

This reference level also corresponds to a pressure of 0.0002 dynes per square centimeter.

A stated sound level in decibels, unless otherwise defined, will thus be related to a threshold of  $10^{-16}$  watts. For example, a level of 60 db above this reference threshold is  $10^{-10}$  watts. In a similar manner, when sound measurements are given in actual intensity or energy units, they can be converted to decibels by this relation.

Since the decibel is a ratio, it can only be employed when related to a reference threshold level as given. Noise levels, which vary with frequency as well as intensity, must not only be related to this reference threshold level, but also to a reference frequency, which is taken as 1000 cycles. These terms and procedures may be found in Tentative Standards<sup>1</sup> published by the *American Standards Association*.

### APPARATUS FOR MEASURING NOISE

Since the relative loudness to the ear, rather than the actual physical intensity, is the quantity in which engineers are usually interested, it has been found necessary to allow for the varying sensitivity of the ear at different frequencies in designing noise measuring equipment. The most satisfactory method of measuring noise is by means of a sound level meter which usually consists of a microphone, a high gain audio-amplifier, and a rectifying milliammeter which will read directly in decibels. This meter is calibrated to give readings above the standard reference level and usually contains a weighing network to make it less sensitive at those frequencies where the ear is less sensitive. For complete specifications relative to the approved type of sound level meters refer to the information<sup>2</sup> published by the *American Standards Association*.

### GENERAL PROBLEM OF SOUND CONTROL

As previously stated, the problem confronting the air conditioning engineer is that of designing a system which will operate without increasing the noise level in the conditioned space. To be sure that this is accomplished, it is necessary:

1. To determine the noise level existing without the equipment.
2. To ascertain the noise level which would exist if the equipment were installed without sound control.
3. To provide as a part of the installation sufficient sound control appliances to reduce the noise level substantially to that found in Item 1.

To accomplish this the engineer should have information of three kinds:

1. A knowledge of the noise levels currently considered acceptable in various rooms in order that he may have a basis on which to proceed.
2. A knowledge of the nature and intensity of the noise created by the various parts of the equipment.
3. A knowledge of how, when necessary, to vary and control the noise level between the equipment and the conditioned space.

In addition, the engineer should have information to analyze noises

<sup>1</sup>American Tentative Standards for Noise Measurement, *American Standards Association*.

<sup>2</sup>American Tentative Standards for Sound Level Meters for Measurement of Noise and Other Sounds, *American Standards Association*.

which may be transmitted by the duct system from one conditioned space to another, or from an outside space to the conditioned space.

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

TABLE 1. TYPICAL NOISE LEVELS

| Rooms                                                        | NOISE LEVEL IN DECIBELS<br>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 <sup>a</sup>                              | 70             | 80   |
| Pullman Car.....                                             | 55 <sup>a</sup>                              | 65             | 75   |
| Automobile.....                                              | 50                                           | 65             | 80   |
| Vehicular Tunnel.....                                        | 75                                           | 85             | 95   |
| Airplane.....                                                | 80                                           | 85             | 100  |

<sup>a</sup>For train standing in station a level of about 45 db is the maximum which can ordinarily be tolerated.

certain manufacturers are prepared to offer such data and do state the noise producing properties of their products. A sound test code for fans has been developed by the *National Association of Fan Manufacturers* which uses the flat response network of the sound level meter. However, when determining the noise generated by an air distribution system, it is customary to use the noise level of the fan as determined by the weighting network most nearly approaching the noise level of the space. In most cases this will be the noise level of the fan as determined on the 40 decibel weighting network. Refer to Table 1 for typical noise levels.