

of at least 20 to 30 fps before these wind velocities would have any appreciable influence upon the propagation of sound.

If there is to be any appreciable motion of air in an auditorium, it is advantageous to have the upper layers of air moving in a direction from the stage toward the audience, as this will tend to refract the sound waves down toward the audience. However, unless the speed of the air is as great as 20 or 30 fps, the amount of refraction will not be noticeable. Therefore, as a rule the motion of air in an auditorium does not have an appreciable effect upon the acoustical properties of the room.

EFFECT OF HUMIDITY UPON ACOUSTICS

Recent experiments⁵ have shown that both the humidity and the temperature of air have a marked influence upon the rate of absorption of high-pitched sounds. Perfectly dry air is less absorptive than air containing any amount of water vapor. At relative humidities of 5 to 25 per cent, the air is highly absorptive but becomes less and less absorptive as the humidity is increased. High-frequency sounds are propagated better in cold humid air than in hot dry air, and since high-frequency sounds are particularly important for the preservation of good quality in speech and music it is advantageous to maintain the air in a room at a relatively high humidity, not less than about 55 to 60 per cent. On the other hand, where it is desirable to absorb all frequency components of sound, as for the reduction of noise in offices, it is advantageous to maintain relatively dry air.

The time of reverberation in a room is given by the following equation:

$$t = \frac{0.049V}{-S \log_e (1 - \alpha) + 4mV} \quad (5)$$

where

V = volume of room in cubic feet.

S = interior surface of room.

α = average coefficient of sound-absorption of the interior surface of the room.

m = the absorption coefficient of the air in the room.

The coefficient m depends upon the frequency of the sound and the humidity (and probably the temperature) of the air. At a temperature of 70 F, and for sound waves having a frequency of 4096 vibrations per second, $m = 0.0027$ at 25 per cent relative humidity, 0.0018 at 54 per cent, and 0.0013 at 82 per cent. It will be seen, therefore, that the absorption of sound in the air is twice as great at a relative humidity of 25 per cent as it is at a relative humidity of 82 per cent. (This explains why sounds in the open travel so much better on humid days than they do on dry days). Although this dependence of absorption upon humidity is characteristic of low-frequency as well as high-frequency sound, the actual amount of absorption in the air is negligible for frequencies below about 1024 vibrations per second. However, the absorption of the higher frequencies in the air is a significant factor, and its dependence upon humidity calls for careful consideration in planning the air-conditioning equipment for buildings.

⁵Effect of Humidity upon the Absorption of Sound in a Room, by V. O. Knudsen (*Journal Acoustical Society of America*, July, 1931). Also see report presented at the May, 1933, meeting of A. S. of A.

Chapter 19

AIR DUCT DESIGN

Pressure Losses, Friction Losses, Friction Loss Chart, Proportioning the Losses, Sizes of Ducts, General Rules, Procedure for Duct Design, Air Velocities, Proportioning the Size for Friction, Main Trunk Ducts with Branches for Public Buildings, Equal Friction Method, Details of Duct Construction

THE flow of air due to large pressure differences is most accurately stated by thermodynamic formulae for air discharge under conditions of adiabatic flow, but such formulae are complicated, and the error occasioned by the assumption that the gas density remains constant throughout the flow may be considered negligible when only such pressure differences are involved as occur in ordinary heating and ventilating practice.

In the development of the formulae, diagrams and tables for the flow of air, use is made of the following basic formula for the flow of liquids:

$$V = 1096.5 \sqrt{\frac{p}{W}} \quad (1)$$

where

V = velocity in feet per minute.

p = velocity head or pressure in inches of water.

W = weight of air in pounds per cubic foot.

For standard air (70 F and 29.92 barometer) $W = 0.07495$ lb per cubic foot. Substituting this value in Equation 1:

$$V = 1096.5 \sqrt{\frac{p}{0.07495}} = 4005 \sqrt{p} \quad (2)$$

PRESSURE LOSSES

The drop in pressure in air distributing systems is due to the *dynamic* losses and the *friction* losses. The friction losses are those due to the friction of the air against the sides of the duct. The dynamic losses are those due to the change in the direction or in the velocity of air flow.

Dynamic Losses

Dynamic losses occur principally at the entrance to the piping, in the elbows, and wherever a change in velocity occurs. The entrance loss is the difference between the actual pressure required to produce flow and the pressure corresponding to the flow produced; it may vary from 0.1 to