

existing spaces. They are, however, the noise levels of the room and not the noise levels of the ventilating or air conditioning equipment. If the noise level at the room of the equipment is kept at the levels shown in the table the equipment will not add to the acoustical hazard existing without it, provided the equipment noise is heard alone, but if both are heard together the total noise level in the room will be increased about 3 db. This is usually considered an acceptable result.

In some cases it is desirable to keep the equipment noise level at the room at such a value that it actually will not increase the noise level in the room to any measurable degree. This can usually be accomplished if the equipment noise at the room can be kept 10 db below the noise level shown in the table.

NOISE CREATED BY EQUIPMENT

Information concerning the noise levels created by ventilating and air conditioning equipment such as fans, motors, air washers, and similar items is not yet on a basis which permits tabular presentation although certain manufacturers are prepared to offer such data and do state the noise producing properties of their products.

Absence of this information makes it necessary to resort to indirect means in solving certain problems and also prevents a direct logical solution.

KINDS OF NOISE

To solve a sound problem of this type it is desirable to consider separately the several means by which noise reaches the room. This avoids to some extent the necessity of knowing the noise level at the source and places the emphasis on ascertaining the level at the point where the sound enters the room rather than on its point of origin.

The noise introduced into a room or building by ventilating or air conditioning equipment may be divided into two kinds depending on how it reaches the room as:

1. Noise transmitted through the building construction.
2. Noise transmitted through the ducts.

It is convenient to further subdivide these two methods of delivery as:

1. Noise transmitted through the building construction.
 - a. From machine mountings as vibration.
 - b. From equipment through room wall surfaces.
2. Noise transmitted through the ducts.
 - a. From equipment such as sprays, fans, etc.
 - b. From outside, and transmitted through duct walls into air stream.
 - c. From air current, including eddying noises.
 - d. Cross talk and cross noises between rooms connected by the same duct system.

The next step in the solution of this problem is to present data and discuss methods whereby solutions to the noise problem can be obtained when the allowable room noise level and the path through which the noise reaches the room are known.

NOISE THROUGH BUILDING CONSTRUCTION

It is impossible to select ventilating 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 itself to such a degree as to make noisy conditions in the rooms which are to be air conditioned. 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 it is improperly engineered, may actually increase the contact between the equipment and the floor upon which it is supported. In general, the flexible material should be loaded as heavily as possible without impairing its load-carrying capacity.

Controlling Vibration from Machine Mountings

The theory of the insulation of vibration was first worked out by Soderberg³. If a machine of mass m be supported by an elastic pad the amount of vibratory force communicated by the machine to the floor or foundation upon which it rests will be determined by the elastic and viscous properties of the pad. The ratio of the vibratory force communicated to the floor or foundation with the machine resting upon the pad, and with the machine resting directly upon the floor, is given by the following equation:

$$\tau' = \sqrt{\frac{r^2 + \frac{1}{4\pi^2 n^2 c^2}}{r^2 + \left(2\pi n m - \frac{1}{2\pi n c}\right)^2}} \quad (1)$$

where

- τ' = the so-called *transmissibility* of the support.
 c = the compliance (that is, the reciprocal of the force constant).
 r = the mechanical resistance owing to the viscous forces within the support.
 n = the frequency of vibration generated by the machine which is to be insulated, such as the commutation frequency of a motor or the blade frequency of a fan.
 m = the mass of the machine to be insulated.

It should be noted that not only must vibrations within the audible range of frequencies be considered, but those in the sub-audible range as well, since these may cause objectionable vibrations. All the possible frequencies should be considered in the calculation. Sometimes beat effects are introduced by slight irregularities of belts or pulleys that have much lower frequencies than those of the rotating elements.

³C. R. Soderberg, *The Electric Journal* (January, 1924), and succeeding articles. See also V. O. Knudsen, *Physical Review*, Vol. 32, 1928, p. 324, and A. L. Kimball, *Journal Acoustical Society of America*, Vol. 2, 1930, p. 297.