employed in large systems 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 acessible for treatment. (See Fig. 5.)

GRILLE NOISE

In the preceding discussion it is presupposed that the noise level generated at the face of the grille is less than the noise level of the fan minus the attenuation of the duct system up to the face of the grille. If this is not true the grille noise rather than fan noise then becomes the governing factor in room noise. 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:

$$db \text{ change} = 10 \log_{10} \left(\frac{V_{new}}{V_{given}} \right)^{5.5} \tag{9}$$

Where V is the velocity of the air through the grille. For a change in blade setting:

$$db \text{ (change)} = 10 \log_{10} \left[\frac{(\text{Total Pressure}_{new})}{(\text{Total Pressure}_{given})} \right]^{2.75} \tag{10}$$

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. (Further discussion of grille noise is given in Chapter 31). If the grille noise at the face of the grille is more predominant than fan noise, then the resultant room noise level can be approximated by Equation 11.

$$\text{Room Level} = \left[\begin{matrix} \text{Noise Level at Face} \\ \text{of grille} \end{matrix} \right] - 10 \text{ Log}_{10} \frac{\text{Total Room Absorption in Sabines}}{\text{Total Grille Area}} \tag{11}$$

CROSS TRANSMISSION OF NOISE BETWEEN ROOMS

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 ample acoustical treatment. Lagging material similar in character to acoustical board, when placed on the outside of ducts serves to prevent noise originating outside the ducts being carried inside the ducts and into the air stream.

A case where outside lagging is desirable occurs when ducts originate at the fan in the equipment room and pass through this room on the way to the room being conditioned or ventilated. Unless the ducts are lined some of the mechanical noise from the equipment room air may be transmitted through the wall of the duct, thus reaching the air stream and be carried into the room. In such cases, that portion of the duct which is exposed to the sounds in the equipment room should be lagged with material such as cork, pipe covering or other sound damping material to prevent the sound from entering the duct at this point. Numerical data are not available to permit a simple and practical calculating procedure to determine thickness of covering which should be used for this purpose.

Laboratory measurements have shown that the loss through a sheet of No. 22 gage metal is 24 db. When a sheet of rock wool insulation 1 in. thick and weighing 1.4 lb per square foot is added to this, the insulation value is increased to 29 db. In general, however, adding a layer of insulation or pipe covering does not materially increase the sound insulation value unless the material is dense, or unless it is surfaced with another sound impervious layer such as metal or board. Inside lining material used in the case previously mentioned would serve as an absorber of the sound transmitted through the duct walls, and thus act as a means of preventing the transfer of noise into the air stream. Inside lining may also be used in ducts to absorb noise which reaches the air stream from equipment such as fans, sprays and coils; noise due to eddying currents set up by elbows, dampers and similar obstructions; and noise transmitted from room to room where there is a common duct system.

GENERAL CONSIDERATIONS

Often in ventilating duct work the engineer feels that it will not be necessary to line ducts if the sound is traveling against the airflow. However, this is untrue since sound travels more rapidly than air in even high velocity systems, and it will travel as easily against the airflow as it does with it.

Sounds which are low in pitch are much harder to eliminate from a duct system than sound which is high in pitch, consequently equipment which produces low pitched sounds should be avoided as much as possible.

NOISE THROUGH BUILDING CONSTRUCTION

It is impossible to select equipment which will operate without producing some mechanical noise, and since the equipment must be mounted in a building, it is probable that a part of this noise will be transmitted to the building to such a degree as to make noisy conditions in the rooms which are to be air conditioned.

Controlling Vibration From Machine Mountings

Much of this noise may be transmitted by the duct if it is rigidly connected to the fan outlet. It is common practice to make the connection between the fan and the duct with a canvas sleeve which effectively restricts noise at this point. Noise may also enter the building through the mounting of the motor and the fan. Flexible mountings should be provided in all installations but these mountings must be carefully designed so that they will actually reduce the contact between the machinery and the supporting floor. If a flexible material is used, it is desirable to investigate the installation so that it is not short-circuited by through bolts which are improperly insulated and by electrical conduit which is not properly broken and is attached both to the equipment and to the building. The flexible mounting, if improperly engineered, may actually increase the contact between the equipment and the floor upon which it is supported.

In the proper isolation of vibration, which is the lower range of frequencies and does not include the *air borne* vibrations known as sound,