the pilot know the power settings and pitch attitudes that will produce the following conditions of descent.

PARTIAL POWER DESCENT—The normal method of losing altitude is to descend with partial power. This is often termed "cruise" or "enroute" descent. The airspeed and power setting recommended by the airplane manufacturer for prolonged descent should be used. The target descent rate should be 400 – 500 f.p.m. The airspeed may vary from cruise airspeed to that used on the downwind leg of the landing pattern. But the wide range of possible airspeeds should not be interpreted to permit erratic pitch changes. The desired airspeed, pitch attitude, and power combination should be preselected and kept constant.

DESCENT AT MINIMUM SAFE AIRSPEED—A minimum safe airspeed descent is a nose-high, power assisted descent condition principally used for clearing obstacles during a landing approach to a short runway. The airspeed used for this descent condition is recommended by the airplane manufacturer and normally is no greater than 1.3 V_{SO}. Some characteristics of the minimum safe airspeed descent are a steeper than normal descent angle, and the excessive power that may be required to produce acceleration at low airspeed should "mushing" and/or an excessive rate of descent be allowed to develop.

GLIDES—A glide is a basic maneuver in which the airplane loses altitude in a controlled descent with little or no engine power; forward motion is maintained by gravity pulling the airplane along an inclined path and the descent rate is controlled by the pilot balancing the forces of gravity and lift.

Although glides are directly related to the practice of power-off accuracy landings, they have a specific operational purpose in normal landing approaches, and forced landings after engine failure. Therefore, it is necessary that they be performed more subconsciously than other maneuvers because most of the time during their execution, the pilot will be giving full attention to details other than the mechanics of performing the maneuver. Since glides are usually performed relatively close to the ground, accuracy of their execution and the formation of proper technique and habits are of special importance.

Because the application of controls is somewhat different in glides than in power-on descents, gliding maneuvers require the perfection of a technique somewhat different from that required for ordinary power-on maneuvers. This control difference is caused primarily by two factors—the absence of the usual propeller slipstream, and the difference in the relative effectiveness of the various control surfaces at slow speeds.

The glide ratio of an airplane is the distance the airplane will, with power off, travel forward in relation to the altitude it loses. For instance, if an airplane travels 10,000 feet forward while descending 1,000 feet, its glide ratio is said to be 10 to 1.

The glide ratio is affected by all four fundamental forces that act on an airplane (weight, lift, drag, and thrust). If all factors affecting the airplane are constant, the glide ratio will be constant. Although the effect of wind will not be covered in this section, it is a very prominent force acting on the gliding distance of the airplane in relationship to its movement over the ground. With a tailwind, the airplane will glide farther because of the higher groundspeed. Conversely, with a headwind the airplane will not glide as far because of the slower groundspeed.

Variations in weight do not affect the glide angle provided the pilot uses the correct airspeed. Since it is the lift over drag (L/D) ratio that determines the distance the airplane can glide, weight will not affect the distance. The glide ratio is based only on the relationship of the aerodynamic forces acting on the airplane. The only effect weight has is to vary the time the airplane will glide. The heavier the airplane the higher the airspeed must be to obtain the same glide ratio. For example, if two airplanes having the same L/D ratio, but different weights, start a glide from the same altitude, the heavier airplane gliding at a higher airspeed will arrive at the same touchdown point in a shorter time. Both airplanes will cover the same distance, only the lighter airplane will take a longer time.

Under various flight conditions, the drag factor may change through the operation of the landing gear and/or flaps. When the landing gear or the flaps are extended, drag increases and the airspeed will decrease unless the pitch attitude is lowered. As the pitch is lowered, the glidepath steepens and reduces the distance traveled. With the power off, a windmilling propeller also creates considerable drag, thereby retarding the airplane's forward movement.

Although the propeller thrust of the airplane is normally dependent on the power output of the engine, the throttle is in the closed position during a glide so the thrust is constant. Since power is not used during a glide or power-off approach, the pitch attitude must be adjusted as necessary to maintain a constant airspeed.

The best speed for the glide is one at which the airplane will travel the greatest forward distance for a given loss of altitude in still air. This *best glide speed* corresponds to an angle of attack resulting in the least drag on the airplane and giving the best lift-to-drag ratio (L/D_{MAX}). [Figure 3-17]

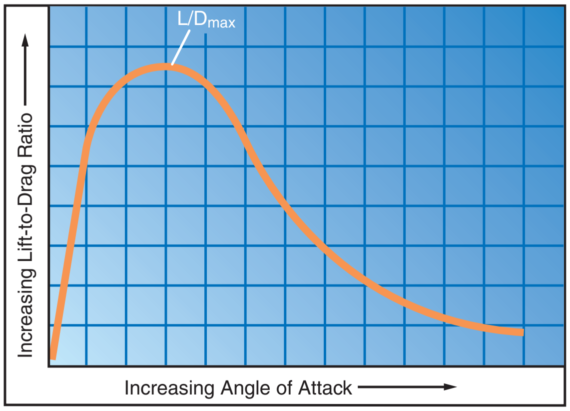

Figure 3-17. L/D$_{MAX}$.

Any change in the gliding airspeed will result in a proportionate change in glide ratio. Any speed, other than the best glide speed, results in more drag. Therefore, as the glide airspeed is reduced or increased from the optimum or best glide speed, the glide ratio is also changed. When descending at a speed below the best glide speed, induced drag increases. When descending at a speed above best glide speed, parasite drag increases. In either case, the rate of descent will *increase.* [Figure 3-18]

This leads to a cardinal rule of airplane flying that a student pilot must understand and appreciate: The pilot must never attempt to "stretch" a glide by applying back-elevator pressure and reducing the airspeed below the airplane's recommended best glide speed. Attempts to stretch a glide will invariably result in an increase in the rate and angle of descent and may precipitate an inadvertent stall.

To enter a glide, the pilot should close the throttle and advance the propeller (if so equipped) to low pitch (high r.p.m.). A constant altitude should be held with back pressure on the elevator control until the airspeed decreases to the recommended glide speed. Due to a decrease in downwash over the horizontal stabilizer as power is reduced, the airplane's nose will tend to immediately begin to lower of its own accord to an altitude lower than that at which it would stabilize. The pilot must be prepared for this. To keep pitch attitude constant after a power change, the pilot must counteract the immediate trim change. If the pitch attitude is allowed to decrease during glide entry, excess speed will be carried into the glide and retard the attainment of the correct glide angle and airspeed. Speed should be allowed to dissipate before the pitch attitude is decreased. This point is particularly important in so-called clean airplanes as they are very slow to lose their speed and any slight deviation of the nose downwards results in an immediate increase in airspeed. Once the airspeed has dissipated to normal or best glide speed, the pitch attitude should be allowed to decrease to maintain that speed. This should be done with reference to the horizon. When the speed has stabilized, the airplane should be retrimmed for "hands off" flight.

When the approximate gliding pitch attitude is established, the airspeed indicator should be checked. If the airspeed is higher than the recommended speed, the pitch attitude is too low, and if the airspeed is less than recommended, the pitch attitude is too high; therefore, the pitch attitude should be readjusted accordingly referencing the horizon. After the adjustment has been made, the airplane should be retrimmed so that it will maintain this attitude without the need to hold pressure on the elevator control. *The principles of attitude flying require that the proper flight attitude be established using outside visual references first, then using the flight instruments as a secondary check.* It is a good practice to always retrim the airplane after each pitch adjustment.

A stabilized power-off descent at the best glide speed is often referred to as a *normal* glide. The flight instructor should demonstrate a normal glide, and direct the student pilot to memorize the airplane's angle and speed by visually checking the airplane's attitude with reference to the horizon, and noting the pitch of the sound made by the air passing over the structure, the pressure on the controls, and the feel of

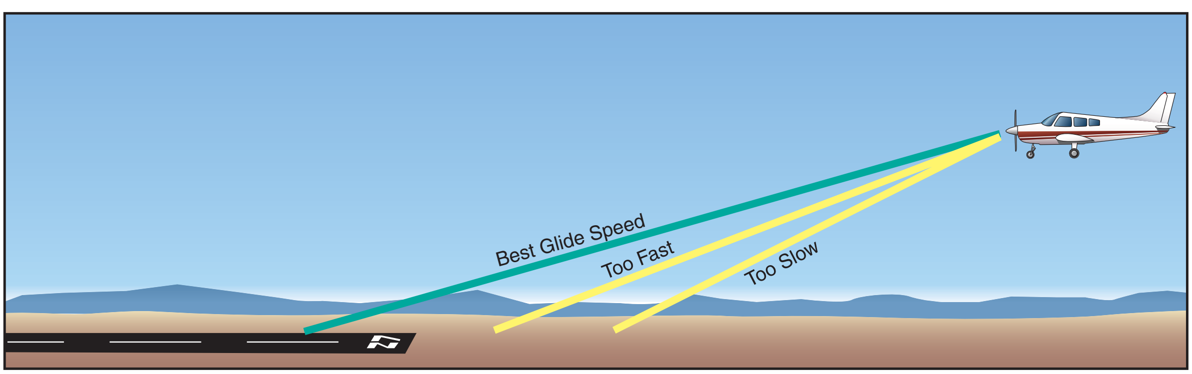

Figure 3-18. Best glide speed provides the greatest forward distance for a given loss of altitude.

the airplane. Due to lack of experience, the beginning student may be unable to recognize slight variations of speed and angle of bank immediately by vision or by the pressure required on the controls. Hearing will probably be the indicator that will be the most easily used at first. The instructor should, therefore, be certain that the student understands that an increase in the pitch of sound denotes increasing speed, while a decrease in pitch denotes less speed. When such an indication is received, the student should consciously apply the other two means of perception so as to establish the proper relationship. The student pilot must use all three elements consciously until they become habits, and must be alert when attention is diverted from the attitude of the airplane and be responsive to any warning given by a variation in the feel of the airplane or controls, or by a change in the pitch of the sound.

After a good comprehension of the normal glide is attained, the student pilot should be instructed in the differences in the results of normal and "abnormal" glides. Abnormal glides being those conducted at speeds other than the normal best glide speed. Pilots who do not acquire an understanding and appreciation of these differences will experience difficulties with accuracy landings, which are comparatively simple if the fundamentals of the glide are thoroughly understood.

Too fast a glide during the approach for landing invariably results in floating over the ground for varying distances, or even overshooting, while too slow a glide causes undershooting, flat approaches, and hard touchdowns. A pilot without the ability to recognize a normal glide will not be able to judge where the airplane will go, or can be made to go, in an emergency. Whereas, in a normal glide, the flightpath may be sighted to the spot on the ground on which the airplane will land. This cannot be done in any abnormal glide.

GLIDING TURNS—The action of the control system is somewhat different in a glide than with power, making gliding maneuvers stand in a class by themselves and require the perfection of a technique different from that required for ordinary power maneuvers. The control difference is caused mainly by two factors—the absence of the usual slipstream, and the difference or relative effectiveness of the various control surfaces at various speeds and particularly at reduced speed. The latter factor has its effect exaggerated by the first, and makes the task of coordination even more difficult for the inexperienced pilot. These principles should be thoroughly explained in order that the student may be alert to the necessary differences in coordination.

After a feel for the airplane and control touch have been developed, the necessary compensation will be automatic; but while any mechanical tendency exists, the student will have difficulty executing gliding turns, particularly when making a practical application of them in attempting accuracy landings.

Three elements in gliding turns which tend to force the nose down and increase glide speed are:

- Decrease in effective lift due to the direction of the lifting force being at an angle to the pull of gravity.
- The use of the rudder acting as it does in the entry to a power turn.
- The normal stability and inherent characteristics of the airplane to nose down with the power off.

These three factors make it necessary to use more back pressure on the elevator than is required for a straight glide or a power turn and, therefore, have a greater effect on the relationship of control coordination.

When recovery is being made from a gliding turn, the force on the elevator control which was applied during the turn must be decreased or the nose will come up too high and considerable speed will be lost. This error will require considerable attention and conscious control adjustment before the normal glide can again be resumed.

In order to maintain the most efficient or normal glide in a turn, more altitude must be sacrificed than in a straight glide since this is the only way speed can be maintained without power. Turning in a glide decreases the performance of the airplane to an even greater extent than a normal turn with power.

Still another factor is the difference in rudder action in turns with and without power. In power turns it is required that the desired recovery point be anticipated in the use of controls and that considerably more pressure than usual be exerted on the rudder. In the recovery from a gliding turn, the same rudder action takes place but without as much pressure being necessary. The actual displacement of the rudder is approximately the same, but it seems to be less in a glide because the resistance to pressure is so much less due to the absence of the propeller slipstream. This often results in a much greater application of rudder through a greater range than is realized, resulting in an abrupt stoppage of the turn when the rudder is applied for recovery. This factor is particularly important during landing practice since the student almost invariably recovers from the last turn too soon and may enter a cross-control condition trying to correct the landing with the rudder alone. This results in landing from a skid that is too easily mistaken for drift.

There is another danger in excessive rudder use during gliding turns. As the airplane skids, the bank will increase. This often alarms the beginning pilot when it occurs close to the ground, and the pilot may respond by applying aileron pressure toward the outside of the turn to stop the bank. At the same time, the rudder forces the nose down and the pilot may apply back-elevator pressure to hold it up. If allowed to progress, this situation may result in a fully developed cross-control condition. A stall in this situation will almost certainly result in a spin.

The level-off from a glide must be started before reaching the desired altitude because of the airplane's downward inertia. The amount of lead depends on the rate of descent and the pilot's control technique. With too little lead, there will be a tendency to descend below the selected altitude. For example, assuming a 500-foot per minute rate of descent, the altitude must be led by 100 – 150 feet to level off at an airspeed higher than the glide speed. At the lead point, power should be increased to the appropriate level flight cruise setting so the desired airspeed will be attained at the desired altitude. The nose tends to rise as both airspeed and downwash on the tail section increase. The pilot must be prepared for this and smoothly control the pitch attitude to attain level flight attitude so that the level-off is completed at the desired altitude.

Particular attention should be paid to the action of the airplane's nose when recovering (and entering) gliding turns. The nose must not be allowed to describe an arc with relation to the horizon, and particularly it must not be allowed to come up during recovery from turns, which require a constant variation of the relative pressures on the different controls.

Common errors in the performance of descents and descending turns are:

- Failure to adequately clear the area.
- Inadequate back-elevator control during glide entry resulting in too steep a glide.
- Failure to slow the airplane to approximate glide speed prior to lowering pitch attitude.
- Attempting to establish/maintain a normal glide solely by reference to flight instruments.
- Inability to sense changes in airspeed through sound and feel.
- Inability to stabilize the glide (chasing the airspeed indicator).
- Attempting to "stretch" the glide by applying back-elevator pressure.
- Skidding or slipping during gliding turns due to inadequate appreciation of the difference in rudder action as opposed to turns with power.
- Failure to lower pitch attitude during gliding turn entry resulting in a decrease in airspeed.
- Excessive rudder pressure during recovery from gliding turns.
- Inadequate pitch control during recovery from straight glides.
- "Ground shyness"—resulting in cross-controlling during gliding turns near the ground.
- Failure to maintain constant bank angle during gliding turns.

PITCH AND POWER

No discussion of climbs and descents would be complete without touching on the question of what controls altitude and what controls airspeed. The pilot must understand the effects of both power and elevator control, working together, during different conditions of flight. The closest one can come to a formula for determining airspeed/altitude control that is valid under all circumstances is a basic principle of attitude flying which states:

> "At any pitch attitude, the amount of power used will determine whether the airplane will climb, descend, or remain level at that attitude."

Through a wide range of nose-low attitudes, a descent is the only possible condition of flight. The addition of power at these attitudes will only result in a greater rate of descent at a faster airspeed.

Through a range of attitudes from very slightly nose-low to about 30° nose-up, a typical light airplane can be made to climb, descend, or maintain altitude depending on the power used. In about the lower third of this range, the airplane will descend at idle power without stalling. As pitch attitude is increased, however, engine power will be required to prevent a stall. Even more power will be required to maintain altitude, and even more for a climb. At a pitch attitude approaching 30° nose-up, all available power will provide only enough thrust to maintain altitude. A slight increase in the steepness of climb or a slight decrease in power will produce a descent. From that point, the least inducement will result in a stall.