as great a speed or one-fourth as much parasite drag at half the original speed. This fact may be appreciated by the relationship of dynamic pressure with speed—twice as much V, four times as much q, and four times as much D_p. This expressed variation of parasite drag with speed points out that parasite drag will be of greatest importance at high speeds and practically insignificant in flight at low dynamic pressures. To illustrate this fact, an airplane in flight just above the stall speed could have a parasite drag which is only 25 percent of the total drag. However, this same airplane at maximum level flight speed at low altitude would have a parasite drag which is very nearly 100 percent of the total drag. The predominance of parasite drag at high flight speeds emphasizes the necessity for great aerodynamic cleanness (low f) to obtain high speed performance.

In the subsonic regime of flight, the ordinary configuration of airplane has a very large portion of the equivalent parasite area determined by skin friction drag. As the wing contributes nearly half of the total parasite drag, the profile drag of the wing can be minimized by the use of the airfoil sections which produce extensive laminar flow. A subtle effect on parasite drag occurs from the influence of the wing area. Since the wing area (S) appears directly in the parasite drag equation, a reduction in wing area would reduce the parasite drag if all other factors were unchanged. While the exact relationship involves consideration of many factors, most optimum airplane configurations have a strong preference for the highest practical wing loading and minimum wing surface area.

As the flight speeds of aircraft approach the speed of sound, great care must be taken to delay and alleviate compressibility effects. In order to delay and reduce the drag rise associated with compressibility effects, the components of the airplanes must be arranged to reduce the early formation of shock waves on the airplane. This will generally require fuselage and nacelles of high fineness ratio, well faired canopies, and thin wing sections which have very smooth uniform pressure distributions. Low aspect ratios and sweepback are favorable in delaying and reducing the compressibility drag rise. In addition, interference effects are quite important in transonic and supersonic flight and the airplane cross section area distribution must be controlled to minimize local velocity peaks which could create premature strong shock wave formation.

The modern configuration of airplane will illustrate the features required to effect very high speed performance—low aspect ratio, sweepback, thin low drag sections, etc. These same features produce flight characteristics at low airspeeds which necessitate proper flying technique.

AIRPLANE TOTAL DRAG

The total drag of an airplane in flight is the sum of the induced and parasite drag. Figure 1.35 *illustrates the variation of total drag* with speed for a given airplane in level flight at a particular weight, configuration, and altitude. The parasite drag increases with speed varying as the square of the velocity while the induced drag decreases with speed varying inversely as the square of the velocity. The total drag of the airplane shows the predominance of induced drag at low speed and parasite drag at high speed. Specific points of interest on the drag curve are as follows:

(A) Stall of this particular airplane occurs at 100 knots and is indicated by a sharp rise in the actual drag. Since the generalized equations for induced and parasite do not account for conditions at stall, the actual drag of the airplane is depicted by the "hook" of the dotted line.

(B) At a speed of 124 knots, the airplane would incur a minimum rate of descent in power-off flight. Note that at this speed the induced drag comprises 75 percent of the total drag. If this airplane were powered with a reciprocating-propeller type powerplant, maximum endurance would occur at this airspeed.