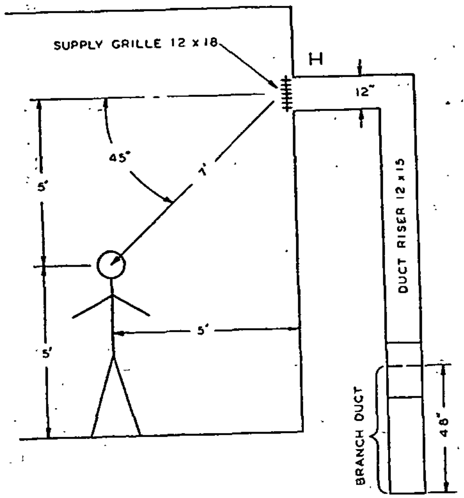

FIG. 20. LOCATION OF NEAREST LISTENER TO A SUPPLY GRILLE

2, 3, 4, and 5 of Table 7, the result appears in line 6. This total attenuation may now be substracted from the unattenuated power level in line 1 to give the estimated acoustic power level radiated into the room from the outlet grille at station H. Line 7 of Table 7 gives the result.

Determining Room Sound Pressure Levels

The next step, then, is to calculate the sound pressure level at the position in the room occupied by the listener nearest to any one grille, and for the overall reverberant sound pressure level in the room due to the sound power radiated from all of the grilles. Fig. 20 shows that the position of the nearest listener is 7 ft from the grille. To determine L_p at this position, determine the directivity factor Q at 45 deg to the grille face; this is found from Fig. 16. The parameter $fL/1000$ is determined by taking the characteristic length L as the shortest side of the grille face or 12 in. Thus, for the first octave band, $fL/1000 = 40\,(12)/1000 = 0.48$. This value together with all the corresponding values for the other seven octave bands are entered in line 8 of Table 7. Line 9 of the table gives the corresponding directivity factors as read from Fig. 16, using curve B since the grille is flush with the wall but not at an edge or corner.

It was initially assumed that the library reading room had average acoustical properties, consequently, the room constant R in sq ft may be read from the line marked *average room* of Fig. 17. For a total room volume of 80,000 cu ft the result

is $R = 2000$ sq ft. The relative sound pressure levels for an observer 7 ft from the grille may now be read from Fig. 18 making use of the directivity factors and the room constant as found. The dotted line in Fig. 18 shows that the relative L_p for the 20–75 cps band is −22 db. This relative L_p is entered in line 10 of Table 7. The sound pressure level at the 7 ft position from the grille is given by the addition of line 7 and line 10 in the calculation table. This result appears as line 11.

If there were only one grille in the room the calculation for room sound pressure level would be the only one required. However, since there are four grilles it is necessary to determine the general reverberant sound pressure level in the room due to the acoustic power radiated from these four sources to see if it is greater than the previous calculation. Neglecting the small additional duct attenuation which occurs in the somewhat longer duct runs to the other three room grilles, the total acoustic power radiated from the four grilles will be four times that from one grille. Hence the total acoustic power level from all grilles will be 10 Log 4 or 6 db higher than from a single grille. In line 12 of Table 7, therefore, enter the PWL of all grilles by adding 6 db to the single grille value of line 7. The relative L_p for an observer in the reverberant sound field is read from the horizontal part of the $R = 2000$ sq ft curve of Fig. 18 as −26 db, and entered in line 13 of Table 7. The sum of line 12 and line 13 values from Table 7 gives, in line 14, the general reverberant sound pressure level in the room. Comparison of line 11 and line 14 shows that the latter is 2 db higher at the lower frequencies and, therefore, should be used in determining any noise treatment for the ventilating system or room.

Room Criteria

For this example the speech interference level criteria will be used. Examination of Table 1 shows that an acceptable noise level for libraries will be given by the NC-30 curve of Fig. 3. The values read from this curve are entered as line 15 of Table 7. The difference between these criterion sound pressure levels and the computed L_p in line 14 of the table gives the required attenuation for the ventilating system. This final result appears as line 16 in Table 7.

Treatment

The type of treatment of the ventilating system to obtain the attenuation given in line 16 of the calculation table will depend on many factors as discussed in the section on Sound Attenuation. One satisfactory treatment might employ a 4-foot package unit whose attenuation characteristics, as given in Fig. 13, are entered in the final line 17 of Table 7. The additional 2 db of attenuation required in the second and third octave bands could be obtained by lining approximately 10 ft of the 12 × 48-inch duct with 1-inch liner.

A calculation is now made of the acoustic power level generated by the grille itself. The face velocity of the grille is 1500 cfm/1.5 sq ft = 1000 fpm. From Fig. 7, assuming a vertical or horizontal bar deflection type grille, the average power level in the speech interference bands (600–1200, 1200–2400, 2400–4800 cps) for a face velocity of 1000 fpm is 41 dbe per square foot of grille area or 41 + 10 log 1.5 = 43 dbe for the grille in this example.

From line 10 of the calculation table the relative L_p in the speech interference bands (600–4800 cps) is −20 db. Consequently the L_p of the grille noise at 7 ft is 43 − 20 = 23 db. This is well below the 30 db criterion selected for this room and, therefore, is satisfactory.

In reverberant fields all four grilles contribute so the total acoustic power level of the four grilles is 43 + 10 log 4 = 49 dbe. From line 13 of Table 7 the relative L_p is −26 db and therefore the reverberant L_p will be 49 − 26 or 23 db, which by coincidence is the same as that calculated at the 7 ft distance from one grille and, therefore, is also satisfactory.

The calculation of grille noise in this example was left to the end in order to keep a simple continuity to the principal problem of calculating the fan noise in the room. Experience shows that it is advantageous to calculate the grille noise early in the problem as indicated in the outline given in the text so that if the grille size must be changed its correct value may be used in calculating fan noise attenuation.

CROSS TRANSMISSION BETWEEN ROOMS AND THROUGH DUCT WALLS

Ducts serving more than one room permit cross talk between the rooms and should be lined with acoustical material. Where the rooms are close together and the ducts short, the ducts should be sub-divided to provide