

the proper application of sound absorptive material within the ducts. The application of the absorptive material is a problem in balancing the room noise level requirements against the intensity of the noise generated. The four steps in the problem are:

1. Determination of acceptable room noise level resulting from the operation of the equipment.

2. Determination of noise level generated by the equipment.

The difference between steps 1 and 2 in decibels is the overall noise reduction required between the equipment and the room. In the discussion which follows reduction of noise will be referred to as *attenuation* of noise.

3. Determination of the natural attenuation of the duct system.

4. Selection of the proper sound treatment for the duct system.

The difference in decibels between the overall attenuation required and the natural attenuation (3) is the additional sound attenuation to be obtained by absorptive materials installed in the duct system.

DESIGN ROOM NOISE LEVEL

Measurements of noise levels have been observed by several investigators in various rooms and locations and are listed in Table 1. The values given were determined with the air conditioning or ventilation equipment not in operation, and with all windows and doors closed simulating the conditions of an actual installation.

This is an important consideration, for in offices or stores adjacent to busy thoroughfares the difference between the typical noise level in the space with the windows and doors open and closed may be as high as 10 db. Minimum, representative, and maximum levels are given for each type of space. The values are intended to give the variation with respect to location and not to time, and may be roughly classified by the following:

Minimum loudness refers to: Spaces of expensive construction, typified by double windows, carpeted floors, heavy upholstered furniture, or acoustically treated walls and ceilings.

Representative loudness refers to: Spaces of average construction and furnishings which are exposed to external noises typical of the locality in which the space is usually found.

Maximum loudness refers to: (1) Any space of inexpensive construction, and bare furnishings where noise is not an important factor. (2) Spaces in close proximity to very intense street traffic or to intense factory noise. (3) Any space containing machinery which is a constant source of noise, typewriters, adding machines, printing presses, etc.

In general, if the noise level in the space resulting only from the operation of the air conditioning equipment is equivalent to or less than the typical level given in Table 1, the installation will prove satisfactory. If the typical level and the equipment level are heard together the resultant level will be 3 db higher than either of them.

In some cases it is desirable to keep the equipment noise level in the ventilated or conditioned room at such a value that it actually will not increase the noise level in the room to any measureable degree. This can be accomplished if the equipment noise at the room can be kept 10 db below the noise levels shown in Table 1.

TABLE 1. TYPICAL NOISE LEVELS

Rooms	NOISE LEVEL IN DECIBELS TO BE ANTICIPATED		
	Min.	Representative	Max.
Sound Film Studios.....	10	14	20
Radio Broadcasting Studios.....	10	14	20
Planetarium.....	15	20	25
Residence, Apartments, etc.....	33	40	48
Theaters, Legitimate.....	25	30	35
Theaters, Motion Picture.....	30	35	40
Auditoriums, Concert Halls, etc.....	25	30	40
Churches.....	25	30	35
Executive Offices, Acoustically Treated Private Offices	30	38	45
Private Offices, Acoustically Untreated.....	35	43	50
General Offices.....	50	60	70
Hospitals.....	25	40	55
Class Rooms.....	30	35	45
Libraries, Museums, Art Galleries.....	30	40	45
Public Buildings, Court Houses, Post Offices, etc.....	45	55	60
Small Stores.....	40	50	60
Upper Floors Department Stores.....	40	50	55
Stores, General, Including Main Floor Dept. Stores.....	50	60	70
Hotel Dining Rooms.....	40	50	60
Restaurants and Cafeterias.....	50	60	70
Banking Rooms.....	50	55	60
Factories.....	65	77	90
Office Machine Rooms.....	60	70	80
VEHICLES			
Railroad Coach.....	60 ^a	70	80
Pullman Car.....	55 ^a	65	75
Automobile.....	50	65	80
Vehicular Tunnel.....	75	85	95
Airplane.....	80	85	100

^aFor train standing in station a level of about 45 db is the maximum which can ordinarily be tolerated.

NOISE GENERATED BY FANS

Noise generated by fan wheels may be divided into two classifications, rotational noise and vortex noise. In ventilation and air conditioning work, where the maximum ratio between the fan tip speed and the velocity of sound is not greater than 0.12, vortex noise is by far the most important. The rotational noise may be described as that due to the thrust and torque implied to the air. Vortex noise is that due to the shedding of vortices from the blade and is dependent on the angle of attack, velocity, air turbulence, and blade shape. Vortex noise is due to pressure variations on the blade as a result of variations of air circulation. Given the noise level at the outlet or inlet of one type of fan construction under specific conditions of size, tip speed, and total pressure, noise levels at other values of tip speed, total pressure, and size may be approximated by the relationships:

1. With total pressure and size constant.

$$db \text{ (change)} = 10 \log_{10} \left[\frac{(\text{Tip Speed})_{\text{new}}}{(\text{Tip Speed})_{\text{old}}} \right]^5 \quad (1)$$