Experiment 3

Objective:

To verify the existence and shape of the boundary layer.

Discussion:

A moving fluid adjacent to a solid boundary has the same velocity as the boundary. As the distance from a boundary increases, the fluid velocity changes until it equals the free stream velocity or if there are two boundaries, the velocity of the other boundary. The boundary layer is the layer of fluid near a surface that has experienced a change in velocity caused by shear stress at the surface. The boundary layer is confined to a region which is relatively close to the boundary. As distance, in the direction of flow, along the boundary layer increases, the thick ness of the boundary layer increases. The boundary layer can be either laminar or turbulent in nature and this determines the shape of the velocity distribution within the boundary layer.

The velocity distribution in the laminar boundary layer is relatively simple in that it is governed by one relation. The thickness of the laminar boundary layer is given by:

$$\delta = \frac{5x}{Re_x^{1/2}}$$

The laminar boundary layer will become turbulent awt a Reynolds number approximately equal to 500,000 for very thin, smooth plates. If the boundary is not smooth then the change to a turbulent boundary layer will occur at smaller Reynolds numbers.

The turbulent boundary layer is more complex than the laminar boundary layer. Where the velocity distribution in the laminar boundary layer was given by a single relation, the velocity distribution in the turbulent layer consists of three distinct regions. The fluid layer adjacent to the boundary is the viscous sublayer. This layer, which is very thin, remains relatively smooth. The next region is governed by a logarithmic velocity distribution and the other region is governed by the velocity defect law.

The velocity distribution in the viscous sublayer is related to the shear stress and viscosity by Newton's viscosity law. The results of this are:

$$\frac{u}{u_*} = \frac{y}{\nu / u_*} \qquad \text{where} \quad u_* = \sqrt{\tau_0 / \rho}$$

The thickness of the viscous sublayer, δ' is given by:

$$\delta' = 5\frac{\nu}{u_*}$$

The next region is governed by the logarithmic velocity distribution. The equation governing this region is valid for values of yu_*/ν from 30 to 500. The velocity distribution is given by:

$$\frac{u}{u_*} = 5.75\log\left(y\frac{u_*}{\nu}\right) + 5.56$$