therefore,

$$V = 1096.5 \sqrt{\frac{h_v}{d}} \tag{1}$$

where

V = velocity, feet per minute.
h_v = velocity head or pressure, inches of water.
d = weight of air, pounds per cubic foot.

For dry air (70 F and 29.921 in. *Hg* barometer) d = 0.075 lb per cubic foot[1]. Substituting this value in Equation 1:

$$V = 1096.5 \sqrt{\frac{h_v}{0.075}} = 4005 \sqrt{h_v} \tag{2}$$

The relation of air velocity and velocity head expressed in Equation 2 is shown diagrammatically in Fig. 1 for air at 70 F and 29.92 in. *Hg* barometer.

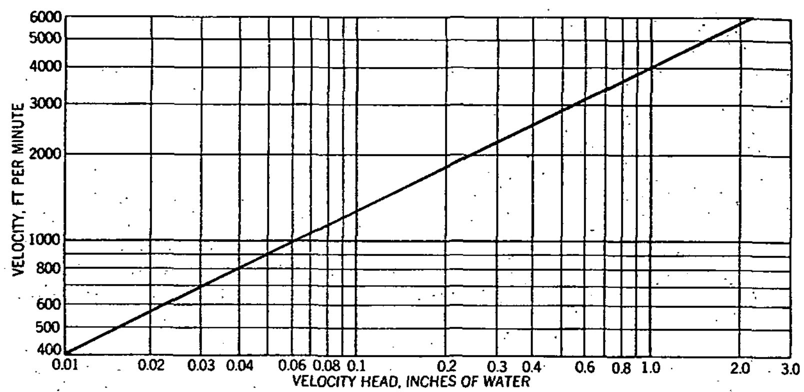

Fig. 1. Relation Between Velocity and Velocity Head for Dry Air

The drop in pressure in air distributing systems is due to the *dynamic* losses and the *friction* losses. The friction losses for turbulent flow (which occur in all practical air flow problems) are due to the friction of air against the sides of the duct and to internal friction between air molecules. The dynamic losses are those due to the change in the direction or in the velocity of air flow.

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 0.5 times the velocity head. The pressure loss in elbows must also be allowed for in the design.

FRICTION LOSSES

A study of the frictional resistance to the flow of air in ducts was begun by the A.S.H.V.E. Research Laboratory in 1938. This study

[1]See Chapter 47 for definition of standard air.

resulted in modifications of the Fanning friction loss formula, for 100 ft of round galvanized iron duct and for air at standard conditions[2]:

For round duct with no joints,

$$H_s = \frac{1.157}{D^{1.212}} \left(\frac{V}{4000}\right)^{1.83} \tag{3}$$

For round duct with 40 joints per 100 ft,

$$H_s = \frac{1.48}{D^{1.237}} \left(\frac{V}{4000}\right)^{1.83} \tag{4}$$

where

H_s = friction loss, inches of water at standard conditions.
V = velocity of air, feet per minute.
D = diameter of duct, feet.

The chart shown in Fig. 2 was constructed from Equation 4 and therefore applies only for round galvanized iron duct of good construction with 40 joints per 100 ft, and for air at standard conditions. *No factor of safety has been applied.* In view of the many variations that may occur in duct construction and application, it is recommended that a factor of safety be used, which in the judgment of the engineer, will make due allowance for these variations. In the Laboratory tests the variation found in pressure loss between the best joints and the worst joints was approximately 10 per cent. This would suggest a minimum factor of safety of 10 per cent.

Since the friction chart applies only for standard conditions, it is necessary to apply correction factors for other than standard conditions. These corrections are as follows:

$$H_A = H_s \times S \left(\frac{\gamma_A}{\gamma_s}\right)^{0.17} \tag{5}$$

where

H_A = friction loss, inches of water at actual conditions.
S = ratio of density of air at actual conditions to density of air at standard conditions.
γ_A = kinematic viscosity at actual conditions.
γ_s = kinematic viscosity at standard conditions.

$$\text{Kinematic Viscosity} = \frac{\mu}{\rho}$$

where

μ = absolute viscosity, pounds per foot second (see Fig. 3).
ρ = density, pounds per cubic foot (see Chapter 1).

The absolute viscosity of dry air at various temperatures is given in Fig. 3. It is assumed that the viscosity is not appreciably affected by the moisture content.

For temperatures ordinarily used in heating, ventilating and air conditioning work, the correction for viscosity may be neglected without

[2]Frictional Resistance to the Flow of Air in Straight Ducts, by F. C. Houghten, J. B. Schmieler, J. A. Zalovcik and N. Ivanovic (A.S.H.V.E. Transactions, Vol. 45, 1939, p. 35). Analysis of Factors Affecting Duct Friction, by J. B. Schmieler, F. C. Houghten and H. T. Olson (A.S.H.V.E. Transactions, Vol. 46, 1940).