shock wave forms as the boundary between the supersonic flow and the subsonic flow on the aft portion of the airfoil surface. The acceleration of the airflow from subsonic to supersonic is smooth and unaccompanied by shock waves if the surface is smooth and the transition gradual. However, the transition of airflow from supersonic to subsonic is always accompanied by a shock wave and, when there is no change in direction of the airflow, the wave form is a normal shock wave.

Recall that one of the principal effects of the normal shock wave is to produce a large increase in the static pressure of the airstream behind the wave. If the shock wave is strong, the boundary layer may not have sufficient kinetic energy to withstand the large, adverse pressure gradient and separation will occur. At speeds only slightly beyond critical Mach number the shock wave formed is not strong enough to cause spearation or any noticeable change in the aerodynamic force coefficients. However, an increase in speed above critical Mach number sufficient to form a strong shock wave can cause separation of the boundary layer and produce sudden changes in the aerodynamic force coefficients. Such a flow condition is shown in figure 3.9 by the flow pattern for $M=0.77$. Notice that a further increase in Mach number to 0.82 can enlarge the supersonic area on the upper surface and form an additional area of supersonic flow and normal shock wave on the lower surface.

As the flight speed approaches the speed of sound the areas of supersonic flow enlarge and the shock waves move nearer the trailing edge. The boundary layer may remain separated or may reattach depending much upon the airfoil shape and angle of attack. When the flight speed exceeds the speed of sound the "bow" wave forms at the leading edge and this typical flow pattern is illustrated in figure 3.9 by the drawing for $M=1.05$. If the speed is increased to some higher supersonic value all oblique portions of the waves incline more greatly and the detached normal shock portion of the bow wave moves closer to the leading edge.

Of course, all components of the aircraft are affected by compressibility in a manner somewhat similar to that of basic airfoil. The tail, fuselage, nacelles, canopy, etc. and the effect of the interference between the various surfaces of the aircraft must be considered.

FORCE DIVERGENCE. The airflow separation induced by shock wave formation can create significant variations in the aerodynamic force coefficients. When the free stream speed is greater than critical Mach number some typical effects on an airfoil section are as follows:

(1) An increase in the section drag coefficient for a given section lift coefficient.

(2) A decrease in section lift coefficient for a given section angle of attack.

(3) A change in section pitching moment coefficient.

A reference point is usually taken by a plot of drag coefficient versus Mach number for a constant lift coefficient. Such a graph is shown in figure 3.10. The Mach number which produces a sharp change in the drag coefficient is termed the "force divergence" Mach number and, for most airfoils, usually exceeds the critical Mach number at least 5 to 10 percent. This condition is also referred to as the "drag divergence" or "drag rise."

PHENOMENA OF TRANSONIC FLIGHT. Associated with the "drag rise" are buffet, trim and stability changes, and a decrease in control surface effectiveness. Conventional aileron, rudder, and elevator surfaces subjected to this high frequency buffet may "buzz," and changes in hinge moments may produce undesirable control forces. Of course, if the buffet is quite severe and prolonged, structural damage may occur if this operation is in violation of operating limitations. When airflow separation occurs on the wing due to