POWER-OFF GLIDE PERFORMANCE

The gliding performance of an airplane is of special interest for the single engine airplane in the case of powerplant failure or malfunction. When a powerplant failure or malfunction occurs, it is usually of interest to obtain a gliding flight path which results in the minimum glide angle. The minimum glide angle will produce the greatest proportion of glide distance to altitude loss and will result in maximum glide range or minimum expenditure of altitude for a specific glide distance.

GLIDE ANGLE AND LIFT-DRAG RATIO.

In the study of climb performance, the forces acting on the airplane in a steady climb (or glide) produce the following relationship:

$$\sin \gamma = \frac{T - D}{W}$$

where

γ = angle of climb, degrees
T = thrust, lbs
D = drag, lbs
W = lbs

In the case of power-off glide performance, the thrust, T, is zero and the relationship reduces to:

$$\sin \gamma = \frac{D}{W}$$

By this relationship it is evident that the minimum angle of glide - or minimum negative climb angle - is obtained at the aerodynamic conditions which incur the minimum total drag. Since the airplane lift is essentially equal to the weight, the minimum angle of glide will be obtained when the airplane is operated at maximum lift-drag ratio, $(L/D)_{max}$. When the angle of glide is relatively small, the ratio of glide distance to glide altitude is numerically equal to the airplane lift-drag ratio.

$$\text{glide ratio} = \frac{\text{glide distance, ft}}{\text{glide altitude, ft}}$$

$$\text{glide ratio} = (L/D)$$

Figure 6.6 illustrates the forces acting on the airplane in a power-off glide. The equilibrium of the steady glide is obtained when the summation of forces in the vertical and horizontal directions is equal to zero.

{p 370 Figure 6.6. Glide Performance}

In order to obtain maximum glide ratio, the airplane must be operated at the angle of attack and lift coefficient which provide maximum lift-drag ratio. The illustration of Figure 6.6 depicts a variation of lift-drag ratio, L/D, with lift coefficient, C_L, for a typical airplane in the clean and landing configurations. Note that $(L/D)_{max}$ for each configuration will occur at a specific value of lift coefficient and, hence, a specific angle of attack. Thus, the maximum glide performance of a given airplane configuration will be unaffected by gross weight and altitude when the airplane is operated at $(L/D)_{max}$. Of course, an exception occurs at very high altitudes where compressibility effects may alter the aerodynamic characteristics. The highest value of $(L/D)_{max}$ will occur with the airplane in the clean configuration. As the airplane is changed to the landing configuration, the added parasite drag reduces $(L/D)_{max}$ and the C_L which produces $(L/D)_{max}$ will be increased. Thus, the best glide speed for the landing configuration generally will be less than the best glide speed for the clean configuration.

The power-off glide performance may be appreciated also by the graph of rate of descent versus velocity shown in Figure 6.6. When a straight line is drawn from the origin tangent to the curve, a point is located which produces the maximum proportion of velocity to rate of descent. Obviously, this condition provides maximum glide ratio. Since the rate of descent is proportional to the power required, the points of tangency define the aerodynamic condition of $(L/D)_{max}$.

FACTORS AFFECTING GLIDE PERFORMANCE.

In order to obtain the minimum glide angle through the air, the airplane must be operated at $(L/D)_{max}$. The subsonic $(L/D)_{max}$ of a given airplane configuration will occur at a specific value of lift coefficient and angle of attack. However, as can be noted from the curves of Figure 6.6, small deviations from the optimum C_L will not cause a drastic reduction of $(L/D)_{max}$ and glide ratio. In fact, a 5 percent deviation in speed from the best glide speed will not cause any significant reduction of glide ratio. This is fortunate and allows the specifying of convenient glide speeds which will be appropriate for a range of gross weights at which power-off gliding may be encountered, for example, small quantities of fuel remaining.

An attempt to *stretch a glide* by flying at speeds above or below the best glide speed will prove futile. As shown by the illustration of Figure 6.6, any C_L above or below the optimum will produce a lift-drag ratio less than the maximum. If the airplane angle of attack is increased above the value for $(L/D)_{max}$ a transient reduction in rate of descent will take place but this process must be reserved for the landing phase. Eventually, the steady- state conditions would be achieved and the increased angle of attack would incur a lower airspeed and a reduction in $(L/D)_{max}$ and glide ratio.

The effect of *gross weight* on glide performance may be difficult to appreciate. Since $(L/D)_{max}$ of a given airplane configuration will occur at a specific value of C_L, the gross weight of the airplane will not affect the glide ratio if the airplane is operated at the optimum C_L. Thus, two airplanes of identical aerodynamic configuration but different gross weight could glide the same distance from the same altitude. Of course, this fact would be true only if both airplanes are flown at the specific C_L to produce $(L/D)_{max}$. The principal difference would be that the heavier airplane must fly at a higher airspeed to support the greater weight at the optimum C_L. In addition, the heavier airplane flying at the greater speed along the same flight path would develop a greater rate of descent.

The relationship which exists between gross weight and velocity for a particular C_L is as follows:

$$\frac{V_2}{V_1} = \sqrt{\frac{W_2}{W_1}}$$

where

V_1 = best glide speed corresponding to some original gross weight, W_1

V_2 = best glide speed corresponding to some new gross weight, W_2

As a result of this relationship, a 10 percent increase in gross weight would require a 5 percent increase in glide speed to maintain $(L/D)_{max}$. While small variations in gross weight may produce a measurable change in best glide speed, t airplane can tolerate small deviations from the optimum C_L without significant change in (L/D) and glide ratio. For this reason, a standard, single value of gli speed may be specified for a small range of gross weights at which glide performance can be of importance. A gross weight which is considerably different from the normal range will require a modification of best glide speed to maintain the maximum glide ratio.

The *effect of altitude* on glide performance is insignificant if there is no change in $(L/D)_{max}$. Generally, the glide performance of the majority of airplanes is subsonic and there is no noticeable variation of $(L/D)_{max}$ with altitude. Any specific airplane configuration at a particular gross weight will require a specific value of dynamic pressure to sustain flight at the C_L for $(L/D)_{max}$. Thus the airplane will have a best glide speed which is a specific value of equivalent airspeed (EAS) independent of altitude. For convenience and simplicity, this best glide speed is specified as a specific value of indicated airspeed (IAS) and compressibility and position errors are neglected. The principal effect of altitu is that at high altitude the true airspeed (TAS) and rate of descent along the optimum glide path are increased above the low altitude conditions. However, if $(L/D)_{max}$ is maintained, the glide angle and glide ratio are identical to the low altitude conditions.

The *effect of configuration* has been noted previously in that the addition of parasite drag by flaps, landing gear, speed brakes, external stores, etc. will reduce the maximum lift-drag ratio and cause a reduction of glide ratio. In the case where glide distance is of great importance, the airplane must be maintained in the clean configuration and flown at $(L/D)_{max}$.

The *effect of wind* on gliding performance is similar to the effect of wind on cruising range. That is, a headwind will always reduce the glide range and a tailwind will always increase the glide range. The maximum glide range of the airplane in still air will be obtained by flight at $(L/D)_{max}$. However, when a win is present, the optimum gliding conditions may not be accomplished by operation a

$(L/D)_{max}$. For example, when a headwind is present, the optimum glide speed will b increased to obtain a maximum proportion of ground distance to altitude. In this sense, the increased glide speed helps to minimize the detrimental effect of the headwind. In the case of a tailwind, the optimum glide speed will be reduced to maximize the benefit of the tailwind. For ordinary wind conditions, maintaining t glide speed best for zero wind conditions will suffice and the loss or gain in glide distance must be accepted. However, when the wind conditions are extreme an the wind velocity is large in comparison with the glide speed, for example, wind velocity greater than 25 percent of the glide speed, changes in the glide speed must be made to obtain maximum possible ground distance.

THE FLAMEOUT PATTERN.

In the case of failure of the powerplant, every effort should be made to establish a well planned, stabilized approach if a suitable landing area is available. Generally a 360 degree overhead approach is specified with the approach beginning from the "high key" point of the flameout pattern. The function of a standardized pattern is to provide a flight path well within the capabilities of the airplane and the abilities of the pilot to judge and control the flight path. The flight handbook will generally specify the particulars of the flameout pattern such as the altitude at the high key, glide speeds, use of flaps, etc. Of course, the particulars of the flameout pattern will be determined by the aerodynamic characteristics of the airplane. A principal factor is the effect of glide ratio, or $(L/D)_{max}$, on the altitude required at the high key point at the beginning of the flameout pattern. The airplane with a low value of $(L/D)_{max}$ will require a high altitude at the high key point.

The most favorable situation during a flameout would be for the airplane to in position to arrive over the intended landing area the altitude for the high key point {sic.}. In this case, the standard flameout pattern could be utilized. If the airplane does not have sufficient glide range to arrive at the landing area with the altitude for the high key point, it is desirable to fit the approach into the lower portions of the standard flameout approach. If it is not possible to arrive at the intended landing area with sufficient altitude to "play" the approach, serious consideration should be given to ejection while sufficient altitude remains. Deviations from a well planned approach such as the standard flameout pattern may allow gross errors in judgment. A typical error of a nonstandard or poorly executed flameout approach is the use of excessive angles of bank in turns to correct the approach. Because of the great increase in induced drag at large angles of bank, excessive rates of descent will be incurred and there will be further deviations from a desirable flight path.

The power-off gliding characteristics of the airplane can be simulated in power-on flight by certain combinations of engine power setting and position of the speed brake or dive flap. This will allow the pilot to become familiar with the power-off glide performance and the flameout landing pattern. In addition, the simulated flameout pattern is useful during a precautionary landing when the powerplant is malfunctioning and there is the possibility of an actual flameout.

The final approach and landing flare will be particularly critical for the airplane which has a low glide ratio but a high best glide speed. These airplane characteristics are typical of the modern configuration of airplane which has low aspect ratio, sweepback, and high wing loading. Since these airplane characteristics also produce marginal flare capability in power-off flight, great care should be taken to follow the procedure recommended for the specific airplane.

As an example of the power-off glide performance of an airplane with low aspect ratio, sweepback, and high wing loading, a best glide speed of 220 knots and a glide ratio of 6 may be typical. In such a case, the rate of descent during the glide at low altitude would be on the order of 3,700 FPM. Any deviations from the recommended landing technique cannot be tolerated because of the possibility of an excessive rate of descent. Either premature flare or delayed flare may allow the airplane to touch down at a rate of descent which would cause structural failure. Because of the marginal flare characteristics in power-off flight, the best glide speed recommended for the landing configuration may be well above the speed corresponding to the exact maximum lift-drag ratio. The greater speed reduces induced drag and provides a greater margin for a successful power-off landing flare.

In the extreme case, the power-off glide and landing flare characteristics may be very critical for certain airplane configurations. Thus, a well planned standard flameout pattern and precise flying technique are necessary and, if very suitable conditions are not available, the recommended alternative is simple: *eject!*