the pressure forces created on an aerodynamic surface can be studied in a simple form which at first neglects the effect of friction and viscosity of the airflow. The most appropriate means of visualizing the effect of airflow and the resulting aerodynamic pressures is to study the fluid flow within a closed tube.

Suppose a stream of air is flowing through the tube shown in figure 1.2. The airflow at station 1 in the tube has a certain velocity, static pressure, and density. As the airstream approaches the constriction at station 2 certain changes must take place. Since the airflow is enclosed within the tube, the mass flow at any point along the tube must be the same and the velocity, pressure, or density must change to accommodate this continuity of flow.

BERNOULLI'S EQUATION. A distinguishing feature of *subsonic* airflow is that changes in pressure and velocity take place with small and negligible changes in density. For this reason the study of subsonic airflow can be simplified by neglecting the variation of density in the flow and assuming the flow to be *incompressible*. Of course, at high flow speeds which approach the speed of sound, the flow must be considered as compressible and "compressibility effects" taken into account. However, if the flow through the tube of figure 1.2 is considered subsonic, the density of the airstream is essentially constant at all stations along the length.

If the density of the flow remains constant, static pressure and velocity are the variable quantities. As the flow approaches the constriction of station 2 the velocity must increase to maintain the same mass flow. As the velocity increases the static pressure will decrease and the decrease in static pressure which accompanies the increase in velocity can be verified in two ways:

(1) Newton's laws of motion state the requirement of an unbalanced force to produce an acceleration (velocity change). If the airstream experiences an increase in velocity approaching the constriction, there must be an unbalance of force to provide the acceleration. Since there is only air within the tube, the unbalance of force is provided by the static pressure at station 1 being greater than the static pressure at the constriction, station 2.

(2) The total energy of the air stream in the tube is unchanged. However, the airstream energy may be in two forms. The airstream may have a *potential* energy which is related by the static pressure and a *kinetic* energy by virtue of mass and motion. As the total energy is unchanged, an increase in velocity (kinetic energy) will be accompanied by a decrease in static pressure (potential energy). This situation is analagous to a ball rolling along a smooth surface. As the ball rolls downhill, the potential energy due to position is exchanged for kinetic energy of motion. If friction were negligible, the change of potential energy would equal the change in kinetic energy. This is also the case for the airflow within the tube.

The relationship of static pressure and velocity is maintained throughout the length of the tube. As the flow moves past the constriction toward station 3, the velocity decreases and the static pressure increases.

The Bernoulli equation for incompressible flow is most readily explained by accounting for the energy of the airflow within the tube. As the airstream has no energy added or subtracted at any point, the sum of the potential and kinetic energy must be constant. The kinetic energy of an object is found by:

$$K.E. = \tfrac{1}{2}MV^2$$

where $K.E.$ = kinetic energy, ft.-lbs.
M = mass, slugs
V = velocity, ft./sec.

The kinetic energy of a cubic foot of air is:

$$\frac{K.E.}{\text{ft.}^3} = \tfrac{1}{2}\rho V^2$$

where $\frac{K.E.}{\text{ft.}^3}$ = kinetic energy per cu. ft., psf
ρ = air density, slugs per cu. ft.
V = air velocity, ft./sec.