$$db = 10 \log_{10}\left(\frac{I}{10^{-16}}\right) \quad (2)$$

where I = the sound intensity in watts per square centimeter.

The reference intensity is 10^{-16} watts per square centimeter, coinciding with the reference pressure of 0.0002 dynes per sq cm or 2×10^{-4} microbar. A microbar is the unit of pressure commonly used in acoustics, one microbar being equal to one dyne per sq cm.

The relationship of the decibel scale to sound pressure and sound intensity is shown in Table 1. A stated sound level in decibels, under standardized procedure, will thus be related to a threshold of 0.0002 dynes per square centimeter, or to a threshold of 10^{-16} watts per sq cm. The standardization upon terminology, procedures and reference levels may be found in Standards[1] published by the *American Standards Association.*

APPARATUS FOR MEASURING SOUND

The measurement of sound or noise is conventionally made by means of a sound-level meter[2] consisting of a microphone, an amplifier, a variable attenuator, weighting networks, and an indicating meter which reads directly in decibels. The approved sound-level meter must comply with the specifications of the American Standard for Sound Level Meters for Measurement of Noise and Other Sounds, Z24.3–1944, approved and published by the *American Standards Association.* The meter is designed to indicate sound level above the standard reference level. Three measuring networks are generally provided: (1) flat response, (2) 70 db network and (3) 40 db network. The various networks are approximations of the equal-loudness contours relating intensity and frequency sensation response of the normal human ear.[1] Where there are no specific codes which specify the particular network to be used, general practice would indicate use of the 40 db network for sound levels up to about 55 db, the 70 db network for sound levels from about 55 db to 85 db, and the flat response network for higher levels. When sound level measurements are stated, the specific weighting network used, *i.e.*, 40 db, 70 db or flat response, should always be reported. Complexity in design and calibration, and variations in component parts of the sound level meter impose some deviation from design objective response. Allowable deviations in response or acceptable tolerations recognized in the Standard, vary from ± 2 db in the 1000 cycle range to ± 5 db, or more, below 100 cycles and above 1200 cycles per second.

GENERAL PROBLEM OF SOUND CONTROL

The problem confronting the air conditioning engineer is to design a system which will operate without increasing the noise level in the conditioned space. It is therefore 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 and treatment to reduce the sound level due to the installation to a sound level at least three decibels, and preferably five decibels, below 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.

Table 1. Decibel Scale vs. Sound Pressures and Sound Intensities

Decibel Level	Pressure dynes per sq cm	Intensity watts per sq cm	Decibel Level	Pressure dynes per sq cm	Intensity watts per sq cm
0	0.000200	1.000×10^{-16}	40	0.0200	1.000×10^{-12}
1	0.000224	1.259×10^{-16}	50	0.0631	1.000×10^{-11}
2	0.000252	1.585×10^{-16}	60	0.200	1.000×10^{-10}
3	0.000282	2.000×10^{-16}	70	0.631	1.000×10^{-9}
4	0.000317	2.520×10^{-16}	80	2.00	1.000×10^{-8}
6	0.000399	4.000×10^{-16}	90	6.31	1.000×10^{-7}
8	0.000503	6.310×10^{-16}	100	20.0	1.000×10^{-6}
10	0.000631	1.000×10^{-15}	110	63.1	1.000×10^{-5}
20	0.00200	1.000×10^{-14}	120	200.0	1.000×10^{-4}
30	0.00631	1.000×10^{-13}			

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 sufficient information to predict the levels produced by noises which may be transmitted by the duct system from one conditioned space to another, or from an outside space to the conditioned space. In either case, the designer must know the probable noise level at the point where the noise originates. From this he can compute the attenuation or transmission loss required in order to bring this level down to that required in the conditioned space. If there is likelihood of direct transmission through a duct, the attenuation required may be computed as shown in section Noise Transmitted Through Ducts. If the transmission is through dividing walls, it will be necessary to refer to published data on losses through standard building constructions.[3]

Information concerning the sound levels created by ventilating and air conditioning equipment such as fans, motors, air washers and similar items, has not yet been completely established. However, numerous manufacturers are in a position to supply such data for many of their products. Additional information is being collected. Uniformity in method of test and presentation of sound measurement data for fans, has been standardized in the Sound Measurement Test Code for Centrifugal and Axial Fans, developed by the *National Association of Fan Manufacturers.* The Code prescribes that the sound level shall be measured by the flat response network of the sound-level meter. Readings on the 40 db and 70 db networks may also be taken and reported, but the flat response reading is required to comply with the Code requirement. General practice is to use the *slow* or damped needle reading of the meter. The *fast* or undamped needle of the indicating meter generally reads one to two db lower than the *slow* or damped meter needle. The same Code prescribes a method of determining the sound level reading at each of seven stations, spaced at 5 ft from the outside of the fan housing, and located in a horizontal plane passing through the fan shaft. The sound level of the fan is the average of the seven readings. The level so determined is valuable primarily for comparative purposes rather than absolute values. Of more value to the design engineer would be the sound level at the fan outlet and at the beginning of the distribution duct system.

The technique of sound measurement in a moving air stream of ap-