$$h_f = f \frac{L}{D} \frac{v^2}{2g} \qquad (1)$$

where

h_f = head loss due to friction, in feet of fluid flowing.
L = length of conduit, feet.
D = inside diameter of conduit, feet.
v = fluid velocity, feet per second.
g = acceleration due to gravity, 32.17 fps per second.
f = a non-dimensional friction coefficient, which for ventilation work depends upon Reynolds Number and the relative roughness of the conduit. Appropriate values of f were taken from the work of Moody.[3] See Chapter 4, Fig. 4, Relation Between Friction Factor and Reynolds Number.

The air friction chart is based on standard air[3] with a density of 0.075 lb per cu ft, flowing through average, clean, round, galvanized metal ducts having approximately 40 joints per 100 ft. Figs. 1 and 2 should not be used to obtain values below the charts by extrapolation, because critical flow would occur in this region and values so obtained would be unreliable. For the average application, values from the charts should prove sufficiently accurate, without corrections, for any air temperature from 50 F to 90 F, for any relative humidity, and for any normal variation in barometric pressure. For widely varying air pressures or temperatures, or for unusual duct conditions, the friction values obtained from the chart should be corrected.[4]

For ordinary ventilating work, friction may be assumed to vary directly as the density without serious error, and therefore

$$h_o = h_s \left(\frac{\rho_o}{\rho_s}\right) \qquad (2)$$

where

h_o = friction loss under actual operating conditions, any consistent units.
h_s = friction loss under standard conditions, any consistent units.
ρ_o = density of air under actual operating conditions, any consistent units.
ρ_s = density of air under standard conditions, any consistent units.

For ducts of other than standard sheet metal construction, correction factors may be obtained from Fig. 3.[4] The correction factors shown in Fig. 3 were computed for the values of ϵ, the roughness in feet, shown in Table 1.[4] The correct friction loss for such ducts may then be determined by multiplying the losses obtained from Figs. 1 and 2 by these factors.

Examples 1 and 2 illustrate the use of Fig. 2 to determine friction loss, and the use of Fig. 3 to apply a correction for roughness.

Example 1. Determine the friction loss when circulating 10,000 cfm of air through 75 ft of 24 in. diameter galvanized duct.

Solution. Find 10,000 cfm on the left scale of Fig. 2 and move horizontally right to the diagonal line marked 24 in. The other intersecting diagonal shows that the velocity in the pipe is 3200 fpm. Directly below the intersection it is found that the friction per 100 ft is 0.50 in.; then for 75 ft the friction will be 0.75 × 0.50 = 0.38 in. In a like manner any two variables may be determined by the intersection of the lines representing the other two variables.

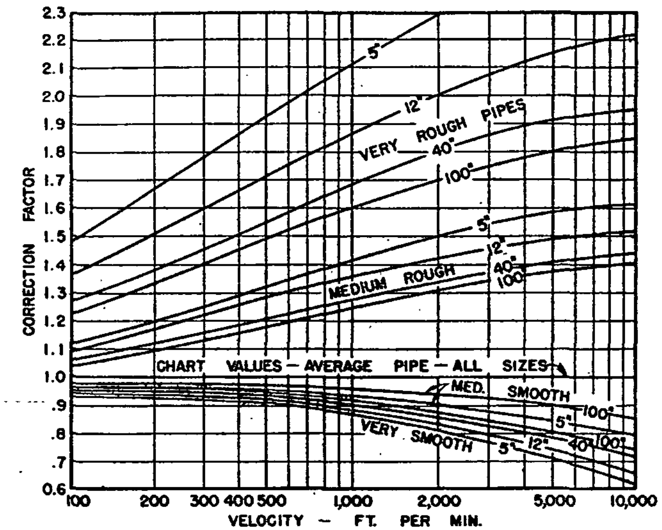

Fig. 3. Correction Factors for Pipe Roughness

To correct for pipe roughness multiply friction loss obtained from Figs. 1 and 2 by correction factor obtained from Fig. 3.

Example 2. If the duct in Example 1 is very rough, instead of galvanized, with 40 joints per 100 ft, find the total friction.

Solution. On Fig. 3 find (by interpolation between 12 in. and 40 in. pipe) the intersection of the 24 in. *very rough pipe* line and the 3200 fpm velocity ordinate, and at the left margin read a correction factor of 2. The friction loss in the rough duct is therefore 2 × 0.38 = 0.76 in.

CIRCULAR EQUIVALENTS OF RECTANGULAR DUCTS

An air handling system is usually sized first for round ducts and, if rectangular ducts are desired, their sizes are selected to provide air carrying capacities equivalent to those of the round ducts originally selected.

A recent comprehensive study at the A.S.H.V.E. Research Laboratory proved that for most practical purposes rectangular ducts of aspect ratios not exceeding 8:1 will have the same static friction pressure loss for equal

Table 1. Values of Roughness ϵ for Different Pipes[a]

Pipe	Degree of Roughness	ϵ Roughness in Feet
Drawn Tubing	Very smooth	0.0000015
New Steel or Wrought-Iron Pipe	Medium smooth	0.00015
Galvanized Iron	Average	0.0005
Average Concrete	Medium rough	0.003
Average Riveted Steel	Very rough	0.01

[a] Used in computing values for Fig. 3.