the direction of the air flow. Static and velocity pressure are mutually convertible and either can increase or decrease in the direction of flow.

Typical pressure changes in a duct system are illustrated in Fig. 1. Between Sections A and B, the static and total pressures decrease uniformly because of friction between air molecules along the sides of the duct. Pressure losses in straight pipes are termed *friction losses* and are characterized by dependence upon Reynolds number. (See Chapter 4.)

Section BC is a converging section. The duct area is reduced, and consequently the flow is accelerated. This is a stable and efficient process and

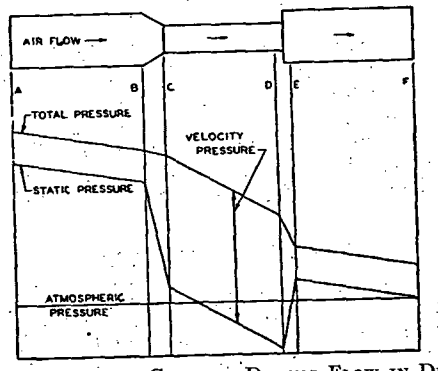


FIG. 1. PRESSURE CHANGES DURING FLOW IN DUCTS

the loss in total pressure is seen to be small. The marked decrease in static pressure is caused by conversion of static to velocity pressure in accordance with the equations above.

Section CD presents the friction loss in the section of smaller duct. Since friction losses increase with nearly the square of the velocity, the pressure line falls much more rapidly than in Section AB.

An abrupt expansion occurs at DE. The duct area is abruptly increased and the flow decelerated. The process is an inefficient one and the loss in total pressure is therefore large. The velocity pressure is decreased at E in accordance with Equations 2 and 3, and the static pressure rises. This and the pressure loss at BC are termed *dynamic losses*, and are characterized by being essentially independent of Reynolds number. Dynamic losses occur because of changes in the direction or velocity of the air, and hence occur at duct transitions, bends (elbows) and obstructions such as dampers. As will be shown later, dynamic losses can be specified in terms of a constant times the velocity pressure at a reference cross section.

Beginning at Section E the velocity pressure is constant, and the static and total pressures again decrease uniformly due to wall friction. The static pressure at F is zero, as referred to atmospheric. The total pressure is the velocity pressure and is a measure of the kinetic energy of the stream as it discharges from the duct.

The distinction between *static* and *total pressure* is important, because the former is conventionally used as the basis for system design, but the latter dictates the actual mechanical energy that must be supplied to the

system. Note in Fig. 1 that the static pressure decreases and then increases in the direction of flow. Moreover, it even becomes negative (below atmospheric). Therefore, in dealing with static pressures, distinction must always be made between static pressure *loss* (Section AB) and static pressure *change* as a result of conversion of velocity pressure (Section BC).

FRICTION LOSSES

Pressure drop in a *straight* duct is caused by surface friction, and this friction loss is most readily calculated by means of the Air Friction Charts, Figs. 2 and 3, covering volume ranges of 10 to 2000 cfm, and 1000 to 100,000 cfm, respectively. These charts were developed by the A.S.H.A.E. Research Laboratory.[1]

The charts, Figs. 2 and 3, were constructed from the basic flow equation for the pressure loss in circular ducts (see Chapter 4):

$$H_f = f\left(\frac{l}{D}\right) H_v \qquad (4)$$

where

H_f = head loss due to friction, inches of water.

f = a non-dimensional friction coefficient, which for air conditioning work depends upon Reynolds number and the relative roughness of the conduit. Approximate values of f were taken from the work of Moody[2] where e = 0.0005 ft. (See Chapter 4, Fig. 4, Relation Between Friction Factor and Reynolds number.) It is numerically equivalent to the reciprocal of the number of duct diameters required to cause a pressure loss equivalent to one velocity pressure.

l = length of conduit, feet.

D = inside diameter of conduit, feet.

H_v = velocity pressure of mean velocity, inches of water.

The air friction chart is based on standard air 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. Fig. 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 have sufficient precision, 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.[3]

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

$$h_o = h_s\left(\frac{\rho_o}{\rho_s}\right) \qquad (5)$$

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